



वार्षिक
प्रतिवेदन
ANNUAL
REPORT
2025

ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE

≡ Karnal, Haryana-132001 ≡



वार्षिक प्रतिवेदन
Annual Report
2025



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

Citation

Annual Report, 2025, ICAR-Central Soil Salinity Research Institute,
Karnal-132001, Haryana, India

Edited by

S.K. Sanwal, Suresh Kumar, Arvind Kumar, Awtar Singh, Sagar Vibhute, A.K. Rai,
Satyendra Kumar and R.K. Yadav

Compiled by

Yudhvir Singh Ahlawat

Photography and Designing

Yudhvir Singh Ahlawat

Cover Photo

Front side: Eddy Covariance Tower, 2-DE gel images of proteins of CS 60 treated
with salt stress & Livelihood resilience score chart for certain blocks
Back side: ICAR-CSSRI Headquarters building (Karnal)

Published by

Director, ICAR-Central Soil Salinity Research Institute, Karnal-132001, India
Telephone : + 91-184-2290501
Email: cssridirector@gmail.com; website: www.cssri.res.in

Printing

AARON MEDIA,
Sec-12, Karnal
Email : aaronmedia1@gmail.com

Contents

प्रस्तावना	01
कार्यकारी सारांश	03
Executive Summary	11
Introduction	19
Research Achievements	
Database on Salt Affected Soils	27
Reclamation and Management of Alkali Soils	29
Management of Waterlogged/Saline Soils	39
Management of Marginal Quality Waters	55
Crop Improvement for Salinity, Alkalinity and Waterlogged Stresses	63
Alternate Land Use	105
Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains	111
Reclamation and Management of Salt Affected Vertisols	141
Reclamation and Management of Coastal Saline Soils	157
AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture	181
Technology Assessed and Transferred	193
Miscellaneous	
Training and Capacity Building	207
Deputation of Scientists Abroad	207
Awards and Recognitions	209
Linkages and Collaborations	213
Publications	215
Conference/ Seminar/Symposia/Workshop papers	223
Technical Bulletin/Popular Article/Folder	227
Book/Manual/Chapter	229
Participation In Conference/Seminar/Symposium/Workshop	233
List of On-going Projects	235
Institute Activities	243
List of Scientific, Technical and Administrative Personnel	245
ICAR-CSSRI Staff Position	247
Weather Report 2024	249
संस्थान कार्यकलापों में राजभाषा हिन्दी	253

Mandate

1

Identify the nature and characteristics of salinity/water quality problems and areas prone to salinity development in a GIS framework

2

Undertake strategic and adaptive research to manage salinity related problems at different scales and develop options for preventing land degradation due to excess salts based on better understanding of salt and water balances

3

Develop national level network of salinity related activities and provide funding support to address location specific problems

4

Research capacity building for prevention, control and management of salinity problems



भाकृअनुप-केंद्रीय मृदा लवणता अनुसंधान संस्थान, करनाल लवण-प्रभावित मिट्टियों के पुनर्वास और प्रबंधन के लिए समर्पित प्रमुख संस्थान जिसकी स्थापना 1969 में हुई थी। अवनत क्षेत्रों में फसल उत्पादकता को बनाए रखने के लिए संस्थान ने जिप्सम-आधारित, उपसतह जल निकासी, और लवण-प्रतिरोधी फसल किस्मों के विकास सहित अन्य नवोन्मेष तकनीकों में के विकास अग्रणी भूमिका निभाई है। जिप्सम-आधारित क्षारीय मृदा पुनर्वास प्रौद्योगिकी के व्यापक प्रसार के फलस्वरूप 2.2 मिलियन हेक्टेयर से अधिक क्षारीय भूमि का सफल पुनर्वास संभव हुआ है, जिससे देश के खाद्यान्न उत्पादन में प्रतिवर्ष लगभग 17 मिलियन टन की अतिरिक्त वृद्धि हुई है। इसके अतिरिक्त, उप-सतही जल निकास के प्रभावी क्रियान्वयन के परिणामस्वरूप हरियाणा, महाराष्ट्र, गुजरात एवं कर्नाटक राज्यों में 75,000 हेक्टेयर से अधिक जलभरावग्रस्त एवं लवणीय भूमि का सफल पुनर्वास संभव हुआ है। भविष्य की आवश्यकताओं को ध्यान में रखते हुए, संस्थान ने नवीन मृदा संशोधन पदार्थों के विकास, ट्रांसजेनिक फसलों के अनुसंधान, जैव-पुनर्वास तकनीकों के उपयोग तथा डिजिटल प्रौद्योगिकियों के विकास की दिशा में कार्य कर रहा है, ताकि भूमि की उत्पादकता में वृद्धि की जा सके तथा लवण-प्रभावित क्षेत्रों का प्रभावी पुनर्वास सुनिश्चित किया जा सके। वर्ष 2025 के दौरान संस्थान ने लवण-प्रभावित मृदाओं के प्रबंधन, सिंचाई एवं भूजल की गुणवत्ता में सुधार तथा कृषि की जलवायु सहनशीलता को सुदृढ़ करने के क्षेत्र में अनेक महत्वपूर्ण वैज्ञानिक उपलब्धियाँ अर्जित कीं। इस अवधि की प्रमुख उपलब्धियों में लवण-प्रभावित मृदाओं एवं भूजल की गुणवत्ता के राष्ट्रीय मानचित्र का अतः विशेष रूप से उल्लेखनीय रहा, जिसने देश में लवणीय एवं क्षारीय क्षेत्रों की वर्तमान स्थिति का वैज्ञानिक आकलन उपलब्ध कराया। संस्थान ने लवण-प्रभावित क्षेत्रों में स्थिर एवं उच्च उत्पादकता सुनिश्चित करने के लिए गेहूँ की KRL-423 एवं KRL-1083, धान की CSR-108 तथा सरसों की CS-68 जैसी लवण-सहनशील उन्नत किस्मों का सफलतापूर्वक विकास किया गया। जैविक समाधानों के क्षेत्र में लवणीय परिस्थितियों में फसल उत्पादकता बढ़ाने हेतु अर्बस्कुलर माइक्रोराइजल कवक आधारित जैव-उद्दीपक का सफल विकास किया गया। जलवायु परिवर्तन के प्रति संवेदनशील क्षेत्रों, विशेषकर भारतीय गंगा डेल्टा, में जलवायु

The ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI), Karnal, established in 1969, is a leading institute dedicated to reclamation and sustainable management of salt-affected soils. Over the years, it has pioneered innovative technologies, including gypsum-based soil amendments, subsurface drainage systems (SSD), and the development of salt-tolerant crop varieties for sustaining crop productivity and thereby livelihood security of farmers dwelling in degraded areas. The extensive adoption of gypsum-based sodic soil reclamation has successfully reclaimed over 2.2 mha, contributing an incremental annual foodgrain production of around 17 mt. Furthermore, the implementation of SSD has led to the reclamation of more than 75,000 ha of waterlogged saline soils in the states of Haryana, Maharashtra, Gujarat, and Karnataka. Nevertheless, obstacles such as high implementation costs, a lack of awareness among farmers, and variations in site-specific soil conditions impede broader adoption. Moreover, issues related to climate change, including secondary salinization, and the inadequate scalability of technology, continue to pose significant challenges. Looking ahead, ICAR-CSSRI intends to innovate new amendment materials, develop transgenic crops, explore bioremediation techniques, and create digital tools aimed at enhancing land productivity and rehabilitating salt-affected regions.

During 2025, the Institute has made notable scientific advancements in managing salt-affected soils, water quality, and climate resilience. A major milestone was the updation of the national map of salt-affected soil and groundwater quality. The Institute strengthened crop adaptation efforts through the release of salt-tolerant varieties, including KRL-423 and KRL-1083 of wheat, CSR-108 of rice, and CS-68 in mustard. Technological innovations such as groundwater recharge filtration units and the cut-soiler-

अनुकूलन रणनीतियों को सुदृढ़ करने के लिए ग्राम-स्तरीय प्राथमिकता मानचित्रण तैयार किए गए हैं। संस्थान ने राष्ट्रीय डेयरी विकास बोर्ड तथा हरियाणा, महाराष्ट्र एवं गुजरात राज्य सरकारों के सहयोग से जलभरावग्रस्त एवं लवणीय मृदाओं में उप-सतही जल निकास प्रणाली के क्रियान्वयन संबंधी परामर्शी परियोजनाओं के माध्यम से अपने तकनीकी प्रसार एवं विस्तार कार्यक्रमों को और सुदृढ़ किया। वैकल्पिक भूमि उपयोग प्रणालियों को प्रोत्साहित करने की दिशा में चंदन के लवण-सहनशील जर्मप्लाज्म की पहचान कर कृषि विविधीकरण के नए अवसर विकसित किए गए। संस्थान ने अधोसंरचना विकास के क्षेत्र में भी महत्वपूर्ण उपलब्धियाँ अर्जित करते हुए जीनोम संपादन प्रयोगशाला, स्पीड ब्रीडिंग इकाइयों तथा ब्रैसिका फाइटोट्रॉन जैसी अत्याधुनिक अनुसंधान सुविधाओं की स्थापना की। इसके अतिरिक्त, संस्थान ने गुणवत्तायुक्त बीज उत्पादन, उच्च-स्तरीय शोध प्रकाशनों तथा राष्ट्रीय एवं अंतरराष्ट्रीय स्तर पर वैज्ञानिक सम्मान एवं मान्यताओं के क्षेत्र में उत्कृष्ट उपलब्धियाँ प्राप्त करते हुए मृदा लवणता अनुसंधान तथा सतत कृषि विकास के क्षेत्र में अपनी अग्रणी भूमिका को और सुदृढ़ किया।

इस वर्ष के दौरान संस्थान ने 12 मार्च को अपना 57वाँ स्थापना दिवस हर्षोल्लास के साथ मनाया, जिसमें भाकृअनुप के वित्तीय सलाहकार और अतिरिक्त सचिव (DARE) श्रीमती अलका नागिया अरोड़ा ने मुख्य अतिथि के रूप में अपनी गरिमामयी उपस्थिति से समारोह की शोभा बढ़ाई। संस्थान में राजभाषा हिंदी के संवर्धन एवं प्रोत्साहन के उद्देश्य से 'हिंदी पखवाड़ा' का आयोजन किया गया। इसके अतिरिक्त, कर्मचारियों, विद्यार्थियों, कृषकों तथा स्थानीय समुदाय के मध्य स्वच्छता के प्रति जागरूकता एवं जनभागीदारी को बढ़ावा देने के लिए 'स्वच्छता पखवाड़ा' का सफलतापूर्वक आयोजन किया गया।

मैं, कृषि अनुसंधान एवं शिक्षा विभाग के सचिव तथा भारतीय कृषि अनुसंधान परिषद के महानिदेशक डॉ. मांगी लाल जाट एवं भाकृअनुप के उपमहानिदेशक (प्राकृतिक संसाधन प्रबंधन) डॉ. ए. के. नायक के प्रति उनके सतत मार्गदर्शन, प्रेरणा एवं अमूल्य सहयोग के लिए अपनी हार्दिक कृतज्ञता व्यक्त करता हूँ। मैं संस्थान के समस्त प्रभागध्यक्षों एवं क्षेत्रीय अनुसंधान केंद्रों के केंद्राध्यक्ष के प्रति भी अपना विशेष आभार व्यक्त करता हूँ। साथ ही, डा. एस. के. संवाल, डा. सुरेश कुमार, डॉ. अरविंद कुमार, डॉ. सागर विभूते, डॉ. अवतार सिंह, डा. ए. के. राय, डा. सत्येन्द्र कुमार तथा श्री वाई. एस. अहलावत द्वारा वार्षिक प्रतिवेदन 2025 के संकलन, संपादन तथा समयबद्ध प्रकाशन सुनिश्चित करने में किए गए सराहनीय एवं समर्पित प्रयासों के लिए मैं उनका विशेष रूप से आभारी हूँ। अंत में, मैं अपने सभी सहयोगियों के प्रति भी हार्दिक धन्यवाद ज्ञापित करता हूँ, जिनके बहुमूल्य सहयोग, सक्रिय सहभागिता एवं समर्पण के फलस्वरूप इस वार्षिक प्रतिवेदन-2025 का समयबद्ध प्रकाशन संभव हो सका।

मुझे पूर्ण विश्वास है कि इस वार्षिक प्रतिवेदनद्वारा 2025 में समाहित जानकारी संस्थान की वर्तमान अनुसंधान एवं विकास गतिविधियों, उभरते वैज्ञानिक रुझानों तथा कृषि क्षेत्र में मृदा लवणता प्रबंधन से संबंधित चुनौतियों के संबंध में महत्वपूर्ण एवं उपयोगी जानकारी प्रदान करेगी। यह प्रतिवेदन नीति-निर्माताओं, वैज्ञानिकों, शोधार्थियों, विस्तार कार्यकर्ताओं तथा अन्य हितधारकों के लिए एक महत्वपूर्ण संदर्भ दस्तावेज सिद्ध होगा। मैं पाठकों से अपेक्षा करता हूँ कि वे इस वार्षिक प्रतिवेदन की गुणवत्ता, उपयोगिता एवं प्रभावशीलता को और अधिक सुदृढ़ बनाने के उद्देश्य से अपने बहुमूल्य सुझाव एवं रचनात्मक परामर्श प्रदान करेंगे। उनके सुझाव भविष्य में इस प्रतिवेदन को और अधिक समृद्ध, उपयोगी एवं गुणवत्तापूर्ण बनाने में सहायक सिद्ध होंगे।



राजेन्द्र कुमार यादव
निदेशक

based subsurface sodicity management system demonstrated field-level success in Haryana and Punjab. Advances in biological solutions included the development of an Arbuscular Mycorrhizal Fungi-based biostimulant, enhancing crop productivity under saline conditions. Strategic planning tools like village-level priority mapping supported climate adaptation in vulnerable regions such as the Indian Ganges Delta. The Institute also expanded its outreach through a consultancy project with NDDDB and government of Haryana, Maharashtra and Gujarat implementing subsurface drainage in waterlogged-saline soils. Diversification efforts include identification of salt-tolerant sandalwood germplasm for alternative land use systems. In the policy domain, collaborative economic impact assessments and the development of the AgrilImpactSuite software strengthened evidence-based decision-making. Infrastructure development was notable with the establishment of advanced facilities including a genome editing lab, speed breeding units, and a Brassica phytotron. The Institute also maintained strong outputs in seed production, research publications, and scientific recognition, reflecting its continued leadership in salinity research and sustainable agricultural development.

During this year, the institute celebrated its 57th Foundation Day on 12th March, Smt. Alka Arora, Additional Secretary (DARE) & Financial Advisor (ICAR) graced the occasion as Chief Guest. Activities such as *Hindi Pakhwada* were organized to promote the use of Hindi, and *Swachhhta Pakhwada* was conducted to raise awareness on cleanliness among employees, students, farmers, and the local community.

I would like to express my heartfelt gratitude to Dr. M. L. Jat, Secretary (DARE) and Director General (ICAR), and Dr. A. K. Nayak, DDG (NRM), ICAR, for their continued guidance and support. Special thanks are due to Head of Divisions and RRSs, Dr. S.K. Sanwal, Dr. A.K. Rai, Dr. Satyendra Kumar, Dr. Suresh Kumar, Dr. Arvind Kumar, Dr. Sagar Vibbute, Dr. Awtar Singh and Er. Y.S. Ahlawat for their commendable efforts in compiling, editing, and ensuring the timely printing of this Annual Report-2025. I also extend my appreciation to my colleagues for their valuable contributions, which have made it possible to publish this report on schedule.

I am certain that the information contained in this annual report will deliver important insights into the institute's current research and development activities, emerging trends, and challenges in managing salinity in agriculture. I encourage our readers to provide suggestions and feedback to enhance the quality of our annual report.



राजेन्द्र कुमार यादव
निदेशक

कार्यकारी सारांश

आईसीएआर-केन्द्रीय मृदा लवणता अनुसंधान संस्थान ने मृदा लवणता एवं भूजल गुणवत्ता संबंधी चुनौतियों के समाधान हेतु तकनीकी नवाचारों, किस्म विकास, प्रदर्शन एवं विस्तार कार्यक्रमों के माध्यम से उल्लेखनीय प्रगति की है। लवण-प्रभावित मृदाओं तथा भूजल गुणवत्ता के अद्यतन राष्ट्रीय मानचित्र तैयार किए गए। लवणीय परिस्थितियों में फसल उत्पादकता बनाए रखने के लिए अनेक लवण-सहिष्णु फसल किस्मों विकसित की गईं, जिनमें गेहूँ की KRL-423 एवं KRL-1083, धान की CSR-108 तथा सरसों की CS-68 प्रमुख हैं। बाढ़-प्रवण क्षेत्रों में भूजल पुनर्भरण को सुदृढ़ करने हेतु नव-डिजाइन किए गए भूजल पुनर्भरण निस्संदन (फिल्ट्रेशन) इकाइयों को करनाल, कैथल एवं कुरुक्षेत्र के 14 स्थलों पर स्थापित किया गया। लवणीय मृदाओं में फसल वृद्धि एवं फास्फोरस अवशोषण को बढ़ाने के लिए आर्बस्कुलर माइकोराइजल फफूंद (AMF) आधारित एक जैव-उत्तेजक (बायो-स्टिमुलेंट) विकसित किया गया। जलवायु परिवर्तन अनुकूलन रणनीतियों के मार्गदर्शन हेतु भारतीय गंगा डेल्टा क्षेत्र के लिए ग्राम-स्तरीय प्राथमिकता सूचकांक मानचित्र तैयार किया गया। हरियाणा एवं पंजाब के चयनित स्थलों पर उपसतही सोडिसिटी प्रबंधन के लिए कट-सॉइलर की प्रभावशीलता का प्रदर्शन किया गया। एन डी डी बी द्वारा वित्तपोषित परामर्श परियोजना के अंतर्गत 200 एकड़ जलभराव एवं लवणीय भूमि का रिक्लेमेशन किया गया। इसके अतिरिक्त, वैकल्पिक भूमि उपयोग के लिए लवण-सहिष्णु चंदन जर्मप्लाज्म की पहचान की गई। लवण-सहिष्णु गेहूँ की किस्मों तथा उपसतही जल निकास के आर्थिक प्रभावों को रेखांकित करने वाले दो नीतिगत शोध-पत्र प्रकाशित किए गए, जिन्होंने साक्ष्य-आधारित नीति निर्माण को समर्थन प्रदान किया। लवण-प्रभावित कृषि-पारिस्थितिकी तंत्रों की बहुआयामी चुनौतियों के समाधान हेतु प्रभागों/क्षेत्रीय अनुसंधान केन्द्रों/इकाइयों के प्रमुख अनुसंधान परिणाम नीचे प्रस्तुत किए गए हैं।

आईसीएआर-केन्द्रीय मृदा लवणता अनुसंधान संस्थान के **मृदा एवं फसल प्रबंधन प्रभाग** ने लवण-प्रभावित मृदाओं की चुनौतियों के समाधान हेतु उन्नत मृदा विशेषीकरण तकनीकों, नवीन पुनर्वास रणनीतियों, पोषक तत्व प्रबंधन, जलवायु-स्मार्ट कृषि पद्धतियों तथा सतत कृषि-वानिकी प्रणालियों के विकास में उल्लेखनीय प्रगति की है। प्रॉक्सिमल विजिबल एवं नियर-इन्फ्रारेड स्पेक्ट्रोरेडियोमेट्री का उपयोग कर मृदा नमूनों का तीव्र एवं सटीक विशेषीकरण किया गया। इस तकनीक द्वारा मृदा के पीएच मान, विद्युत चालकता, सोडियम अवशोषण अनुपात, विनिमेय सोडियम प्रतिशत, मृदा जैविक कार्बन, जिप्सम आवश्यकता तथा बनावट (Texture) जैसे गुणों का विश्वसनीय पूर्वानुमान संभव हुआ। यह तकनीक पारंपरिक प्रयोगशाला विश्लेषण की तुलना में तीव्र, गैर-विनाशकारी तथा कम लागत वाला विकल्प सिद्ध हुई। राजस्थान के वर्षा-आधारित क्षेत्रों की क्षारीय मृदाओं में बाजरा-आधारित फसल प्रणाली के अंतर्गत FGDG, RFS, रैपिड एसिडुलेटेड मैन्योर तथा सिलिशियस चॉक जैसे मृदा संशोधकों का जिप्सम के विकल्प के रूप में मूल्यांकन किया गया। इन संशोधकों की भूमि पुनर्वास क्षमता का सफलतापूर्वक परीक्षण किया गया। सूक्ष्म पोषक तत्व प्रबंधन के अंतर्गत जिंक, आयरन एवं कॉपर की नैनो-फॉर्मूलेशन विकसित की गईं, जिन्होंने पोषक तत्व उपयोग दक्षता में वृद्धि की तथा धान एवं गेहूँ के दानों के जैव-सुदृढ़ीकरण में निरंतर बेहतर प्रदर्शन प्रदर्शित किया। जलवायु परिवर्तन शमन हेतु एडी कोवेरिएंस टावर (स्थापित किया गया, जिसके माध्यम से धान-गेहूँ फसल प्रणाली में कार्बन डाइऑक्साइड प्रवाह, सकल प्राथमिक उत्पादकता तथा शुद्ध पारिस्थितिकी तंत्र विनिमय की सतत निगरानी की गई। इससे लवण-प्रभावित परिस्थितियों में कार्बन गतिकी संबंधी महत्वपूर्ण जानकारी प्राप्त हुई। जैविक नाइट्रीफिकेशन अवरोधन (Biological Nitrification Inhibition - BNI) की उत्कृष्ट पंक्तियों ने अपने मूल जनकों की तुलना में अधिक उपज तथा 7-17 प्रतिशत अधिक नाइट्रोजन अवशोषण प्रदर्शित किया। यह परिणाम नाइट्रोजन उपयोग दक्षता बढ़ाने एवं पर्यावरणीय हानियों को कम करने की दिशा में महत्वपूर्ण संभावनाएँ दर्शाते हैं। आईसीएआर-केन्द्रीय मृदा लवणता अनुसंधान संस्थान एवं खाद्य एवं कृषि संगठन (FAO) की संयुक्त परियोजना के अंतर्गत करनाल एवं कैथल जिलों के चयनित स्थलों पर आधारभूत मृदा विशेषीकरण किया गया। अध्ययन से ज्ञात हुआ कि अधिकांश मृदाएँ क्षारीय

प्रकृति की हैं तथा मृदा जैविक कार्बन एवं उपलब्ध पोषक तत्वों में मध्यम स्थानिक भिन्नता पाई जाती है। दीर्घकालिक संरक्षण कृषि प्रयोगों से यह सिद्ध हुआ कि फसल अवशेष संरक्षण के साथ शून्य जुताई गेहूँ, विशेषकर ड्रिप सिंचाई के अंतर्गत, गेहूँ की उपज में उल्लेखनीय वृद्धि करता है। विकसित फफूंदीय संघ (Fungal Consortia) आधारित सूत्रीकरण "CSR-Manage-R" द्वारा सामान्य, लवणीय एवं क्षारीय मृदाओं में धान के पुआल का 60–70 प्रतिशत अपघटन छह माह के भीतर प्राप्त किया गया। यह तकनीक खेत में अवशेष प्रबंधन के लिए प्रभावी सिद्ध हुई। जैव-उत्तेजकों पर किए गए अनुसंधान से यह प्रदर्शित हुआ कि पोषक तत्व तनाव की स्थिति में हाइड्रोपोनिक प्रणाली के अंतर्गत आर्बस्कुलर माइकोराइजल फफूंद (AMF) का सफल संवर्धन किया जा सकता है। इसके अतिरिक्त, संपीड़ित जैव-गैस (CBG) संयंत्रों से प्राप्त समृद्ध किण्वित जैविक खाद (Fermented Organic Manure - FOM) को रासायनिक उर्वरकों की कम मात्रा के साथ उपयोग करने पर फसल उत्पादकता एवं मृदा उर्वरता में उल्लेखनीय सुधार हुआ। क्षारीय मृदाओं में इसका प्रदर्शन जिप्सम की उच्च मात्रा के समकक्ष पाया गया। कृषि-वानिकी के क्षेत्र में चंदन के जीनोटाइपों में लवणता सहिष्णुता हेतु पर्याप्त आनुवंशिक विविधता की पहचान की गई। कई श्रेष्ठ जीनोटाइपों ने बेहतर आयनिक संतुलन तथा शारीरिक क्रियात्मक प्रदर्शन प्रदर्शित किया। मेजबान अनुकूलता अध्ययनों एवं व्यापक प्रसार कार्यक्रमों के माध्यम से हरियाणा के किसानों में चंदन आधारित कृषि-वानिकी को बढ़ावा दिया गया, जिससे सीमांत भूमि की उत्पादकता में सुधार की संभावनाएँ बढ़ी हैं। इसके अतिरिक्त, प्रोसोपिस, विलो तथा अन्य उच्च-मूल्य वृक्ष प्रजातियों के आशाजनक जीनोटाइपों का भी लवण-प्रभावित परिस्थितियों में मूल्यांकन किया गया।

फसल सुधार प्रभाग ने लवण-प्रभावित मृदाओं में कृषि उत्पादकता बढ़ाने के उद्देश्य से लवण-सहिष्णु किस्मों एवं प्रजनन तकनीकों के विकास में उल्लेखनीय प्रगति की है। इस दिशा में एक प्रमुख उपलब्धि दो लवण-सहिष्णु धान किस्मों, CSR 108 एवं CSR 64, किस्में विकसित की गईं। CSR 108 को उच्च उपज क्षमता तथा लवणता एवं क्षारीयता दोनों के प्रति सहिष्णुता के साथ विकसित किया गया है। इसने क्षारीय परिस्थितियों में औसतन 3819 किग्रा/हेक्टेयर उपज दर्ज की, जो CSR 10 की तुलना में 38 प्रतिशत अधिक थी। इसी प्रकार, लवणीय परिस्थितियों में इसकी औसत उपज 4472 किग्रा/हेक्टेयर रही, जो CSR 10 की तुलना में 52 प्रतिशत अधिक थी। एक अन्य महत्वपूर्ण उपलब्धि CSR 64 की अधिसूचना रही, जो एक प्रीमियम गुणवत्ता वाली लवण-सहिष्णु बासमती धान किस्म है। इसने उत्तर प्रदेश की क्षारीय मृदाओं में लगातार उत्कृष्ट प्रदर्शन किया तथा 36 की तुलना में 5.7 प्रतिशत, बासमती CSR 30 की तुलना में 16.6 प्रतिशत तथा अन्य किस्मों की तुलना में लगभग 10 प्रतिशत अधिक उपज प्रदान की। CS 68 सरसों किस्म की पहचान 10–13 डेसीसीमेंस प्रति मीटर विद्युत चालकता (EC_e/EC_{wv}) तथा 9.0–9.4 पीएच मान वाली लवणीय एवं क्षारीय परिस्थितियों में खेती के लिए की गई। इसकी उपज क्षमता लवणीय तनाव की स्थिति में 22–24 क्विंटल/हेक्टेयर तथा सामान्य मृदाओं में 26–30 क्विंटल/हेक्टेयर पाई गई। यह किस्म अल्टरनेरिया ब्लाइट, श्वेत रतुआ, चूर्णिल आसिता (पाउडरी मिल्ड्यू), डाउनी मिल्ड्यू तथा माहू जैसे प्रमुख रोगों एवं कीटों के प्रति प्रतिरोधी है। गेहूँ में संयुक्त रतुआ प्रतिरोध वाली आशाजनक प्रविष्टि KRL 2402 को राष्ट्रीय एवं राज्य स्तरीय लवणता परीक्षणों के लिए प्रोत्साहित किया गया। चना एवं मसूर में व्यापक जर्मप्लाज्म संग्रहों का मूल्यांकन किया गया तथा लवणीय परिस्थितियों में बेहतर उपज, अधिक फली संख्या, उच्च बीज भार तथा अनुकूल आयनिक संतुलन (कम Na^+ एवं अधिक K^+) वाले श्रेष्ठ दाताओं की पहचान की गई। इसके अतिरिक्त, नव-अधिसूचित CSR 108 एवं CSR 64 सहित विभिन्न लवण-सहिष्णु धान किस्मों के 26.25 क्विंटल प्रजनक बीज का उत्पादन किया गया, जिससे इन किस्मों के व्यापक प्रसार हेतु समय पर गुणवत्तायुक्त बीज उपलब्ध कराना सुनिश्चित हुआ।

आईसीएआर-केन्द्रीय मृदा लवणता अनुसंधान संस्थान के **सिंचाई एवं जल निकास अभियांत्रिकी प्रभाग** ने लवणता प्रबंधन, जल संरक्षण तथा लवण-प्रभावित क्षेत्रों के लिए स्मार्ट सिंचाई तकनीकों के विकास में महत्वपूर्ण उपलब्धियाँ प्राप्त की हैं। DRAINMOD मॉडल का अंशांकन (Calibration) एवं सत्यापन (Validation) जल-स्तर गहराई तथा मृदा लवणता के पूर्वानुमान के लिए सफलतापूर्वक किया गया, जिसमें क्रमशः 0.95 एवं 0.86 के उच्च R^2 मान प्राप्त

हुए। मॉडल के अनुसार, पश्चिमी यमुना नहर कमांड क्षेत्र में प्रतिवर्ष लगभग 1,819 टन लवण सुरक्षित रूप से निकाला जा सकता है। लवण-प्रभावित मृदाओं के लिए कम लागत वाला सेंसर एवं इंटरनेट ऑफ थिंग्स (IoT) आधारित सिंचाई तंत्र विकसित किया गया। यह प्रणाली मृदा की विद्युत प्रतिरोधकता (Electrical Resistivity) के आधार पर नमी की निगरानी करती है। मृदा आद्रता बढ़ने के साथ सेंसर का आउटपुट 720 से बढ़कर 1295 उट तक पहुँच गया, जिससे वास्तविक समय (Real-time) में सटीक सिंचाई निर्धारण संभव हुआ। उपसतही जल निकास प्रणाली की स्थापना से पुनः प्राप्त (Reclaimed) लवणीय मृदाओं में उल्लेखनीय सुधार देखा गया। धान-गेहूँ फसल प्रणाली में सतही मृदा लवणता में लगभग 40 प्रतिशत की कमी दर्ज की गई तथा भूजल की विद्युत चालकता 16.07 से घटकर 5.38 डेसीसीमेंस प्रति मीटर हो गई। प्लांट डायरेक्ट परियोजना के अंतर्गत आशाजनक धान पंक्ति IR22EL1055 ने 5.09 टन/हेक्टेयर की उपज प्राप्त की तथा 33–50 प्रतिशत सिंचाई जल की बचत की। सिमुलेशन अध्ययनों से यह भी स्पष्ट हुआ कि दीर्घावधि धान की अपेक्षा अल्पावधि प्रत्यक्ष बुवाई धान अपनाने से दस वर्षों में भूजल स्तर में होने वाली गिरावट को 3 मीटर तक कम किया जा सकता है। HIROS परियोजना के अंतर्गत गन्ने में ड्रिप सिंचाई एवं अनुकूलित उर्वरक प्रबंधन के संयोजन से जल उत्पादकता बढ़कर 29.4 किलोग्राम प्रति घन मीटर (kg m^{-3}) हो गई तथा नाइट्रोजन उपयोग दक्षता में भी वृद्धि हुई। इन तकनीकों से 21–26 प्रतिशत जल की बचत हुई तथा उपज में 12–38 प्रतिशत तक वृद्धि दर्ज की गई।

सामाजिक विज्ञान अनुसंधान प्रभाग द्वारा लवण-सहिष्णु गेहूँ किस्मों के आर्थिक प्रभाव का आकलन किया गया। अध्ययन के परिणामों से स्पष्ट हुआ कि लवण-प्रभावित मृदाओं में इन किस्मों से उल्लेखनीय उपज वृद्धि प्राप्त होती है। पीएच मान 8.5 से अधिक वाली क्षारीय मृदाओं में लवण-सहिष्णु गेहूँ किस्मों ने गैर-लवण-सहिष्णु किस्मों की तुलना में औसतन 11.80 प्रतिशत अधिक उपज प्रदान की, जबकि विद्युत चालकता (EC_e) 4 डेसीसीमेंस प्रति मीटर से अधिक वाली लवणीय मृदाओं में यह लाभ 24.30 प्रतिशत तक दर्ज किया गया। सोडिक एवं लवणीय क्षेत्रों के क्षेत्रफल को भार (Weight) के रूप में शामिल करते हुए औसत भारित उपज वृद्धि 14.82 प्रतिशत आंकी गई। अध्ययन के अनुसार लवण-सहिष्णु गेहूँ किस्मों की वर्तमान अनुमानित स्वीकृति 9.77 प्रतिशत है। आर्थिक अधिशेष (Economic Surplus) मॉडल के आधार पर वर्ष 2012 से 2024 के दौरान सामान्य परिदृश्य (Business-as-Usual Scenario) में कुल आर्थिक अधिशेष 58,170 मिलियन रुपये (वार्षिक औसत 4,474.6 मिलियन रुपये) आंका गया, जिसमें 22,850 मिलियन रुपये उपभोक्ता अधिशेष तथा 35,320 मिलियन रुपये उत्पादक अधिशेष शामिल हैं। वर्ष 2030 तक के अनुमानों के अनुसार, सामान्य परिदृश्य में कुल आर्थिक अधिशेष 259,000 मिलियन रुपये तथा आशावादी परिदृश्य (Optimistic Scenario) में 278,050 मिलियन रुपये तक पहुँच सकता है। ये परिणाम दर्शाते हैं कि लवण-सहिष्णु गेहूँ किस्मों में लवण-प्रभावित क्षेत्रों की उत्पादकता एवं कृषकों की आय बढ़ाने की अत्यधिक क्षमता विद्यमान है। नीतिगत सुझावों में स्पीड ब्रीडिंग एवं जीन संपादन जैसी उन्नत तकनीकों के माध्यम से प्रजनन कार्यक्रमों को गति देना, गुजरात जैसे विशिष्ट क्षेत्रों के लिए उपयुक्त किस्मों का विकास, बहु-तनाव सहिष्णुता एवं जैव-सुदृढ़ीकरण (Biofortification) गुणों का समावेश, सार्वजनिक-निजी भागीदारी (Public-Private Partnership) के माध्यम से बीज आपूर्ति तंत्र को सुदृढ़ करना तथा मृदा स्वास्थ्य कार्डों के आधार पर किस्मों की अनुशंसा को बढ़ावा देना शामिल है। हरियाणा के जलभरावयुक्त एवं लवणीय कृषि-पारिस्थितिकी तंत्रों में संचालित फार्मर फर्स्ट परियोजना के अंतर्गत उपसतही जल निकास प्रणाली की स्थापना से फसल प्रदर्शन में उल्लेखनीय सुधार देखा गया। गेहूँ में लवण-सहिष्णु किस्म झत्स-210 ने उपसतही जल निकास प्रणाली द्वारा पुनर्वासित खेतों में औसतन 56.25 क्विंटल/हेक्टेयर अनाज उपज प्राप्त की, जो नियंत्रण किस्म भ्व-2967 की तुलना में 9.22 प्रतिशत अधिक थी। धान में भी उन्नत किस्मों ने उपसतही जल निकास प्रणाली परिस्थितियों में स्थानीय प्रचलित किस्मों की तुलना में बेहतर प्रदर्शन किया। इनमें PB 1692 ने सर्वाधिक 57.20 क्विंटल/हेक्टेयर उपज दर्ज की, जो अन्य प्रचलित किस्मों की तुलना में 34.58 प्रतिशत अधिक थी। ये प्रदर्शन स्पष्ट रूप से दर्शाते हैं कि उपसतही जल निकास प्रणाली आधारित भूमि पुनर्वास तथा उपयुक्त लवण-सहिष्णु किस्मों का संयुक्त उपयोग जलभरावयुक्त एवं लवणीय क्षेत्रों की उत्पादकता में उल्लेखनीय वृद्धि कर सकता है।

आईसीएआर-केन्द्रीय मृदा लवणता अनुसंधान संस्थान के **क्षेत्रीय अनुसंधान केंद्र, भरुच** ने गुजरात की लवणीय वर्टिसोल मृदाओं में लवणीय भूजल सिंचाई के अंतर्गत फसल उत्पादकता बढ़ाने हेतु महत्वपूर्ण उपलब्धियाँ प्राप्त की हैं। लवण-सहिष्णु सरसों किस्मों का मूल्यांकन किया गया, जिसमें CS 62 ने सर्वाधिक 8.96 क्विंटल/हेक्टेयर बीज उपज दर्ज की। इसके बाद CS 61 (8.71 क्विंटल/हेक्टेयर) तथा CS 58 (8.60 क्विंटल/हेक्टेयर) का स्थान रहा। सभी लवण-सहिष्णु किस्मों ने स्थानीय किस्म GDM-4 (5.12 क्विंटल/हेक्टेयर) की तुलना में बेहतर प्रदर्शन किया। इन किस्मों में बेहतर वृद्धि, प्रति पौधा अधिक फलियाँ, उच्च हार्वैस्ट इंडेक्स तथा गुणवत्तापूर्ण विशेषताएँ पाई गईं। विशेष रूप से CS 61 में अधिक तेलांश तथा कम एरुसिक अम्ल पाया गया। रोपण विधियों एवं ज्यामितीय विन्यासों के अध्ययन में फरो इरिगेटेड रेज्ड बेड (FIRB) प्रणाली, जिसमें 60 सेमी चौड़ी क्यारी पर 30 सेमी की दूरी पर दो कतारें लगाई गईं, ने सर्वाधिक 9.81 क्विंटल/हेक्टेयर बीज उपज प्रदान की। इसी प्रकार, 90 सेमी दूरी पर मेड़ एवं नाली पद्धति द्वारा बुवाई करने से बेहतर जड़ क्षेत्र वातन (Aeration), कम लवणीय तनाव, अधिक शाखाएँ, प्रति पौधा अधिक फलियाँ तथा उच्च परीक्षण भार प्राप्त हुआ। ड्रैगन फ्रूट पर किए गए क्षेत्रीय प्रयोगों से यह स्पष्ट हुआ कि बढ़ते लवणता स्तर (विद्युत चालकता 9 डेसीसीमेंस प्रति मीटर तक) का विभिन्न किस्मों की वृद्धि एवं संरचनात्मक गुणों पर प्रतिकूल प्रभाव पड़ता है। हालाँकि, जंबो रेड किस्म ने लवणीय परिस्थितियों में बेहतर अनुकूलन क्षमता एवं सशक्त वृद्धि प्रदर्शित की। जैव-उत्तेजक के रूप में समुद्री शैवाल अर्क के प्रयोग से लवणीय तनाव के प्रभाव को कम किया गया तथा पौधों की ऊँचाई एवं छत्र विस्तार (Canopy Spread) में वृद्धि हुई। इसके अतिरिक्त, ह्यूमिक अम्ल के प्रयोग से कांटों की चौड़ाई, घनत्व एवं एरिओल दूरी में सुधार हुआ, जिससे लवणीय सिंचाई जल के साथ सफल खेती संभव हुई। भूमि उपयोग प्रणालियों पर किए गए अध्ययनों ने कार्बन अवशोषण तथा लवणीय वर्टिसोल मृदाओं के सुधार में कृषि-वानिकी की महत्वपूर्ण भूमिका को रेखांकित किया। बबूल के अंतर्गत 0-15 सेमी गहराई पर सर्वाधिक 1.28 प्रतिशत मृदा जैविक कार्बन दर्ज किया गया, जबकि यूकेलिप्टस ने सर्वाधिक 2482.6 टन/हेक्टेयर जैवभार उत्पन्न किया। इन पुनर्स्थापनात्मक प्रणालियों ने न केवल मृदा जैविक कार्बन में वृद्धि की बल्कि मृदा की भौतिक गुणवत्ता में सुधार करते हुए दरार बनने की प्रवृत्ति को भी कम किया। साथ ही, इन प्रणालियों में कार्बन क्रेडिट प्राप्त करने की भी पर्याप्त संभावनाएँ पाई गईं। साबरमती आश्रम गौशाला में किए गए विस्तृत मृदा विश्लेषण से यह पुष्टि हुई कि लम्बे समय तक लवणीय भूजल के उपयोग के कारण मृदा में गंभीर लवणीकरण एवं क्षारीयता विकसित हो गई है। यहाँ मृदा की विद्युत चालकता 45.57 डेसीसीमेंस प्रति मीटर तथा सोडियम अवशोषण अनुपात 48.38 तक दर्ज किया गया, जिसके परिणामस्वरूप चारे की उत्पादकता में कमी आई। गेहूँ के आनुवंशिक सुधार कार्यक्रम के अंतर्गत KRL 2310, KRL 99, KRL 1803 एवं SPLASN 23 जैसे आशाजनक जीनोटाइपों की पहचान की गई, जिन्होंने लवणीय वर्टिसोल मृदाओं (EC_e 6-7 डेसीसीमेंस प्रति मीटर) में अनाज उपज, जैवभार उत्पादन तथा फसल अवधि संबंधी गुणों में उत्कृष्ट प्रदर्शन किया। मक्का में विभिन्न लवणता स्तरों (0, 6 एवं 9 डेसीसीमेंस प्रति मीटर) पर किए गए परीक्षणों में IIMR4 तथा IIMR9 जीनोटाइपों ने तनाव की परिस्थितियों में भी अपेक्षाकृत अधिक भुट्टा एवं दाना उपज बनाए रखी, जिससे उनकी लवणीय परिस्थितियों में खेती की संभावनाएँ उजागर हुईं।

आईसीएआर-केन्द्रीय मृदा लवणता अनुसंधान संस्थान, **क्षेत्रीय अनुसंधान केंद्र, लखनऊ** ने क्षारीय मृदाओं की चुनौतियों के समाधान हेतु नवीन पुनर्वास रणनीतियों, संसाधन-कुशल फसल प्रणालियों तथा सतत उत्पादन तकनीकों के विकास में उल्लेखनीय प्रगति की है। उप-मृदा सोडिसिटी के सल्फामिक अम्ल आधारित प्रबंधन के अंतर्गत सतह पर 12.5 जीआर सल्फामिक अम्ल तथा उप-सतह में 25 जीआर सल्फामिक अम्ल के संयुक्त प्रयोग से गेहूँ की सर्वाधिक 5.39 टन/हेक्टेयर उपज प्राप्त हुई। यह परिणाम समुद्री जिप्सम एवं सल्फामिक अम्ल के संयुक्त उपयोग के समान पाया गया। अत्यधिक क्षारीय एवं अवनत क्षारीय मृदाओं (पीएच मान > 9.9) में 50 जीआर सल्फामिक अम्ल अथवा पयूमंड सल्फामिक अम्ल के सतही प्रयोग से मृदा का पीएच मान घटकर 8.64 तक तथा विनिमेय सोडियम प्रतिशत 60.09 से घटकर 35.14 तक आ गया। विजिबल-नियर इन्फ्रारेड स्पेक्ट्रोस्कोपी के अंतर्गत हरदोई, उन्नाव एवं लखनऊ जिलों से संकलित 73 भारी बनावट वाली क्षारीय मृदा नमूनों का विश्लेषण किया गया। अध्ययन में

975–1010 नैनोमीटर तथा 2200–2500 नैनोमीटर तरंगदैर्घ्य क्षेत्रों में विशिष्ट स्पेक्ट्रल संकेत प्राप्त हुए, जिन्होंने बहुविविध मॉडलिंग के माध्यम से पीएच मान, विद्युत चालकता एवं विनिमय सोडियम प्रतिशत जैसे क्षारीय मानकों के तीव्र एवं गैर-विनाशकारी आकलन की संभावनाएँ प्रदर्शित कीं। लो-बजट प्राकृतिक खेती के अंतर्गत गेहूँ की उपज केवल 9.8–14.9 क्विंटल/हेक्टेयर रही, जबकि रासायनिक आदानों पर आधारित प्रबंधन में यह 31.8 क्विंटल/हेक्टेयर दर्ज की गई। अधिकांश प्राकृतिक खेती उपचारों में उपलब्ध नाइट्रोजन तथा डिहाइड्रोजनेज एंजाइम गतिविधि में भी कमी पाई गई। शारदा सहायक नहर कमांड क्षेत्र के पाँच जिलों में क्षारीय मृदाओं का कुल विस्तार 87,147 हेक्टेयर (भौगोलिक क्षेत्रफल का 5.33 प्रतिशत) पाया गया, जिससे लक्षित पुनर्वास योजनाओं के लिए महत्वपूर्ण आधारभूत जानकारी प्राप्त हुई। बिहार की कैल्केरियस क्षारीय मृदाओं में किए गए इनक्यूबेशन अध्ययनों से यह पुष्टि हुई कि प्रथम एवं द्वितीय क्रम दर समीकरणों के एकीकृत मॉडल तथा एलोविच मॉडल (Elovich Model), प्राकृतिक कैल्शियम कार्बोनेट के घुलनशीलन की गतिज प्रक्रियाओं का सर्वाधिक उपयुक्त वर्णन करते हैं। बैसिलस प्यूमिलस, बैसिलस ऑस्ट्रेलिमैरिस, बैसिलस टकीलेंसिस तथा नियालिया सर्कुलांस जैसे आशाजनक हैलोफिलिक जीवाणुओं की पहचान एवं विशेषीकरण किया गया। इनके आधार पर "Halo-Cal-D" नामक जैव-उत्पाद विकसित किया गया, जिसकी भंडारण अवधि 360 दिन है। यह उत्पाद खेत में ही CaCO_3 के घुलनशीलन तथा मृदा के स्व-पुनर्वास (Self-Reclamation) में सहायक सिद्ध हुआ। कृषक खेतों पर किए गए प्रदर्शनों में लवण-सहिष्णु धान किस्मों, विशेषकर CSR 46, ने हरी खाद एवं Halo-Mix समृद्ध जैविक खाद के साथ पारंपरिक किस्मों की तुलना में 23 प्रतिशत से अधिक अतिरिक्त अनाज उपज प्रदान की। विविधीकृत फसल प्रणालियों के मूल्यांकन में बाजरा (मेड़ पर), ढ़ैंचा (नाली में) ब्राउन मैन्योर दू तोरिया दू सूरजमुखी (CS7) प्रणाली सर्वाधिक उत्पादक पाई गई। इस प्रणाली ने 9.03 टन/हेक्टेयर धान समतुल्य उपज (Rice Equivalent Yield - REY) प्राप्त की, जो पारंपरिक धान-गेहूँ प्रणाली की तुलना में 44 प्रतिशत अधिक थी। फल फसलों में खुनेजी खजूर किस्म ने उच्च पीएच मान (9–10) की परिस्थितियों में सर्वश्रेष्ठ प्रदर्शन किया। वहीं ओपन फील्ड पेडोपोनिक्स प्लांटिंग सिस्टम (OFPP) के अंतर्गत पॉलीथीन बैगों में मृदारूरेतरुगोबर खाद (1:1:1) अथवा मृदारूकोकोपीटरुगोबर खाद माध्यम का उपयोग करने से अमरुद, नींबू एवं सीताफल जैसी उथली जड़ वाली फल फसलों की जीवितता एवं वृद्धि में उल्लेखनीय सुधार हुआ। ड्रैगन फ्रूट में कोकोपीट आधारित माध्यम के साथ छ्च्छ प्रणाली के उपयोग से पौधों की ऊँचाई, क्लैडोड लंबाई, छत्र विस्तार तथा फल उपज में सर्वश्रेष्ठ परिणाम प्राप्त हुए। समेकित कृषि प्रणाली मॉडलों ने पारंपरिक धान-गेहूँ प्रणाली की तुलना में अधिक आर्थिक लाभ प्रदान किया। मत्स्यदृफसलदृउद्यानिकी आधारित मॉडल से 6000 वर्गमीटर क्षेत्र में 1,02,725 रुपये की आय प्राप्त हुई, जबकि समान क्षेत्रफल के नियंत्रण प्लॉट से केवल 41,705 रुपये की आय हुई। हरदोई जिले में 1064 कृषक खेतों पर किए गए प्रदर्शनों में CSR-36, CSR-46, Halo-Mix, समुद्री जिप्सम तथा Halo-Cal-D जैसी तकनीकों का सफल सत्यापन किया गया। इन हस्तक्षेपों से उपज में उल्लेखनीय वृद्धि तथा मृदा pH में कमी दर्ज की गई।

आईसीएआर-केन्द्रीय मृदा लवणता अनुसंधान संस्थान, **क्षेत्रीय अनुसंधान केंद्र, कैनिंग टाउन** ने पश्चिम बंगाल के संवेदनशील सुंदरबन पारिस्थितिकी तंत्र में तटीय लवणता, जलवायु परिवर्तन तथा आजीविका सुरक्षा की चुनौतियों के समाधान हेतु उल्लेखनीय प्रगति की है। लवण-सहिष्णु धान किस्म कैनिंग-7 ने सर्वाधिक 3.69 टन/हेक्टेयर अनाज उपज दर्ज की तथा लवणीय सिंचाई जल (ECiw 4 एवं 6 डेसीसीमेंस प्रति मीटर) की परिस्थितियों में मध्यम सहिष्णु किस्म सादा मिनीकिट एवं संवेदनशील किस्म BPT 5024 की तुलना में बेहतर सहनशीलता एवं स्थिरता प्रदर्शित की। एफएओ एक्वाक्रॉप मॉडल का सफलतापूर्वक सत्यापन किया गया, जिसमें वास्तविक एवं अनुकरणित (Simulated) उपज के मध्य उच्च सहसंबंध प्राप्त हुआ (अनाज उपज के लिए $R^2 = 0.91$ तथा जैवभार के लिए $R^2 = 0.92$)। इस मॉडल ने बदलती जलवायु एवं लवणता परिस्थितियों में भविष्य की धान उत्पादकता के विश्वसनीय पूर्वानुमान की क्षमता प्रदर्शित की। लो-बजट प्राकृतिक खेती के अंतर्गत किए गए परीक्षणों में शून्य जुताई (Zero Tillage) के साथ फसल अवशेष संरक्षण से 4.73 टन/हेक्टेयर तथा ढ़ैंचा समावेशन से 4.71 टन/हेक्टेयर धान उपज प्राप्त हुई, जो कृषकों की पारंपरिक पद्धति (3.01 टन/हेक्टेयर) के

समान अथवा उससे अधिक थी। यह उपलब्धि बिना किसी बाह्य पोषक तत्व के प्रयोग के प्राप्त हुई। साथ ही, समेकित एवं प्राकृतिक खेती प्रणालियों में मृदा जैविक कार्बन, उपलब्ध पोषक तत्वों तथा सूक्ष्मजीवी गतिविधियों में भी सुधार देखा गया। धान-भिंडी फसल प्रणाली में बायोचार के उपयोग संबंधी अध्ययनों से सकारात्मक परिणाम प्राप्त हुए। एक प्रतिशत बायोचार प्रयोग से प्रति रिंग 1.341 किलोग्राम भिंडी उपज प्राप्त हुई, जो सर्वाधिक थी। इसके अतिरिक्त, बिना बायोचार वाले उपचार की तुलना में फसल कटाई के बाद मृदा की विद्युत चालकता भी कम पाई गई। इससे तटीय लवणता प्रबंधन में बायोचार की उपयोगिता सिद्ध हुई। शून्य जुताई आलू में ड्रिप सिंचाई एवं भूसा मल्लिंग के साथ निम्न गुणवत्ता वाले जल के संयुक्त उपयोग का अध्ययन अत्यंत प्रभावी सिद्ध हुआ। अच्छी गुणवत्ता वाले जल एवं IW/CPE 0.5 अनुपात पर 25.2 टन/हेक्टेयर कंद उपज तथा 34.9 किलोग्राम प्रति घन मीटर जल उत्पादकता प्राप्त हुई, जो सर्वाधिक थी। मतला मुहाना में किए गए मत्स्य जीव विविधता अध्ययनों में कुल 57 मछली प्रजातियों का दस्तावेजीकरण किया गया। इसमें मांसाहारी मछलियाँ खाद्य शृंखला में प्रमुख पाई गईं तथा क्रोकर को एक प्रमुख आधारभूत प्रजाति के रूप में चिन्हित किया गया। लघु देशी मछली हेटेरोपन्यूस्टेस फॉसिलिस (सिंधी) को भारतीय प्रमुख कार्प मछलियों (Indian Major Carps) के साथ उपयुक्त घनत्व पर एकीकृत करने से तालाब उत्पादकता में उल्लेखनीय वृद्धि हुई। इस प्रणाली में 3502 किलोग्राम/हेक्टेयर भारतीय प्रमुख कार्प तथा 273.6 किलोग्राम/हेक्टेयर सिंधी उत्पादन प्राप्त हुआ। इससे ₹2,38,150 प्रति हेक्टेयर की शुद्ध आय तथा 58 प्रतिशत लाभप्रदता दर्ज की गई। क्षेत्र की आजीविका सुरक्षा का आकलन करने हेतु पर्यावरणीय, आर्थिक एवं सामाजिक आयामों से संबंधित 23 संकेतकों पर आधारित आजीविका प्रत्यास्थता सूचकांक विकसित किया गया। संकेतकों को वस्तुनिष्ठ भार प्रदान करने के लिए एंटरॉपी वेट विधि का उपयोग किया गया। अध्ययन में आजीविका प्रत्यास्थता सूचकांक का औसत मान 0.340 तथा मानक विचलन 0.068 पाया गया, जो क्षेत्र में मध्यम स्तर की विविधता को दर्शाता है। समेकित कृषि प्रणाली को बढ़ावा देने हेतु भूमि आकारिकी तकनीक (Land Shaping Technology) का किसानों के बीच प्रसार किया गया। साथ ही, संसाधन उपयोग दक्षता बढ़ाने के लिए कम लागत वाली बायोचार उत्पादन तकनीक तथा जल प्रबंधन रणनीतियाँ विकसित की गईं। क्षमता निर्माण कार्यक्रमों के अंतर्गत प्रशिक्षण एवं प्रदर्शन गतिविधियों के माध्यम से 775 से अधिक किसानों तक वैज्ञानिक तकनीकों का सफल प्रसार किया गया, जिससे तटीय लवणीय क्षेत्रों में सतत कृषि एवं आजीविका सुरक्षा को बढ़ावा मिला।

कृषि में लवणीय जल प्रबंधन एवं उससे संबंधित लवणीकरण पर अखिल भारतीय समन्वित अनुसंधान परियोजना के अंतर्गत देश के विभिन्न कृषि-पारिस्थितिकीय क्षेत्रों में किए गए सर्वेक्षणों एवं क्षेत्रीय प्रयोगों से महत्वपूर्ण वैज्ञानिक निष्कर्ष प्राप्त हुए हैं। इन अध्ययनों ने लवणीय एवं क्षारीय जल प्रबंधन तथा मृदा लवणीकरण नियंत्रण के लिए उपयोगी तकनीकी जानकारीयों प्रदान की हैं। भूजल गुणवत्ता के व्यापक आकलन से विभिन्न क्षेत्रों में लवणता एवं क्षारीयता की भिन्न-भिन्न स्तरों की समस्याएँ उजागर हुईं। मध्य प्रदेश के शाजापुर जिले में दूरसंवेदी तकनीक (Remote Sensing) एवं स्थल सत्यापन (Ground Truthing) के माध्यम से लवण-प्रभावित मृदाओं की संसाधन सूची तैयार की गई। अध्ययन से कुछ स्थानों पर क्षारीयता की उपस्थिति की पुष्टि हुई, जहाँ मृदा का पीएच मान (pH_e) मान 7.38 से 8.43 के बीच तथा विनिमय सोडियम प्रतिशत का स्तर विभिन्न श्रेणियों में पाया गया। आगरा में तिलदृमसूर फसल क्रम के अंतर्गत क्षारीय जल एवं नहर जल के संयुक्त उपयोग पर किए गए अध्ययनों से यह पाया गया कि दोनों जल स्रोतों का वैकल्पिक उपयोग अथवा 1:1 अनुपात में मिश्रण करने पर प्राप्त उपज केवल नहर जल के उपयोग के समान रही। उच्च अवशिष्ट सोडियम कार्बोनेट (RSC) वाले क्षारीय जल में जिप्सम का प्रयोग कर RSC को 2.5 me L⁻¹ तक कम करने से तिल की वृद्धि एवं उपज में उल्लेखनीय सुधार हुआ। ड्रिप सिंचाई के अंतर्गत भिंडी फसल में वर्षा जल संचयन से प्राप्त जल तथा जिप्सम-उपचारित नलकूप जल को 1:1 अनुपात में मिलाकर उपयोग करने पर पौध वृद्धि एवं उपज के सर्वश्रेष्ठ परिणाम प्राप्त हुए। लवणीय जल प्रबंधन संबंधी परीक्षणों से यह सिद्ध हुआ कि ड्रिप सिंचाई एवं फर्टिगेशन लवणीय परिस्थितियों में प्रभावी विकल्प हैं। मक्का में 4 डेसीसीमेंस प्रति मीटर तक की लवणता वाले जल का अच्छी गुणवत्ता वाले जल के साथ वैकल्पिक उपयोग करने पर उपज सर्वोत्तम गुणवत्ता वाले जल से प्राप्त उपज के लगभग समान

रही। समेकित पोषक तत्व प्रबंधन के अंतर्गत ग्लोमस मोसी नामक माइकोराइजा कवक के उपयोग से उच्च लवणता (EC_e 8 डेसीसीमेंस प्रति मीटर) की परिस्थितियों में कपास-गेहूँ फसल प्रणाली में उपज हानि को प्रभावी रूप से कम किया गया। सिंचाई जनित लवणीकरण की समस्या के समाधान हेतु सोडिक वर्टिसोल मृदाओं में जिप्सम एवं ग्लिरिसिडिया सेपियम के संयुक्त उपयोग का मूल्यांकन किया गया। धानदृगेहूँ प्रणाली में इस समेकित प्रबंधन से मृदा गुणों एवं फसल उत्पादकता में सुधार पाया गया। साथ ही, केवल ग्लिरिसिडिया का उपयोग भी कम लागत वाला एवं पर्यावरण-अनुकूल विकल्प सिद्ध हुआ। तुंगभद्रा परियोजना कमांड क्षेत्र की जलभरावयुक्त एवं लवणीय वर्टिसोल मृदाओं में नियंत्रित उपसतही जल निकास प्रणाली अत्यंत प्रभावी पाई गई। इस तकनीक ने निकास जल की मात्रा को कम किया, पोषक तत्वों के संरक्षण में सहायता की तथा नाइट्रोजन हानि को न्यूनतम रखते हुए धान की अच्छी उपज सुनिश्चित की। केरल की लवणीय-अम्लीय पोक्कली मृदाओं (Pokkali Soils) में मेड़/टीला आधारित रोपाई तथा धान की भूसी की राख एवं डोलोमाइट जैसे संशोधकों के उपयोग से धान की स्थापना, वृद्धि एवं उपज में उल्लेखनीय सुधार प्राप्त हुआ।

पुरस्कार और सम्मान

डॉ. एस.के. सनवाल को बागवानी (सब्जी विज्ञान) के क्षेत्र में इंडियन एकेडमी ऑफ हॉर्टिकल्चरल साइंसेज-2025 का फेलो और इंडियन सोसाइटी ऑफ सॉइल सेलिनीटी एंड वॉटर क्वालिटी-2023-24 का फेलो चुना गया। डॉ. कैलाश प्रजापत को इंटरनेशनल सेलिनीटी कॉन्फ्रेंस 3.0 में इंडियन सोसाइटी ऑफ सॉइल सेलिनीटी एंड वॉटर क्वालिटी की ओर से यंग साइंटिस्ट अवार्ड से सम्मानित किया गया। डॉ. अजय भारद्वाज को NAAS का फेलो और सोसाइटी फॉर एडवांसमेंट ऑफ व्हीट एंड बार्ली रिसर्च का फेलो चुना गया। डॉ. संजय अरोड़ा को लवण मृदा के प्रबंधन में बेहतरीन योगदान के लिए CSSRI एक्सीलेंस अवार्ड और ब्रिटिश इकोलॉजिकल सोसाइटी की फेलोशिप से सम्मानित किया गया।

सम्मेलन/कार्यशालाओं का आयोजन

- ICAR-CCARI, गोवा में खेती में खारे पानी और उससे जुड़ी खारेपन की समस्या के प्रबंधन पर 29वीं AICRP द्विवार्षिक कार्यशाला 2023-2024 आयोजित की गई।
- ICAR-CCARI, गोवा में 29 अक्टूबर से 01 नवंबर, 2025 के दौरान इंडियन सोसाइटी ऑफ सॉइल सैलिनीटी एंड वॉटर क्वालिटी के सहयोग से इंटरनेशनल सैलिनीटी कॉन्फ्रेंस 3.0 (WE-CARE-2025): लवण इकोसिस्टम को बहाल करने के लिए अत्याधुनिक तरीकों पर वैश्विक प्रयास का आयोजन किया गया।

प्रदर्शनी और क्षेत्रीय दौरे

2025 के दौरान, भारत और विदेश से 805 किसानों, 1690 छात्रों, 125 प्रशिक्षुओं, 15 विस्तार कार्यकर्ताओं और 10 वैज्ञानिकों सहित कुल 2645 हितधारकों ने संस्थान के प्रौद्योगिकी सूचना केंद्र और प्रायोगिक फार्मों का दौरा किया और व्यावसायीकृत और विकसित की जा रही तकनीकों के बारे में जानकारी प्राप्त की।

किसान परामर्श सेवाएँ

वर्ष 2025 के दौरान, टोल फ्री नंबर 1800 180 1014 के माध्यम से किसानों को मृदा परीक्षण, लवणता एवं क्षारीयता प्रबंधन, लवण सहनशील फसल किस्मों, फसल प्रबंधन पद्धतियों, पशुपालन, बागवानी फसलों और पोषक तत्व प्रबंधन पर कुल 118 कृषि परामर्श प्रदान किए गए। इसके अलावा, संस्थान के साथ व्हाट्सएप समूहों के माध्यम से जुड़े 242 से अधिक किसानों को लवण प्रभावित क्षेत्रों के लिए फसल एवं मृदा प्रबंधन पर परामर्श दिए गए।

क्षमता निर्माण

आईसीएआर-सीएसएसआरआई ने 2025 में 21 विविध प्रशिक्षण कार्यक्रम आयोजित किए, जिनमें आईसीएआर द्वारा प्रायोजित शीतकालीन विद्यालय, संरक्षण कृषि पर उन्नत पाठ्यक्रम, खेत एवं प्रयोगशाला प्रबंधन, और अनुसूचित जाति के किसानों एवं महिलाओं के लिए क्षमता निर्माण

कार्यक्रम शामिल हैं। करनाल, भरुच और लखनऊ तथा कैनिंग टाउन जैसे क्षेत्रीय केंद्रों पर कार्यक्रम आयोजित किए गए, जिनमें लवण प्रभावित मृदा सुधार, जलवायु-अनुकूल खेती, कृषि-उद्यमिता और सतत तटीय कृषि जैसे विषयों को शामिल किया गया। वैज्ञानिकों, किसानों और तकनीकी कर्मचारियों सहित 1500 से अधिक प्रतिभागियों ने लाभ उठाया। एससी-एसपी कार्यक्रम के अंतर्गत 452 सीमांत किसानों और कृषक महिलाओं के लिए कुल 25 क्षमता निर्माण प्रशिक्षण, 4 प्रदर्शन और 12 गोष्ठियाँ आयोजित की गईं।

अंतर्राष्ट्रीय सहयोग

- जलवायु परिवर्तन कृषि और खाद्य सुरक्षा (सीसीएएफएस) – (सीआईएमएमवाईटी द्वारा वित्त पोषित)
- उच्च जिनक युक्त धान की किस्मों का विकास वर्षा आधारित पारिस्थितिकी में गुणों की खोज धान की गुणवत्ता और पोषण संबंधी गुणवत्ता कम आर्सेनिक युक्त धान, धान में जैवसक्रिय तत्व और कम जीआई धान (आईआरआरआई द्वारा वित्त पोषित)
- भारत के जल संवेदनशील क्षेत्रों में सतत संसाधन प्रबंधन प्रणालियों का विकास (जेआईआरसीएस द्वारा वित्त पोषित)
- जलवायु स्मार्ट प्रबंधन पद्धतियाँ (आईआरआरआई द्वारा वित्त पोषित)
- बांग्लादेश और पश्चिम बंगाल, भारत के लवण प्रभावित तटीय क्षेत्रों में फसल प्रणाली गहनीकरण (एसीआईएआर ऑस्ट्रेलिया द्वारा वित्त पोषित)

प्रकाशन

संस्थान ने प्रतिष्ठित राष्ट्रीय और अंतर्राष्ट्रीय पत्रिकाओं में 137 शोध पत्र प्रकाशित किए हैं। इसके अतिरिक्त, 50 पुस्तकें/मैनुअल/अध्याय और 44 तकनीकी बुलेटिन, फोल्डर और लोकप्रिय लेख प्रकाशित किए गए हैं। ये प्रकाशन संस्थान के शोध, आउटरीच और ज्ञान प्रसार पर केंद्रित दृष्टिकोण को दर्शाते हैं।

शोध परियोजनाएँ

संस्थान में वर्तमान में कुल 56 शोध परियोजनाएँ चल रही हैं, जिनमें 42 संस्थान द्वारा वित्तपोषित, 11 विदेशी-वित्तपोषित, 25 बाह्य-वित्तपोषित परियोजनाएँ, 1 सहयोगात्मक, 2 परामर्शदात्री और 1 अनुबंधित शोध शामिल हैं।

Executive Summary



ICAR-CSSRI has made significant progress in addressing soil salinity and groundwater quality challenges through technological advancements, varietal development, demonstration and outreach programmes. The updated salt-national maps of salt-affected soils and groundwater quality were prepared. A number of salt-tolerant crop varieties were developed and released such as KRL-423 and KRL-1083 for wheat, CSR-108 of rice, and CS-68 of mustard to sustain crop productivity in saline environments. Newly designed groundwater recharge filtration units were implemented in 14 sites across Karnal, Kaithal, and Kurukshetra to improve groundwater recharge in flood prone areas. A bio-stimulant based on Arbuscular Mycorrhizal Fungi (AMF) was developed to enhance crop growth and phosphorus uptake under saline soils. To guide climate change adaptation strategies, prepared a village-level priority index map for the Indian Ganges Delta. Efficacy of Cut-soiler in subsurface sodicity management was demonstrated in selected sites of Haryana and Punjab. Reclamation of waterlogged-saline lands (200 acres) was undertaken in a NDDDB funded consultancy project. Additionally, salt-tolerant sandalwood germplasm was identified for alternative land use. Two policy papers were published highlighting the economic impact of salt-tolerant wheat varieties and subsurface drainage, supporting evidence-based policymaking. Division/ Regional Research station/units-wise key research outcomes for addressing the multifaceted challenges in salt-affected agro-ecosystems are highlighted below:

The Division of Soil and Crop Management has made remarkable progress in tackling the challenges of salt-affected soils through advanced characterization techniques, innovative reclamation strategies, nutrient management, climate-smart practices, and sustainable agroforestry systems. Proximal Visible and Near-Infrared Spectroradiometry was successfully used to rapidly characterize soil samples, facilitating a reliable prediction of soil properties such as pH, EC, SAR, ESP, SOC, gypsum requirement, and texture. This approach provides a fast, non-destructive, and cost-effective alternative to conventional

laboratory soil analysis methods. Soil amendments such as FGDG, RFS, Rapid Acidulated Manure (RAM), and siliceous chalk were evaluated against gypsum in pearl millet-based cropping systems to assess their reclamation efficacy in alkali soils in rainfed regions of Rajasthan. In micronutrient management, nano-formulations of Zn, Fe, and Cu developed for high nutrient use efficiency and consistent performance in biofortification of rice and wheat grains. For climate change mitigation, an eddy covariance tower installed for continuous monitoring of carbon dioxide fluxes, Gross Primary Productivity (GPP), and Net Ecosystem Exchange in rice-wheat systems for generating valuable insights relating to carbon dynamics under salt-affected conditions. Biological Nitrification Inhibition (BNI) elite lines exhibited superior performance, recording higher grain yield and 7–17% greater nitrogen uptake compared to parental lines, indicating strong potential for improving nitrogen use efficiency and reducing environmental losses. To design site-specific soil management interventions under the ICAR-CSSRI-FAO project, the baseline soil characterization was conducted at selected sites in Karnal district and Kaithal district. The results show that soils are predominantly alkaline with moderate spatial variability in soil organic carbon and available nutrient status. Long-term CA Conservation Agriculture) experiment showed zero-tillage wheat with residue retention, particularly under drip irrigation, significantly increased wheat yields. In-situ residue management using a developed fungal consortia formulation “CSR-Manage-R” achieved 60–70% decomposition of rice straw within six months across normal, saline, and sodic soils. Research on biostimulants demonstrated successful propagation of Arbuscular Mycorrhizal Fungi (AMF) in hydroponic systems under nutrient stress, while enriched Fermented Organic Manure (FOM) from CBG plants, when integrated with reduced chemical fertilizers, improved crop yields and soil fertility, performing at par with higher doses of gypsum in sodic soils. In agroforestry, substantial genetic diversity for salinity tolerance was identified in sandalwood genotypes, with several superior lines showing better ionic homeostasis and physiological performance. Host compatibility studies and large-scale dissemination efforts have promoted sandalwood-based agroforestry among farmers in Haryana for improving productivity of marginal lands. Promising genotypes of Prosopis, willow, and other high-value tree species were also evaluated for salt-affected environments.

The Division of Crop Improvement has made significant advances in the development of salt-tolerant crop varieties and breeding technologies aimed at enhancing agricultural productivity in salt-affected soils. A major milestone was the release and notification of two salt-tolerant rice varieties, CSR 108 and CSR 64. CSR 108 was developed for higher yield potential with dual tolerance to salinity and sodicity. It recorded an average yield of 3819 kg/ha under alkaline stress, showing 38% superiority over CSR 10, and 4472 kg/ha under saline stress, with 52% superiority over CSR 10. Another important achievement was the notification of CSR 64, a premium quality salt-tolerant basmati rice variety, demonstrated consistent superior performance under sodic soils of Uttar Pradesh with yield advantages of 5.7% over CSR 36, 16.6% over Basmati CSR 30, and around 10% over other varieties. CS 68 mustard variety was identified for cultivation under saline and alkaline conditions with EC_e/EC_{iw} of 10–13 dS/m and pH 9.0–9.4. Its yield potential is 22–24 q/ha under salt stress and 26–30 q/ha under normal soils along with resistance to major diseases such as Alternaria blight, white rust, powdery mildew, downy mildew, and aphid infestation. In wheat, the promising entries such as KRL 2402 (with combined rust resistance) were promoted to national and state salinity trials. In chickpea and lentil, large germplasm sets were screened, and superior donors with better yield, pod number, seed weight, and favorable ionic balance (low Na^+ , high K^+) under salinity were identified. Produced 26.25 quintals of breeder seed of various salt-tolerant rice varieties, including newly released CSR 108 and CSR 64, ensuring timely seed availability for large-scale dissemination.

The Division of Irrigation and Drainage Engineering at ICAR-CSSRI has achieved key breakthroughs in salinity management, water saving, and smart irrigation practices for salt-affected areas. DRAINMOD model was calibrated and validated for predicting the water table depth and soil salinity with high R^2 values of 0.95 and 0.86, respectively. Model estimated that 1,819 tonnes of salt can be safely removed every year in the Western Yamuna Canal Command. A low-cost sensor and IoT-based irrigation system was developed for salt-affected soils, and the system uses soil electrical resistivity to monitor moisture. Sensor output rose from 720 to 1295 mV with increasing soil moisture, enabling precise real-time irrigation scheduling. Subsurface drainage installation brought major improvements in reclaimed saline soils with reduced surface soil salinity by nearly 40% and lowered groundwater EC from 16.07 to 5.38 dSm⁻¹ in rice-wheat cropping systems. Under the Plant Direct project, promising rice lines such as IR22EL1055 produced 5.09 t/ha grain yield while saving 33–50% irrigation water. Simulation studies further showed that switching to short-duration direct-seeded rice can prevent groundwater decline by up to 3 metres over ten years compared to traditional long-duration rice. In the HIROS project, combining drip irrigation with optimized fertilizer use in sugarcane improved water productivity to 29.4 kg m⁻³ and boosted nitrogen-use efficiency. These practices saved 21–26% water and increased yield by 12–38%. Mobile-based IrriWatch advisories supported better irrigation decisions for sugarcane cultivation.

The Division of social sciences research assessed the economic impact of Salt Tolerant Wheat Varieties (STWVs), the results revealed that there is a substantial yield gains in salt-affected soils. In sodic soils with pH >8.5, STWVs recorded an average yield gain of 11.80% over non-STWVs, while in saline soils (ECe >4 dS/m), the advantage reached 24.30%. The weighted average yield gain across sodic and saline areas, considering the area of sodic and saline soils as weight, stood at 14.82%. The estimated present adoption rate of STWVs, is 9.77%. Using the economic surplus model, the total economic surplus generated from 2012 to 2024 under the business-as-usual scenario was Rs. 58,170 million (annualized Rs. 4,474.6 million), with consumer surplus of Rs. 22,850 million and producer surplus of Rs. 35,320 million. Projections up to 2030 indicate the total economic surplus could rise to Rs. 259,000 million under the business-as-usual scenario and Rs. 278,050 million under the optimistic scenario, highlighting the strong potential of STWVs for enhancing productivity and farm income in salt-affected regions. Policy recommendations emphasize accelerating breeding using speed breeding and gene editing, developing varieties for specific regions like Gujarat, incorporating multiple stress tolerance and biofortification traits, strengthening seed supply chains through public-private partnerships, and aligning variety recommendations with soil health cards. In the Farmer FIRST Project in waterlogged saline agroecosystems of Haryana, sub-surface drainage (SSD) installation significantly improved crop performance. In wheat, the salt-tolerant variety KRL 210 achieved an average grain yield of 56.25 q/ha in SSD-reclaimed plots, with a gain of 9.22% over the control variety HD 2967. In rice, improved varieties outperformed the local check under SSD conditions, with PB 1692 recording the highest yield, which was 57.20 q/ha with gain of 34.58% over other prevailing varieties. These demonstrations clearly show that SSD reclamation combined with suitable salt-tolerant varieties substantially enhances productivity of waterlogged saline areas.

The ICAR-CSSRI Regional Research Station, Bharuch, made significant progress in improving crop productivity in saline Vertisols of Gujarat using saline groundwater irrigation. Salt-tolerant varieties of mustard (STMV) were evaluated, and it was found that CS 62 recorded the highest seed yield of 8.96 q/ha, followed by CS 61 (8.71 q/ha) and CS 58 (8.60 q/ha), and STMV outperformed the local variety GDM-4 (5.12 q/ha). STMV also showed superior growth parameters, higher number of pods per plant, better harvest index, and desirable quality traits such as higher oil content and lower erucic acid in CS 61.

Among planting methods and geometries, the FIRB (furrow irrigated raised bed) system with 60 cm bed width and two rows at 30 cm spacing produced the highest seed yield of 9.81 q/ha. Ridge and furrow sowing at 90 cm spacing proved effective in improving branching, pods per plant, and test weight due to better root zone aeration and reduced salinity stress. In dragon fruit, a field experiment demonstrated that increasing salinity levels (up to 9 dS/m) significantly suppressed vegetative growth and structural traits across cultivars. However, the Jumbo Red cultivar exhibited superior adaptability and vigour under saline conditions. Application of bio-stimulants (seaweed extract) effectively mitigated salt stress and, enhanced plant height and canopy spread. Furthermore, the humic acid improved spine width, density, and areole distance helping in cultivation with saline irrigation water. Studies on land-use systems highlighted the potential of agroforestry for carbon sequestration and improvement of saline Vertisols. *Acacia nilotica* recorded the highest soil organic carbon (1.28% at 0-15 cm depth), while *Eucalyptus* sp. produced the maximum biomass (2482.6 t/ha). These restorative systems not only enhanced soil organic carbon but also improved physical properties by reducing cracking behavior, offering opportunities for generating carbon credits. At Sabarmati Ashram Gaushala, a detailed soil analysis confirmed severe salinization and sodicity (ECe up to 45.57 dS/m and SAR up to 48.38) due to prolonged use of saline groundwater, resulting in reduced fodder productivity. Genetic improvement efforts in wheat identified promising genotypes such as KRL 2310, KRL 99, KRL 1803, and SPLASN 23, which performed well in terms of grain yield, biomass, and phenological traits under saline Vertisols (ECe 6-7 dS/m). In maize, screening under different salinity levels (0, 6, and 9 dS m⁻¹) showed that IIMR 4 and IIMR 9 maintained relatively higher cob and grain yields across stress levels.

ICAR-CSSRI-RRS, Lucknow made significant strides in addressing the challenges of sodic soils through innovative reclamation strategies, resource-efficient cropping systems, and sustainable production technologies. In the sulphamic acid-based management of sub-soil sodicity, the combined application of 12.5 GR sulphamic acid (SA) on the surface + 25 GR SA in the sub-surface recorded the highest wheat yield of 5.39 t/ha, statistically similar to the integration of marine gypsum and SA. In highly degraded sodic soils (pH >9.9), surface application of 50 GR SA or FSA significantly lowered surface pH (up to 8.64) and ESP (from 60.09 to 35.14). Vis-NIR spectroscopy studies on 73 heavy-textured sodic soil samples from Hardoi, Unnao, and Lucknow districts established characteristic spectral signatures with prominent scattering in 975–1010 nm and 2200–2500 nm regions, paving the way for rapid, non-destructive estimation of sodicity parameters (pH, EC, ESP) through multivariate modelling. Under low-budget natural farming (LBNF), wheat yields were drastically lower (9.8–14.9 q/ha) compared to chemical input-based practices (31.8 q/ha), with reductions in available nitrogen and dehydrogenase activity in most NF treatments. Across five districts in the Sharda Sahayak Canal Command, sodic soils covered 87,147 ha (5.33% of geographical area), providing critical inputs for targeted reclamation planning. In calcareous sodic soils of Bihar, incubation studies confirmed that integrated first- and second-order rate equations and the Elovich model best described native CaCO₃ dissolution kinetics. Promising halophilic bacterial isolates (*Bacillus pumilus*, *B. australimaris*, *B. tequilensis*, and *Niallia circulans*) were characterized and formulated as “Halo-Cal-D” with a 360-day shelf life for in-situ CaCO₃ dissolution and self-reclamation. On-farm demonstrations showed salt-tolerant rice varieties (e.g., CSR 46) yielding over 23% higher grain than traditional varieties when combined with green manuring and halo-mix enriched manure. Diversified cropping systems evaluation identified Pearl millet (ridge) + Dhaincha (furrow) as brown manure – Toria – Sunflower (CS7) as the most productive system with 9.03 t/ha rice equivalent yield (REY), recording 44% higher productivity than the traditional rice-wheat system. In fruit crops, date palm variety Khuneji performed best under high pH (9-10), while the Open

Field Pedoponics Planting System (OFPP) using polythene bags with Soil:Sand:FYM (1:1:1) or Soil:Cocopeat:FYM media significantly enhanced survival and growth of shallow-rooted fruits like guava, lemon, and custard apple. Dragon fruit under OFPP with cocopeat-based media recorded superior plant height, cladode length, canopy spread, and fruit yield. Integrated Farming System (IFS) models demonstrated higher economic returns than traditional rice-wheat systems. The fish-field crop-horticulture model generated Rs 1,02,725 per 6000 sqm compared to Rs 41,705 from the control plot of similar scale. On-farm demonstrations in Hardoi district across 1064 farmers' fields validated salt-tolerant varieties (CSR-36, CSR-46) and technologies like Halo-Mix, marine gypsum, and Halo-Cal-D, achieving notable yield improvements and pH reduction.

ICAR-CSSRI, Regional Research Station, Canning Town made significant strides in addressing the challenges of coastal salinity, climate change, and livelihood security in the fragile Sundarbans ecosystem of West Bengal. The salt-tolerant variety Canning 7 recorded the highest grain yield (3.69 t ha^{-1}) and demonstrated better resilience under saline irrigation ($\text{EC}_{\text{iw}} 4$ and 6 dS m^{-1}) compared to moderately tolerant Sada Minikit and sensitive BPT 5024. The FAO Aquacrop model was validated with good correlation between observed and simulated yields (R^2 0.91 for grain yield and 0.92 for biomass), enabling reliable prediction of future rice productivity under changing climate and salinity regimes. In low-budget natural farming (LBNF) trials, rice yields under zero-tillage scenarios with residue retention (4.73 t ha^{-1}) and dhaincha incorporation (4.71 t ha^{-1}) were comparable or superior to farmers' practice (3.01 t ha^{-1}) despite no external nutrient application. Additionally, improvement in soil organic carbon, available nutrients, and microbial activity observed in integrated and natural farming systems. Biochar amendment studies in rice-okra systems showed positive effects on okra yield and reduced soil salinity, with 1% biochar application recording the highest okra yield (1.341 kg per ring) and lower post-harvest soil EC compared to no-biochar control, highlighting its potential for coastal salinity management. Conjunctive use of poor-quality water in zero-tillage potato under drip irrigation with straw mulching proved highly effective, achieving the highest tuber yield (25.2 t ha^{-1}) and water productivity (34.9 kg m^{-3}) with good quality water at IW/CPE 0.5. Integration of small indigenous fish *Heteropneustes fossilis* (Singhi) with Indian Major Carps under optimized stocking density significantly enhanced pond productivity (3502 kg ha^{-1} IMCs + 273.6 kg ha^{-1} Singhi) and generated net returns of $238,150 \text{ ha}^{-1}$ with 58% profitability. A Livelihood Resilience Index (LRI) was developed from 23 indicators across environmental, economic, and social dimensions. The entropy weight method assigned objective weights to the indicators. The overall mean LRI was 0.340 with a standard deviation of 0.068, showing moderate variability in the region. Land shaping technology was promoted among farmers for integrated farming, while low-cost biochar production and water management strategies were developed to enhance resource-use efficiency. Capacity building efforts reached over 775 farmers through trainings and demonstrations.

The All India Coordinated Research Project (AICRP) on Management of Saline Water and Associated Salinization in Agriculture has generated valuable insights through systematic surveys and field experiments across diverse agro-ecological regions. Comprehensive groundwater quality assessments revealed varying degrees of salinity and alkalinity challenges. Resource inventories of salt-affected soils in Shajapur district using remote sensing and ground truthing confirms the presence of sodicity in certain locations, with pHs values ranging from 7.38 to 8.43 and variable ESP levels. Conjunctive use of alkali and canal water in til-lentil sequences at Agra produced comparable yields to canal water alone when alternating irrigations or mixing waters in 1:1 ratio. Gypsum treatment of high-RSC alkali water to reduce RSC to 2.5 meq L^{-1} significantly enhanced sesame growth and yield. In bhendi under drip irrigation, combining harvested rainwater

with gypsum-treated borewell water (1:1) proved highly effective for growth and yield. Saline water management trials demonstrated the viability of drip irrigation and fertigation. Alternate use of saline water (up to 4 dS m⁻¹) with good quality water in maize produced yields comparable to best available water. Integrated nutrient management, including mycorrhizal inoculation (*Glomus mosseae*), mitigated yield losses in cotton-wheat systems under high salinity (EC_{iw} 8 dS m⁻¹). For irrigation-induced salinization, conjunctive use of gypsum and *Gliricidia sepium* in sodic Vertisols improved soil properties and productivity under paddy-wheat systems, with *Gliricidia* alone offering a cost-effective, sustainable option. Controlled subsurface drainage in waterlogged saline Vertisols of the Tungabhadra Project (TBP) command area effectively reduced drain discharge, conserved nutrients, and maintained good paddy yields while minimizing nitrogen losses. In saline-acidic Pokkali soils of Kerala, ridge/mound-based transplanting and amendments like rice husk ash and dolomite significantly improved rice establishment and yields.

Awards and Recognitions

Dr. S.K. Sanwal conferred with fellow of Indian Academy of Horticultural Sciences-2025 in the field of Horticulture (Vegetable Science) and also the fellow of Indian Society of Soil Salinity and Water Quality-2023-24. Dr. Kailash Prajapat was awarded with Young Scientist Award by Indian Society of Soil Salinity and Water Quality, Karnal in International Salinity Conference 3.0. Dr. Ajay Bhardwaj conferred with fellow of NAAS and fellow of Society for Advancement of Wheat and Barley Research. Dr. Sanjay Arora conferred with CSSRI Excellence Award for outstanding contribution in management of salt affected soils and fellowship of British Ecological Society.

Conference/Workshops organized

- Conducted the 29th AICRP Biennial Workshop 2023-2024 on Management of Saline Water and associated Salinization in Agriculture at ICAR-CCARI, Goa.
- Organized International Salinity Conference 3.0 (WE-CARE-2025): Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems in association with Indian Society of Soil Salinity and Water Quality at ICAR-CCARI, Goa during 29 Oct – 01 Nov, 2025

Exhibition and Field Visits

During 2025, a total of 2645 stakeholders including 805 farmers, 1690 students, 125 trainee, 15 extension workers and 10 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 2025, a total of 118 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 over 242 farmers associated through WhatsApp groups with the institute.

Capacity building

ICAR-CSSRI organized 21 diverse training programmes in 2025, including ICAR-sponsored winter schools, advanced courses on conservation agriculture, farm and lab management, and capacity-building for SC farmers and women. Programmes were held at Karnal, Bharuch, and regional stations like Lucknow and Canning Town, covering topics such as salt-affected soil reclamation, climate-smart farming, agri-entrepreneurship, and sustainable coastal agriculture. Over 1500 participants including scientists, farmers, and

technical staff benefited. A total of 25 capacity building trainings, 4 demonstrations and 12 Goshthis were organized for 452 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 137 research papers in reputed national and international journals. Additionally, 50 books/manuals/chapters and 44 technical bulletins, folders, and popular articles were brought out. These publications reflect the Institute's focus on research, outreach, and knowledge dissemination.

Research projects

A total of 56 research projects are currently ongoing at the institute, comprising 42 Institute Funded Projects, 11 Foreign Funded Projects, 25 Externally Funded, and 1 Collaborative, 2 Consultancy: and 1 Contract Research.



Introduction

Historical Perspective

ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) is a premier research institute dedicated to pursue interdisciplinary research on salinity/alkalinity management and use of poor quality water irrigation 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, Bapatla, Bikaner, Gangawati, Hisar, Indore, Kanpur and Tiruchirapalli). In 2014, four new voluntary centres have started functioning at Bathinda (Punjab), Panvel (Maharashtra), Vytilla (Kerala) and Port Blair (Andaman & Nicobar Islands).

Over the years, Institute has grown into an internationally recognized 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, developing technologies for the optimal management of gypsum amended alkali soils and the use of high RSC and saline water for crop production. In recent past, Institute focussed on conservation agriculture based management practices in cereal systems to address the degradation of resource base. 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 specific areas. 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 M.Sc. and Ph.D students of IARI and 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 dryland 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.

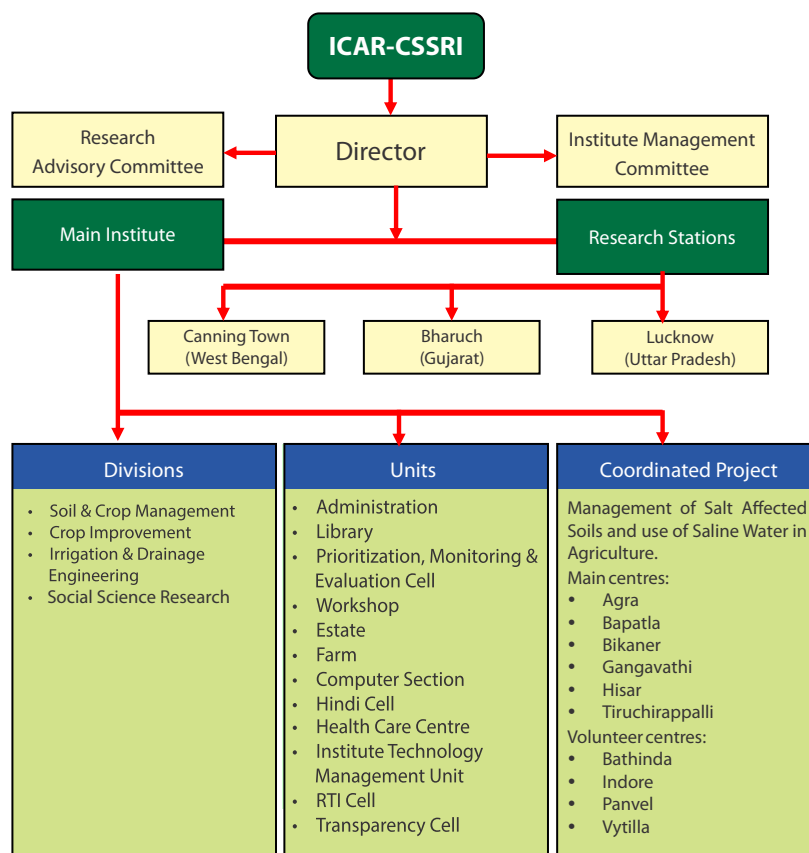
Mandate

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

- Identify the nature and characteristics of salinity/water quality problems and areas prone to salinity development in a GIS framework.
- Undertake strategic and adaptive research to manage salinity related problems at different scales and develop options for preventing land degradation due to excess salts based on better understanding of salt and water balances.
- Develop national level network of salinity related activities and provide funding support to address location specific problems.
- Research on capacity building for prevention, control and management of salinity problems.

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, 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 25 ha area, while general crops and orchards are grown in 18.5 ha, which also includes the 9.5 ha area under seed production mainly of salt tolerant varieties of rice and wheat. A seed processing plant is also installed to provide

Productivity of crops at CSSRI farm

Crop	Variety	Average yield (t ha ⁻¹)
Rabi 2024 - 25		
Wheat [*]	KRL-210	6.59
	KRL-213	5.94
	KRL-283	5.51
Mustard [*]	CS 58	1.31
	CS 60	1.11
	CS 61	1.03
	CS 62	1.01
	CS 64	1.10
Chick Pea [*]	Karnal chana 1	2.20
Kharif 2024		
Paddy [*]	CSR 30	1.61
	CSR 56	3.56
	CSR 76	4.15
	CSR 36	3.98

*Breeder Seed Production

[#] TL Seed production

quality of seed of salt tolerant varieties to the farmers. During the period under report, the farm unit generated revenue of Rs. 88.5 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 4.5 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 guava (*Psidium guajava* L.), litchi (*Litchi chinensis* Sonn.) and mango (*Mangifera indica*) is 2.6 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/CSSRIKarnal>

Twitter Account URL: <https://twitter.com/CSSRIKarnal>

Instagram Account URL: <https://www.instagram.com/cssrikarnal/>

YouTube Acc.URL: <https://www.youtube.com/channel/UCJZ2S2Alm1-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 2025-26 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)	125.00	2.50	-	127.5
Establishment Expenses (grant in aid-salaries)	2932.77	-	-	2932.77
Pension	747.00	-	-	747.00
Grant in aid general	635.00	5.00	-	640.00
SCSP (General)	60.00	-	-	60.00
Grand Total	4499.77	7.50	-	4507.27
Loan and advance	-	-	-	-

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	59	22	27.16
Technical	117	77	40	34.18
Administrative	55	24	31	56.36
Skilled Supporting Staff	48	6	42	87.5
Total	301	166	135	44.85

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 staff 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 any collection. It helps to find the physical location of information in easier to search method 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), spectrophotometer, 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, 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

Rapid characterization of salt affected soils using Proximal spectroscopic techniques (Amresh Chaudhary, Nirmalendu Basak, Gajender Yadav, Nishant Kumar Sinha, Rahul Mishra, A.K. Rai and R. K. Yadav)

Salt-affected soils (SAS) constitute a major global challenge, significantly undermining agricultural productivity, environmental sustainability, and food security. Conventional soil survey and laboratory-based analytical methods are often labour-intensive, time-consuming, and inadequate in capturing the spatial heterogeneity of soil salinity at operational scales. These limitations restrict informed decision-making by land managers, policymakers, and farmers regarding appropriate soil management practices, crop selection, and irrigation strategies. The present study aims to employ proximal soil spectroscopy specifically Visible and Near-Infrared (VNIR) spectroradiometry. A total of 292 soil samples were collected from four depth intervals (0–15, 15–30, 30–45, and 45–60 cm) across salt-affected regions of Uttar Pradesh, including Azamgarh, Lucknow, Raebareli, Jaunpur, Mau, Etawah, Mathura, Agra, and Budaun, under three land-use systems: barren land, rice-fallow, and rice-wheat systems.

The soil samples were analyzed for a wide range of physicochemical properties, including pH_2 , EC_2 , pH_s , pH_e , EC_e , Ca^{2+} , Mg^{2+} , Na^+ , K^+ , CO_3^{2-} , HCO_3^- , Cl^- , SO_4^{2-} , SAR, soil organic carbon, gypsum requirement, CaCO_3 , particle-size fractions (sand, silt, clay), exchangeable cations (ExCa, ExMg, ExK, ExNa), and exchangeable sodium percentage. VNIR reflectance spectra (350–2500 nm) were acquired using an SVC 1024i spectroradiometer.

The raw VNIR reflectance spectra were visually inspected to assess noise characteristics. Pronounced noise was observed in the <450 nm, 950–1050 nm, and >2400 nm regions, along with increased spectral scattering at higher wavelengths. Consequently, bands below 450 nm and above 2400 nm were removed. To ensure spectral continuity across the 950–1050 nm region, spectra were trimmed, spliced, and smoothed using the Savitzky–Golay (SG) filtering technique (Fig. 1.1). Despite SG filtering, multiplicative scattering effects persisted, particularly at longer wavelengths. Therefore, Standard Normal Variate (SNV) transformation was applied to correct for scattering effects arising

Spliced, Trimmed, and Smoothed Soil Spectra

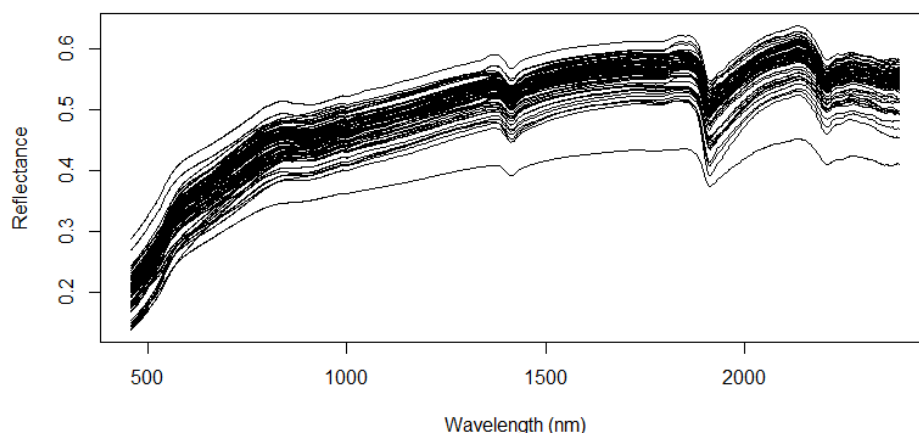


Fig 1.1 Spliced, trimmed and smoothered soil spectra after Savistky-Golay filtering pre-processing

Fig. 2.2 Standard Normal Variate (SNV) pre-processing to correct multiple scattering effect

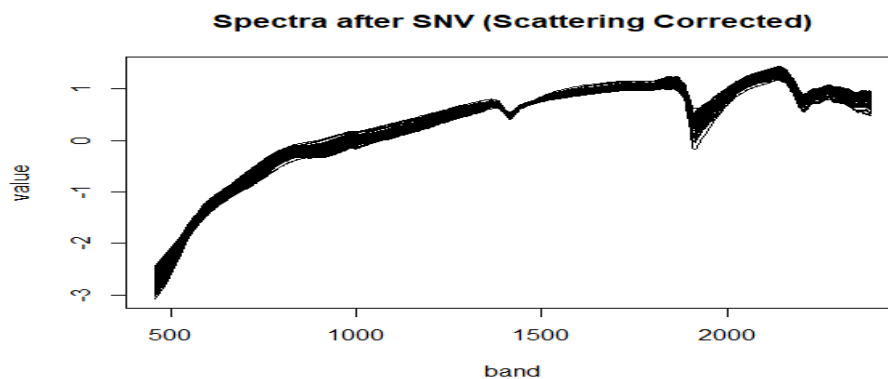
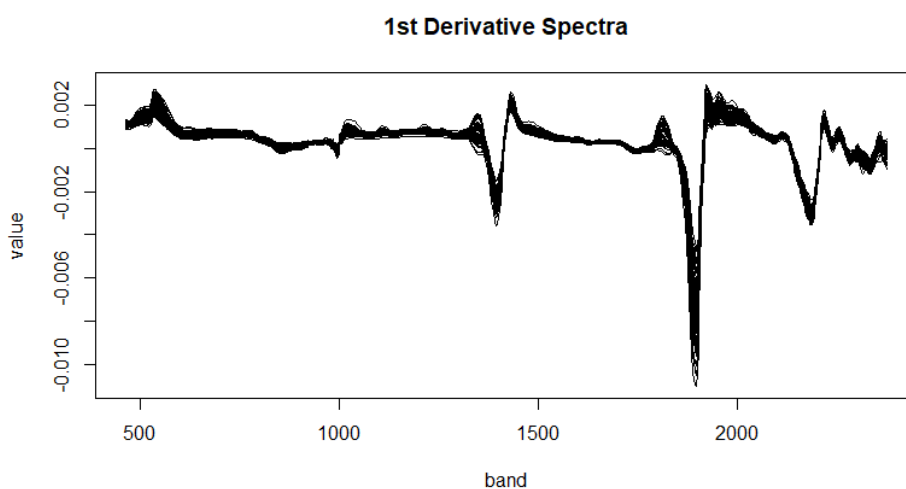


Fig. 3.3 First-order derivative of spectra used for modelling properties of salt affected soils with labroatary analysed data.



from particle size variability and light scattering (Fig. 1.2). Subsequently, first-order derivative spectra were computed to enhance diagnostic absorption features prior to model development (Fig. 1.3).

Reclamation and Management of Alkali Soils

Utilizing innovative reclamation strategies for enhancing productivity and soil health of sodicity affected rainfed production system of Rajasthan (Parul Sundha, Arvind Kumar Rai, Gajender Yadav, Kailash Prajapat, Priyanka Chandra, BL Meena, Suresh Kumar, SK Jha, R. K. Yadav and team from Agriculture University, Kota, Rajasthan: Santosh Jhajharia, BL Meena, Suresh Bairwa, MK Sharma and Nupur Sharma)



Experimental site at KVK, Sawaimadhopur, Rajasthan

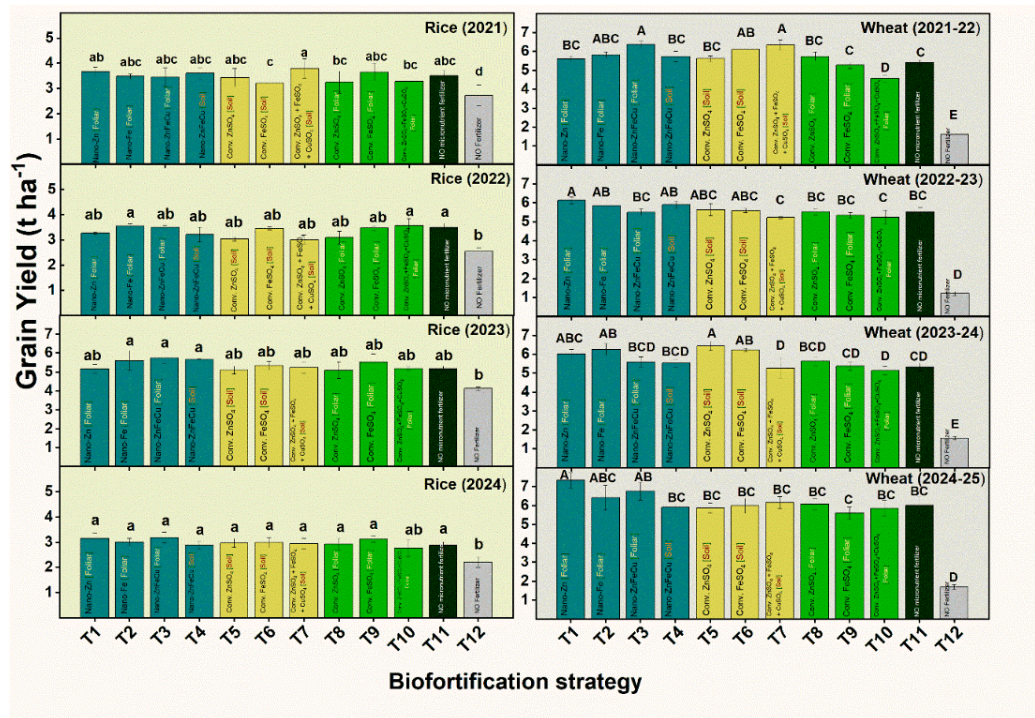
Soil sodicity adversely affects soil health and crop productivity across many arid and semi-arid regions of India, and the problem is further intensified by emerging secondary salinization. In Rajasthan, agricultural production is constrained by multiple factors, including water scarcity, erratic rainfall, soil erosion, and chemical degradation of soils. The state has approximately 0.5 million hectares of salt-affected soils, of which about 0.18 million hectares are affected by sodicity. This issue is further aggravated by the use of saline and sodic groundwater for irrigation, leading to salt accumulation in the root zone and negatively impacting crop growth. The ICAR–Central Soil Salinity Research Institute has developed several innovative soil amendments as alternatives to mined gypsum. These amendments have demonstrated appreciable reclamation efficiency compared to mineral gypsum under irrigated rice–wheat production systems across diverse agro-ecological regions of Haryana, Punjab, Uttar Pradesh, and Madhya Pradesh. The present study evaluates the performance of these amendments under rainfed upland production systems in Rajasthan. The objectives are: (i) to assess the effectiveness of different reclamation strategies developed by ICAR–CSSRI for sodic soils under rainfed conditions, and (ii) to evaluate their impact on productivity, quality, and profitability of dominant cropping systems. The experiment is being conducted across three cropping systems: pearl millet–wheat, pearl millet–barley, and pearl millet–mustard. The treatments include: gypsum at 50% gypsum requirement (GR), flue gas desulfurization gypsum (FGDG) based on 50% GR, pressmud-based amendment (RFS) based on 50% GR, rapid acidulated manure (RAM) applied at 5 t ha^{-1} combined with 25% GR gypsum, and siliceous chalk applied as a 10% replacement of 50% GR.

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

Soil fertility and crop nutrition management are key technologies contributing to a major increase in yield, especially under salt-affected conditions. The fertility status of salt-affected soils is generally poor due to high pH, excess soluble and exchangeable Na^+ , adverse soil physical conditions, and non-available forms of minerals that render unsustainable crop production. The micronutrient status of the crops grown in alkaline pH conditions is especially poor because the availability of most micronutrients becomes extremely low as the pH increases above 7. Nano formulations have the advantage of having a lesser amount of active ingredients and higher nutrient use efficiency. The objective of the project was to compare the performance of four formulations of micronutrients for Zinc, Iron, and Copper, developed at CSSRI [Nano-Zinc, Nano-Iron, Nano-NMN (liquid combination of Zn, Fe, Cu), and Nano-ECO (granular combination of Zn, Fe, Cu)] with conventional micronutrient fertilizer, on biofortification and to understand the effect of the mode of application on the biofortification of the nutrient in the 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. FeSO_4 + 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. FeSO_4 0.5% solution), 10) Foliar Conv. ZnSO_4 + 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 at 30, 45, and 60 days after rice transplanting and 60, 75, and 90 days after wheat sowing. The yearly grain yield performance of rice and wheat under different biofortification treatments exhibited consistent trends across seasons (Fig. 2.1). During the first year, rice grain yield in T_1 , T_2 , T_3 , T_4 , T_5 , T_7 , T_9 , and T_{11} was statistically at par. Soil application of FeSO_4 (T_6), foliar application of Conv. ZnSO_4 (T_8), and T_{10} recorded comparatively lower yields, while the lowest yield was observed under T_{12} . In wheat during the first year, T_3 and T_7 produced the highest grain yields. All foliar applications of conventional salts, viz., T_8 , T_9 , and T_{10} , along with soil application of Conv. ZnSO_4 @ 10 kg acre^{-1} (T_5) and T_{11} , yielded comparatively lower than the best-performing treatments. The minimum yield was recorded under T_{12} . In the subsequent years (2022–2024), rice exhibited no significant differences in grain yield among treatments except T_{12} , which recorded significantly lower yield. However, nano micronutrient treatments viz; T_1 , T_2 , T_3 , and T_4 gave best yields compared to all others. In wheat, foliar application of nano micronutrients viz; T_1 , T_2 , and T_3 gave the highest grain yields among all, and were significantly higher to foliar applications of conventional salts viz: T_8 , T_9 , and T_{10} as well as soil-based applications viz; T_5 , T_6 , and T_7 , clearly indicating a long-term advantage of nanoformulations for yield enhancement.

Fig 2.1 Effect of different biofortification strategies on the grain yield of rice and wheat crop across four consecutive cropping seasons (2021–2022 to 2024–2025)



Climate change mitigation and adaptation strategies for salt affected soils (Ajay Kumar Bhardwaj, Raj Kumar, Bhaskar Narjary, Satyendra Kumar and Uttam Kumar Mandal)



Fig 2.2 Eddy Covariance Tower

An eddy covariance tower is a micrometeorological system designed to measure the exchange of gases and energy between the land surface and the atmosphere at the ecosystem scale. It directly quantifies carbon dioxide (CO_2), water vapor, and heat fluxes by capturing high-frequency fluctuations in vertical wind speed and gas concentrations, and calculates fluxes using the covariance between these variables to provide accurate estimates of Net Ecosystem Exchange (NEE).

An eddy covariance (EC) tower was installed in April 2025 at the farm of the ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, to monitor ecosystem-atmosphere exchanges in rice-wheat system (Fig. 2.2). The tower was positioned at the center of the experimental site to ensure uniform fetch and representative flux measurements. The total experimental area covered approximately 10 acres (about $200 \text{ m} \times 200 \text{ m}$), which was divided into four equal blocks of 2.5 acres each for management and experimental purposes. The data were collected and compiled on a weekly basis. The diurnal patterns of Gross Primary Productivity (GPP) and Carbon Dioxide Flux (FCO_2) show a clear daily cycle of ecosystem carbon exchange (Fig. 2.3). The diurnal patterns of GPP and FCO_2 exhibit a well-defined daily cycle closely linked to solar radiation availability. During night-time hours (00:00-06:00 h), GPP values remain relatively stable with low biological activity, while FCO_2 shows positive fluxes (approx. $3\text{--}4 \mu\text{mol m}^{-2} \text{ s}^{-1}$), indicating net CO_2 emission due to ecosystem respiration. After sunrise, GPP declines and becomes negative by mid-morning, reaching its minimum around 12:00-14:00 h, which corresponds to the period of strongest photosynthetic activity. Simultaneously, FCO_2 decreases and crosses zero around 08:00-09:00 h, marking the transition from net emission to net CO_2 uptake. Maximum CO_2 assimilation occurs between 11:00 and 14:00 h, when median FCO_2 values reach their lowest levels. Both GPP and FCO_2 show the highest variability ($\pm 1\sigma$) during midday, indicating strong sensitivity to environmental factors such as radiation, temperature, and vapor pressure deficit. During the afternoon (14:00-18:00 h), GPP gradually recovers toward neutral values, while CO_2 uptake weakens and FCO_2 returns to positive values by evening, reflecting the dominance of respiration.

Fig. 2.3 Diurnal variation of Gross Primary Productivity (GPP) and Carbon Dioxide Flux (FCO_2). The line shows median values, ± 1 standard deviation ($\pm 1\sigma$).

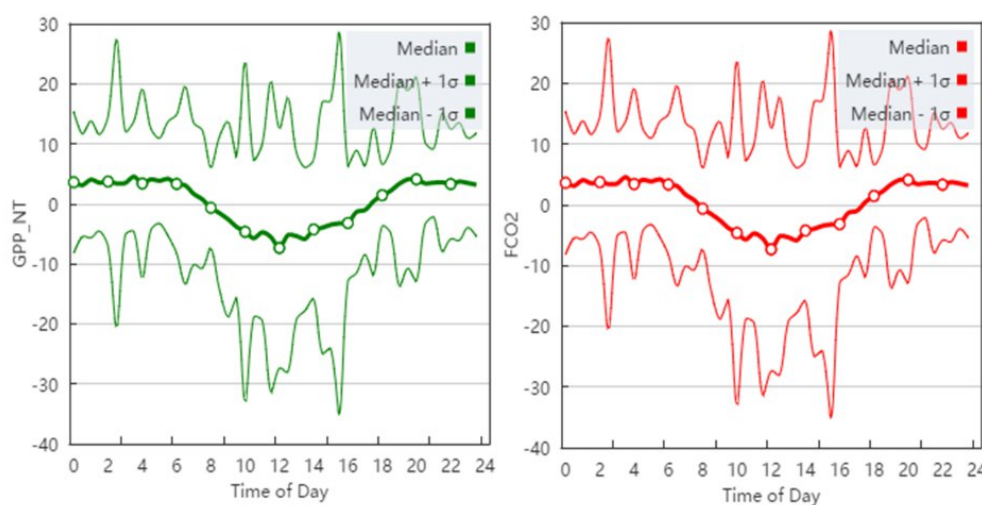
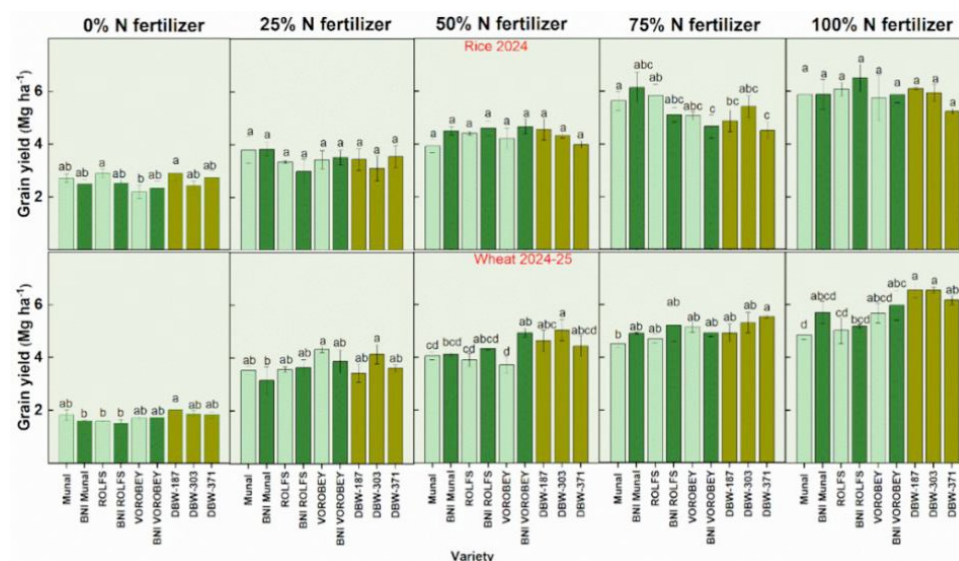


Fig 2.4 Effect of fertility gradient on the grain yield of rice and wheat crop during 2024-25



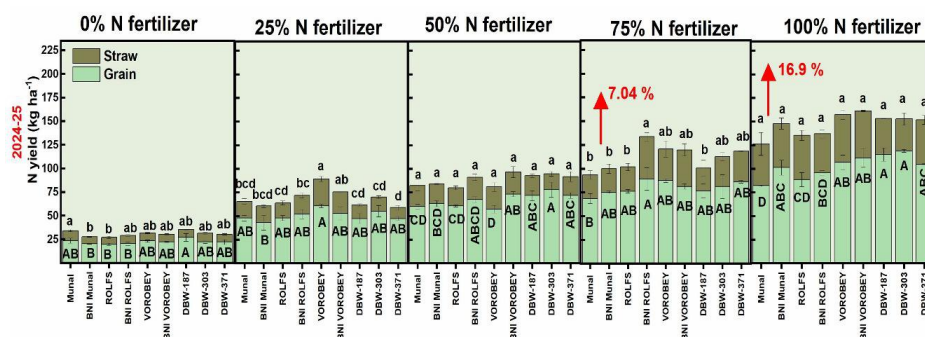
The project for establishment of nitrogen-efficient wheat production system in Indo-Gangetic plains by the deployment of BNI technology (Ajay Kumar Bhardwaj, Awatar Singh, R. K. Yadav)

Three types of experiments, for investigating the nitrogen dynamics as affected by the BNI function, were initiated: 1) BNI function-Nitrogen Fertility Interaction Trials [BNI-FIT], 2) BNI function-Soil pH Interaction Trials [BNI-SMALYS], and 3) BNI-Crop Residue Interaction Trials [BNI-LYS], at ICAR-CSSRI, Karnal. The BNI-FIT trials at CSSRI were initiated in 2023 rice season to test the effects of soil N-fertility gradient on BNI function. The trials have 5 fertility gradient blocks [0%, 25%, 50%, 75%, 100% of recommended N fertilizer application] with six BNI elite lines and three local checks [9 treatments] planted in 3 replications in each block. The data is being collected systematically in each of these trials on N_2O emissions, NO_3^- formation in soil solution and leachate, plant growth and yield parameters, soil and plant enzymatic activity, plant N dynamics, and soil N mineralization dynamics.

The soil and plant samples from different location trials as affected by BNI-function were collected and analyzed for soil and plant N. Grain yield of both rice and wheat crops consistently increased with higher fertilizer levels (Fig. 2.4), indicating a strong positive response to nutrient application. The yield enhancement was more pronounced at 100% recommended fertilizer dose. Notably, BNI-enabled lines exhibited a significant yield advantage over their non-BNI parental lines at the 100% fertilizer level. The lowest yields were recorded under 0% N in both crops, with relatively small varietal differences. Application of 25% and 50% N substantially improved grain yield, while the highest yields were achieved at 75% and 100% N levels. Varietal differences became more evident at higher N rates, indicating varied responsiveness among genotypes.

Nitrogen (N) uptake (grain + straw) of wheat increased progressively with increasing N fertilizer levels across all varieties (Fig. 2.5). Under 0% N, total N yield was lowest, with relatively small varietal differences. Application of 25% and 50% N significantly enhanced N accumulation in both grain and straw, indicating improved nutrient uptake with fertilizer addition. Compared to its parent variety Munali, BNI Munali showed clear improvement in total N yield (grain + straw) at higher nitrogen levels. At 75% N fertilizer, BNI Munali recorded a 7.04% increase in total N yield over Munali. This improvement

Fig 2.5 Effect of fertility gradient on the grain and straw N of wheat crop during 2024-25



became more pronounced at 100% N, where BNI Munal exhibited a 16.9% higher N yield compared to its parent.

Promotion of sustainable food systems in India through transforming rice-wheat systems (Gajender, R. K. Yadav, Suresh Kumar, Satyender Kumar and Amresh Chaudhary)

The high-input intensive rice-wheat production systems, which currently dominate in the project districts of Punjab and Haryana (located in the Indo-Gangetic Plain), have generated significant environmental and health concerns both nationally and globally. These concerns include soil degradation, groundwater depletion, water and air pollution. These challenges are evident both on-farm and in the degradation of the watersheds they depend on ecosystem services. Keeping these in view, the project, “Promotion of Sustainable Food Systems in India through Transforming Rice-Wheat Systems” is funded by the GEF (Global Environment Facility), coordinated by FAO and implemented by the Ministry of Agriculture and Farmers Welfare (MoA&FW) in four states: Punjab, Haryana, Chhattisgarh and Odisha. ICAR-CSSRI is implementing the project in Karnal and Kaithal districts of Haryana. In Karnal district, three blocks viz: Karnal, Gharaunda, Indri and in Kaithal district Guhla, Rajaund and Siwan block were selected for interventions. Soil samples were collected from 30 sites at farmer fields covering 3 blocks each of Karnal and Kaithal districts. Soil pH across the six blocks indicated alkaline conditions ($\text{pH} > 7.5$ but less than 8.5 at 0-15 cm soil), with values largely ranging from moderately to strongly alkaline. Higher pH values were consistently observed in the sub-surface layer (15–30 cm) compared to the surface layer, particularly in Karnal, Rajound, Siwan and Guhla blocks. In contrast, Gharaunda block exhibited relatively lower pHs values and narrower interquartile ranges, suggesting more uniform soil reaction and comparatively lower sodicity risk.

Soil organic carbon (SOC) content showed a clear depth-wise decline across all blocks, with surface soils consistently showing higher SOC levels than sub-surface soils. Overall, the mean SOC (%) across all the blocks and depths was 0.55%. Among the blocks, Gharaunda and Rajound exhibited comparatively higher SOC, 0.75 and 0.64% at surface soil. Indri block showed the highest median nitrogen content (175 kg ha^{-1}), especially in the surface layer. In contrast, Karnal and Siwan exhibited comparatively lower nitrogen availability, 94 and 90 kg ha^{-1} , respectively. Surface soils generally contained higher phosphorus than sub-surface soils, likely due to fertilizer placement and limited downward mobility of phosphorus. Karnal and Rajound blocks showed relatively higher phosphorus availability, whereas Guhla and Siwan exhibited lower and more constrained phosphorus levels. Available potassium showed the highest concentrations among the nutrients studied and demonstrated marked block-wise variability. Rajound block

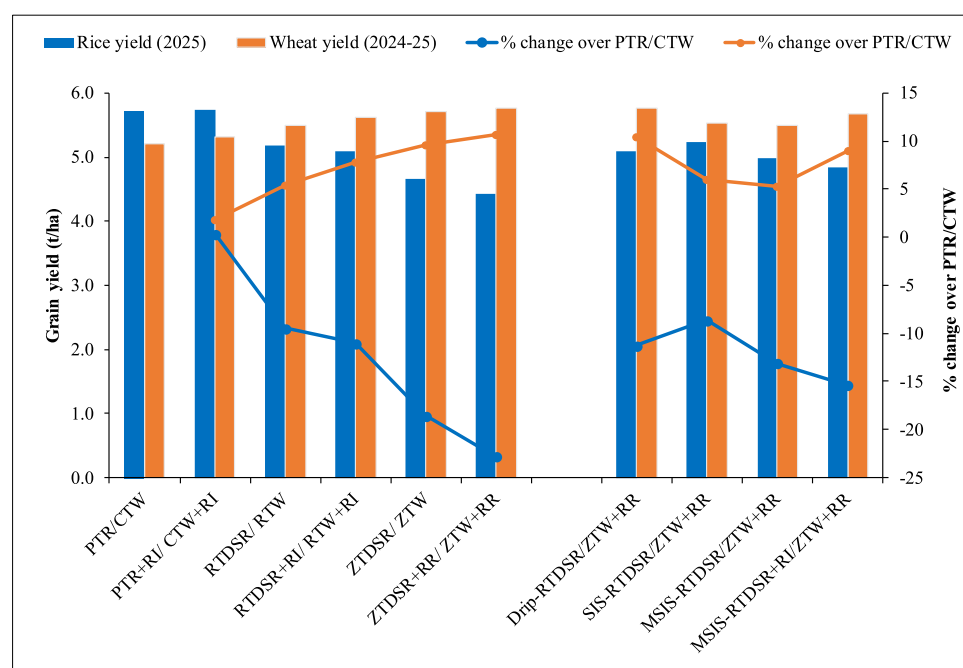
showed higher potassium levels 453 kg ha^{-1} , followed by Karnal and Indri, 249 and 225 kg ha^{-1} in surface soils. In contrast, Gharaunda and Siwan exhibited comparatively lower potassium content. Unlike nitrogen and phosphorus, potassium showed a relatively modest decline with depth, suggesting its association with soil mineral fractions and limited susceptibility to leaching under the prevailing conditions.

Enhancing productivity of reclaimed sodic soils through conservation agriculture and pressurized irrigation systems in a rice–wheat cropping system (R. K. Fagodiya, A. K. Rai, Kailash Prajapat and Priyanka Chandra)

Impact of long-term tillage and residue management, with revised treatments of drip and sprinkler irrigation on crop productivity was evaluated. The high-yielding variety rice (*Arize 6129 Gold*) and salt tolerant variety of wheat (*KRL 210*) were cultivated as test crops during the year 2024-25. The treatment combinations studied were 1) Puddled transplanted rice followed by conventional tilled wheat (PTR/CTW); 2) PTR with $1/3^{\text{rd}}$ wheat residue incorporation followed by CTW with $1/3^{\text{rd}}$ rice residue incorporation (PTR+RI/CTW+RI); 3) Reduce tillage direct seeded rice followed by reduced tillage wheat (RTDSR/RTW); 4) RTDSR with $1/3^{\text{rd}}$ wheat residue incorporation followed by RTW with $1/3^{\text{rd}}$ rice residue incorporation (RTDSR+RI/RTW+RI); 5) Zero tillage direct seeded rice followed by zero tillage wheat (ZTDSR/ZTW); 6) ZTDSR with $1/3^{\text{rd}}$ wheat residue retention followed by ZTW with $1/3^{\text{rd}}$ rice residue retention (ZTDSR+RR/ZTW+RR); 7) Drip irrigated RTDSR followed by ZTW wheat with 100% rice residue (Drip-RTDSR/ZTW+RR); 8) Surface irrigated RTDSR followed by ZTW wheat with 100% rice residue (Drip-RTDSR/ZTW+RR); 9) Mini-sprinkler irrigated RTDSR followed ZTW wheat with 100% rice residue (MSIS-RTDSR/ZTW+RR); 10) Mini-sprinkler irrigated RTDSR with $1/3^{\text{rd}}$ wheat residue incorporation followed by ZTW wheat with 100% rice residue (MSIS-RTDSR+RI/ZTW+RR);

The grain yield of rice during 2025 and wheat yield during 2024-25 under different treatments were presented in Fig 2.6. Among all the treatments, only PTR+RI/CTW+RI system produced higher (0.3%) rice yield compared to PTR/CTW (5.73 t ha^{-1}). The grain

Fig 2.6 Effects of tillage, residue and irrigation management practices on grain yield of rice and wheat.



yield in DSR treatments under long-term tillage and residue management practices was 9.5–22.8% lesser compared to PTR. However, the reduction was higher under long-term zero tillage DSR as compared to long-term reduce tillage DSR. The DSR yield under different irrigation systems was 8.6%, 11.2% and 13.15–15.0% lesser in surface, drip and sprinkler irrigation systems. With respect to wheat grain yield, the reduced tillage and zero tillage treatments increased wheat yield by 5.4–7.8% and 9.6–10.7%, respectively, relative to the CTW yield (5.2 t ha^{-1}). Drip irrigated ZTW+RR recorded the highest wheat grain yield (5.76 t ha^{-1}), representing a 10.4% increase over the CTW, followed by mini-sprinkler irrigated ZTW+RR which produced a yield of 5.68 t ha^{-1} . PTR remained the most stable and high-yielding practice for rice, with only PTR+RI showing a marginal advantage. In contrast, wheat responded positively to conservation practices, with zero tillage wheat with residue retention (ZTW+RR), especially under drip irrigation, producing the highest yields. Pressurized irrigation systems enhanced wheat performance but requires further refinement for DSR. Overall, integrating residue management with conservation tillage in wheat while maintaining transplanted rice offers the best strategy for sustaining and improving rice–wheat system productivity.

Effect of residue management on soil microbial activities under salt affected soils in rice-wheat system (Madhu Choudhary, Sanjay Arora, Hardev Jat and Rajender Kumar Yadav)



CSR-Manage-R

For the in-situ management of crop residue the studies were conducted in normal, saline and sodic soils. After harvesting of rice crop, straw was incorporated and placed on the surface. Spray of consortia of fungal isolates (*Aspergillus flavus*, *Aspergillus terreus* and *Penicillium pinophilum*) was done twice. The decomposition was observed more in residue incorporation treatment than residue retention treatment. This trend was observed in all three types of soils. After six months of treatment the weight loss was found in the range of 60–70%. Formulation was also developed and tested for the growth of fungi up to 30 days and different parameters like EC, pH and microbial cell count were found in desired range. For further testing of the formulation in the field, bottles of 500 mL “CSR-Manage-R” are prepared and will be distributed to the different agencies and farmers.

Developing biostimulants for stress mitigation, soil health, nutrient cycling, and resiliency of the cropping system in salt affected soils (Priyanka Chandra, Arvind Kumar Rai, Parul Sundha, Awtar Singh, Amresh Chaudhary and R. K. Yadav)

Arbuscular mycorrhizal fungi (AMF) play pivotal roles in enhancing plant nutrient acquisition and overall ecosystem sustainability. The propagation of AMF involves several methodologies tailored to address specific research or practical objectives. So, enhancing methods for propagating AMF is pivotal for fostering sustainable agriculture and maintaining ecosystem balance at the application level. However, traditional substrate-based techniques focus on the isolation, purification, and cultivation of AMF spores, thereby enabling the establishment of pure cultures. Hydroponic systems have emerged as valuable platforms for AMF cultivation, offering controlled environments to study spore germination, hyphal growth, and mycorrhizal colonization. Hydroponic techniques for AMF spore propagation involve cultivating these beneficial fungi in nutrient-rich liquid solutions rather than in traditional soil-based media. This methodology has gained attention because of its potential to enhance spore production

Fig 2.7 Evaluation of Arbuscular Mycorrhizal Fungi (AMF) propagation in a sorghum-based hydroponic system under varying nutrient-supplemented treatments



and facilitate controlled experimental conditions. This study utilizes Sorghum as a host plant in a 24-day experimental timeline (Fig. 2.7). The process begins with a 10-day establishment phase in a nutrient-rich solution to ensure robust root development. This is followed by a 7-day treatment phase, where phosphorus deficiency conditions were imposed. The cycle concludes with a 7-day drought condition phase which stimulates the fungi to produce spores as a survival mechanism, thereby increasing the total harvestable spore count. AMF serves the plant primarily by scavenging phosphorus; consequently, when the hydroponic solution is phosphorus-deficient, the plant increases its signaling to the fungi, leading to significantly higher colonization rates. As observed in the results under phosphorus stress exhibited denser root structures and higher symbiosis.

Enrichment of FOM produced from CBG plants and development of package of practices (PoP) for major crops (Arvind Kumar Rai, Parul Sundha, Priyanka Chandra and Kailash Prajapat)

Fermented organic manure (FOM) is an efficient organic amendments source to supplement major, secondary and micronutrient for agricultural crop. Therefore, combined application of organic manure and mineral fertilizers produces higher crop yield. Further, FOM has synergism for improvement in soil physical and biological properties of soil. Besides being a source of N, P, K and S and micronutrients, FOM influences availability of the most of the nutrients through regulating soil pH, oxidation-reduction regime, increase chelation capacity. These organic amendment helps in restoring soil physical and biological properties of soils. This project explores the potentiality of FOM application in soil for crop growth, yield, nutrient uptake and soil fertility with objectives to characterize the FOM/LFOM produced from different CBG plants and assess its quality parameters for use as manure, development of pretreatment techniques and converting them as a manure with suitable quality parameters, enrichment and value addition of FOM with N reduction process and suitable strains of bio-consortia for nutrient mobilization and mixing with molasses, rock phosphate, and vermicomposting and to evaluate the proper dose and application of enriched fermented organic manure (EFOM) in different cropping system at different locations and its popularisation. The initial characterization of the FOM collected from different sites was carried out. The material has potential to be used as source of nutrition and amendment in sodic soils. The potentially toxic elements Cd, Ni, Pb and Cr were not detected or below the permissible standards in all the samples. The incubation



Salt tolerant Rice- CSR 56 in lysimeters at CSSRI experimental site

experiment carried out to treat the FOM/BGS with diluted nitric acid and neutralized with lime increased the availability of mineralizable nitrogen and water soluble Ca in the FOM samples. The ammonical-N was increased in all the treatments while nitrate-N declined after 30 days of incubation. The integrated application of RDF (recommended dose of N, P, K and Zn fertilizer) + FOM @ 300, 600, 900 and 1200 kg per acre and 80% RDF NPK + FOM @ 300, 600, 900 and 1200 kg per acre reported higher grain and straw yield and grain to straw ratio than the unamended control. The application of 25GR+enriched-FOM increased the rice grain yield at par to 50 GR.



Management of Waterlogged/Saline Soils

Regional Salt Balance Modeling of Western Yamuna Canal Command of Haryana (Satyendra Kumar, Bhaskar Narjary and Sagar Vibhute)

While canal irrigation has significantly improved agricultural productivity, it has also contributed to the development of secondary salinization in many areas of the Western Yamuna Canal Command of Haryana due to injudicious and unscientific irrigation practices. The sub surface drainage (SSD) is proven technology being promoted for restoration of land productivity of such waterlogged land. In SSD system, water is allowed to percolate through the saline soil profile, and the percolated water is collected through installed perforated lateral and collector pipes. The collected drainage effluent is pumped into a surface drain. Consequently, the pumped water contributes to the salt load in the surface drain, which may cause environmental problems downstream. Therefore, for the safe disposal of drainage effluent, both the volume of water to be disposed of from the project and the carrying capacity of the nearby surface drain are crucial.

To quantify the volume and salinity of drained water at the farm or project level, water and salt balance modeling using the DRAINMOD model was undertaken for a representative project site at *Kahni*, located in the Western Yamuna Canal (WYC) command. Input data related to drainage system design, soil hydraulic properties, irrigation, crop parameters, and soil salinity were used for model calibration and validation. These parameters were adjusted within their realistic ranges based on actual field conditions. The field data recorded during the first year of operation of the project were used for model calibration, while the second-year data were used for model validation. During calibration, different parameters were adjusted so that the predicted daily water table depth and soil profile salinity closely matched the observed data. These parameters included drainage system design parameters such as effective drain radius (3.2 cm) and equivalent depth from the surface to the impermeable layer (246 cm), lateral saturated hydraulic conductivity (1.44, 1.34, and 1.04 cm h⁻¹ for the 0-30, 30-100, and 100-180 cm soil depths, respectively), relationships between void volume and water table depth, soil water characteristics in relation to void volume and upward flux, and Green-Ampt infiltration parameters (A: 0.00-0.02 and B: 0.11-0.35). Subsequently, the performance of the model during the calibration period was evaluated using different model performance indicators. A close agreement was observed between the observed and predicted water table depths, with a mean absolute error (MAE) of 7.63 cm, model efficiency (ME) of 93%, coefficient of determination (R²) of 0.95, and normalized root mean square error (NRMSE) of 11.64 cm.

To predict the daily salt concentration in different soil layers, the model was also calibrated and validated using the recorded data on soil profile salinity (ECe). Model parameters related to solute transport, such as dispersivity and tortuosity factors, were adjusted to obtain a close match between the observed and predicted soil salinity values. The calibrated values of dispersivity and tortuosity were 4.13 and 0.8, respectively. The model showed good agreement between the observed and predicted soil salinity values, with MAE, ME, R², and NRMSE values of 0.98 dS m⁻¹, 0.95, 0.86, and 1.03 dS m⁻¹, respectively. The observed and predicted values of water table depth and soil salinity (ECe) are presented in figure 3.1.

Fig 3.1 Observed and predicted values of water table depth and soil EC for calibration period

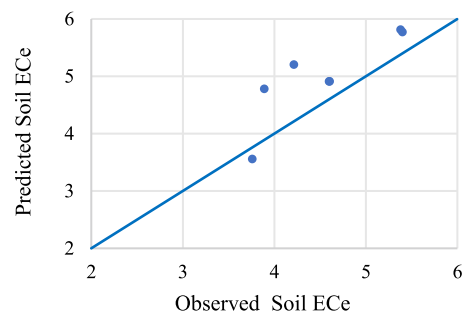
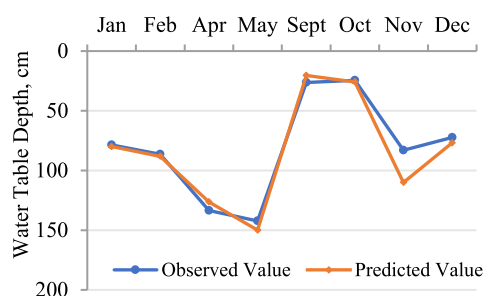
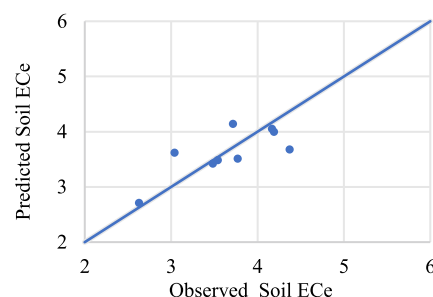
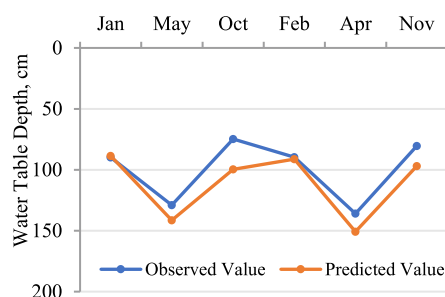


Fig 3.2 Observed and predicted values of water table depth and soil ECe during validation



The calibrated model was further used for validation of water table depth and soil EC during subsequent year, results are presented in figure 3.2.

The model performance during validation for water table depth simulation was satisfactory, with a MAE of up to 24.9 cm, ME of 63%, R^2 of 0.87, and normalized root mean NRMSE of 14.56 cm. The model performance for simulating soil salinity was also found to be satisfactory, with MAE, ME, R^2 , and NRMSE values of 0.69 dS m^{-1} , 0.93, 0.65, and 0.35 dS m^{-1} , respectively.

Estimation of surface drainage capacity for safe disposal of drainage effluent

The daily drainage flux and salinity were also simulated using the calibrated and validated DRAINMOD model to determine the minimum surface drain flow required for safe disposal. For a representative site of 19 ha, it was estimated that a minimum drain discharge of 48.39 L s^{-1} would be sufficient to safely dispose of the salt load carried by the SSD network. Moreover, for the safe disposal of the salt load from the entire 160 ha SSD project area, the drain discharge should be at least 407.50 L s^{-1} . Further, it is estimated that about 1,819 tones salts were disposed of in surface drain in a year from the project area of 160 ha.

Modelling Soil Salinization in Irrigated Agriculture under Climate Change Scenarios (Bhaskar Narjary, Satyendra Kumar, Jitendra Kumar and Sagar Vibhute)

Soil salinization in irrigated agriculture is a complex process influenced by irrigation water quality, soil characteristics, climatic conditions, and interactions with the groundwater system. Rohtak district of Haryana, which represents an irrigated agricultural region and is affected by waterlogging and salinity was selected to study the effect of climate change on soil salinization. Soil samples were collected from 262 locations across the Rohtak district to characterize soil texture and root zone soil salinity (Fig 3.3). Groundwater table depth and salinity data for 2020-21 were collected from CGWB for characterizing groundwater hydrology. Soil texture analysis showed high variability across the district. The soils of the Rohtak district texturally categories as clay loam to sandy clay loam with sand percentage varying from 60%-88%. The root zone soil

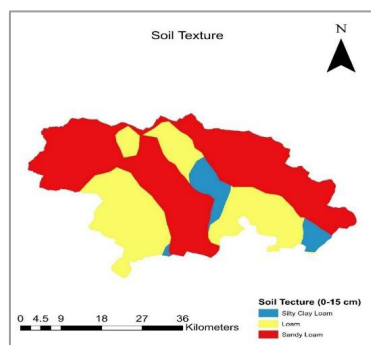


Fig 3.3 Soil texture map of the study area

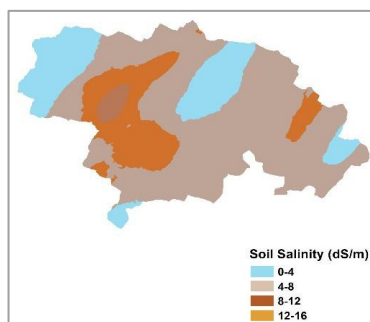


Fig 3.4 Root zone soil salinity of the study area

Table 3.1 Groundwater table and groundwater salinity area of the study area (Rohtak)

WTD (m)	Area (ha)	Water Salinity (dS m ⁻¹)	Area (ha)
< 1.5	7,310.25	< 2	78,873
1.5 – 3	179,194.56	> 2	87,945
3 – 5	272,070.80		
5 – 10	315,281.96		
10 – 20	313,188.52		

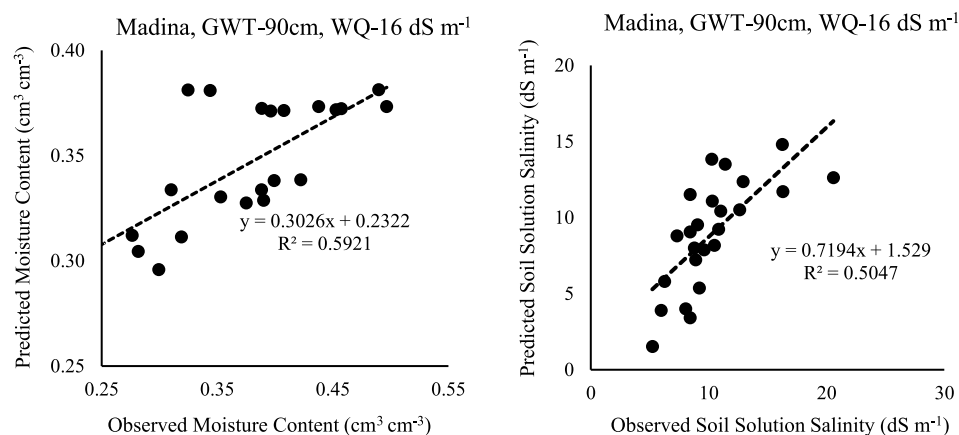


Fig 3.5 Hydrus model calibration for sandy loam soil

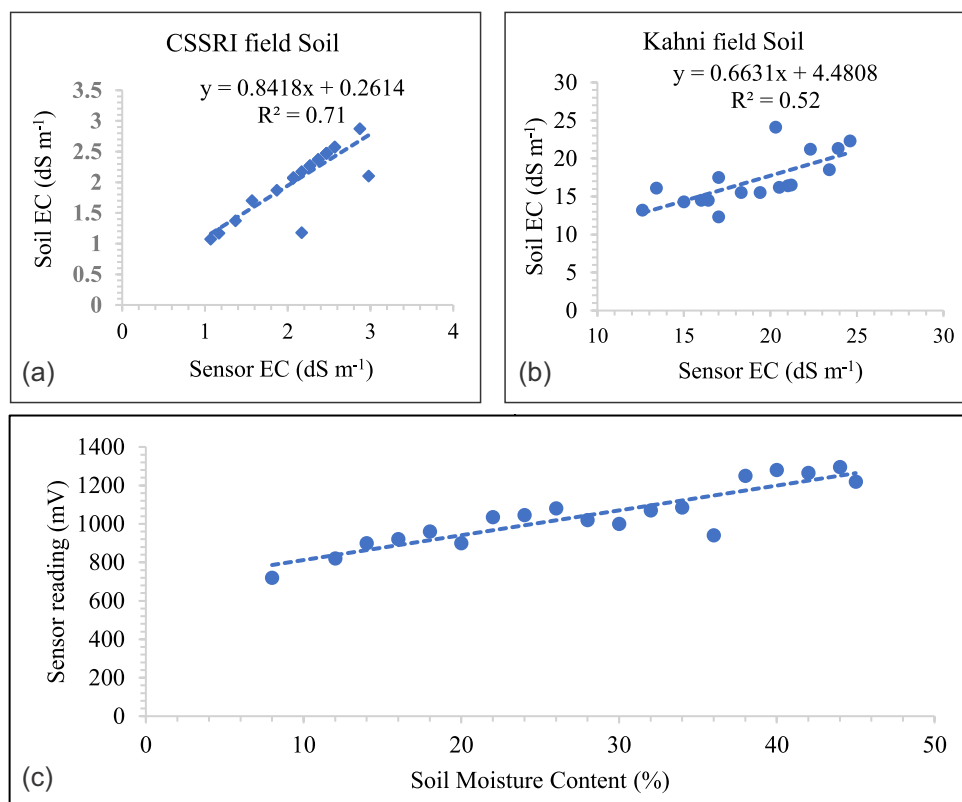
salinity classification of Rohtak district indicates that moderately saline soils (4-8 dS m⁻¹) dominate the area, covering 88,351 ha. Non-saline to slightly saline soils (< 4 dS m⁻¹) occupy 31,154 ha while strongly saline soils (8-12 dS m⁻¹) extend over 26,377 ha, posing moderate to high constraints on crop productivity. The severely saline class (12-16 dS m⁻¹) is limited to 3016 ha, indicating that extreme salinity occurs only in small pockets (Fig 3.4).

The groundwater classification of the Rohtak district shows that substantial areas with shallow to moderately shallow watertable (1.5-5 m) are vulnerable to waterlogging and salinity development. Groundwater salinity analysis reveals that a considerable area (87,945 ha) is affected by saline groundwater (>2 dS m⁻¹), while 78,873 ha have low-salinity water (<2 dS m⁻¹) suitable for irrigation (Table 3.1). From these major soil types, two soil types representing heavy (Clay loam) and light (Loam) texture soil were collected for lysimeter study from Kahnai and Madina Villages of Rohtak. For simulating salt water dynamics, shallow saline groundwater table and saline condition were created in lysimeter. Salt and water movement was simulated through Hydrus model in shallow saline groundwater table condition (water table depth: 90 cm and groundwater salinity: 16 dS m⁻¹) for loam type of soil. The model was calibrated using observed data of soil moisture content and soil salinity relating to 0-15, 15-30, 30-60 and 60-90 cm soil profile. There was good agreement between observed and simulated soil moisture contents and soil salinity as indicated by high R² values. During calibration periods model accounted R² of 0.60 for soil moisture content and 0.50 for soil salinity (Fig. 3.5).

Development of Sensor and IoT based Irrigation System for Enhancing Water Productivity under Salt Affected Environment (Jitendra Kumar, Bhaskar Narjary, Sagar Vibhute, Satyendra Kumar and Ashwani Kumar)

The sensor-based irrigation system enables continuous monitoring of soil salinity and

Fig 3.6 Sensor Performance with variation of soil electrical conductivity(dS m^{-1}) at site



moisture thresholds in conjunction with decision support advisories and control mechanisms, thereby facilitating real-time irrigation scheduling based on crop water requirements. With the aim to develop soil moisture and salinity sensor, an experiment was conducted to establish the relationship between soil electrical resistivity and moisture content across different soil types for the developed sensor. Soil resistivity decreased with increasing moisture content due to enhanced ionic mobility and improved continuity of the liquid phase within the soil matrix. In general, fine-textured soils exhibited lower resistivity values than coarse-textured soils; however, under saturated conditions, sandy soils may also exhibit low resistivity compared to dry soils. The average soil moisture decreased from 39.71% at 0 h to 37.54% (4 h), 29.32% (12 h), 26.32% (24 h), 24.11% (36 h), 23.18% (48 h), and 21.19% (72 h), corresponding to an increase in resistance from 11 to 478 ohm-m. A non-linear relationship between soil resistance and moisture content was observed with R^2 values ranging from 0.71 to 0.52 as electrical conductivity increased from 1.2 to 24.5 dS m^{-1} in CSSRI field soil and Kahni village soil under pot conditions (Fig.3.6 a,b). Sensor output voltage increased from 720 to 1295 mV as soil moisture content increased from 7.7% to 44.6% in sandy loam soil (Fig. 3.6c).

Management of Nitrogen Losses in Reclaimed Waterlogged Saline Soil using Agro-Engineered Techniques (Raj Mukhopadhyay, Sagar Vibhute, Kailash Prajapat, Ram Kishor Fagdiya and Satyendra Kumar)

Nutrient loss is a major concern in subsurface drainage (SSD)-reclaimed saline soils. Nitrogen (N), the most critical nutrient for plant growth, is particularly important in the rice–wheat cropping system, which requires substantial N inputs. However, significant N losses through leaching and volatilization often result in soil N deficiency and nitrate contamination of groundwater, compelling farmers to apply excessive nitrogenous



(a) SSD-reclaimed (b) non-reclaimed

Fig 3.7 Soil profile of (a) SSD reclaimed and (b) non-reclaimed (control) waterlogged saline soil (depth 0-90 cm)

fertilizers. Therefore, mitigating N losses from soil profiles following SSD installation is essential and requires the adoption of suitable agro-engineered techniques. This project aims to develop integrated agro-engineered strategies to minimize N losses from soil, assess nitrogen budgeting in SSD-reclaimed waterlogged saline soils, and provide farmers with practical, user-friendly recommendations for reducing N losses through SSD-drained water while promoting efficient and sustainable use of nitrogenous fertilizers in the rice–wheat system. The SSD-reclaimed site at Kathura was selected for this study, where 289 ha of waterlogged saline land has been reclaimed over the past four years. Initial soil and groundwater salinity at both the SSD-installed and control (non-SSD) sites have been characterized. At the SSD-reclaimed Kathura site, groundwater at a depth of 90 cm exhibited an average pH of 7.90 ± 0.45 and EC of $5.38 \pm 1.02 \text{ dS m}^{-1}$, compared to corresponding values of 7.16 ± 0.02 and $16.07 \pm 0.31 \text{ dS m}^{-1}$ at the non-reclaimed site, indicating significant improvement in groundwater quality due to SSD installation (Fig. 3.7). The bulk density of surface soil (0–30 cm) at the SSD-reclaimed site was 1.87 Mg m^{-3} , lower than that of the non-reclaimed site (2.03 Mg m^{-3}), while soil texture (sandy clay loam) remained unchanged. The pH_s and EC_e of the upper 0–30 cm soil layer was 7.48 ± 0.25 and $4.3 \pm 0.32 \text{ dS m}^{-1}$ at the SSD-reclaimed site, compared to 7.44 ± 0.04 and $7.18 \pm 1.68 \text{ dS m}^{-1}$ at the non-reclaimed site, respectively, suggesting that SSD operation reduced soil salinity by approximately 40% within four years of continuous pumping.

Optimizing Drain Spacing of Subsurface Drainage System in Sugarcane Growing Areas of Saline Vertisols (Vibhute Sagar Dattatraya, Pathan Aslam Latif, Satyendra Kumar, Raj Mukhopadhyay, D. S. Bundela, Suresh Kumar and Anil R. Chinchmalatpure)

Subsurface Drainage (SSD) Technology is rapidly expanding across the *Vertisol* regions of Maharashtra, Karnataka, and Gujarat, with particularly high adoption in sugarcane cultivation. However, determining the optimum spacing of lateral drains in *Vertisols* remains a subject of ongoing debate, as farmers currently use a wide range of spacing from 10 to 30 m in sugarcane fields. Different drain spacing has varying implications for crop yield, salinity control, cost economics, and nutrient losses, each presenting distinct advantages and limitations. Therefore, the present study aims a system-based approach to comprehensively evaluate SSD performance under different lateral spacing (10–30 m). The study will assess multiple parameters in an integrated manner, including soil salinity reduction, water table drawdown, drain outflow quality (nutrient losses and salt concentration), economic returns, and potential environmental risks. The methodology combines field experimentation for generating site-specific data and simulation modelling using the DRAINMOD model to determine the optimum drain spacing.

A recently installed SSD system located in the salt affected *Vertisol* region of Gujarat was selected for calibration and validation of the DRAINMOD model to analyze salt and water movement under different drain spacing. SSD system with lateral spacing of 10 m and 20 m have been installed at the site. The initial soil conditions corresponding to both spacing treatments are presented in Table 3.2. It was observed that very high soil salinity is present in the upper 90 cm soil layer under both drain spacing. In addition, the Exchangeable Sodium Percentage (ESP) values exceed 20 in these layers, confirming the saline-sodic nature of the soil. Data on crop performance, drainage effluent, and water table levels will be collected during the upcoming cropping seasons to develop the required model input files. The hydrology and salinity modules of the DRAINMOD model will then be used to

Table 3.2 Initial soil properties under different drain spacing

Soil Depth cm	10 m		20 m	
	ECe (dS m ⁻¹)	pHs	ECe (dS m ⁻¹)	pHs
0-30	9.61	7.68	10.02	7.80
30-60	10.24	7.78	14.9	7.80
60-90	6.23	7.87	11.77	7.56
90-120	2.82	8.08	7.85	7.52
120-150	1.80	8.20	4.28	7.58

simulate drainage outflow volume, salt load in the effluent, water table fluctuations, and changes in soil salinity under different drain spacing in salt-affected *Vertisols*.

Hydro-Salinity Modeling to Assess Salinization Risk in Bhalaut Distributary of WYC Command (Pathan Aslam Latif, D. S. Bundela, Vibhute Sagar Dattatraya, Kailash Prajapat and Raj Mukhopadhyay)

Soil salinity is a major global challenge and a significant constraint to agricultural productivity, particularly in irrigated canal command areas. In India, nearly 2.7 million ha in canal command regions impacted by secondary salinization due to shallow groundwater tables, excess irrigation, seepage losses, and inadequate drainage (FAO, 2021; Sharma et al., 2015). These problems are more severe in intensively irrigated regions where high evaporation and changing climatic conditions accelerate salt accumulation and waterlogging (CSSRI, 2015). The Western Yamuna Canal command (WYC) area, including areas under Bhalaut distributary, represents such a vulnerable irrigated region where improper water management and shallow groundwater conditions may increase the risk of secondary salinization. Therefore, the present study titled “Hydro-salinity

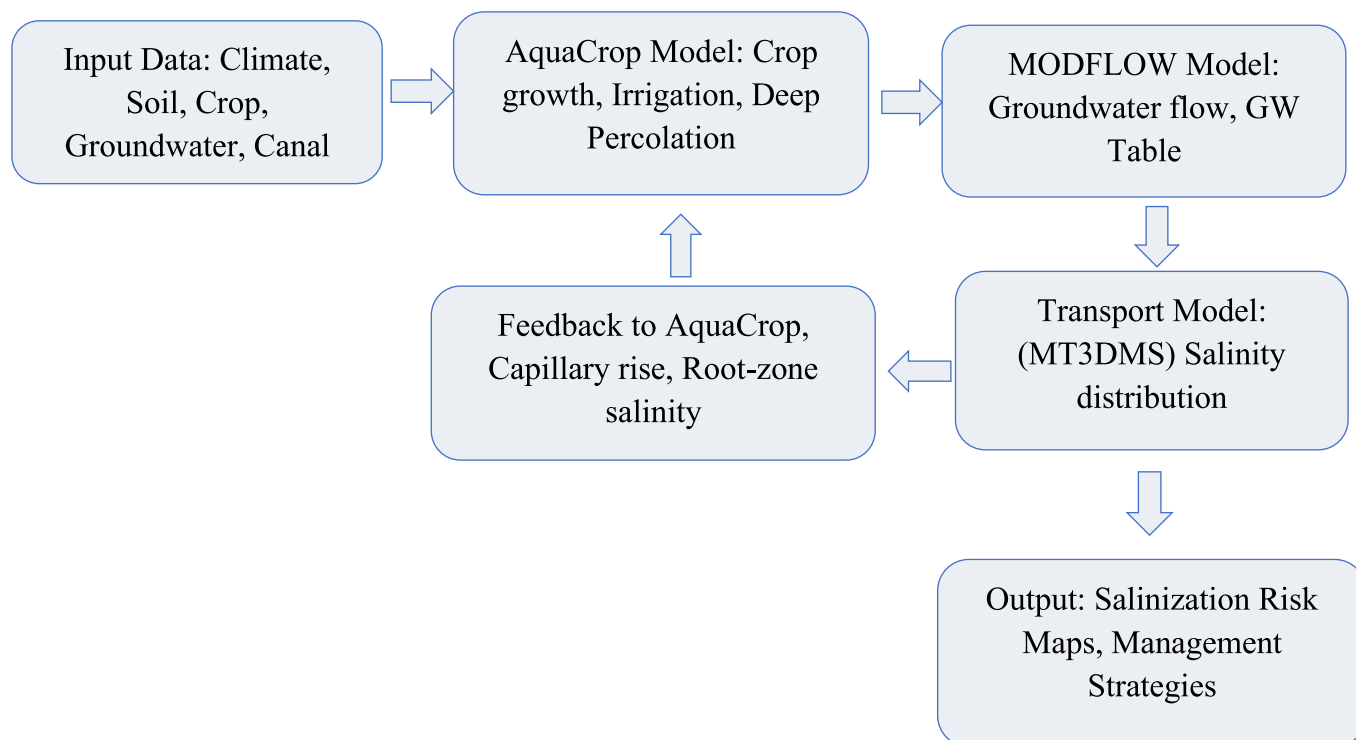


Fig 3.8 Conceptual frame work of hydro-salinity modelling for the study area

modeling to assess salinization risk in Bhalaut distributary of WYC command” aims to assess the spatio-temporal distribution of soil salinity, identify high-risk salinization zones, and develop adaptive management strategies for sustainable agricultural production.

Based on literature review and data availability, a preliminary conceptual hydro-salinity model for the study has been developed (Fig. 3.8). The conceptual framework identifies major hydrological components including canal seepage, irrigation return flow, groundwater recharge, evapotranspiration, and groundwater withdrawal.

For numerical simulation, the groundwater flow model MODFLOW has been identified for simulating groundwater dynamics within the command area, while the crop-water productivity model (AquaCrop) is being considered to simulate crop water requirements, evapotranspiration, and irrigation demand. Integration of these models will allow simulation of irrigation recharge, groundwater level fluctuations, and potential salinity risks under different irrigation scenarios.

Plant Direct: Integrated DSR System for India (Satyendra Kumar, Gajender, Bhaskar Narjary and Jitendra Kumar)

The present field study was undertaken to evaluate the response of different rice cultivars to various water stress levels under dry direct seeded rice (DSR) establishment. The crop was sown on 14th June, 2025 and four water stress regimes were adopted to evaluate performance of seven varieties/advance lines. The soil matric potential varied from -10 to -35 kPa were imposed during the different crop growth stages to create stage wise different water stress level for the crop. The details of water stress treatments are given in table 3.3. Two released varieties (PR126 and DRR 42) and five advance lines of IRRI (IR22EL1105, IR22EL1492, IR22EL1071, IR22EL1527 and IR22EL1055) were included in the study. The water stress regimes were taken as main plot treatment and varieties were sown in sub plots and considered as sub-treatment. The plot size was 28 x 10 m, in which each variety was sown in a sub plot of 3.5 x 10 m and 0.5 m buffer was left in between the two varieties. Each treatment was replicated thrice. To quantify the amount of water applied to each plot, a pipe network was laid with an independent water meter and outlet for each plot.

The average yield obtained for different crop varieties and advance lines under different irrigation regimes is presented in Fig. 3.9. Figure 3.9a shows that overall (average of all water stress levels) rice grain yield was the highest under IR22EL1055 (5.09 t ha⁻¹), followed by PR126 (4.96 t ha⁻¹) and IR22EL1105 (4.96 t ha⁻¹). The grain yield of other varieties/lines was substantially lower. Further, response of different varieties/lines to water stress levels was

Table 3.3 Crop growth stage wise water stress level adopted under different irrigation regimes

Treatment	Establishment phase (0-21 DAS)	Vegetative phase (22-74 DAS)	Flowering & Maturity phase (75-115 DAS)
	Soil matric potential (kPa)		
T1	10	10	10
T2	15	15	15
T3	15	25	15
T4	15	35	15

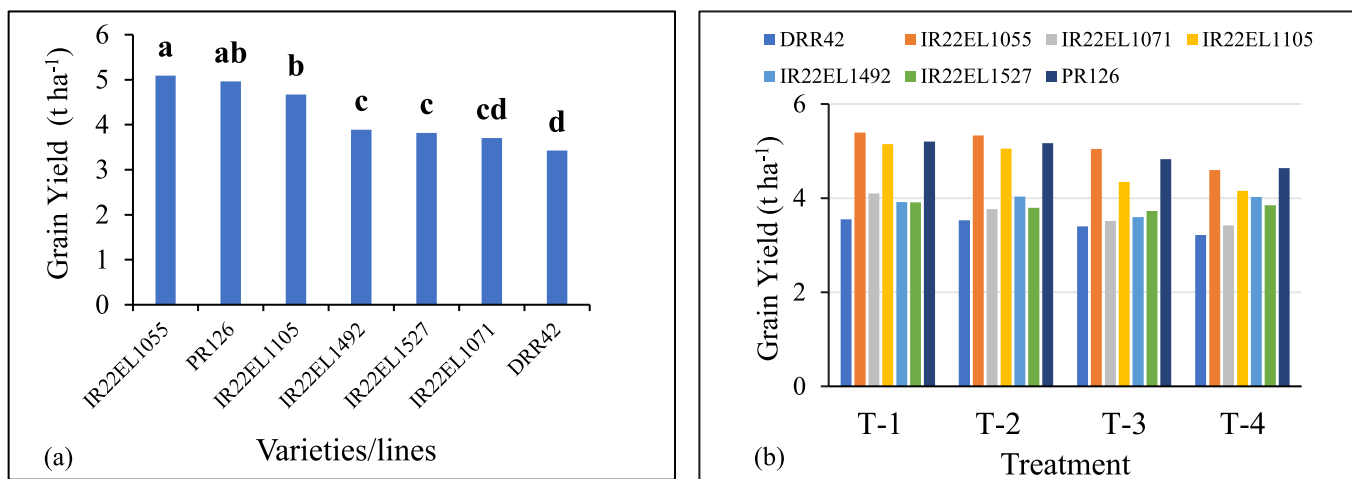
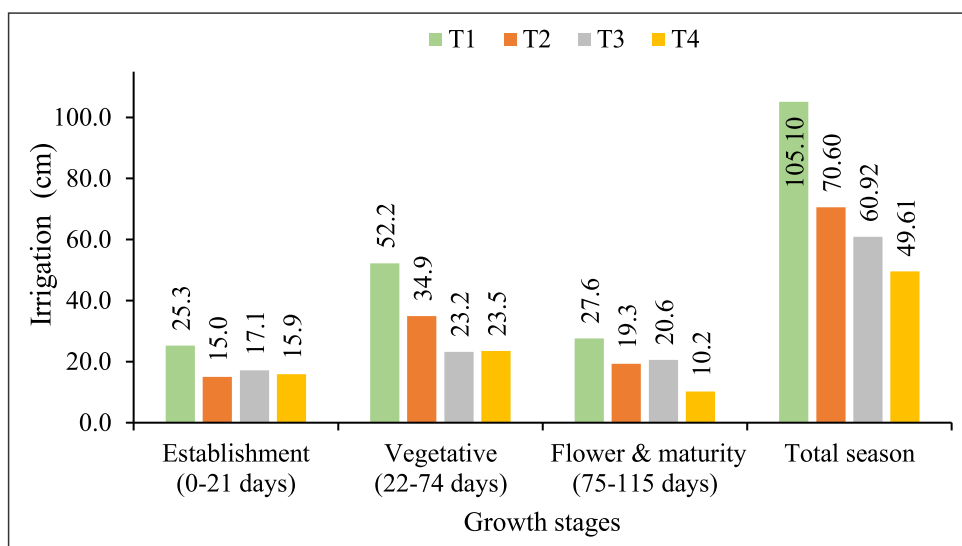


Fig 3.9 The obtained rice grain yield a) under different varieties/ advance lines and b) various water regime

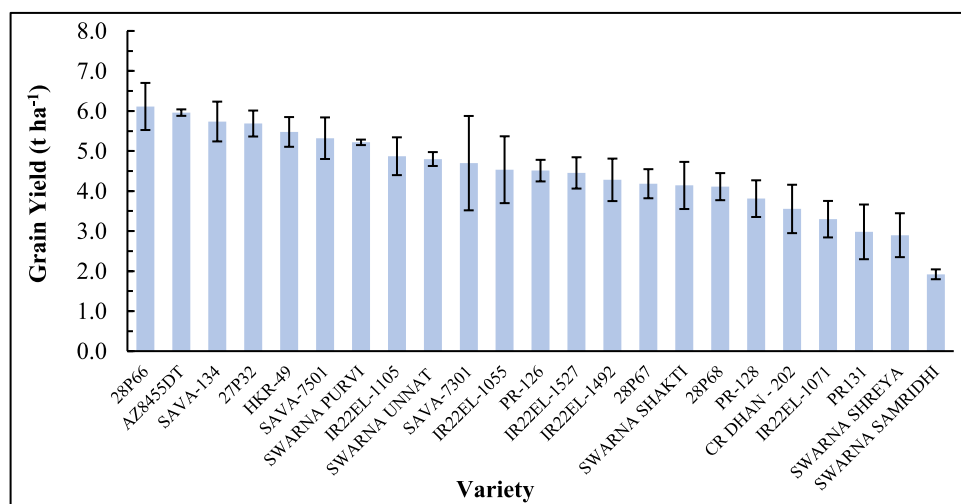
Fig 3.10 Irrigation applied under different water stress regimes during different growth stages and entire growing season



different (Fig 3.9b). The grain yield of IR22EL1055 was highest i.e. 5.39 and 5.33 t ha⁻¹ under T1 and T2 treatments, respectively, followed by PR 106. However, yield reduction was recorded in PR 126 variety under T3 and T4 where irrigation was scheduled ≥ 25 kPa during the vegetative phase and at 15 kPa during the remaining period. IR22EL1105 advance lines also produced at par yield i.e. 5.15 and 5.05 t ha⁻¹, under T1 and T2 treatments, respectively. However, yield penalty was recorded in IR22EL1105 with further increase in water stress level beyond 15 kPa during the vegetative phase.

The irrigation amount varied from 23.2 to 52.2 cm under different treatments during vegetative phase coincides with rainy season (Figure 3.10). The variation in water applied during vegetative phase resulted into variable total amount of irrigation and the highest (~105 cm) was recorded under T1, while the lowest irrigation (~50 cm) was found in treatment T4. Thus, T4 saved almost 50 percent irrigation water as compared to T1, while saving of ~33% was achieved in T2 as compared to T1. That indicates scheduling irrigation on slightly higher matric potential (-15 kPa) than -10 kPa (near saturation) can also save significant irrigation. The saving in irrigation and variable varietal response to water regimes also translated into variable irrigation water productivity (IWP). Overall, IR22EL1055 line recorded the highest IWP (0.77 kg m⁻³), followed by (0.74 kg m⁻³).

Fig 3.11 Obtained yield for different varieties and advance lines



Various coarse grain varieties were also evaluated their suitability to dry DSR conditions. Field data on grain yield indicates significant variation among the varieties (Fig 3.11). The highest yield was recorded for the variety 28P66 (6.11 t ha⁻¹) which was statistically comparable to AZ8455DT (5.96 t ha⁻¹), SAVA-134 (5.74 t ha⁻¹), 27P32 (5.69 t ha⁻¹), HKR-49 (5.48 t ha⁻¹), SAVA-7501 (5.32 t ha⁻¹), SWARNA PURVI (5.22 t ha⁻¹), IR22EL-1105 (4.87 t ha⁻¹), SWARNA UNNAT (4.80 t ha⁻¹), SAVA-7301 (4.70 t ha⁻¹), IR22EL-1055 (4.53 t ha⁻¹) and PR-126 (4.51 t ha⁻¹), but significantly higher than IR22EL-1527 (4.45 t ha⁻¹), IR22EL-1492 (4.28 t ha⁻¹), 28P67 (4.18 t ha⁻¹), SWARNA SHAKTI (4.14 t ha⁻¹), 28P68 (4.11 t ha⁻¹), PR-128 (4.11 t ha⁻¹), CR DHAN-202 (3.55 t ha⁻¹), IR22EL-1071 (3.30 t ha⁻¹), PR-131 (2.98 t ha⁻¹), SWARNA SHREYA (2.90 t ha⁻¹) and SWARNA SAMRIDHI (1.92 t ha⁻¹).

North Indian Centre for Water Technology Research in Agriculture (Satyendra Kumar, B.L. Meena, Bhaskar Narjary, R.K. Fagodiya and Awtar Singh)

The rice-wheat dominant cropping system, supported by intensive groundwater irrigation, has resulted in a significant decline in the groundwater table in the study area covering the districts of Karnal, Kaithal, Panipat, and Kurukshetra (29°9'46.8" to 30°14'52.8" N latitude and 76°10'33.6" to 77°13'22.8" E longitude), covering an area of 7,736.185 km². To support the sustainable management of groundwater resources, a simulation study was conducted focusing on demand-side reduction, particularly through changes in irrigation requirements. Such reductions can help to bridge the gap between groundwater demand and supply, thereby moderating or potentially arresting groundwater decline. Based on this hypothesis, simulations were performed using the previously calibrated and validated MODFLOW groundwater flow model to evaluate the impact of rice crop duration on groundwater resources. Two prevalent crop durations were considered for the analysis i.e. long-duration rice (150 days) and short-duration rice (125 days). The duration of the wheat crop was assumed to be the same in both scenarios. The irrigation demand under the short-duration transplanted rice-wheat system was found to be substantially lower than that of the long-duration rice-wheat system. Groundwater behaviour was simulated for the period 2013-2021. Simulation results reveal that if short duration direct seeded rice was grown during last decade (2013-21), the groundwater decline below ground level would have been 3 m less as compared to the actual (Fig 3.12). However, difference in declined groundwater level would have been only ~1.34 m less as compared to actual if long duration DSR was adopted. A critical view

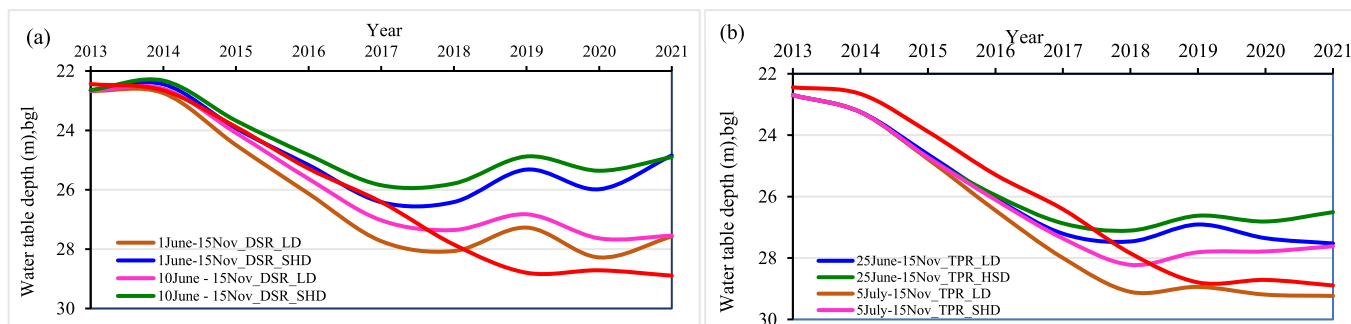


Fig 3.12 Effect of duration of rice crop on groundwater fluctuation of study area under a) DSR and b) TPR establishment technique

on Fig 1b also indicates that short duration transplanted rice is also having positive effect in controlling declining groundwater level of the study region. The adoption of short duration TPR (transplanting on 25 June) with 15 Nov of wheat sowing would result in 2.4 m less groundwater level decline as compared to the actual.

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

The HIROS project was implemented in the Hindon River Basin (Western Uttar Pradesh) to improve sugarcane productivity, reduce groundwater use, and optimize fertilizer and pesticide inputs. Three Agro-Innovation Platforms (AIPs) each covering ~2.5 acres with plot sizes of ~0.5 acre were established (fig. 3.13) at Nandi Firozpur (Saharanpur), Titawi (Muzaffarnagar), and Doula (Baghpat). Five sugarcane management scenarios (table 3.4) were tested across three planting seasons (autumn 2022, spring 2023, summer 2023). Intercrops included black gram (spring) and mustard (autumn). Across all the scenarios, irrigation scheduling was carried out on soil matric potential (–45 kPa) basis using tensiometers installed at 30 cm soil depth. Results of five sugarcane management scenarios (S-1 to S-5) at Titawi and Nandi Firozpur AIP sites for two cropping cycles (Plant and ratoon) were analyzed and presented. The results (Table 3.5) clearly demonstrate the advantage of improved management practices over farmers' practice (S-1), particularly under drip irrigation and reduced input scenarios.

Fig 3.13 Location of 3 AIPs and 4 FPs in the Hindon river Basin (Western UP) with five scenarios

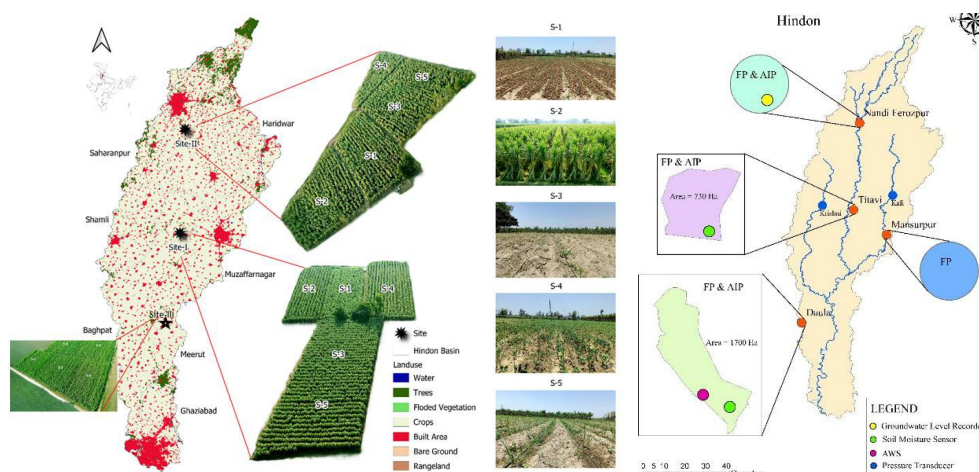


Table 3.4 Details of five experimental scenarios imposed for plant and ratoon sugarcane at two AIP sites

Scenarios	Drivers of change	Crop Rotations	Water Management	Fertilizer Management	Pesticide Management
S-1	Farmers' Practice (FP)	*Sugarcane -Ratoon **Sugarcane - Ratoon	Flood Irrigation	Farmers' Fertilizer Practice: #NPK (kg/ha) – 200:60:60 ## NPK (kg/ha) –300:00:00	Farmers' Pesticide Practice (FPP)
S-2	Improved FP with RDF and RDP	*Sugarcane-Ratoon **Sugarcane - Ratoon	Flood Irrigation	RDF #NPK (kg/ha) – 150:60:60 ##NPK (kg/ha) –200:60:60	Recommended Dose of Pesticide(RDP)
S-3	Improved FP (15% less fertilizers & pesticides)	*Sugarcane-Ratoon **Sugarcane+ Mustard – Ratoon	Drip Irrigation	~15% reduction in RDF: #NPK (kg/ha) – 128:51:51 ## NPK (kg/ha) –170:51:51	~13% reduction in RDP through bio-mechanical control
S-4	Improved FP (15% less fertilizers & pesticides)	*Sugarcane+Black Gram-Ratoon **Sugarcane+Mustard – Ratoon	Flood Irrigation	~15% reduction in RDF: #NPK (kg/ha) – 128:51:51 ##NPK (kg/ha) –170:51:51	~13% reduction in RDP through bio-mechanical control
S-5	Improved FP (30 % less fertilizers & pesticides)	*Sugarcane-Ratoon **Sugarcane + Mustard – Ratoon	Drip Irrigation	~30% reduction in RDF: #NPK (kg/ha) – 105:42:42 ## NPK (kg/ha) –140:42:42	~26% reduction in RDP through bio-mechanical control

* represents spring season planted sugarcane at Titawi AIP & ** represents autumn season planted sugarcane at Nandi F irozpur AIP site

represents NPK dose for first year sugarcane (plant cane) and ## represents NPK dose for 2nd year sugarcane (ratoon)

FPP: Farmers' Pesticide Practice; RDP: Recommended Dose of Pesticide

In spring-planted sugarcane, cane yield varied from 89.4 to 114.2 t ha⁻¹ in plant crop and 61.6 to 72.4 t ha⁻¹ in ratoon. While S-1 and S-4 recorded the highest plant yields, S-5 achieved comparable yields with substantially lower irrigation water (~65% less) and reduced inputs. Drip-based scenarios (S-3 and S-5) significantly enhanced IWP (25.0-29.4 kg m⁻³) and TWP (6.8-8.0 kg m⁻³) compared to flood irrigation (9.0-11.8 and 4.5-5.9 kg m⁻³, respectively). PFPN increased markedly, with S-5 recording the highest values (1032 and 517 kg cane kg⁻¹ N in plant and ratoon), indicating superior nitrogen use efficiency. S-4 also improved PFPN due to intercropping benefits. In autumn-planted sugarcane, yields were generally lower but showed strong improvement under S-3, S-4, and S-5. S-5 recorded the highest yields (80.5 and 62.4 t ha⁻¹) along with maximum IWP (8.7-14.1 kg m⁻³), TWP (4.4-6.0 kg m⁻³), and PFPN (767 and 448). Drip irrigation again outperformed flood irrigation in water productivity, while intercropping in S-4 enhanced productivity compared to S-1 and S-2. Overall, S-5 (drip + 30% reduced inputs) emerged as the most efficient scenario, achieving high yields with maximum water and nutrient use efficiency, while S-4 (intercropping) provided a viable alternative under flood irrigation with improved resource productivity.

The economic analysis (Table 3.6) highlights clear advantages of improved management scenarios over farmers' practice, with differences driven by input costs, irrigation method, and intercropping

In spring-planted sugarcane, the cost of cultivation was the highest in S-1, while S-4 recorded the lowest cultivation cost, followed by S-2. Although drip-based scenarios (S-3 and S-5) involved relatively higher costs due to initial investment on drip system installation, they generated higher gross returns. S-5 achieved the highest gross return (Rs. 6.69 lakh ha⁻¹); however, S-4 recorded the highest net return (Rs. 3.98 lakh ha⁻¹) due to

Table 3.5 Effect of different scenarios on SEY/cane yield, irrigation water productivity (IWP), total water productivity (TWP), and partial factor productivity of nitrogen (PFPN)

Scenario	Cane yield (t ha ⁻¹)		IW applied (mm)		IWP (kg m ⁻³)		TWP (kg m ⁻³)		PFPN (kg cane kg ⁻¹ N)	
	Plant*	Ratoon	Plant*	Ratoon	Plant*	Ratoon	Plant*	Ratoon	Plant*	Ratoon
Spring-planted sugarcane at Titawi AIP										
S-1	113.2a	61.6c	1010	1001	11.2c	6.2c	5.7c	3.5c	566d	205d
S-2	89.4b	66.6bc	988	1027	9.0d	6.5c	4.5d	3.7c	596d	333c
S-3	91.3b	67.8ab	366	624	25.0b	10.9b	6.8b	4.8b	713c	399b
S-4	114.2a	63.0bc	967	1012	11.8c	6.2c	5.9c	3.5c	892b	370b
S-5	108.4a	72.4a	369	627	29.4a	11.5a	8.0a	5.2a	1032a	517a
Autumn-planted sugarcane at Nandi Firozpur										
S-1	51.8b	58.6a	987	716	5.2b	8.2b	2.7b	4.4b	259c	195d
S-2	44.3b	60.1a	939	686	4.7b	8.8b	2.4b	4.6b	296c	300c
S-3	76.9a	59.8a	907	437	8.5a	13.7a	4.3a	5.7a	601b	352b
S-4	79.3a	62.4a	1078	713	7.4a	8.8b	4.0a	4.7b	620b	367b
S-5	80.5a	62.4a	920	444	8.7a	14.1a	4.4a	6.0a	767a	448a

*SEY including intercropping of black gram and mustard in spring season and autumn season respectively.

lower cultivation cost and additional income from intercropping. Net returns under S-4 and S-5 were substantially higher than S-1, indicating better profitability of improved practices. In autumn-planted sugarcane, cultivation costs were comparatively lower, with S-4 and S-2 being the least expensive. S-5 recorded the highest gross return (Rs. 5.29 lakh ha⁻¹), closely followed by S-4. However, maximum net return was again obtained in S-4 (Rs. 2.95 lakh ha⁻¹), owing to its lower input cost and stable yield performance. Farmers' practice (S-1) resulted in the lowest profitability, particularly in the planted sugarcane. Overall, S-4 (intercropping with reduced inputs) emerged as the most profitable scenario across seasons due to lower costs and stable returns, while S-5 (drip with reduced inputs) maximized gross returns but with slightly higher investment.

Daily IrriWatch thermal remote sensing data for 15 experimental fields under three AIPs (planted sugarcane: Jan 2023–March 2024; ratoon sugarcane: March–Dec 2024) were processed using SEBAL 4.0 and AI to estimate vegetation cover, biomass, evapotranspiration, applied water, soil moisture, and leaf nitrogen at 10 m resolution. The projected cane yield was validated against field and factory measurements, showing satisfactory accuracy (4%-11%) at Titawi and Doula, while deviations at Nandi Firozpur were found due to monsoon flooding. Yield prediction was highly accurate (within 4%) for S-2, S-3, and S-4, and slightly underestimated (7%-11%) for S-1 and S-5. Applied water was overestimated by 11%-28% in flood irrigation and underestimated (<11%) in drip systems. Overall, IrriWatch proved reliable for field applications.

Following validation, IrriWatch was deployed across 172 fields under five Farmers' Platforms (FPs). Daily soil moisture, crop growth alerts, and irrigation advisories were delivered through KVKs and sugar mills, enabling proactive crop management. A key advantage of the tool is early detection of crop and water stress before visible symptoms. Initially, 24 staff from KVKs and sugar mills were trained, and advisories were disseminated to farmers via WhatsApp. To improve accessibility, the IrriWatch portal and mobile app were translated into Hindi, and farmers were trained through hands-on

Table 3.6 Effect of different scenarios on sugarcane economics at both AIP sites

Scenario	Cost of cultivation (Rs ha ⁻¹)			Gross return (Rs ha ⁻¹)			Net return (Rs ha ⁻¹)		
	Plant	Ratoon	System	Plant	Ratoon	System	Plant	Ratoon	System
Spring season planted sugarcane									
S-1	2,11,258	99,100	3,10,359	4,18,685	2,28,103	6,46,788	2,07,427	1,29,003	3,36,429
S-2	1,67,835	92,675	2,60,511	3,30,725	2,46,242	5,76,967	1,62,889	1,53,567	3,16,456
S-3	1,92,392	1,10,070	3,02,462	3,37,627	2,50,914	5,88,541	1,45,235	1,40,844	2,86,079
S-4	1,68,680	88,964	2,57,643	4,22,490	2,32,950	6,55,440	2,53,810	1,43,987	3,97,797
S-5	1,92,458	1,05,777	2,98,235	4,00,986	2,67,960	6,68,945	2,08,528	1,62,183	3,70,710
Autumn season planted sugarcane									
S-1	1,66,732	95,187	2,61,919	1,91,603	2,16,679	4,08,282	24,871	1,21,493	1,46,363
S-2	1,54,912	73,371	2,28,283	1,64,045	2,22,357	3,86,402	9,133	1,48,986	1,58,119
S-3	1,69,898	1,00,911	2,70,809	2,84,668	2,21,197	5,05,865	1,14,770	1,20,286	2,35,056
S-4	1,53,318	75,794	2,29,112	2,93,567	2,30,791	5,24,358	1,40,249	1,54,997	2,95,246
S-5	1,68,609	94,339	2,62,948	2,97,827	2,30,980	5,28,807	1,29,218	1,36,641	2,65,859

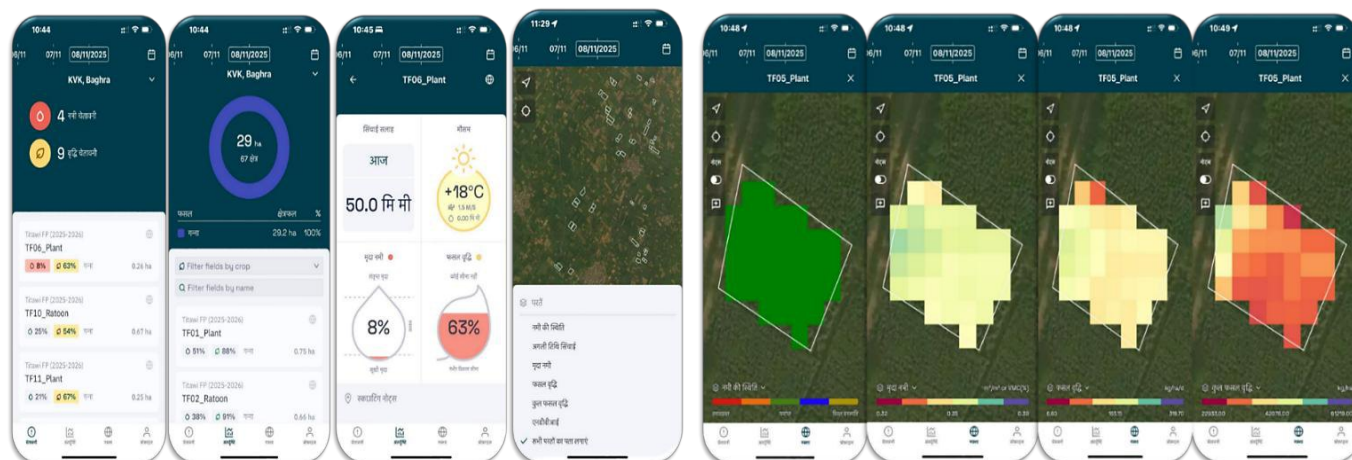


Fig 3.14 Views of IrriWatch App (Hindi) with Moisture and growth alerts, Insight, Irrigation planner, Geotagged fields under KVK Baghra, and field maps (Soil moisture status, Absolute soil moisture, Cane growth, and Total cane growth)

sessions. Fields were geotagged and linked to individual farmer accounts (figure 3.14), allowing access to real-time alerts, 7-day irrigation plans, and field maps (soil moisture, crop growth, NDVI, etc.).

The decision-support system uses AI-based alerts: soil moisture alerts trigger irrigation when depletion exceeds thresholds, while crop growth alerts help diagnoses moisture stress, nitrogen deficiency, or pest/disease issues. Farmers respond through irrigation, fertilizer application, or pest management based on advisory guidance. Field monitoring and farmer feedback (2025) showed that full compliance of advisories resulted in 21%-26% water savings, 12%-38% yield improvement, and 10%-21% fertilizer savings, while partial compliance yielded lower benefits. Overall, IrriWatch demonstrated strong potential to enhance water and nutrient use efficiency and improve sugarcane productivity..

Astral Consultancy on Subsurface Drainage for Reclamation of Water logged Saline Heavy and Alluvial Soils in Maharashtra, Karnataka, Gujarat and Haryana States (D. S. Bundela, Sagar Vibhute, Anil R. Chinchmalatpure, Suresh Kumar, Satyendra Kumar and R.K. Yadav)



Fig 3.15 SSD technology installation with controlled drainage in two sites (Ghalwad and Gatadwadi in Sangli and Kolhapur), Good sugarcane crop growth and farmers' interaction meeting at Shirol (Kolhapur).

Consultancy services on site identification, pre-drainage investigations and field surveys, design and technical approval of new SSD projects for reclamation of waterlogged and saline black and alluvial soils in Maharashtra, Karnataka, Gujarat and Haryana states were provided to M/s Astral Ltd, Ahmedabad (Gujarat) during 2025. Four SSD sites at Shedshal, Shirol, and Ghalwad (Kolhapur district) and Gatadwadi (Sangli) were monitored for the system performance. Sugarcane crop was planted first time at Shedshal site in November 2024 after 3 years of SSD installation with controlled drainage in 195 ha (Zone-III). Good sugarcane growth was observed in the field on 23-24 April 2025 whereas bumper sugarcane crop was harvested with average yield of 148-150 tons per ha after SSD installation at Shirol site (Fig 3.15). The SSD systems were functioning well and drainage water was disposed off safely. Installation of pipe main line and SSD system at Ghalwad site in 240 ha area and Gatadwadi site in 180 ha was being undertaken to reclaim and dispose saline drainage water to available outlet drain. Soil and water samples were collected for system performance analysis. New initiatives such as construction of farm ponds for storage, and reuse of treated saline drainage water through drip system were also promoted in SSD projects. These initiatives were quite useful in improving downstream water quality and ensuring sustainable SSD operations. The Consultancy firm also launched a new Astral drainage corrugated pipe- Vardaan. The Vardaan pipe has relative cost advantage compared to GeoRex SWC pipe with similar pipe quality, and it is being promoted in current implementation of SSD projects.

A meeting of 40 farmers from Kolhapur, Sangli and Belgavi districts was organized in consultation with Shree Datta Shetkari Sahakari Sakhar Karkhana Ltd (SDSSSKL) and Astral Ltd at Shirol (Kolhapur) on 23 April 2025 where farmers shared their experiences of SSD system quality and performance in sugarcane (Fig 3.15). The SSD systems are widely recognized by farmers and drainage industry experts and as a highly successful technology for reclaiming waterlogged and saline/saline-sodic Vertisols, often leading to significant improvements in sugarcane yield and farm income. However, the performance of the system is heavily dependent on precise installation. Improper installation by inexperienced local contractors often leads to partial system failure, creating a negative perception of the SSD technology. The Institute is willing to conduct training for local inexperienced contractors on design and installation of SSD system at Sangli and all drainage pipe manufacturing companies in Sangli and Kolhapur will be contacted on this issue. Farmers were of opinion that the SSD installations done by the government contractors through tendering are often not fully satisfactory while those implemented by co-operative land reclamation societies with active farmers' participation are successful in terms of quality of SSD pipes, and system installation and performance.

In discussions with Deputy Executive Engineer and his team, Irrigation Research & Development (IRD) in Sangli, key challenges for SSD project implementation were identified, primarily focusing on low farmer participation and difficulties in collecting 20% beneficiary contribution. A cooperative drainage society model was recommended

to improve collective action and financial participation of farmers. Suitability of PVC SWC lateral and collector pipes conforming to IS 9271: 2004 for SSD system was also discussed while PE/HDPE DWC pipes are only suitable for collectors and pipe main drain, not for lateral pipes. A meeting with Director, DIRD and his team was organized at Pune on 25 April 2025 in consultation with Astral Ltd to discuss the technical and field level difficulties hindering the progress of SSD installation in Maharashtra. Design parameters and economics of SSD system and experiences of SSD installation in Vertisols were shared. A capacity enhancement training for DIRD Engineers on SSD designing and implementation in Vertisols was also suggested. Subsequently, a training on Sub-Surface Drainage technology for reclamation of waterlogged and saline black soils for 19 DIRD Engineers was held at ICAR-CSSRI, Karnal during 19-23 August 2025.



Management of Marginal Quality Water

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

Alkalinity related problems in soils and irrigation water significantly threaten to the long-term sustainability of irrigated agriculture, especially in India's arid and semi-arid zones. These issues primarily arise from the continuous use of poor-quality irrigation water containing high amounts of salts. In India's Trans-Indo-Gangetic Plains, groundwater contributes nearly 60-65% of irrigation needs for the rice-wheat cropping system. However, due to overuse of good-quality water, farmers increasingly depend on marginal or poor-quality groundwater. The uncontrolled use of such water, without proper soil, water, and crop management strategies, leads to degrade soil health and causes secondary salinization, affecting nearly 17% of irrigated lands. Globally, freshwater availability for irrigation is a major constraint that limits agricultural productivity. High-salt irrigation water hampers crop yields by harming soil's physical, chemical, and biological properties. Bicarbonate-rich water triggers sodium buildup in soil, leading to clay dispersion, pore clogging, reduced aeration, and lower permeability. These changes ultimately decrease crop productivity.

This study evaluates the effect of varying alkalinity levels, induced through different concentrations of residual sodium carbonate (RSC) in irrigation water on crop growth, seed development, seed quality and subsequent germination in rice. A long-term experiment is being conducted in lysimeters at the experimental farm of ICAR-Central Soil Salinity Research Institute, Karnal, India. The lysimeters (2 m × 2 m × 2 m) are equipped with individual drainage outlets connected to a common gallery. Two saline water treatments (SW1 and SW2) were prepared with the similar amounts of total salts (total electrolyte concentration 30 me L⁻¹), but differed in residual sodium carbonate (RSC) (5 me L⁻¹ in SW1 and 10 me L⁻¹ in SW2), and SW2 was treated to neutralize RSC equivalent to 5 me L⁻¹ using gypsum (SW2 + Gypsum) in SW3 and sulphuric acid (SW2 + H₂SO₄) in SW4. The irrigation with good quality water (GQW) as a control was contrasted with these treatments. These treatments were compared to irrigation with good quality water as control. The experiment was conducted with rice varieties PR 126 and CSR 60. The reduction in rice grain yield was higher in var. PR 126 and reduction was more with

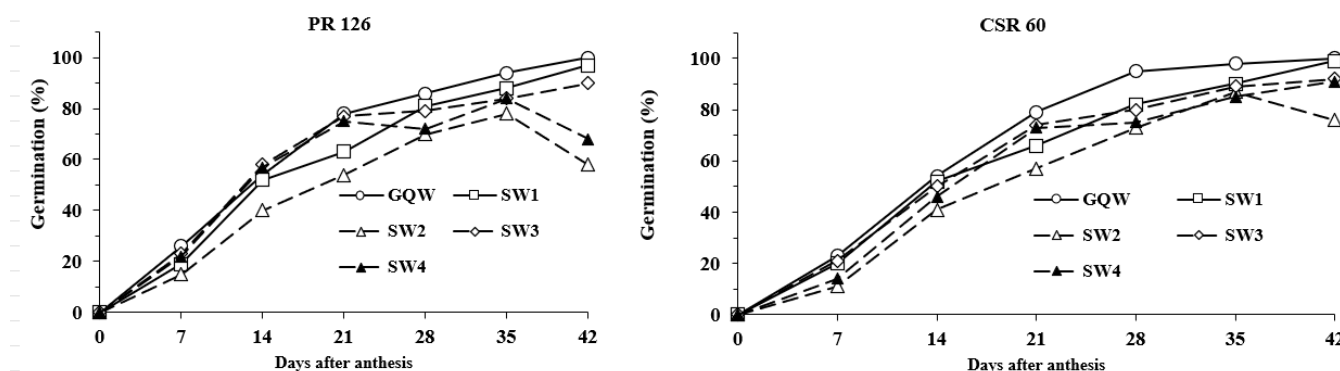


Fig 4.1 Effect of residual alkalinity water on germination of Rice cultivars

increase in residual alkalinity irrigation water. In var. PR 126, rice yield was reduced under RSC 5 that was further reduced in RSC 10 compared to control. In var. CSR 60 the reduction was less as compared to PR 126. Time to achieve highest germination (%) increased with residual alkalinity of irrigation water. The germination (%) was significantly lower at RSC 10 (SW2), this trend of germination was recorded in both rice varieties (fig 4.1).

Seed moisture content was estimated on the fresh weight basis using the high-constant-temperature-oven method with ground seed. The seed moisture dries down trend was similar across the alkali treatments, but the rate was faster in Var. PR 126 than CSR 60 (Fig 4.2). The average seed weight (g) was reduced significantly at RSC 5 (SW1) and further at RSC 10 (SW2). The mean seed weight was higher in Var CSR 60 across the treatments except GQW. RSC 5 neutralized with gypsum or H_2SO_4 (SW 3 and SW 4) slightly increased the seed filling period.

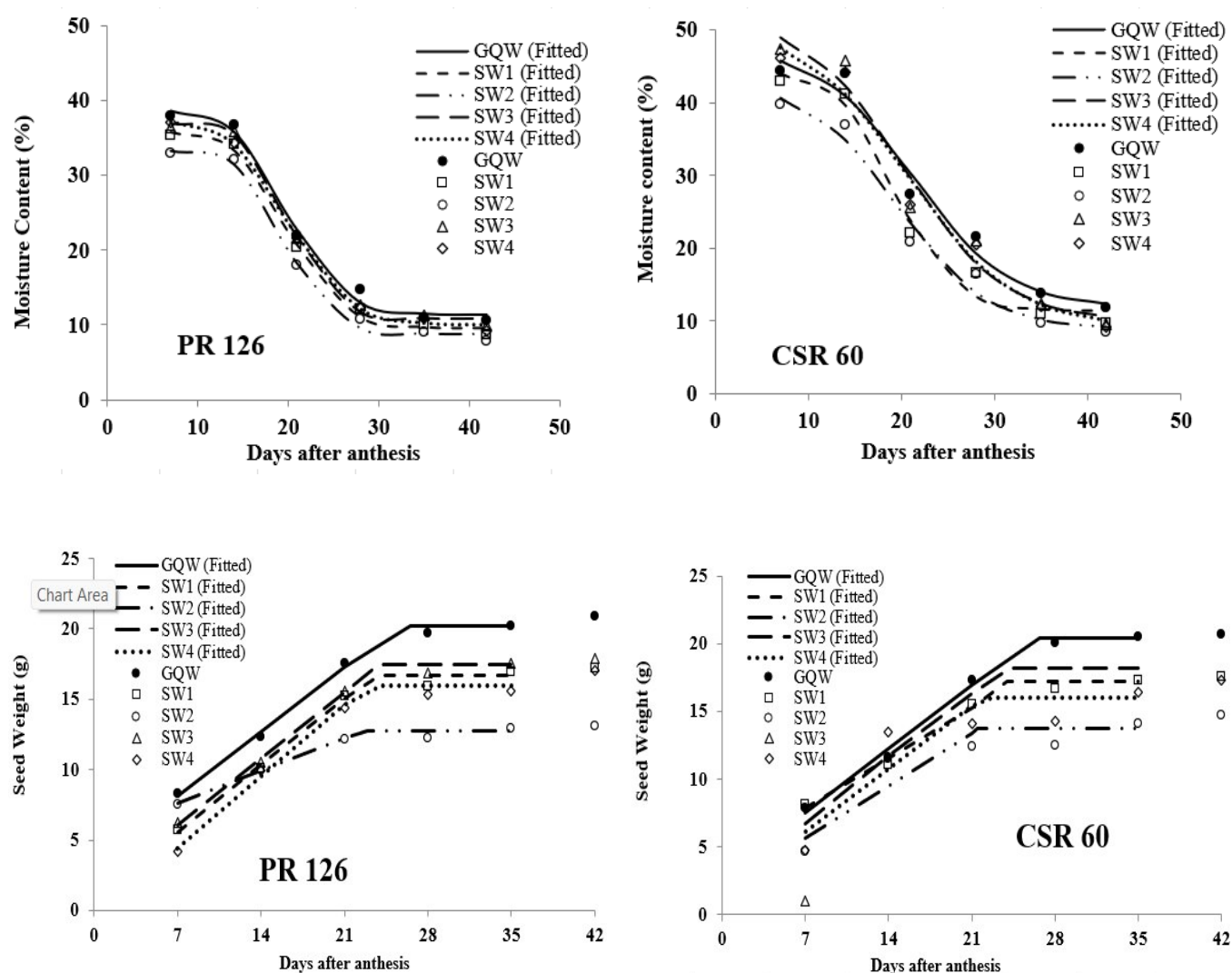


Fig 4.2 Changes in moisture content of fresh seeds and seed weight (g) of rice cv. PR 126 and CSR 60 in differential RSC induced alkali water irrigation regimes

Development of sustainable resources management systems in the water-vulnerable areas of India (ICAR-JIRCAS) (Gajender, R.K. Yadav, D.S. Bundela, Satyendra Kumar, Bhaskar Narjary, A.K. Rai, Suresh Kumar and Amresh Chaudhary)

Sustainable agricultural production in arid and semi-arid regions is increasingly constrained by land degradation, declining water quality, and climate variability. Among the major forms of land degradation, soil salinization poses a serious constraint to crop productivity, soil health, and long-term agricultural sustainability. Globally, salt-affected soils cover approximately one billion hectares across more than 100 countries, while in India nearly 6.73 million hectares are affected. The extent of salinity is expected to increase further due to continued groundwater depletion, use of poor-quality irrigation water, inadequate drainage, and increasing climatic stress.

In many irrigated regions, secondary salinization has emerged as a major challenge resulting from inefficient water management practices and excessive reliance on marginal-quality groundwater. Salt accumulation in the root zone reduces water availability to plants, disturbs nutrient balance, and ultimately leads to significant yield losses. Although conventional drainage-based reclamation methods are effective in controlling salinity, their high establishment costs and limited adaptability often restrict large-scale adoption, particularly under resource-constrained farming systems. Therefore, there is a critical need to develop cost-effective, field-applicable technologies that improve soil drainage and regulate water-salt dynamics while enhancing crop productivity.

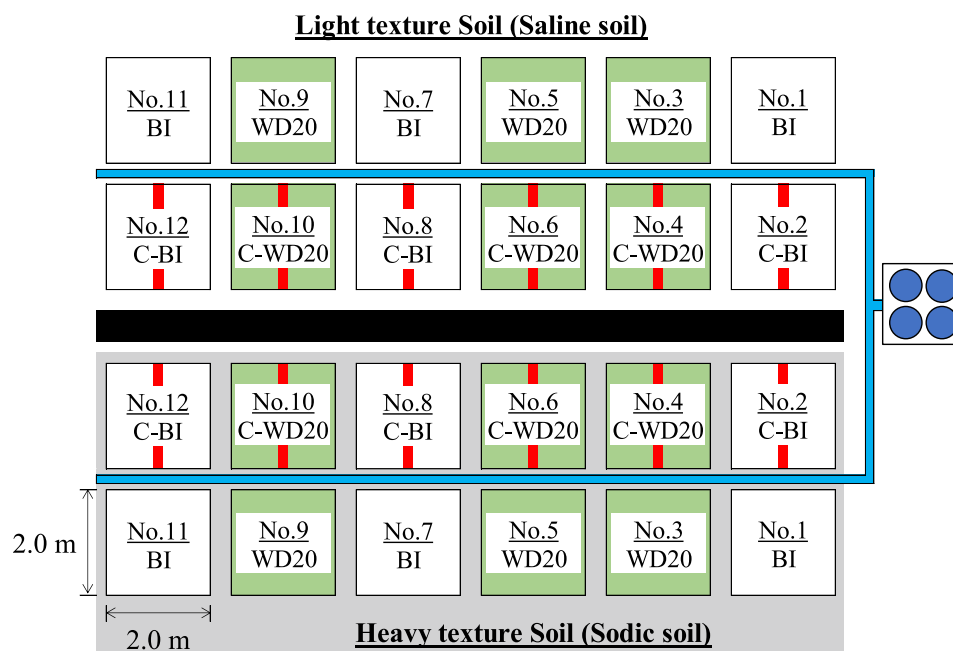
To address these challenges, ICAR-Central Soil Salinity Research Institute, Karnal, in collaboration with Japan International Centre for Agricultural Sciences, Japan, has implemented the project entitled *“Development of sustainable resources management systems in the water-vulnerable areas of India.”* The project focuses on developing integrated resource management strategies aimed at improving soil-water-salt balance and enhancing agricultural resilience under saline and waterlogged conditions. A key component of this initiative is the evaluation of Cut-soiler-constructed Preferential Shallow Subsurface Drainage (PSSD), an innovative and low-cost intervention designed to enhance subsurface drainage through residue-filled channels.

The Cut-soiler technology is integrated with water drop tubes, to improve water distribution, promote salt leaching, and maintain favourable root-zone conditions. Field experiments are being conducted in salt-affected environments at ICAR-CSSRI, Karnal, and IIWBR Research Farm, Hisar, to evaluate the effectiveness of the combined approach under semi-arid conditions. Supporting infrastructure for controlled saline irrigation has been established, including subsurface installation of water drop tubes at 20 cm depth and monitoring systems such as 5TE sensors for soil moisture, electrical conductivity, and temperature, along with observation wells for groundwater level assessment. These measurements enable comprehensive evaluation of soil-water dynamics and long-term system performance under saline environments.

Cut-soiler Drainage and water drop tube experiment in Lysimeter at ICAR-CSSRI, Karnal

The Cut-soiler and water drop tube sub surface irrigation were installed in semi controlled lysimeter at ICAR-CSSRI, Karnal. Border irrigation (BI) and sub-surface saline (4 dS m^{-1}) irrigation (20 cm depth by water drop tube) was applied to saline sandy loam soil and

Fig 4.3 Layout of Cut-soiler and water drop tube experiment in semi controlled Lysimeter at ICAR-CSSRI, Karnal



heavy-textured silty clay soil with Cut-soiler and without Cut-soiler. The layout of treatment plan is given in figure 4.3.

A field experiment to study the effect of cut-soiler drainage and subsurface drainage via water drop tube on reclamation of salinity is in progress at ICAR-CSSRI, Karnal, in a semi-controlled Lysimeters. The experiment aims to assess how different soil and irrigation management strategies influence salinity dynamics, particularly under saline irrigation conditions. One of the significant findings is that there is no salinity buildup in the cut-soiler-treated plots where wheat was irrigated with saline water ($EC\ 4\ dS\ m^{-1}$). This suggests that the cut-soiler can effectively disrupt compacted soil layers, improve water infiltration and reduce salt accumulation in the root zone. Additionally, subsurface irrigation at a depth of 20 cm through the water drop tube proved beneficial in lowering soil salinity levels by facilitating better water movement and leaching of salts from the upper soil layers.

Soil E_c showed distinct temporal and depth-wise variation under both treatments (Fig. 4.4). In the surface (0-15 cm) and subsurface (15-30 cm) layers, E_c decreased from February 2024 to October 2024, with greater reductions under the Cut-soiler (CS) treatment compared with the conventional system (WCS), indicating improved salt removal from the active root zone. In the 30-60 cm layer, E_c initially declined followed by a slight increase toward February 2025, suggesting seasonal redistribution of salts. At the 60-90 cm depth, WCS exhibited gradual salt accumulation, whereas CS maintained relatively stable E_c levels, implying improved drainage and regulation of downward salt movement. The results emphasize that the Cut-soiler-based system improved soil water-salt dynamics and moderated salinity across the soil profile under saline conditions.

Grain and straw yields were significantly influenced by Cut-soiler intervention, soil type, and irrigation method (Fig. 4.5). The Cut-soiler treatment recorded higher grain and straw yields compared to the without-cut soiler, indicating the positive role of improved drainage and salinity management on crop performance. Similarly, yields were

Fig 4.4 Changes in soil ECe (dS m⁻¹) at Karnal (WCS: conventional system; CS: Cut-soiler)

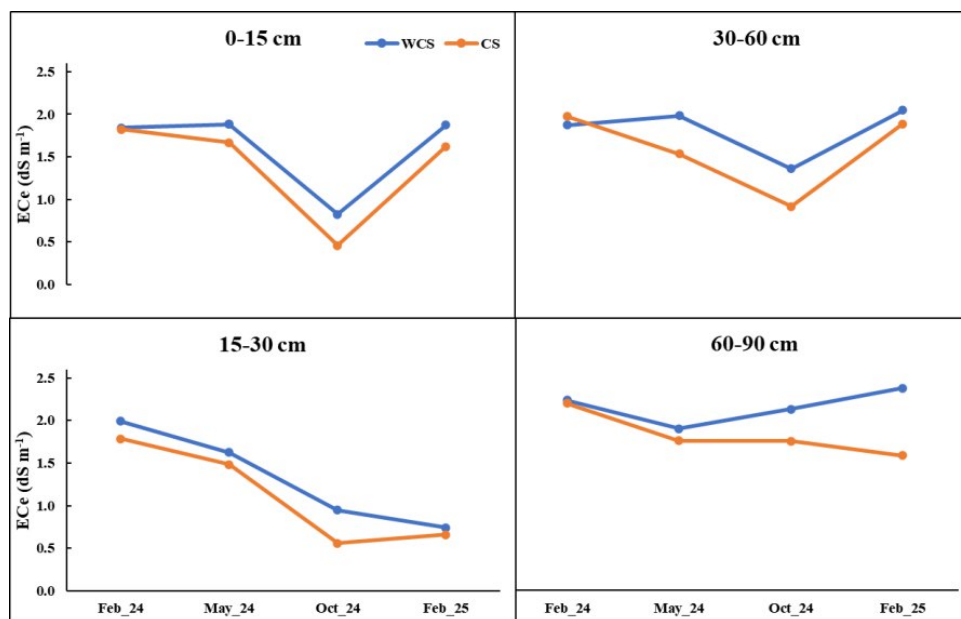
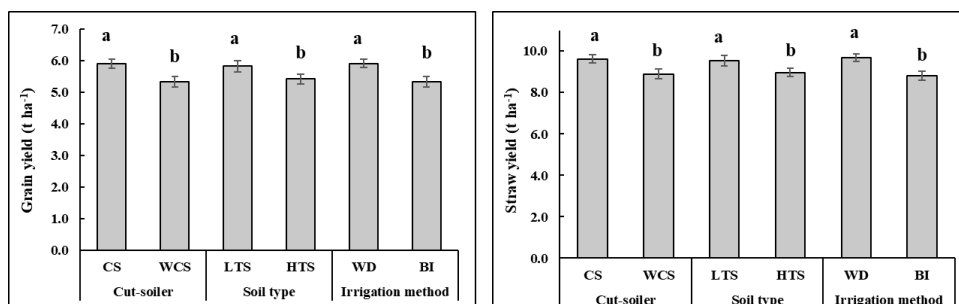


Fig 4.5 Grain and straw yield of wheat under lysimeter condition at Karnal



significantly higher in the light-textured soil compared to heavy-textured soil which may likely be due to better aeration and drainage conditions favouring root growth. Among irrigation methods, water drop tube irrigation produced higher grain and straw yields than border irrigation, suggesting improved water distribution and reduced salt stress under efficient irrigation. The results highlighted that integration of cut-soiler-based drainage with efficient irrigation practices contributed to improved crop productivity under salt-affected conditions.

Field Experiment on Cut-soiler and water drop tube at ICAR-IIWBR Research Farm, Hisar

A field experiment is being conducted at the ICAR-IIWBR research farm in Hisar to evaluate the effects of cut-soiler operations and water drop tube irrigation on groundwater dynamics, soil salinity, and crop performance. The experiment involved continuous monitoring of the groundwater table and electrical conductivity (EC) using HYDROS 21, while HH2 sensors were employed to track soil moisture and salinity variations. These advanced monitoring tools provided real-time data on the hydrological and salinity conditions in the experimental plots.

Observations from the study revealed that the groundwater level began to rise after June and remained elevated until March of the following year. This seasonal fluctuation posed a risk of waterlogging and salt accumulation in the soil, negatively impacting crop growth. Groundwater level rises after June and remains high until March of the following

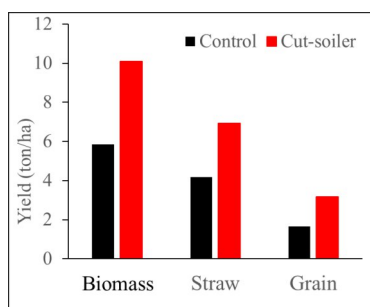


Fig 4.6 Effect of cut-soiler intervention on productivity of wheat at Hisar

year. Cut-soiler construction after dry season crops proved effective in controlling the rise of groundwater levels and leaching and reduced the soil salinity by 25.6% as compared to control plots.

The Cut-soiler treatment markedly improved crop productivity compared with the control (Fig. 4.6). Higher biomass, straw, and grain yields were recorded under the Cut-soiler treatment. The increase in total biomass suggests better resource utilization and plant vigour, which translated into higher partitioning toward both straw and grain yield. These results indicated that improved soil-water-salt regulation under the Cut-soiler system contributed to enhanced crop performance in salt-affected conditions.

Evaluation of potassium aluminium sulphate (alum) for treatment of irrigation water having residual alkalinity (Awatar Singh, Raj Mukhopadhyay, Gajender Yadav, AK Bhardwaj, Priyanka Chandra, AK Rai, RK Yadav)

The alkali water neutralization in the country is primarily based on the use of mined gypsums. However, the long-term application of gypsum for neutralizing residual alkalinity (RSC) of irrigation water leads to CaCO_3 build-up in soils of Punjab and Haryana (such areas, where RSC water continuously used for irrigation since several years), resulting concretion problems, which further creates stress to rice-wheat system. Moreover, the declining gypsum reserve of requisite quality is identified as a major challenge in neutralization of the RSC water. ICAR-CSSRI Karnal develops many alternatives to gypsum for counter acting sodicity stress created by alkali water irrigation. However, our interaction with around 1000 farmers (during Vikshit Krishi Sanklap Abhiyan: 29 may to 12 June, 2025) of Kaithal districts of Haryana, it is noticed that non availability of these amendments is a big challenge to the farmers of these regions. Several farmers requested for developing locally available amendment for treating alkali water before irrigation, so they can halt secondary sodification of their lands. Therefore, potassium aluminium sulphate (alum) is a locally available material, having rich source of sulfur can be a viable option for treating the alkali water for halting the secondary sodification in the areas of Haryana and Punjab, where alkali water has been continuously utilized for irrigation purposes. Therefore, experiments were initiated in July 2025 to evaluate the effectiveness of potassium aluminium sulphate (alum) for the treatment of irrigation water having residual alkalinity. A review of the available literature indicated that RSC values in the range of $5\text{--}7\text{ me L}^{-1}$ are commonly reported for groundwater in the Patiala district of Punjab and the Kaithal district of Haryana. Accordingly, synthetic irrigation water with an RSC of 7.0 me L^{-1} was prepared by dissolving NaCl , Na_2SO_4 , NaHCO_3 , $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, and $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ in the best available groundwater, following an ionic composition representative of these regions (Table 4.1). This high-RSC water was subsequently neutralized using alum to reduce the RSC to 3.5 me L^{-1} , the threshold value recommended for soils containing 20–30% clay. The treated water with alum will be used for irrigation in a rice–wheat cropping system during the subsequent season

Table 4.1 Chemical composition of prepared irrigation water having residual sodium carbonate.

Water quality parameters	RSC	SAR	TEC	EC (dS/m)	pH	Cl ⁻ (me/L)	SO ₄ ²⁻ (me/L)	HCO ₃ ⁻ (me/L)	Na ⁺ (me/L)	Ca ²⁺ (me/L)	Mg ²⁺ (me/L)
Values	7.0	10.0	30	3.0	7.6	12.05	3.15	15.9	21.2	4.4	4.5

Development of leachate collector, rapid GR meter and hydraulic conductivity measuring device (Arvind Kumar Rai, Nirmalendu Basak, Priyanka Chandra, Parul Sundha, Gajender, R.K. Yadav)

Agriculture and other land management practices often face the issue of the monitoring of the movement of water and associated electrolyte. Often face criticism of polluting ground as well as surface water bodies because of the movement of nutrients and other constituents with percolating water down the soil profile. Thus, real risk assessment needs real time monitoring of the leachate volume and its composition. Several studies from CSSRI also highlight the possibility of predicting soil health and nutrient supplying capacity by monitoring the quality leachate emanating from the soil profile. Till now real time monitoring device for leachate quantity and hydraulic conductivity assessment is not available. ICAR-CSSRI has developed a prototype for low-cost monitoring of the leachate and profile leaching characteristic along with other features. The objectives of the study are to develop low-cost device for measuring leachate volume and in-situ hydraulic conductivity, portable GR meter for rapid analysis of gypsum requirement and refining prototype for the measurement of the low cost device for column sampling and measuring saturated hydraulic conductivity using falling head method. This work is being conducted in collaboration with knowledge partners for the development and refinement of the *insitu* leachate collector cum hydraulic conductivity measuring device, soil column sampler and *exsitu*-saturated hydraulic conductivity measuring device using falling head method. The Bharuwa Agri Science Pvt. Ltd., Kankhal, Haridwar, Uttarakhand after developing an MOU are jointly refining the existing prototype. The Bharuwa Agri Science is working on improving the pumping device for efficient and effective extraction of the leachate and data transfer system. The precision agriculture, Bawal is collaborator for developing low cost column sampler. The three design patents have been granted under this project namely, saturated unsaturated hydraulic conductivity meter, rapid gypsum requirement estimation device and leachate collection cum hydraulic conductivity measuring device..



Crop Improvement for Salinity, Alkalinity and Waterlogged Stresses

Genetic improvement of rice genotypes for salt tolerance using Conventional and Molecular breeding methods (BM Lokeshkumar, Ravikiran KT, Nitish Ranjan Prakash and Devika S)

This project focuses on identifying salt-tolerant rice donors from diverse genetic backgrounds and using them to develop improved salt-tolerant genotypes. It includes the development, evaluation, and dissemination of superior rice varieties through station and AICRP trials. During Kharif 2025, various AICRP and experimental trials were conducted, and breeding materials were advanced accordingly. Observations from these trials were systematically recorded and submitted to the Director, IIRR, Hyderabad. Detailed findings and trial information are documented in the Progress Report 2025, Vol. 1 on Varietal Improvement under the All India Coordinated Research Project on Rice, published by ICAR-IIRR, Hyderabad.

A. AICRP trials conducted:

- a) IVT-Alkaline and Inland Saline Tolerant Variety Trial-2025
- b) AVT-Alkaline and Inland Saline Tolerant Variety Trial-2025
- c) Coastal Saline Tolerant Variety Trial- 2025
- d) IVT Basmati Varietal Trial-2025
- e) IVT and AVT - Aerobic trial and Direct Seeded Rice trail- 2025
- f) Bio fortification Trail -2025

B. Station Trials

Monitoring, maintenance and development of breeding materials and genetic stocks

Important 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. Numbers of segregating populations around 50 crosses F_1 , 20 crosses F_2 , F_3 - F_5 of 50 crosses and 250 fixed lines were maintained and screened under high salinity (EC_{iw} ~10-12 dS/m) in micro plots and stress field. The top performing progenies were selected from each segregating population for further screening/evaluation in the next cropping season. In addition to this we have collected and maintained different breeding materials and germplasm from IRRI and evaluated for desirable traits. These lines will be maintained and conserved properly for future breeding programme.

Evaluation of genotypes from different back ground for saline stress (EC_e ~10 dS/m) condition

A total of 306 lines from both IRRI and CSSRI developed materials from various crosses were tested under saline stress (EC_e ~8dS/m) condition in microplots. The grain yield of 306 genotypes ranged from 90 to 4912 kg/ha with a mean grain yield of 883 kg/ha (Figure 5.1 & Table 5.1). The lines IR22EL1505 and IR22EL1050 were showing highest grain yield of more than 4000 kg/ha under saline stress condition. The list of top performing lines over the check CSR 27 is presented in (Table 5.2).

Table 5.1 Descriptive statistics of performance of 306 genotypes under saline stress condition (ECe ~8 dS/m)

Statistics	D50% Flowering	Plant height	Panicle length	Total tiller	Productive tiller	Gain Yield (kg/ha)
Min	74.0	38	10.0	4.6	3.0	90.8
Max	119.0	123.3	26.7	17.3	17.3	4912.3
Average	85.1	87.4	17.9	10.5	7.5	883.6

Fig 5.1 Response of 306 genotypes for flowering and grain filling under saline stress condition (ECe ~8 dS/m)

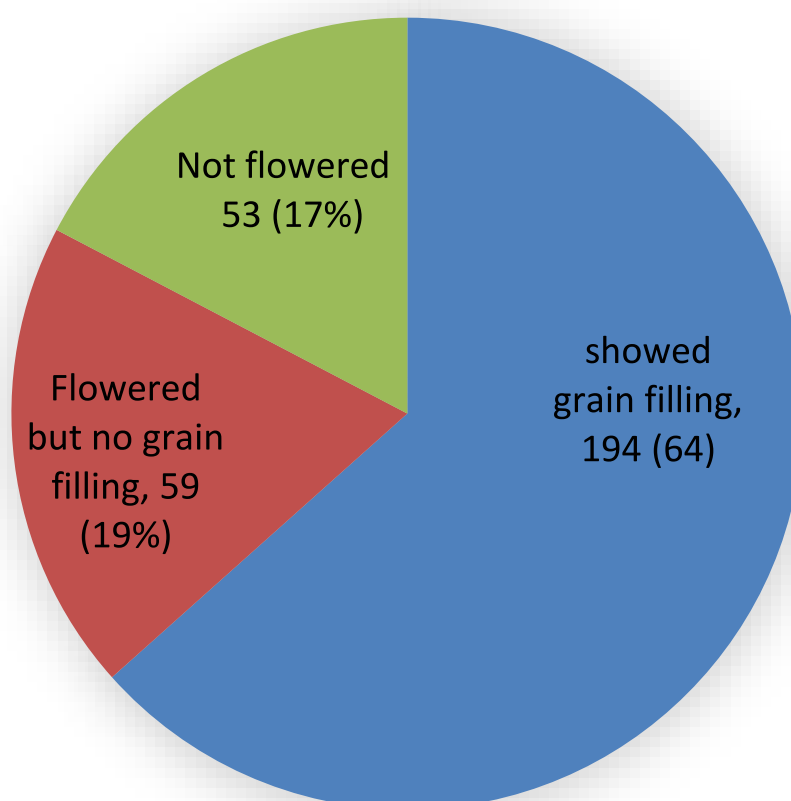


Table 5.2 Best performing genotypes out of 306 genotypes under saline stress condition (ECe ~8 dS/m)

Top performing lines	Gain Yield (kg/ha)
IR22EL1505	4912.32
IR22EL1050	4378.12
CSR453-18-442-35	3998.86
IR22EL1562	3727.96
IR22EL1234	3642.40
IR22EL1119	3551.96
CSR 27 (Check)	3538.94

Evaluation of 108 rice genotypes from NBPGR under saline stress condition

A total of 108 lines from NBPGR tested under saline stress (ECe ~8 dS/m) condition in microplots. The vigor score of the genotypes indicated that 92% of the lines showed vigor score >7 or susceptible symptoms, only five genotypes exhibited score of 7 and only two

genotypes exhibited vigor score 5. The grain yield distribution varied from 0 to 2499 kg/ha with an average of 529 kg/ha. The plant height varied from 39 to 109 cm with an average of 62 cm.

Mapping of the genomic regions associated with salt stress tolerance at Reproductive stage

A total of 254 genotypes from IRRI lines were evaluated under moderate sodic stress (pH 9.2-9.5) and saline (Ece ~ 6 dS/m) stress conditions. Grain yield of genotypes was ranged from 266 to 3666 kg/ha with a mean yield of 1454 kg/ha under saline stress condition. Similarly, the grain yield of genotypes was ranged from 280 to 4130 kg/ha with a mean yield of 2155 kg/ha under sodic stress condition was recorded. The observations on different trait also measured and used for the identification of QTLs.

Rice entries nominated to AICRP during 2025

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:

Trial	Name
IVT – DSR	CSR 2023-1-160-2-8
	CSR 202-340-01-91
IVT -Aerobic	CSR 2023-11-60-32
	CSR 2023-400-246
IVT-AL&ISTVT	CSR 401 -16-125
	CSR 388-16-198
	CSR 269-16-121

Rice entries promoted from IVT to AVT 1:

Trial	IET	Name
AVT-1AL&ISTVT	32783	CSR 2022 BR-41-4-64
	32776	CSR 2022 ABC-165
	32778	CSR2021-AL-29-485

Rice entries promoted from AVT1 to AVT 2:

Trial	IET	Name
AVT2-AL&ISTVT	31861	CSR2021-AL-2-94-112
	31862	CSR2021-AL-294-72
	31858	CSR2021-ST-294-168

Breeder seed production

Breeder seed of the salt tolerant rice varieties i.e., CSR 10 (0.5 Q), CSR 13 (0.25 Q), CSR 23 (0.5 Q), CSR 27 (0.5 Q), CSR 30 (4.5 Q), CSR36 (0.5 Q), CSR 43 (0.5 Q), CSR 46 (2.0 Q), CSR49 (0.25 Q), CSR52 (0.25 Q), CSR56 (1.5 Q), CSR60(2.0 Q), CSR 76 (1.5 Q) the newly release varieties namely CSR 101(4.Q), CSR 104 (1.5 Q), CSR 105 (2.5Q), CSR 108 (1.5Q) and CSR 64 (2.0Q). A total of 26.25 Q of breeder seed produced to meet the demand of seed producing agencies as per DAC (Department of Agriculture and Cooperation) during 2025.

Rice varieties

During 2025, salt-tolerant rice varieties, namely CSR 108 & CSR 64 were notified and released through CVRC. The details of the variety are given below.



- **Designation:** CSR 108 (IET 31055 / CSR 141-11-112)
- **Parentage:** Pusa44 / CSR 27
- **Flowering duration (FD):** Alkaline: ~78 days
- **Saline:** ~85 days
- **Maturity duration:** 115–120 days
- **Grain type:** Long Slender (LS)
- **Yield performance:**
- **Alkaline soils (pH up to 9.5) :** 3819 kg/ha
- **Saline soils (ECe~8-10 dS/m) :** 4472 kg/ha
- **Normal Soil :** 5500-6000 kg/ha
- **Recommendation for:** Recommended for Haryana and Uttar Pradesh (Zone II)



- **Designation:** CSR 64
- **Cross:** PB1 / TRY1
- **Flowering duration (FD):** ~100 days
- **Maturity duration:** 125–135 days
- **Grain type:** Long Slender (LS)
- **Quality traits:** Hulling recovery (HRR): 55.74%, Amylose content (AC): 23.1%, Gel consistency (GC): 26.6 mm, ASV: 5,
- **Disease reaction:** Moderately tolerant to leaf blast, neck blast and sheath rot
- **Insect pest reaction:** Moderately tolerant to leaf folder
- **Yield performance:** 43.85 q/ha
- **Yield advantage over national and local checks:** 5.7–10.8%
- **Recommended for:** sodic soils of Uttar Pradesh

Fig 5.2 Field view and details of CSR 108 & CSR 64

Molecular genetic analysis of resistance/tolerance in rice wheat chickpea and mustard including sheath blight complex genomics (Sub-project 1: Rice component) (ICAR funded)

(Lokeshkumar BM)

The main aim of this project is to map the important genomic regions / QTLs controlling salinity 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 (Pusa44/Bhurarata) for salinity tolerance

The salient findings of the systematic phenotyping of 190 recombinant inbred lines (RILs)

derived from Pusa44xBhurarata cross are presented, 190 RILs along with two parents were evaluated under saline stresses ($EC_e \sim 8dS/m$) with two replication during *Kharif*, 2025. Grain yield (Kg/ha) ranged from 585 (RIL306) to 4587 (RIL 280) in under salinity stress, while spikelet fertility (%) ranged from 8.7 (RIL370) to 89.5 (RIL246). The genotype RIL280 (4587kg/ha) showed the highest grain yield followed by RIL299 (4192kg/ha), RIL302 (3937 kg/ha), RIL246 (3877 kg/ha), RIL360 (3619kg/ha), RIL222 (3545 kg/ha), RIL227 (3483 kg/ha), RIL324 (3466kg/ha) and RIL307 (3434 kg/ha) under saline stress (Fig 5.3). Descriptive statistics of Pusa44/Bhurarata RIL population is given in Table 5.3.

Identification of QTLs for yield and yield related traits

Quantitative Trait Loci (QTL) mapping is a vital genomic tool used to identify regions of the genome associated with complex traits. Table 5.4 provides a list of QTLs for key physio-morphological traits in the RIL population derived from a cross between Pusa44 and Bhurarata under saline stress during the reproductive stage. Two significant QTLs, *qDFF1*, were identified for days to flowering. *qDFF1* located on chromosome 8 with a LOD score of 7.11, explained 18.53% of the phenotypic variance. The QTL for productive tillers (*qPT1*) located on chromosome 3, had a LOD score of 2.67 and explained 7.1% of the phenotypic variance. The spikelet fertility QTL *qSF1* found on chromosome 1 between positions 22037276 and 41841813 had a LOD score of 6.8 and a PVE of 11.3%, indicating significant genetic influence. For grain yield, *qGY1*, located on chromosome 1, had a LOD score of 5.19 and explained 10.45% of the phenotypic variance. The other QTL *qGT4* located on

Table 5.3 Descriptive statistics of Pusa44/Bhurarata RIL population

Sl. No.	Traits	Mean	Range (saline)	Pusa44	Bhurarata
1.	Days to flowering	95.9	69.8 (RIL354) – 151.2 (RIL386)	105.00	101.33
2.	Plant height	92.6	57.2 (RIL353) – 129.3 (RIL383)	83.25	102.26
3.	Panicle length	18.9	12.9 (RIL212) – 27.2 (RIL301)	1.00	17.75
4.	Total tiller	7.5	4.33 (RIL337) – 14.35 (RIL306)	5.42	7.65
5.	Productive tiller	6.4	3.12 (RIL387) – 13.1 (RIL306)	4.00	5.50
6.	Grain Yield (Kg/ha)	1828.4	585 (RIL306) - 4587 (RIL 280)	855.08	2879.57
7.	Spikelet fertility (%)	48.2	8.7 (RIL370) – 89.5 (RIL 246)	0.15	78.59

Fig 5.3 Top performing RILs on the basis of grain yield under saline stress



Table 5.4 List of QTLs identified in the RILs of Pusa44/Burarata under saline stress condition ECe~8 dS/m

Trait Name	QTL	Left Marker	Right Marker	LOD	PVE (%)	Add
Days to flowering	qDFF	8:3742236	8:3969555	7.11	18.53	-6.88
Productive tillers	qPT	3:11371003	3:966332	2.67	7.10	0.52
Spikelet fertility	qSF	1:22037276	1:41841813	6.85	11.31	-12.21
Grain Yield	qGY1	1:22191683	1:22254275	5.19	10.45	-271.9
	qGY2	4:9989298	4:10940059	3.05	9.16	255.02
	qGY3	9:15488464	9:15598039	3.15	6.38	239.25

Table 5.5 Salt responsive genes Associated with the QTLs identified from RILs of Pusa44/Bhurarata under saline stress condition ECe~8 dS/m

QTLs	Under Lying genes
qDFF	LOC_Os08g06440, LOC_Os08g06490, LOC_Os08g06610, LOC_Os08g06630, LOC_Os08g06840, LOC_Os08g06890, LOC_Os08g07020, LOC_Os08g07010
qGY 1	LOC_01g39399, LOC_01g39420, LOC_01g39430, LOC_01g39440, LOC_01g39480, LOC_01g39490, LOC_01g39510
qGY2	LOC_Os04g18320, LOC_Os04g18170, LOC_Os04g18260, LOC_Os04g18830, LOC_Os04g18700, LOC_Os04g18760, LOC_Os04g19370, LOC_Os04g19390, LOC_Os04g19600, LOC_Os04g20100, LOC_Os04g20320
qGY3	LOC_09g25880, LOC_09g25870, LOC_09g25890, LOC_09g25900, LOC_09g25910, LOC_09g25960, LOC_09g25970, LOC_09g26000, LOC_09g26004, LOC_09g26030

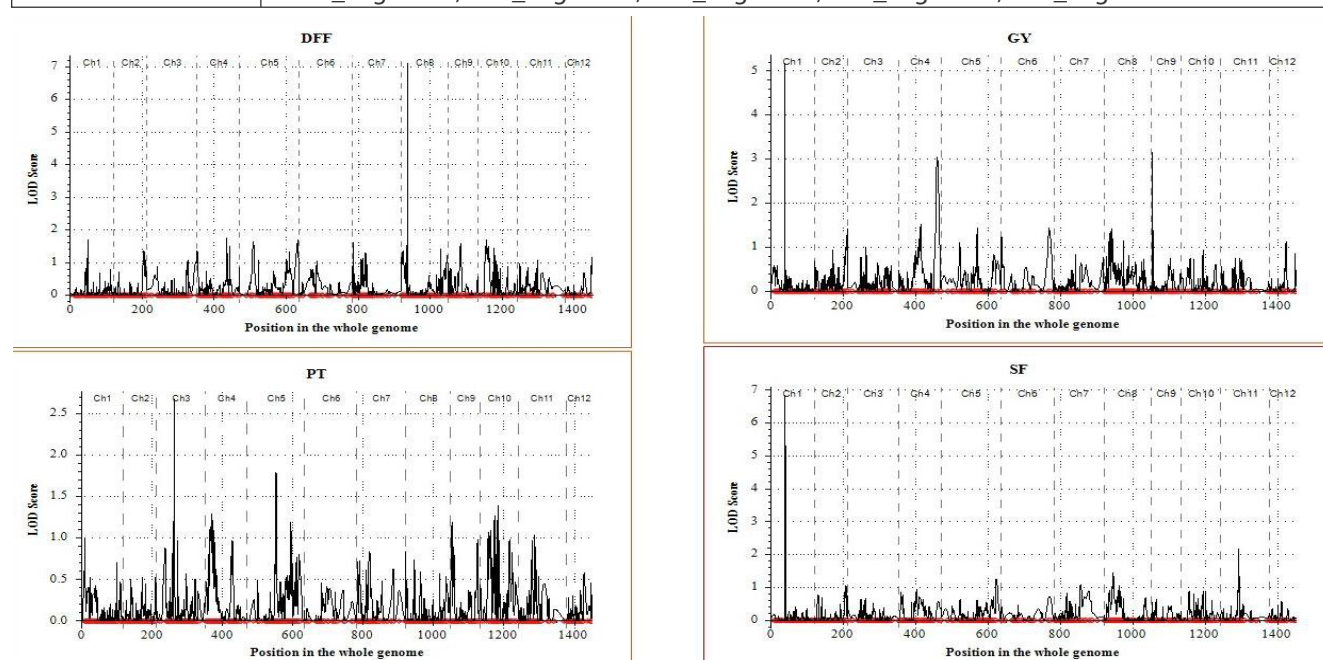


Fig 5.4 Important QTLs identified in the RILs of Pusa44/Bhurarata under saline stress condition ECe~8 dS/m

chromosome 3, had a LOD score of 3.0 and explained 9% of the phenotypic variance. The third QTL was identified qGTY3 located on chromosome 9, had a LOD score of 3.0 and explained 6% of the phenotypic variance (Fig 5.4). Salt responsive genes associated with the QTLs identified from RILs of Pusa44/Bhurarata under saline stress are displayed in the Table 5.5. These QTLs harbor key genes associated with salinity tolerance mechanisms. Salt-responsive genes within these QTLs play a role in regulating various physiological

and molecular responses to salinity stress. Identifying these genes is crucial for marker-assisted breeding to develop salt-tolerant rice varieties.

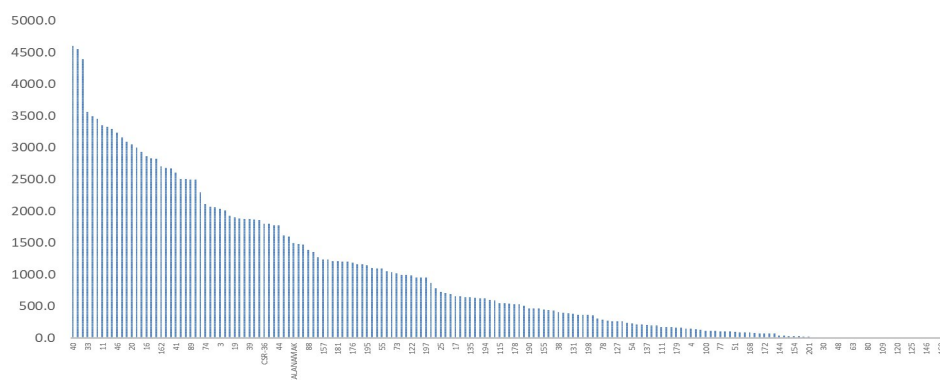
Network project on functional genomics and genetic modification in crop (NPFGGM): Salt Tolerance in Rice (ICAR funded) (Lokeshkumar B M)

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 National Institute for Plant Biotechnology (NIPB), New Delhi (for genotyping). A total of 140 RILs developed from cross combination of MTU 1001 × Kalanamak. A total of 140 genotypes were phenotyped in saline stress ($EC_e \sim 8$ dS/m) during *Kharif* 2025. The grain yield was ranged from 9.5 to 4603 kg/ha (RIL40) with mean of 951 kg/ha under saline condition. The lines RIL-40, RIL-66, RIL-85, RIL33, RIL-103 RIL-32, RIL-11 and RIL76 performed over the CSR 27 (Figure 5.5). Descriptive parameters of RILs under saline and sodic conditions are presented in Table 5.6. The correlation analysis clearly indicated that the grain yield is significantly correlated with plant height ($r=0.40$), productive tillers ($r=0.57$) and panicle length ($r=0.64$).

Table 5.6 Mean and range of grain yield and yield contributing traits under of MTU 1001 × Kalanamak RIL population saline ($EC_e \sim 8$ dS/m) stress condition during 2025

Parameter	Plant height	Total tiller	Productive tiller	Panicle length	Yield (Kg/ha)
Min	62.3	5.8	5.7	0.6	9.5
Max	157.7	51.6	13.0	8.1	4603.9
Average	110.9	17.4	8.9	4.6	971.0
KALANAMAK	97.67	15.65	8.00	5.83	1500.65
MTU-1001	78.44	12.11	7.67	4.17	527.28

Fig 5.5 Graphical distribution of grain yield (kg/ha) of 140 RILs under saline condition ($EC_e \sim 8$ dS/m) during 2025



One-IRRI Network Breeding Project at Canning and Lucknow (N.R. Prakash, Lokeshkumar, B.M., Ravikiran K.T. and Devika S.)

Under the ICAR-IRRI collaborative project, the centres at Canning and Lucknow are actively involved in developing salinity and sodicity-tolerant rice varieties under Thematic Area 4, which focuses on creating and deploying stress-tolerant crops. During *Kharif* 2024, a total of 130 entries, including local checks, were evaluated at both centres using an alpha lattice design under Stage 1 (SS1) trials. The phenotypic data generated from all 10 collaborating centres across India were analyzed using a Sparse Testing Design approach, and Genomic Estimated Breeding Values (GEBVs) were predicted for selection. Based on these evaluations, 40 promising entries were shortlisted and advanced to Stage 2 trials for *Kharif* 2025. These selected entries are currently being tested across both

Canning and Lucknow, as well as the other eight collaborating centres in India, ensuring multi-location validation. Additionally, during Kharif 2025, a fresh set of 100 entries is being evaluated across all participating centres to continue the breeding pipeline. Among the tested lines, the entry “IR22LT1610” emerged as a superior genotype based on GEBVs across all centres during Kharif 2024. This line was multiplied at the Canning centre during Kharif 2025 and is planned for submission to AICRIP in Kharif 2026 for further evaluation and potential release.

Morphological and molecular characterization of salt-tolerant coastal rice landraces (N.R.Prakash)

In this project, an association mapping panel of 243 genotypes was developed and evaluated under low and high salinity conditions during Rabi 2022-23 and 2023-24 at Canning and Kharif-2023 at Canning, Lucknow, Machhilipattnam, and Dandi centres. We received the usable genotypic data of 236 genotypes from this panel. Using different models (MLM, MMLM, CMLM, SUPER, FarmCPU, BLINK), genome-wide association studies (GWAS) were conducted for all the traits under study, which were related to salt tolerance at the reproductive stage in rice. The association panel was genotyped using dd-RAD-Genotyping by sequencing (dd-RAD-GBS), and a total of 6917 workable homozygous SNPs (MAF>0.01) were used for predicting marker-trait associations (MTAs) for all these traits. We identified high-quality MTAs (a total of 130 MTAs governing 17 traits) consistent across either two or more than two environments. It included MTAs for plant height (1), grain yield (3), straw yield (4), harvest index (2), sodium content in leaves (14), sodium-potassium ratio in leaves (16), panicle length (11), number of primary branches per panicle (45), panicle primary branch length (16), Panicle Weight (1), and Spikelet Fertility (17). The identified marker-trait associations can be used in genomic-assisted breeding to improve salt tolerance in rice. Of all these traits, grain yield, Straw yield, harvest index, sodium content in leaves, sodium-potassium ratio in the leaves, panicle weight, and Spikelet fertility are directly involved in tolerance to reproductive stage salt stress. 210 MTAs (single and multiple environments) were predicted in 190 SNPs governing these traits. These were 41 on Chr1, 24 on Chr2, 29 on Chr3, 19 on Chr4, 16 on Chr5, 14 on Chr6, 13 on Chr7, 14 on Chr 8, 11 on Chr9, 9 on Chr10, 14 on Chr11, and 6 on Chr12. Among all these, we found 17 SNPs within the range of Meta-QTLs, which are reported to affect salt tolerance at the reproductive stage.

Genetic approaches to improve wheat (*Triticum aestivum* L.) germplasm for salt tolerance (Neeraj Kulshreshtha, Arvind Kumar, Ashwani Kumar, Ravi Kiran and Monika Shukla)

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. A number of experiments related to wheat breeding programme were laid down during the project period in microplots, sodic soils of ICAR-CSSRI farm and other reclaimed soils during November-December 2024.

Varietal development

Two salt tolerant varieties KRL 423 and KRL 1803 were approved for release for sodic soils of UP state on 30.12.2025 during varietal release committee meeting held in Lucknow on



- **Variety Name:** KRL-423
- **Plant height (cm):** 99-112
- **Maturity duration (days):** 124-153
- **1000-seed weight (g):** 40-48
- **Salinity tolerance (ECe in dS m⁻¹):** 8.8 ± 0.23
- **Sodicity tolerance (pH2):** 9.2 ± 0.76
- **Date of sowing:** 5 November to 20 November
- **Average grain yield in normal soil (q/ha):** 64-68 qt/ha
- **Potential grain yield in normal soil (q/ha):** 73.2 qt/ha
- **Average grain yields in salt affected soils (q/ha):** 42-45 qt/ha



- **Variety Name:** KRL1803
- **Plant height (cm):** 98-115
- **Maturity duration (days):** 132-153
- **1000-seed weight (g):** 41-43
- **Salinity tolerance (ECe in dS m⁻¹):** 8.5 ± 0.21
- **Sodicity tolerance (pH2):** 9.3 ± 0.18
- **Date of sowing:** 5 November to 20 November
- **Average grain yield in normal soil (q/ha):** 62-65 qt/ha
- **Potential grain yield in normal soil (q/ha):** 72.1 qt/ha
- **Average grain yields in salt affected soils (q/ha):** 40-44 qt/ha

Fig 5.6 Field view and details of KRL 423 & KRL 1803

account of their superior performance consistently over checks for three years during varietal trials in salt affected soils.

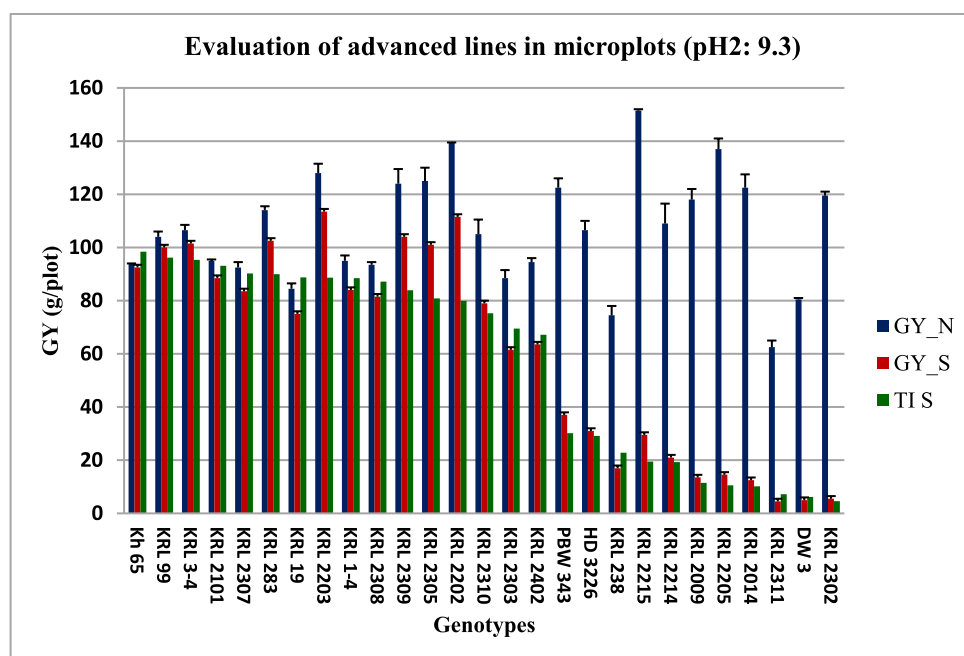
Hybridization and generation advancement

Three hundred forty one new cross combinations were attempted and approximately 2200 ear heads were emasculated and hybridized to create the variability for desired traits. A large number of diverse parents were involved in crossing program which included Elite or released cultivars (KRL 370, KRL 386, KRL 3-4, KRL 99, KRL 210, KRL 213, KRL 283, KRL 1803, KRL 1818, KRL 2002, KRL 2009, KRL 2202, KRL 2205, KRL 2207, KRL 2213, KRL 2302, KRL 2309, KRL 2305, KRL 2306, KRL 2310, KRL 2401, KRS 21026, KRS 23070 and KRS 23073) developed at CSSRI, Karnal and popular varieties and genetic stocks (DBW 187, DBW 316, Unnat PBW 550, PBW 870, PBW 902, PBW 835, HD 3369, HS 545, WH 1403, QLD 122, QLD 120, VL 3028, HPW 489, BRW 3992, DBW 371, DBW 444, GW 543, HI 1669, HI 1673, HS628, LOK 79, PBW 824, PBW 889, PBW 893 and PBW 897) and many superior lines from 15th HZAN which are carrying the high yielding genes as well as gene pyramids for resistance to rust and other major diseases, quality characteristics, high Zn uptake. Under advanced/segregation generation F₁ (351 crosses), F₂ (65 Crosses), F₃ (370 Crosses), F₄ (850 Crosses), F₅ (170 Crosses), F₆ and higher generations (134 Crosses) were advanced under intensive selections pressure of salt stress and rust diseases. Selections

Table 5.7 Top 15 genotypes under different stresses in microplots based upon tolerance indices (TI)

SN	Normal	Saline (EC _{iw} :10 dS/m)	TI	Sodic (pH ₂ : 9.3)	TI	S+WL (pH ₂ : 9.3)	TI
1	KRL 2215	KRL 3-4	0.95	Kh 65	0.98	Kh 65	0.96
2	KRL 2202	KRL 1-4	0.92	KRL 99	0.96	KRL 99	0.90
3	KRL 2207	Kh 65	0.89	KRL 3-4	0.95	KRL 238	0.85
4	KRL 2205	KRL 19	0.88	KRL 2101	0.93	KRL 283	0.77
5	KRL 2203	KRL 2311	0.87	KRL 2307	0.90	KRL 3-4	0.77
6	KRL 2305	KRL 2308	0.87	KRL 283	0.90	KRL 2101	0.66
7	KRL 2309	KRL 238	0.85	KRL 19	0.89	KRL 2402	0.61
8	KRL 2014	KRL 283	0.84	KRL 2203	0.89	KRL 2307	0.58
9	PBW 343	KRL 2307	0.84	KRL 1-4	0.88	KRL 2308	0.58
10	KRL 2302	KRL 210	0.82	KRL 2308	0.87	KRL 19	0.57
11	KRL 370	KRL 2402	0.81	KRL 2309	0.84	KRL 2203	0.55
12	KRL 2009	KRL 2401	0.80	KRL 2305	0.81	KRL 1-4	0.55
13	KRL 386	KRL 1803	0.79	KRL 2202	0.80	KRL 2303	0.53
14	KRL 210	KRL 99	0.74	KRL 2310	0.75	KRL 210	0.52
15	KRL 283	KRL 2101	0.73	KRL 2303	0.69	KRL 2202	0.51

Fig 5.7 Performance of advanced breeding lines in microplots



were made on the basis on salt tolerance, disease resistance and agro-morphological traits during the *rabi* season 2024-25.

Evaluation of wheat varieties for salt stress in Microplots

During the cropping season 2024-25, forty two wheat genotypes including 28 advanced lines were evaluated under four environments (Control, Saline: irrigation with saline water of EC_{iw}:10 dS/m , Sodic; pH₂ 9.3 ± 0.11 and Sodic waterlogged: pH₂ 9.3 ± 0.19) for their *per se* performance in micro plots. Genotypes were evaluated in RBD with three replications. Following is the performance of genotypes in different microplots

Fig 5.8 Genetic variation among wheat lines in sodic microplots (pH₂9.3±0.11)



Results of microplots evaluation

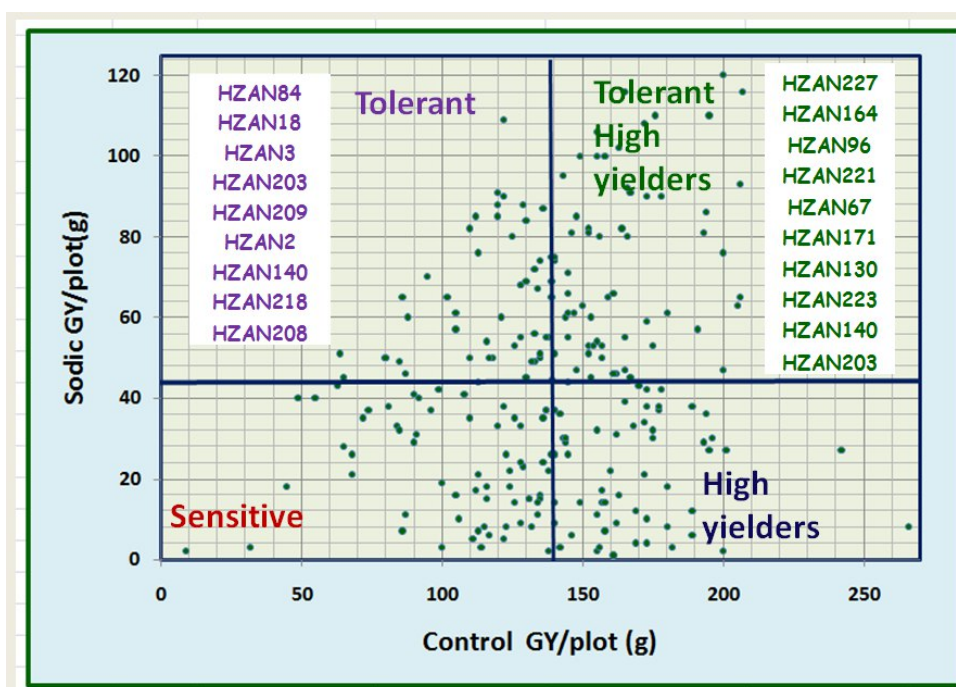
- Normal microplots - top performing genotypes were KRL 2215 followed by KRL 2202, KRL 2207, KRL 2205, KRL 2203, KRL 2305, KRL 2309, KRL 2014, PBW 343 and KRL 2302.
- Saline microplots – KRL 3-4, 1-4, Kharchia 65, KRL 19, KRL 2311, KRL 2308, KRL 238, KRL 283 and KRL 210 based on tolerance indices.
- Sodic microplots – Kharchia 65, KRL 99, KRL 3-4, KRL 2101, KRL 2307, KRL 283, KRL 19, KRL 2203, KRL 1-4 and KRL 2308 based on tolerance indices.

Sodic waterlogged microplots – Kharchia 65 was the top performer followed by KRL 99, KRL 238, KRL 283, KRL 3-4, KRL 2101, KRL 2402, KRL 2307, KRL 2308 and KRL 19 based on tolerance indices.

Evaluation of CIMMYT's HZAN in sodic microplots under waterlogging

During the cropping season 2023-24, a set 230 entries of CIMMYT's High Zinc Advanced

Fig 5.9 Genetic variation among HZAN lines under waterlogged sodic microplots (pH₂: 9.3) in comparison to control microplots



Nursery (15th HZAN) was evaluated under control as well as waterlogged microplots (pH₂: 9.3) in augmented design. Each set was comprised of 10 entries and 3 checks. Following is the performance of nursery. The entries HZAN 227 followed by HZAN 164, HZAN 96, HZAN 221, HZAN 67, HZAN 171, HZAN 130, HZAN 223, HZAN 140 and HZAN 203 were found to possess high tolerance index coupled with high yield in control plots (Fig 5.9). Some of these entries have undergone introgression with salt-tolerant/high-yielding genotypes to potentially further improve their performance.

Evaluation of advanced breeding lines for salt stress

During the 2024-25 cropping season, the per se performance of 110 advanced wheat breeding lines was evaluated at ICAR-CSSRI Karnal. The genotypes were assessed under two environments: control (normal soil) and sodic soil (pH₂ 9.2). An augmented design with five blocks, each comprising 22 test entries and five checks, was employed. The top 15 performing lines identified in each environment are presented in the table 5.8

Entries contributed for IPPSN 2024-25

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

Entries Promoted/nominated

- KRL 2402 was promoted from Salinity/Alkalinity Tolerance Screening Nursery 2024-25 to Salinity alkalinity trial 2025-26 as the entry was at par with the best check KRL 210 along with resistance to stem, leaf and stripe rusts.
- KRL 2407 was nominated to NIVT 1A from SATSN 2024-25.
- Salt tolerant entries KRL 2202 and KRL 2214 were promoted for the Uttar Pradesh Salinity trial 2025-26 where as KRL 2403, KRL 2307 and KRL 2308 were nominated as new entries for sodicity trial of UP state.
- Entries submitted to SATSN 2024-25: KRL 2407, KRL 2408, KRL 2413, KRL 2414, KRL 2501, KRL 2502, KRL 2503, KRL 2504, KRL 2505 and KRL 2506
- IPPSN 2025-26: 16 entries from KRL 2507 to KRL 2522

Table 5.8 Top 10 genotypes among advanced breeding lines with respect to grain yield/plot (g) in different environments

SN	Normal	Sodic (pH ₂ : 9.2)	Tolerance index
1	KRS23001	KRS23001	KRS 23090
2	KRS 23038	KRS 23037	KRS 23024
3	KRS 23057	KRS 23093	KRS 23037
4	KRS 23095	KRS 23090	KRS 23108
5	KRS 23103	KRS 23095	KRS 23093
6	KRS 23107	KRS 23094	KRS23001
7	KRS 23037	KRS 23089	KRS 23077
8	KRS 23040	KRS 23030	KRS 23067
9	KRS 23051	KRS 23108	KRS 21114
10	KRS23003	KRS 23054	KRS 23089
11	KRS 23094	KRS 23078	KRS 23054
12	KRS 23027	KRS 23027	KRS 23074
13	KRS 23032	KRS 23099	KRS 23091
14	KRS 23028	KRS 21007	KRS 23078
15	KRS 23106	KRS 21114	KRS 23100

Trials/nurseries conducted

During 2024-25 following trials and nurseries were conducted and the data was sent to the coordinating center for compilation. Detailed findings and trial information are documented in Progress Report of AICRP on Wheat and Barley 2024-25, Crop Improvement. ICAR – IIWBR, Karnal, Haryana, India. p262.

- Salinity Alkalinity tolerance screening nursery 2024-25 at ICAR-CSSRI Karnal (pH₂: 9.1)
- Salinity Alkalinity tolerance screening nursery 2024-25 at ICAR-CSSRI RRS Lucknow (pH₂: 8.9)
- Salinity Alkalinity tolerance screening nursery 2024-25 at ICAR-CSSRI RRS Bharuch (EC_{iw}: 7-8 dS/m)
- Salinity Alkalinity tolerance screening nursery 2024-25 at ICAR-CSSRI Microplots (pH₂: 7.5) Normal
- Salinity Alkalinity tolerance screening nursery 2024-25 at ICAR-CSSRI Microplots (pH₂: 9.3) Sodic
- Special Alkalinity Salinity Trial 2024-25 at ICAR-CSSRI Karnal (pH₂: 9.1)
- Special Alkalinity Salinity Trial 2024-25 at ICAR-CSSRI RRS Lucknow (pH₂: 8.9)
- Special Alkalinity Salinity Trial 2024-25 at ICAR-CSSRI RRS Bharuch (EC_{iw}: 7-8 dS/m)

Others AICRP trials/nurseries conducted

- National genetic stock nursery 2024-25
- 57th IBWSN (221 genotypes)
- 32nd SAWYT (50 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.

Station Trial conducted at Lucknow & Bharuch

A station trial comprised of 31 wheat genotypes including checks such as KRL 210, KRL 283 and Kharchia 65 which were tested under sodicity (pH₂: 9.5 to 9.8) in RCBD with three replications. Observations were recorded on grain yield (plot basis) and its contributing traits including biomass, test weight, days to heading and maturity, spike length and

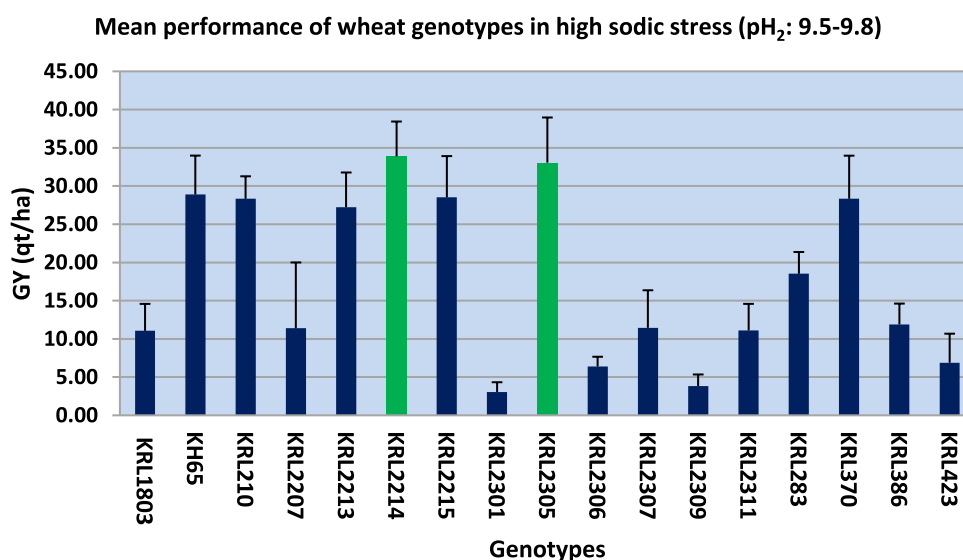


Fig 5.10 Performance of wheat genotypes under sodicity stress at RRS Lucknow

Performance of wheat genotypes in saline vertisols (EC_{iw}: 6-8 dSm⁻¹)

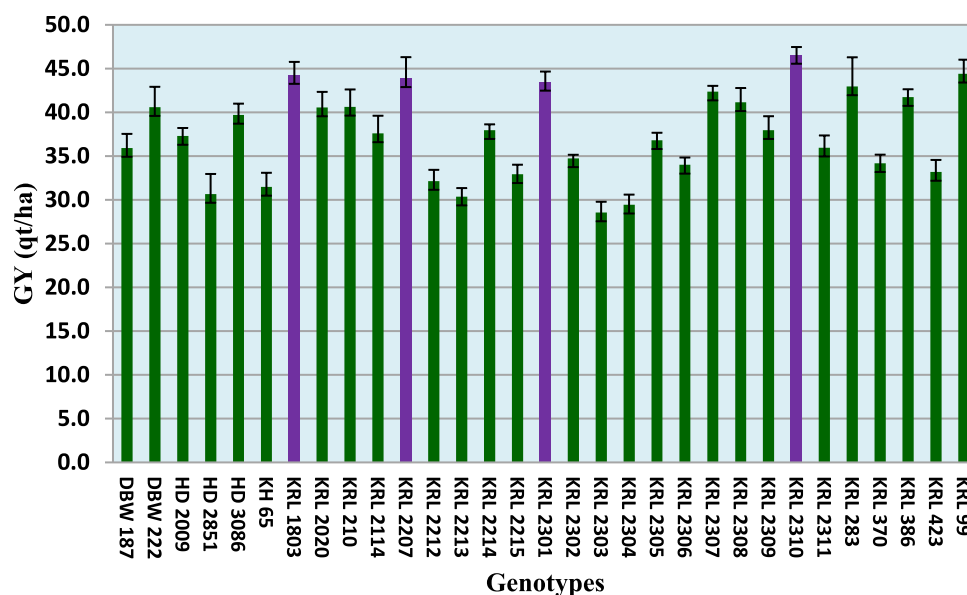


Fig 5.11: Performance of wheat genotypes in terms of grain yield under saline vertisols (EC_{iw}: 6-8 dSm⁻¹) at RRS, Bharuch, Gujarat

number of grains per spike. Based on grain yield, the genotypes KRL 2214 and KRL 2305 outperformed best check Kharchia 65 and KRL 210 in terms of grain yield. Performance of wheat genotypes tested at RRS, Lucknow centre can be seen in the Fig 5.10.

In Bharuch, the same experiment was conducted on salt affected Vertisols (EC_{iw} 6-8 dS m⁻¹). Genotypes KRL 2310, KRL 1803, KRL 2207 and KRL 2301 outperformed best checks KRL 210 and KRL 283 in terms of grain yield. Performance of wheat genotypes tested at RRS, Bharuch, Gujarat centre can be seen in the Fig 5.11.

Advancement of mapping populations for salt tolerance

During the cropping season three mapping populations namely IC564103-A/Kharchia 65 (population size 290 in F₉ generation), HD2985/Kharchia Local (population size 360 in F₈ generation) and KRL 283/IC 401976 (size 120 in F₁₀ generation) were advanced.

Breeder/ nucleus seed production and seed multiplication

The following seed-related activities were conducted during the cropping season:

Breeder Seed Distribution: Breeder seed of CSSRI varieties was distributed as follows:

To public and private agencies: KRL 210 (6 qt), KRL 213 (1.5 qt), KRL 283 (4 qt)

To the seed production unit (for TL seed): KRL 210 (7 qt), KRL 213 (0.5 qt), KRL 283 (1.5 qt)

Nucleus Seed Production: Nucleus seed of five released varieties (KRL 1-4, KRL 19, KRL 210, KRL 213, KRL 283) and 20 advanced lines was produced at the CSSRI experimental farm.

Seed Multiplication: Seed was multiplied for: IPPSN and SATSN entries, three NIVT entries and important germplasm (Kharchia 65, KRL 99, KRL 3-4, and Kharchia local) for use as checks.

Genetic Improvement in Barley for Managing Salt-Affected Agro-Ecosystems (Arvind Kumar, Anita Mann, Neeraj Kulshrestha, Priyanka Chandra, Monika Shukla, Ravi Kiran, K.T. and Devika S.)

Salt-affected agro-ecosystems pose a major constraint to agricultural productivity in India, particularly in arid and semi-arid regions. Barley (*Hordeum vulgare* L.), being the

most salt-tolerant cereal crop capable of withstanding salinity levels up to 250 mM NaCl, offers significant potential for reclaiming sodic and saline soils. Keeping this in view, the present project was initiated at ICAR-CSSRI, Karnal, with the objective of developing high-yielding, salt-tolerant barley genotypes suitable for salt-affected environments.

Germplasm Collection and Parental Line Assembly

During 2024–25, a total of 234 barley germplasm lines were assembled, comprising 210 exotic accessions procured from ICARDA, Morocco, and 24 indigenous lines obtained from IIWBR, Karnal. In addition, a set of promising good-combiner parental lines (Karan03, Karan04, Karan18, Karan19, Karan231, Karan265, Karan163, Karan201, Karan92, Karan15, and Karan280) was consolidated to support hybridization and breeding strategies aimed at salinity and sodicity tolerance.

Salinity/Alkalinity Tolerance Trials

The Advanced and Initial Varietal Trials for salinity/alkalinity tolerance (AVT/IVT-SST) were conducted under sodic field conditions (pH_2 9.2; ESP 32.2–37.0) using a randomized block design with three replications. The trial included 18 test entries and three checks. Grain yield ranged from 24.50 to 39.81 q ha⁻¹, with RD3140 emerging as the top performer (39.80 q ha⁻¹), followed by RD3109, RD3138, and RD3102, all significantly superior to the check RD2794.

Hull-less Barley Evaluation

The IVT-IRTS-NB (Hull-less Barley) trial was conducted under reclaimed sodic soil (pH_2 8.3; ESP 10.6–14.86) using an alpha lattice design. Grain yield varied from 16.14 to 48.29 q ha⁻¹. Five entries namely PL976, DWRB2428, DWRB2407, RD3125, and DWRB2436 recorded significantly higher yields than the best check DWRB223, indicating strong potential for further advancement.

International and Exotic Germplasm Evaluation

The International Spring Barley Observation Nursery (IBON 2024–25), comprising 130 genotypes, was evaluated under reclaimed sodic conditions. Grain yield ranged from 26.75 to 63.62 q ha⁻¹, with nine entries significantly outperforming the check Rihane-03. Additionally, 108 barley germplasm lines were evaluated under micro-plot conditions with high sodicity stress (pH_2 9.4; ESP up to 45.7%). Genotypes such as SAGGIA, AZAD, RD2508, NB2, and RD2592 exhibited higher grain yield with lower yield reduction, indicating superior sodicity tolerance. A separate evaluation of 30 exotic hull-less barley genotypes identified CSB24353, CSB24125, and CSB24119 as promising donors, combining high grain yield with excellent hull-less recovery. Further, 104 ICARDA elite lines were screened under sodic field conditions, five entries (including FFM2300951 and FFM2301077) significantly outperforming the check DWRB137.

Station Trial and Breeding Progress

In the station trial, 160 advanced breeding lines were evaluated, of which 34 lines recorded significantly higher yield (40.3–68.83 q ha⁻¹) than the check NDB-1173 and were promoted to IBDSN for 2025–26.

Hybridization and Generation Advancement

More than 400 single crosses were attempted using diverse parental lines. Advancement of 8 F₁, 87 F₂, and 48 F₃ populations was successfully completed for strengthening the breeding pipeline for developing salt-tolerant barley varieties. Overall, the project made substantial progress in identifying promising genetic resources and advancing breeding material for sustainable barley production in salt-affected agro-ecosystems.



Field view of Saggia

Summary

- A total of 34 entries (KRLB2501 to KRLB2534) promoted to Initial Barley Disease Screening Nursery (IBDSN) 2025-26.
- More than 400 single crosses were attempted in best adapted diverse barely cultivars for enhancing sodicity tolerance.
- Two advance lines i.e. CSB24119 and CSB24125 were identified almost completely hull less and potential for cultivar development.
- The Germplasm SAGGIA, AZAD, RD2508, NB2, RD2592, BHS46, BS544, PI532038, NB3, and IBON24-40 were identified as sodicity tolerant candidate parental lines.
- For sodicity stress tolerance above ground biomass, days to 50 % heading, plant height, ear weight and seeds weight per ear are utilized for selecting the candidate parental lines.

Development of salt tolerant and high yielding Indian Mustard (*Brassica juncea* L. Czern & Coss) genotypes using Classical and Modern breeding approaches (Jogendra Singh, Vijayata Singh, Ravikiran KT, Ashwani Kumar and Kailash Prajapat)

Development of salt tolerant Indian Mustard CS 68 (CS 2020-10; IC657307)

Developed salt tolerant Indian Mustard CS 68 and identified by "Varietal Identification Committee" during "32nd Annual group meeting of AICRP on Rapeseed & Mustard on 06/08/2025 for salt affected soils and water [EC_e/EC_{iw} 10-13 dS m⁻¹/alkalinity (pH) 9-9.4] of the country. It yielded 22-24 q/ha in salt stress and 26-30 q/ha in normal soils. It flowers in 54 days and attains a height of 190 cm. It produces a high number of primary (7) and secondary (14) branches, with a main shoot length of 70 cm, bears an average of 60 siliqua on the main shoot, and a 1000-seed weight of 5.2 g. The oil content in the seeds is approximately 40%. This variety showed resistance to *Alternaria* blight, White rust, Powdery Mildew, Downy Mildew, Stag head, *Sclerotinia* stem rot and mustard aphid under field conditions also.



Field view of CS 68

Germplasm collection, documentation and conservation-2024-25

We conserved, maintained, evaluated, and documented a diverse range of Indian mustard germplasm, including wild relatives, landraces, and cultivated varieties from various environments as Germplasm accessions (2750); advanced breeding lines (1350 lines: PYT, YET, BC, segregating generation); multiple stress tolerant line (31), four Recombinant Inbred Lines (RILs) population [1000 lines: (1) CS 614-1-100-13xCS 56; (2) CS 245-2-80-7xCS 56; (3) CS 245-2-80-7xVaruna; and (4) CS 614-1-100-13xVaruna], Introgressed lines (209) of *Brassica* super pan-genome combining genomic elements of *B. juncea*, *B. fruticulosa*, *Erucastrum abyssinicum*, and *Diplotaxis tenuisiliqua*; donors for heat, drought, frost (6 lines): Pusa Bahar (Heat tolerance); RH-781 (Drought and frost tolerance); RH-819 (Drought tolerance) and white rust/*Alternaria* (3 lines: DRMR 2019, Bio YSR & DRMR 2035; donors for salt tolerance (6 lines: CS 60, CS 52-SPS-1-2012, CS 2009-159, CS 2009-420, CS 2009-124, and Swarn Jyoti/RH-9801).

Development and Evaluation of advanced breeding lines (PYT) in semi-reclaimed alkali soils 2024-25

A total of 25 advanced breeding lines and 8 checks (Kranti, Pusa Bahar, Giriraj, CS 60, RH 781, RH 819, RH 749 and CS 58) were evaluated in PYT for seed yield in normal and reclaimed alkali soils (pH₂ 9.3) at Karnal. Seed yield ranged from 1.3 to 2.6 t ha⁻¹ (Mean 2.0 t ha⁻¹, CD_(0.05%) 0.17 t) under normal conditions while it ranged from 0.9 to 1.5 t ha⁻¹ (Mean 1.2

t ha⁻¹, CD_(0.05%) 0.10 t) under alkali condition. 12 genotypes produced significantly higher yield over the best check CS 60 (1.9 t ha⁻¹) with CS 2013-39 (2.6 t ha⁻¹) followed by CS 2013-47 (2.5 t ha⁻¹) recorded maximum seed yield under normal conditions, while two lines gave significantly higher yield over the best check CS 60 (1.4 t ha⁻¹) with CS 2013-47 and CS 2020-24 (1.5 t ha⁻¹) recorded maximum seed yield under alkali stress.

Development and Evaluation of advanced breeding lines (YET) in semi-reclaimed alkali soils-2024-25

A total of 32 advanced breeding lines and 8 checks (Kranti, Pusa Bahar, Giriraj, CS 60, RH 781, RH 819, RH 749 and CS 58) were evaluated in YET for seed yield in normal and alkali soils (pH₂ 9.3) at Karnal. Seed yield ranged from 1.3 to 3.4 t ha⁻¹ (Mean 2.4 t ha⁻¹, CD_(0.05%) 0.20 t) under normal conditions while it ranged from 0.8 to 1.6 t ha⁻¹ (Mean 1.1 t ha⁻¹, CD_(0.05%) 0.13 t) under alkali condition. Twenty-seven lines gave significantly higher yield over the best check CS 60 (1.9 t ha⁻¹) with CS 17000-2-3 (3.4 t ha⁻¹) followed by CS 2013-51 (3.0 t ha⁻¹) under normal condition, while Three lines gave significantly higher yield over the best check CS 60 (1.4 t ha⁻¹) with CS 22000-7-5 (1.6 t ha⁻¹) followed by RIL87& RIL199 (1.6 t ha⁻¹) recorded maximum seed yield under alkali stress.

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

The objective behind these crosses was to develop multi-stress (salinity, heat, drought and frost) tolerant mustard genotypes with higher yields. A total 25 advanced breeding lines and 4 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 up to -5 °C and heat stresses up to 42 °C along with sodic soils pH₂ 9.78) conditions (Table 5.9).

AICRP research trials

Rapeseed- Mustard Salinity/Alkalinity Trial-2024-25 and agronomic trial 2024-25 were successfully conducted and Observations systematically recorded and submitted to the Director, DRMR, Bharatpur. Detailed findings and trial information are documented in the Progress Report 2025 of All India Coordinated Research Project on rapeseed Mustard, published by ICAR-DRMR, Bharatpur.

Table 5.9. Development of multi stress tolerance advanced breeding line

Sr. No.	Genotype	Pedigree	Sr. No.	Genotype	Pedigree
1	CS2020-1	CS 204-2-2 x Rohini	14	CS2020-14	CS 330-1 x Q 2061-41
2	CS2020-2	RH 781 x CS 204-2-2	15	CS2020-15	Q 2061-41 x CS 56
3	CS2020-3	CS 204-2-2 x Q 2061-41	16	CS2020-16	CS 330-1 x Rohini
4	CS2020-4	Rohini x CS 54	17	CS2020-17	Rohini x CS 330-1
5	CS2020-5	Pusa Bahar x CS 330-1	18	CS2020-19	Q 2061-41 x CS 330-1
6	CS2020-6	Pusa Bahar x CS 204-2-2	19	CS2020-20	Pusa Bahar x CS 54
7	CS2020-7	Rohini x CS 56	20	CS2020-21	CS 56 x RH 781
8	CS2020-8	Rohini x CS 204-2-2	21	CS2020-23	CS 330-1 x Q 2061-41
9	CS2020-9	CS 56 x Rohini	22	CS2020-25	RH 781 x CS 330-1
10	CS2020-10	RH 781 x CS 56	23	CS2020-27	CS 54 x Rohini
11	CS2020-11	CS 56 x Q 2061-41	24	CS2020-29	CS 54 x RH 781
12	CS2020-12	CS 54 x Q 2061-41	25	CS2020-30	RH 781 x CS 54
13	CS2020-13	CS 204-2-2 x Pusa Bahar			

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

During the year 2024-25, breeder seed (1.50 tonnes graded) of Indian mustard varieties; CS 52 (0.05 t), CS 54 (0.05 t), CS 56 (0.05 t), CS 58 (0.7 t), CS 60 (1.2 t), CS 61 (0.5 t) and CS 64 (0.6 t) while 0.4 tonnes of TL seed of CS 62 was produced and distributed to stakeholders, central and state govt. agencies.

Output during the period under report

- Developed genotypes CS 2009-154 (CS 66; IC654506), CS 2009-335 (CS 65; IC654507) identified by UP State SVRC for release under Sodic condition-2025.
- Developed and maintained 1000 lines of 4 Recombinant Inbred Lines (RILs) population (250 lines of each) in $F_{2:12}$ generation and 1250 advanced breeding lines (F_{15r} , F_{17} and F_{18r} Mutant, BILs) of Mustard according to objectives of the project.
- Developed genotypes CS 2009-219, and submitted to AICRP on Rapeseed & mustard for AVT-I Timely sowing and irrigated trial-2025-26.
- Developed genotype CS 2002-63, CS 2004-102, CS 2013-63, CS 22000-7-5, CS 2013-47 and CS 2020-24 and submitted to UP State Adaptive Trial 1st year under Sodic condition-2025-26.
- Developed genotypes RIL 199 and CS 2013-5, and submitted to UP State Adaptive Trial 2nd year under Sodic condition-2025-26.

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 (Jogendra Singh and Vijayata Singh)

Insight into the mechanism of Salt stress responsive genes through Proteomics to uncover promising candidate proteins that regulate metabolic processes, hormonal crosstalk, and signalling pathways interpreting salinity tolerance in Mustard (*Brassica juncea*) cultivar CS 60

Experimental material for this study comprised of Indian mustard (*Brassica juncea*) genotype CS 60 (salt tolerant variety released by CVRC). Seeds of CS 60 were germinated on sterile germination paper (Axiva, 135 g/m² GSM) moistened with double distilled water, placed in a plastic tray for 6–7 days at 24 °C temperature. On 7th day, the seedlings were separated carefully from germination paper and 120 seedlings were transferred to hydroponic tray prefilled with Hoagland solution till 10th day. After 10th day, 40 seedlings were exposed to Hoagland solution (as control), 40 seedlings treated with Hoagland solution supplemented with saline salts (as salt treatment) for 24 h, 48 h and 72 h. Saline mixture was prepared by dissolving Na₂SO₄, NaCl, CaCl₂, and MgCl₂ with Na: Ca and Cl:SO₄ ratios as 6.3: 1 and 6.1: 1, respectively, to maintain the sodium absorption ratio within the permissible limit of 11.3. To avoid osmotic shock to seedlings, salinity was gradually increased. On 15th day, the desired level of salinity (EC_{iw} 12 dS/m) was achieved which was considered as salt treatment. Post 15th day, the effects of salinity were observed at 24 h, 48 h and 72 h. After salt stress treatment, seedlings were harvested and immediately frozen in liquid nitrogen and kept at –80°C for further experiments. Three independent biological replicates were prepared for proteomic analyses.

Proteome dynamics in response to salt stress

The effects of salt stress on the protein profiles of CS 60 were analyzed using 2-DE. To

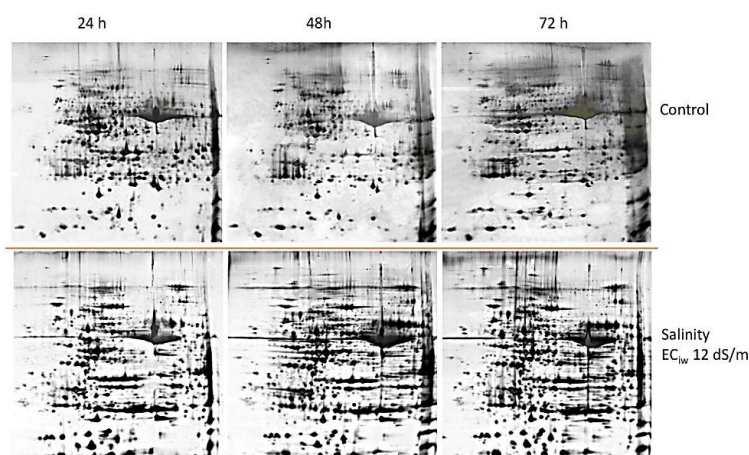


Fig 5.12 Two-dimensional electrophoresis (2-DE) gel images of proteins of CS 60

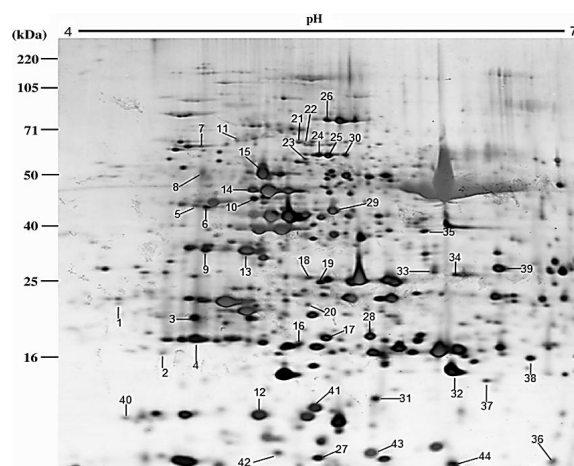


Fig 5.13 Two-dimensional electrophoresis (2-DE) gel images of proteins of CS 60 treated with salt stress EC_{iw} 12 dS/m. The 42 salt-stress-responsive protein spots identified by tandem mass spectrometry (MS/MS), which are numbered and indicated by arrows, correspond to the spot numbers in Table 5.10.

analyze proteome dynamics in response to salt stress, we measured several time points, from 24 h to 72 h, after EC_{iw} 12 dS/m salinity treatment (Fig. 5.12).

Approximately 500 protein spots were detected on silver-stained 2-DE gels in the range of pH 4–7. Differential protein abundance between the control and salt stressed plants under different time points was assessed. Total 62 protein spots were observed to be reproducibly and significantly ($p < 0.05$) altered in abundance by more than two-fold in at least one-time point after salt treatment (Fig. 5.13).

Among these, 42 were identified by MS/MS analysis (Table 5.10). To determine the functional roles of these proteins in salt adaptation, their dynamic changes in abundance were analyzed. ATP synthase (chloroplast) was identified in seven spots (spot 13, 18, 28, 31, 32, 36 and 37), and 60-kDa chaperonin was identified in three spots (spot 4, 16, and 19), whereas chloroplast ribulose-1, 5-bisphosphate carboxylase/ oxygenase activase (spot 7 and 30), heat shock protein 70 (spot 20 and 25), and chitinase (spot 26 and 29) were identified in two spots. These phenomena are commonly observed in 2-DE gel analysis and may result from the presence of different isoforms, differential post-translational modification or degradation in the protein extracts; they can also be related to allelic polymorphism.

The identified salt-stress-responsive proteins were further divided into seven categories on the basis of their functions (Fig. 5.14), including Chl biosynthesis (3.0%), photosynthesis (2.0%), stress and defence (12.9%), signal transduction (7.9%), ROS homeostasis (23.8%), protein metabolism and energy synthesis (23.8%), and cell structure damage repair (5.9%), transcription (5.9%) and membrane transport (5.9%). At the 24-h time point, 12 protein spots exhibited increased abundance and 16 spots exhibited decreased abundance. The number of down-accumulated proteins upon salt stress decreased and was much lower than the number of salt-induced proteins.

Only five spots were down-accumulated, while 15 protein spots were up-accumulated, at the 48-h time point. The changes persisted and at the 72-h time point, the abundance of 18 protein spots was increased and only four spots showed decreases in abundance. The

Table 5.10. Quantification summary of differentially accumulated proteins of *B. juncea* var. CS 60 under salt stress

Spot	Protein	Prot score	Peptide sequence (LC-MS/MS)	Cellular location
Biosynthesis				
1	glutamate 1-semialdehyde aminotransferase	62	DNGALLIFDEVMTGFR	chloroplast
Photosynthesis, energy synthesis and membrane transport				
3	photosystem I subunit VII	193	IYDTCIGCTQCVR,CESACPTDFLSVR	chloroplast
5	Sedoheptulose-1,7-bisphosphatase	120	NEIIRFEETLYGTSR, FEETLYGTSR	chloroplast
7	Chloroplast ribulose- 1,5-bisphosphate carboxylase/oxygenase activase	256	GLAYDTSDDQDDITRGK, LMEYGNMLVMEQENVKR, VQLADQYLNEAALGDANADAIGR	chloroplast
10	phosphoribulokinase	164	ANDFDLMYEQVK,ILVIEGLHPMFDERVR, KPFDFAFIDPQK	chloroplast
12	Lhcb6 protein	27	TAENFANYTGDDQGYPGGR	chloroplast
14	33 kDa oxygen-evolving protein	130	GGSTGYDनावलPAGGR	chloroplast
17	chlorophyll a/b binding protein	84	GPSGSPWYGSR, NRELEVIHCR	chloroplast
23	23kD protein of oxygen evolving system of PS II	139	WNPSREVEYPGQVLR, EVEYPGQVLR	chloroplast
30	chloroplast ribulose- 1,5-bisphosphate carboxylase/oxygenase activase	62	VQLADQYLNEAALGDANADAIGR	chloroplast
38	Ribulose bisphosphate carboxylase large chain	54	DTDILAAFR	chloroplast
39	transketolase-1	124	SIITGELPAGWEK, ALPTYTPESPGDATR	chloroplast
42	clpA	254	QLGHNYIGSEHLLGLLR, TAIAGLAQR, YRGEFEER, GELQCIGATTLDYRK, YTDESLVAAAQLSYQYISDR, HAQVPEEARELEK, RPYTWLFDEIEK	chloroplast
13	ATP synthase - β subunit	42	GMDWDMGNPLSVPVGGATLGR	chloroplast
18	ATP synthase gamma chain, chloroplast precursor	43	RPYIPVDKYLEAGTLPTAK, GIYPAVDPLDSTSTMLQPR	chloroplast
27	F1-ATPase - α subunit	100	AVDSLVPIGR, EAFPGDVFYLHSR	mitochondrion
28	ATP synthase CF1- β subunit	158	TREGNDLYMEMK, MPSAVGYQPTLSTEMGSLQER, VALVYGQMNEPPGAR	chloroplast
31	ATP synthase CF1- α subunit	167	IAQIPVSEAYLGR, ASSVAQWTSLQER, VINALANPIDGR	chloroplast
32	ATP synthase- β subunit	613	AHGGVSVFGGVGER,VGLTALTMAEYFR, DVNEQDVLLFIDNIFR, FVQAGSEVSALLGR, ELQDIIAILGLDELSEDR	chloroplast
36	ATP synthase- β subunit	204	AHGGVSVFGGVGER,DVNEQDVLLFIDNIFR, ELQDIIAILGLDELSEDR	chloroplast
37	ATP synthase- β subunit	68	VGLTALTMAEYFR, FVQAGSEVSALLGR	chloroplast
6	pyruvatedehydrogenaseE1 β	149	VLAPYSAEDAR, AAEKLAEEGISAIEVINLR, IAGADVPMPPYAANLER	mitochondrion
34	malate dehydrogenase	126	ELVKNDYLNGEFITTQQR	mitochondrion

Transcription and Protein metabolism				
2	cyclophilin, partial	38	IVMELYADTVPETAENFR	plasma membrane
4	60-kDa chaperonin	104	NWLDEFGSPKWNDGVTIAR, AIELPDAMENAGAALIR	mitochondrion
15	20S proteasome α - subunit B	64	ETIPVTQLVR	cytoplasm
16	60 kDa chaperonin subunit- β	90	SAENALYWEGMQFDR, AAVEEGIWGGGCTLLR	chloroplast
19	60 kDa chaperonin subunit- β	108	AAVEEGIWGGGCTLLR, YEDLMAAGIIDPTKWR	chloroplast
20	heat shock protein 70 cognate	410	TTPSYVAFTDSER, MVNHFVQEFKR, DAGVIAGLNVMR, IINEPTAAAIAYGLDKK	nucleus
21	heat shock protein 60-3A	67	ASLDDLAULTGAEVISEER, ALDNLQTENEDQRR	mitochondrion
25	heat shock cognate protein hsc70	408	DAGVIAGLNVMR, IINEPTAAAIAYGLDKK, MVNHFVQEFKR, TTPSYVAFTDSER	nucleus
33	elongation factor Tu	411	KYDEIDAAPEER, QTLPFLAVEDVFSITGR, VGETVDLVGLRETR, ILDEALAGDNVGLLLR	chloroplast
41	chaperonin hsp60	271	GYTSPYFITNQK, AAVEEGILPGGGVALLYAAR, ELEKLPTANFDQK	cytoplasm
Signal transduction, Cell structure damage repair, ROS homeostasis, and Stress defense				
8	Fe superoxide dismutase 1	32	TFMNNLVSWAEVSSR	peroxisome
9	glutathione transferase	78	KIPVLLHDGR	peroxisome
22	dehydroascorbate reductase	203	ESFKNTEAQTEDVIAGWRPK, NTEAQTEDVIAGWRPK	mitochondrion
11	thiazole biosynthetic enzyme	175	ALDMNTAEDAIVR, EWPGMIVTGMEVAEIDGAPR	chloroplast
35	RSH2	195	ADILDSALLRPGRFDR, TPGFSGADLANLLNEAAILAGR, AILSEFTEIPPENR	chloroplast
24	cinnamyl alcohol dehydrogenase	78	AGDTVGVGYFLDSCR	cytoplasm
26	chitinase	27	LPGYGVITNIINGGLECAGR	cytoplasm
29	chitinase	189	SFPSFGNTGDLAMR, DLGLELLKNPDVASSDPVIAFK, LPGYGVITNIINGGLECAGR	cytoplasm
40	N-glyceraldehyde-2-phosphotransferase-like	120	GDKLIEGVPETLDMLR, ENPGCLFIATNR	cytoplasm

Fig 5.14. Functional (biological, cellular and molecular) classification of differentially accumulated proteins (DEPs) identified in *B. juncea* under salt stress.

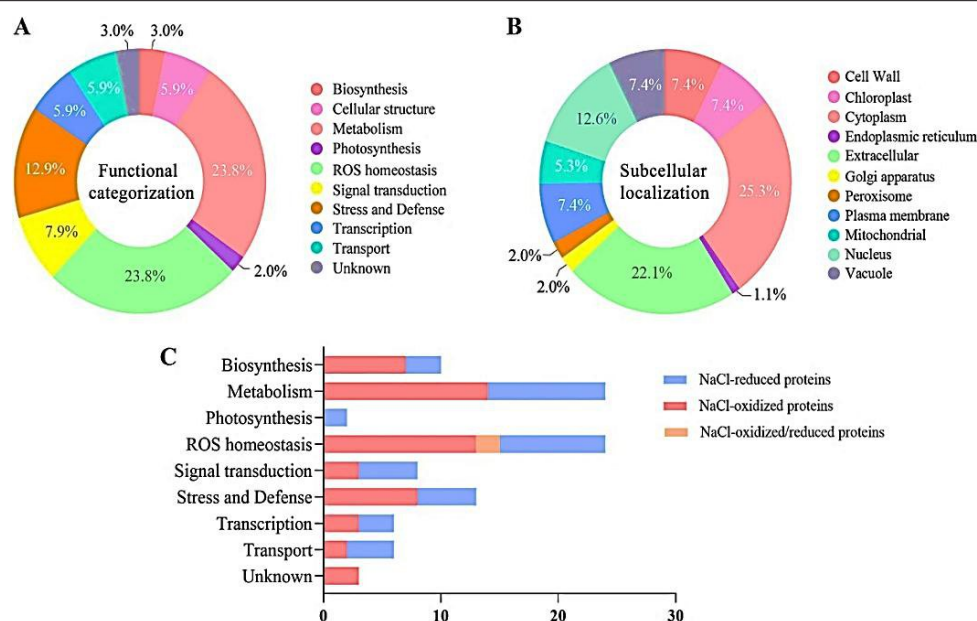
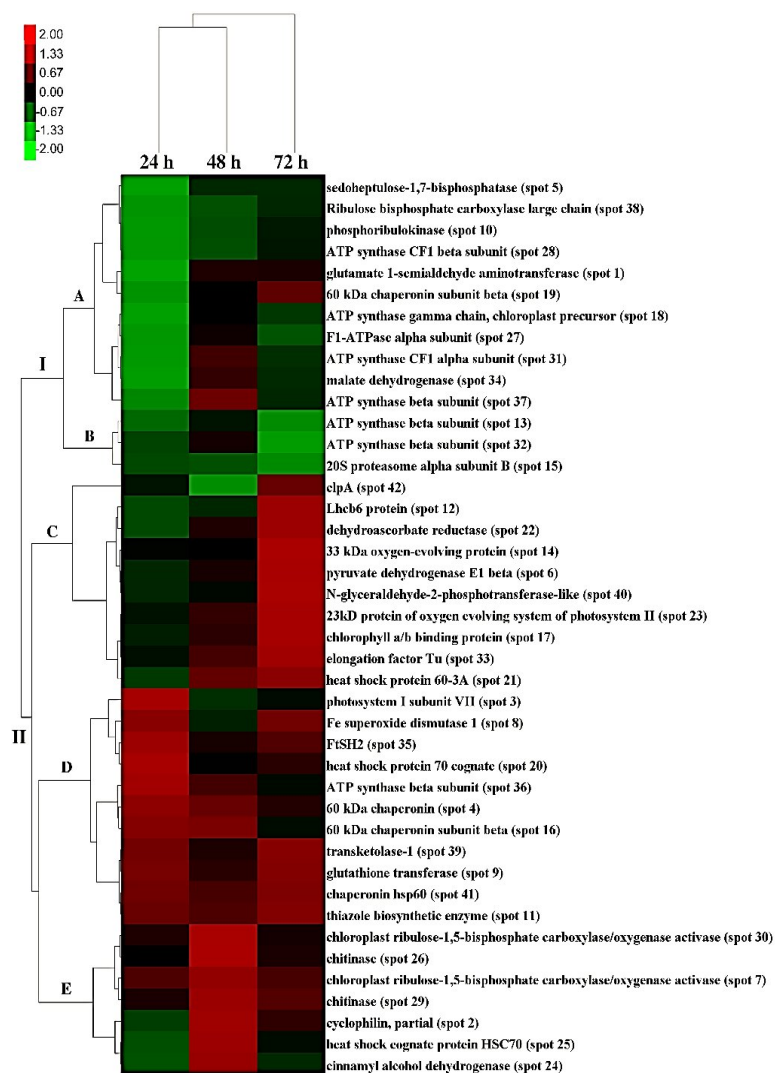


Fig 5.15. Hierarchical cluster analysis of the dynamic profiles of the 42 identified proteins. Protein names and spot numbers are labelled to the right of the corresponding heat maps. The proteins that increased and decreased in abundance are indicated in red and green, respectively. Proteins showing no significant changes are indicated in black. The intensity of the colours increases with increasing accumulation differences, as shown to the left of the bar. I and II indicated Cluster I and II, while A-E indicated subgroup A-E.



salinity-responsive proteins displayed different dynamic patterns during the time course experiments. For example, no significant change in protein abundance was detected for chitinase (spot 29) at 24 h; however, it was up-accumulated at 48 h. The abundance of the ATP synthase beta subunit (spot 37) was significantly decreased at 24 h, and then increased at 48 h.

To further reveal the proteome dynamics in response to salt stress, hierarchical cluster analysis was performed (Fig. 5.15). The results indicated that leaves at 24 h and 48 h were grouped into a single group, and leaves at 72 h were in another cluster. The 42 differentially accumulated protein spots in response to salt stress were grouped in two main clusters. The first cluster (Cluster I) included 14 protein spots whose abundance mainly decreased upon high salinity. Most of these proteins are involved in Chl biosynthesis, photosynthesis, respiration and energy synthesis. This cluster could be separated into two subgroups according to the changing patterns of the spots. In subgroup A, the abundance of most down accumulated proteins at time point 24 h was increased at time point 48 h and 72 h, while the highest depression effect of salinity on the accumulation of proteins in subgroup B was observed at time point 72 h. The second cluster (Cluster II) included 28 protein spots whose abundance was increased by salt

treatment. Most of them belong to protein families for protein metabolism, damage repair and defense response. This cluster could be further divided into three subgroups. The first subgroup (subgroup C) included 10 protein spots showing the highest up-regulation upon salt stress treatment at time point 72 h. The accumulation levels of 11 spots in the second subgroup (subgroup D) and seven spots in the third subgroup (subgroup E) was strongly induced by salinity at time point 24 h and 48 h, respectively.

Photosynthesis under salt stress

Proteomic analysis showed that 12 proteins related to photosynthesis were salinity responsive, including six photosynthetic proteins and six enzymes crucial for CO₂ fixation. Interestingly, most of the proteins involved in the light reaction, including photosystem I subunit VII (spot 3), Lhcb6 protein (spot 12), 33 kDa oxygen-evolving protein (spot 14), Chl a/b binding protein (spot 17), and 23kD protein of oxygen evolving system of photosystem II (spot 23), were up-accumulated in response to salt stress. However, the protein abundance of enzymes in CO₂ assimilation, including Ribulose biphosphate carboxylase (RuBisCO) large chain (spot 38), sedoheptulose-1, 7-bisphosphatase (spot 5) and phosphoribulokinase (spot 10), was significantly decreased after salt-stress treatment, especially at the 24-h time point. In support of this finding, the reduction in stomatal conductance and transpiration rate was far larger than the reduction in intercellular CO₂ concentration after salt stress treatment (Table 5.10). These observations suggested that the salt-induced reduction in photosynthesis capacity could be mainly attributed to impaired CO₂ fixation in mustard seedlings.

Energy synthesis under salt stress

In this study, proteomic analysis identified eight spots (spots 13, 18, 27, 28, 31, 32, 36, 37) as ATP synthase subunits, whose abundances changed under salt-stress conditions (Table 5.10). Most of these proteins were down-accumulated, especially at the 24 h time point, and the enzyme activity analysis result was consistent with this finding. These results suggested that energy synthesis might be repressed in salt-stressed *Brassica juncea*.

Protein metabolism under salt stress

Salt stress can severely affect protein synthesis and disrupt protein folding in the endoplasmic reticulum (ER), leading to the accumulation of unfolded proteins and ER stress in plants. Proteomic analysis in the present study indicated that elongation factor Tu (spot 33), which is involved in protein biosynthesis and chaperones (cyclophilin, 60 kDa chaperonin/HSP60 and HSP70) related to protein folding, was significantly induced in salt-stressed leaves (Table 5.10). By contrast, a protein associated with protein degradation (20S proteasome) was decreased by salinity stress treatment. The up-accumulation of elongation factor *Tu* might enhance protein biosynthesis and thus repair the damage of salt stress on photosynthetic proteins in chloroplasts. The results suggested that these proteins related to protein metabolism might participate in salt-stress tolerance in *Brassica juncea* seedlings

Damage repair and defense response under salt stress

Oxidative stress caused by the generation of excess ROS is a well-documented indirect form of damage caused by salt stress. The up-accumulation of antioxidant enzymes, such as FeSOD 1 (spot 8), glutathione transferase (spot 9), and dehydroascorbate reductase (spot 22), might promote ROS scavenging and mitigate the oxidative damage under salt

stress in *Brassica juncea*. The thiazole biosynthetic enzyme (THI) protein (spot 11) plays a role in thiamine biosynthesis, and its involvement in DNA damage repair and stress-tolerance mechanisms has been observed in bacteria, yeast and *Arabidopsis thaliana* (Table 5.10). Three up-accumulated proteins related to the defense response were identified in Mustard, including cinnamyl alcohol dehydrogenase (spot 24), chitinase (spot 26 and 29) and N-glyceraldehyde-2-phosphotransferase-like protein (spot 40). Cinnamyl alcohol dehydrogenase (CAD) is a key enzyme in lignin biosynthesis and enhanced CAD might increase the extent of lignification, which might represent a salt-adaptation response in plant roots.

Analysis of proteome changes shows that proteins involved in reactive oxygen species (ROS) detoxification, photosynthetic adjustment, energy synthesis, and protein metabolism and damage repair are differentially accumulated under saline conditions, suggesting their crucial roles in alleviation of the deleterious effect of salt stress and conferring salt tolerance. These findings provide valuable molecular targets for developing salt-tolerant mustard varieties through breeding or genetic engineering approaches.

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

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

Phenotypic screening of Chickpea germplasm

A total 986 diverse panel of chickpea pan-gene germplasm and 3550 accessions of Chickpea for their maintenances along with national checks CSG 8962 (Salt tolerant) and HC5 (Salt sensitive) were sown in normal and salinity ($EC_{iw} 6 \text{ dS m}^{-1}$) conditions for phenotypic screening (Fig. 5.16).

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 5.11. The Perusal of the results indicate that checks are superior than the test entries for all the traits studied except for yield/plant and no. of filled pods under the normal condition. However, test entries are superior on checks all the remaining traits studied. The checks recorded more productive branches, filled pods, 100 seed weight and yield/plant under saline ecology, since they are developed and selected for the situation and hence, they are more adapted than the test entries. However, several accessions were found better than checks for particular traits under the specific environment. Of these, the accessions for Yield/plant: ICC16921, ICC83787; Filled pods: ICC83787, ICC83869; Productive branches: ICC19036, ICC18917; 100 seed weight: ICC14216 and ICC15452 were found better than checks under the normal condition.

However, Yield/plant: ICC18933, ICC18937; Filled pods: ICC18933, ICC83526, ICC18937; Productive branches: ICC18933, ICC18937, ICC83526; 100 seed weight: ICC19114, ICC19064, ICC19001; Highest shoot K conc.: ICC18889, ICC13185, ICC19150; Least Cl⁻ conc. in shoot: ICC83559, ICC83555, ICC83751; Least Cl⁻ conc. in root: ICC16186, ICC15295 and ICC83380 were found better than checks under saline environment. Hence, these genotypes may be used as a potential parent in hybridization programmes to obtain superior genotypes for selected traits.

Fig 5.16. 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 EC_{iw} 6 dS/m, (C) Comparison of genotype with national checks

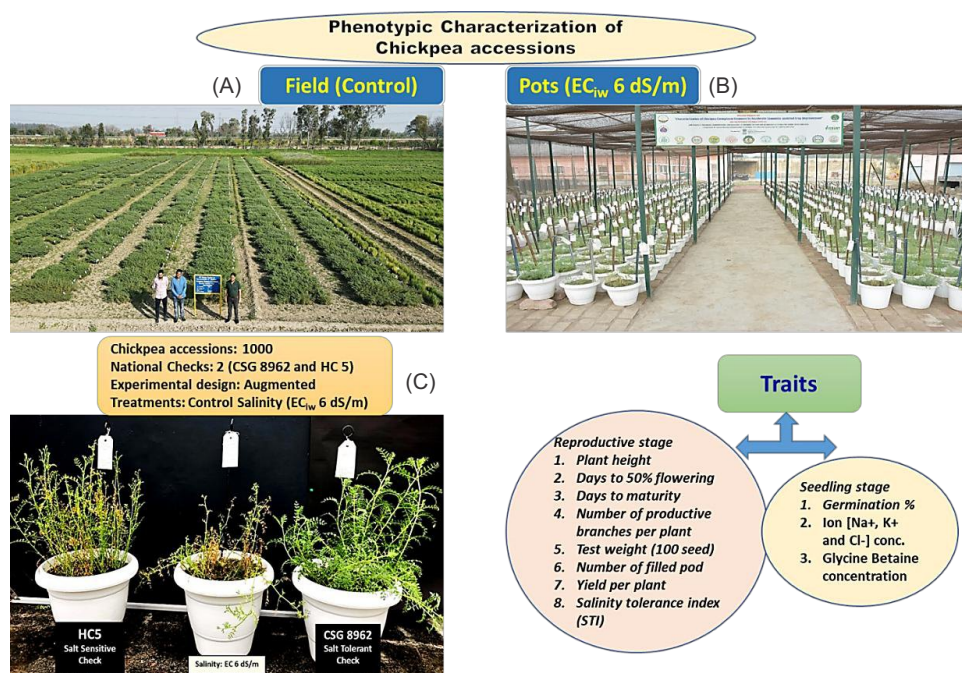


Table 5.11 Descriptive statistics of parameters for 986 accessions of Chickpea

Traits 2024-25	Mean						Range						CV (%)	
	Normal			Salinity			Normal		Salinity				Normal	Salinity
	Test entries	Checks	SE±	Test entries	Checks	SE±	Test entries	Checks	Test entries	Checks	Test entries	Checks		
Days to 50% flowering	84.51	83.80	0.35	75.47	80.75	0.61	86.0-109.0	95.0-108.0	76.0-107.0	86.0-91.0	3.86	4.04		
Days to maturity	123.78	125.60	0.49	136.62	132.50	0.89	136.0-153.0	141.0-132.0	118.0-142.0	126.0-137.0	2.15	2.41		
Plant height (cm)	50.60	59.23	0.35	34.37	51.59	0.36	31.67-79.00	36.33-73.0	17.0-59.0	33.67-47.70	12.96	4.93		
Productive branches	5.44	8.93	0.06	0.13	2.00	0.02	3.0-13.67	4.33-12.0	1.0-12.33	2.33-6.0	3.50	16.86		
No. of filled pods	111.60	131.52	1.76	0.55	6.66	0.10	5.0-326.0	98.0-229.3	1.0-32.63	3.0-35.3	12.68	15.69		
Yield/plant (g)	21.06	32.40	0.37	0.46	7.86	0.08	0.18-97.05	40.18-70.73	0.10-29.98	1.62-27.0	11.01	20.69		
100 Seed weight (g)	18.88	17.84	0.27	0.29	3.73	0.05	7.34-39.0	16.75-27.13	1.8-13.6	4.20-9.18	11.40	22.84		
Na ⁺ conc. shoot (mg/g dw)	34.64	29.65	1.88	38.32	57.00	0.70	10.0-29.81	18.20-25.19	0.61-99.9	41.57-94.95	12.59	16.69		
K ⁺ conc. shoot (mg/g dw)	87.33	56.73	30.43	39.13	33.36	0.67	25.70-99.89	28.25-36.39	0.19-99.95	11.25-28.17	9.22	17.82		
Cl ⁻ conc. shoot (mg/g dw)	1.54	1.28	0.03	3.06	2.44	0.08	0.38-2.40	1.0-2.80	0.14-7.90	2.20-4.20	1.54	18.80		
Na ⁺ conc. root (mg/g dw)	34.88	33.85	0.71	38.22	54.67	0.69	10.18-98.16	18.05-22.62	2.05-99.7	45.33-95.12	10.72	17.90		
K ⁺ conc. root (mg/g dw)	52.78	56.57	3.06	36.94	34.98	0.72	11.89-98.16	29.89-37.78	1.70-99.8	11.17-28.30	11.44	17.98		
Cl ⁻ conc. root (mg/g dw)	1.27	1.04	0.03	2.03	2.49	0.05	0.21-5.10	0.95-2.50	2.1-6.0	2.10-3.80	1.27	20.24		

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.

Standard errors of mean and LSI for comparison of adjusted means

The standard errors of difference (Table 5.12) were computed for all traits for comparison of difference between two check varieties (Sc), difference between adjusted means of

Table 5.12 SE of mean and LSI for comparison of adjusted means for traits of 986 accessions of Chickpea under normal and saline conditions

Traits 2024-25	Difference between adjusted test entry and check mean (Svc): $\sqrt{\{(R+1)(C+1)MSE\}/R.C}$		Least sig. increase (LSI): $ta(1.833).Svc$		Test entries Mean value		Critical value for traits = Check mean $\pm$ LSI		No. of entries desired for trait	
	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity
Days to 50% flowering	3.24	2.57	5.94	4.71	84.51	75.47	77.86	76.04	3	203
Days to maturity	6.70	1.73	12.28	3.17	123.78	136.62	113.32	129.33	0	31
Plant height (cm)	13.63	7.91	24.98	14.50	50.60	34.37	84.21	66.09	0	2
Productive branches	3.05	0.81	5.59	1.48	5.44	0.13	14.52	3.48	0	6
No. of filled pods	29.67	2.07	54.39	3.79	111.60	0.55	185.91	10.45	87	18
Yield/plant (g)	10.38	1.41	19.03	2.58	21.06	0.29	51.43	10.44	10	4
100 Seed weight (g)	2.51	0.43	4.60	0.79	18.88	0.46	22.44	4.52	250	32
Na ⁺ conc. shoot (mg/g dw)	26.21	73.44	48.04	134.62	34.64	38.32	18.39	77.62	202	213
K ⁺ conc. shoot (mg/g dw)	39.19	37.02	71.84	67.86	87.33	39.13	128.57	101.22	0	0
Cl ⁻ conc. shoot (mg/g dw)	0.69	2.48	1.26	4.55	1.54	3.06	0.02	2.11	0	450
Na ⁺ conc. root (mg/g dw)	43.99	59.30	80.63	108.70	34.88	38.22	46.78	54.03	723	752
K ⁺ conc. root (mg/g dw)	68.14	44.99	124.90	82.47	52.78	36.94	181.47	117.45	0	0
Cl ⁻ conc. root (mg/g dw)	1.07	2.49	1.96	4.56	1.27	2.03	0.92	2.07	277	544

two test entries in the same block (Sb), difference between adjusted means of two test entries in different blocks (Sv) and difference between adjusted test entry and check mean (Svc). The least significant increase was computed to identify the test genotypes that significantly surpassed the best check. In our study, the number of accessions that surpassed the best check under the non-saline condition was 10 (yield/plant), 87 (no. of filled pods), 250 (100 seed weight), and 277 (Cl⁻ conc. root). However, accessions that surpassed the best check were 4 (yield/plant), 6 (productive branches), 32 (100 seed weight), 450 (Cl⁻ conc. shoot), 544 (Cl⁻ conc. root), 203 (Days to flowering and 31 (Days to maturity) under the salinity. The genotype CSG 8962 was the best check for all traits than HC 5.

Association between traits

The knowledge of trait associations in Chickpea breeding material is essential for a variety of reasons: it enables us to perceive the diversity of breeding material and identify the trait through which a chickpea plant is able to grow successfully in a given ecological condition with optimum productivity and to avoid characters that have little or no breeding value. In combination with the principal component analysis, it enables us to narrow down to a very few traits that not only account for large amount of variation but have a breeding value correlated with seed yield.

In this research, the traits like no. of filled pods ($r=0.82^{**}$), productive branches ($r=0.28^{**}$), 100 seed weight ($r=0.17^{**}$), days to 50% flowering and maturity ($r=0.09^{**}$) were associated significant positively with yield per plant under the non-saline condition. However, under the salinity, traits like no. of filled pods ($r=0.91^{**}$), productive branches ($r=0.79^{**}$), 100 seed weight ($r=0.77^{**}$), K⁺ conc. in shoot ($r=0.39^{**}$) and root ($r=0.11^{*}$), and plant height ($r=0.09^{*}$), exhibited a highly significant positive association with yield per plant, while Cl⁻ conc. in shoot ($r= -0.11^{**}$) and root ($r= -0.07^{**}$), Na⁺ conc. in shoot ($r= -0.14^{*}$) and root ($r= -0.11^{*}$) associated significantly negatively with the yield under salinity.

Salt tolerance index (STI)

The salt tolerance index (STI) was calculated as: $STI = (Y_n \times Y_s) / (M_n)^2$

Where Y_n and Y_s are the yields of accession under normal and salt stress conditions

respectively and M_n is the mean yield of all the accessions under normal conditions. Based on the salinity tolerance index, we categorized genotypes as sensitive ($STI=0.00 - 0.30$), and tolerant ($STI > 0.30$). We found 8 accessions ICC 18933 ($STI=0.73$), IC83644 ($STI=0.45$), IC95053 ($STI=0.42$), ICC 18937 ($STI=0.41$), IC83526 and IC95076 ($STI=0.37$), IC83789 ($STI=0.33$) and IC83785 ($STI=0.32$) as highly tolerant, and 978 salt sensitive from 986 chickpea accessions. The accessions with the higher number of filled pods; productive branches, 100 seed weight and K^+ conc. in shoot; the least concentration of Cl^- and Na^+ in shoot and root should be given priority in breeding for enhanced yield under the saline ecology. Donors for various traits were identified which may be used in future Chickpea breeding to target yield enhancement and diverse geographical adaptation.

Genetic Improvement of Lentil (*Lens culinaris Medikus*) for Salinity Tolerance and Yield Enhancement Using Conventional Breeding Approaches (Vijayata Singh, Ravi Kiran KT, Kailash Prajapati and Jogendra Singh)

The present work integrates agro-physiological screening, ionic balance assessment, large-scale germplasm evaluation, and comparative analysis of advanced RIL populations during 2024-2025 to identify elite genotypes and breeding populations suitable for developing salt-tolerant, high-yielding lentil cultivars.

A. Agro-Physiological and Ionic Responses of Lentil Genotypes under Salinity Stress in ICARDA germplasm

Twelve lentil accessions comprising ICARDA lines and Indian cultivars (FLRP-10, FLRP-15, FLRP-21, FLRP-22, FLRP-27, FLRP-28, FLRP-31, FLRP-32, FLRP-45, FLRP-46, PSL-9, and PDL-1) were evaluated under control and salinity stress ($EC_e 7 \text{ dS/m}$) conditions. Both pot and field experiments were conducted to assess phenological traits, growth parameters, yield components, biomass accumulation, and ionic homeostasis. Salinity stress generally resulted in earlier flowering and reduced maturity duration, indicating stress-induced phenological acceleration. FLRP-10 and FLRP-22 maintained early flowering and stable maturity, suggesting an effective escape mechanism under saline conditions. In contrast, PSL-9 and PDL-1 exhibited delayed maturity under stress, reflecting susceptibility. Salinity significantly reduced plant height, pods per plant, seed yield, and biological yield. Among the traits, seed yield and biomass were the most sensitive to salinity, showing nearly 60% reduction across genotypes. However, FLRP-45 and FLRP-10 consistently outperformed other genotypes, maintaining higher pod number, seed weight stability, and yield retention. PDL-1, despite showing tolerance at the ionic level, suffered severe yield penalties, indicating poor agronomic stability.

Biomass partitioning: Root and shoot dry weights declined under stress; however, FLRP-45 showed balanced root–shoot development, with even increased shoot biomass under salinity, suggesting improved osmotic adjustment and assimilate partitioning. Such balanced biomass allocation is critical for sustained growth under salt stress.

Ionic balance and tolerance mechanisms: Na^+ exclusion in PDL-1 restricted Na^+ uptake efficiently but failed to translate this into yield stability. K^+ retention in FLRP-10 and FLRP-21 maintained higher K^+ concentrations and favorable K^+/Na^+ ratios, supporting metabolic activity under stress. Balanced ionic regulation in FLRP-45 combined moderate Na^+ exclusion with strong K^+ retention, resulting in superior yield stability.

Identification of tolerant genotypes: Based on combined agro-physiological performance, yield stability, biomass retention, and ionic balance: FLRP-45 emerged as

the most promising genotype with balanced tolerance. FLRP-10 showed early flowering, stable yield, and high K⁺ retention. FLRP-21 demonstrated strong ionic regulation. PDL-1 can serve as a donor for Na⁺ exclusion but not as a direct cultivar.

B. Preliminary Evaluation of Lentil Germplasm for Seed Weight and Yield (Rabi 2024–25)

Experimental material: A total of 725 lentil germplasm lines sourced from NBPGR were evaluated during Rabi 2024–25 under field conditions using single-row plots. The objective was to assess phenotypic variability for 100-seed weight and seed yield per line.

Variation in seed yield: The germplasm exhibited wide variability for seed yield, indicating a broad genetic base. Several accessions showed outstanding performance, including: EC257528 (450 g/line), IC268243 (435 g/line), IC424852 (430 g/line), along with other lines yielding ≥400 g/line. These accessions represent elite high-yielding genetic resources suitable for advancement and multi-location evaluation.

Variation in seed weight: IC255504 recorded an exceptionally high 100-seed weight (5.66 g), followed by IC329161 and EC255503. Although some bold-seeded genotypes exhibited moderate yields, they constitute valuable donor parents for improving seed size and market preference.

(C) Comparative Performance of F₄ RIL Populations

The IPL 220 × PDL-1 population consisted of the largest number of RILs (270), providing a broad genetic base and greater opportunity to capture rare favorable recombinants. In contrast, IPL 526 × PSL-9 (45 RILs) represented a smaller but more uniform population, while IPL 316 × ZS3 (105 RILs) showed intermediate population size. Comparative descriptive statistics for yield and 100-seed weight is presented in Table 5.13.

100-seed weight: The highest mean 100-seed weight was observed in IPL 526 × PSL-9 (2.86 g), indicating a generally bolder-seeded population. However, this population exhibited the narrowest range (1.97–3.31 g), suggesting relatively lower variability for seed size. In contrast, IPL 220 × PDL-1 recorded the lowest mean seed weight (2.02 g) but the widest range (1.17–2.94 g), indicating substantial segregation and strong scope for improving seed boldness through selection. The IPL 316 × ZS3 population showed an intermediate mean (2.62 g) with considerable variability (1.81–3.48 g), reflecting balanced potential for selection.

Seed yield per line: Mean seed yield was highest in IPL 220 × PDL-1 (222 g/line), highlighting its superior overall productivity. This population also displayed a very wide yield range (25–390 g), indicating the presence of both poor and exceptionally high-yielding recombinants. The IPL 316 × ZS3 population exhibited the widest yield range (10–385 g), despite a lower mean yield (160.28 g), suggesting strong transgressive segregation and high responsiveness to selection. In IPL 526 × PSL-9, the mean yield (180.44 g) and narrower range (60–289 g) indicate moderate variability and relatively stable yield performance.

Table 5.13 Comparative descriptive statistics for yield and 100-seed weight

Mapping population (F ₄)	No. of RILs	Mean 100-seed weight (g)	Range (g)	Mean seed yield (g/line)	Range (g)
IPL 316 × ZS3	105	2.62	1.81–3.48 (1.67)	160.28	10–385 (375)
IPL 526 × PSL-9	45	2.86	1.97–3.31 (1.34)	180.44	60–289 (229)
IPL 220 × PDL-1	270	2.02	1.17–2.94 (1.77)	222	25–390 (365)

Table 5.14 Genetic advance (GA) and response to selection (5% intensity)

Population	GA for 100-seed weight (% of mean)	GA for seed yield (% of mean)	Selection efficiency
IPL 316 × ZS3	13.70%	53.20%	Very high for yield; valuable for identifying extreme high-yielding segregants.
IPL 526 × PSL-9	10.90%	35.10%	Offers bold seed size with moderate yield variation, suitable for targeted improvement of seed traits.
IPL 220 × PDL-1	21.30%	36.20%	Combines high mean yield with wide variability, making it ideal for simultaneous improvement of yield and seed weight. (High for both traits)

Genetic Advance and Selection Efficiency in mapping population

The genetic advance (GA) expressed as a percentage of the population mean for 100-seed weight and seed yield in three F_4 lentil RIL populations, providing insight into the expected response to selection and overall selection efficiency (Table 5.14).

Across all populations, seed yield exhibited higher GA than 100-seed weight, confirming that yield is more responsive to selection at the F_4 stage. IPL 316 × ZS3 is best suited for aggressive yield improvement. IPL 220 × PDL-1 is ideal for simultaneous improvement of yield and seed size. IPL 526 × PSL-9 is useful for moderate gains, particularly when combined with multi-trait selection.

Genetic improvement of chickpea for salt tolerance through conventional and molecular breeding approaches (S.K. Sanwal, Avni Dahiya and Anita Mann)

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

Phenotyping of chickpea RILs for salinity tolerance

During the rabi season 2024-25, 330 chickpea RILs along with their salt tolerant parent (CSG-8962) and salt susceptible parent (BG1103) were tested for their performance in saline (EC_{iw} 6 dS/m), sodic and control condition. Three saline irrigation of EC_{iw} 6 dS/m was done at 30, 60 and 90 days after sowing to give the salt stress to the population. However, in control condition field trial was irrigated with normal tube well water and in sodic condition irrigation was not given. In the experiment quantitative data on days to 50% flowering, plant height(cm), number of pods/plant, blank pod, 100 seed weight(g), grain yield per plant(g), ionic analysis of root and shoot (Na^+ and K^+) were recorded to find out the effect of salinity stress in both conditions.

Variability in the RIL population for salinity tolerance

The days to 50% flowering were significantly delayed under control conditions compared to salinity stress (Table 5.15). The RIL population comprising 330 lines exhibited significant variability for salinity stress tolerance in traits such as days to 50% flowering, number of pods per plant, and grain yield per plant. The mean performance, range and coefficient of variation (CV) of the population for all traits are given in the Table 5.15. The coefficient of variation (CV) was higher under salinity stress compared to control and sodic conditions, with values of 5.5% for days to 50% flowering, 47.6% for pods per plant, and 44.3% for grain yield per plant under salinity stress. But for blank pods highest

Table 5.15 Mean performance, range and coefficient of variation(CV) of 330 RILs along with their parents

Sr.no.	Trait	Mean			Range			CV		
		Control	Saline	Sodic	Control	Saline	Sodic	Control	Saline	Sodic
1	Days to 50% Flowering	90.31	93.93	89.26	85-95	83-114	85-94	2.1	5.5	2.3
2	Plant Height(cm)	68.51	26.71	58.01	36.7-88.3	17-42.17	31.3-85.6	10.6	13.3	19.2
3	No. of pods/plant	189.55	7.49	71.27	67.7-361.3	0.4-22	10-203	29.7	47.6	39.6
4	Blank pod	12.35	1.83	5.71	0-50	0-9	0-27	60.8	53.1	81.9
5	100 seed weight(g)	14.84	8.51	15.72	4.08-27.1	2.8-28.81	11.7-28.3	21.5	35.5	20.9
6	Yield/plant(g)	53.52	3.32	19.93	22.3-102.6	0.11-9.22	4.5-40.9	28.8	44.3	37.6
7	Na ⁺ /K ⁺ _R	0.67	1.95	3.10	0.2-1.73	0.72-4.49	0.9-7.5	38.3	38.7	29.4
8	Na ⁺ /K ⁺ _S	0.18	0.24	0.42	0.06-0.46	0.09-0.84	0.12-1.09	45.3	33.7	38.5

variability was observed under sodic conditions (81.9), followed by the control environment (60.8). This increased variability is due to the wide range in total pod number across genotypes, resulting in values ranging from zero to a high number of blank pods. In contrast, under control conditions, the CV values were 2.1% for days to 50% flowering, 29.7% for pods per plant, and 21.5% for grain yield per plant. The higher CV for grain yield per plant and hundred seed weight under salinity stress followed by sodic stress conditions suggests substantial genetic variation within the population for these traits under stress conditions. This genetic variability highlights the potential of this RIL population for selecting salinity and sodicity tolerant genotypes.

STI in salinity tolerant group of genotypes, having highest grain yield/plant in saline stress, was greater than 0.1, while in the sodicity tolerant group it was 0.49-1.05 (Table 5.16). The seed yield ranged from 22.26g (RIL95) to 102.63g (RIL48) under control, 0.11g (RIL327) to 9.22(RIL233) under saline and 4.54g (RIL29) to 40.91(RIL14) under sodic stress conditions. Na⁺/K⁺ ratio under all three conditions is provided in Table 5.15. The top ten lines from each treatment were selected based on higher grain yield/plant (Table 5.16).

Introgression of Salinity tolerance traits into elite chickpea cultivars

High-yielding but salt-susceptible chickpea cultivars were strategically crossed with salinity-tolerant genotypes, ICCV-10 and CSG-8962 to introduce salinity tolerance without compromising yield potential. The resulting F2 progenies were advanced to F3, and F3 to F4 generations, with selection pressure applied for salinity tolerance. In the selected crosses, backcrossing was employed to recover the genotypic background of high-yielding recurrent parental lines while maintaining salinity tolerance. This breeding scheme facilitated the development of promising elite lines that combine stress resilience with productivity.

Table 5.16: Promising genotypes along-with their parents based on yield/plant

Treatment	Promising Genotypes GY/plant(g)	Range (GY/plant)	Parents performance (GY/plant)	STI range
Control	RIL48(102.63), RIL317(99.11), RIL159(96.40), RIL209(94.7), RIL269(90.71), RIL300(89.97), RIL272(89.16), RIL36(87.73), RIL282(86.99), RIL204(85.92)	85.92-102.63	CSG-8962(46.12), BG1103(52.24)	-
Saline	RIL233(9.22), RIL286(7.25), RIL23(6.92), RIL84(6.69), RIL255(6.41), RIL8(6.39), RIL11(6.2), RIL14(6.18), RIL289(6.1), RIL263(6.09)	6.09-9.22	CSG-8962(3.2), BG1103(0.62)	0.10-0.14
Sodic	RIL94(40.91), RIL92(40.51), RIL326(39.71), RIL201(38.42), RIL234(38.25), RIL314(37.48), RIL185(36.99), RIL172(36.43), RIL294(36.09), RIL96(35.62)	35.62-40.91	CSG-8962(18.53), BG1103(20.14)	0.49-1.05

Maintenance of germplasm and parental lines

A total of 392 germplasm lines and 84 parental lines were maintained for their use in future breeding programme.

Breeder seed production

During 2024-25, 6.3 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 Anita Mann)

Phenotyping of F₂-derived F₃ lines under saline environment

Three hundred forty F₂-derived F₃ lines were phenotyped at the vegetative stage under both control and salinity stress conditions (ECiw 10 dS/m). The experiment was conducted on sand medium over a period of 35 days under both conditions. In the control treatment, plants were irrigated with normal tube well water at 8-day intervals. For the salinity stress treatment, the first two irrigations were with normal water, followed by two saline irrigations (ECiw 10 dS/m) given at 18 and 27 days after sowing to impose salt stress. One genotype failed to establish under salinity stress. Quantitative measurements of 339 genotypes were recorded for root and shoot length, fresh and dry biomass of root and shoot, and sodium (Na⁺) and potassium (K⁺) content in roots and shoots of the plants. These data were used to identify genotypes exhibiting tolerance and susceptibility to salinity at the early growth stage.

Root and shoot ion accumulation as indicators of salinity tolerance in Chickpea at vegetative stage

Based on their ability to absorb less Na⁺ under salt stress, 11 top-performing genotypes were selected from 339 F₂-derived F₃ lines and were categorized as salinity-tolerant (Table 5.17). The table presents data on sodium (Na⁺) and potassium (K⁺) concentrations

Table 5.17 Na⁺ and K⁺ content and biomass traits of 11 Low-Na⁺ absorbing, salinity tolerant F₂-derived F₃ lines at the vegetative stage under salt stress

Genotype	SFW	RFW	SDW	RDW	Shoot K ⁺	Shoot Na ⁺	Root K ⁺	Root Na ⁺
7	3.34	3.51	0.49	0.397	3.89	6.33	17.66	27.48
159	2.93	3.11	0.512	0.462	17.34	2.38	11.5	17.08
256	5.15	6.45	0.75	0.525	29.14	18.76	1.82	4.73
257	5.3	6.59	0.72	0.538	36.32	24.42	3.08	7.44
281	3.64	5.11	0.68	0.388	0.83	4.55	18.53	31.67
290	3.24	5.61	0.53	0.472	23.62	4.18	4.91	9.6
329	4.74	4.77	0.59	0.37	13.98	16.74	38.73	5.14
333	3.54	2.81	0.52	0.24	42.39	15.9	15.52	23.57
334	3.8	3.35	0.55	0.26	18.45	11.1	7.89	13.63
341	4.28	4.88	0.67	0.32	16.2	7.04	14.3	21.77
343	3.65	4.08	0.56	0.29	12.37	6.4	9.21	10.58

SFW: Shoot fresh weight (gm); RFW: Root fresh weight (gm); SDW: Shoot dry weight (gm); RDW: Root dry weight (gm); Shoot and Root K⁺ and Na⁺ in mg/Kg.

Table 5.18 Ionic composition and biomass traits of 15 salinity tolerant chickpea genotypes having high root Na⁺ and low shoot Na⁺ at vegetative stage

Lines	SFW	RFW	SDW	RDW	Shoot K ⁺	Shoot Na ⁺	Root K ⁺	Root Na ⁺
36	4.53	2.7	0.58	0.194	38.96	30.93	36.1	56.97
223	3.33	4.1	0.48	0.305	20.42	27.81	24.49	52.34
233	2.62	2.3	0.39	0.302	7.55	9.31	37.05	52.78
236	4.09	5.99	0.61	0.483	7.80	8.61	40.6	56.58
243	3.24	4.05	0.43	0.284	26.9	31.52	38.33	58.05
293	4.22	3.12	0.61	0.256	36.63	28.67	58.89	83.84
305	3.31	4.83	0.55	0.40	31.93	29.87	33.29	56.24
308	3.78	4.92	0.61	0.39	31.98	35.7	65.29	81.04
313	2.95	2.02	0.43	0.17	26.67	15.47	33.59	53.43
315	3.84	3.93	0.6	0.32	23.38	15.44	72.31	85.99
322	3.68	5.41	0.58	0.42	29.44	25.38	40.08	57.59
324	4.25	5.35	0.64	0.41	32.08	31.73	41.03	58.6
335	4.14	4.78	0.75	0.36	9.12	6.69	86.28	104.14
360	3.35	4.93	0.62	0.37	12.35	6.23	34.58	53.32
381	1.78	3.4	0.4	0.28	22.66	34.66	37	56.15

SFW: Shoot fresh weight (gm); RFW: Root fresh weight (gm); SDW: Shoot dry weight (gm); RDW: Root dry weight (gm); Shoot and Root K⁺ and Na⁺ in mg/Kg.

in roots and shoots, as well as biomass-related traits shoot and root fresh weight (SFW, RFW) and dry weight (SDW, RDW) at the vegetative stage under salt stress. Genotypes 159, 290, and 257 demonstrated higher shoot K⁺ and lower shoot Na⁺ levels, reflecting efficient ionic regulation. Additionally, genotypes 256 and 257 exhibited greater biomass accumulation, indicating better growth under saline stress conditions.

Based on their capacity to retain high sodium (Na⁺) levels in roots while limiting its accumulation in shoots, 15 top-performing chickpea genotypes were selected from F₂ derived F₃ lines and identified as salinity-tolerant (Table 5.18). These genotypes exhibited efficient ionic regulation under salt stress, characterized by elevated root Na⁺ and potassium (K⁺) levels and reduced shoot Na⁺ content. Genotype 335 recorded the highest root Na⁺ (104.14) and root K⁺ (86.28), with low shoot Na⁺ (6.69) and shoot K⁺ (9.12), reflecting strong Na⁺ sequestration. Genotype 315 also showed high root Na⁺ (85.99) and root K⁺ (72.31), with moderate shoot Na⁺ (15.44) and shoot K⁺ (23.38), along with favorable biomass traits (SFW: 3.84 g, RFW: 3.93 g, SDW: 0.60 g, RDW: 0.32 g). This trend was consistent across all 15 genotypes, highlighting their potential in developing salinity-tolerant chickpea cultivars.

Thus, the genotypes given in Table 5.17 & 5.18 demonstrate a physiologically efficient response to salinity stress by minimizing Na⁺ toxicity in shoots, which could be valuable for breeding salt-tolerant cultivars targeting vegetative-stage performance.

Coordinated evaluation of advance material for salinity tolerance

Ninety eight chickpea genotypes including advance breeding lines, interspecific crosses, backcross inbred lines of CSSRI, IARI, IIPR and PAU, Ludhiana along with salt tolerant checks (KC-1 and ICCV 10) were tested for their performance in saline (ECiw 6 dS/m) conditions. Three saline irrigation of ECiw 6dS/m was done at 30, 60 and 90 days after sowing to give the salt stress to the genotypes. In the experiment quantitative data on

Fig 5.17 Design of the tray experiment (A) Image of the set-up of the experiment taken from the front (B, C) Experiment in the control condition (D, E, F) Experiment in the salinity-stress condition

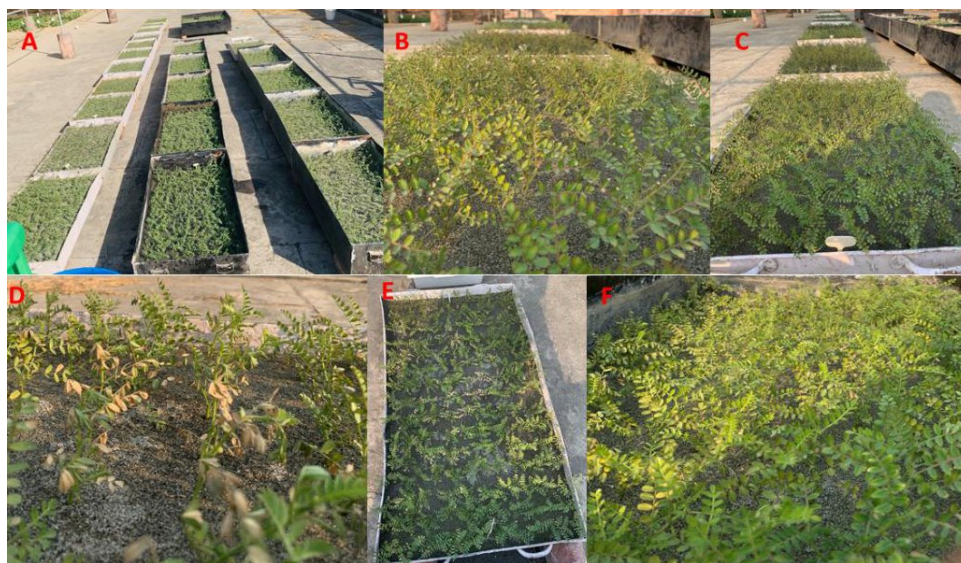


Table 5.19 Basic statistics for agronomic and ionic parameters of 100 chickpea genotypes grown on saline soil

Traits	mean	SD	median	MAD	Min	Max	Range	SE
DF	87.81	2.8	88	2.97	83	94	11	0.28
DM	123.97	2.6	124	2.97	119	129	10	0.26
PH(cm)	47.47	8.8	47.5	8.77	27.0	79.67	52.67	0.88
HSW(gm)	11.35	3.4	11.1	3.85	4.99	22.98	17.99	0.34
GY/plant(gm)	7.73	3.6	7.0	3.83	1.56	15.65	14.09	0.36
K ⁺ /Na ⁺ _root(mg kg ⁻¹)	0.61	0.21	0.58	0.16	0.23	1.46	1.23	0.02
K ⁺ /Na ⁺ _shoot(mg kg ⁻¹)	2.45	0.67	2.39	0.67	1.13	4.20	3.07	0.07

days to 50% flowering (DF), 50% physiological maturity (DM), plant height (PH), hundred seed weight (HSW), grain yield per plant, ionic analysis of root and shoot (Na⁺ and K⁺) were recorded to find out the salinity tolerant and susceptible genotypes. Basic statistics of agronomic and ionic parameters of 100 chickpea genotypes grown on saline soil is presented in table 5.19.

The mean represents the central tendency of trait performance under salinity stress. In this study, the average K⁺/Na⁺ ratio was higher in shoot tissues (2.45) compared to roots (0.61), indicating that, on average, genotypes maintained a more favourable ionic balance in the shoot. A higher shoot K⁺/Na⁺ ratio (>2.45) is considered advantageous under saline conditions, as it reflects the plant's ability to selectively accumulate potassium over sodium an essential mechanism for maintaining physiological function and sustaining yield under salt stress.

Ranking Chickpea Genotypes for Salinity Tolerance Using Multivariate Analysis

Principal Component Analysis (PCA) reduced the multidimensional trait data into seven components. The first two components, PC1 and PC2, explained 31.5% and 26.6% of the total phenotypic variance, respectively (Fig. 5.18B). PC1 was predominantly influenced by grain yield per plant (GY/plant), hundred seed weight (HSW), and plant height (PH), indicating its relevance to productivity under salinity stress (Fig. 5.18C & 5.18D). In contrast, PC2 was mainly associated with days to flowering (DF) and maturity (DM), suggesting it captures variation in phenological traits (Fig. 5.18A). Thus, genotypes with higher PC1 scores are likely to exhibit better productivity under saline conditions, while

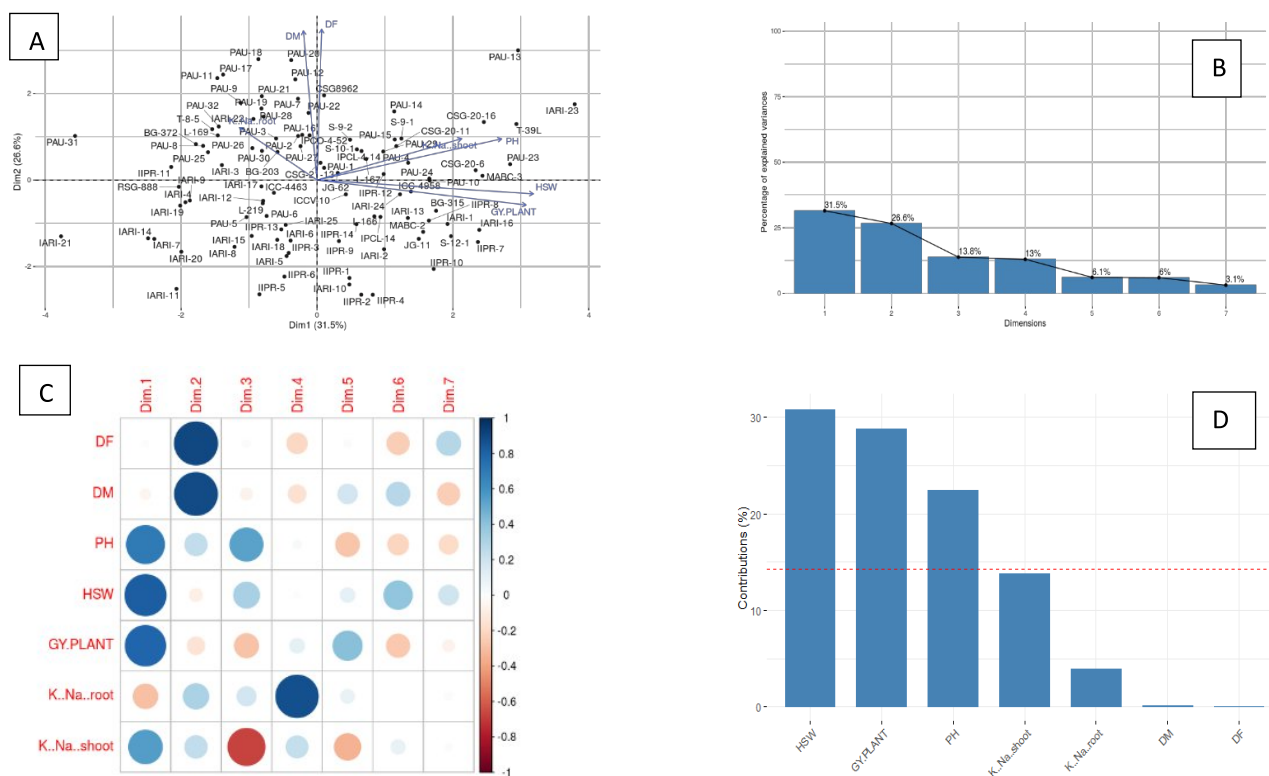


Fig 5.18 Principal component analysis (PCA) plot of agronomic and ionic traits in the 100 investigated chickpea genotypes under salinity stress conditions (A) PCA Biplot (B) Scree plot showing contribution of each PC to variance (C) Correlation plot of PCs vs Variables (D) Contribution of variables to PC1. DF: Days to 50% flowering; DM: Days to 50% maturity; PH: Plant height (cm); HSW: Hundred seed weight (gm); GY/plant: Grain yield per plant (gm); K⁺/Na⁺ root: potassium by sodium ratio in root (mg/kg); K⁺/Na⁺ shoot: potassium by sodium ratio in shoot (mg/kg)

PC2 differentiates genotypes based on their phenological adaptation. Based on the PCA results, genotypes were classified into tolerant and susceptible groups. Genotype ranking were provided using PC1 score as we wanted to select the best performing genotypes under salinity stress. Genotypes IARI-23, PAU-13, T-39L, PAU-23, and CSG-20-16 exhibited the highest PC1 scores, indicating superior performance for yield-related

Table 5.20 Rank of genotypes based on their multivariate performance under salinity

Genotype	PC1 score	Rank	DF	DM	PH (cm)	HSW (g)	GY/plant (g)	K ⁺ /Na ⁺ root	K ⁺ /Na ⁺ shoot	Group
IARI-23	3.77	1	91	128	56.33	22.98	12.68	0.5	3.51	Tolerant
PAU-13	2.95	2	93	129	56.33	14.34	15.63	0.74	4.2	Tolerant
T-39L	2.92	3	91	126	64.33	14.05	13.21	0.31	3.31	Tolerant
PAU-23	2.83	4	88	125	56.00	18.33	13.51	0.61	3.13	Tolerant
CSG-20-16	2.44	5	90	126	58.00	16.33	13.83	0.79	3.07	Tolerant
MABC-3	2.42	6	89	123	48.33	16.70	12.08	0.52	3.8	Tolerant
IARI-16	2.38	7	86	121	49.00	13.51	15.65	0.55	3.66	Tolerant
IIPR-7	2.36	8	83	124	42.67	16.65	15.60	0.51	3.35	Tolerant
CSG-20-6	2.32	9	88	123	57.00	15.07	11.79	0.69	3.64	Tolerant
S-12-1	1.96	10	86	120	66.33	14.74	11.72	0.63	2.04	Tolerant
ICCV-10	0.42	41	89	123	42.10	9.72	11.72	0.39	2.73	Tolerant
CSG8962	0.10	45	94	126	41.50	7.75	11.85	0.59	3.14	Tolerant

DF: Days to 50% flowering; DM: Days to 50% maturity; PH: Plant height (cm); HSW: Hundred seed weight (gm); GY/plant: Grain yield per plant (gm); K⁺/Na⁺ root: potassium by sodium ratio in root (mg/kg); K⁺/Na⁺ shoot: potassium by sodium ratio in shoot (mg/kg)

traits in salinity stress. In contrast, genotypes like IARI-21, PAU-31, IARI-14 and IARI-7 showed strongly negative PC1 scores and were considered less suited for saline environments. Performance for other traits of ten most tolerant genotypes, along with the check varieties, are presented in Table 5.20.

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

One of the objectives of this project was development of the mapping population for key physiological traits underlying salt stress response using accessions from the reference set. So after two year screening, a total 12 mapping population were developed by using contrast parents for different physiological and yield parameters. Out of 12 populations, 4 mapping population are F3 stage and eight are F2 stage. In due course of time these lines will be stabilized.

F3	F2	F2
T397 x Shubhra	EC0041478-B x IC0499060	EC041467 x IC0498672
IC0384566 x Mukta	EC0041478-B x IC0498452	EC041467 x IC620559
IC0499182 x Shubhra	IC0427794 x IC0498672	IC0520865 x IC620559
T397 x Heera	IC0427794 x IC0498935	IC0520865 x IC0498561

Developing strategies for sustainable integration of nano N and P for enhancing nutrient use efficiency under salt stress (Ashwani Kumar, Anita Mann, A.K. Bhardwaj and R.K. Yadav)

Field Experiment - Wheat

Morpho-Physiological parameters: Significant differences were observed among treatments for various morpho-physiological traits in wheat under integrated nutrient management (Table 5.21). Plant height was significantly highest under T3 (100.0 cm), which included DAP with split urea application, and was statistically at par with T4 (99.1 cm) and T5 (97.6 cm) involving nano-N applications. The lowest plant height was recorded under the control T1 (65.7 cm). SPAD values followed a similar trend, with maximum chlorophyll content in T3 (40.0), statistically at par with T4 (39.8) and slightly reduced in nano-based treatments T5–T8 (38.5–38.2). The control recorded the minimum SPAD (27.9). Leaf area was significantly influenced by the treatments, with the highest value in T3 (562.7 cm²/plant), followed by T4 (535.2 cm²/plant), while T1 (167.8 cm²/plant) had the lowest.

Significant differences were observed in leaf relative water content (RWC), chlorophyll content, and photosynthetic parameters among different N treatments. The highest RWC was recorded in T3 (86.94%), which received DAP along with three equal urea splits, followed by T2 (83.65%). Replacement of the third split of urea with nano-N (T4 and T5) showed a slight reduction in RWC (80.76% and 79.92%, respectively), while extensive nano-formulation use in T11 reduced RWC by 18.52% in comparison to T3. The control (T1) recorded the lowest RWC (67.59%). Total chlorophyll content was highest in T3 (3.04 mg/g FW) followed by T4 (2.89 mg/g FW) and T2 (2.82 mg/g FW), indicating the positive effect of N and P on pigment synthesis. Conventional urea-based treatments (T11 and T9) showed moderate chlorophyll values (2.32–2.46 mg/g), while T1 recorded the lowest (1.58 mg/g FW). Photosynthetic rate (Pn) showed maximum value in T3 (22.42 µmol

Figure 5.19 Effect of integrated conventional and nano-fertilizer application on grain and straw yield of wheat

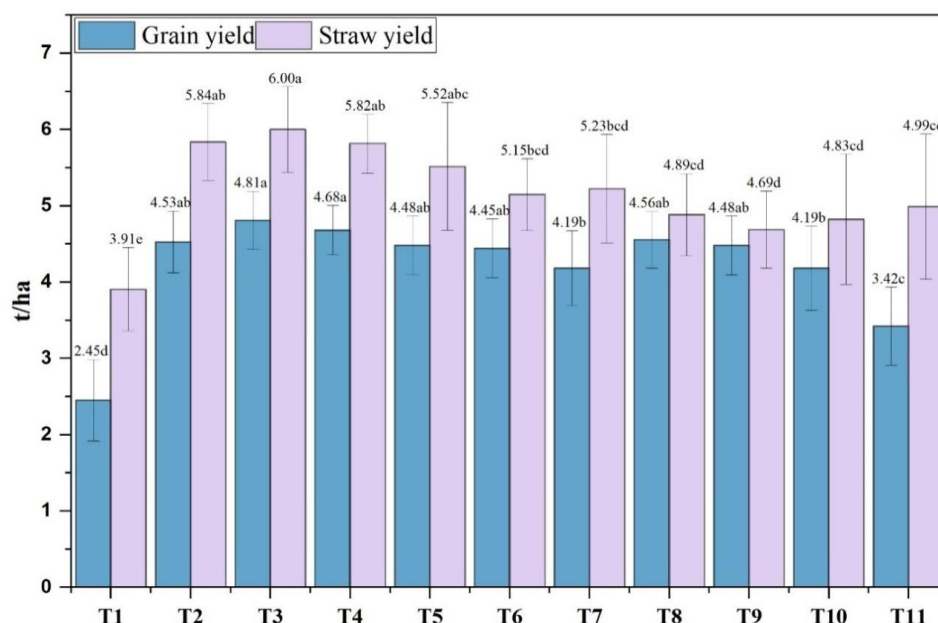


Table 5.21 Effect of integrated conventional and nano-fertilizer on Yield and yield attributes of wheat

	Treatments/Traits	Number of tillers	Spike length (cm)	Spike weight (g)	Spikelet's /Spike	Number of grains/spike	Weight of grains/Spike (g)	100 seed weight (g)
Nitrogen treatments	Control (No N & P) (T1)	165.67g	7.98d	1.76d	26.17g	32.17e	1.16d	3.90e
	½ Urea + ½ Urea + ½ Urea (T2)	258.50cd	9.82ab	2.50ab	46.83ab	47.33ab	2.15ab	4.62ab
	DAP + ½ Urea + ½ Urea + ½ Urea (T3)	289.17a	10.07a	2.66a	49.50a	48.50a	2.21a	4.73a
	DAP + ½ Urea + ½ Urea + ½ Nano-N (Spray) (T4)	277.17ab	9.45bc	2.53ab	43.50bc	42.00bc	1.96abc	4.49abc
	Nano DAP (Seed priming) + ½ Urea + ½ Urea + ½ Nano-N (Spray) (T5)	257.50cd	9.40bc	2.49ab	41.67bcd	41.17bc	1.93abc	4.40bcd
	Nano DAP (Seed priming) & 50% DAP (Broadcast) + ½ Urea + ½ Urea + ½ Nano-N (Spray) (T6)	261.33cd	9.32bc	2.48ab	39.67cde	40.83cd	1.92abc	4.34bcd
	Nano DAP (Seed priming) + ½ Urea + ½ Urea & Nano-DAP (Spray) + ½ Nano-N (T7)	251.50d	9.25c	2.42ab	36.67def	39.00cd	1.84abc	4.44bc
	Nano DAP (Seed priming) + ½ Urea + ½ Urea + ½ Nano-N & Nano-DAP (Spray) (T8)	267.50bc	9.23c	2.56ab	39.50cde	39.33cd	1.80abc	4.41bcd
	Nano DAP (Seed priming) + ½ Urea + ½ Urea & Nano-DAP (Spray) + ½ Nano-N & Nano DAP (Spray) (T9)	230.67e	9.07c	2.44ab	36.67def	38.17cde	1.75bc	4.29cd
	Nano DAP (Seed priming) & 50% DAP (Broadcast) + ½ Urea + ½ Urea & Nano-DAP (Spray) + ½ Nano-N (Spray) (T10)	226.17e	8.92c	2.30bc	35.50ef	37.00cde	1.69c	4.23cd
	Nano DAP (Seed priming) + ½ Nano-N & DAP (Spray) + ½ Nano-N & DAP (Spray) + ½ Nano-N (Spray) (T11)	208.17f	8.23d	2.09cd	33.17f	34.50de	1.57cd	4.16de
	CD @ 5%	12.981	0.559	0.337	5.431	6.363	0.415	0.279

Means with at least one letter common are not statistically significant ($p < 0.05$) using Tukey's Test. **Represent significant at $p < 0.01$.

$\text{CO}_2/\text{m}^2/\text{s}$), statistically higher than T2 ($20.31 \mu\text{mol CO}_2/\text{m}^2/\text{s}$) and T4 ($21.01 \mu\text{mol CO}_2/\text{m}^2/\text{s}$). Nano-N addition maintained photosynthetic efficiency similar to conventional treatments, while excessive nano formulations reduced Pn, particularly in T10 ($17.19 \mu\text{mol CO}_2/\text{m}^2/\text{s}$) and T11 ($16.24 \mu\text{mol CO}_2/\text{m}^2/\text{s}$), with the lowest in T1 ($10.71 \mu\text{mol CO}_2/\text{m}^2/\text{s}$).

Yield attributes: The data presented in table 5.21 show significant differences in yield and yield-attributing traits of wheat with varied nitrogen treatments. The total number of tillers was highest in T3 (289.17), followed by T4 (277.17), with a comparable performance under T2 (258.50). Treatments involving nano-DAP and nano-N, such as T5 to T8,

maintained moderate tiller numbers (257.50–267.50), while T11 (208.17) and control (T1–165.67) showed the lowest tiller count. Spike length varied significantly among treatments, with maximum spike length in T3 (10.07 cm), followed closely by T2 (9.82 cm). Replacement of urea with nano-N reduced spike length slightly in T4 (9.45 cm), and further integration with nano-DAP led to reduced values in T5–T10 (9.40 cm–8.92 cm). The minimum spike length was observed in T1 (7.98 cm) and T11 (8.23 cm). Spike weight was also significantly affected, with the highest recorded in T3 (2.66 g) followed by T4 (2.53 g) and T8 (2.56 g). Treatments T9 to T11 showed a gradual decline in spike weight (2.44–2.09 g), with the control (1.76 g) being the lowest. The number of spikelet's per spike showed maximum value in T3 (49.50), statistically at par with T2 (46.83). Treatments with partial nano-replacement showed reduced spikelet numbers, particularly in T9–T11 (36.67–33.17), with T1 recording the lowest (26.17). Number of grains per spike followed a similar pattern, with the highest in T3 (48.50), T2 (47.33), and moderate values in T4–T6 (42.00–40.83). Nano-based treatments (T7–T11) exhibited a reduction in grain number, especially in T11 (34.50), while T1 recorded the minimum (32.17).

Grain weight per spike was significantly higher in T3 (2.21 g) and T2 (2.15 g), followed by T4 (1.96 g). Treatments involving extensive nano formulations resulted in lower grain weight (T8–T11; 1.57–1.80 g), and the lowest value was observed in T1 (1.16 g). The 100-seed weight was found to be highest in T3 (4.73 g) and T2 (4.62 g), indicating the positive impact of balanced DAP and urea application. Treatments T4–T8 maintained moderately high seed weights (4.49–4.41 g), while T11 and T1 recorded the lowest values (4.16 g and 3.90 g, respectively).

Data presented in Figure 5.19 shows the effect of integrated conventional and nano-fertilizer application on wheat grain and straw yield. Maximum grain yield was recorded in T3 (4.81 t/ha) followed by T4 (4.68 t/ha) and T2 (4.53 t/ha), indicating the positive impact of combining DAP and urea. Maximum straw yield (6.00 t/ha) was also observed in T3, followed closely by T4 (5.82 t/ha) and T2 (5.84 t/ha), highlighting the superior performance of T3 (DAP + urea application in three splits). Treatments T5 and T8, which included nano-DAP seed priming along with partial replacement of nitrogen through nano-N spray, also showed statistically comparable grain yields (4.48 t/ha and 4.56 t/ha, respectively) but lower than T3. The lowest grain (2.45 t/ha) and straw yield (3.91 t/ha) were recorded under control (T1), Notably, T11, with complete replacement of urea and DAP through nano-forms, showed reduced grain yield (3.42 t/ha), reflecting the limitations of exclusive nano-fertilizer use under field conditions.

Soil data

Among the various Nano-NP management scenarios (figure 5.20), the highest available soil nitrogen N was noted in T3 (167.87 kg ha⁻¹) treatment which was statistically at par with T4 (152.88 kg ha⁻¹), T6 (150.27 kg ha⁻¹), T8 (152 kg ha⁻¹), T10 (160.72 kg ha⁻¹), and T11 (152.88 kg ha⁻¹). The lowest available soil N was recorded in T1 (130.67 kg ha⁻¹) treatment. The highest available soil phosphorus (P) was noted in T3 (51.30 kg ha⁻¹) treatment which was statistically at par with T4 (43.61 kg ha⁻¹), and T10 (46.22 kg ha⁻¹) treatment. The lowest available P was achieved in T5 (32.55 kg ha⁻¹) treatment. The maximum grain N uptake was observed in T3 (86.93 kg ha⁻¹) treatment which was statistically at par with T2 (30.6 kg ha⁻¹), T4 (82.90 kg ha⁻¹), T5 (74.55 kg ha⁻¹), T8 (77.31 kg ha⁻¹), and T9 (78.64 kg ha⁻¹) treatment. The lowest grain nitrogen uptake was observed in T1 (41.93 kg ha⁻¹) treatment which was statistical at par with T11 (53.88 kg ha⁻¹). In case N uptake in straw (figure 5.21), the highest

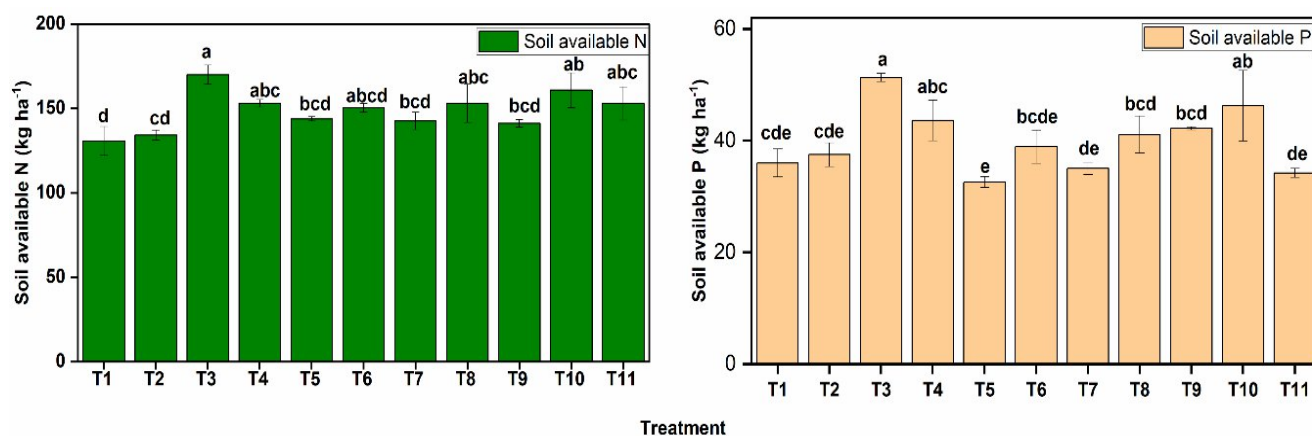


Fig 5.20 Effect of different Nano NP management treatment on soil available nitrogen and phosphorus.

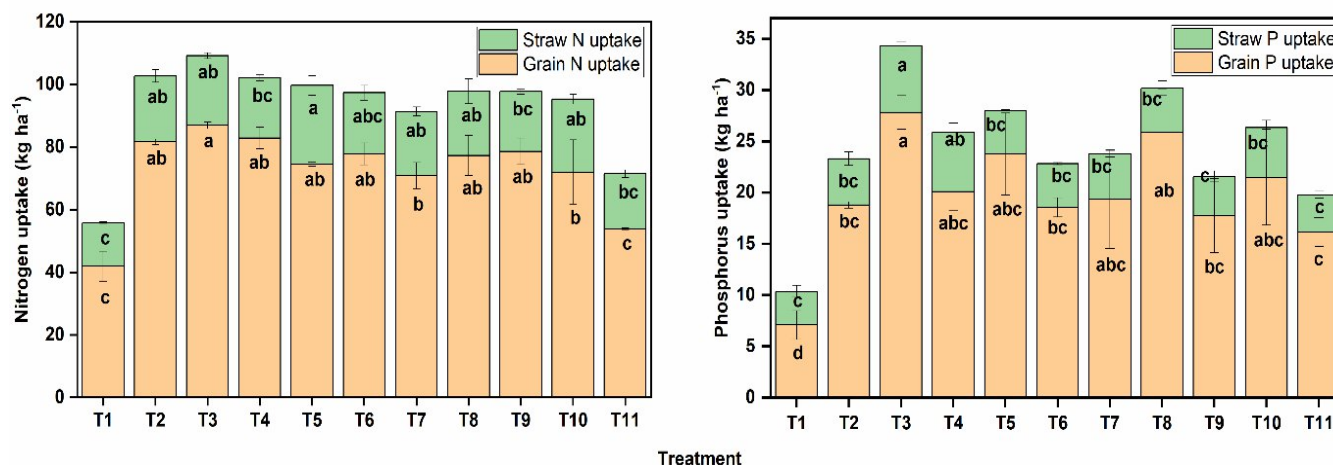


Fig 5.21 Effect of various Nano-NP management scenarios on uptake of nitrogen and phosphorus.

value was recorded in T5 (25.11 kg ha⁻¹) treatment which was statistically at par with T2 (21.08 kg ha⁻¹), T3 (22.29 kg ha⁻¹), T6 (19.54 kg ha⁻¹), T7 (20.46 kg ha⁻¹), T8 (20.49 kg ha⁻¹), and T10 (23.30 kg ha⁻¹) treatment. The lowest straw N uptake was observed in T1 (13.81 kg ha⁻¹). The maximum grain P uptake was observed in T3 (27.81 kg ha⁻¹) treatment which was statistically at par with T4 (20.09 kg ha⁻¹), T5 (23.75 kg ha⁻¹), T7 (19.35 kg ha⁻¹), T8 (25.88 kg ha⁻¹), and T10 (21.49 kg ha⁻¹) treatments, while lowest grain P uptake was recorded in T1 treatment (7.07 kg ha⁻¹). The highest straw P uptake was recorded in T3 (6.48 kg ha⁻¹) treatment which was statistically at par with T4 (5.78 kg ha⁻¹) treatments. The lowest straw P uptake was achieved in T1 (3.28 kg ha⁻¹) followed by T11 (3.63 kg ha⁻¹) treatment.

Enhancing climate resilience and ensuring food security with genome editing Tools

Wheat Component (Anita Mann, Arvind Kumar, Ashwani Kumar, Avni Dahiya, S.K. Sanwal, R. K. Yadav)

Two wheat varieties, HD 3406 & HD 3226 have been taken for improvement of salt tolerance using CRISPR-Cas9 system through genome editing targeting two genes *TaTre1* and *TaSal1*. Short and long amplicon primers were designed and synthesized for identification of conserved domain through the accurate amplification of three copies of *Tre1* gene on 1A, 1B, 1D each and multiple copies of *Sal1* on 4A, 5A, 5B, 5D, 7A & 7D (Table 5.22). The targeted genes were aligned at NCBI Databases including all exons of all the homologs. Primer3 was used for designing primers targeting the divergent exonic region

Table 5.22 Identification of full gene sequence along with functional domain of Trehalase and Sal1 gene details in wheat genome through amplicons sequencing

1A	Gene <i>TaTre1</i> Sequence	Gene Position		Hit	Complete Hit
		Start from	Product size		
Region1F	ACCACTGACCAGCGTATGATAT	223	2949	2	1A: 331,323,548-331,323,572 1B: 355,678,973-355,678,997
Region1R	TCTGGTCTAGGTTTGTCCACA	3172		8	1A: 331,320,620-331,320,644 1D: 257,412,193-257,412,217
Region2F	GACAGTCTACCCGGTCCAAA	2615	3351	2	1A: 331,321,159-331,321,179 1B: 355,676,564-355,676,584
Region2R	TAGTGTGGCTGTAGGTCGG	5966		4	1A: 331,317,827-331,317,847
Region3F	TGGGATTTAGCTCTCGATGGA	3377	2794	3	1A: 331,320,394-331,320,418 1B: 355,675,800-355,675,824
Region3R	ATCAAGAGGGTTGGTGTTTTGG	6171		2	1D: 257,411,966-257,411,990 1A: 331,317,621-331,317,645
5A					
Gene <i>TaSal1</i>					
Region 1F	CGTATCTCACATCCGCTCCT	314	3739	10	5A: 253,597,011-253,597,031
Region 1R	AGGCCAGCTACTCACAAT	4053		3	5A: 253,597,212-253,597,232
Region 2F	GTACGTCGTAGTCTCCAG	1138	3214	40	5A: 253,593,816-253,593,836 4A: 243,906,125-243,906,145 1B: 162,192,025-162,192,045
Region 2R	TGTTGATGTTGGACTCCGGA	4352		6	5A: 253,593,292-253,593,312 5D: 193,637,290-193,637,310
Region 3F	TGGTCTTGCGCAAATGAACA	3196	2588	15	5A: 253,595,874-253,595,894
Region 3R	ACGAATCCTCTTGGCCTTGA	5784		17	5A: 253,598,443-253,598,463 7D: 139,194,977-139,194,997 1A: 462,130,215-462,130,235 6A: 33,309,278-33,309,298 3D: 93,450,455-93,450,475
Region 4F	TCAATGTGGTCTTGCGCAAA	3190	3947	6	5A: 253,595,868-253,595,888 7B: 111,950,330-111,950,350
Region 4R	GGACCTCCTTCAGACTTCCC	7137		5	5A: 253,599,796-253,599,816 5B: 216,656,272-216,656,292 5D: 193,636,125-193,636,145
Region 5F	AATTGTGAGTAGCTGGGCCT	4534	3590	3	5A: 253,597,212-253,597,232
Region5R	GGTTTACCACTTCTGCAGC	8124		6	5A: 253,600,783-253,600,803 5B: 216,655,290-216,655,310

of gene copies for full gene sequence. Primer sequences were aligned against the complete wheat genome in Ensemble Plants to confirm binding at the intended locus for precise amplification and sequencing of multiple gene copies present in the wheat A, B, and D sub-genomes. High-fidelity PCR and optimized annealing conditions were employed to ensure specific amplification. Subsequent sequencing and bioinformatics analysis confirmed the successful discrimination of homeologous and paralogous gene sequences in our wheat varieties and Single-nucleotide differences (SNPs) were identified using Chinese Spring genome as a reference. Each small amplified fragment size ranged between 400-600bp and long amplicons between 2000-4100 bp (Figure 5.21) with overlapping regions to ensure complete gene assembly. Competent cells of *E.Coli* and *Agrobacterium* were prepared for gene cloning and transformation. A total of

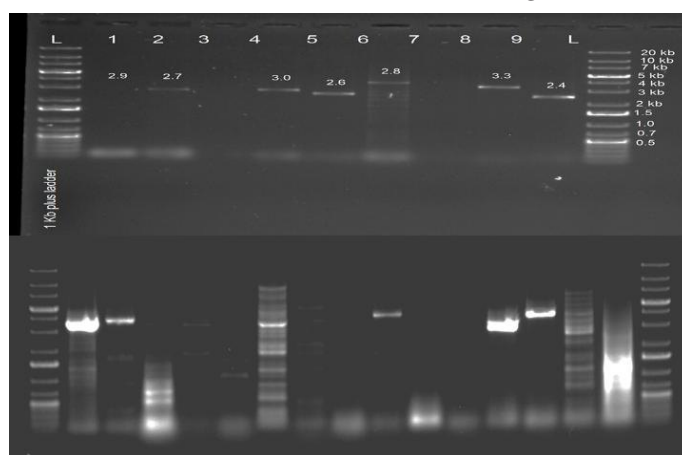


Fig 5.21 Resolution of long amplicons (2-4 Kb) in wheat varieties

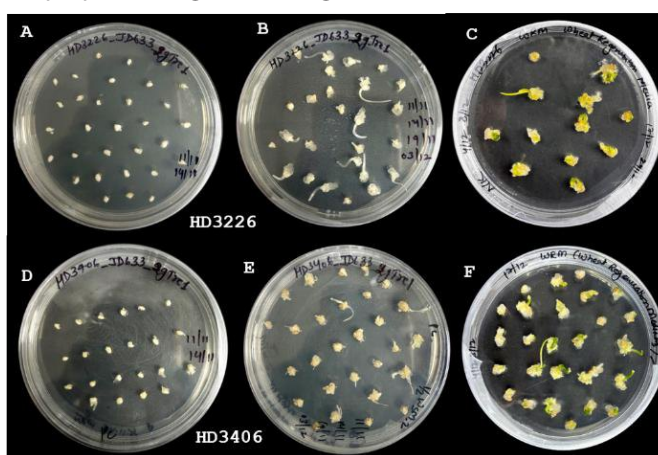
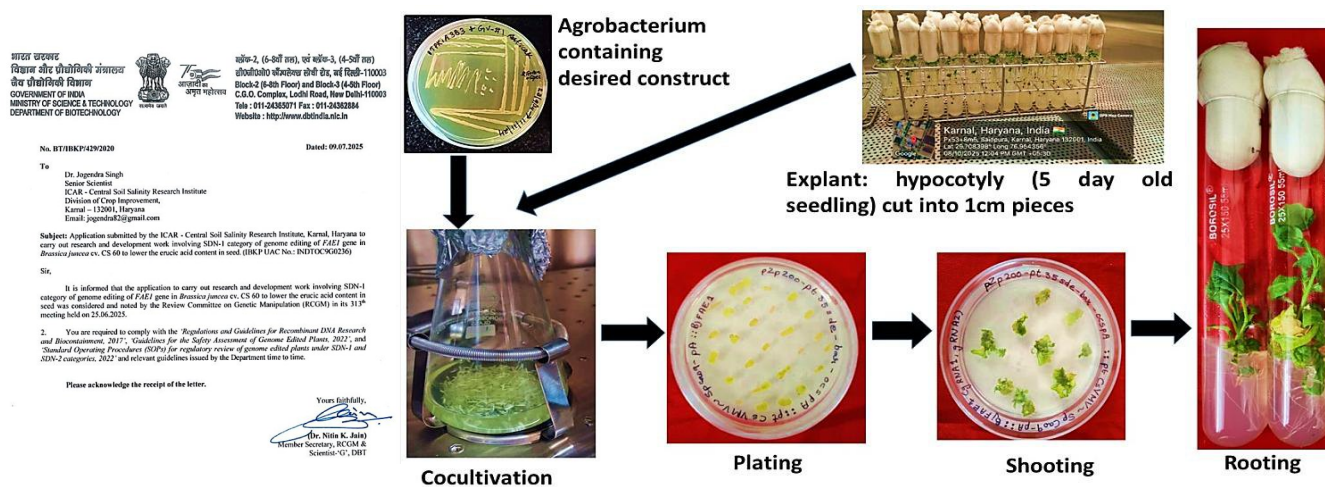


Fig 5.22 Co-cultivation (A,D), Selection (B,E) and Regeneration (C,F) in variety HD3226 and HD3406 with gene construct JD633_g2Tre1.

1946 wheat embryos (both mature and Immature embryos) of both the wheat varieties have been rescued for gene transformation. Two guide RNAs for *Tre1* gene for both the varieties have been transferred in *Agrobacterium* (Figure 5.22) and plants are in shooting stage. Regeneration protocol for rooting and shoot emergence for the both the varieties is being standardized.

Rice Component (N.R. Prakash and Lokeshkumar B.M.)

In this activity the *OsARF18* gene region (chr06:28586493–28590206), spanning approximately 3714 bp, was targeted in the rice variety BPT5204 (Samba Mahsuri). Amplification of the gene was carried out using 14 overlapping PCR primers, followed by paired-end Sanger sequencing to ensure sequence accuracy and coverage. For functional validation, three guide RNAs (sgRNAs) were designed from different exons of the gene to generate knockout mutants through CRISPR/Cas9-mediated genome editing. A binary vector construct (*HPTII::P35S-POsU3::sgRNA-PUBI::SpCas9*) based on pRGE32 was developed incorporating all three sgRNAs. Cloning of the construct was initially performed in *Escherichia coli* strain DH5a using the BsaI Golden Gate cloning strategy. The confirmed plasmid was subsequently mobilized into *Agrobacterium tumefaciens* strain EHA105 following a standardized laboratory protocol for plant transformation. All necessary regulatory approvals were obtained prior to experimentation, including clearance from the Institute Biosafety Committee (IBSC) and approval of the D1 form by the Review Committee on Genetic Manipulation (RCGM). Callus induction protocols for the target variety BPT5204 were optimized using a Murashige and Skoog (MS) medium background. Additionally, whole-genome resequencing data (SRA: SRR14553101) for BPT5204 was retrieved from NCBI and assembled using IR64 as a reference genome. This assembly will facilitate downstream functional analysis and molecular characterization.



Mustard Component (Jogendra Singh, Vijayata Singh and N. Kulshreshtha)

The main aim of this activity is the establishment of genome editing methods and tools, and deciphering the function of *FAE 1* genes and it's knocking down by CRISPR-Cas9-based Site-Directed Nuclease 1 (SDN1) approach for improving nutritional quality (Zero Erucic Acid) in the Mustard variety CS 60. The *FAE1* (Fatty Acid Elongase 1) gene is a critical component in the biosynthesis of very-long-chain fatty acids (VLCFAs) in plants. It

encodes an enzyme known as β -ketoacyl-CoA synthase (KCS), which catalyzes the initial and rate-limiting step in the elongation of long-chain fatty acids. These VLCFAs play vital roles in seed oil biosynthesis, influencing the oil composition in plants like *Brassica juncea*. In *Brassica* species, the *FAE1* gene is responsible for converting C18 fatty acids (oleic acid) into C20 and C22 fatty acids, primarily erucic acid. Erucic acid is a major component in *Brassica* oil and has industrial applications, though it is undesirable for human consumption. Reducing or knocking out the *FAE1* gene is a common breeding objective to produce low-erucic acid (canola-quality) oils.

Output/outcome during the reporting period-2024-25

RCGM considered and noted Form D1 with IBKP UAC No. INDTOC9G0236 to carry out R&D - using the CRISPR-Cas9 SDN1 approach to edit the *FAE1* gene in *Brassica juncea* cv CS 60 to lower the erucic acid content in seed.

Standardization of protocol for *Agrobacterium tumefaciens* mediated transformation in CS 60 is completed and transformation was done using gene construct pZP200-pt35Sdebar-ocspA::ptCsVMV-SpCas9-pA::BjFAE1 (gRNA1,2). A total of 8 Transformant (with selection marker gene Basta resistant) were obtained for further development of root and shoot (Fig. 5.23).

Metatranscriptomics and Systems Biology Approach for Deciphering the Molecular Basis of Salt Stress Response in Crop Plants (Avni Dahiya, Anita Mann, Nitish Ranjan Prakash)

Building upon the foundational work completed during previous year, which involved extensive dataset curation, methodological standardization, and initiation of meta-transcriptomic analysis in rice, the current reporting year focused on comprehensive differential expression analysis, identification of core salt-responsive genes, and functional characterization in rice and wheat, along with initiation of similar analyses in chickpea. Publicly available RNA-seq datasets representing salt-tolerant and salt-sensitive cultivars across diverse tissues, developmental stages, and experimental conditions were rigorously curated and processed through a standardized analytical workflow to ensure cross-study comparability, reproducibility, and statistical robustness. In rice, differential expression analyses conducted independently across datasets under uniform thresholds identified 14,326 unique differentially expressed genes (DEGs). Comparative intersection analysis revealed a consensus set of 420 core salt-responsive DEGs consistently regulated across independent studies, representing a robust gene set associated with salinity adaptation (Fig. 5.24A). Functional enrichment analysis demonstrated significant overrepresentation of biological processes related to stress response, ion transport and homeostasis, oxidative stress mitigation, and transcriptional regulation (Fig. 5.25A). Pathway enrichment further highlighted key metabolic pathways, including carbon metabolism, photosynthesis, amino acid metabolism, and secondary metabolite biosynthesis, reflecting coordinated metabolic reprogramming under salt stress conditions.

Parallel meta-analysis in wheat, based on three independently curated RNA-seq studies, led to the identification of 1,659 core salt-responsive DEGs conserved across datasets (Fig. 5.24 B). Functional annotation and pathway enrichment analyses revealed significant enrichment of stress signalling, cellular homeostasis, and metabolic adjustment pathways, including carbon and carbohydrate metabolism and amino acid

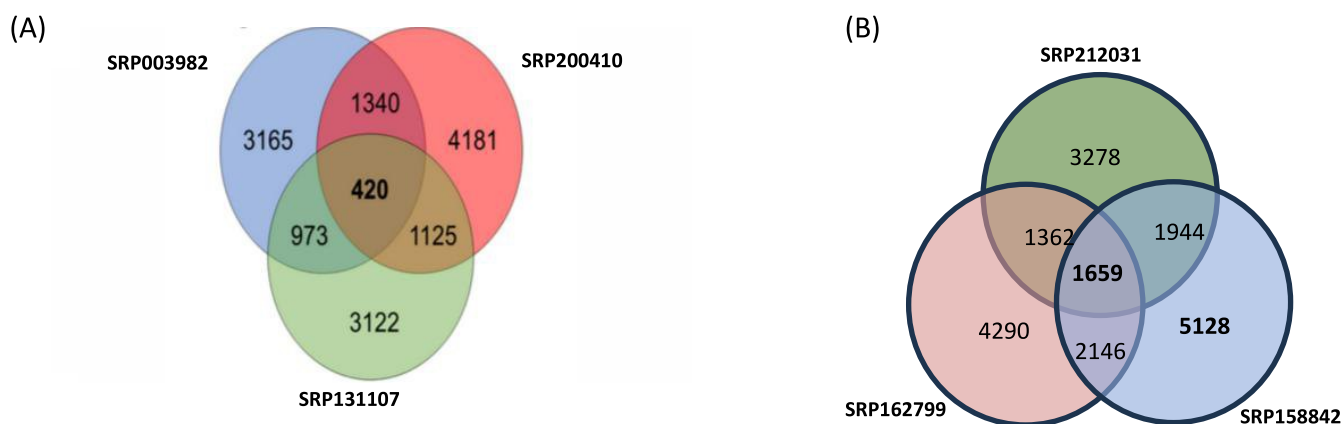


Figure 5.24 Identification of consensus salt-responsive genes through meta-analysis

Venn diagrams illustrating dataset-specific and shared DEGs across independent RNA-seq studies in (A) rice and (B) wheat. Intersection analysis identified 420 and 1,659 core salt-responsive genes in rice and wheat, respectively.

biosynthesis, suggesting conserved molecular mechanisms underlying salinity tolerance in cereal crops (Fig. 5.25 B).

To advance beyond differential expression analysis and prioritize key regulatory determinants, systems biology-based network modelling has been initiated. Weighted gene co-expression network analysis (WGCNA) is currently underway in rice and wheat to identify stress-responsive co-expression modules and highly connected hub genes. Concurrently, RNA-seq datasets for chickpea are being systematically curated to extend the meta-transcriptomic framework to a legume crop, enabling cross-species comparative analyses to distinguish conserved and crop-specific regulatory mechanisms governing salinity tolerance.

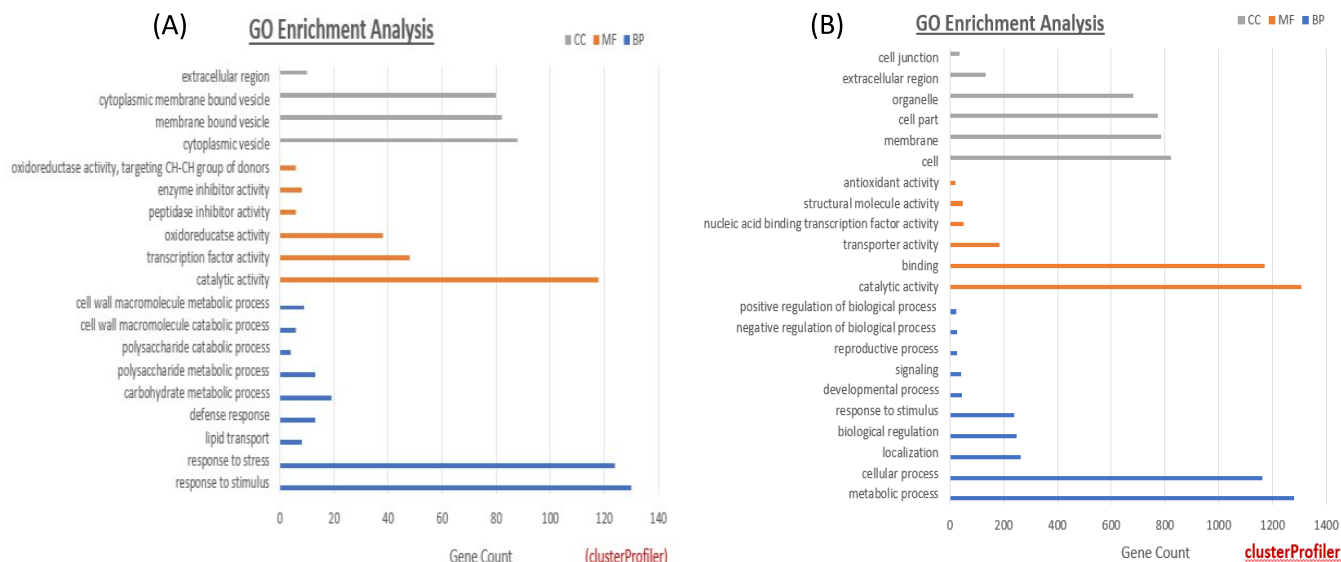


Figure 5.25 Gene Ontology enrichment analysis of core salt-responsive genes in rice and wheat

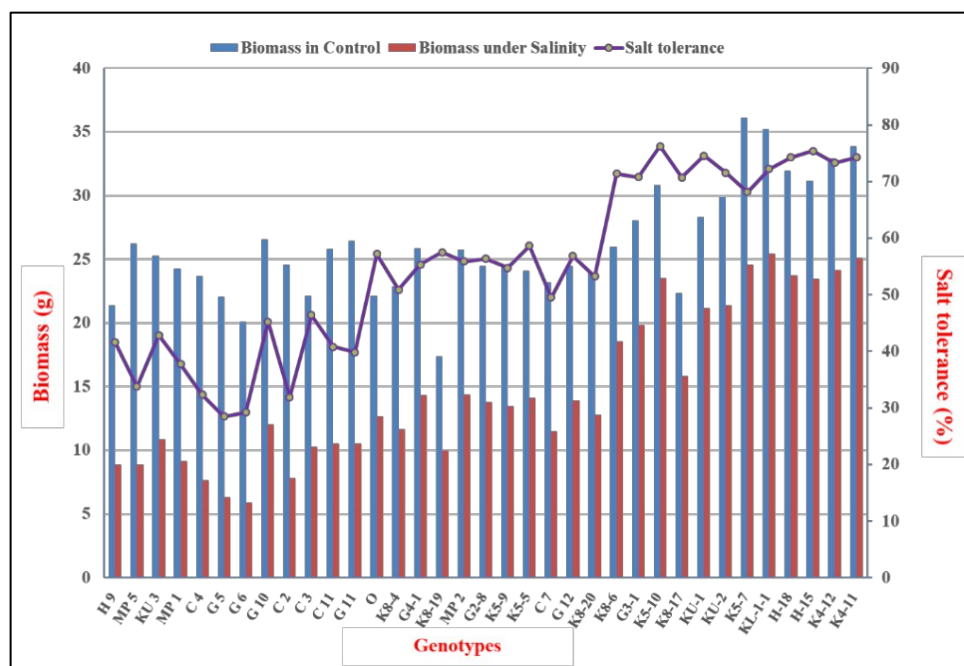
Bar plots showing significantly enriched GO terms among the 420 core DEGs in rice (A) and 1,659 core DEGs in wheat (B). Enriched categories are grouped into Biological Process (BP), Cellular Component (CC), and Molecular Function (MF), highlighting conserved stress response, metabolic regulation, and cellular homeostasis under salinity stress.

Alternate Land Use

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

Assessment of genetic diversity: This project was initiated during October 2021 with the aim to assess genetic diversity and identify germplasm for salinity tolerance in the sandalwood (*Santalum album* L.). A total of 122 sandalwood genotypes collected from across the country were examined at $\text{EC}_{\text{iw}} 8 \text{ dS m}^{-1}$ to determine mechanisms of salinity tolerance and identify superior genotypes (Fig. 6.1). Experimental data demonstrated significant genetic diversity and relationships in genotypes for salinity-induced morphological and physiological traits. The findings revealed that the salinity stress caused an average reduction of 27% in plant height, 22% in collar diameter, and 38% in biomass. However, significant variability was observed among genotypes as some genotypes (H-18, H-15, K4-12, and K4-11) maintained more than 90% of plant height and collar diameter, indicating strong tolerance potential. Salt tolerance varied widely among genotypes, ranging from approximately 30% in sensitive to nearly 75–80% in highly tolerant genotypes (Fig. 6.1). Genotypes such as H-15, H-18, K4-12, and K4-11 maintained over 70% tolerance by sustaining higher biomass under salinity stress. In contrast, several genotypes exhibited lower tolerance (<40%), reflecting greater biomass reduction and higher sensitivity to saline conditions. These genotypes were subsequently validated under field conditions, where 100 genotypes were planted in August 2024 and recorded an overall survival rate of 80%. Tolerance was closely associated with improved ionic regulation, particularly reduced sodium accumulation, higher potassium retention, and a favorable K^+/Na^+ ratio. Physiologically, tolerant genotypes maintained comparatively higher photosynthetic efficiency and chlorophyll content. Molecular analysis revealed activation of antioxidant and nitrogen metabolism pathways under salinity stress.

Fig 6.1 Biomass of sandalwood genotypes under control and salinity ($\text{EC}_{\text{iw}} 8 \text{ dS m}^{-1}$) with corresponding salt tolerance (%), showing genotypic variation in stress response.



Plantation of sandalwood with different host species



Notably, the APX (ascorbate peroxidase) gene showed enhanced expression, especially when sandalwood was associated with compatible host species.

Development of cultivation and management practices

Given the semi-root parasitic nature of sandalwood, host association played a decisive role in growth and stress response. Nine host species were evaluated for their effect on growth performance of sandalwood (Photo). Results showed that the growth performance varied markedly depending on host compatibility. Maximum plant height and DBH were recorded with *Dalbergia sissoo* and *Melia Dubia*, while highest total biomass was observed with *Casuarina equisetifolia*. Plants grown without a host exhibited consistently inferior growth attributes. Nutrient uptake patterns were also host-dependent: nitrogen content was highest with *Dalbergia sissoo*, phosphorus with *Melia dubia*, potassium with *Swietenia macrophylla*, and calcium with *Casuarina equisetifolia*, while micronutrient accumulation varied across species. Physiological traits such as photosynthesis, transpiration, and stomatal conductance were highest when sandalwood was associated with *Dalbergia sissoo*. Principal Component analysis confirmed distinct host-driven growth patterns, with overlapping responses between *Melia dubia* and *Casuarina equisetifolia*. Root studies and haustorial observations further highlighted the structural and functional importance of host integration. Application of 300 ppm IBA improved root development and establishment in sandalwood seedlings.



Sandalwood plantation at farmers' field in Haryana state

Upscaling and adoption of sandalwood-based agroforestry systems

The cultivation of sandalwood (*Santalum album*) has gained notable momentum in recent years due to its high economic value and long-term benefits. Farmers across Haryana are increasingly adopting sandalwood-based agroforestry systems as a profitable and sustainable farming practice, with strong institutional support from ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal. Through on-farm trials, demonstration plots, and farmer-centric initiatives, ICAR-CSSRI has actively promoted sandalwood cultivation (Photo). This shift is particularly important as conventional agriculture in many areas has become less profitable and increasingly unsustainable. Between 2022 and 2024, the Institute facilitated the establishment of sandalwood-based agroforestry models by distributing over 7,000 high-quality seedlings to farmers. More

than 20 farmer-led trials have demonstrated the viability and profitability of sandalwood farming, generating wide interest in the community. To build capacity, nearly 50 farmers received hands-on training and demonstrations on host species selection, planting techniques, irrigation management, and intercropping models. As a result of these efforts, around 100 farmers across Haryana have already taken up sandalwood cultivation, generating employment in nursery management, field operations, and agroforestry enterprises. A notable achievement has been the development of an 8-acre model sandalwood farm in Village Sambli (District Karnal), which now serves as a learning hub for farmers from across the state. Farmers are additionally benefitting from intercropping with cereals, vegetables, and fruits, generating annual returns of 40,000–50,000 per acre during the initial years before sandalwood reaches maturity. Beyond its economic potential, sandalwood cultivation is also contributing to soil health improvement, biodiversity enhancement, and carbon sequestration, thus aligning with climate change mitigation goals. Importantly, this innovation is transforming unproductive and abandoned lands into valuable assets, creating a long-term, reliable source of income. The long lifecycle of sandalwood trees acts as a form of natural savings and security for farming families, enhancing their resilience against climate variability and market fluctuations.



Glimpses of plantation activities at Hisar Farm, Haryana (a) and Samni farm, Bharuch Gujarat (b)

Exploring the potential of salt tolerant genotypes of high value agroforestry tree species in diverse agro-ecological regions: A field evaluation (R. Banyal, Rajkumar, Manish Kumar, B.L. Meena, A.K. Dubey and David Camus D.)

A field out-planting evaluation study was conducted to identify salt-tolerant genotypes of *Salix* spp. (clones), *Santalum album*, *Melia dubia*, and *Moringa oleifera* suitable for salt-affected environments across agro-ecological regions ranging from AER-2 (Western Plains: hot arid region with saline soils) to AER-5 (Central Highlands and Gujarat Plains with deep black soils) (Photos). The study aimed to assess their adaptability and potential for soil improvement under salt-affected conditions.

In the first phase, 150 saplings comprising 90 willow clones, 30 *Melia dubia*, 12 sandalwood (*Santalum album*), and 12 *Moringa oleifera* were planted at the Seed Farm of ICAR-IIWBR, Hisar, Haryana. Plantation was carried out using the sub-surface furrow planting method in block-line geometry with spacings of 6×2 m, 6×3 m, and 6×5 m, covering about 1.5 acres. Baseline soil characterization indicated extremely adverse conditions, with electrical conductivity (ECe) ranging from 19.5–45.7 dS m⁻¹, soil pH 8.78–9.27, and soil organic carbon 0.21–0.32%. Available nitrogen ranged from 19.6–51.0 kg ha⁻¹, phosphorus 19.9–27.8 kg ha⁻¹, and potassium 261–405 kg ha⁻¹ across the 0–90 cm soil profile. Exchangeable sodium ranged from 24.8–86.0 me L⁻¹, calcium 11.5–47.5 me L⁻¹, and magnesium 8.0–16.5 me L⁻¹. Beating-up operations were undertaken twice during January–February and August–September 2025 to compensate for early mortality. However, saplings exhibited extremely poor establishment, with survival limited to 5.56% in willow clone J799, 13.3% in *Melia dubia*, and 6.25% in sandalwood, followed by complete mortality. The failure was mainly attributed to extremely high soil salinity and prolonged waterlogging. Site-specific salinity levels ranged from 20.9–95.6 dS m⁻¹ in willow plots, 22.4–90.3 dS m⁻¹ in *Melia dubia*, 21.7–95.4 dS m⁻¹ in sandalwood, and 27.0–97.5 dS m⁻¹ in *Moringa*. These extreme physico-chemical conditions exceeded the tolerance limits of the tested genotypes, indicating that these species are unsuitable for plantation in sites with severe salinity combined with waterlogging.

In the second phase, the same clones and genotypes were planted under identical spacing in deep black soils (Vertisols) at Samni Farm, RRS-CSSRI, Bharuch, Gujarat (AER-5). A total of 180 saplings were planted, including 75 willow (*Salix*) clones, 45 *Melia dubia*, and 60 sandalwood (*Santalum album*). Soil EC increased with depth from about 0.12–0.25 dS m⁻¹ in the surface layer (0–15 cm) to 0.40–1.00 dS m⁻¹ at 90–120 cm. The *Salix* clone SI-64-017 recorded the highest EC (~0.95–1.00 dS m⁻¹), followed by sandalwood (~0.75 dS m⁻¹) and *Melia dubia* (~0.65 dS m⁻¹). Soil pH_s also increased with depth, ranging from near-neutral (≈7.0–7.9) at the surface to moderately alkaline values (≈8.0–8.3) in deeper layers. Among the species, *Salix* clone 131/25 recorded the highest height (76.5 cm), while SI-64-017 showed the maximum collar diameter (16.0 mm), indicating better vigor. *Melia dubia* attained moderate height (62.9 cm) with slender stems (3.5 mm), whereas *Santalum album* recorded the lowest height (48.6 cm) but maintained a moderate collar diameter (6.5 mm).

Development of *Prosopis* germplasm bank (R Banyal)

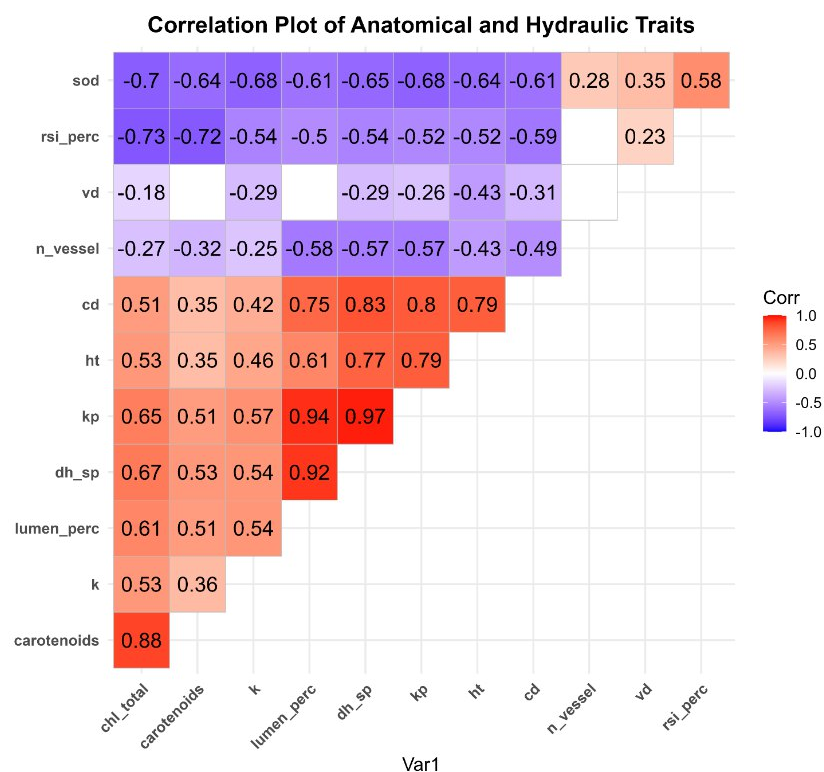
Eleven *Prosopis* genotypes maintained in the germplasm bank were evaluated during 2025–26 for survival and growth performance (Table 6.1). Survival ranged from 75.0–91.7%, with the highest survival observed in PG6, PG7, PG8, PG10 and PG11 (91.7%), while PG1–PG5 recorded relatively lower survival (75%). Among the genotypes, PG4 (*P. juliflora*) attained the maximum plant height (8.78 m), whereas PG5 (*P. juliflora*) recorded the highest stem diameter (18.3 cm) and crown spread (45.1 m²), indicating superior canopy development. PG9 (*P. laevigata*) and PG10 (*P. juliflora*) also exhibited relatively larger crown spreads (33.8 and 31.1 m², respectively). In contrast, PG11 (*P. alba*) showed the poorest growth with the lowest height (3.98 m), stem diameter (3.10 cm), and crown spread (4.10 m²). Overall, PG5 and PG10 of *P. juliflora* demonstrated superior growth performance, while PG6, PG8 and PG10 combined high survival with moderate growth, indicating their suitability for plantation under the prevailing conditions. The overall performance ranking of genotypes based on survival and growth traits was: *P. juliflora* (PG5) > *P. juliflora* (PG10) > *P. pallida* (PG6) > *P. laevigata* (PG9) > *P. cineraria* (PG8) > *P. pallida* (PG7) > *P. juliflora* (PG4) > *P. cineraria* (PG2) > *P. cineraria* (PG3) > *P. cineraria* (PG1) > *P. alba* 0579 (PG11) in the eight-year-old germplasm bank.

Table 6.1 Survival and growth of *Prosopis* genotypes

Prosopis genotype(s)*	Survival (%)	Plant height (m)	Stem dia. (cm)	Crown spread (m ²)
PG1	75.0 (+0.77)	5.64 (+0.05)	11.9 (+0.31)	12.0 (+0.27)
PG2	75.0 (+0.79)	6.54 (+0.21)	11.5 (+0.26)	15.3 (+0.04)
PG3	75.0 (+0.69)	5.81 (+0.19)	12.4 (+0.37)	14.8 (+0.02)
PG4	75.0 (+0.77)	8.78 (+0.13)	15.9 (+0.51)	14.3 (+0.20)
PG5	75.0 (+0.45)	7.87 (+0.17)	18.3 (+0.51)	45.1 (+0.34)
PG6	91.7 (+0.94)	6.70 (+0.03)	11.9 (+0.39)	27.8 (+0.08)
PG7	91.7 (+0.05)	4.63 (+0.07)	6.40 (+0.00)	15.0 (+0.12)
PG8	91.7 (+0.34)	6.98 (+0.13)	13.0 (+0.23)	13.1 (+0.15)
PG9	83.3 (+0.48)	7.43 (+0.01)	13.2 (+0.20)	33.8 (+1.03)
PG10	91.7 (+0.39)	6.84 (+0.08)	11.6 (+0.16)	31.1 (+0.23)
PG11	91.7 (+0.46)	3.98 (+0.09)	3.10 (+0.10)	4.10 (+0.08)

(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. laevigata* and PG10: *P. juliflora*; PG11: *P. alba* 0579)

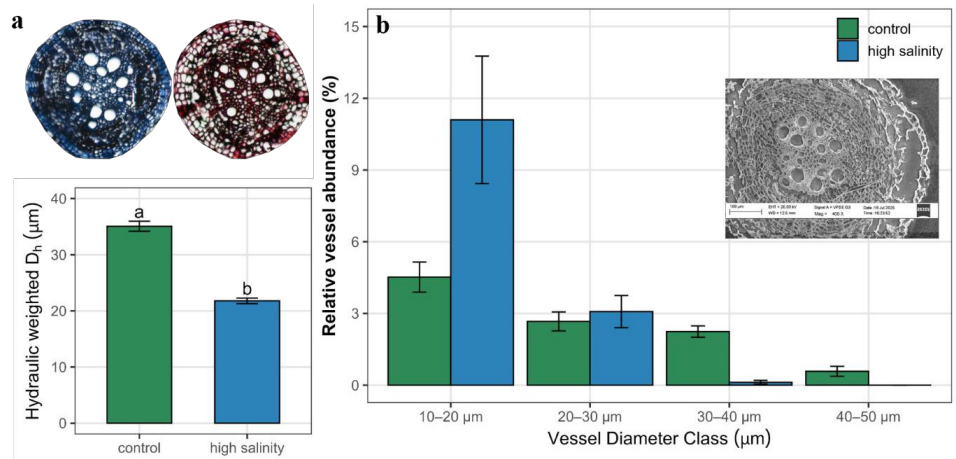
Fig 6.2 Correlation matrix illustrating relationships among growth attributes, xylem anatomical traits, biochemical parameters, and hydraulic conductivity in mahogany seedlings under varying saline irrigation treatments



Evaluation of Willow and Mahogany genotypes for salt tolerance (Manish Kumar, Raj Kumar, R. Banyal and A.K. Rai)

An experiment was conducted at the ICAR–Central Soil Salinity Research Institute, Karnal, to evaluate the effects of saline irrigation on growth, biochemical responses, and xylem anatomical and hydraulic traits of mahogany seedlings. Nine–ten-month-old seedlings were grown under sand culture and subjected to different levels of saline irrigation treatments ranging from 4 to 20 dS m⁻¹, along with a non-saline control. Salinity treatments were imposed for 110–120 days, and plants were harvested at 120 days after treatment (DAT) for detailed physiological, biochemical, and anatomical assessments. Salinity stress resulted in significant reductions across all measured growth parameters. Seedlings receiving non-saline irrigation exhibited superior growth performance, characterized by greater collar diameter, plant height, and leaf number. In contrast, progressive declines in these parameters were observed with increasing salinity levels. Relative to the control, collar diameter declined by 16–67%, plant height by 18–60%, and leaf number by 17–72%, indicating significant growth inhibition under saline conditions. Further, correlation analysis of anatomical and hydraulic traits under salinity revealed strong negative associations between tissue sodium (Na⁺) concentration and key functional traits (Fig 6.2). Increasing Na⁺ accumulation was associated with reductions in hydraulically weighted vessel diameter (Dh), potential specific hydraulic conductivity (Kp), plant height, and collar diameter. These results demonstrate that salinity-induced ionic stress constrains xylem development and hydraulic efficiency, ultimately limiting plant growth. A strong positive correlation between Dh and Kp was observed, confirming a close functional linkage between xylem anatomy and hydraulic performance. Larger vessel diameters contributed to enhanced hydraulic conductivity, whereas salinity-induced reductions in vessel size led to diminished water transport capacity.

Fig 6.3 Microscopic view of xylem vessels in mahogany (*Swietenia macrophylla*) seedlings. The illustration of saline irrigation impact on xylem vessel characteristics: (a) changes in hydraulically weighted vessel diameter (D_h) at salinity levels, and (b) distribution and relative abundance of xylem vessel diameter classes under control and salinity treatments



Growth–hydraulic coordination was further supported by a significant positive relationship between collar diameter and D_h ($R^2 = 0.66$), indicating that trees with greater radial growth develop larger xylem vessels. Similarly, root hydraulic conductivity (K_p) increased significantly with collar diameter ($R^2 = 0.61$), emphasizing coordinated adjustments between growth and water transport capacity. Control plants consistently exhibited higher hydraulic conductivity, reflecting superior water transport efficiency under non-saline conditions. Hydraulically weighted vessel diameter (D_h) decreased significantly with increasing salinity (Fig 6.3). At 16 dS m^{-1} , D_h was reduced by 37.8% relative to the control. Salinity also altered vessel size distribution patterns. Under high salinity, 62% of vessels were confined to the smaller 10–20 μm diameter class, and larger vessels ($>30 \mu\text{m}$) were nearly absent. In contrast, control plants exhibited a broader vessel size spectrum, with diameters extending up to 40–50 μm . The reduction in both the frequency and range of vessel sizes under saline conditions represents an adaptive anatomical adjustment aimed at minimizing cavitation risk in high osmotic environments. Furthermore, lumen area percentage varied markedly among treatments and was strongly influenced by salinity stress. The highest lumen area (approximately 22%) was recorded under control conditions, whereas it declined sharply to $\sim 11\%$ under high salinity (16 dS m^{-1}). The pronounced reduction in lumen area under saline irrigation exerted a strong inhibitory effect on hydraulic conductivity, further constraining water transport and growth. Overall, the results indicate a clear stress-response pathway: salinity leads to vessel narrowing, reduced hydraulic efficiency, and suppressed growth in mahogany seedlings. While reduced vessel diameter and lumen area limit hydraulic conductivity and growth, these structural adjustments likely represent adaptive strategies to enhance hydraulic safety and reduce cavitation risk under prolonged salt-induced water stress.

Salinity → Smaller vessels → Lower conductivity → Reduced growth

In another study, twenty specific *Salix* clones were selected for a study aimed at identifying salt-tolerant genotypes and advancing the understanding of underlying tolerance mechanisms. Acquired from UHF Nauni, the clones were propagated in a nursery for experimental use. A hydroponic system using saline water ($4\text{--}12 \text{ dS m}^{-1}$) was established to screen rootstocks with enhanced salinity tolerance. This approach is anticipated to yield valuable insights into the physiological responses of willow to salinity stress.

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

Sulphamic Acid Based Management of Sub-soil Sodicity in Partially Reclaimed Sodic Soil (S.K. Jha, Sanjay Arora and A.K. Dixit)

The experiment which was initiated in 2024 considering treatments : T1– Control; T2 – 50 GR gypsum (GYP) at surface (S); T3 – 50 GR marine gypsum (MG) at surface (S); T4 – 25 GR MG (S)+25 GR MG at sub-surface (SS); T5 – 12.5 GR sulphamic acid (SA) at surface (S)+25 GR SA (SS); T6 – 12.5 GR SA (S)+12.5 GR SA (SS); T7 – 12.5 GR MG (S)+25 GR SA (SS); T8 – 12.5 GR formulation (FSA) at surface (S)+25 GR FSA (SS) continued for the second year at Shivri research farm of ICAR-Central Soil Salinity Research Institute, Regional Research Station, Lucknow. After the rice harvest, wheat was sown in November, 2024 which was harvested in April, 2025. The performance of the crop is depicted in Fig. 7.1. Maximum wheat yield of 5.39 t ha⁻¹ was found in the treatment T5 as statistically similar to treatment T7 (Fig. 7.2). The soil samples (augur hole) were collected after wheat harvest from three depths viz 0-15 cm, 15-30 cm, and 30-45 cm and subjected to physico-chemical analysis. Among the treatments, the average pH₂ varied from 8.71 to 9.0 in 0-15 cm depth with maximum reduction in T₃ treatment (pH 8.71) statistically similar to each other treatments. In 15-30 cm soil depth maximum decrease was noticed in the treatment T5 where followed by T7, statistically similar to T3 and T8 (Table 7.1). In 30-45 cm depth, there was no significant



Fig. 7.1 Performance of wheat crop

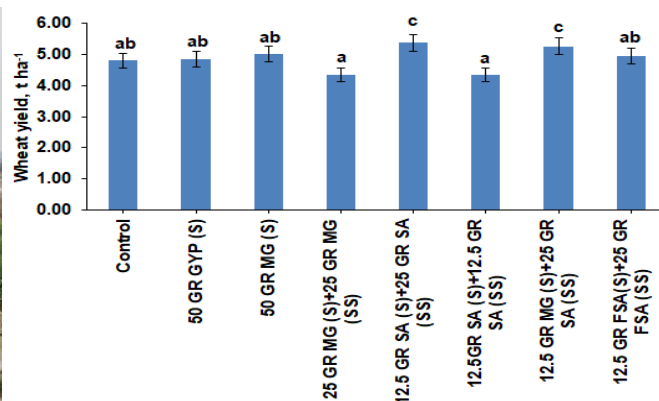


Fig. 7.2. Effect of amendment on wheat yield

Table 7.1 Changes in pH and Electrical conductivity under different treatments

TRT	Treatments	pH (1:2)			EC (1:2), dS m ⁻¹		
		0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
T1	Control	8.97	9.52	9.92	0.41	0.53	0.79
T2	50 GR GYP (S)	8.91	9.44	9.84	0.54	0.63	1.03
T3	50 GR MG (S)	8.71	9.23	9.75	0.38	0.60	0.77
T4	25 GR MG (S)+25 GR MG (SS)	8.73	9.31	9.69	0.41	0.77	0.74
T5	12.5 GR SA (S)+25 GR SA (SS)	8.73	9.05	9.59	0.39	0.67	0.88
T6	12.5GR SA (S)+12.5 GR SA (SS)	9.00	9.35	9.59	0.54	0.75	0.55
T7	12.5 GR MG (S)+25 GR SA (SS)	8.77	9.20	9.67	0.46	0.64	1.06
T8	12.5 GR FSA(S)+25 GR FSA (SS)	8.74	9.26	9.69	0.44	0.51	1.04

Table 7.2. Change in pH of soil under different depth after rice harvest

Treatments	pH 0-15 cm	pH 15-30 cm	pH 30-45 cm
Control	9.60 ^c	9.89 ^c	9.99 ^b
50 GR Gyp (S)	9.14 ^{bc}	9.71 ^c	9.92 ^b
50 GR SA (S)	8.64 ^a	9.21 ^a	9.67 ^{ab}
25 GR SA (S)+25 GR SA (SS)	9.03 ^{ab}	9.34 ^a	9.60 ^{ab}
25 GR SA (S)	9.07 ^{ab}	9.66 ^{bc}	9.89 ^b
50 GR FSA (S)	8.62 ^a	9.35 ^a	9.74 ^{ab}
25 GR FSA (S)+25 GR FSA (SS)	9.18 ^{bc}	9.37 ^a	9.52 ^a
25 GR FSA-2 (S)+25 GR FSA-2 (SS)	9.15 ^{bc}	9.42 ^{ab}	9.62 ^{ab}

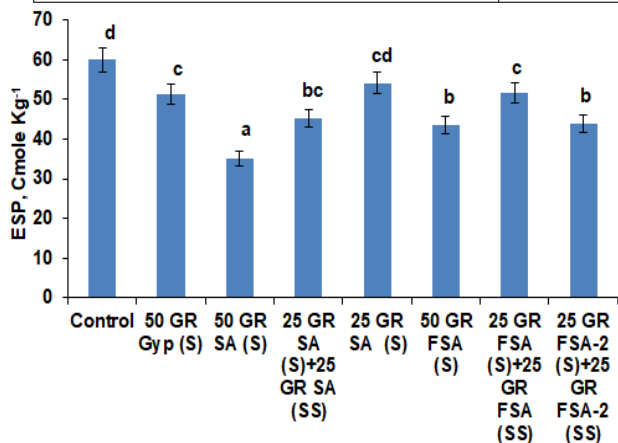


Fig 7.3 Changes in exchangeable sodium percentage under different treatments

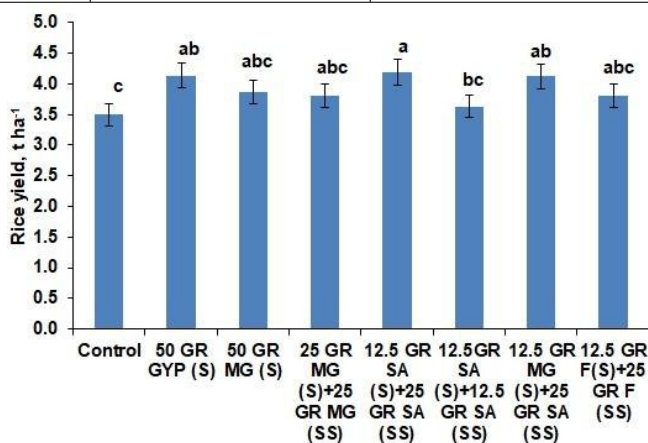


Fig 7.4 Rice yield in partially reclaimed sodic soil in kharif season

change in pH observed after the after wheat harvest. The electrical conductivity, EC₂ varied from 0.38 to 0.54 dS m⁻¹ in 0-15 cm soil depth whereas in 15-30 cm and 30-45 cm depths, the EC₂ varied from 0.53 to 0.77 dS m⁻¹ and 0.55 to 1.06 dS m⁻¹, respectively.

In Kharif season, along with the present experiment, an experiment was also conducted on highly degraded sodic soil having pH 9.98, 10.1, and 10.22 for 0-15 cm, 15-30 cm, and 30-45 cm soil depth, respectively taking sulfamic acid (SA) as the main ameliorant. The experiment on highly sodic soil was conducted by taking 8 treatments and 3 replications on 20 m² plot size in RBD design. The treatments were: T1– Control; T2 – 50 GR gypsum (GYP) at surface (S); T3 – 50 GR SA at surface (S); T4 – 25 GR SA (S)+25 GR SA at sub-surface (SS); T5 – 25 GR SA at surface (S); T6 – 50 GR formulation, FSA (S); T7 – 25 GR FSA (S)+25 GR FSA (SS); T8 – 25 GR formulation (FSA-2) at surface (S)+25 GR FSA-2 (SS). The rice was transplanted in July, 2025 in which mortality were noticed in some of the SA treated plots, which might be due to incomplete reaction of SA with soil system. But the soil physico-chemical properties improved significantly after the rice harvest. The pH of 0-15 cm soil depth decreased maximum in the treatment 50 GR SA (S) with pH 8.64 w.r.t. control, which was statistically similar to 50 GR FSA (S) while in 15-30 cm depth, maximum decrease in pH was observed in 50 GR SA (S) having pH 9.21 w.r.t. control (pH 9.89), statistically similar to 25 GR SA (S)+25 GR SA, 50 GR FSA (S), and 25 GR FSA (S)+25 GR FSA (SS). But, in 30-45 cm soil depth maximum decrease in pH was noticed (pH 9.52) w.r.t. control (pH 9.99) in 25 GR FSA (S)+25 GR FSA (SS) (Table 7.2). Similarly, under 0-15 cm soil depth, maximum decrease in exchangeable sodium percentage (ESP) was noticed in 50 GR SA (S) (ESP 35.14) w.r.t. control (ESP 60.09) (Fig. 7.3).

Table 7.3 Changes in soil pH in partially reclaimed sodic soil after rice harvest

Treatments	pH 0-15 cm	pH 15-30 cm	pH 30-45 cm
Control	9.07 ^b	9.62 ^b	9.94
50 GR Gyp (S)	8.86 ^{ab}	9.59 ^b	9.84
50 GR MG (S)	8.66 ^a	9.45 ^{ab}	9.78
25 GR MG (S)+25 GR MG (SS)	8.75 ^{ab}	9.52 ^{ab}	9.65
12.5 GR SA (S)+25GR SA (SS)	8.76 ^{ab}	9.24 ^a	9.82
12.5 GR SA (S)+12.5GR SA (SS)	8.97 ^{ab}	9.52 ^{ab}	9.93
12.5 GR MG+25 GR SA (SS)	8.85 ^{ab}	9.51 ^{ab}	9.87
12.5 GR FSA(S)+25 GR FSA (SS)	8.84 ^{ab}	9.50 ^{ab}	9.78

However, under partially reclaimed sodic soil, the rice yield was observed maximum (4.19 t ha⁻¹) in treatment T5 where 12.5 GR sulfamic acid (SA) was applied on surface (S) and 25 GR SA applied on sub-surface (SS) i.e. (12.5 GR SA (S)+25GR SA (SS) (Fig. 7.4) followed by 50 GR GYP (S) (4.14 t ha⁻¹), which was statistically on par to 12.5 GR MG (S)+25 GR SA (SS). A significant decrease in pH was observed in T3 treatment (pH 8.66) under 0-15 cm soil depth where MG was applied on surface @ 50 GR (Table 7.3). This was followed by T8 where 12.5 GR FSA on surface and 25 GR FSA on subsurface was applied which was statistically similar to T2, T4, T5, T6, and T7. Under 15-30 cm soil depth, a significant decrease in pH was observed in treatment T5 (pH 9.24) with respect to control while no significant difference was noticed in 30-45 cm soil depth.

The experiment is still in progress and a subsequent change in the soil characteristics has to be observed. Sulphamic acid could be a very good ameliorant of heavy textured sodic soils where CO₃²⁻ and HCO₃⁻ salts of Na and CaCO₃ (amorphous and calcrete) dominates.

Feasibility of harvesting salt from high salinity lands using polythene lined pond and enhanced evaporation techniques (A. Rahman, Sanjay Arora and A.K Dixit)

This project was continued with objectives to assess salt flushing under the bordered surface flush irrigation technique with good quality of water and observing treatment effect on crop yield attributes under the rice-wheat cropping system. The description of experimental setup and treatments undertaken during *rabi* season 2024-25 are given in Table 7.4. The relevant soil attributes before the sowing of wheat crop in the experimental plots is given in Table 7.5.

Data in Table 2 showed that the pH was minimum in treatment T₄ (1% slope + gypsum) in the soil depth zones of 0-15 cm and 15-30 cm, both. Similarly, the Na⁺ ions was also minimum in the depth zone 0-15 cm and this was due to the application of gypsum, which chemically freed more Na⁺ ions due to addition of Ca⁺⁺ ions in soil. This freed Na⁺ ions flushed out along the field slope and pH is reduced. In T₂ (level field+ gypsum) the soil pH and Na⁺ ions both were high due to less horizontal flushing and relatively more vertical

Table 7.4 Description of experimental setup and treatments during rabi season 2024-25

S.N.	Item	Features	Treatment
1.	Plot size	24 m x4.0 m (96 m ²)	T1: level field+ no gypsum
2.	Date of sowing	16/11/2024	T2: level field+ gypsum@50GR
3.	Wheat variety	KRL-283	T3:1% field slope+ no gypsum
4.	Fertilizer basal dose	NPS: 20:20:13; 2.9 kg/plot	T4:1% field slope + gypsum @ 50GR
5.	Split doses of urea	635g/plot (twice)	-

7.5 Soil chemical parameters before wheat sowing

Treatment	pH		Na ⁺		CO ₃ ²⁻		HCO ₃ ⁻	
Depth (cm)→	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
T1	9.23	9.70	18.21	12.51	4.0	2.0	7.0	6.33
T2	9.24	9.55	18.24	18.25	2.0	1.8	5.0	6.17
T3	9.16	9.61	16.60	12.00	3.0	2.3	5.3	5.50
T4	9.02	9.52	17.08	13.90	1.7	2.3	4.7	6.67

Table 7.6 The yield parameters of wheat crop under different treatment

Treatment	Plant height (cm)	Ear head (cm)	Straw yield (t/ha)	Grain Yield (t/ha)	Harvest Index
T1	69.7	9.0	4.00	2.30	0.365
T2	69.5	9.0	3.98	2.30	0.366
T3	70.3	9.1	4.03	2.37	0.370
T4	74.30	9.2	4.30	2.53	0.373



Wheat crop in experimental plots (Rabi 2024-25)

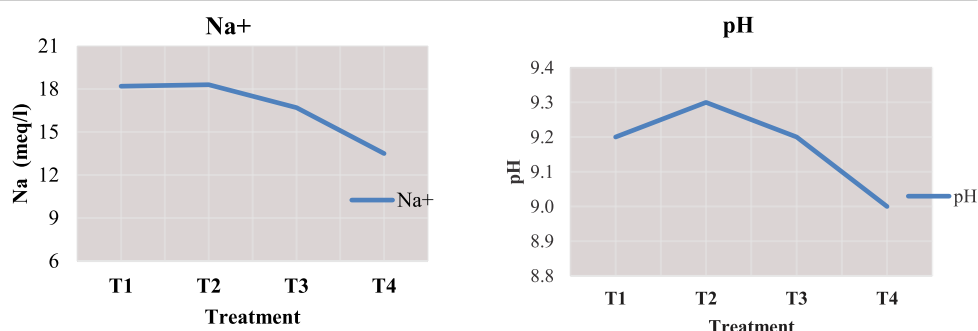


Fig 7.5 Effect of treatment on sodium ions and pH

leaching. The flushing effect is also visible in T₃ (1% slope+ no gypsum), as Na⁺ concentration and pH both were low compared to T₂ (level field+ gypsum).

In the experimental plots, the standing wheat crop is shown in photo. The plant height, ear-head length, straw and grain yield of wheat, recorded at the end of crop period, are reported in Table 7.6.

It was observed that the straw yield, grain yield and the harvest index all were highest in T₄ (1% slope + gypsum) with corresponding values of 4.3 t/ha, 2.53 t/ha and 0.373, respectively. This was followed by T₃ (1% slope+ no gypsum) with values of 4.03 t/ha, 2.37 t/ha and 0.370, respectively. A minimum value of wheat straw, grain yield and harvest index were observed in T₁ (level field+ no gypsum) with values of 4.0 t/ha, 2.30 t/ha and 0.365, respectively. The data trend showed that the gypsum application under slopy land condition was most beneficial, in terms of wheat yield attributes. Further, in case of no application of gypsum, creating a small gradient in the land slope would be helping the farmers in lowering the pH value and getting good crop in high sodic fields, as slope aggravates the salt removal from the field, particularly in 0-15 cm soil depth zone. The effect of treatments on Na⁺ ions and pH reduction is shown in Fig. 7.5.

Characterization of heavy textured sodic soils of Uttar Pradesh by Vis-NIR spectroscopy for rapid and non-destructive estimation SAS parameters (A. Rahman, Sanjay Arora, Amresh Choudhary and R.H. Rizvi)

The vis-NIR spectroscopy is a proximal sensing technique for rapid and non-destructive

Table 7.7 Ranges of chemical parameters of samples (N=73)

pH	EC	pH _e	EC _e	Na ⁺	K ⁺	Ca ⁺⁺	S
10.7 – 7.5	5.378 – 0.184	10.02 – 7.67	8.67 – 0.127	95.0 – 11.92	0.345 -0.041	5.5 -0.5	56.08-6.41
Mg ⁺⁺	CO ₃ ⁼⁼	HCO ₃ ⁻	Cl ⁻	OC	CEC	ESP	
3.5 – 0.5	80.0 – 0.00	44.0 - 1.50	55.0 – 1.50	0.538 – 0.03	18.73 – 4.894	98.23 – 1.085	



Fig 7.6 Soil sample for spectral signatures

estimation of soil parameters. The spectral dispersion due to absorption of electromagnetic energy by soil constituent leads to their quantification, as dispersion is proportional to the concentration of the components. The spectral absorptions in vis-NIR region are weak, and sources of absorption overlaps, hence quantitative analysis are implemented through empirical, multivariate statistical models. The performance of vis-NIR spectral absorptions is objectively evaluated for different soil samples of wide area for accuracy in measurement. The objective of this project was to acquire soil samples from the heavy textured highly sodic areas such as Hardoi, Unnao and Lucknow districts of Uttar Pradesh and to analyze the samples in laboratory for chemical properties, and for vis-NIR spectroscopic spectral signatures. Based on these objectives 73 samples were collected from these areas and analyzed in laboratory for pH, EC, pHs, ECe, Na⁺, K⁺, Ca⁺⁺, Mg⁺⁺, CO₃⁼⁼, HCO₃⁻, Cl⁻, OC, CEC and ESP, and ranges of chemical parameters are reported in Table 7.7.

The collected and chemically analyzed soil samples were processed and sieved through 2.0 mm sieve and put in the sample holders for spectral scanning, as shown in Fig 7.6. The

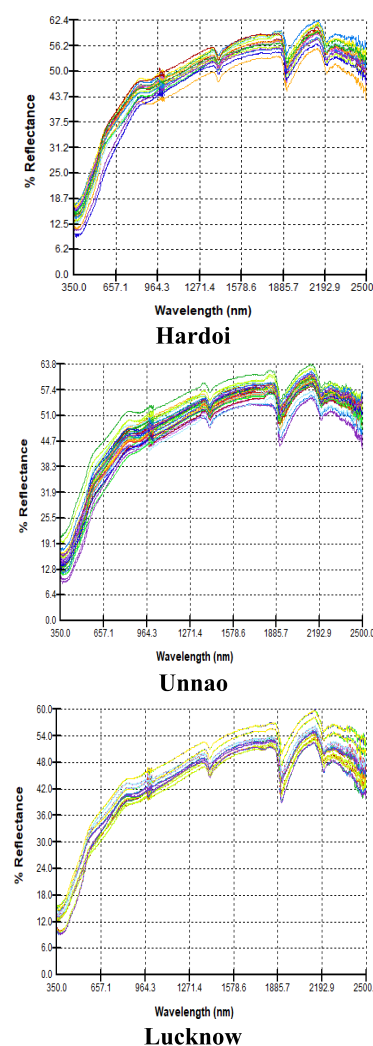


Fig 7.7 Raw spectral data of sodic soils of different districts

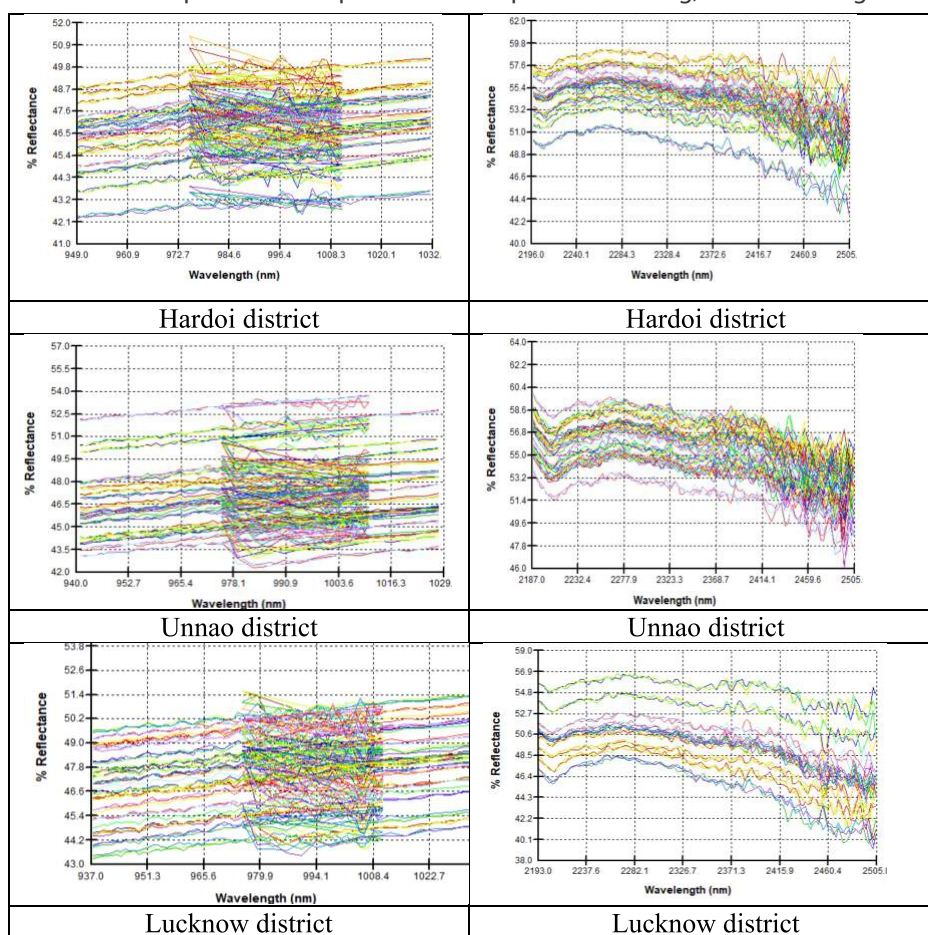


Fig 7.8 Diffused scattering view of between 975-1010 nm and 2200-2500 nm

samples were put inside a black wooden box for reflectance spectral signatures using XHR-1024i spectroradiometer operated in Vis-NIR (350–2500 nm). The spectroradiometer was calibrated using a white Teflon plate. The necessary adjustments were done to standardize the reflectance intensity.

The raw spectral signatures for samples were recorded as shown in Fig 7.7. Irrespective of the location of soil sampling, the spectral signatures showed prominent diffused scattering over the wavelength range of 975-1010 nm and 2200-2500 nm (Fig 7.8). The diffused scattering could be attributed to the soil attributes which could be estimated on the basis of their own scattering nature.

The raw spectral signatures was processed by averaging multiple observations of reflectance data of a sample and then all were integrated, cleaned and normalized. This processed spectral signature will be smoothen further by Saitzky-Golay filtering for first-order derivative of signals, and a standard normal variate spectra (SNV) would be developed with removal of linear trend for modelling of the processed spectra to extract relevant information using mathematical and statistical techniques. Further, some strong absorption were observed at ~1400 nm, ~1900 nm and 2200 nm, but all of them are related to feature of water, ~1400 nm and ~1900 nm, and clay lattice OH features at ~1400 nm and ~2200 nm.

Low Budget natural farming for sustainable crop production (Arjun Singh, S K Jha and A.K. Dixit)

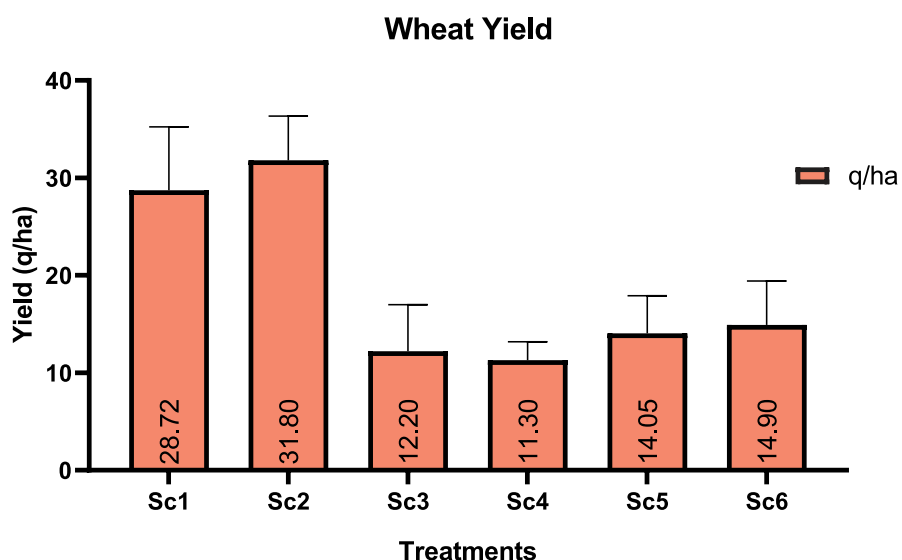
In the sixth cropping cycle of the project, effect of the natural farming component was evaluated on growth and productivity of the wheat (var KRL283). Six treatments among which 2 treatments (viz; Sc-1 and Sc-2) were based on recommended chemical input-based farming practices whereas 4 treatments (viz; Sc-3, Sc-4, Sc-5 and Sc-6) were based on package and practices of LBNF components. There was drastic reduction in yield of wheat under the treatments receiving natural farming components, the plot yield ranged from 9.8 q/ha to 13 q/ha. The results of the field experiments with wheat showed significant changes in the soil chemical as well as biological activity. With respect to the OC data in wheat natural farming registered decrease in OC levels except for Sc4 (Table 7.8). Under the NF treatments the reduction in availability of soil nitrogen was also observed as compared to control treatment, it was found that under NF treatments, Avl N ranged from 78 to 107 kg/ha whereas the treatments receiving chemical inputs has Avl N

Table 7.8. Changes in soil properties (chemical and biological) under wheat cultivation (var. KRL 283) following low budget natural farming as well as fertilizer based agronomic practices.

Treatments	Organic Carbon (%)		Available Nitrogen (Kg/ ha)		Available Phosphorous (Kg/ ha)		Available Potassium (Kg/ha)		Dehydrogenase activity (µg/ml/hr)	
	I	F	I	F	I	F	I	F	I	F
Sc1	0.47	0.43	198.6	190.5	15.71	16.55	189.1	175.8	132.2	107.0
Sc2	0.46	0.48	196.6	200.8	15.40	15.94	189.3	192.4	110.9	125.1
Sc3	0.50	0.43	89.52	78.04	9.803	10.15	164.3	154.3	106.7	89.05
Sc4	0.42	0.46	113.3	107.0	10.08	11.80	165.7	162.4	121.2	94.26
Sc5	0.53	0.44	111.9	107.7	14.29	14.82	166.2	165.2	101.9	126.6
Sc6	0.50	0.43	114.7	105.4	14.45	15.69	167.0	163.7	118.2	126.4

I-Initial; F-Final

Fig 7.9 Trends of yield under LBNF (Sc3, Sc4, Sc5, Sc6) as well as fertilized treatments (Sc1, Sc2) with wheat



to the range of 190-200 kg / ha. Changes in soil microbial biomass was estimated in terms of dehydrogenase activity. It was found that dehydrogenase activity also decreased in all the natural farming treatments, only Sc5 (LBNF + HaloMix + Residue) and Sc6 (LBNF + HaloMix + Residue+ Green Manuring) showed increase in dehydrogenase activity (Table 7.8). The yield response of the wheat was low under the application of natural farming components. It was found that maximum yield of 14.9 q/ha was obtained under natural farming whereas under conventional farming yield response was 31.8 q/ha (Figure 7.9).

The use of natural farming components increased the microbial biomass of the soil and improved its soil organic carbon and nitrogen. Still the recommended doses of the components are not sufficient to meet out the yield potential of rice and wheat.

Investigating role of bacterial endophytes for ameliorating salt stress in wheat (Arjun Singh and S.K. Jha)

Bacterial root endophyte isolation was initiated from wheat cultivars Kh65, KRL210, KRL238 and HD3226 grown under sodic conditions pH 9.2, 9.5 and 10.0. The bacterial isolation scheme from the varieties started with surface sterilization of the root surface with crushing in phosphate buffer saline. The crushed samples in PBS were subjected to serial dilution and were plated on following culture media viz; Nutrient agar, nutrient agar (half strength), nutrient agar (1/10 strength), SCA, R2A, TYA, Norris N free medium, SEA and King's B medium. The isolation experiment resulted 300 bacterial isolates in which 25 bacterial isolated could not be revived back hence; a stock of 275 bacterial isolates has been maintained. The bacterial isolates were subjected to functional screening for stress amelioration, for their alkaline pH tolerance, aminocyclopropane-1-carboxylate (ACC) deaminase production, alkaline protease production, beta-glucosidase production, exopolysaccharide (EPS) production, Auxin production and seed germination assay. Among 275 isolates, 91 isolates were found to be tolerating pH 10.0 when subjected to screening on Horikoshi-1 medium. Hence these alkali tolerant isolates were further selected for functional characterizations for stress ameliorating traits in which 57 isolates showed ACC deaminase activity, EPS production was observed in 38 isolates, 6 bacterial isolate showed alkaline protease production, 7 bacterial isolates showed halo-tolerant β -glucosidase production. The auxin production was recorded in all the 81 alkali tolerant

Table 7.9 Quantitative estimation of effect of bacterial endophytes in increasing seed vigour

Bacterial Isolate	Auxin (IAA mg-1)	Seed vigour		Wheat Host
		Plumule (cm)	Radicle (cm)	
Isolate 12	17.15	3.3	1.5	Kharchia 65
Isolate 13	17.76	3.5	2.2	KRL283
Isolate 09	18.45	3.6	2.6	Kharchia 65
Isolate 22	18.34	0	1.5	KRL 283
Isolate 1	10.2	0	3.0	Kharchia 65
Isolate 2	8.45	0.5	3.0	Kharchia 65
Control		0	0.5	

Fig 7.10 Morphological diversity of root bacterial endophytes from wheat

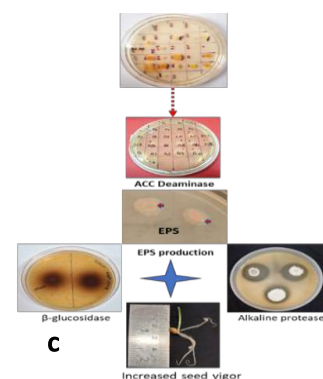
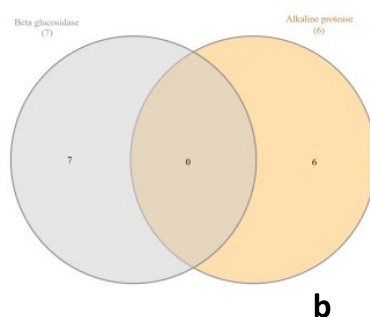
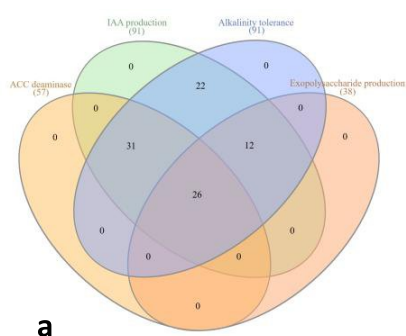


Fig 7.11 (a,b)- Distribution of salt stress ameliorating traits in bacterial endophyte isolates. (c)- Effect of bacterial endophytes in improving seed vigour of wheat variety KRL 283

isolates. The seed vigour assay was performed by selecting the top ten-auxin producing bacteria in which five bacterial isolates were found to induce early germination in the KRL 283 seeds. The bacterial root endophytes were possessed many of the stress ameliorating traits which are being extended to its host plant (table 7.9). The bacterial endophytes were also able to induce breaking of the seed dormancy which proves that it is being colonising the spermo-sphere of the wheat seeds and improving the seed vigour.

Spatial and Temporal Analysis of Waterlogging and Salt Dynamics for Crop Planning in Sharda Sahayak Canal Command of Uttar Pradesh (R.H. Rizvi and Sanjay Arora)

This project was initiated in March, 2022 with the aim of mapping waterlogged salt affected areas in Sharda Sahayak Canal Command. This command comprises of 18 districts of Uttar Pradesh and has geographical area of 359864.38 km². For this project, six districts namely Amethi, Barabanki, Jaunpur, Pratapgarh, Lucknow and Raibareli were selected from Canal Command. Field survey was conducted in Sharda Canal Command of

Table 7.10 Summary statistics for soil samples of Jaunpur district in Sharda Canal Command

Depth: 0-15cm	pH	EC (dS/m)	Na (ppm)	pH _e	EC _e	CEC	ESP
Minimum	8.38	0.476	18.76	7.10	1.422	5.754	28.66
Maximum	10.63	4.29	611.52	10.24	18.92	9.495	70.97
Mean	9.34	1.72	195.79	8.44	6.47	7.49	56.59

Table 7.11 LULC statistics of Jaunpur district for May 2023 and May 2025

LULC classes	May-2023		May-2025	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Sodic soils	48496.14	12.02	50647.25	12.55
Water' W' bodies	12725.99	3.15	9431.27	2.34
Builtups/ Sandy areas	73148.22	18.13	79369.39	19.67
Bareland/ Fallowland	66046.1	16.37	86071.88	21.34
Vegetation/ Plantations	202991.88	50.32	177888.546	44.10
	403408.33		403408.33	

Table 7.12 District-wise area under Sodic soils in study districts (May 2023)

District	Geog. Area (ha)	Sodic soils	
		Area (ha)	Area (%)
Amethi	275064.47	17563.67	6.38
Barabanki	358582.32	20125.16	5.61
Pratapgarh	370932.86	11298.54	3.05
Raebareli	227385.70	12054.34	5.30
Jaunpur	403283.57	26105.31	6.47
Total	1635248.92	87147.02	5.33

Jaunpur district of Uttar Pradesh and 15 geo-referenced soil samples (at 2 depths) were collected. These samples were analysed in lab for soil parameters viz. pH, EC, OC, Na, K, Ca, Mg and saturation extract pH_e and EC_e.

I. Soil Analysis

The geo-referenced soil samples from 15 sites each (2 depths) were collected from Jaunpur district in Sharda Sahayak Canal Command of Uttar Pradesh. These soil samples were analysed in laboratory by standard methods for soil parameters like pH, EC, Na, K, OC, etc (Table 7.10). Analysis of these samples revealed that mostly samples were sodic (pH>8.5) and non-saline (EC<4). Soil pH of the samples varied from 8.38 to 10.63 and EC varied from 0.476 to 4.29 dS/m. maximum pH and pH_e for sodic samples was as high as 10.63 and 10.24, respectively. Exchangeable sodium percent (ESP) was found as high as 70.97 in these samples. A very wide variation was observed in Na ranging from 18.76 to 611.52 ppm.

II. Remote Sensing Analysis

Land use and land cover (LULC) analysis

Sentinel-2 MSI data for two periods (May 23 & May 25) has been downloaded. These remote sensing images were mosaicked and clipped from district boundary. Land use land cover (LULC) classification was done by ISODATA method in QGIS software. LULC analysis revealed that area under sodic soils in the district increased from 48496.14 ha in May 2023 to 50647.25 ha in May 2025 (Table 7.11). LULC map of Jaunpur district is depicted in figure 7.12 (sodic soils in pink colour). Under the Sharda Sahayak Canal

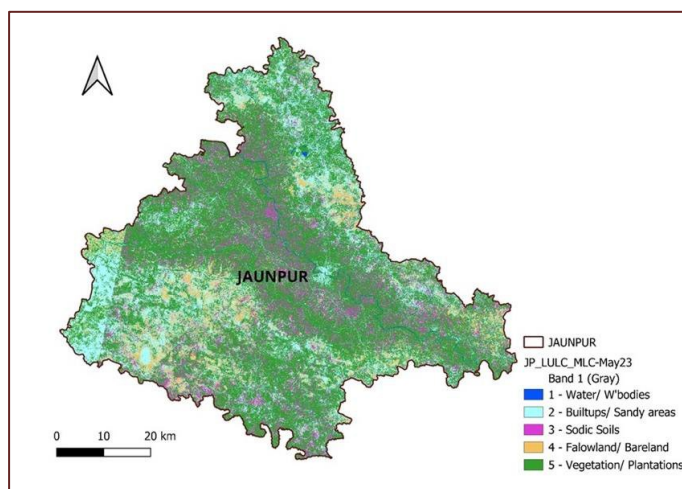


Fig 7.12 LULC map of Jaunpur district for May 2023

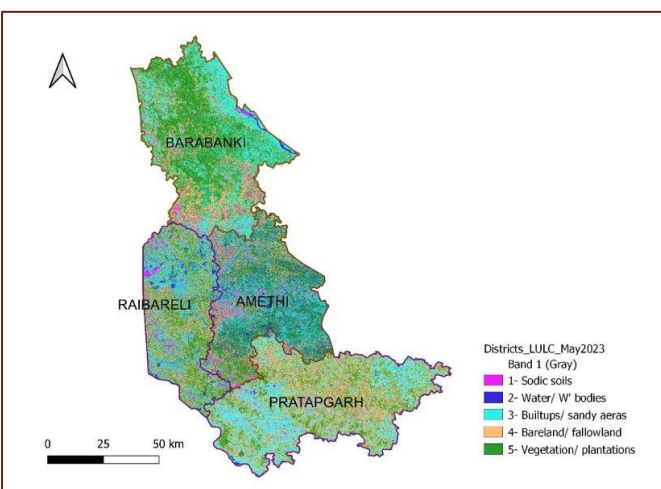


Fig 7.13 LULC of study districts in Sharda Sahayak Canal command

project, LULC analysis for five study districts namely Amethi, Barabanki, Raebareilly, Jaunpur and Pratapgarh was done. Area under sodic soils in these districts was estimated to be 87147.02 ha, which is 5.33% of their geographical area (Table 7.12 & Figure 7.13).

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

Development of model for estimating native CaCO_3 dissolution in calcareous sodic soils

Incubation batch kinetics study was conducted on 10 calcareous sodic soils of Bihar at field capacity to ascertain a suitable dissolution model. It showed an initial release of Ca ranging from 3.0 to 6.25 meq/l on day 1 of incubation that increased to the extent of 8.5 to 25.5 meq/l after 4 weeks of incubation (Table 7.13).

Different dissolution rate models were tested and it was observed that integrated rate equation (first and second order integration) best fitted with R^2 value dominating between 0.96 to 0.99 and SE values 0.002 to 0.029 for first order and 0.008 to 0.032 for 2nd order in soils have diverse CaCO_3 content. Elovich equation also fitted well in almost all soils with free CaCO_3 content ranging from 5.8 to 23.2% (Fig. 7.14).

Table 7.13 Kinetic rate equations for dissolution of CaCO_3 in calcareous sodic soils

Calcareous sodic soils	Integrated rate equation				Elovich		Power function		Parabolic diffusion	
	R2I	S.E.I	R2II	S.E.II	R2	S.E.	R2	S.E.	R2	S.E.
S1 (16.2%)	0.96	0.029	0.99	0.025	0.99	0.193	0.98	0.015	0.88	0.067
S2 (5.8%)	0.99	0.004	0.99	0.016	0.96	0.159	0.98	0.004	0.95	0.016
S3 (9.2%)	0.99	0.013	0.99	0.025	0.95	0.369	0.92	0.019	0.75	0.065
S4 (6.4%)	0.99	0.013	0.99	0.028	0.98	0.204	0.98	0.009	0.84	0.048
S5 (12.3%)	0.99	0.002	0.99	0.021	0.99	0.142	0.99	0.006	0.92	0.039
S6 (14.1%)	0.99	0.007	0.99	0.020	0.95	0.231	0.94	0.012	0.76	0.048
S7 (18.5%)	0.99	0.002	0.98	0.032	0.96	0.116	0.96	0.005	0.79	0.026
S8 (20.4%)	0.99	0.011	0.99	0.008	0.98	0.278	0.97	0.019	0.84	0.078
S9 (23.2%)	0.99	0.012	0.99	0.023	0.96	0.199	0.90	0.019	0.79	0.056
S10 (16.5%)	0.99	0.009	0.99	0.019	0.98	0.228	0.99	0.004	0.96	0.024

Fig 7.14 Kinetics of Ca release from calcareous sodic soils of Bihar

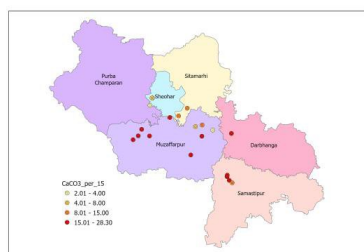
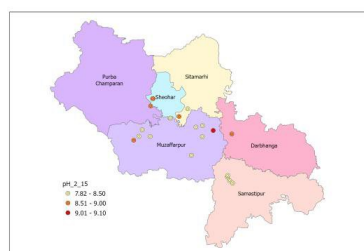
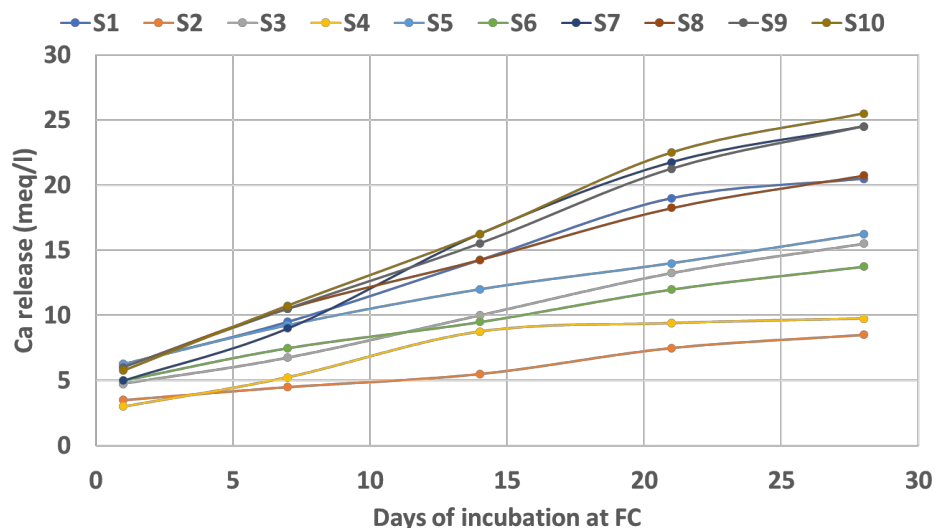


Fig 7.15 Digital maps depicting the calcareous sodic soils of Bihar

Database of extent and nature of calcareous salt affected soils of Bihar

The GPS based soil samples were collected from different districts of Bihar and analysed for different soil properties including soil pH and free CaCO_3 content. The calcareous sodic soils geo-coordinate sites were digitally mapped and using district boundary maps (Fig. 7.15). The same is being refined as decision support tool for effective use of stakeholders for deciding the possible suitable intervention based on soil properties.

Bio-Chemical characterization of potential CaCO_3 dissolution bacterial isolates

Bio-chemical characterization of 12 potential bacterial isolates having traits for calcium carbonate dissolution was done. It was observed that the IAA production by the isolates ranged from 7.9 to 22.7 $\mu\text{g/ml}$ and out of 12 isolates, 9 were positive for catalase, 6 were positive for MR and citrate utilization test to ascertain organisms to utilize citrate as sole C source. Nine bacterial isolates were positive for starch and 6 were positive for HCN production. Three isolates were only positive for siderophore production, 5 were positive for ACC deaminase activity and 7 were positive for urease activity (Table 7.14). Based on the biochemical tests, salt tolerance and from the quantification of Ca release kinetics in liquid media, the 4 isolates were subjected to molecular characterization and consortia

Table 7.14 Biochemical characterization of CaCO_3 dissolving bacterial isolates

Culture ID	IAA ($\mu\text{g/ml}$)	Catalase	MR	Citrate	Starch	HCN	Siderophore	ACC	Urease
CDHB-1	18.453	+ve	+ve	+ve	+ve	+ve	-ve	+ve	+ve
CDHB-2	9.616	-ve	+ve	-ve	+ve	-ve	-ve	-ve	+ve
CDHB-3	11.477	+ve	-ve	-ve	-ve	+ve	+ve	-ve	+ve
CDHB-4	17.640	+ve	+ve	+ve	+ve	-ve	-ve	+ve	+ve
CDHB-5	7.899	-ve	-ve	+ve	-ve	+ve	-ve	+ve	+ve
CDHB-6	16.709	+ve	+ve	+ve	+ve	-ve	-ve	-ve	-ve
CDHB-7	22.756	-ve	-ve	-ve	+ve	+ve	-ve	-ve	-ve
CDHB-8	13.570	+ve	+ve	+ve	+ve	+ve	-ve	-ve	-ve
CDHB-9	13.337	+ve	+ve	-ve	+ve	+ve	-ve	-ve	-ve
CDHB-10	16.471	+ve	-ve	-ve	+ve	-ve	-ve	+ve	-ve
CDHB-11	18.570	+ve	-ve	+ve	+ve	-ve	+ve	-ve	+ve
CDHB-12	12.988	+ve	-ve	-ve	-ve	-ve	+ve	+ve	+ve

Table 7.15 Dissolution of CaCO₃ by isolates in broth

Culture Id	pH		Ca (meq/l)	
	3d	10d	3d	10d
		0.5% CaCO₃		
Control	7.84	6.41	12.0	9.5
CDHB-9	8.19	7.80	51.0	59.0
CDHB-10	7.84	7.94	23.0	15.5
CDHB-11	8.24	7.66	58.5	60.5
		1.0% CaCO₃		
Control	7.98	6.58	14.0	13.5
CDHB-9	8.19	8.00	51.5	58.5
CDHB-10	8.24	8.18	26.5	46.5
CDHB-11	8.51	8.36	55.0	59.5
		1.5% CaCO₃		
Control	8.25	7.84	16.5	16.5
CDHB-9	8.00	8.37	57.0	64.0
CDHB-10	8.01	7.28	28.0	40.5
CDHB-11	8.31	8.37	56.0	62.5

Halo-Cal-D (halophilic calcium carbonate dissolving bacteria) was mass multiplied, standardized carrier media and shelf life for validation in calcareous sodic soils.

A broth experiment was conducted to quantify the amount of dissolution of CaCO₃ by isolates during time interval with different concentration of calcium carbonate. It was observed that pH of broth reduced from 7.84 to 6.41, 7.98 to 6.58 and 8.25 to 7.84 in control with 0.5, 1.0 and 1.5% CaCO₃. Inoculation of calcite dissolving bacteria decreased the pH and increased Ca content in broth with maximum value observed in CDHB-9 and CDHB-11 bacterial strains (Table 7.15).

16S rRNA for molecular identification

The 4 potential bacterial isolates were subjected to DNA extraction and the PCR product is purified and subjected to Sanger sequencing using universal primers (27F and 1492R) to target the 16S gene, producing an amplicon of roughly 1500 bp. Through BLAST repository, the three potential isolates were identified as *Bacillus pumilus*, *Bacillus australimaris*, *Bacillus tequilensis* and *Niallia circulans* (Table 7.16).

Standardization of Media and Bioformulation development

The potential consortia of calcite dissolving bacteria having compatibility were continued for ascertain for shelf life test in liquid standardized carrier media as per norms. Liquid based formulation prepared Halo-Mrida Sudharak was transformed to "Halo-Cal-D" with a satisfactory shelf life of 360 days at room temperatures. The formulation is ready for widespread multi-location testing for promoting in-situ dissolution of native CaCO₃ in calcareous sodic soils for self-reclamation and plant growth promotion (Fig 7.16).

Table 7.16 Molecular identification of potential calcite dissolving isolates

CDHB-8	<i>Bacillus pumilus</i>
CDHB-9	<i>Bacillus australimaris</i>
CDHB-10	<i>Bacillus tequilensis</i>
CDHB-11	<i>Niallia circulans</i>



Fig 7.16 Liquid formulation 'Halo-Cal-D' consortia of efficient calcite dissolving bacteria

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

In Samastipur and Muzaffarpur district of Bihar, on-farm demonstrations during *Kharif* 2025 were conducted at 4 locations where farmers have preserved the seeds of STV of previous season. The paddy was found to be superior with interventions viz. green manuring, halo-mix enriched cow manure and pressmud with salt tolerant variety (CSR 46). It was observed that salt tolerant rice variety (STV) performed better over the traditional variety with more than 23% more grain yield on an average.

Development of resource efficient cropping systems for sodic environment (Anoop Kumar Dixit, Anil Kumar Dubey, Sanjay Arora and Arjun Singh)

To develop remunerative and resource efficient cropping system in place of traditional rice-wheat system under sodic environment, a field study was initiated at research farm of CSSRI-Regional Research Station, Lucknow. In field experiment, nine cropping systems viz.; CS 1: Rice – Wheat, R-W (Farmer's Practice), CS 2: Rice – Wheat – Dhaincha as green manure, R-W-DGM, CS 3: Rice-Barley-Dhaincha as green manure, R-Ba-DGM, CS 4: Rice – Berseem, R-Be, CS 5: Rice (Early variety) – Lentil + Mustard (6:1) - Dhaincha as green manure, RE-L+M-DGM, CS 6: Dhaincha (Seed production) – Barley, DSP-Ba, CS 7: Pearl millet (Ridge) + Dhaincha (Furrow) as brown manure – Toria – Sunflower, PMR+DBM-T-S, CS 8: Pearl millet (Line) + Dhaincha (Broadcasting) as brown manure – Toria – Sunflower, PMF+DBM-T-S up to rabi 2024-25 and Rice (Early variety) – Toria – Sunflower - Dhaincha as green manure, RE-T-S-DGM from *kharif* 2025 and CS 9: Fodder sorghum (Raised bed) + Rice (Sunken bed) – Lentil (Raised bed) + Barley (Sunken bed) - Dhaincha as green manure, FS(RB)+R(SB)-L(RB)+Ba(SB)-DGM were tested in randomized block design with three replications. In CS9 treatment, 15 cm height raised beds were made by cutting of 7.5 cm top soil from shunken bed area and put that soil on raised bed area. All the component crops were established at their suitable time with recommended package of practices. 1/3rd crop residue of rice, pearlmillet, wheat, barley, mustard/toria and sunflower was used as residue for succeeding crop cultivation in different cropping systems.

During *rabi*, 2024-25, treatment wise rabi crops viz., toria, berseem, lentil, mustard, barley and wheat were sown with recommended package of practices. Yield of various rabi season crops have been recorded (Table 7.17) and to compare it among different cropping system, yield of different component crops have converted into rice equivalent yield. During *rabi* 2024-25, highest REY (3.00 t/ha) was recorded under CS 2 and CS 7 followed by CS 4 & CS 8 (2.88 t/ha), CS 1 (2.83 t/ha), CS 6 (1.87 t/ha), CS 3, (1.76 t/ha), CS 9 (1.73 t/ha) and CS 5 (1.44 t/ha) cropping system. Similarly during *zaid* season 2025, yield of different component crops was recorded and converted into REY (Table 7.17 and 7.18).

Data on rice equivalent yield of different cropping system during 2024-25 was calculated and presented in table 7.18 & figure 7.17. It was observed that cropping system CS 7: Pearl millet (Ridge) + Dhaincha (Furrow) as brown manure – Toria – Sunflower, PMR+DBM-T-S, recorded significantly higher rice equivalent yield (9.03 t/ha) than all the other cropping systems except CS 8: Pearl millet (Line) + Dhaincha (Broadcasting) as brown manure – Toria – Sunflower, PMF+DBM-T-S which was at par, whereas significantly lowest REY (3.11 t/ha) was recorded by CS 6: Dhaincha (Seed production) – Barley, DSP-Ba cropping system. CS 7 cropping system recorded 44 per cent higher REY and CS 6 recorded 50.4 per cent lower REY than traditional Rice – wheat system (CS 1) under sodic soil environment.

Table 7.17 Yield (t/ha) of different component crops under various cropping systems during rabi, 2024-25 & zaid, 2025.

Cropping system	Rabi, 2024-25								Zaid, 2025	
	Fodder Berseem (4 cuts)	Wheat/Barley		Lentil		Mustard		Sunflower		DGMA*
		Grain	Straw	Grain	Stover	Seed	Stover	Seed	Stover	
CS1: R-W (FP)		2.31	3.69	-	-	-	-	-	-	-
CS2: R-W-DGM		2.58	2.56	-	-	-	-	-	-	30.67
CS3: R-Ba-DGM		1.79	2.02							26.56
CS4: R-Berseem	26.48	-	-	-	-	-	-	-	-	-
CS5: Re-L+M-DGM	-	-	-	0.16	0.26	0.35	0.51	-	-	26.56
CS6: DSP-Ba	-	1.90	2.13	-	-	-	-	-	-	-
CS7: PMR+DBM-T-S	-	-	-	-	-	1.13	1.70	1.48	1.86	-
CS8: PMF+DBM-T-S	-	-	-	-	-	1.08	1.68	1.49	1.86	-
CS9: FS(RB)+R(SB) -L(RB) +Ba(SB)-DGM	-	1.01	1.07	0.23	0.65	-	-	-	-	14.17

*dhaincha biomass as green manure addition

Table 7.18 Rice equivalent yield, REY (t/ha) of different cropping systems during kharif, 2024, rabi, 2024-25 & zaid, 2025

Cropping system	Rice equivalent yield, 2024-25												System	
	Total kharif, 2024	Rabi, 2024-25								Zaid, 2025				
		Fodder Berseem (4 cuts)	Wheat /barley		Lentil		Mustard		Total	Sunflower				Total
			Grain	Straw	Seed	Stover	Seed	Stover		Seed	Stover			
CS1: R-W (FP)	3.44	-	2.43	0.40	-	-	-	-	2.83	-	-	-	6.27	
CS2: R-W-DGM	3.40	-	2.72	0.28	-	-	-	-	3.00	-	-	-	6.40	
CS3: R-Ba-DGM	3.30	-	1.54	0.22	-	-	-	-	1.76	-	-	-	5.06	
CS4: R-Berseem	3.47	2.88	-	-	-	-	-	-	2.88	-	-	-	6.35	
CS5: Re-L+M-DGM	2.93	-			0.48	0.03	0.91	0.02	1.44	-	-	-	4.38	
CS6: DSP-Ba	1.23	-	1.64	0.23	-	-	-	-	1.87	-	-	-	3.11	
CS7: PMR+DBM-T-S	1.27	-	-	-	-	-	2.93	0.07	3.00	4.68	0.08	4.76	9.03	
CS8: PMF+DBM-T-S	1.14	-	-	-	-	-	2.81	0.07	2.88	4.73	0.08	4.81	8.84	
CS9: FS(RB)+R(SB) - L(RB) +Ba(SB)-DGM	3.24	-	0.87	0.11	0.68	0.07	-	-	1.73	-	-	-	4.97	

Note: Price of different commodities used for the calculation of REY: MSP of Paddy (common): Rs 2300, Paddy straw: Rs 100, Green fodder: Rs 250, Pearlmillet grain MSP: Rs 2625, Pearl millet stover: Rs 250, Dhaincha seed: Rs 9000 and Dhaincha stover: Rs 150 per quintal, MSP of Wheat: Rs 2425, MSP of Barley: Rs 1980, MSP of Lentil: Rs 6700, Wheat/barley/lentil straw/berseem green fodder: Rs 250, MSP of mustard: Rs 5960, MSP of Sunflower: Rs 7280, Mustard/Sunflower stover: Rs 100 per quintal.

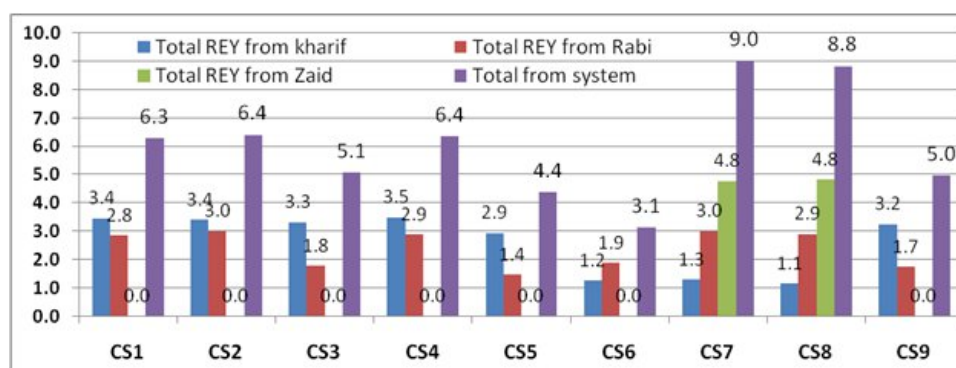


Fig 7.17 Rice equivalent yield (t/ha) by different cropping systems under soidic soil environment

Table 7.19 Organic carbon content (%) and DHA (ug/ml/hr) in soil after harvesting of rabi crop 2025

Cropping system		Organic carbon, %		DHA, ug/ml/hr
		0-15 cm	15-30 cm	
CS 1: Rice – Wheat (Farmers practice)		0.19	0.14	21.39
CS 2: Rice – Wheat – Dhaincha as green manure, DGM		0.21	0.15	30.15
CS 3: Rice – Barley – DGM		0.20	0.13	35.20
CS 4: Rice – Berseem		0.21	0.17	35.61
CS 5: Rice (Early variety) – Lentil + Mustard (6:1) - DGM		0.22	0.14	36.08
CS 6: Dhaincha for Seed – Barley		0.23	0.15	31.15
CS 7: Pearl millet (R) + Dhaincha (F) as BM– Toria – Sunflower		0.24	0.15	33.93
CS 8: Pearl millet (L) + Dhaincha (BC) as BM– Toria – Sunflower		0.23	0.15	28.53
CS 9: Fodder sorghum (RB) + Rice (SB) – Lentil (RB) + Barley (SB) - DGM (only in furrow)	Raised Bed	0.24	0.19	51.04
	Shunken bed	0.17	0.12	30.62
Initial		0.19	0.13	-

Note: Prices of different component crops considered for conversion of individual crop yield into rice equivalent yield (REY): Paddy grain @ Rs 23.69/kg, paddy straw @ Rs 1.00/kg, pearl millet grain @ Rs 27.75/kg, green fodder/ pearl millet stover @ Rs 2.50/kg, dhaincha seed @ Rs 90/kg and dhaincha stover @ Rs 1.5/kg.

Soil samples after harvesting of rabi season 2025 were taken and analyzed for organic carbon (OC) content and dehydrogenase activity (DHA). Data on organic carbon content shows that with the diversification or inclusion of legumes or 1/3rd crop residue management in Rice-wheat, there was a remarkable improvement in all the cropping systems. However, in case of Shunken beds of CS9 treatment OC content was lower than its initial value, this may be due to the turning of top soil (7.5 cm) from shunken bed area for making of raised bed. In case of DHA, raised beds of CS9 system recorded highest dehydrogenase activity (51.0 ug/ml/hr) followed by CS5, CS4, CS3, CS7, CS9 (Shunken beds), CS2, CS8 and CS1 systems (Table 7.19).

During *kharif* 2025, all the *kharif* crops were sown and treatments were executed as per approved technical programme for the year 2025-26. Among different *kharif* season crops, all the crops thrive well except pearl millet which fail to properly establish due to continuous rainfall during initial growth phase. Yield of various *kharif* season crops have been recorded and to compare it among different cropping systems, yield of different crops have been converted into rice equivalent yield (Table 7.20 and figure 7.18). Highest REY (3.68 t/ha) was recorded under CS 6: Dhaincha for Seed – Barley (3.68 t/ha), followed by CS2: Rice – Wheat – Dhaincha as green manure (3.29 t/ha), CS9: Fodder sorghum (Raised bed) + Rice (Sunken bed) – Lentil (Raised bed) + Barley (Sunken bed) - Dhaincha as green manure (3.28 t/ha), CS3: Rice-Barley-Dhaincha as green manure (3.22 t/ha), CS4:

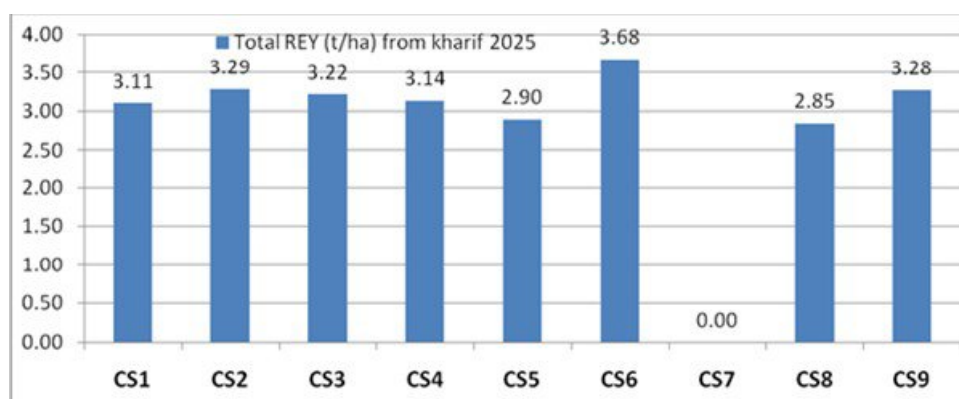


Fig 7.18 Rice equivalent yield (t/ha) by different cropping systems under soidic soil environment during kharif 2025

Table 7.20 Crop wise yield (t/ha) and rice equivalent yield, REY (t/ha) of different kharif season crops under various cropping systems under sodic environment during kharif, 2025

Cropping system	Dhaincha biomass addition	Fodder sorghum		Rice			Pearl millet/ dhaincha			Total REY
		Fodder	REY	Grain	Straw	REY	Grain/seed	Stover	REY	
CS1: R-W (FP)	-	-	-	2.90	4.96	3.11	-	-	-	3.11
CS2: R-W-DGM	-	-	-	3.14	3.52	3.29	-	-	-	3.29
CS3: R-Ba- DGM	-	-	-	3.07	3.45	3.22	-	-	-	3.22
CS4: R-Be	-	-	-	3.00	3.31	3.14	-	-	-	3.14
CS5: RE-L+M- DGM	-	-	-	2.78	2.85	2.90	-	-	-	2.90
CS6: DSP-Ba	-	-	-	-	-	-	0.89	4.86	3.68	3.68
CS7: PMR+DBM-T-S	2.61	-	-	-	-	-	0.00	0.00	0.00	0.00
CS8: RE -T-S-DGM	-	-	-	2.73	2.80	2.85	-	-	-	2.85
CS9: FS(RB) +R(SB) - L(RB)+Ba(SB) - DGM	-	13.85	1.46	1.74	1.89	1.82	-	-	-	3.28

Note: Prices of different component crops considered for conversion of individual crop yield into rice equivalent yield (REY): Paddy grain @ Rs 23.69/kg, paddy straw @ Rs 1.00/kg, pearl millet grain @ Rs 27.75/kg, green fodder/ pearl millet stover @ Rs 2.50/kg, dhaincha seed @ Rs 90/kg and dhaincha stover @ Rs 1.5/kg.

Rice – Berseem (3.14 t/ha), CS1: Rice – Wheat (3.11 t/ha), CS5: Rice (Early variety) – Lentil + Mustard (6:1) - Dhaincha as green manure (2.90 t/ha) and CS8: Rice early – Toria – Sunflower- dhaincha green manuring (2.85 t/ha) cropping system. However, due to poor establishment of pearl millet in CS 7: Pearl millet (R) + Dhaincha (F) as BM– Toria – Sunflower system, no any significant yield has been recorded from the pearl millet crop and only 2.61 t green biomass of dhaincha has been incorporated in soil as brown manuring.

Exploring production potential of economically important fruit crops and development of sustainable fruit production systems for salt affected soils (A.K Dubey, Arjun Singh and S.K. Jha)

Evaluation of different varieties of date palm under varying pH levels of high textured soils

Vegetative performance of four date palm varieties were assessed after two years planting under two soil pH conditions: (1) pH 9-10 and (2) pH <9.0, at the Shivri Research Farm. These all varieties were spaced at a distance of 7m x 7m and planted during 2023 on raised beds and pits filled with a mixture of soil, sand, and FYM in a 1:1:1 ratio. Varying performance were noticed under two regimes of pH. The Khuneji performed better at higher pH i.e., 9-10 in terms of survivability and growth. Growth data indicated significant variations in plant height, trunk girth, canopy spread, total cross sectional area and canopy volume after two years growth under both pH conditions. In soil with pH 9-10, the higher plant height was noted in Khuneji (1.38 m) and Khadrawi (1.33), similarly trunk girth, spread, canopy diameter and canopy volume were also found to be the highest in Khuneji followed by Khadrawi (Table 7.21). However, all varieties performed significantly better in pH <9. The highest plant height (1.62 m) was measured in Khuneji, while it was Khadrawi which had highest trunk girth (27.00 cm) followed by Medjool (26.67 cm). out of four varieties, Khuneji and Khadrawi had higher canopy spread, TCSA and canopy volume under pH <9. Compared to the higher pH, all four varieties performed remarkably better when planted in pH <9 soil under high-textured sodic conditions.

Table 7.21 Performance of date palm under varying pH of high textured sodic soils.

Characters	Plant height (m)	Plant girth (cm)	Canopy spread (m)		TCSA (cm ²)	Canopy volume (m ³)
pH above 9-10			E-W	N-S		
Khuneji	1.38	21.67	0.83	0.70	37.82	143.15
Medjool	1.08	15.18	0.82	0.43	18.36	31.70
Barhi	1.10	13.15	0.40	0.60	13.82	34.19
Khadrawi	1.33	15.88	1.33	0.59	20.10	57.32
pH <9.0						
Khuneji	1.62	25.33	1.12	1.17	51.43	368.66
Medjool	1.23	26.67	0.97	0.83	56.69	224.91
Barhi	1.15	23.33	1.05	1.20	43.79	222.86
Khadrawi	1.45	27.00	1.17	0.97	64.89	389.53
CD at 5%	0.14	3.45	0.34	0.27	6.45	15.23

Evaluation of open filed pedoponics planting system (OFPPS) for shallow rooted fruit crops under high pH conditions of highly textured sodic soils

An experiment was conducted with five shallow-rooted fruit crops: pomegranate (var. Bhagwa), pummelo (var. Pusa Arun), sweet orange (var. Pusa Sharad), lemon, custard apple, and guava (var. CISH Sweta) under high pH conditions in highly textured sodic soils. Polythene bags of 100-gauge, measuring 3 x 2 feet, were filled with a mixture of virgin sodic soil, sand, and FYM (1:1:1) and inserted into previously dug pits measuring 4 x 3 feet. Two holes were made in each bag to drain excess water. Twelve saplings of each crop were planted in these bags in two rows. Control plants were planted on the same raised beds using the traditional planting method. Due to the non-survivability of control plants, data could not be recorded for the controls. Except pomegranate, all other fruit crops such as pummelo, sweet orange, and lemon, guava and custard apple performed satisfactorily in terms of plant height, trunk circumference, and mortality. The custard apple (1.87 m) had highest plant height followed by lemon (1.83 m) and guava (1.82 m), while TCSA was measured highest in guava (2875.41 mm²) followed by lemon and custard apple (Table 7.22). Likewise, canopy volume was also found to be the higher in guava and lemon after two year of growth. Observations on chlorophyll fractions, chlorophyll 'a' to 'b' ratio, and relative water content (RWC) revealed variations among treatments. Chlorophyll 'a' (1.84 mg/g fwt), chlorophyll b (1.15 mg/g fwt) and total chlorophyll (2.93 mg/g fwt) were highest in pomegranate, followed by custard apple and lemon. The chlorophyll a/b ratio was recorded highest in lemon (2.45), followed by pomegranate (1.60). Similarly, RWC varied among crops, with pomegranate, sweet orange and acid lime showing more than 70% RWC (Table 7.22). Lemon and guava has started flowering and fruiting after two years of growth and lemon yielded 60 fruits/tree, while guava yielded 24 fruits/tree (Table 7.22 and 7.23).

Evaluation of dragon fruit varieties in different media and planting methods in high textured sodic soils

Two dragon fruit varieties (red-pulped and white-pulped), were evaluated for their performance under different planting methods and growing media. The experiment consisted of three planting methods: Traditional planting (TP, T1), Alternate pit planting (APP, T2), and (3) Open-Field Pedoponics planting (OFPP, T3); and three growing media:

Table 7.22 Performance of shallow rooted fruit crops under high pH >10 planted in of open field pedoponics planting system (OFPP)

Crop/variety	Plant height (m)	Trunk diameter (mm)	TCSA (mm ²)	Canopy volume (m ³)	Canopy diameter (m)
Pomegranate 'Bhagwa'	0.93	22.18	782.80	2.79	0.850.80
Pummelo 'Pusa Arun'	0.77	21.99	774.70	1.58	0.680.80
Sweet orange 'Pusa Round'	1.43	35.23	1969.09	4.74	0.821.05
Lemon	1.83	38.62	2372.93	28.36	1.832.27
Custard apple	1.87	32.79	1718.84	3.49	0.680.73
Guava 'CISH Sweta'	1.82	42.77	2875.41	29.22	2.052.12
CD at 5%	0.39	6.56	309.21	4.56	0.480.56

Table 7.23 Performance of shallow rooted fruit crops under high pH >10 planted in open field pedoponics system (OFPP)

Crop/variety	Chlorophyll 'a' (mg/g fwt)	Chlorophyll 'b' (mg/g fwt)	Total Chlorophyll (mg/g fwt)	a/b ratio	RWC (%)	No of fruits/ tree
Pomegranate 'Bhagwa'	1.84	1.15	2.93	1.60	75.74	3.00
Pummelo 'Pusa Arun'	0.76	0.65	1.35	1.17	72.55	
Sweet orange 'Pusa Round'	0.97	0.85	1.72	1.14	74.31	
Lemon	1.25	0.51	1.76	2.45	69.56	60.33
Custard apple	1.32	1.05	2.35	1.26	68.55	
Guava 'CISH Sweta'	1.22	1.12	2.32	1.09	71.22	24.00
CD at 5%	0.07	0.05	0.08	0.03	2.67	

Table 7.24 Initial chemical composition of soils of experiment of open field pedoponics system (OFPP) of different fruit crops

Character	Soil depth	
	0-15 cm	15-30 cm
EC _{1:2}	0.77	1.01
pH _{1:2}	9.21	9.44
EC _e	1.57	1.60
pH _e	8.69	8.71

M1 – Soil:sand:FYM (1:1:1), M2 – Soil:FYM (1:1), and M3 – Soil:cocopeat:FYM (1:1:1). In each planting system, two plants were established adjacent to a cement pole used for support. In all treatments, the central pit was used for fixing the cement pole. The planting media were filled into the designated pits according to the treatment. In T1, planting was done in both pits adjacent to the pole. In T2, planting was carried out in alternate pits, while the remaining pits were also filled with the same growing media. In the OFPP system (T3), polyethylene/gunny bags (100 × 30 cm) filled with the respective planting media were placed in pre-dug pits on both sides of the cement poles. A proper drainage system was provided in all treatments to avoid waterlogging.

Data pertaining to plant height and cladode length indicated significant effect of media and planting system. Mean effect of media exhibited highest plant height in M3 medium (1.80 m), while mean effect of planting system showed highest plant height in OFPP and lowest was found in TP in both varieties. Furthermore, combined effect suggested higher plant height in both varieties while planting was done following OFPP system in

Table 7.25 Growth and survival of dragon fruit planted in Alternate pit Planting system and OFPP compared to traditional planting system in different growing media under high textured sodic soils

Treatment	Plant height (cm)		Mean	
Red pulped	M1	M2	M3	
TPS	1.55	1.49	1.80	1.61
APP	1.70	1.67	1.70	1.69
OFPP	1.85	1.80	1.90	1.85
Mean	1.70	1.65	1.80	
White pulped				
TP	1.28	1.68	1.48	1.48
APP	1.47	1.11	1.58	1.39
OFPP	1.45	1.59	1.97	1.67
	1.40	1.46	1.68	
Red pulped	Cladode length (m)			
TP	0.51	0.60	0.91	0.67
APP	0.71	0.87	0.74	0.77
OFPP	0.87	0.82	0.95	0.88
	0.70	0.76	0.87	
White pulped				
TP	0.30	0.64	0.46	0.47
MP	0.65	0.50	0.50	0.55
OFPP	0.71	0.49	0.53	0.58
	0.55	0.54	0.50	

TP; Traditional planting, APP; Alternate Pit Planting, OFPP, Open Field Pedoponics Planting, T1, Soil: sand: FYM (1:1:1); T2, Soil:FYM (1:1); T3, Soil:cocopeat:FYM (1:1:1)

M3 medium. The length of cladode varied across treatments. Irrespective of varieties and planting system, the highest length of cladode was measured in M3 media in red pulped variety, while M1 and M2 media exhibited superiority for white pulped variety over M3. Considering the effect of planting system alone produced longest cladode in both varieties. Joint effect of variety, media and planting system showed that in red pulped variety, the longest cladode was noted in M3 media while planted under OFPP. However, in white pulped highest length of cladode was measured in M1 media in OFPP. Compared both varieties, red pulped variety exhibited superiority in terms of plant height and cladode length under each planting system and media (Table 7.25).

Media and planting system significantly impacted canopy spread in dragon fruit varieties (Table 7.26). Considering the effect of media alone, M2 and M3 media was found equally effective with respect to canopy spread in both directions. The mean effect of planting system indicated better performance of OFPP in both side canopy. The combined effect of treatments showed highest canopy diameter (E-W and N-S) with M2 media while red pulped variety planted under OFPP. However, in white pulped, M1 media had longer canopy diameter in both directions while planted under OFPP.

DHA activities also showed significant alterations due treatment alone and jointly (Table 7.26). The higher MDH activities were noted in M2 media in Red pulped variety, but it was non-significant in white pulped variety. Mean effect of planting system indicated superiority of M3 media for red pulped variety, but it was found to be non-significant for white pulped variety. The combined effect showed highest MDH activities in OFPP in M2

Table 7.26 Canopy spread of dragon fruit planted in Alternate Pit Planting system and OFPP compared to traditional planting system in different growing media under high textured sodic soils

Treatment	Canopy spread (m) E-W		Mean	
Red pulped	M1	M2	M3	
TPS	1.07	1.08	1.38	1.18
APP	1.42	1.50	1.38	1.43
OFPP	1.70	1.93	1.78	1.80
Mean	1.40	1.50	1.51	
White pulped				
TP	0.75	1.06	0.85	0.89
APP	0.95	0.71	0.86	0.84
OFPP	1.55	1.08	0.80	1.14
	1.08	0.95	0.84	
Red pulped	Canopy spread (m) E-W			
TP	1.32	1.17	1.46	1.32
APP	1.55	1.37	1.28	1.40
OFPP	1.69	1.95	1.77	1.80
	1.52	1.50	1.50	
White pulped				
TP	0.38	0.82	1.08	0.76
MP	0.78	0.79	0.76	0.78
OFPP	1.52	1.30	0.83	1.22
	0.89	0.97	0.89	
	Mean DHA (IU/ml)			
Red pulped				
TP	17.37	17.73	21.21	18.77
APP	16.31	16.64	18.76	17.24
OFPP	24.81	32.08	22.62	26.50
	19.50	22.15	20.86	
White pulped				
TP	17.53	19.34	13.48	16.78
MP	17.77	19.03	14.49	17.10
OFPP	20.38	16.04	19.55	18.66
	18.56	18.14	15.84	

TP; Traditional planting, APP; Alternate Pit Planting, OFPP, Open Field Pedoponics Planting, T1, Soil: sand: FYM (1:1;1); T2, Soil:FYM (1:1); T3, Soil:cocopeat:FYM (1:1:1)

media in red pulped variety, but it was M1 media which has higher MDH activities in white pulped variety. The data presented in table 7.27 clearly indicated variation among treatments. In red pulped variety, the mean effect of media showed highest fruits (9.00) in M2 followed by M3 (soil: cocopeat:FYM). Irrespective of media, planting system exhibited highest fruits in OFPP system (19.67) followed by TP (2.33). In white pulped also, mean effect of media and planting system showed that M2 media and OFPP produced higher fruits. Interaction between treatments showed highest fruit (27) in OFPP system under M2 media, similarly, in white fleshed also same combination had highest fruits.

Table 7.27 Yield of dragon fruit planted in Alternate Pit Planting system and OFPP compared to traditional planting system in different growing media under high textured sodic soils

Treatment	Yield (No of fruits)		Mean	
Red Flesh	M1	M2	M3	
TPS	0	0	7	2.33
APP	1	0	2	1.00
OFPP	18	27	14	19.67
Mean	6.33	9.00	7.67	
White Flesh				
TP	0	3	0	1.00
APP	0	0	0	0.00
OFPP	6	7	0	4.33
	2	3.33	0.00	

Table 7.28 Growth and survival of dragon fruit planted in Alternate Pit Planting system and OFPP compared to traditional planting system in different growing media under high textured sodic soils

Treatment	Fruit weight (g)		
Red Flesh	M1	M2	M3
TPS	176.67	171.00	-
APPS	-	169.00	186.00
OFPS	185.67	207.67	216.67
White Flesh			
TPS			
APPS			
OFPS	215.33	218.33	231.67
Red Flesh	Pulp (%)		
TPS	63.40	61.87	
APPS		58.53	64.47
OFPS	63.73	60.33	64.13
White Flesh			
TPS			
APPS			
OFPS	61.80	61.80	63.47
Red Flesh	TSS (%)		
TP	15.30	12.80	
MP		14.70	13.90
OFHP	14.70	14.60	15.30
White Flesh			
TP			
APP			
OFPS	11.80	12.20	13.40

TP; Traditional planting, APP; Alternate Pit Planting, OFPP, Open Field Pedoponics Planting, T1, Soil: sand: FYM (1:1:1); T2, Soil:FYM (1:1); T3, Soil:cocopeat:FYM (1:1:1)

Fruit weight, pulp recovery and TSS varied among treatments (Table 7.28). In red pulped varieties, no flowering and fruiting were observed in plants planted in APP in M1 medium and TP planting in M3 media. In white pulped variety, flowering and fruiting was noted in



IFS 1



IFS 2

OFPP in all media, while none plant produced flowering neither in TP nor APP in either medium. In red pulped variety, highest fruit weight (216.67 g), pulp recovery (64.13%) and TSS (15.60 °B) were recorded in M3 medium planted under OFPP. Almost similar pattern was noted in white pulped variety. It is worth mentioning that in both varieties, M3 medium and OFPP system had earlier flowering in both varieties. Harvesting span was noted from August to December.

Development of integrated farming system for resource poor farmers of sodic soil of Uttar Pradesh (A.K Dubey, A.K. Dixit, S.K. Jha, Arjun Singh, Deepa Hansraj Dwivedi (BBAU, Lucknow) and Aditya Kumar (NBFGFR)

Evaluation different models under high textured sodic soils

Three IFS models, each based on different commodities, were tested alongside the traditional farming system known for high-textured sodic soils.

IFS-1: Fish+water+ chestnut-date palm-vegetables based model

This system has total area of 6300 sqm (pond covering an area of 4100 sqm, 800 sqm meter for vegetable production and 1400 sqm was used for roads and paths. A total 30 trees of Khuneji variety of date palm was planted on the three side of embankment of the pond at a distance of 7 meter. Additionally, 10 plants of sweet orange/pummelo were also planted along the fourth side of the embankment. During the monsoon season, bottle gourd and during winter season lettuce, tomato, brinjal, cauliflower etc., were planted in area earmarked for vegetables. The vegetables yielded a harvest that has market value of Rs 1.42 lakh/. The performance of winter crops such as spinach, cauliflower and lettuce, as well as in rainy season crops such as bottle gourd was found highly satisfactory. Cauliflower and lettuce was found to be highest remunerative. The vegetative growth performance of the date palm variety 'Khuneji' was found highly satisfactory. Due to non-availability of water, fish and water chest cultivation was not initiated.

IFS-2: Fish- Horticulture (guava- marigold) -fodder crop-dairy based model for high textured sodic soils

A total 5700 sqm area was earmarked for this model. This model is based on fish-horticulture-dairy. In this model, 3000 sqm area was earmarked for fish pond, 600 sqm for guava plantation, 1000 sqm for fodder/marigold, 300 sqm was allotted to dairy unit and remaining area of 800 sqm was allocated to paths and roads. The guava varieties BNR and CISH Sweta was planted at distance of 4m x 4m. The total income from this system was Rs 25000/- from selling of fish. A cow was also kept in this system utilizing and Rs 30440/- was realized from milk.in addition FYM and cow urine was added to the filed. A total Rs 60880/- was realized from the system. Guava plant did not start flowering so far.

IFS-3: Fish-field crop (paddy+wheat+mustard) -Horticulture (vegetables + fruit) based model for high textured sodic soils

A total 6000 sqm area was allotted in this system. A pond (1500 sqm) for fish culture and two varieties of fish was applied in the pond, vegetable (400 sqm area), 650 sqm for fodder, field crops (1700 sqm) was allotted and remaining was used for road and paths. The embankment of pond was used for perineal grasses in three directions and forth direction was utilized row planting of fruit crops and the 10 plants of different citrus species have been planted. Yield of wheat, paddy and different vegetables were recorded. During summer monsoon season, bottle gourd was planted, however, lettuce, brinjal,



IFS 3

tomato and cauliflower were planted. Vegetables were harvested and yield was recorded. This year, Rs 35000/- was earned from selling of fish plush Rs 33934/- was realized from vegetables. In addition, Rs 6180/- was earned from paddy and wheat from an area of 3000 sqm. In addition, Rs 30440 was obtained from milk. Grass planted on the ridge of pond, beseem (3200 kg), paddy straw and wheat straw was used as fodder for cow. Cow manure and urine was used for cultivation of wheat, paddy and also in fish ponds. The total Rs 102725/- was realized from the system.

Control: Traditional farming system: Rice-wheat based traditional system

Traditional rice-wheat/mustard system was also tested for comparison with above mentioned model. Total 2300 sqm area was used in this system. A yield of 5 q and 8 q of paddy and wheat was realized from this system. In addition, wheat straw (12 q) and paddy straw (8 q) was also obtained from the system. his system yielded Rs 41705 from an area of 2300 sqm

Sodic Soil management through farmers adaptable technological interventions for boosting productivity of Hardoi (HCL-CSSRI Consultancy project) (Sanjay Arora, Atul K. Singh, C.L.Verma, S.K. Jha, A.K. Dubey and R.K. Yadav)

During Rabi 2024-25 and Kharif 2025, demonstrations of salt tolerant varieties of wheat, mustard and paddy, reclamation and amelioration technologies at CATT, Sandila has been continued. These demonstrations were visited by 14 batches of farmers representing 7 blocks of Hardoi district during 2025. On-farm assessment of varieties demonstrated in crop cafeteria and technological interventions including microbial bioformulations, nano formulations was done. Soil samples of about 1272 farmers selected for demonstration of halophilic microbial bioformulation based amelioration coupled with salt tolerant varieties was done. Three on-site farmer's trainings were organized in different blocks of Hardoi district with total beneficiary of 136 farmers to boost productivity of sodic soils. On-farm demonstrations in wheat and mustard were conducted during rabi 2024-25 and paddy in Kharif 2025 on about 1064 farmers field in 8 blocks of Hardoi district with moderate to high sodic soils. Different interventions like residue management through Halo-CRD, salt tolerant variety, dhiancha and liquid formulation Halo-Mix.

On-farm demonstrations

Crop Cafeteria

In a Crop Cafeteria, eleven varieties of paddy that includes CSR 101, CSR 56, CSR 10, CSR 30, CSR 23, CSR 36, CSR 60, CSR 46, N-97, Ganga kaveri and Damini were demonstrated on sodic soil at CATT center, Sandila, Hardoi. Paddy variety CSR-36 and CSR-46 out performed with grain yield of 0.63 kg/m² followed by Ganga Kaveri with yield of 0.58 kg/m² and N-97 with yield of 0.57 kg/m² compared to Damini with yield of only 0.36 kg/m² in sodic soil of pH 9.32. The growth and yield observations for performance of varieties are presented in Table 7.29.

Technology Demonstrations

Technology demonstration was continued at CATT demonstration plots where seven improved technologies for sodic soil management were demonstrated in paddy (variety CSR 46). These include liquid halophilic bioformulations Halo Azo, Halo PSB, Halo Zinc and Halo-Mix, Compost enricher block and nano-formulations Nano Zinc and Nano NMN as foliar spray compared with spray of zinc sulphate. It was observed that plant height was

Table 7.29 Performance of paddy varieties in crop cafeteria plots

Variety	Avg Plant Height (cm)	No. of tillers (Avg)	Avg Production of Grains (kg/m ²)	1000 grainweight (g)
CSR-101	86.0	11.0	0.355	28.5
CSR-56	91.0	11.5	0.520	36.5
CSR-10	79.0	11.5	0.460	35.0
CSR-30	127.5	10.5	0.440	30.0
CSR-23	92.0	12.5	0.545	31.5
CSR-36	108.5	12.5	0.610	33.5
N-97	100.0	13.0	0.575	29.0
CSR-60	111.0	14.0	0.545	32.0
CSR-46	116.0	14.5	0.610	31.0
Ganga Kaveri	133.5	13.5	0.585	23.5
Damini	88.0	8.5	0.360	18.5

Table 7.30 Paddy growth and yield as influenced by different technological interventions in sodic soils

Technology	Plant Height (cm)	Number of tillers	Number of Panicle	Grain Yield (kg/m ²)
Control	92	11	10	0.33
Compost EB	110	14	13	0.47
Halo-AZO	105	12	12	0.49
Halo-PSB	112	14	12	0.53
Halo-Zinc	107	10	12	0.47
Halo-Mix	115	13	12	0.57
Nano Zinc	101	10	9	0.53
Nano NMN	115	13	12	0.54

Table 7.31 Paddy performance as influenced by sodic soil reclamation technological interventions

Technology	Plant height (cm)	Number of tillers	Number of Panicles	Grain yield (kg/m ²)	1000 weight (g) grain
CEA	115	10	9	0.55	27
Halo-Cal-D (Mrida sudharak)	105	10	8	0.61	28
Halo-CaRe	98	7	7	0.57	24
F-SA 2	86	10	10	0.42	24
Mineral Gypsum	112	9	8	0.61	29
Marine Gypsum	120	10	9	0.58	26

maximum of 115 with the application of Halo-Mix and Nano-NMN while minimum in control (Table 7.30). Grain yield was maximum of 0.57 kg/m² in Halo-Mix followed by 0.54 kg/m² in Nano-NMN, 0.53 kg/m² each in plots applied with Halo-PSB and Nano-Zinc.

Technological interventions in paddy (variety CSR46) was executed in demonstration plots in sodic soils of Sandila, Hardoi during Kharif 2025. It was observed that maximum plant height was recorded in marine gypsum treatment followed by compost enricher block amendment. Grain yield was maximum of 0.61 kg/m² in mineral gypsum and Halo-Cal-D treated plots followed by 0.58 kg/m² in plots treated with marine gypsum and 0.57 kg/m² with Halo-CaRe as amendment (Table 7.31). Similarly, 1000 grain weight was maximum in marine gypsum treatment followed by Halo-Cal-D showing an increase of about 20% over Halo-CaRe and F-SA2 applications.

Table 7.32 Effect of reclamation technological interventions on sodic properties

Treatment	Depth	EC (dS/m)	pH
FSA-2	0-15	0.51	7.69
	15-30	0.37	8.90
	30-45	0.50	9.63
Marine Gypsum	0-15	1.44	8.23
	15-30	0.39	9.13
	30-45	0.58	9.73
Gypsum	0-15	0.17	8.35
	15-30	0.75	9.25
	30-45	0.50	9.97
CEB	0-15	0.47	8.26
	15-30	0.43	8.95
	30-45	0.37	9.47
Halo Care	0-15	0.91	8.73
	15-30	0.26	8.95
	30-45	0.314	9.21
Halo-Cal-D	0-15	0.449	8.89
	15-30	0.213	8.76
	30-45	0.413	9.39

Maximum reduction in surface soil pH (7.69) was observed in FSA-2 followed by 8.23 in marine gypsum and 8.26 in compost enricher block application for reclaiming sodic soil of pH 9.36. Further sub-soil pH was also improved with the FSA-2, compost enricher block, Halo-CaRe and Halo-Cal-D application in paddy (CSR-46) (Table 7.32).

Horticultural demonstrations in sodic soils of Hardoi

Fourteen horticultural demonstrations on 1 bigha each representing 7 blocks were established with guava (L-49) orchard on farmers field in sodic soils of Hardoi. The pH₂ of surface soil ranged from 8.33 to 9.42 where guava were planted using planting mixture including gypsum, Halo-Mix and compost treated with compost enricher block. The success of establishment was 97% cumulating to all the sites.

IFS Demonstration Model in sodic

Total of 5 kg fish fingerlings of different species were released in the pond size of 600 m² in the IFS demonstration model developed in sodic soil of Sandila, Hardoi. The pond water was having pH of 8.87 and EC 0.458 dS/m. Fingerlings of Catla, Rohu and Grass carp were released in the pond. On the dykes of the pond, plantation of napier grass and lemon plants were established.

Sulphur oxidizing bacteria for enhancing efficiency of chemical ameliorants for sodic soils

Bio-chemical characterization of the 13 isolated sulphur oxidizing bacteria were continued as per standard protocol and screened 3 promising salt tolerant strains based on solubility of insoluble S and production of IAA (ranging from 7.41 to 21.24 µg/ml) as well as ACC deaminase activity which was positive in 6 of the 13 isolates. The other bio-chemical tests for each bacterial isolate are presented in Table 7.33.

Out of the 13 sulphur oxidizing bacterial isolates, 8 isolates showed tolerance upto 12.5%

Table 7.33 Bio-chemical characterization of the isolated sulphur oxidizing bacteria

Isolates	Catalase Test	Citrate utilization	Starch Hydrolysis	Gelatin lequification	MR	IAA (µg/ml)		ACC
						Qual.	Quan.	
SOHB-1	-ve	+ve	-ve	-ve	+ve	+ve	19.151	-ve
SOHB-2	-ve	-ve	-ve	+ve	-ve	-ve	14.849	-ve
SOHB-3	+ve	+ve	-ve	-ve	-ve	-ve	7.756	-ve
SOHB-4	+ve	+ve	+ve	-ve	+ve	-ve	9.616	+ve
SOHB-5	-ve	+ve	-ve	-ve	+ve	+ve	15.779	+ve
SOHB-6	+ve	-ve	-ve	+ve	+ve	+ve	19.151	-ve
SOHB-7	-ve	-ve	-ve	-ve	-ve	+ve	7.407	-ve
SOHB-8	+ve	-ve	+ve	-ve	-ve	+ve	12.407	-ve
SOHB-9	+ve	+ve	-ve	-ve	+ve	+ve	8.105	+ve
SOHB-10	+ve	-ve	-ve	-ve	+ve	-ve	18.686	+ve
SOHB-11	-ve	-ve	-ve	-ve	-ve	-ve	14.733	+ve
SOHB-12	+ve	-ve	-ve	-ve	-ve	-ve	18.570	+ve
SOHB-13	+ve	+ve	-ve	-ve	-ve	+ve	21.241	-ve

Table 7.34 Change in pH and sulphur oxidation by isolated sulphur oxidizing bacteria

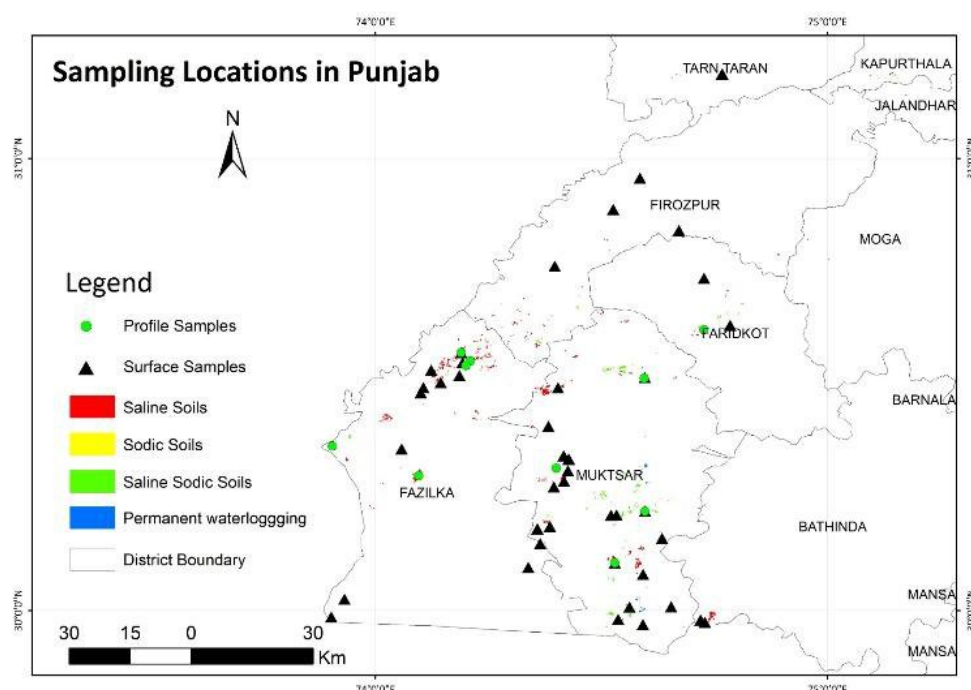
ID of the SOB isolate	Zone size	Reduction of pH in Thiosulphate broth (initial pH 8.0)	Sulphur @450nm	Sulphur (mg/L)
SOHB-1	8	7.26	0.417	1.259
SOHB-2	10	6.14	0.638	3.811
SOHB-3	10	6.12	0.744	5.035
SOHB-4	5	5.47	1.235	10.704
SOHB-5	13	6.89	0.914	6.998
SOHB-6	6	6.15	1.028	8.314
SOHB-7	2	6.86	0.621	3.614
SOHB-8	2	5.28	0.743	5.023
SOHB-9	2	5.12	1.103	9.480
SOHB-10	3	5.38	0.430	1.409
SOHB-11	14	5.53	0.704	4.573
SOHB-12	14	4.85	0.855	6.316
SOHB-13	4	6.72	0.392	0.970
Control		7.64	0.281	0.678

NaCl while all isolates tolerated upto 10.0% NaCl concentration in the culture media. Similarly, all the isolates were able to tolerate pH ranging from 5 to 11 in the liquid media indicating halotolerance of the isolates. In broth, reduction in pH was also noticed ranging from 4.85 to 7.26 with the initial pH of 8.0 indicating production of acids by the organisms. Sulphur oxidation to the extent of 10.704 mg/L by bacterial isolate SOHB-4 followed by 9.480 mg/L by SOHB-9 and 8.314 mg/L by isolate SOHB-6 compared to 0.678 mg/L in uninoculated control (Table 7.34).

Geospatial mapping of sodic soils in the parts of Punjab for estimation of gypsum requirement (PRSC Collaborative project) (Sanjay Arora, CCPI)

Using historical information, sites were identified using remote sensing imageries and geocoordinates marked for sampling from different districts of Punjab.

Fig 7.19 Geo-coordinate points of probable salt affected soils of Punjab



Soil sampling will be conducted in the probable sites after harvest of rabi crops followed by laboratory assessment of soil properties in relation of ESP and gypsum requirements.

Characterization and standardization of agro-techniques for millet varieties and land races in salt-affected soils to boost productivity (Ravikiran K.T., Sanjay Arora and Arjun Singh)

As part of the first objective, exploratory surveys were conducted to collect millet landraces from farmers who have been cultivating these crops traditionally over several generations. Field visits were carried out across multiple districts, including Sitapur, Hardoi, Amethi, Raebareli, Bahraich, Gonda, Mau, Ghazipur, Azamgarh, Deoria, Ayodhya, Basti, Shravasti, Prayagraj, Pratapgarh, Chitrakoot, Kanpur, Kushinagar, and Sonbhadra. In addition, millet germplasm originating from Uttar Pradesh, along with associated GPS coordinates, was procured from the ICRISAT genebank, Hyderabad. In total, 149 landraces were assembled, comprising 20 genotypes of sorghum, 20 of pearl millet, 42 of finger millet, 14 of foxtail millet, 28 of kodo millet, 32 of barnyard millet, one proso millet genotype, and seven little millet genotypes (Fig. 7.20). These landraces were sown in February 2025 at the Experimental Research Farm, Shivri, CSSRI Regional Research Station, Lucknow, for seed multiplication. Of these, 144 genotypes successfully germinated. Distinctness, Uniformity, and Stability (DUS) characterization revealed substantial phenotypic variation both within and among the different millet species, underscoring the richness of the collected germplasm.

A preliminary observational experiment was conducted to identify millet groups capable of surviving under extreme sodicity (soil pH > 9.6). Performance of various millet crops in high sodicity can be seen in the table 7.35. Three randomly selected landraces from each millet group were evaluated under control and sodic conditions until physiological maturity in a pot experiment. The results, summarized in Table 7.36, demonstrated that only finger millet and barnyard millet were able to complete their life cycle up to seed set under high sodicity, indicating their inherent tolerance. In contrast, the remaining millet

Table 7.35 Performance of various millet crops in high sodicity (pH > 9.6)

Millet	Response in high sodicity
Pearl millet	Poor germination followed by seedling death
Sorghum	No germination
Kodo millet	Seedling death
Barnyard millet	Completed lifecycle
Finger millet	Completed lifecycle
Foxtail millet	Poor germination, seedling death, death at vegetative stage
Proso millet	Death at vegetative stage
Little millet	Seedling death

Table 7.36 Mean grain yield per plant (g) of landraces belonging to different millets tested under normal (pH₂ ~ 7.5), moderate sodic (pH₂ ~ 9.0) and high sodic (pH₂ ~ 9.7) conditions

Mille group	Normal	Moderate sodic	High sodic	% reduction	
				Moderate sodic	High sodic
Sorghum	9.53	8.95	-	6.09	-
Pearl millet	16.23	9.59	-	40.91	-
Finger millet	1.95	-	1.44	-	26.15
Foxtail millet	3.16	-	-	-	-
Barnyard millet	2.01	1.91	1.84	4.98	8.46
Kodo millet	3.16	-	-	-	-

Fig 7.20 Crop wise millet landraces collected from various millet growing areas of Uttar Pradesh

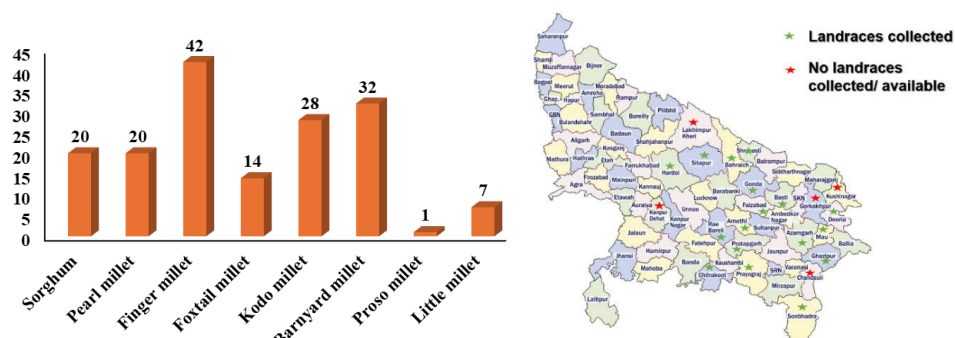


Fig 7.21 Field evaluation of millet landraces under normal (pH₂ ~ 7.5), moderate sodic (pH₂ ~ 9.0) and high sodic (pH₂ ~ 9.7)



groups either failed to germinate or succumbed at the seedling or vegetative stages. During the subsequent Kharif season, 137 millet genotypes successfully multiplied in the previous summer were evaluated under three soil conditions: normal (pH₂ ~ 7.5), moderately sodic (pH₂ ~ 9.0), and highly sodic (pH₂ ~ 9.7), along with widely cultivated varieties as checks (Fig 7.21). Agronomic data recorded to date revealed that only finger millet and barnyard millet survived under high sodicity, corroborating the pot experiment findings. Under moderately sodic conditions, sorghum, pearl millet, finger millet, and

barnyard millet exhibited appreciable growth, whereas foxtail and kodo millet failed to establish even at this stress level. All millet groups, however, showed luxuriant growth under normal soil conditions. Comparative analysis of grain yield reduction under high sodicity relative to the control revealed a mean reduction of 26.15% in finger millet, whereas barnyard millet exhibited remarkable resilience with an exceptionally low mean reduction of only 8.46%. This tolerance was also evident under moderate sodicity, where barnyard millet showed a yield reduction of merely 4.98%. In contrast, pearl millet experienced substantial yield losses under moderate sodicity (40.91%), largely attributable to sodicity-induced waterlogging, while sorghum showed moderate yield reduction (6.09%). Notably, sorghum displayed tolerance to sodicity-associated waterlogging stress, highlighting its adaptive potential under moderate sodic conditions.

Understanding the impact and the fate of microplastic contaminants in agricultural ecosystem Vis a Vis developing pathways for future abatement strategy (Arjun Singh, Sanjay Arora and Ram Kishore Fagodiya)

As per the first activity of the project the presence of microplastics in the agricultural soil as well as irrigation water was assessed in agricultural fields of Shivari, district Lucknow, Uttar Pradesh. In this regard sampling of the soil (9 sites) and irrigation water from borewell (n=4) were collected to detect presence of microplastics. The borewell water does

Fig 7.22 Occurrence and distribution of microplastic contaminates across the sampling sites representing agricultural fields of Shivari, Lucknow, Uttar Pradesh

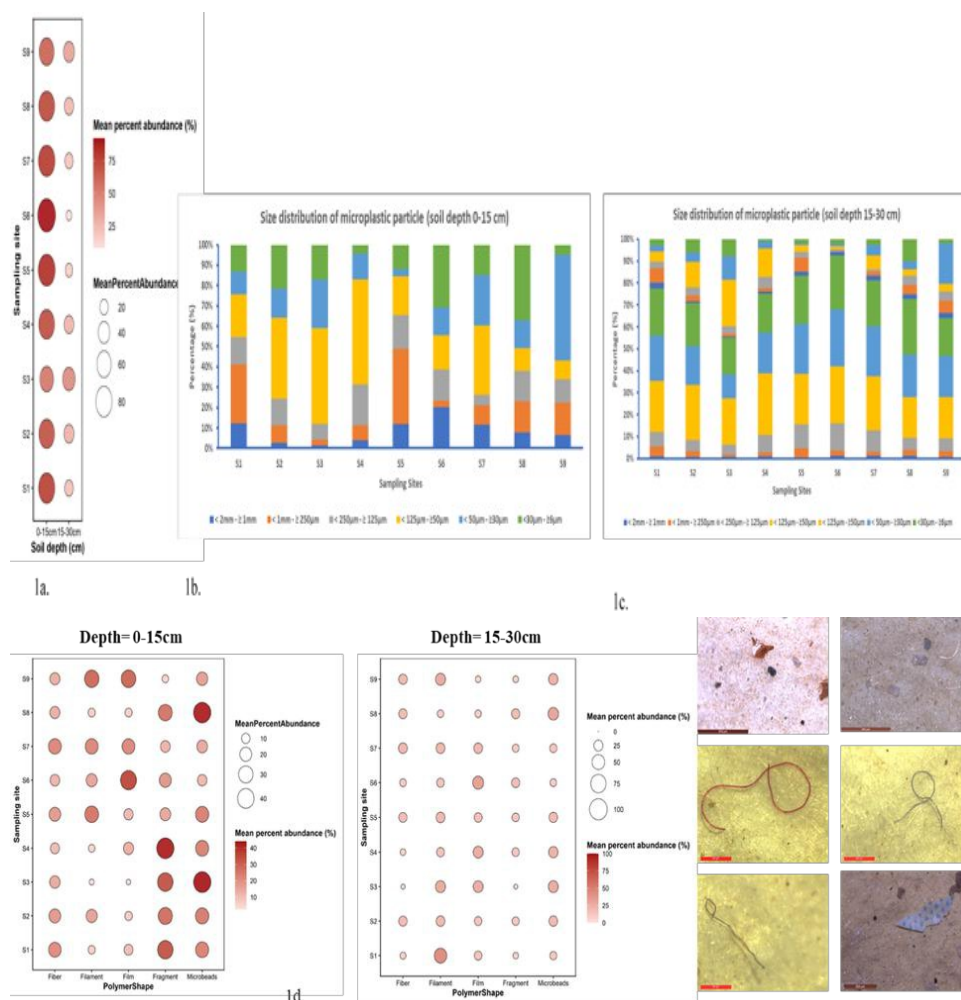
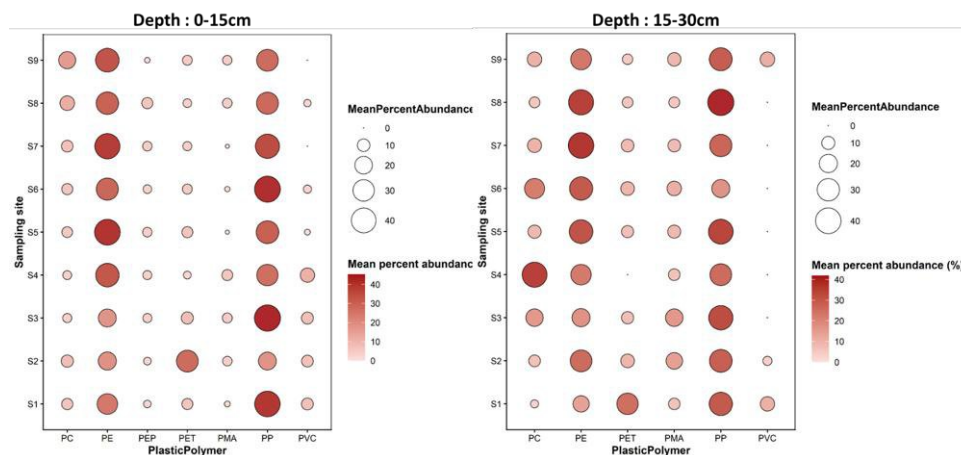


Fig 7.23 Fingerprints of microplastic polymers across the sampling sites representing agricultural fields of Shivari, Lucknow, Uttar Pradesh.



not showed any presence of microplastic, but the analysis of the soil samples from the agricultural fields in Shivari, Lucknow revealed contamination with microplastic. The abundance of the microplastic were detected from 0-30 cm of the soil depth, in which at 0-15cm of depth the particles abundance was high whereas lower abundance was recorded at 15-30 cm depth (Figure 7.22a,b). Among the sites most contaminated site was S9 (2336 MP particles Kg^{-1} soil), whereas site S6 (326 MP particles Kg^{-1} soil) had the lowest abundance. Distribution with respect to the size indicated MP particle in the range of $125\mu\text{m}$ - $\geq 50\mu\text{m}$ were the most abundant whereas the smallest MP particle size recorded in the study was of $6\mu\text{m}$ size in all the sites and in both the depths (Figure 7.22c). The shape wise characterization of MP particle revealed that fragments and microbeads were the most abundant in the soil (Figure 7.22d). The plastic polymer fingerprints indicated prevalence of polyethylene, polyvinyl chloride, polypropylene, poly-carbonate in the sampled sites (Figure 7.23). This is the first report of detection of microplastic in agricultural soil from Lucknow region and which further indicates risk to the environment and the human population in and around this region.

Reclamation and Management of Salt Affected Vertisols

Improved Agronomic Practices for Enhancing Indian Mustard (*Brassica juncea* L.) Yield under Saline Vertisols of Gujarat (Monika Shukla, and Anil R. Chinchmalatpure, David Camus and Bisweswar Gorain)

Oilseeds rank second globally after cereals in terms of area and production. Several studies have shown that saline groundwater with an EC of 6-7.5 dS m⁻¹ can be safely used for supplemental irrigation in mustard, with only a marginal reduction in yield. In the Bara tract, nearly 75% of the land is affected by subsurface soil salinity, and more than 50% of the area is irrigated using tubewells, where groundwater quality ranges from saline to highly saline. Consequently, *rabi* cropping is largely restricted to salt-tolerant crops.

Earlier, the potential of salt-tolerant mustard varieties developed by ICAR-CSSRI for saline Vertisols of Gujarat was explored; however, the yields obtained (8-10 q ha⁻¹) were significantly lower than the crop's potential. Refinement of region-specific agronomic practices could help improve mustard productivity under these conditions. In view of this, the present study was undertaken to evaluate the performance of different salt-tolerant Indian mustard varieties under saline water irrigation in saline Vertisols, and identify suitable planting methods and geometries for achieving higher mustard productivity in such environments.

EXPERIMENT-1

Salt Tolerant Mustard Varieties: Performance Evaluation under Saline Vertisols

Experiment was conducted with 6 salt tolerant varieties released from ICAR-CSSRI (CS 56, 58, 60, 61, 62 & 64) and one locally popular variety of Gujarat (GDM 4). At 30 DAS, CS 60 gave highest plant height (26.80 cm). At 60 & 90 DAS, CS 58 recorded the highest plant height (101.67 cm & 176.73 cm), which was statistically at par with CS 60 and CS 56, while the minimum was observed in GDM 4 (148.33 cm) (Table 8.1). Regarding branching, the number of primary branches were statistically non-significant and the maximum number of secondary branches was observed in CS 61 (19.00), followed by CS 58 and CS 62. Plant population per meter row length indicated better establishment in the CS series varieties. The highest number of pods per plant was recorded in CS 62 (258), followed by CS 61 and CS 64, while the lowest was observed in GDM 4. Highest seed yield was obtained from CS 62 (8.96 q ha⁻¹), followed by CS 61 (8.71 q ha⁻¹) and CS 58 (8.60 q ha⁻¹), whereas the lowest yield was recorded in GDM 4 (5.12 q ha⁻¹). A similar trend was observed for total biological yield, and stovar yield. Harvest index ranged from 17.95% in GDM 4 to 22.20% in CS 62, indicating more efficient partitioning of biomass towards seed yield in CS 62. Test weight varied from 3.84 g in GDM 4 to 4.73 g in CS 58. Oil content among varieties ranged from 38.32% in GDM 4 to 38.87% in CS 61. Erucic acid content showed noticeable variation, with the lowest value recorded in CS 61 (11.55%), while the highest was observed in CS 60 (15.75%). Overall, varieties CS 62, CS 61, and CS 58 performed better in terms of yield and associated traits compared to the other varieties, while GDM 4 recorded the lowest values for most of the parameters. These results indicate that salt tolerant CS series varieties, particularly CS 62 and CS 61, have superior growth, yield potential, and desirable quality attributes under the saline conditions of Vertisols as compared to the local variety.

The highest number of pods per plant was recorded in CS 62 (258), followed by CS 61 and

Table 8.1 Growth and yield parameters of different mustard varieties under saline water irrigation

Variety	Plant Height (cm)			No. of Branches		Plants per m Row Length	No. of Pods per Plant	Seed Yield (q ha ⁻¹)	Total Biological Yield (q ha ⁻¹)	Stovar Yield (q ha ⁻¹)	Harvest Index	Test Wt. (g)	Oil Content (%)	Erucic Acid
	30 DAS	60 DAS	90 DAS	Pri-ary	Sec-on-dary									
GDM 4	25.3	86.8	148.3	5.4	12.8	8.7	118.4	5.12	28.53	23.41	17.95	3.84	38.32	14.51
CS 56	25.7	99.3	172.9	5.7	16.4	10.8	184.3	8.40	39.23	30.83	21.51	4.52	38.77	14.90
CS 58	26.6	101.7	176.7	6.1	17.2	11.4	183.5	8.60	40.07	31.47	21.54	4.73	38.76	14.80
CS 60	26.8	100.2	173.5	6.1	16.7	11.4	182.5	7.82	37.46	29.65	20.89	4.66	38.55	15.75
CS 61	26.1	96.9	167.8	6.2	19.0	11.4	220.1	8.71	40.13	31.42	21.78	4.35	38.87	11.55
CS 62	25.0	93.0	161.1	6.2	17.1	11.4	258.0	8.96	40.35	31.39	22.20	4.37	38.75	15.06
CS 64	25.8	98.2	170.6	5.9	13.9	11.2	190.8	8.31	39.52	31.21	21.07	4.32	38.43	14.28
SeM	0.8	2.5	4.9	0.4	0.6	0.3	4.6	0.21	1.62	1.48	0.61	0.09	0.06	0.49
CD	2.3	7.5	14.3	NS	1.9	0.9	13.6	0.61	4.77	4.36	1.81	0.25	0.16	1.43

CS 64, while the lowest was observed in GDM 4. Highest seed yield was obtained from CS 62 (8.96 q ha⁻¹), followed by CS 61 (8.71 q ha⁻¹) and CS 58 (8.60 q ha⁻¹), whereas the lowest yield was recorded in GDM 4 (5.12 q ha⁻¹). A similar trend was observed for total biological yield, and stovar yield. Harvest index ranged from 17.95% in GDM 4 to 22.20% in CS 62, indicating more efficient partitioning of biomass towards seed yield in CS 62. Test weight varied from 3.84 g in GDM 4 to 4.73 g in CS 58. Oil content among varieties ranged from 38.32% in GDM 4 to 38.87% in CS 61. Erucic acid content showed noticeable variation, with the lowest value recorded in CS 61 (11.55%), while the highest was observed in CS 60 (15.75%). Overall, varieties CS 62, CS 61, and CS 58 performed better in terms of yield and associated traits compared to the other varieties, while GDM 4 recorded the lowest values for most of the parameters. These results indicate that salt tolerant CS series varieties, particularly CS 62 and CS 61, have superior growth, yield potential, and desirable quality attributes under the saline conditions of *Vertisols* as compared to the local variety.

EXPERIMENT-2

Suitable Planting Method and Planting Geometry for Mustard Crop under Saline *Vertisols*

An experiment was conducted to evaluate the effect of different planting methods and crop geometries on mustard. A total of nine treatments were tested in plots of 7 m × 5 m, comprising various sowing methods and spacing arrangements. Under the flatbed sowing method, four crop geometries were evaluated: T1 (30 cm × 10 cm), T2 (40 cm × 10 cm), T3 (45 cm × 20 cm), and T4 (50 cm × 20 cm). Treatment T5 involved ridge and furrow sowing with 90 cm spacing. The remaining treatments were based on the Furrow Irrigated Raised Bed (FIRB) system with different bed widths and row arrangements. Treatment T6 consisted of FIRB with 60 cm bed width having two rows at 30 cm; T7 FIRB with 120 cm bed width, four rows at 30 cm; T8 FIRB with 90 cm bed width with two rows at 45 cm spacing. Treatment T9 consisted of FIRB with 180 cm bed width with four rows at 45 cm spacing.

Growth parameters

Data in table 8.2 revealed that highest plant height at 60 DAS and 90 DAS was recorded under T5 (ridge furrow sowing at 90 cm spacing) with values of 57.27 cm and 183.13 cm, respectively. This was followed by T8 (FIRB 90 cm bed with 2 rows at 45 cm) and T3 (flatbed sowing 45 cm × 20 cm). The maximum number of primary and secondary branches was recorded under T5 (ridge furrow sowing at 90 cm spacing), with 5.73 and 16.60 branches, respectively, followed closely by T8 (FIRB 90 cm bed with 2 rows at 45 cm), whereas the

Table 8.2 Growth parameters and plant stand of mustard under different Planting method and planting Geometry

Treatment	Plant Height (cm)			No. of Branches		No. of Rows per Plot	Plant Population per m Row Length	Plant Population per Plot	Plant Population (lakh ha ⁻¹)
	30 DAS	60 DAS	90 DAS	Primary Branches	Secondary Branches				
T1 : Flatbed sowing 30 cm X 10 cm	19.33	44.67	156.87	4.33	7.93	23	11.22	1290.56	3.69
T2 : Flatbed sowing 40 cm X 10 cm	19.00	49.67	173.80	4.60	10.67	17	11.32	962.39	2.75
T3 : Flatbed sowing 45 cm X 20 cm	20.00	53.00	176.87	5.00	12.60	15	7.78	583.33	1.67
T4 : Flatbed sowing 50 cm X 20 cm	18.73	48.40	170.47	5.13	13.53	14	7.86	549.89	1.57
T5 : Ridge furrow sowing at 90 cm	19.60	57.27	183.13	5.73	16.60	8	11.52	460.89	1.32
T6 : FIRB (60 cm bed, 2 rows at 30 cm)	18.07	50.07	163.67	5.27	10.73	12	11.29	677.33	1.94
T7 : FIRB (120 cm bed, 4 rows at 30 cm)	17.40	45.40	154.73	5.07	8.47	16	11.22	897.78	2.57
T8 : FIRB (90 cm bed, 2 rows at 45 cm)	18.27	54.60	177.87	5.73	16.20	10	11.33	566.67	1.62
T9 : FIRB (180 cm bed 4 rows at 45 cm)	17.60	50.27	165.87	5.47	14.07	12	11.16	669.33	1.91
SeM	0.73	2.37	6.02	0.21	1.03		0.43	31.50	0.09
CD	NS	6.88	17.50	0.61	3.00		1.25	91.58	0.26

Table 8.3 Yield parameters and Yield of mustard under different Planting method and planting Geometry

Treatment	No. of Pods per Plant	Seed Yield/ Plant (g)	No. of Seed per pod	Seed Yield (q ha ⁻¹)	Biological Yield (q ha ⁻¹)	Stovar Yield (q ha ⁻¹)	Test Weight (g)	Harvest Index
T1 : Flatbed sowing 30 cm X 10 cm	179.67	4.76	7.79	8.39	46.71	38.33	3.17	17.95
T2 : Flatbed sowing 40 cm X 10 cm	213.87	5.93	9.04	8.14	42.30	34.15	3.19	19.31
T3 : Flatbed sowing 45 cm X 20 cm	230.80	7.27	9.33	8.66	40.45	31.80	4.35	21.51
T4 : Flatbed sowing 50 cm X 20 cm	215.13	8.11	9.34	8.74	40.76	32.02	4.55	21.48
T5 : Ridge furrow sowing at 90 cm	257.27	8.51	10.06	8.35	39.29	30.94	4.66	21.55
T6 : FIRB (60 cm bed, 2 rows at 30 cm)	203.00	7.02	8.98	9.81	42.96	33.15	4.33	22.87
T7 : FIRB (120 cm bed, 4 rows at 30 cm)	193.87	6.00	8.48	7.74	36.97	29.23	3.36	21.11
T8 : FIRB (90 cm bed, 2 rows at 45 cm)	236.80	8.14	9.74	8.50	43.04	34.54	4.33	19.74
T9 : FIRB (180 cm bed 4 rows at 45 cm)	220.33	7.04	9.12	7.12	36.01	28.89	4.18	19.82
SeM	7.65	0.39	0.37	0.35	1.79	1.77	0.11	1.23
CD	22.23	1.13	1.08	1.01	5.19	5.16	0.31	NS



Furrow Irrigated raised bed System, 2 rows on bed



Flatbed sowing System 30 cm spacing

minimum number was observed under T1. The maximum number of rows per plot was recorded under T1 (23 rows) due to closer spacing, followed by T2 (17 rows) and T7 (16 rows), while the minimum number of rows was observed under T5 (8 rows) because of the wider ridge-furrow spacing. Plant population varied considerably with spacing. The highest plant population per plot and per hectare was recorded under T1 (3.69 lakh ha^{-1}), followed by T2 and T7, whereas the lowest was observed under T5 (1.32 lakh ha^{-1}).

Yield Parameters

The maximum number of pods per plant was recorded under T5 (ridge furrow sowing at 90 cm spacing) with 257.27 pods per plant, followed by T8 (FIRB 90 cm bed with 2 rows at 45 cm) and T3 (flatbed sowing 45 cm $\times$ 20 cm). The highest seed yield per plant was recorded under T5 (8.51 g) followed by T8 and T3, while the lowest seed yield per plant was observed under T1 (Table 8.3). This increase in seed yield per plant under wider spacing was mainly due to better branching and pod development. The maximum number of seeds per pod (10.06) observed under T5 followed by T8. The highest seed yield was recorded under T6 (FIRB 60 cm bed with 2 rows at 30 cm) with 9.81 q ha^{-1} , which was significantly superior to most treatments. This was followed by T4 (flatbed sowing 50 cm $\times$ 20 cm) with 8.74 q ha^{-1} , T3 (flatbed sowing 45 cm $\times$ 20 cm) with 8.66 q ha^{-1} , and T8 (FIRB 90 cm bed with 2 rows at 45 cm) with 8.50 q ha^{-1} . The maximum biological yield was recorded under T1 (46.71 q ha^{-1}) followed by T8 and T6. A similar trend was observed in stover yield, where T1 recorded the highest stover yield (38.33 q ha^{-1}) followed by T8 and T2. The highest test weight was recorded under T5 (4.66 g) whereas the lowest was observed under T1 (3.17 g). Harvest index ranged from 17.95% under T1 to 22.87% under T6; however, the differences among treatments were statistically non-significant. Overall, the results indicate that ridge-furrow and FIRB planting systems improved yield attributes and FIRB with 60 cm bed and two rows at 30 cm spacing (T6) produced the highest seed yield per hectare.

Combined Effects of Salinity Stress and Bio-stimulants on Growth, Physiology, and Fruit Quality of Dragon Fruit (David Camus D., Anil R. Chinchmalatpure, Monika Shukla and Bisweswar Gorain)

A field experiment was initiated during the year 2024 at the ICAR-CSSRI, Regional Research Station, Bharuch, to evaluate the combined effects of saline irrigation water and bio-stimulants on the growth and structural traits of dragon fruit. Three cultivars (Jumbo Red, Sri Lankan Red, and Lemon Orange) were evaluated under four salinity levels (control, 3, 6, and 9 dS m^{-1}) along with bio-stimulant treatments comprising seaweed extract and humic acid. Results revealed that increasing salinity significantly reduced plant height, canopy spread, cladode dimensions, and rib width, indicating strong

Table 8.4 Impact of bio-stimulants on dragon fruit salt tolerance under high salinity (9 dS m⁻¹)

Category	Parameter	Cultivar	Untreated Control (I1B1)	Stress +Bio-stimulant(I4+B)	% Change vs. Stress Control
Vegetative	Plant Height (m)	Jumbo Red	2.61	2.47 (Seaweed)	+1.2%
	Cladode Width (cm)	Jumbo Red	7.85	5.90 (Seaweed)	+24.2%
	Rib Width (cm)	Srilankan Red	4.35	3.55 (Seaweed)	+20.3%
	Canopy Spread (cm)	Lemon Orange	116.0	75.0 (Seaweed)	+226.0%
Structural	Spine Width (cm)	Srilankan Red	0.30	0.20 (Humic Acid)	+100.0%
	Spine Density	Jumbo Red	3.0	3.0 (Humic Acid)	+50.0%
	Areole Distance (cm)	Jumbo Red	3.85	2.95 (Humic Acid)	+15.7%
	Areole Frequency	Lemon Orange	3.15*	14.2 (Humic Acid)	-23.2%

*Improvement in Areole Frequency is represented by a decrease in value, indicating reduced stunting

growth inhibition under saline conditions. High salinity caused stunted growth characterized by reduced areole distance and increased areole frequency, particularly in the Lemon Orange cultivar, confirming its higher sensitivity to salt stress. Untreated plants under severe salinity also showed reduced development of defensive structures, with spine width decreasing to 0.10 cm and spine density reducing to approximately two spines per areole. Application of bio-stimulants effectively mitigated salinity stress through two distinct mechanisms. Seaweed extract primarily enhanced vegetative growth by improving plant height and canopy development. Conversely, humic acid strengthened structural traits by increasing spine width, spine density, and areole distance. The maximum areole distance (5.65 cm) was recorded in Jumbo Red treated with humic acid, indicating superior recovery compared to untreated controls. The specific impact of these treatments under maximum stress is detailed in table 8.4.

Among cultivars, Jumbo Red exhibited superior growth vigour and adaptability under saline irrigation, responding most effectively to both bio-stimulants. Sri Lankan Red showed moderate structural stability, maintaining spine characteristics under moderate stress conditions. In contrast, Lemon Orange performed poorly, exhibiting severe morphological changes, including the highest areole frequency (18.5) under high salinity stress. Regression and correlation analyses indicated a strong positive relationship between plant height and canopy spread ($R^2 = 0.598$; $r = 0.773^{***}$). A significant correlation was also observed between spine width and spine density ($r = 0.529^{***}$). Principal Component Analysis (PCA) showed that the first five components explained 77.13% of total morphological variation, confirming clear and reliable treatment effects across variables. The study demonstrates that integration of suitable cultivars with bio-stimulant application enables successful dragon fruit cultivation using saline irrigation water. For improving productivity and resilience in saline *Vertisols*, adoption of the Jumbo Red cultivar combined with seaweed extract for growth promotion and humic acid for structural improvement is recommended.

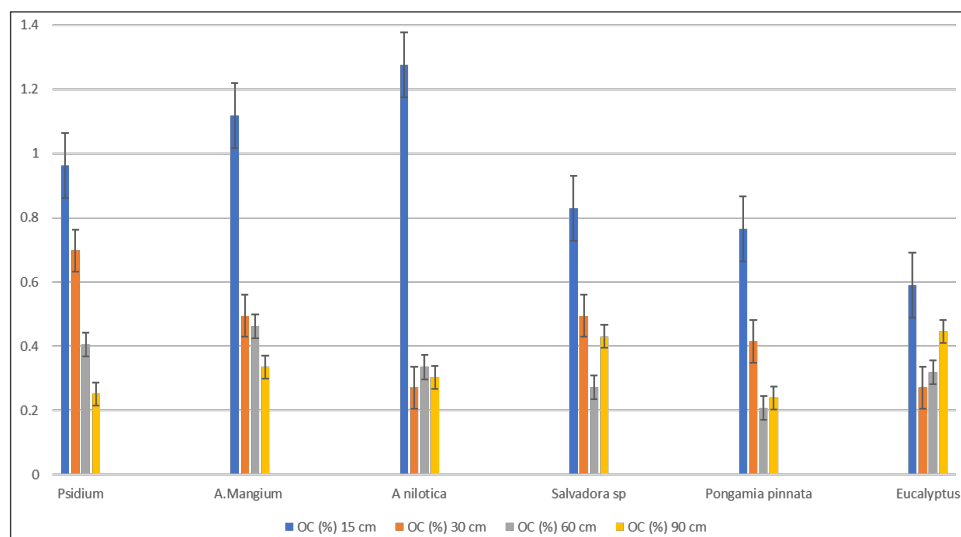
Carbon Credit Generation Potential and Cracking Behavior in the Saline *Vertisols* of Western India: Effect of Land Use Systems (Bisweswar Gorain, Anil R. Chinchmalatpure, Monika Shukla and David Camus)

A study is being conducted at the Experimental farm, Samni of ICAR-CSSRI, RRS Bharuch, Gujarat to investigate the effect of different land-use systems on carbon credit generation potential and cracking behavior of saline *Vertisols*. The land-use systems selected for the study include: agroforestry species viz. *Acacia mangium*, *Salvadora persica*, *Acacia nilotica*,

Table 8.5 Tree attributes and above ground biomass in different tree species

	Height (m)	DBH (cm)	Volume (m ³ tree ⁻¹)	Volume (m ³ ha ⁻¹)	Above ground biomass (t ha ⁻¹)
<i>Mangifera indica</i>	5.30	68	6.18	1710.84	1806.65
<i>Psidium</i> sp	2.60	15.50	0.02	5.68	7.35
<i>Manilkara zapota</i>	2.60	38.00	0.13	35.18	56.64
<i>E.tereticornis</i>	14.44	65.00	2.00	3324.56	2482.45
<i>A.mangium</i>	4.5	33.33	0.08	137.33	101.56
<i>A.nilotica</i>	6.27	40.00	0.62	247.60	314.58
<i>Pongamia pinnata</i>	3.07	25.00	0.02	7.61	8.67

Fig 8.1 Soil organic carbon in different tree species across the soil profile



Pongamia pinnata, and *Eucalyptus* sp., horticultural species viz., guava (*Psidium guajava*), chikoo (*Manilkara zapota*), and mango (*Mangifera indica*), arable crops: cotton, pigeon-pea, and wheat. The key objectives include quantifying carbon (C) sequestration and economic credit values, assessing soil organic carbon (SOC) under different land use systems and understanding land-use effects on soil physical properties and cracking behavior. Tree biomass was estimated using allometric equations based on diameter at breast height (DBH) and tree height. Carbon inventory for trees considered four pools (aboveground biomass, belowground biomass, litter, and SOC), while crop inventory focused on belowground biomass and SOC. The study aims to identify land use systems that improve soil cracking behavior while enhancing C sequestration and carbon credit generation. Soil analysis at different depths revealed that the highest organic carbon (1.28%) was recorded in *Acacia nilotica* (0–15 cm depth), whereas the lowest (0.59%) was observed under *Eucalyptus* (Fig. 8.1). Organic carbon content decreased consistently with soil depth across all land use systems. *Eucalyptus* sp. recorded the maximum biomass production (2482.6 t ha⁻¹), while *Psidium* sp. recorded the minimum (7.35 t ha⁻¹) (Table 8.5). The maximum soil electrical conductivity (EC_e) of 8.17 dS m⁻¹ was observed under *Eucalyptus* sp. at 0–15 cm depth, whereas the minimum value (0.25 dS m⁻¹) was recorded under *Acacia nilotica* at 15–30 cm depth. Soil pH ranged from 6.03 at 0–15 cm to a maximum of 7.78 at 60–90 cm depth under *Acacia nilotica*.

The study highlights that restorative land-use systems, particularly agroforestry species such as *Acacia nilotica*, significantly enhance SOC, while *Eucalyptus tereticornis* exhibits the highest biomass production potential. These systems may offer a dual benefit:

improving the physical stability of saline *Vertisols* and generating substantial economic value through carbon credits.

Planning, Monitoring and Evaluation of Subsurface Drainage Project at the Farm of Sabarmati Ashram Goshala (Anil R. Chinchmalatpure, Sagar D. Vibhute, Monika Shukla, Satyendra Kumar and R. K. Yadav)

The Economics and viability of an animal production system largely depend on availability of quality fodder. The continuous use of groundwater having EC_{iw} 3 to 8 dS m⁻¹ for irrigating fodder crops (oat, Jowar, paddy and other) in about 160-acre area of Malarpura Sabarmati Ashram Gaushala, Bidaj Farm, has led to the development of salinity and sodicity in medium black soils (Typic Haplusterts), resulting in a decline in soil productivity. In addition to the continuous application of low-quality saline irrigation water, prevailing climatic conditions have further degraded soil quality. Consequently, salinization has severely impaired crop growth, causing forage yield to decrease from 6.4 metric t acre⁻¹ to 4.0 metric t acre⁻¹. To mitigate soil salinity and sodicity, a comprehensive reclamation project has been developed, incorporating multiple interventions such as subsurface drainage (SSD), gypsum application, and the use of green manuring crops. To assess the initial status of soil salinity and sodicity, soil samples were collected from 15 different blocks of the farm using a soil auger. Sampling was carried out at four depths (0-15 cm, 15-30 cm, 30-60 cm, and 60-90 cm), and geocoordinates were recorded for each sampling point. The collected samples were processed in the laboratory and analyzed for key soil properties, including pH, electrical conductivity (EC), soluble cations, and anions. Descriptive statistical analysis revealed that soil salinity across the farm varied widely, with EC values ranging from 0.63 to 45.57 dS m⁻¹. The standard deviation of 6.87 indicated high variability in salinity levels. The surface layer is highly salinized as compared to subsurface layers. Inadequate irrigation management with water of high salt content and lack of drainage has contributed to soil salinization in these soils. The pH of soils ranged from 7.00 to 8.43 showing neutral to alkaline in nature. Sodium adsorption ratio is ranged from 6.27 to 48.38 (Table 8.6). The major dominating soluble cation is sodium followed by

Table 8.6 Soil properties of the Malarpura farm

Plot No.	Depth (cm)	EC _e (dS m ⁻¹)	pH	EC _e (dS m ⁻¹)	PH _s	Organic Carbon (%)	SAR
A1	0-15	1.27	7.85	3.37	7.32	0.54	13.73
	15-30	0.98	8.53	1.32	8.02	0.26	11.17
	30-60	1.02	8.68	1.21	7.97	0.30	10.99
	60-90	1.09	8.57	0.96	8.02	0.09	6.94
A2	0-15	16.39	7.49	45.57	7.00	0.27	48.38
	15-30	5.90	8.03	17.48	7.10	0.21	47.70
	30-60	4.32	8.03	8.44	7.32	0.24	34.87
	60-90	4.23	7.97	9.35	7.50	0.38	26.31
B1	0-15	1.40	8.24	3.22	7.56	0.62	18.87
	15-30	1.81	8.51	3.25	7.77	0.08	16.46
	30-60	1.77	8.45	3.51	7.70	0.33	18.92
	60-90	1.65	8.45	3.26	7.64	0.20	22.28
B2	0-15	4.35	8.02	10.93	7.38	0.44	26.91
	15-30	3.44	8.23	9.01	7.55	0.39	27.40
	30-60	3.84	8.35	9.25	7.73	0.26	39.21
	60-90	2.91	8.52	5.12	7.80	0.15	28.47

Plot No.	Depth (cm)	EC ₂₇ (dS m ⁻¹)	pH	EC _e (dS m ⁻¹)	PH _s	Organic Carbon (%)	SAR
C1	0-15	1.08	8.12	3.49	7.67	0.56	17.27
	15-30	1.33	8.55	2.72	7.92	0.08	19.37
	30-60	1.23	8.60	3.02	7.93	0.12	19.10
	60-90	1.07	8.70	1.94	7.96	0.15	14.02
D1	0-15	1.04	8.00	3.46	7.42	0.63	10.29
	15-30	0.94	8.32	3.13	7.68	0.23	11.32
	30-60	0.84	8.58	2.75	7.82	0.27	15.66
	60-90	0.68	8.71	1.14	8.12	0.27	11.15
E1	0-15	0.74	8.25	2.27	7.60	0.62	10.66
	15-30	0.65	8.56	1.84	7.89	0.39	25.62
	30-60	0.60	8.81	0.84	7.94	0.41	6.27
	60-90	0.69	8.80	0.63	8.02	0.18	11.40
E2	0-15	0.68	8.21	1.93	7.61	0.50	8.87
	15-30	0.71	8.60	1.56	7.90	0.35	11.91
	30-60	0.69	8.92	0.97	8.30	0.29	8.41
	60-90	0.96	8.95	1.13	8.43	0.26	13.79
F	0-15	0.73	8.05	2.37	7.48	0.57	8.84
	15-30	0.83	8.11	3.11	7.60	0.33	11.76
	30-60	1.18	8.12	3.56	7.63	0.41	19.89
	60-90	1.15	8.49	3.65	7.76	0.18	25.90
G	0-15	0.67	8.20	2.17	7.47	0.68	9.89
	15-30	0.78	8.56	2.38	8.04	0.32	17.14
	30-60	1.18	8.52	1.95	8.20	0.33	15.96
	60-90	1.42	8.70	2.18	8.23	0.38	20.83
H	0-15	1.12	8.30	3.43	7.82	0.48	17.95
	15-30	1.55	8.49	3.26	7.99	0.32	23.96
	30-60	1.67	8.55	2.23	8.23	0.26	20.67
	60-90	1.52	8.60	2.14	8.30	0.23	18.91
I	0-15	2.18	8.15	5.73	7.94	0.50	22.34
	15-30	1.34	8.47	3.81	8.05	0.39	24.20
	30-60	1.38	8.40	4.03	8.04	0.39	25.54
	60-90	1.52	8.50	3.82	7.99	0.36	25.34
K	0-15	8.02	7.96	22.97	7.51	0.66	33.32
	15-30	4.11	8.30	11.30	7.69	0.41	28.06
	30-60	3.71	8.36	10.90	7.64	0.51	36.67
	60-90	3.35	8.34	11.01	7.56	0.39	27.32
L	0-15	1.03	8.01	3.21	7.62	0.44	17.58
	15-30	1.20	8.18	3.16	7.78	0.59	21.76
	30-60	1.15	8.20	3.59	7.81	0.33	17.77
	60-90	1.16	8.31	3.88	7.60	0.44	19.67
Descriptive statistics	Maximum	16.39	8.95	45.57	8.43	0.68	48.38
	Minimum	0.60	7.49	0.63	7.00	0.08	6.27
	Mean	2.04	8.37	5.14	7.78	0.35	20.09
	Std. Deviation	2.42	0.28	6.85	0.29	0.15	9.32
	Coeff of variation	118.80	3.39	133.23	3.78	42.84	46.40

Table 8.7 Soluble cations and anions in saturation extract of soil samples

Plot No.	Depth, cm	Ca ⁺⁺ (me L ⁻¹)	Mg ⁺⁺ (me L ⁻¹)	Na ⁺ (me L ⁻¹)	Cl ⁻ (me L ⁻¹)	SO ₄ ⁻ (me L ⁻¹)	CO ₃ ⁻ (me L ⁻¹)	HCO ₃ ⁻ (me L ⁻¹)
A1	0-15	4.50	4.00	28.30	35.00	8.58	0.90	2.10
	15-30	1.00	1.00	11.17	10.00	2.07	0.80	0.50
	30-60	1.00	1.00	10.99	10.00	3.94	0.00	0.35
	60-90	1.50	1.00	7.76	5.00	2.40	0.60	1.70
A2	0-15	83.00	69.50	422.48	545.00	25.53	0.90	2.00
	15-30	22.50	17.00	212.00	150.00	23.17	1.00	1.50
	30-60	12.50	4.00	100.15	55.00	22.89	0.90	0.20
	60-90	13.00	10.50	90.20	50.00	26.23	0.80	0.50
B1	0-15	3.50	4.00	36.54	25.00	5.59	0.90	2.40
	15-30	3.00	2.00	26.03	30.00	7.74	1.30	1.35
	30-60	3.50	3.50	35.39	35.00	8.73	0.60	1.50
	60-90	3.00	2.00	35.22	25.00	8.89	0.70	0.75
B2	0-15	16.50	12.50	102.48	90.00	8.09	1.30	0.75
	15-30	7.50	8.50	77.51	65.00	13.87	0.60	1.35
	30-60	8.50	6.00	105.57	55.00	26.49	0.60	0.90
	60-90	3.00	3.50	51.33	45.00	8.49	0.70	0.65
C1	0-15	3.00	4.00	32.31	25.00	4.29	2.20	1.10
	15-30	2.50	1.50	27.40	25.00	3.69	0.60	0.60
	30-60	1.50	2.50	27.01	20.00	4.26	0.60	1.55
	60-90	1.00	2.00	17.18	15.00	3.62	0.30	1.35
D1	0-15	4.50	5.50	23.01	30.00	2.94	1.20	1.95
	15-30	3.50	4.00	21.93	25.00	3.31	1.30	0.45
	30-60	3.00	1.50	23.49	20.00	1.54	0.90	1.05
	60-90	0.50	1.00	9.65	165.00	0.42	0.70	0.90
E1	0-15	3.50	3.50	19.94	15.00	2.50	1.50	2.65
	15-30	0.50	0.50	18.12	10.00	2.59	0.60	1.00
	30-60	2.00	1.50	8.30	15.00	1.52	0.60	2.00
	60-90	0.00	0.50	5.70	5.00	0.41	1.00	0.20
E2	0-15	3.00	3.50	16.00	15.00	2.75	1.50	1.00
	15-30	1.50	2.50	16.84	15.00	1.73	0.60	1.40
	30-60	0.50	1.50	8.41	10.00	0.21	0.90	0.90
	60-90	0.00	1.50	11.94	10.00	3.03	0.90	1.35
F	0-15	3.00	4.50	17.13	20.00	2.62	1.60	1.65
	15-30	2.50	5.50	23.52	20.00	4.84	0.90	0.60
	30-60	2.50	3.00	32.98	30.00	5.68	0.50	1.15
	60-90	1.50	2.50	36.62	25.00	5.55	0.80	0.90
G	0-15	1.50	4.00	16.41	15.00	1.75	1.60	2.35
	15-30	0.50	2.50	20.99	15.00	3.72	1.20	1.95
	30-60	0.50	2.50	19.55	15.00	4.89	0.30	1.55
	60-90	0.00	2.00	20.83	15.00	3.05	0.90	1.10
H	0-15	2.00	4.00	31.09	25.00	1.65	1.90	3.90
	15-30	1.00	2.50	31.69	25.00	0.89	0.60	2.00
	30-60	0.50	1.50	20.67	15.00	1.57	0.70	1.30
	60-90	1.00	1.50	21.14	15.00	4.93	0.60	1.20

Plot No.	Depth, cm	Ca ⁺⁺ (me L ⁻¹)	Mg ⁺⁺ (me L ⁻¹)	Na ⁺ (me L ⁻¹)	Cl ⁻ (me L ⁻¹)	SO ₄ ⁻ (me L ⁻¹)	CO ₃ ⁻ (me L ⁻¹)	HCO ₃ ⁻ (me L ⁻¹)
A1	0-15	0-15	4.00	6.00	49.96	45.00	5.60	1.101.85
	15-30	2.00	2.00	34.23	25.00	4.34	0.70	1.15
	30-60	2.00	3.00	40.38	30.00	5.32	0.70	1.30
	60-90	1.50	2.50	35.84	30.00	5.15	0.90	1.20
K	0-15	14.00	51.00	189.96	215.00	15.60	1.30	2.75
	15-30	8.50	15.50	97.20	80.00	8.87	0.70	1.25
	30-60	7.50	14.50	121.61	95.00	8.38	1.10	1.00
	60-90	7.00	17.50	95.61	95.00	10.23	0.50	0.80
L	0-15	1.50	4.50	30.45	25.00	4.79	1.50	2.50
	15-30	1.00	3.00	30.77	25.00	6.14	0.50	1.20
	30-60	2.00	3.50	29.47	25.00	3.60	0.30	1.50
	60-90	2.00	4.00	34.06	30.00	5.83	0.30	2.00
Descriptive statistics	Maximum	83.00	69.50	422.48	545.00	26.49	2.20	3.90
	Minimum	0.00	0.50	5.70	5.00	0.21	0.00	0.20
	Mean	5.13	6.25	48.62	46.52	6.54	0.88	1.36
	Std. Deviation	11.38	11.26	65.30	78.05	6.52	0.42	0.70
	Coeff of variation	221.68	180.18	134.32	167.79	99.67	47.31	51.33

Table 8.8 Properties of irrigation water samples and drain water sample of the farm

Sample	EC (dS m ⁻¹)	pH	Na ⁺ (me L ⁻¹)	K ⁺ (me L ⁻¹)	Ca ⁺⁺ (me L ⁻¹)	Mg ⁺⁺ (me L ⁻¹)	CO ₃ ⁻ (me L ⁻¹)	HCO ₃ ⁻ (me L ⁻¹)	Cl ⁻ (me L ⁻¹)	SO ₄ ⁻ (me L ⁻¹)	SAR	Class
Tube well 1	5.99	7.35	36.40	0.13	6.90	14.85	4.0	10.0	5.0	7.58	12.03	C4S2
Tube well 3	4.60	7.59	31.09	0.10	5.22	11.37	2.4	7.0	4.0	3.58	11.75	C4S2
Tube well 4	4.40	8.43	31.24	0.12	0.80	8.90	4.0	7.4	3.8	6.24	14.48	C4S2
Drain water	20.93	7.55	173.00	0.11	19.26	23.77	2.8	13.2	18.4	29.08	42.33	-

calcium and magnesium. Among anions chloride is dominant followed by sulphate, bicarbonate and carbonate (Table 8.7). The origin of salt in these soils is saline irrigation water of C4S2 type (Table 8.8). These soils are classified as highly saline sodic soils. The most effective approach to restore their productivity is through an integrated use of multiple reclamation technologies. The productivity of these degraded soils can be restored to optimum levels by adopting an integrated reclamation strategy that includes engineering options such as subsurface drainage (SSD), chemical amendments like gypsum, and biological measures including the use of salt-tolerant forage species and green manuring crops.

Genetic Enhancement of Maize (*Zea mays* L.) for the Development of High Yielding and Climate Resilient Hybrids (Monika Shukla; Collaborative project with ICAR-IIMR, Ludhiana)

Thirty maize genotypes (IMR-1 to IMR-30) were evaluated under varying levels of irrigation water salinity (EC_{iw} values 0, 6 and 9 dS m⁻¹) on salt affected *Vertisols* in *rabi* 2024-25. The objective was to identify salt tolerant lines along with key physiological traits related to enhanced salt tolerance. It was observed that the germination and plant growth affected significantly with saline water irrigation. IMR-5 did not germinate in the experiment. The performance of thirty maize entries under three treatments (T1: Control,

Table 8.9 Range of various growth and yield parameters under different levels of saline water irrigation

Parameter	Best available water		6 dS m ⁻¹ irrigation water		9 dS m ⁻¹ irrigation water	
	Max	Min	Max	Min	Max	Min
Plant height	284 (IIMR 10)	156 (IIMR 30)	268 (IIMR 11)	133 (IIMR 30)	253 (IIMR 11)	112 (IIMR 30)
No. of cobs per plant	2.5 (IIMR 7, 12, 30)	1.3 (IIMR 11, 27)	2.3 (IIMR 30)	1.0 (IIMR 14, 23, 27)	1.8 (IIMR 12)	1.0 (several varieties)
Cob length (cm)	20.0 (IIMR 4)	11.9 (IIMR 26)	19.4 (IIMR 4)	11.1 (IIMR 26)	17.2 (IIMR 4)	10.3 (IIMR 29)
Biomass yield per plot (kg)	10.26 (IIMR 9)	2.69 (IIMR 30)	8.89 (IIMR 4)	1.26 (IIMR 7)	6.16 (IIMR 4)	0.54 (IIMR 7)
Cob yield per plot (kg)	3.97 (IIMR 4)	0.50 (IIMR 29)	3.39 (IIMR 4)	0.09 (IIMR 29)	2.76 (IIMR 4)	0.05 (IIMR 29, 30)
Grain yield per plot (kg)	3.07 (IIMR 9)	0.26 (IIMR 30)	2.71 (IIMR 2)	0.04 (IIMR 29)	1.69 (IIMR 4)	0.07 (IIMR 7)
100-seed weight (g)	41.5 (IIMR 8)	21.4 (IIMR 21)	35.0 (IIMR 8)	19.8 (IIMR 21)	32.2 (IIMR 8)	14.3 (IIMR 27)

T2: EC_{iw} 6 dS m⁻¹, and T3: EC_{iw} 9 dS m⁻¹) revealed substantial variation in growth, yield, and yield-attributing characters (Table 8.9). Across entries, plant height consistently declined with increasing irrigation water salinity levels. Under control conditions, plant height ranged from 156 to 284 cm, with varieties IIMR 9 and IIMR 10 recording the maximum height (283-284 cm). Exposure to 6 dS m⁻¹ and 9 dS m⁻¹ water resulted in a progressive reduction in plant height, indicating the adverse effect of higher EC_{iw} on vegetative growth. The number of cobs per plant also showed a declining trend with increasing EC_{iw}. Under control conditions, the number of cobs ranged from 1.3 to 2.5, while under 9 dS m⁻¹ it reduced to 1.0-1.8 across entries. Entries IIMR 7, IIMR 12, and IIMR 30 recorded relatively higher cob numbers under control conditions, but this advantage diminished under elevated EC levels. Cob length was significantly affected by EC_{iw}. Under control conditions, cob length ranged from 11.9 to 20.0 cm, with variety IIMR 4 producing the longest cobs (20.0 cm). Increasing EC_{iw} reduced cob length across all entries, with the lowest values observed under 9 dS m⁻¹, reflecting stress-induced reductions in reproductive growth. Biomass yield followed a similar declining trend. Under control conditions, biomass yield ranged from 2.69 to 10.26 kg per plot, with variety IIMR 9 recording the highest biomass

Table 8.10 Best performing maize genotypes under different levels of saline water irrigation

Best available water		6 dS m ⁻¹ irrigation water		9 dS m ⁻¹ irrigation water	
Germplasm	Cob yield per plot (g)	Germplasm	Cob yield per plot (g)	Germplasm	Cob yield per plot (g)
IIMR 4	3.97	IIMR 4	3.39	IIMR 4	2.76
IIMR 9	3.89	IIMR 2	3.29	IIMR 1	2.56
IIMR 1	3.78	IIMR 1	3.19	IIMR 20	2.27
IIMR 13	3.64	IIMR 9	2.95	IIMR 9	2.21
IIMR 6	3.37	IIMR 6	2.59	IIMR 6	2.20
IIMR 18	3.42	IIMR 24	2.52	IIMR 18	2.00
IIMR 24	3.02	IIMR 25	2.48	IIMR 24	1.93
IIMR 2	3.45	IIMR 11	2.43	IIMR 2	1.80
IIMR 25	2.73	IIMR 20	2.39	IIMR 17	1.52
IIMR 17	2.71	IIMR 17	2.21	IIMR 25	1.53



Different Maize lines screening experiment at different salinity levels conducted at RRS Bharuch

yield. Biomass production decreased markedly under 6 dS m^{-1} and further under 9 dS m^{-1} , particularly in sensitive varieties such as IIMR 7, IIMR 27, and IIMR 30. Cob yield per plot and grain yield per plot were significantly influenced by EC stress. Under control conditions, cob yield ranged from 0.50 to 3.97 kg, while grain yield varied from 0.26 to 3.07 kg per plot. Entries IIMR 4 and IIMR 9 consistently recorded higher cob and grain yields across all treatments, indicating better tolerance to EC_{iw} stress. In contrast, varieties IIMR 7, IIMR 27, IIMR 29, and IIMR 30 showed sharp yield reductions under higher EC levels, suggesting higher sensitivity. The 100-seed weight also declined progressively with increasing EC_{iw} . Under control conditions, seed weight ranged from 21.4 to 41.5 g, with entry IIMR 8 recording the highest test weight (41.5 g). Under 9 dS m^{-1} , seed weight declined substantially across most entries, indicating impaired grain filling under stress conditions. Overall, increasing EC_{iw} negatively affected plant height, cob number, cob length, biomass yield, cob yield, grain yield, and seed weight across all maize varieties. However, varieties IIMR 4, IIMR 9, IIMR 6, and IIMR 11 maintained comparatively higher yield and yield components under stress conditions (Table 8.10).

Genetic Approaches to Improve Wheat (*Triticum aestivum* L.) Germplasm for Salt Tolerance (Neeraj Kulshreshtha, Arvind Kumar, Ashwani Kumar, Ravi Kiran KT and Monika Shukla)

Experiments at ICAR CSSRI RRS Bharuch

Experiment no. 1: KRL, Screening Wheat

Thirty-one 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* ($\text{ECe } 6\text{-}7 \text{ dS m}^{-1}$) in 2024-25. Considerable variation was observed among the wheat varieties with respect to growth parameters, phenological traits, yield attributes and yield (Table 8.11). Plant height ranged from 68.56 cm (HD 2851) to 110.78 cm (KH 65), indicating wide genetic variability. Most KRL varieties exhibited moderate plant height (82-94 cm), which is desirable for lodging resistance. Days to flowering varied from 56 to 64 days, while days to maturity ranged between 105 and 116 days. Early maturity was recorded in KRL 2207, KRL 2309 and HD 2851 (105 days), whereas KRL 2304 showed the longest maturity duration (116 days). Among yield parameters panicle length ranged from 8.10 cm (KRL 99) to 10.43 cm (KRL 2214). Higher panicle weight was observed in DBW 187 (4.25 g), followed by KRL 2307 (4.09 g) and DBW 222 (4.06 g), reflecting better sink strength in these varieties.

Table 8.11 Growth, yield attributes and yield of top 10 performing KRL entries during 2024-25

Variety	Plant height (cm)	Days to 50% Flowering	Days to Maturity	Panicle length (cm)	Panicle weight (g)	Grain yield/plot (g)	Biomass yield (g)	1000-seed weight (g)
KRL 2310	88.22	64	115	9.13	3.62	419	986	55.4
KRL 99	86.00	57	106	8.10	2.47	400	858	50.2
KRL 1803	85.33	58	107	8.82	2.84	398	876	49.3
KRL 2207	93.78	58	105	10.05	3.87	395	1029	49.2
KRL 2301	90.44	57	107	8.33	3.41	391	914	49.1
KRL 283	79.44	59	107	8.33	2.86	387	880	45.2
KRL 2307	87.56	58	114	9.85	4.09	381	998	48.2
KRL 386	89.33	58	115	8.62	3.50	376	965	45.5
KRL 2308	88.44	64	115	9.47	4.05	370	1077	48.0
DBW 222	87.33	64	115	9.63	4.06	365	896	42.9

KRL, Screening Wheat



Grain yield showed substantial variation, ranging from 257 g (KRL 2303) to 419 g (KRL 2310) (Plot size 0.9 m²). The highest grain yield was recorded in KRL 2310 (419 g), followed by KRL 99 (400 g) and KRL 1803 (398 g), indicating their superior yield potential. Biomass yield ranged from 767 g (KRL 423) to 1162 g (KRL 2304), with KRL 2304, KRL 2308 and KRL 2303 producing higher biomass. The 1000-seed weight varied from 39.1 g (KRL 2306) to 55.4 g (KRL 2310). Varieties KRL 2310, KRL 2303 and KRL 99 recorded higher test weight, which contributed positively to grain yield. Overall, varieties KRL 2310, KRL 99, KRL 1803, KRL 2207 and KRL 2301 exhibited superior performance in terms of grain yield and yield-attributing traits.

Experiment no. 2: SPLASN, Screening Nursery wheat

Wheat SPLASN trial with 24 entries with 3 checks was conducted in 2024-25. (Plot size 3 m²). The data presented in table 8.12 reveal substantial variability among the SPLASN entries for agromorphological traits, yield attributes, and yield. Plant height ranged from 80.3 cm (SPLASN 17) to 110.9 cm (SPLASNCK 03). Most entries exhibited medium plant height (85-95 cm), which is considered desirable for better lodging resistance and efficient biomass partitioning. Days to flowering varied from 56 to 64 days, while days to maturity ranged from 102 to 116 days. The earliest maturity was observed in SPLASNCK 01 and SPLASNCK 02 (102 days), whereas SPLASN 04 and SPLASNCK 03 matured later at 116 days. Panicle length showed marked differences among entries, ranging from 5.21

Table 8.12 Growth and yield attributes and Yield of top 10 performing SPLASN entries during 2024-25

Entry	Plant height (cm)	Days to flowering	Days to maturity	Panicle length (cm)	Panicle weight (g)	1000-grain wt. (g)	Grain yield (g/plot)	Biological yield (kg/plot)
SPLASN 23	86.7	58	115	9.60	3.47	39.25	1900	4.35
SPLASN 24	87.7	57	115	9.40	3.43	36.85	1600	3.41
SPLASN 05	91.3	64	115	9.65	3.36	32.40	1510	4.03
SPLASN 12	98.7	56	106	8.95	2.56	42.70	1500	3.52
SPLASN 18	92.0	56	115	9.50	3.43	41.10	1500	3.17
SPLASN 15	81.0	64	115	9.40	3.70	40.20	1490	3.71
SPLASN 09	87.3	64	115	8.10	2.75	43.80	1475	3.48
SPLASN 22	92.7	57	115	10.15	3.79	33.40	1470	3.37
SPLASNCK 02	83.4	56	102	8.95	2.86	31.58	1467	3.84
SPLASN 08	91.0	56	106	8.60	3.29	45.45	1434	3.28

SPLASN, Screening Nursery wheat



cm (SPLASN 10) to 10.20 cm (SPLASN 04). Longer panicles were also recorded in SPLASN 16, SPLASN 20 and SPLASN 22 (10.15 cm), which may contribute to higher sink capacity. Panicle weight varied from 2.22 g (SPLASN 02) to 3.84 g (SPLASN 07), indicating significant differences in grain-bearing potential. The 1000-grain weight ranged from 31.58 g (SPLASNCK 02) to 55.35 g (SPLASN 13). Higher test weight observed in SPLASN 13, SPLASN 21 and SPLASN 08 reflects better grain filling and seed quality. Grain yield per plot exhibited wide variation, ranging from 960 g (SPLASN 03) to 1900 g (SPLASN 23). The highest grain yield was recorded in SPLASN 23 (1900 g/plot), followed by SPLASN 24 (1600 g/plot). Biological yield ranged from 2.50 kg/plot (SPLASN 02) to 4.39 kg/plot (SPLASN 19), with higher biomass also recorded in SPLASN 23 and SPLASNCK 03, suggesting better overall growth performance. Overall, entries SPLASN 23, SPLASN 24, SPLASN 05, SPLASN 12 and SPLASN 18 emerged as superior in terms of grain yield and biomass production.

Experiment no. 3: SPLAST, Screening Nursery wheat

Wheat SPLAST trial with 4 entries with 3 replications was conducted in 2024-25 (Plot size 14.4 m²). The agromorphological performance of four SPLAST entries exhibited considerable variation across growth, yield, and yield-attributing traits (Table 8.13). Plant height ranged from 84 to 120 cm, with SPLAST-04 recording the maximum height (120

Table 8.13 Growth and yield attributes and Yield of different SPLAST entries 2024-25

Entry	Height (cm)	Days to Maturity	Days to Heading	Length of Panicle (cm)	Weight of Panicle (g)	Grain Yield (g)	Biomass Yield (kg)	1000 Grain Wt. (g)
SPLAST-01	90	106	57	8.18	2.95	4574	12.12	44.37
SPLAST-02	89	114	58	8.85	2.69	4392	12.77	42.20
SPLAST-03	84	102	56	9.40	2.63	5179	12.44	47.79
SPLAST-04	120	116	64	8.28	2.42	3322	13.05	52.30

SPLAST, Screening Nursery wheat



cm), while SPLAST-03 was the shortest (84 cm). Days to maturity varied from 102 to 116 days; SPLAST-03 matured earliest (102 days), whereas SPLAST-04 was the latest maturing genotype (116 days). A similar trend was observed for days to heading, which ranged from 56 to 64 days, with SPLAST-03 showing the earliest heading and SPLAST-04 the latest. Panicle length differed moderately among entries, ranging from 8.18 to 9.40 cm. The longest panicles were recorded in SPLAST-03 (9.40 cm), followed by SPLAST-02 (8.85 cm). Panicle weight ranged from 2.42 to 2.95 g, with SPLAST-01 producing the heaviest panicles (2.95 g). Grain yield showed marked variation, with SPLAST-03 producing the highest grain yield (5179 g), followed by SPLAST-01 (4574 g), while SPLAST-04 recorded the lowest yield (3322 g). Biomass yield ranged from 12.12 to 13.05 kg, with SPLAST-04 registering the highest biomass yield (13.05 kg). The 1000-grain weight varied from 42.20 to 52.30 g, with SPLAST-04 recording the highest test weight (52.30 g), indicating bolder grains, whereas SPLAST-02 had the lowest (42.20 g). Overall, SPLAST-03 emerged as a superior genotype in terms of early maturity, longer panicles, and highest grain yield.



Reclamation and Management of Coastal Saline Soils

Impact of climate change on rice yield in the coastal deltaic region of West Bengal (T.D. Lama, U.K. Mandal, D. Burman, N.R. Prakash and K.K. Mahanta)

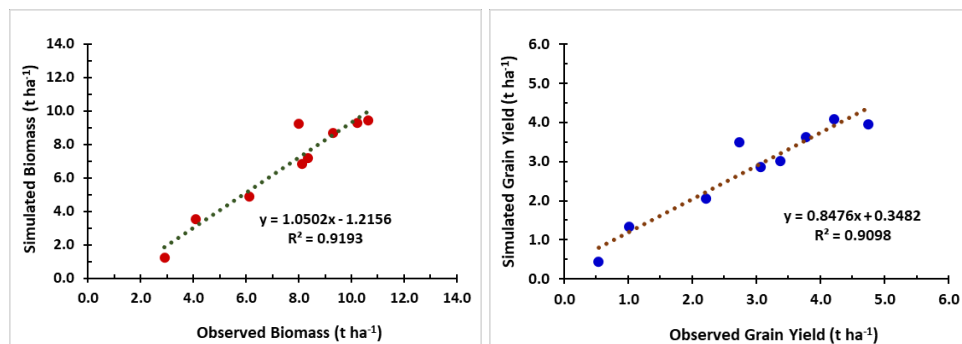
Climate change poses a major threat to fragile coastal ecosystems by intensifying salinity, water scarcity, and sea water intrusion, thereby reducing agricultural productivity and endangering food and livelihood security of the resource-poor farmers. This study aims to assess the impact of climate change and salinity on rice yields and validate the FAO Aquacrop model for predicting future yield responses. A field experiment was conducted during the dry season of 2024-25 at the ICAR-CSSRI, RRS, Canning Town, West Bengal, to evaluate the response of rice varieties, namely, Canning 7 (tolerant), Sada Minikit (moderately tolerant), and BPT 5027 (sensitive) under three irrigation water quality (good water, $EC_{iw} - 4$ and $EC_{iw} - 6 \text{ dS m}^{-1}$) to calibrate the FAO Aquacrop model. Canning 7 recorded the highest average yield (3.69 t ha^{-1}), followed by Sada Minikit (3.45 t ha^{-1}) and BPT 5204 (1.43 t ha^{-1}) (Table 9.1). While the highest grain yield (3.90 t ha^{-1}) was recorded with good quality irrigation water, the lowest (1.95 t ha^{-1}) was observed with irrigation water salinity of 6 dS m^{-1} . Significant interaction effects between salinity and variety were also noticed. Similarly, straw yield declined with increasing salinity and the highest straw yield was recorded by the tolerant variety Canning 7 (5.53 t ha^{-1}), followed by Sada Minikit (moderately tolerant, 4.92 t ha^{-1}) and BPT 5204 (sensitive, 3.57 t ha^{-1}). There was a reduction in rice yield by 10.4-27.1% in Canning 7 followed by 28.8 to 53.2% in Sada Minikit with saline water irrigation of 4 and 6 dS m^{-1} , respectively. Whereas in the sensitive variety BPT

Table 9.1 Grain and straw yields of rice varieties at different salinity levels of irrigation water

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Water quality		
Good quality water (GW)	3.90a	5.73a
Saline irrigation water (SW_1 , $EC_{iw} - 4 \text{ dS m}^{-1}$)	2.72b	4.52b
Saline water (SW_2 , $EC_{iw} - 6 \text{ dS m}^{-1}$)	1.95c	3.77c
Variety		
Canning 7 (V1)	3.69a	5.53a
Sada Minikit (V2)	3.45a	4.92b
BPT 5024 (V3)	1.43b	3.57c
Interaction		
GWV1	4.22ab	6.02a
SW1V1	3.78bc	5.51ab
SW2V1	3.08de	5.05b
GWV2	4.75a	5.88a
SW1V2	3.38cd	4.98b
SW2V2	2.23f	3.92c
GWV3	2.73ef	5.28b
SW1V3	1.01g	3.07d
SW2V3	0.54g	2.36e

Treatment means with the same letter are not significantly different at $p \leq 0.05$

Fig 9.1 Observed and simulated grain yield and biomass of rice



5204, the yield reduction was by 62.6 to 80.2%. Yield penalty was higher under saline water irrigation with 6 dS m^{-1} even in case of tolerant variety and was severe in case of sensitive variety like BPT 5204. FAO Aquacrop model was validated using the field experiment data obtained during 2025 and its performance was evaluated (Fig.9.1). The average per cent deviation of the simulated data from the observed data was -3.04% for rice grain yield and -11.13% for biomass. RMSE, model efficiency (E), index of agreement (d) and R^2 obtained during validation were respectively, 0.36, 0.90, 0.97 and 0.91 for grain yield and 1.00, 0.79, 0.95 and 0.92 for total biomass yield. Assessment of rice yields under future climate change and salinity regimes using the validated model is in progress.

Low budget natural farming for sustainable crop production (D. Burman, U.K. Mandal and T.D. Lama)

The field experiment was conducted during 2025-26 at RRS, Canning Town to evaluate the components of low budget natural farming under coastal agro-ecosystem. The experiment consisted of the following scenarios, S_1 : Rice-Mungbean-Fallow (CT-CT) (Rice-transplanted, Mungbean-line sown, all residue removed, Nutrient: farmers' recommendation); S_2 : Rice-Mungbean-Dhaincha (CT-ZT-ZT) (Rice-transplanted, Mungbean-line sown, dhaincha-broadcast; full rice and mungbean residue retained, dhaincha incorporated; rice – RDF, Mungbean – RDF); S_3 : Rice-Mungbean (CT-ZT) (Rice-DSR, Mungbean-line sown, full rice and mungbean residue retained; rice – RDF, Mungbean – RDF (N through FYM + CSSRI Formulation)); S_4 : Rice-Mungbean (CT-ZT) (Rice-DSR, Mungbean-line sown, full rice and Mungbean leaf residue retained, Nutrient: 50% through organic & 50% through inorganic); S_5 : Rice-Mungbean-Dhaincha (CT-ZT-ZT) (Rice-transplanted, Mungbean-line sown, dhaincha-broadcast, full rice and Mungbean residue retained, dhaincha incorporated; Nutrients – Nil; Low budget natural farming (LBNF)); S_6 : Rice-Mungbean-Dhaincha (ZT-ZT-ZT) (Rice- unpuddled transplanted, Mungbean-line sown, dhaincha-broadcast, full rice and Mungbean residue retained, dhaincha retained; Nutrients – Nil; Low budget natural farming (LBNF)); S_7 : Rice-Mungbean-Dhaincha (CT-CT-CT) (Rice-transplanted, Mungbean-line sown, dhaincha-broadcast, anchored rice and Mungbean residue retained, dhaincha incorporated; Nutrients: rice – 50% RDF, Mungbean – 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 S_5 .

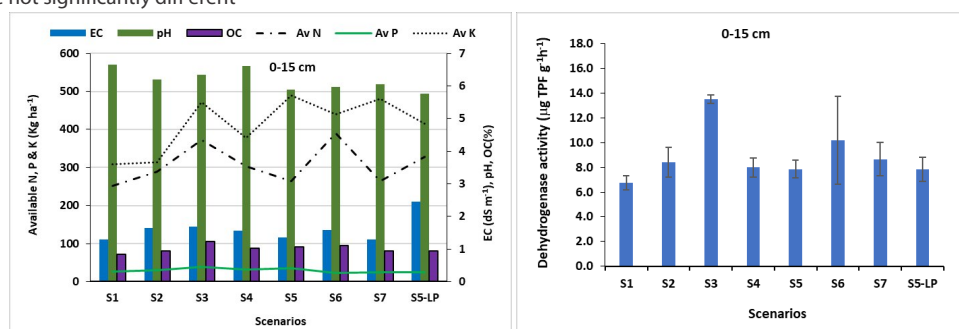
During *summer* 2025 mungbean (variety Sea Label) and during *kharif* 2025 rice (variety Amalmana) were taken as test crops as per the scenarios. Mung bean yield was significantly highest under S_2 (3.18 q ha^{-1}) followed by S_1 (2.84 q ha^{-1}), while LBNF-only scenarios showed comparatively lower mung productivity. In S_7 (LBNF + 50% inorganic),

Table 9.2 Rice growth and productivity under different scenarios

Scenarios	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Mungbean grain yield(q ha ⁻¹)	Mungbean haulm yield (q ha ⁻¹)
S1	3.01a	9.26a	2.84ab	1.17
S2	4.08a	7.87a	3.18a	1.56
S3	3.37a	9.80a	0.85cd	0.13
S4	3.80a	9.14a	0.79cd	0.09
S5	3.18a	9.20a	1.26cd	1.20
S6	4.73a	9.54a	0.18d	0.09
S7	3.19a	10.67a	1.66bc	1.03
S5-LP	4.71a	11.52a	0.50cd	0.15

Values followed by the same letters are not significantly different

Fig 9.2 Variation in soil properties under different scenarios



the yield was 1.66 q ha⁻¹ followed by 1.26 q ha⁻¹ in S₅. In S₃ and S₄ as well as S₆ scenarios, the yields obtained was significantly very low below 1 q ha⁻¹. The highest haulm yield of mungbean was obtained in S₂ (1.56 t ha⁻¹). During *kharif* 2025 highest grain yield of rice (4.73 t ha⁻¹) was obtained in scenario S₆ which was at par with S₅-LP (large plot) (4.71 t ha⁻¹), followed by S₂ (4.08 t ha⁻¹). The lowest yield was recorded in S₁ (3.01 t ha⁻¹) (Table 9.2). However the variations in grain yield across the scenarios was not statistically significant. No significant variation in straw yield was noticed with the highest straw yield in S₅-LP and S₇. The results indicated that the performance of rice crop under LBNF was comparable to those with use of chemical fertilizers as well as with its integrated use with FYM. Analysis of the soil samples collected from 0-15 cm depth after the harvest of mungbean crop revealed that highest organic carbon content was observed in scenario S₃ (1.23%), where 100% N had been applied through FYM and full crop residue was retained (Fig. 9.2). The lowest soil organic carbon content was recorded in scenario S₁ (0.84%). The available N, P and K was also found to be higher in scenario S₃. The highest soil dehydrogenase activity was recorded in S₃ (13.5 μg TPF g⁻¹ h⁻¹) followed by S₆ (10.2 μg TPF g⁻¹ h⁻¹) in 0-15cm (Fig. 9.2). The soil properties showed improvement under integrated and LBNF-based systems, with higher SOC, available N, P, and K and microbial activity compared to farmers' practice (S₁).

Biochar amendment for coastal salinity management in rice-based cropping system (U.K. Mandal, T.D. Lama and D. Burman)

This project explores biochar-based soil amendment as an integrated, climate-resilient, and sustainable strategy for managing coastal salinity while enhancing productivity and soil health in rice-based cropping systems. Experiments were carried out within concrete well rings (70 cm diameter) at the research farm of ICAR-Central Soil Salinity Research Institute, Canning Town, West Bengal during *kharif* and *rabi* season to study the effect of

CSSRI biochar experiment in well ring under rice-vegetable systems



Table 9.3 Properties of biochar prepared from rice straw

Biochar	Value
Maximum water holding capacity (%)	168.1-220.8
pH (1:2)	9.25-9.66
EC (1:50) (dS m ⁻¹)	2.54 - 3.56
Total C (%)	Straw biochar 39.3%; wood biochar 50.1%
Total N (%)	1.42-1.47
Total P (%)	0.010-0.039
Total K (%)	2.019-3.068
Available N (kg ha ⁻¹)	100.35-125.44
Available P (kg ha ⁻¹)	36.13-48.36
available K (kg ha ⁻¹)	303.75-413.50
CEC (meq 100g ⁻¹)	35.42-48.22
Ca (ppm)	112.86
Mg (ppm)	71.42
Na (ppm)	1894

Table 9.4 Okra yield and soil salinity and salinity level in leachate collected during okra

Treatment	Okra Yield		Leachate collected on 29.10.25		Soil collected after Okra harvest (15.1.26)	
	Yield kg/ 70 cm diameter ring	STDEV	EC (dS m ⁻¹)	pH	ECe (dS m ⁻¹)	pH
Biochar @ 1%	1.341	0.014	1.56	7.54	2.99	7.81
Biochar @ 0.5%	1.081	0.178	1.22	7.36	3.09	6.5
Biochar @ 0.2%	1.181	0.221	1.21	7.38	3.42	6.79
No biochar	0.986	0.233	1.08	7.18	3.79	6.6

biochar on soil properties under saline water use for irrigation. Vegetable okra was taken as test crop during *kharif* 2025 while rice was grown during *rabi* season (2025-26) (Photo). There were four biochar treatments. T1: Biochar @ 1% where 1.5 kg biochar was mixed

with 148.5 kg soils in a well ring; T2: Biochar @ 0.5% where 0.750 kg biochar was mixed with 149.250 kg soils in a well ring; T3: Biochar @ 0.2% where 0.300 kg biochar was mixed with 149.700 kg soils in a well ring and T4: No biochar application. Different quality of irrigation water (S) was applied in sub plot treatment; S0: fresh water; S1: irrigation with 6 dS m⁻¹ irrigation water; S2: irrigation with 12 dS m⁻¹ irrigation water. During *kharif* season no irrigation was applied for okra and crop was grown as rainfed whereas different quality of irrigation was applied during *rabi* rice. Properties of biochar prepared from rice straw was presented in Table 9.3. Okra yield showed that application of biochar enhanced the yield of okra (Table 9.4).

Assessment of ground water in sea water inundated locations of coastal West Bengal using geo-electrical method (Shishir Raut, D. Burman and T.D. Lama)

The ground water salinity in the coastal West Bengal leads to low productivity of crops particularly in spring season. In many areas ground water may occur in perched aquifer at greater depths (>30 m and up to 300 m) which is non saline and available for cultivation of crops. Exploration of ground water sources by geo-electrical method is one of the inexpensive and in-situ methods and has been used for long. Therefore, it is necessary to study ground water potential and quality in different areas in the villages of coastal West Bengal.

Field investigations were carried out in the Kanthalberia village. Two vertical section consisting of eight resistivity locations (VES 1,2,3,4 and VES 5,6,7, 8) across the river Matla were carried out (Fig. 9.3) to determine the resistivity of different subsurface layers and correlate with the nearby borehole lithologs to understand the overall geohydrological situations. The field data were interpreted for true resistivity and corresponding thickness of different sub-surface horizons. Ground water samples were collected from tube wells situated near different VES locations and analyzed for EC, pH, Na⁺, K⁺, Ca²⁺, Mg²⁺, CO₃²⁻, HCO₃⁻, Cl⁻ etc. Ground water samples from nearby tube wells were also collected for geochemical analysis.

Resistivity data of VES 1 was compared with the borehole lithology of adjoining tube well to assign resistivity values to different subsurface configuration. The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate five geoelectric layers (Table 9.5). The layer wise description of different subsurface configurations is given in Table 9.6.

Physico-chemical parameters were studied from the soils collected from Kanthalberia village. Soil samples were collected during Feb. –March, 2025. Soils were collected from eight different sites coming near the VES locations and analyzed for texture, EC, pH, organic carbon and saturated moisture content. Clay content in different sites of Kanthalberia village varied from 27-47% and was sandy clay loam to clay (Table 9.7). Sand content for the same soils varied from 34-57%. In 0-20 cm depth, EC_e values were low 0.24-1.05 dS m⁻¹. Organic carbon content varied from 0.20-2.2%. High organic carbon content (2.2%) may be due to the addition of organic matter on that site.

The electrical conductivity (EC) of ground water ranged from 1.08 to 2.25 dS m⁻¹ (Table 9.8), representing medium (C3) salinity group of USDA classification of irrigation water. The relatively high salinity (C3) of irrigation water near one of the VES points was possibly due to the presence of saline aquifer zone. The pH of the water samples varies from 7.1-8.8 with majority of the samples having pH>7.0, which indicates that the ground water was alkaline. Carbonates in the ground water samples were in trace amount in most of the

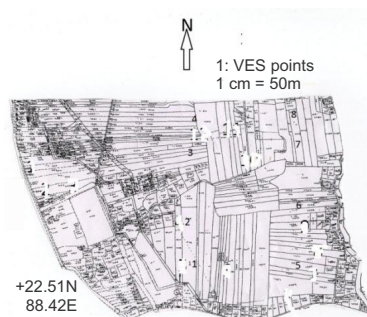


Fig 9.3 The study area (Kathalberia village)

Table 9.5 Interpreted resistivity values for different VES points

VES NO.		Layer no.				
		I	II	III	IV	V
1	h	15	30	37.6	24	?
	p	200	250	370	90	86
2	h	1	6	27	20	?
	p	177	81	201	166	200
3	h	2	10	15	22.5	?
	P	250	300	400	180	150
4	h	1	5.7	20	15	?
	p	300	450	190	150	250
5	h	3	25	30	15	?
	p	300	200	400	100	80
6	h	2	10	20	25	?
	p	350	180	300	150	200
7	h	1.5	15	18	20	?
	p	320	200	320	300	100
8	h	1.5	15	25	15	?
	P	310	200	320	180	170

h- thickness in m; p-resistivity in ohm-m

Table 9.6 Description of different geo-electric layers

Geoelectric layer	Depth below ground level	Resistivity range (Ohm-m)	Inference
1	1-15	177-350	Upper ploughed layer and unsaturated soil. Predominantly clayey, high resistivity of 300 ohm-m at VES 6 is due to the presence of hard plant root. Existence of a hard layer below the puddle rice soil
2	5.7-30	180-450	It is lower ploughed layer and saturated soil
3	15-37.6	190-400	Semi weathered zone of gneisses, contains clay and fine sand at lower depth up to 15-38 m and clay and hard sand (kankar) with relatively high resistivity. Occurrence of good quality ground water.
4	15-25	100-320	Water potential zones. Relatively high resistivity at VES 2, 3, 7 & 8 indicates materials with less saline to good quality ground water.
5	Up to 90	170-320	Relatively low resistivities indicated presence of clay in most of the VES points. High resistivity at VES 4 indicated unsaturated zone

Table 9.7 Physico-chemical parameters of soil collected from Kathalberia village

Sites	Sand %	Silt %	Clay %	EC (1:2) (dS m ⁻¹)	pH	Organic (%)	Saturated moisture (%)
1	53	20	27	0.60	5.9	1.60	60
2	54	19	27	0.24	6.4	1.70	59
3	53	10	37	0.50	6.2	2.20	58
4	57	20	27	1.05	6.7	1.10	58
5	34	19	47	0.86	6.4	0.50	68
6	37	19	44	0.67	6.0	1.30	69
7	34	29	37	0.84	5.7	0.86	61
8	43	10	47	0.50	5.7	0.20	65

Table 9.8 Geochemical parameters of ground water collected from Kanthalberia village

Tube well location	EC (dS m ⁻¹)	pH	Cations and anions (me L ⁻¹)							RSC (me L ⁻¹)	SAR
			Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺	CO ₃ ⁻²	HCO ₃ ⁻	Cl ⁻		
1	1.10	8.0	0.60	0.10	7	7	2	13.0	8.0	1.0	0.23
2	1.13	7.8	0.17	0.12	6	7	1	14.0	15	2.0	0.10
3	1.46	7.7	0.17	0.13	9	3	1	13.5	15	2.5	0.10
4	1.17	7.8	0.3	0.10	4	6	3	10.0	14	3.0	0.13
5	1.72	7.1	0.65	0.35	6	7	2	14.0	4.0	3.0	0.26
6	1.08	8.7	0.17	0.13	6	4	1.5	11.0	9.0	2.5	0.45
7	1.16	8.8	0.17	0.10	4	4	2.0	9.0	8.0	3.0	0.10
8	2.25	7.5	0.43	0.15	5	5	1.0	12.0	10	3.0	0.20

Tube well location: 1. Near VES 1, 2. Near VES 3, 3. Near VES 4, 4. Near VES 5, 5. Near VES 6, 6. Near VES 7, 7. Near VES 8, 8. Near VES 8

Table 9.9 Correlation matrix for geochemical parameter, soil texture and EC

Variables	S (dS) (30 m)	T (ohm m ²) (30 m)
Sand % (0-0.15m)	-0.30	0.20
Silt % (0-0.15m)	-0.26	0.25
Clay % (0-0.15m)	0.24	-0.32
EC (1:2) (dS m ⁻¹)	0.27	-0.21

tube wells (1.0-2.0 me L⁻¹). Bi-carbonate ions ranged from 9.0-14.0 me L⁻¹. High bicarbonate caused slight alkalinity in the ground water. The residual sodium carbonate (RSC) of the samples varied from 1.0 to 3.0 me L⁻¹. According to RSC irrigation water classification, samples 1,2,3,6 could be safe, although RSC of other samples were slightly higher (4, 5, 7, 8), the harmful effects were not prominent because of low carbonate content. In clay loam to loam soil under Indian conditions, the other samples are also considered to be safe, although these are not suitable for use as per USDA classification. The sodium absorption ratio (SAR) of ground water samples varied from 0.10-0.45 me L⁻¹. On the basis of USDA classification, the samples may be classified under S1 (low alkali hazards). The high chloride concentration in sample 2, 3, 4 & 8 (> 5 me L⁻¹) in the ground water samples were responsible for relatively high SAR values. On the whole, the ground water of the study area could be grouped as C3S1 of USDA irrigation water quality classification. The longitudinal conductance value (S) was positively correlated with EC of soil (r= 0.27) and clay (0.24). The S value was negatively correlated with sand and silt content (r values are -0.30 and -0.26, respectively). The transverse unit resistance (T) showed reverse trend (Table 9.9).

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

The rainfall in coastal West Bengal is confined to a few months of monsoon. All the coastal low lands are inundated with rain water during *kharif* season where mainly paddy is cultivated and the productivity is low. As the rainy season ends, the rainfall is erratic and there is fresh water scarcity for agriculture. The water scarcity is more towards summer as the surface water sources dries up. During paddy harvesting time, the excess water ponded in fields is drained out. It takes lot of time to dry the soil and prepare the field for next crop in conventional *rabi* cropping. However, zero tillage potato can immediately be cultivated with less water by utilizing residual soil moisture available during rice harvest, paddy straw mulching and incremental water saving by applying irrigation through

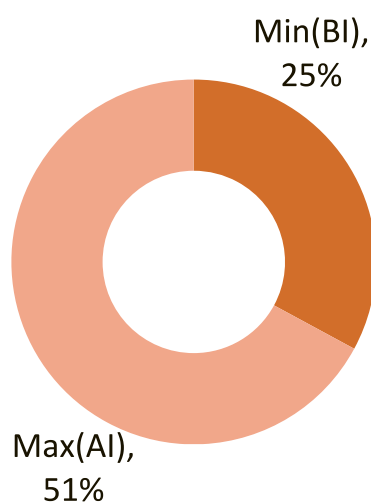


Fig 9.4 Soil moisture in top soil before irrigation (BI) and after irrigation(AI)

efficient micro-irrigation systems. An experiment was carried out 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) evaluates 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 conventional method on crop productivity, (iii) to devise irrigation scheduling for better cropping. The test crop is potato (var. Kufri Pukhraj). The soil type of the experimental plot was silty clay loam. Before experimentation, soil samples were collected in the root zone and analyzed for EC and pH. After *kharif* paddy harvesting, when soil was wet and no water inundation was there in the field, potato seeds were planted. The plots were covered with straw mulch (10 cm thick) after application of FYM and basal dose of fertilizer (10:26:26). The drip laterals are placed over the straw layer and water of desired quality supplied from tanks by a 0.5 hp electric pump. Water salinity such as $1\sim2\text{ dS m}^{-1}$ and $5\sim6\text{ dS m}^{-1}$ are prepared and used in the experiment. Irrigation scheduling is done based on IW/CPE ratios 0.5 and 0.7. There were eight treatments for two water qualities such as T1: ECw($1\sim2\text{ dS m}^{-1}$), IW/CPE=0.5; T2: ECw ($5\sim6\text{ dS m}^{-1}$), IW/CPE=0.5; T3: ECw ($1\sim2\text{ dS m}^{-1}$), IW/CPE=0.7; T4: ECw ($5\sim6\text{ dS m}^{-1}$), IW/CPE=0.7 irrigated with drip system and TC1: ECw ($1\sim2\text{ dS m}^{-1}$) IW/CPE=0.5; TC2: ECw ($5\sim6\text{ dS m}^{-1}$), IW/CPE=0.5; TC3: ECw ($1\sim2\text{ dS m}^{-1}$), IW/CPE=0.7; TC4: ECw ($5\sim6\text{ dS m}^{-1}$), IW/CPE=0.7 irrigated as per farmers' practice (Control) by spraying water on the crop. Saline water irrigation was implemented after 1 month of seed sowing and the crop got established. Recommended doses of fertilizers applied at 30, 45 and 60 days after date of sowing. Irrigation for conventional zero tillage potato was given through garden pipe by spraying water on the crop.

Soil moisture in the top soil (15 cm) was measured before and after irrigation and found to vary from 25~51 % (Fig. 9.4). Sowing of the potato seed was done on 4th week of Nov., 2024 when the soil salinity (ECe) was less than 3 dS m^{-1} and harvesting of potato was done in 3rd week of Feb, 2025. The weather during the cropping period was almost dry with only 4.5 mm rainfall.

It was observed that the growth of potato plant was superior for T1 and T3 where good quality water ($1\sim2\text{ dS m}^{-1}$) was applied with drip irrigation system. The chlorophyll content of potato plants was measured using SPAD (KONICA MINOLTA) and found that there was little variation among the treatments. The highest chlorophyll content of potato plants under drip irrigation was found to be 96.5 and it was 72.4 for plants under conventional practice. The chlorophyll content was found to vary in the range $15\sim96\text{ nmol cm}^{-2}$ (Fig. 9.5).

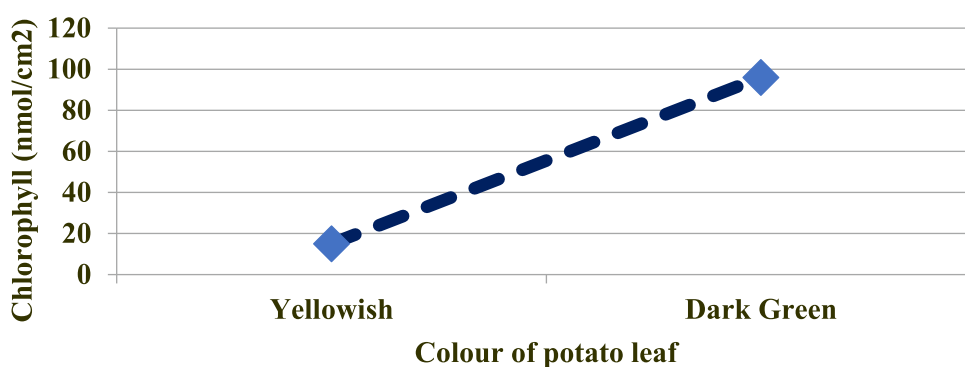


Fig 9.5 Chlorophyll content of potato leaf

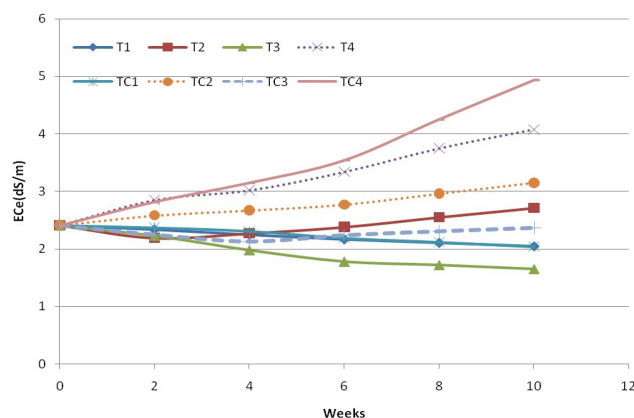


Fig 9.6 Temporal soil salinity variation during the cropping period

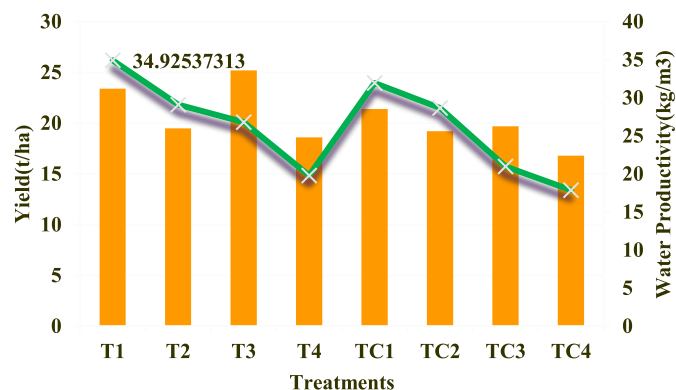


Fig 9.7 Yield and water productivity of zero tillage potato with straw mulch under different treatments

Salinity of the top soil (15 cm) was highest (4.78 dS m^{-1}) for saline water ($5\sim 6 \text{ dS m}^{-1}$) with IW/CPE=0.7 in control (TC4) at the time of harvest (Fig. 9.6).

The harvesting was done by just removing the straw and laterals and picking up the potatoes. Potato yield was highest for T3 where irrigation of good quality water was applied through drip (25.2 t ha^{-1}). However, water productivity was highest (34.9 kg m^{-3}) when drip irrigation was carried out with good quality water at IW/CPE=0.5 (Fig 9.7).

Morpho-physiological responses and grain quality of rice genotypes under salinity stress (Devika S, U.K Mandal, T. D. Lama, N. R. Prakash and Ravi Kiran KT)



Pot experiment on rice genotypes under different salinity treatments

The experiment was conducted during the *kharif* season of 2025 at ICAR-CSSRI, RRS, Canning town under controlled salinity conditions (Photo) using a Factorial Completely Randomized Design (FCRD) with three replications. Twelve rice genotypes (CSR 30, CSR 36, CSR 10, Nona Bokra, Canning 7, Amalmana, CSR 60, CSR 43, CSR 46, IR 29, Swarna, and MTU 1010) representing varying levels of salinity tolerance were evaluated. Salinity treatments included four levels: T0 (0 dS m^{-1}), T1 (4 dS m^{-1}), T2 (6 dS m^{-1}), and T3 (8 dS m^{-1}), imposed at the panicle initiation stage. Observations were recorded on morphological (plant height, root length, days to flowering), physiological (RWC, SPAD, MSI, chlorophyll a and b), and yield traits (tillers, productive tillers, panicle weight, grains per panicle, grain yield, and biomass). Data were analyzed to assess the effects of salinity, genotype, and

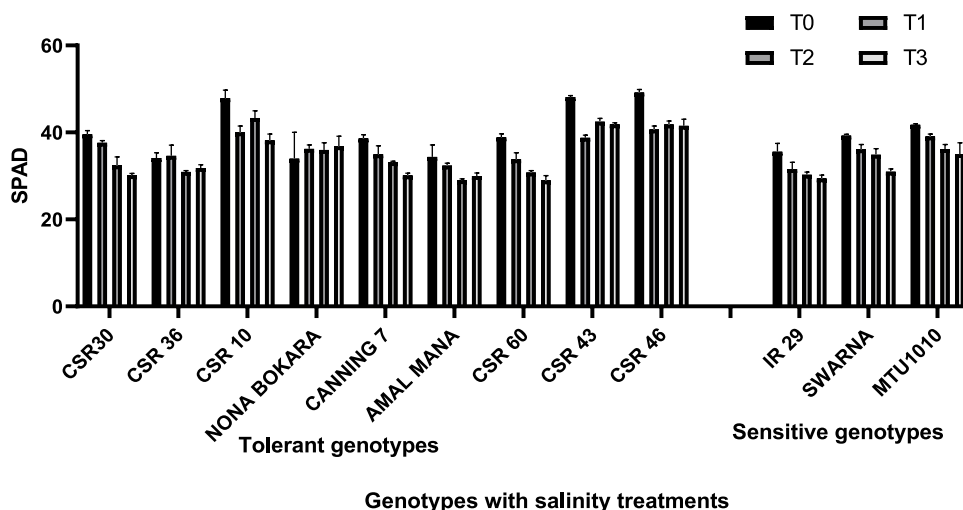
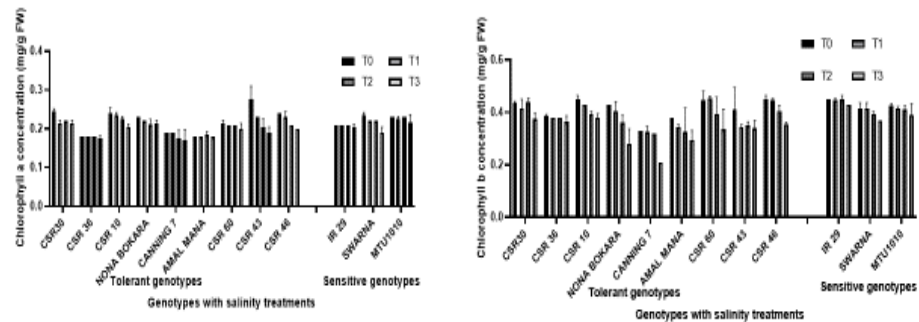


Fig 9.8 Effect of Salinity Stress on SPAD Values in Tolerant and Sensitive Rice Genotypes

Fig 9.9 Effect of salinity stress on chlorophyll content a and b values in tolerant and sensitive rice genotypes



their interaction, and Principal Component Analysis (PCA) was used to identify key traits associated with salinity tolerance.

Salinity stress exerted a significant influence on morpho-physiological traits and yield components of rice genotypes, with all observations expressed as mean $\pm$ standard error (SE) across three replications. A progressive decline in physiological parameters was observed from control (T₀) to severe salinity (T₃). The SPAD values (Fig 9.8) decreased markedly with increasing salinity, indicating reduced chlorophyll content; however, salt-tolerant genotypes such as CSR 46 and CSR 43 maintained relatively higher values (38.5 ± 1.2 at T₂ and 32.4 ± 1.0 at T₃) compared to sensitive genotypes like IR 29 (18.6 ± 0.8 at T₃), suggesting better chlorophyll stability under stress. Similarly, membrane stability index (MSI) declined with increasing salinity, but tolerant genotypes exhibited higher stability (72.3 ± 1.5 at T₃) than sensitive ones (45.2 ± 1.3), reflecting reduced membrane damage. Chlorophyll a and b contents followed a similar trend, with tolerant genotypes showing lesser reduction (chlorophyll a: 2.15 ± 0.09 mg g⁻¹ FW at T₃) compared to sensitive genotypes (1.02 ± 0.05 mg g⁻¹ FW), indicating better preservation of photosynthetic efficiency (Fig 9.9). Morphological traits such as plant height and root length were also significantly affected by salinity stress. Tolerant genotypes maintained relatively higher plant height (98.4 cm) and root length (21.3 cm at T₃) (Fig 9.10A, 9.10B), whereas sensitive genotypes showed a sharp decline under higher salinity levels (plant height: 72.5 cm at T₃). The maintenance of greater root length under stress conditions suggests an adaptive mechanism for enhanced water and nutrient uptake. Yield components including tiller number, productive tillers, panicle weight, and grains per panicle were significantly reduced with increasing salinity. Tolerant genotypes such as CSR 43 maintained higher tiller numbers (18 ± 0.7 at T₂), while sensitive genotypes like IR 29 showed a drastic reduction (10 ± 0.5 at T₃). Panicle weight and grains per panicle also declined across treatments; however, tolerant genotypes maintained comparatively higher values (CSR 46 3.2g at T₃) than sensitive genotypes (1.5 g) (Fig 9.11), indicating better spikelet fertility and assimilate partitioning under stress conditions. Grain yield and total biomass were significantly reduced under salinity stress, with a progressive decline from T₀ to T₃. Nevertheless, tolerant genotypes such as CSR 46, CSR 10, and Nona Bokra exhibited comparatively lower yield reduction (18.6 g plant⁻¹ at T₃) than sensitive genotypes like IR 29 (7.4 g plant⁻¹). Similarly, biomass accumulation was higher in tolerant genotypes (42.5 g) compared to sensitive ones (25.3 g) (Fig 9.12), indicating sustained growth under saline conditions. Overall, the reduction in physiological and yield traits under salinity stress can be attributed to ionic toxicity and osmotic imbalance, which disrupt metabolic activities. The ability of tolerant genotypes to maintain higher chlorophyll content, membrane stability, and yield components highlights their superior adaptive mechanisms. The

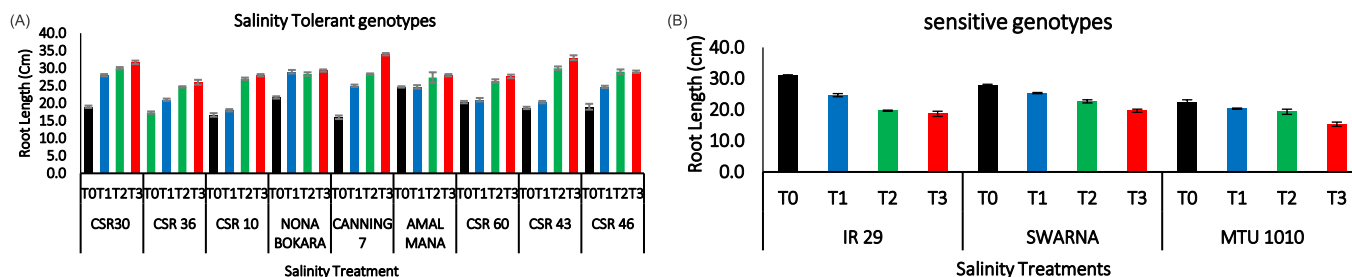


Fig 9.10 (A) Effect of salinity stress on root length (cm) in tolerant sensitive rice genotypes. (B) Effect of salinity stress on root length (cm) in sensitive rice genotypes.

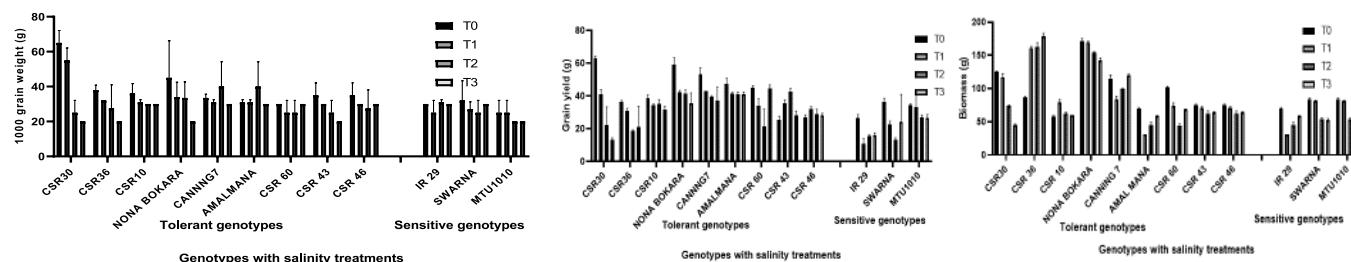


Fig 9.11 Effect of salinity stress on 1000 grain weight (g) in tolerant and sensitive rice genotypes Fig 9.12 effect of salinity stress on grain yield plant⁻¹ (g), plant biomass (g) in tolerant and sensitive rice genotypes

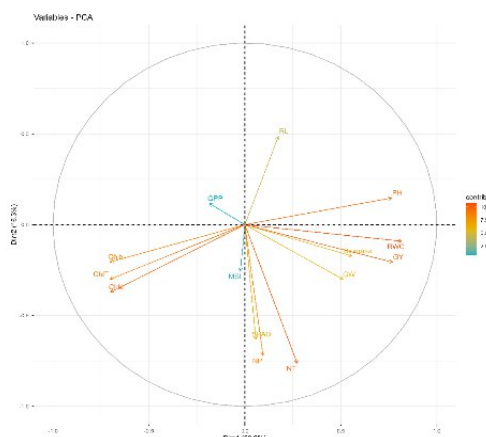


Fig 9.13 Principle component analysis of morphological and physiological traits of rice genotypes under salinity condition

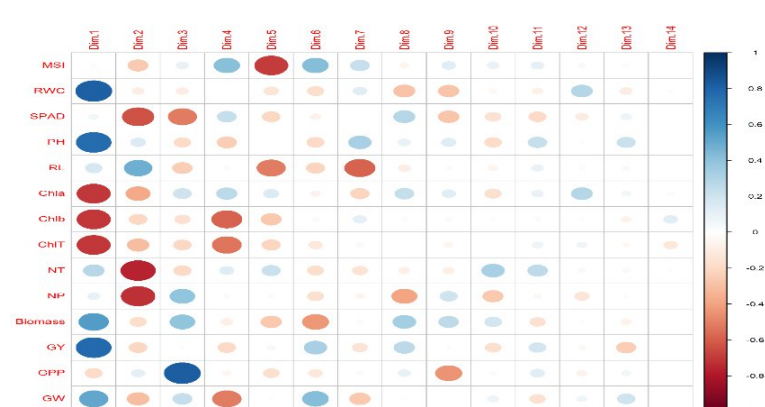


Fig 9.14 Correlation analysis of Morphological and Physiological traits of rice genotypes under salinity condition

significant genotype $\times$ salinity interaction further indicates the presence of genetic variability, and traits such as root length, chlorophyll stability, MSI, and grain yield (Fig 9.13 and 9.14) can be effectively utilized as selection indices for breeding salt-tolerant rice varieties.

Assessment of Ichthyofaunal diversity, biology and population dynamics of selected species along the estuary of Sundarbans (R.N. Bhutia, U.K. Mandal)

Under this project, a total of 57 fish species belonging to 34 families and 15 orders were recorded (Fig. 9.15). Analysis of species composition based on relative abundance indicated a strong dominance pattern within the fish community. The ten most dominant species collectively contributed 61.6% of the total catch, suggesting that a relatively small group of species plays a major role in shaping the overall community structure.

Fig 9.15 Family-wise species richness and relative contribution in the estuary

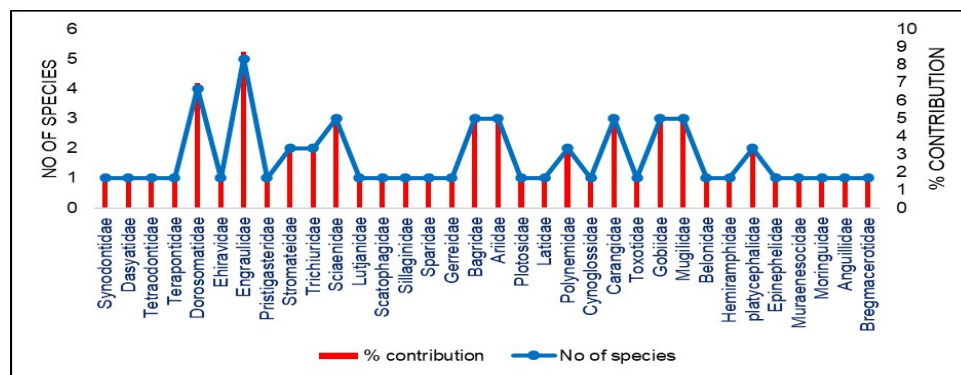
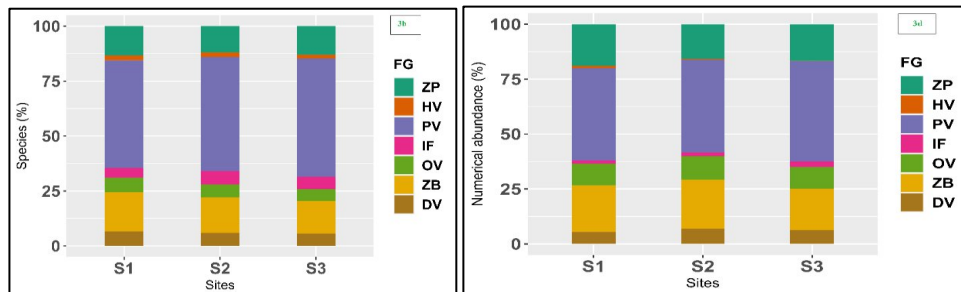


Fig 9.16 Spatial trends of feeding mode guild



Such dominance patterns are typical of estuarine ecosystems, where environmental variability often favours species that are highly adaptable to fluctuating conditions.

From a functional perspective, the analysis of feeding guilds revealed that piscivorous fishes were the dominant group in the Matla Estuary. The dominance of piscivores was consistently observed across all sampling stations, indicating a trophic structure skewed towards higher trophic levels (Fig. 9.16). This suggests a well-developed food web with sufficient prey availability to sustain top predators. The trophic level of the recorded species ranged from 1 to 3.64, reflecting the presence of organisms from primary consumers to higher-level carnivores. Such a range underscores the ecological complexity and energy transfer dynamics within the estuarine ecosystem.

Further insights into ecosystem functioning were obtained through the evaluation of ecotrophic efficiency of different functional groups. Groups such as prawns and shrimps, heterotrophic benthos, small pelagic fishes, and zooplankton exhibited high ecotrophic efficiency ranging from 0.94-0.99, indicating that these groups are effectively utilized within the food web and has high exploitation rate. Another important ecological finding of the study was the identification of croakers as a keystone fish group within the Matla Estuary with relative total impact of 0.872. Overall, the study provides a comprehensive understanding of the fish assemblage structure, trophic organization, and ecological functioning of the Matla Estuary. The dominance of piscivorous species, high salinity conditions even during monsoon, and the identification of key functional groups and keystone species collectively highlight the unique ecological characteristics of this estuarine system. These findings are crucial for informing management and conservation strategies aimed at sustaining the biodiversity and productivity of the Matla Estuary.

Enhancing the production potential and profitability of ponds through integration of small indigenous fishes in coastal region of West Bengal (R.N. Bhutia, D. Burman, U.K. Mandal and S. Mallick)

The integration of *Heteropneustes fossilis* (singhi) with Indian Major Carps (IMCs) has

Table 9.10 Growth and production performance of IMCs and *H. fossilis*

Species	Avg. I. Wt (g)	Avg. Final Wt (g)	Abs. Wt. Gain (g)	Total Production (kg ha ⁻¹)
IMC	35g	550g	515	3502
Singi	3g	41g	38	273.6

previously been identified as a highly viable aquaculture model, offering enhanced productivity and profitability. Previous years findings established that an optimized stocking density of 60,000–80,000 fish/ha of *H. fossilis* resulted in the highest economic returns (Rs. 183,890/ha) while maintaining balanced growth performance. Based upon these findings, the present study was conducted to validate this integrated culture system under real farmer field conditions at Canning I block, where demonstrations were carried out in three farmers' ponds.

The results from the field demonstration indicated strong growth and production performance of both IMCs and *H. fossilis*. IMCs exhibited an average weight gain of 515 g, reaching a final weight of 550 g, while *H. fossilis* attained a final weight of 41 g with an absolute gain of 38 g. The total production recorded was 3502 kg ha⁻¹ for IMCs and 273.6 kg ha⁻¹ for *H. fossilis* (Table 9.10). Farmers observed enhanced growth and higher production of IMCs compared to previous years. This improvement can be attributed to reduced intra- and interspecific competition for space and resources, resulting from the relatively lower stocking density of IMCs in the *H. fossilis* integrated culture system. The findings indicate good ecological compatibility of *H. fossilis* with IMCs under pond conditions. These results emphasize the critical role of optimizing species composition and stocking density in improving overall pond productivity.

The economic analysis of the integrated culture system proved highly profitable, generating a total income of Rs. 648,150 ha⁻¹ against an input cost of Rs. 410,000 ha⁻¹, resulting in a net return of Rs. 238,150 ha⁻¹ and a profitability of 58.08%. The higher profitability was largely driven by the high market value of *H. fossilis*, despite its comparatively lower production volume. Overall, the study confirms that integration of *H. fossilis* with IMCs under optimized stocking densities is a sustainable and economically rewarding strategy, suitable for large-scale adoption in farmers' ponds.

Exploring livelihood resilience of agricultural households in coastal salt-affected region (Sonali Mallick, T.D. Lama, Richen N. Bhutia, U.K. Mandal and D. Burman)

The study reveals important insights into the livelihood resilience of agricultural households in the Sundarbans region. A comprehensive household survey was conducted across 19 administrative blocks in the Indian Sundarbans region. In each block, two villages were selected, and within each village, 20 households were randomly surveyed, resulting in a total sample size of 760 households. A Livelihood Resilience Index (LRI) was constructed based on the survey data, incorporating 23 indicators organized under three primary dimensions: environmental resilience, economic resilience, and social resilience. Indicator weights were objectively determined using the entropy weight method to minimize subjectivity in aggregation. The overall mean livelihood resilience index was found to be 0.340 with a standard deviation of 0.068, indicating moderate variability across the region. Households were categorized into three groups: low resilience (<0.2718), somewhat resilient (0.2718–0.4087), and high resilience (>0.4087). A majority of households (66.97%) fall under the “somewhat resilient” category, while 17.63% and 15.39% of households fall under the low and high resilience category,

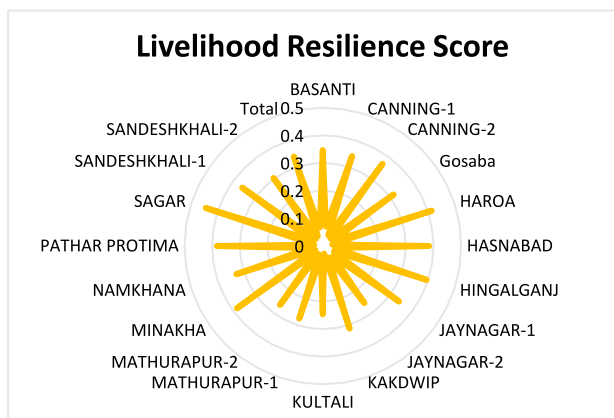


Fig 9.17 Ranking of blocks based on livelihood resilience score

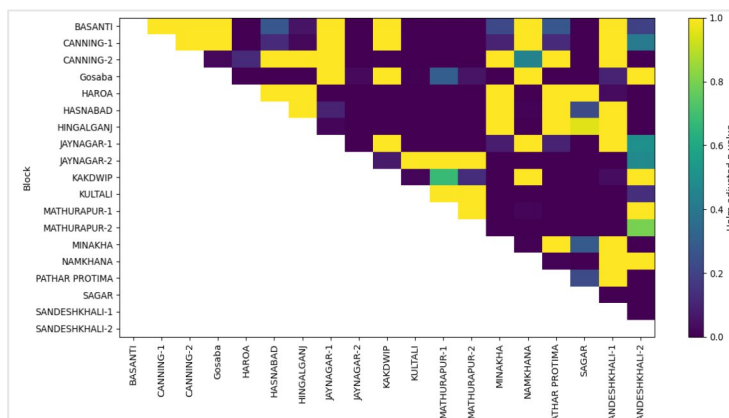


Fig 9.18 Statistical difference of Livelihood Resilience between the blocks

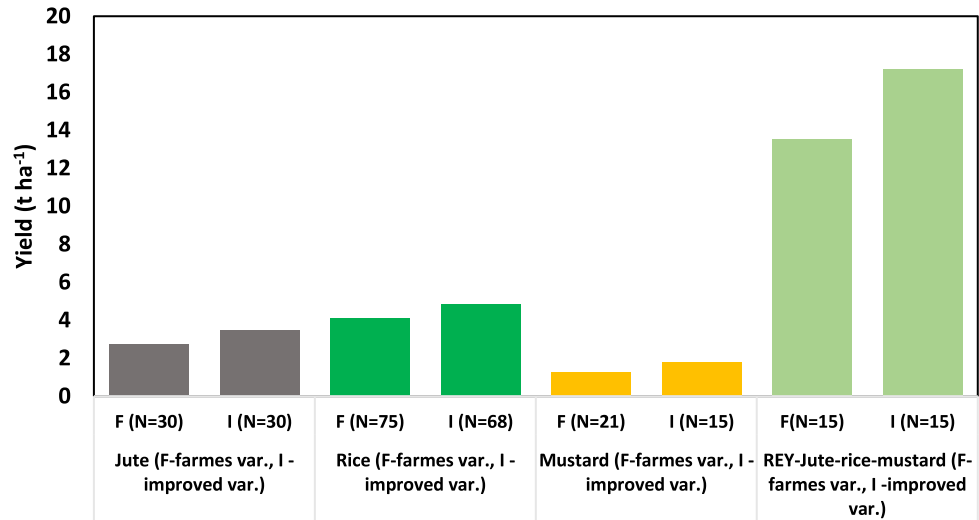
respectively. Significant spatial variation in resilience levels was observed across different blocks (Fig. 9.17). The Kruskal–Wallis test ($H = 470.38$, $p < 0.001$) confirmed statistically significant differences in livelihood resilience among blocks, which was further supported by Dunn's post-hoc test. Block-wise analysis shows that Sagar consistently ranks higher across environmental, economic, and social resilience dimensions (Fig. 9.18). In the environmental resilience dimension, Sagar is ranked higher. In the economic resilience dimension, Sagar, Mathurapur-I ranked higher. Sagar, Kakdwip and Namkhana ranked better in the social resilience category. In contrast, Mathurapur-I, Mathurapur-II, Jaynagar-I, and Kultali resulted as low-resilience blocks, indicating greater vulnerability to climatic and socio-economic stressors.

CGIAR funded project: Asian Mega-Deltas project on Securing the Asian Mega-Deltas from sea-level rise, flooding, salinization and water insecurity (D.Burman, T.D. Lama, U.K. Mandal, R. N. Bhutia and N.R. Prakash)

Under this project, the research activities implemented under WP1 (Adapting Deltaic Production Systems) in the Ganges Delta to develop context-specific agronomic packages for diversified and climate-resilient farming systems. Key strategies included improving land and water productivity through better resource management, crop planning, and agronomic practices, and building the capacity of small and marginal farmers.

Improved varieties of rice (Super Shyamali, Santoshi, CR-1017, Bangabandhu, Mali-4), jute (JROG 1, CO 58, JRO 204, S 19), and mustard (CS 58, CS 62) were demonstrated in farmers' fields across various locations in South and North 24 Parganas. *Kharif* rice yields were significantly higher with improved varieties (4.86 t ha^{-1}) compared to farmers' varieties (4.11 t ha^{-1}) (Fig 9.19). Similarly, improved mustard cultivars yielded 1.78 t ha^{-1} , out performing the traditionally grown varieties (1.24 t ha^{-1}). In jute, improved varieties produced 3.45 t ha^{-1} , compared to 2.75 t ha^{-1} from local cultivars. The adoption of improved rice, mustard, and jute varieties, along with recommended management practices, resulted in a 27.4% increase in rice equivalent yield (REY) under the rice–mustard–jute cropping system compared to rice-rice cropping system in the salt-affected coastal region of the Ganges Delta. Additionally, the introduction of zero tillage potato with rice straw mulching in rice-based systems enabled the inclusion of a third crop-green gram in the cropping system. This intensified system recorded a substantially higher REY (28.5 t

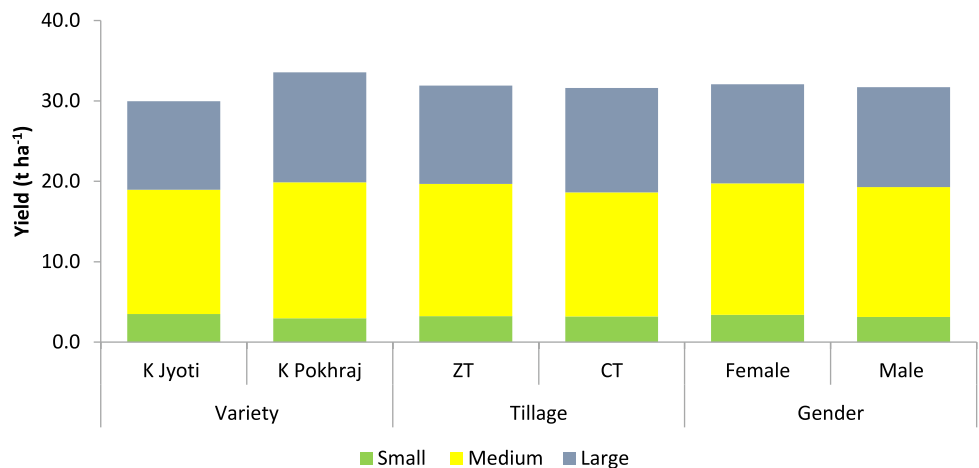
Fig 9.19 Yield of jute, rice, mustard crops and cropping system with improved vs. farmer's varieties



ha⁻¹) compared to the conventional rice–rice system (8.70 t ha⁻¹), indicating its potential for enhancing productivity and profitability in coastal farming systems.

A farmer field trial on potato cultivation was conducted during *rabi* season in three locations across South and North 24 Parganas districts, covering a total of 486 plots managed by 451 farmers. The trial compared two tillage practices, zero tillage with paddy straw mulching and conventional tillage using two potato varieties: Kufri Pukhraj and Kufri Jyoti. In the previous year, only Kufri Jyoti was included in the trials. Of the total trial plots, 76% were under zero tillage, and 30% were managed by women farmers. This second year of experimentation built on earlier work conducted in the villages of Ramgopalpur and Chatrakhal, South 24 Parganas. To reinforce farmers' experience with zero tillage potato cultivation, these two locations were retained for the trial. Additionally, Takipur village in North 24 Parganas was included as a new site with a limited number of participants, aimed at assessing community interest and agro-ecological suitability. Analysis of the trial data revealed that the potato variety had a significant effect on yield across all tuber size categories—small, medium, large, and total yield indicating that varietal differences were the dominant factor influencing productivity (Fig 9.20). Kufri Pukhraj produced a slightly higher total yield (33.56 t ha⁻¹) compared to Kufri Jyoti (29.94 t ha⁻¹).

Fig 9.20 Yield of potato under on-farm trials potato cultivation under ZT&CT



Tillage practice also had a notable impact, significantly affecting yields of medium and large tubers. Furthermore, a significant interaction between variety and tillage was observed for total tuber yield, suggesting differential varietal responses under different planting conditions. However, the average total yield did not differ significantly between tillage types, with 31.90 t ha⁻¹ for zero tillage and 31.60 t ha⁻¹ for conventional tillage. A significant variation in small tuber yield was noted across villages, implying that local environmental or agronomic factors may influence the production of smaller tubers. Gender of the farmer did not have a significant effect on yield in any tuber size category. Similarly, most interaction effects involving village, gender, tillage, and variety were non-significant, with only a few marginal exceptions.

These findings suggest that genetic factors (variety) and to a lesser extent management or environmental conditions (tillage practices) are the primary determinants of potato yield, while socio-demographic variables such as gender had minimal impact in this study. It is possible to get almost similar yield of potato under zero tillage conditions compared to conventional system in the coastal salt affected region.

Screening of potato varieties under zero tillage with paddy straw mulching and conventional tillage was conducted in a rice-potato system at ICAR-CSSRI, RRS Canning Town. The objective was to identify varieties suitable for the deltaic region and support seed system interventions by replacing less adapted cultivars. The study also evaluated the feasibility of zero-tillage. A total of 13 genotypes (Kufri Surya, Kufri Khyati, Kufri Thar 1, Kufri Thar 2, Kufri Thar 3, Kufri Chandramukhi, Kufri Pukhraj, Kufri Himalini, Kufri Sukhyati, Kufri Kanchan, Kufri Lima, Kufri Jyoti and Kufri Mohan) were tested under both management practices.

ANOVA revealed that both total and marketable tuber yields were significantly influenced by tillage ($p = 0.0108$ and 0.0342 , respectively) and genotype ($p < 0.001$). Total yield was consistently higher under zero tillage, with minor genotype $\times$ tillage interaction, suggesting stable genotypic performance. Marketable yield also increased under zero tillage, though interaction effects ($p = 0.0938$) indicated some genotype-specific responses. Zero tillage also improved plant height and average tuber weight, with significant interactions observed for the latter. These results highlight the potential of zero tillage and targeted genotype selection to enhance productivity and resource-use efficiency in potato cultivation systems. Plant vigor at 45 days after planting (DAP) was consistently higher under zero tillage across genotypes. Kufri Surya, Kufri Mohan, Kufri Jyoti, and Kufri Pukhraj recorded the maximum vigor score of 7.0 under ZT, while under CT, the vigor scores for these same genotypes ranged from 2.33 to 4.33. This enhanced early vigor under ZT suggests better physiological establishment in minimally disturbed soil under normal salinity. Plant height showed a marked increase under ZT. The tallest plants were observed in Kufri Mohan (65.69 cm), Kufri Sukhyati (64.56 cm), and Kufri Thar 2 (64.05 cm) under zero tillage. These values were significantly higher compared to their performance under CT, where maximum plant heights ranged from 32.76 cm to 46.95 cm. This suggests that the absence of soil disturbance under ZT may facilitate better root establishment and nutrient uptake. Dry matter content varied across genotypes and tillage systems. Kufri Lima exhibited the highest dry matter under ZT (25.5%), followed by Kufri Kanchan (CT: 22.8%) and Kufri Khyati (CT: 22.3%). Some genotypes, such as Kufri Sukhyati (ZT: 13.2%) and Kufri Jyoti (ZT: 13.7%), showed lower dry matter, indicating variability in processing suitability under zero tillage. Marketable tuber yield was

significantly improved under ZT. The highest yields were recorded in Kufri Surya, Kufri Khyati, and Kufri Pukhraj under zero tillage. In contrast, the same genotypes produced lower marketable yields under CT.

Several meetings, trainings and field visits were conducted involving total 775 farmers (521 male, 254 female) in the project sites for capacity building, implementation of field experiments, dissemination of technologies, demonstrations and up scaling activities.

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

The successful completion of Phase I of the ACIAR-funded project on “Cropping Systems Intensification in the Salt-Affected Coastal Zones of Bangladesh and West Bengal, India” led to the initiation of Phase II, titled “Mitigating Risk and Scaling-Out Profitable Cropping System Intensification Practices in the Ganges Delta.” This phase (2020–2025), implemented by ICAR-CSSRI, RRS, Canning Town, covered farmers' fields in Gosaba (Gosaba, Chandipur, and Bali islands) and Canning I blocks of the Indian Sundarbans. During 2025–26, surface and groundwater quality studies continued alongside cropping system interventions involving 701 farmers (489 male, 212 female). The project focused on enhancing cropping intensity through improved practices, new crops, and varieties, supported by on-farm trials, large-scale demonstrations, and capacity-building programs. Ongoing experiments include evaluation of fodder crops and shade-tolerant crops for homestead intensification.

Water samples from surface (rivers, canals, drainage channels (Nayanjali), ponds) and groundwater sources were analyzed. Groundwater was collected using piezometers at 6.1 m depth. Water pH remained near neutral across locations. At Sonagaon (Gosaba Island), groundwater depth reached 2.03 m below ground level, with salinity ranging from 0.29–38.74 dS m⁻¹ (mean 10.99 dS m⁻¹). In Bali Island, salinity ranged from 0.21–6.78 dS m⁻¹ (mean 2.73 dS m⁻¹), with the lowest groundwater depth of 3.92 m in May. At Chandipur, salinity varied from 0.13–7.10 dS m⁻¹ (mean 1.98 dS m⁻¹), and maximum groundwater depth was 2.96 m in June 2023. Surface water was sampled from 12 locations in Bali, 11 in Chandipur, and 10 in Gosaba. River salinity was generally higher, with lower values during monsoon. Pond water, sustained by rainwater harvesting, remained <2 dS m⁻¹ in monsoon but increased in the dry season. At Bali Island (Fig. 9.21) the salinity increased to 2.67 dS m⁻¹, while highest pond water salinity at Chandipur and Gosaba was observed 3.68 dS m⁻¹ and 9.35 dS m⁻¹, respectively. Tube well salinity was higher than pond water, ranging from 1.11–1.85 dS m⁻¹ in Bali, 2.01–3.78 dS m⁻¹ in Sonagaon (Gosaba), and 1.65–3.96 dS m⁻¹ in Chandipur. Nutrient concentrations showed seasonal variation, highest in pre-*kharif* followed by *kharif* and *rabi*.

The study evaluated the feasibility of cultivating fodder crops in coastal, non-cropped saline areas during the Rabi season under three planting dates: D₁ (1 December), D₂ (1 January), and D₃ (1 February). Mean green fodder yield was highest with 1 December sowing (105.6 t ha⁻¹), followed by 1 January (90.0 t ha⁻¹) and 1 February (79.9 t ha⁻¹), showing a decline with delayed planting (Fig. 9.22). Among crops, highest yields were recorded in super napier (130.3 t ha⁻¹), HNB Co-3 (130.0 t ha⁻¹), smart napier (129.3 t ha⁻¹), HNB Co-5 (128.3 t ha⁻¹), HNB Co-4 (123.0 t ha⁻¹), red napier (121.7 t ha⁻¹), and sorghum (119.3

Fig 9.21 Surface water salinity at Bali Island

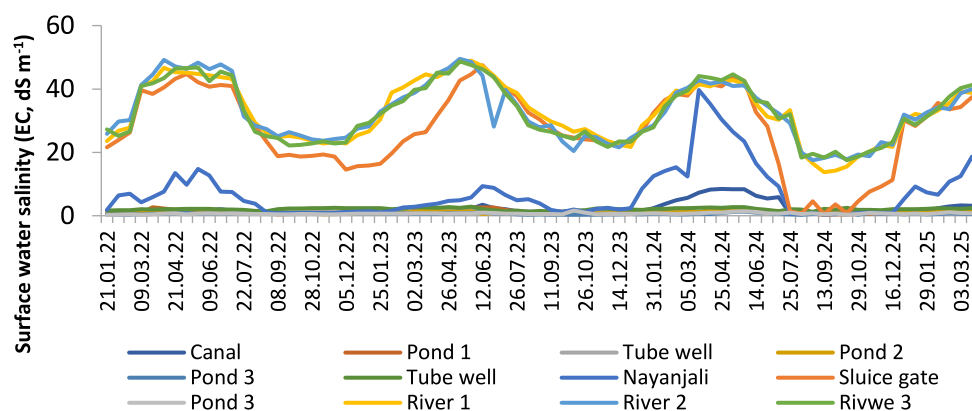
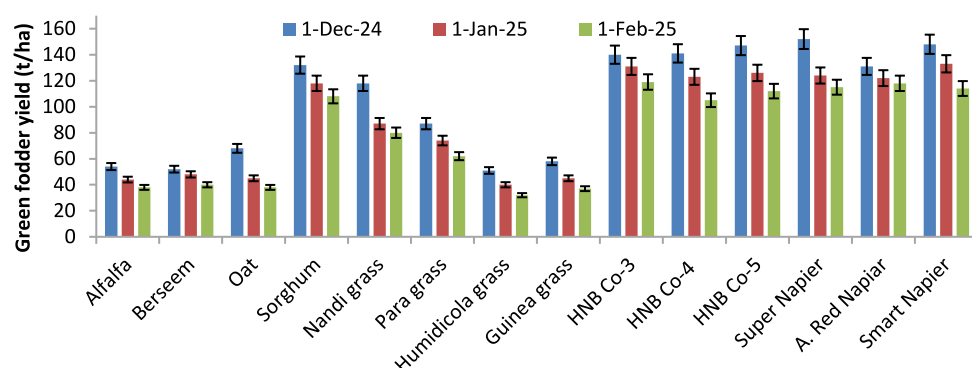


Fig 9.22 Effect of planting dates and fodder crops on green fodder yield at Bali Island.



t ha⁻¹). Moderate yields were obtained from nandi grass (95.0 t ha⁻¹) and para grass (74.3 t ha⁻¹), while lower yields were observed in oat (50.3 t ha⁻¹), guinea grass (48.3 t ha⁻¹), berseem (46.7 t ha⁻¹), alfalfa (45.3 t ha⁻¹), and humidicola grass (41.0 t ha⁻¹). In terms of livestock preference, smart napier and sorghum were suitable for goats, HNB varieties for dairy cattle, and oat for both. Leguminous fodders (alfalfa, berseem) improve nutrition and soil fertility through biological nitrogen fixation, while para grass is suitable for waterlogged lowlands. Overall, integrating cereal and legume fodders enhances soil health, livestock nutrition, and resilience in saline coastal systems.

Homestead farming (HSF), practiced adjacent to farmers' dwellings, was promoted to enhance food and nutritional security in salt-affected coastal areas through the inclusion of shade-tolerant crops. During *kharif*, spinach, beet, and turnip were cultivated, followed by elephant foot yam, turmeric, and ginger; ginger was also successfully grown in soil- and manure-filled bags for space-efficient production. A total of 438 farmers (252 male and 186 female) participated in the intervention.

At Sonagaon (Gosaba), the yield of elephant foot yam ranged from 25.2 to 33.5 t ha⁻¹, turmeric from 17.3 to 108.0 t ha⁻¹, and ginger from 21.1 to 38.6 t ha⁻¹. At Chandipur, elephant foot yam yields varied between 19.0 and 33.9 t ha⁻¹, turmeric from 28.1 to 59.6 t ha⁻¹, and ginger from 24.3 to 36.6 t ha⁻¹. At Bali Island, elephant foot yam yields ranged from 24.4 to 36.7 t ha⁻¹, turmeric from 15.4 to 91.0 t ha⁻¹, and ginger from 25.5 to 56.3 t ha⁻¹. The system also integrated diverse vegetables: bitter gourd, cucumber, cowpea, green chilli, okra, pumpkin, and ridge gourd in *kharif*, and spinach, tomato, cauliflower, cabbage, carrot, beet, broccoli, knol-khol, potato, radish, and coriander in *rabi*. This diversification ensured year-round nutritional supply and additional income from surplus produce, demonstrating HSF as an effective approach for improving livelihood security and nutrition in coastal farming communities.

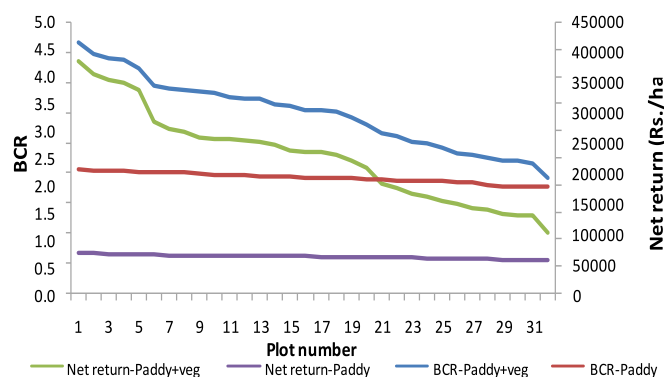


Fig 9.23 BCR and net return from the cultivation of sole paddy and paddy+vegetables during kharif 2025

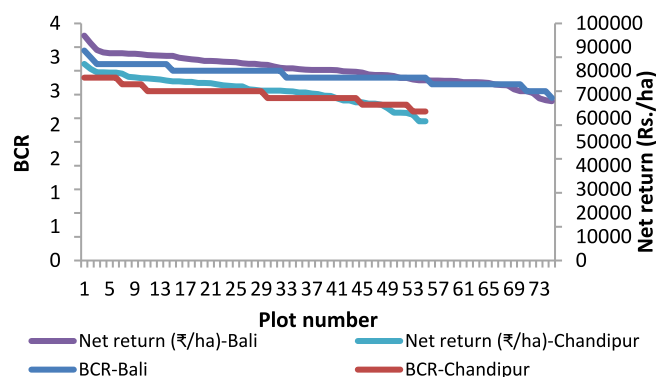


Fig 9.24 BCR and net return from green gram cultivation during rabi 2024-25



Paddy+vegetables cultivation during kharif

During the reporting period, the most promising cropping system intensification option—paddy + vegetable cultivation during the *kharif* season, zero tillage potato with paddy straw mulching -green gram sequence were successfully scaled out across four Sundarbans clusters (Gosaba, Bali, Chandipur, and Canning). The paddy + vegetable system proved highly profitable under coastal rainfed lowland conditions and gained strong acceptance in West Bengal, particularly among women farmers due to favourable labour dynamics. Vegetables (bitter melon, snake melon, sponge melon, cucumber, and ridge melon) were grown in soil and manure filled sacks, enabling cultivation under waterlogged conditions (Photo). By 2024–25, 228 farmers (predominantly women) had adopted the technology. The cost of cultivation for sole paddy ranged from ₹51,173–58,790 ha⁻¹ (avg. ₹54,978), with net returns of ₹56,224–68,041 ha⁻¹ (avg. ₹61,665) and a BCR of 2.0–2.3 (avg. 2.1) (Fig. 9.23). In contrast, the paddy + vegetable system had a higher cost (₹84,148–112,730 ha⁻¹; avg. ₹97,296) but delivered substantially higher net returns (₹101,841–384,356 ha⁻¹; avg. ₹226,887) and BCR (2.1–4.6; avg. 3.3), indicating significantly greater profitability.

Zero tillage potato cultivation with rice straw mulching was demonstrated across 221 farmers' fields in three islands—Bali, Chandipur, and Gosaba. The potato tuber yield ranged from 23.2 to 39.6 t ha⁻¹ (average 31.1 t ha⁻¹) at Bali, 24.4 to 30.6 t ha⁻¹ (average 27.5 t ha⁻¹) at Chandipur, and 26.2 to 29.8 t ha⁻¹ (average 28.0 t ha⁻¹) at Gosaba. Following the harvest of zero tillage (ZT) potato, green gram was cultivated under the rice–ZT potato–green gram cropping system. During the current year, the green gram crop performed well across all sites except Sonagaon, where crop failure occurred due to the ingress of highly saline river water into the cultivated fields. The benefit–cost ratio (BCR) and net returns from green gram cultivation are presented in Fig 9.24.

During the reporting period, several meetings, trainings and field visits were conducted at the project sites to facilitate the dissemination of cropping system intensification technologies, as well as to support the implementation of field experiments, demonstrations, and scaling-up activities.

NICRA Project: Climate change mitigation and adaptation strategies for salt affected soils (U.K. Mandal, K.K. Mahanta, S. Raut; R.N. Bhutia; PI: A.K. Bhardwaj)

Under this project we studied the village scale environmental hazards in the Indian Sundarbans. The Ganges delta has faced numerous environmental hazards that have remarkably affected the lives and livelihoods of its natives. The coastal and low-lying

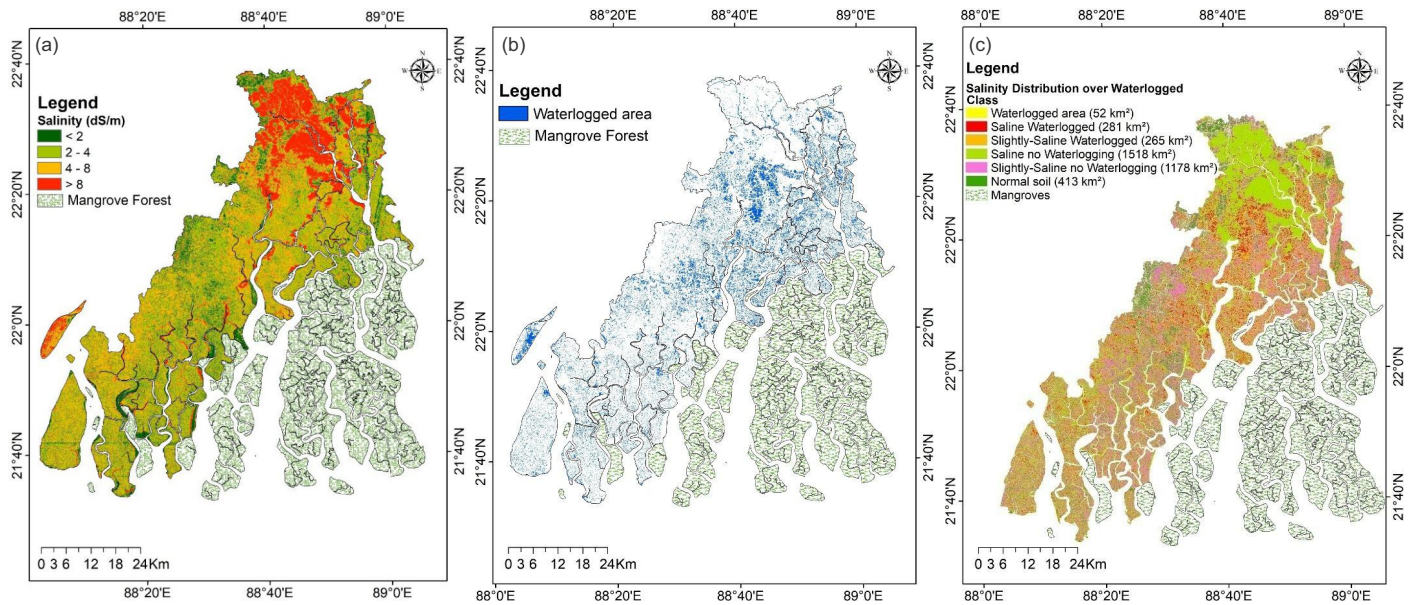


Fig 9.25 Soil salinity (a) inundation area (b) saline inundation area (c) of Indian Sundarbans

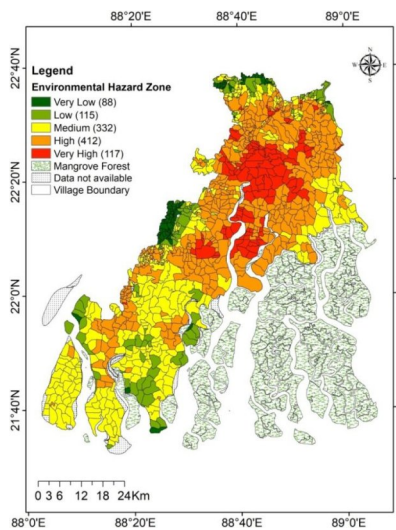


Fig 9.26 Village level environmental hazards map of Indian Sundarbans developed by combining temperature, rainfall, cyclone, salinity and inundation information

areas of the Sundarbans in Gangetic delta are highly vulnerable to multiple hazards. Along with tropical cyclone rising soil salinity and persistent waterlogging have significantly reduced agricultural productivity and made fishing and farming activities highly risk prone in the region. We studied Sentinel-2 multispectral images in identifying soil salinity using soil physico-chemical properties, spectral indices and image analysis techniques (Fig. 9.25). Sentinel-1 images from June, July, August, September and October were used to generate extents of inundation in the corresponding months for 2021 as the year 2021 recorded maximum rainfall in the study region (Fig. 9.26). We have identified 960, 716, 144, 839, 727 km² area as saline waterlogged, slightly saline waterlogged, waterlogged, saline (without waterlogging), and slightly saline (without waterlogging) area, respectively in the region. Climate hazards were assessed using future climate data from the IPCC's 6th assessment report (CMIP6, Coupled Model Intercomparison Project Phase-6). Climate hazard levels were assessed by integrating the impacts of four temperature extremes and five rainfall extremes critical to crop growth. Nine climate parameters of temperature and rainfall, were analysed for climate hazard for both historical value and projected values based on SSP585 (Shared socio-economic pathways) for the period 2041–2060. Cyclone track data since 1895 were downloaded from India Meteorological Department (IMD) to generated maps for windspeed, cyclone frequency and cyclone return periods of the region. Fuzzy logic approach was used to standardise the different factors on a range of 0 to 1 followed by fuzzy GAMMA overlay operation for salinity, waterlogging, cyclone and climate hazard map to produce the environmental hazard map. The output was extracted in village scale for prioritization programme. Out of 1070 No. villages in Indian Sundarbans 453, 385, 159, 64 and 9 villages are very high, high, medium, low and very low category, respectively of environmental hazards indicating vulnerability of the region (Fig. 9.26). The applied approach can help the local authorities in identifying environmental hazard areas and building actionable strategies for mitigation in the Indian Sundarbans.

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)



Measuring temperature using an infrared thermometer while biochar preparation



Biochar prepared from paddy straw

A low-cost biochar kiln was developed using locally available kerosene drum of 200 L capacity. The kiln is about 60 cm diameter and 90 cm height with one square shaped hole of 16 cm 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 equidistance concentric circles at the bottom rim of the drum. 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 through natural convection and radiation. After cooling, 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. The kiln body temperature was monitored during biochar preparation using an infrared thermometer and the temperatures varied between 180-505°C (Photo). A column study was conducted to study the effect of biochar (Photo) on salt leaching from the coastal saline soils of West Bengal. The study indicated that application of biochar in salt effected soil was reducing the salt content of soil by leaching out the salt from the soil.

We also monitored the groundwater depth and quality from groundwater samples collected from shallow and deep tube wells of Basanti block of Sundarbans. The conductivity, salt of both anions (Cl^- , SO_4^{2-} , HCO_3^-) and cations (Na^+ , K^+ , Ca^{+2} , Mg^{+2}) were analysed. The groundwater quality map for Basanti block was prepared. The salt content was inversely proportional with depth. Experiment conducted on okra and sunflower under drip irrigation using different level of saline water up to 12 dS m^{-1} . The results of three years' yield data showed that sunflower crop can be grown without any yield reduction up to 8 dS m^{-1} saline water under no mulching and up to 12 dS m^{-1} with rice straw mulching condition whereas okra showed yield reduction under saline water irrigation both mulching and no mulching condition. We have estimated block wise food requirement, water demand and surface and groundwater available and water gap in Indian Sundarbans region. Our estimation shows that the block Kakdwip, Mathurapur-II and Gosaba may face water scarcity in near future.

DST funded project: Livelihood improvement of the disadvantaged SC farmers through Land Shaping Technology in the Climatically Vulnerable Indian Sunderbans (T.D. Lama, D. Burman, U.K. Mandal, K.K. Mahanta, R.N Bhutia and Sonali Mallick)

Crop productivity in the coastal area (Sundarbans) of West Bengal is limited due to



LOCATION MAP



Project site in the Sundarbans Delta

waterlogging during monsoon and lack of sufficient fresh water for irrigation during the rabi or dry season when the soil salinity is at the highest. Besides there is added risk of losses due to the vagaries of extreme weather events like cyclones. Due to these constraints, the crop yields are low, most of the area are left fallow during dry season and income from agriculture is not sufficient due to which the farmers migrate to other places in search of alternate livelihood options. In this context, land shaping technologies which is a unique technology will help in addressing the key challenges like land degradation (salinity), drainage congestion and scarcity of fresh water for irrigation and in turn have the potential to enhance production, productivity, income and employment. Beside it has the potential as a climate resilient technology and aids in mitigating climate associated risks. The project is being implemented in Uttar Redokhali and Dabu villages Canning I Block and Birajnagar and Bijohnagar villages in Gosaba Block of South 24 Parganas district of West Bengal which are located in the climatically vulnerable Sundarbans delta (Photo).

To address the problems of waterlogging during rainy season and lack of fresh water for irrigation and salinity during dry season, 34 land shaping units (Photo) were implemented in the farmers' field in the selected villages of Canning I and Gosaba blocks of South 24 Parganas. It involves modifying the surface of the farm land for harvesting of excess rain water as well as making the land surface suitably shaped for the adoption of improved cultivation of diversified crops and integrated farming.

Field demonstrations are being conducted to optimize nitrogen fertilizer application in *boro* rice using a leaf colour chart (LCC), aimed at improving nitrogen use efficiency and minimizing excessive N inputs. Improved varieties of rice, Jeerakatti and GMS hybrid 2608 are being demonstrated in the farmers' field during *boro* 2026. Under the project, pumpsets and paddy seeds and fertilisers were also distributed to the project beneficiaries (Photo). For awareness and capacity building of the small and marginal SC farmers, one Stakeholder Analysis Meeting and Awareness Programme and 4 training programmes were conducted on various aspects covering improved technologies for crop production, land shaping an innovative technology to improve productivity and



Land shaping units implemented in the farmers field

Field activities under the project:
Promoting use of leaf colour
chart for N fertilizer application
and distribution of pumpsets,
paddy seeds and fertilizers



resilience of degraded coastal lands improved aquaculture and animal husbandry practices and sustainable eco-friendly bio-intensive management for pest and diseases problem in different agricultural and horticultural crops (Photo). These programmes aim to improve the knowledge and empower the farmers thereby empowering them to take better decisions and adopt scalable innovations which can improve their income and livelihood while addressing and adapting to climatic risks.

Training programmes conducted





AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture

Effect of Different Land Uses on Soil Sodification and Nutrient Dynamics in the Vertisol of Malwa Plateau (BL Meena, AK Rai, Ashim Datta, Priyanka Chandra, RK Yadav, RL Meena, Rajkumar and Bharat Singh)



Chikoo plantation showing the highest SOC and high available nitrogen

A field study was conducted to evaluate the impact of different land use systems (Neem, Ber, Chikoo, Rice–Wheat, and Grassland) on soil sodicity and nutrient dynamics in sodic Vertisols of the Malwa Plateau. The study assessed depth-wise variations in soil pH, EC, organic carbon (OC), available nitrogen, bulk density, and calcium carbonate content.

The results (Table 10.1) revealed that soil pH increased with depth under all land use systems, indicating greater sodicity in deeper soil layers. Tree-based systems, particularly Chikoo and Neem plantations, exhibited comparatively lower surface soil pH than Rice–Wheat and Grassland systems. Soil organic carbon and available nitrogen were generally higher in surface layers and declined with depth. Chikoo-based land use recorded the highest OC and available N, suggesting improved nutrient cycling and organic matter accumulation. Bulk density tended to increase with depth, while CaCO_3 accumulation was more pronounced in deeper layers, especially under Ber and Chikoo plantations.

Overall, tree-based land use systems showed better soil quality indicators and may contribute to long-term improvement of sodic Vertisols compared to conventional cropping systems.

Table 10.1 Effect of Different Land Use Systems on Surface Soil Properties (0–15 cm) in Sodic Vertisol of the Malwa Plateau

Land Use System	pH	EC (dS m^{-1})	Organic Carbon (%)	Available N (kg ha^{-1})	Bulk Density (Mg m^{-3})	CaCO_3 (%)
T1-Neem	8.65	0.46	0.37	73.50	1.46	10.80
T2-Ber	8.85	0.44	0.50	62.72	1.47	11.25
T3-Chikoo	8.92	0.52	0.57	70.56	1.73	13.56
T4-Rice–Wheat	9.72	0.55	0.53	71.54	1.50	3.30
T5-Grassland	9.49	0.46	0.44	57.82	1.63	2.97

Effect of Saline Water Drip Irrigation and Plastic Mulch on Coloured Capsicum under Naturally Ventilated Polyhouse Conditions (BL Meena, RL Meena, SK Sanwal and Jitendra Kumar)

Thirty-day-old seedlings of red capsicum (NS-280) and yellow capsicum (NS-281) were transplanted on 30 September 2025 under a naturally ventilated polyhouse. Three irrigation water salinity treatments, viz., BAW, 3 EC and 6 EC, were evaluated under drip irrigation and plastic mulch conditions. The crop exhibited normal growth and fruit development under all salinity treatments. Colour development in fruits commenced 113 days after transplanting. The cumulative harvest recorded up to March 2026 indicated that saline irrigation up to 6 EC did not adversely affect capsicum production under polyhouse conditions. The highest total marketable yield (79.12 kg) was recorded under the 6 EC treatment, followed by 3 EC (72.26 kg) and BAW (65.79 kg). Preliminary results suggest that coloured capsicum can be successfully grown under polyhouse conditions using moderately saline irrigation water. The 6 EC treatment produced the highest

Performance of Red and Yellow Capsicum under Different Irrigation Water Salinity Treatments



cumulative yield among the treatments evaluated. However, harvesting is still in progress and yield recording is continuing; therefore, the final conclusions will be drawn after completion of the crop season and analysis of the complete yield data.

Resource Inventories of Poor Quality Groundwater for Irrigation

Survey and characterization of underground irrigation water of districts of Andhra Pradesh (Bapatla)

A groundwater quality survey was undertaken across three districts (Bapatla, Guntur, Vizianagaram, and Visakhapatnam) of Andhra Pradesh during December 2022 -March 2024 to revisit earlier monitoring sites to assess and characterize groundwater for irrigation water. In Bapatla district, 883 groundwater samples were collected across all 38 mandals in December 2022. The pH ranged from 5.3 to 8.4, while EC varied from 0.15 to 7.3 dS m⁻¹, covering non-saline to highly saline conditions. Carbonate and bicarbonate concentrations ranged from nil to 1.6 me L⁻¹ and up to 21.2 me L⁻¹, respectively. Chloride levels extended from safe to crop-injurious ranges. High SAR alkali waters was prominent in Gara, Kotturu, and Ponduru mandals. Comparison with data from 2007–08 indicated a decline in good-quality water and an increase in marginally saline and alkali types, reflecting gradual quality deterioration.

In Vizianagaram district, total 736 samples covering all 34 mandals were collected in February 2023. The analysis revealed that chloride, magnesium, and sodium contents varied widely, with sulphate ranged between 0.01 and 4.8 me L⁻¹. About 541 collected samples resembled seawater based on electrical conductivity (EC) and ion concentrations. Based on EC, 90.35% of collected samples were classified as good for irrigation without growth limitations, while based on chloride content, 73.78% were found excellent category. About 98% samples recorded pH > 7.0, and 42.66% were found strongly alkaline. However, based on SAR, 97.42% samples were characterized as safe, while 3.94% and 6.52% samples were classified as marginally alkaline and alkaline, respectively. Overall, 85% samples were found of good quality, which indicates that most groundwater of the district is good for irrigation.

In Visakhapatnam district, 800 samples were collected from 43 mandals during Feb–Mar 2024. Analysed samples revealed pH > 7.0 for 60% samples, while > 8.0 for 2.88%. EC varied from non-saline to saline, and bicarbonate reached 29.4 me L⁻¹. Based on EC, 80.13% were found good for irrigation; while 58.13% samples were classified as excellent based on chloride concentration. About 95% of samples were characterized as safe for SAR, while 7.5% and 5.75% samples were marginally alkaline and alkaline respectively. Overall comparison with 2006–07 revealed a decrease in good-quality water from 96.9% to

85.63% and a rise in salinity, underscoring progressive groundwater degradation and the need for sustainable management.

Compilation and mapping of groundwater quality of Andhra Pradesh using GIS (Bapatla)

The groundwater analytical data of Krishna zone comprising erstwhile districts of Krishna, Guntur and Prakasam districts and scarce rainfall zone comprising of Kurnool, Nandyala, Ananthapuram and Annamaiah districts generated at Saline Water Scheme, Bapatla has been compiled into a common database. The data were cleaned and organized into required format for generation of thematic maps in QGIS. Initially the delimited text layer plotted and exported as shapefile. Further the shapefile containing groundwater location coordinates is clipped for the new district boundaries of the zone viz. Krishna, NTR, Bapatla, Guntur, Palnadu and Prakasam districts and the new district boundaries of the scarce rainfall zone. Further data points were interpolated using IDW and thematic maps of pH, EC, chloride, sodium, RSC and SAR were generated in QGIS. Similarly considering all the data points, the water quality map was generated for Krishna Zone and Scarce rainfall zone in GIS environment.

Survey and Characterization of Underground Water for Irrigation (Bikaner)

Suitability of groundwater for irrigation and its effect on soil while irrigating crop was analysed for Barmer and Jalore districts. In Barmer district, total 247 groundwater samples and 224 surface soil samples were collected from 141 villages spanning eight tehsils-Dhorimana, Gudamalani, Sindhari, Siwana, Baytu, Sheo, Barmer Shahar, and Chohtan. The results revealed significant spatial variability in water and soil chemical composition. Good quality water was observed mostly in Siwana (73.53%) and Barmer Shahar (48.39%), whereas marginally saline water dominated in Chohtan (74.08%) and Sheo (57.58%). Saline water occurred in smaller proportions (3%–18%) across some tehsils, while high SAR saline waters were notably high in Dhorimana (56.67%), Gudamalani (80.01%), and Sindhari (56.67%). Marginally alkali waters appeared only in Dhorimana and Gudamalani (3.33% each), and highly alkali waters were found in Sindhari (43.33%), Dhorimana (13.33%) and Gudamalani (10%). Soil pH₂ values ranged from 7.63 to 9.86, which is higher in Barmer Shahar (8.62–9.86) and Chohtan (8.55–9.44), while variability in EC₂ between 0.03 and 1.82 dS/m, reflects variable salinity levels.

In Jalore district (2023–24), groundwater samples from 240 tube wells across 141 villages and 239 soil samples were collected from eight tehsils namely Ahore, Bhadrarjun, Bhinmal, Jalore, Jaswantpura, Sayla, Bagora, and Raniwara. Analysis of collected samples revealed that good quality water is dominant in Jaswantpura (74.29%), Raniwara (75.68%), Bhadrarjun (72.41%), and Ahore (66.67%), while high SAR saline water is more in Sayla (66.33%), Bagora (50.00%), and Bhinmal (33.33%). Marginally saline water ranged from 6.67% in Ahore to 36.67% in Bagora, and highly alkali water were found highest in Jalore (12.90%) and Bhinmal (5.56%). Soil pH varied from 7.01 to 9.64, with mean values between 8.09 in Jalore and 8.69 in Bhadrarjun, whereas EC_e ranged from 0.06 to 3.99 dS/m. Mean soil EC values spanned from 0.50 in Ahore to 1.29 in Sayla, indicating broad spatial differences in salinity and overall groundwater-soil chemical variability across the district.

Survey and characterization of groundwater for irrigation of Panchkula Ambala, Charkhi Dadri and Yamuna Nagar district of Haryana (Hisar)

A survey and characterization of groundwater for irrigation was carried out in Barwala,

Morni, Pinjaur, and Raipur Rania blocks of Panchkula district during 2022–23, and in Ambala, Charkhi Dadri, and Yamuna Nagar districts during 2023–24. In Panchkula district, the majority of water samples (97.7%) were classified as good quality and only 2.3% fell under the marginally alkali category. In Ambala district, 90.48% samples were found under good quality category, followed by 7.14% and 1.19% categorized as marginally saline, and high SAR saline categories, respectively. In Charkhi Dadri district, only 28.89% of the samples were found of good quality. The remaining samples were distributed across marginally saline (22.22%), saline (0.44%), high SAR saline (30.67%), marginally alkali (15.56%), alkali (0.44%), and highly alkali (1.78%) categories. In contrast, in Yamuna Nagar district, all the water samples (100%) were characterized as good quality.

Survey and characterization of groundwater for irrigation of coastal districts of Tamil Nadu (Tiruchirappalli)

A detailed assessment of groundwater for suitability of irrigation was carried out in the inland districts of Kanchipuram (2023) and Salem (2024) in Tamil Nadu. In Kanchipuram district, 150 groundwater samples were collected using GPS. The pH of collected samples ranged from 3.29 to 8.49 and EC from 0.09 to 5.22 dS m⁻¹, that indicates wide variation in alkalinity and salinity levels. The RSC values varied from nil to 32 meq L⁻¹, while SAR ranged between 0.19 and 34.78. Overall, about 38% of samples were found under good quality, 25% alkali, 17% highly alkali, 15% marginally alkali, 3% marginal saline, and 5% high SAR saline. Block-wise, Uthiramerur and Sriperumbudur had the highest proportion of good-quality water, while alkali water was found the maximum in Kanchipuram (37%) and Walajabad (29%).

Survey and characterization, fluoride and nitrate content in groundwater of Barnala and Sangrur district of Punjab (Bathinda)

Groundwater quality assessment for irrigation in Barnala and Sangrur districts was done based on electrical conductivity (EC), sodium adsorption ratio (SAR), and residual sodium carbonate (RSC). In Barnala, 39% of groundwater samples were categorized as good, 40% as saline, and 21% as alkaline, whereas in Sangrur, only 3% were good and 87% were alkaline. Fluoride concentrations in Barnala ranged from 0.01 to 0.24 mg/L (mean 0.03 mg/L), with all samples ≤ 1.0 mg/L, making them suitable for drinking. However, nitrate levels varied from 22.0 to 408 mg/L (mean 92.41 mg/L), with 88% exceeding the BIS permissible limit, indicating potential health risks. In Sangrur, fluoride content was ≤ 1.0 mg/L in 94% of samples, while 6% exceeded this value. Nitrate concentrations ranged from 25.7 to 995 mg/L (mean 202.3 mg/L), but only 4% samples were within safe limits, demonstrating widespread nitrate contamination and degraded groundwater quality.

Resource Inventories of Salt Affected Soils

Characterization and delineation of salt affected soils using remotely sensed data and ground truth of Shajapur district, Madhya Pradesh (Indore)

A detailed reconnaissance soil survey was conducted in Gulana and Shajapur tehsils of Shajapur district, Madhya Pradesh, to assess the extent and characteristics of salt-affected soils. A total of 101 surface soil samples were collected from different villages, and their analysis revealed that soil pH ranged from 7.38 to 8.43, while electrical conductivity (ECe) varied between 0.94 and 1.99 dS m⁻¹. The sodium adsorption ratio (SAR) ranged from 0.29 to 0.81, and the cation exchange capacity (CEC) was between 30.1 and 51.5 cmol (p⁺) kg⁻¹.

The exchangeable sodium percentage (ESP) was found to vary from 6.5 to 23.0, indicating the presence of sodicity in certain locations.

1. MANAGEMENT OF POOR QUALITY WATERS

Management of Alkali Water

Conjunctive use of alkali and canal water for Til and Lentil Cropping sequence (Agra)

A study was conducted during to evaluate til–lentil crop rotation under conjunctive use of alkali (RSC 8 meq/l) and canal water with different combinations. Results showed that both grain and stover yields were highest under canal irrigation and lowest under alkali water. Both the treatment of alternating one canal irrigation with one alkali irrigation and the 1:1 mixing of canal and alkali water resulted in comparable yields, with similar trends observed for til and lentil crops across treatments.

Management of Alkali water (High RSC) for enhancing the growth and yield of Sesame (Tiruchirappalli)

A field experiment conducted in the Cauvery delta zone aimed to address the challenge of sesame cultivation after rice, where the use of alkaline bore well water adversely affects crop growth and yield. Alkali water was treated with gypsum to lower residual sodium carbonate (RSC) levels to 4, 2.5, and 1.25 meq L⁻¹, with corresponding gypsum doses applied once as a basal soil treatment. The results indicated that reducing RSC to 2.5 meq L⁻¹ was optimal, producing higher sesame yield and an improved benefit–cost ratio under alkali soil conditions. The results of growth and yield parameters (Table 10.2) revealed that application of gypsum either to soil or through irrigation water significantly increased the growth and yield parameters of sesame. Highest yield was recorded in T₂ treatment which involves gypsum bed treated irrigation water to the RSC level of 1.25 meq-1. Though highest yield was recorded in T₂ (Gypsum treated alkali water with RSC level of 1.25 meq. /lit), while comparing the B: C ratio, T₃ (Gypsum bed treated water with RSC of 2.5 meq. /lit) performed (B: C ratio of 2.41) better over other treatments. It was also observed that, gypsum bed treatment of irrigation water (T₂, T₃, and T₄) performed better than soil application of gypsum (T₅, T₆, T₇) for the same quantity of gypsum applied. It can be concluded from the experiment that treating high RSC alkali water with gypsum to the level of 2.5 meqL⁻¹ found to be optimum for getting higher yield and B: C ratio of sesame under alkali soil environment.

Table 10.2 Influence of RSC levels of irrigation water and soil application of gypsum on growth, yield and economics of sesame

Treatments	Plant Height (cm)	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	Oil content (%)	Cost (Rs ha ⁻¹)	Gross income (Rs ha ⁻¹)	B: C ratio
T1	72	320	675	49.8	31250	36800	1.18
T2	87	838	1760	50.6	40970	96370	2.35
T3	85	827	1756	50.9	39350	95105	2.41
T4	84	680	1435	50.7	37730	78200	2.07
T5	85	750	1575	50.5	40970	86250	2.1
T6	83	700	1470	50.4	39350	80500	2.04
T7	82	610	1281	50.4	37730	70150	1.86
S.Ed	1.59	13.2	28.6	0.45			
CD (0.05)	3.1	26	55	0.9			

Management of Saline Water

A case study on the functioning of Doruvu technology in farmers' fields in coastal area (Bapatla)



Field view of Improved Doruvu Technology and Bore wells

Over six years, water quality in Doruvu and shallow bore wells was monitored to assess irrigation suitability. Improved Doruvu wells consistently supplied good-quality water year-round, while bore wells showed higher salinity and reduced availability during summer. Cropping intensity was higher under Doruvu wells, though installation costs were substantially greater (₹1,00,000) compared to bore wells (₹2,000–3,000). From 2019–2025, electrical conductivity (EC) varied seasonally, peaking between June and July and declining between October and December due to monsoon recharge. No clear long-term improvement or decline was observed, but EC levels in 2024–2025 were higher than those in 2021–2023, especially in bore wells. Doruvu wells maintained more stable EC, with slight increases from January to April. To address salinity risks, sustainable measures such as artificial recharge, conjunctive water use, crop scheduling based on EC cycles, and blending with better-quality water are recommended for long-term groundwater management. It was observed that BW SAR is often higher, especially at Sites 10–11: IDW = 4.71, 4.73 vs. BW = 10.4, 8.41. High SAR in BWs indicates greater sodium hazard for irrigation use. Lower SAR in IDWs suggests better water quality in terms of soil structure compatibility. BW has higher sodium hazard than IDW. IDW water is more suitable for irrigation.

Table 10.3 Relationship between IDW and BW based on different parameters

Parameter	IDW (Improved Doruvu)	BW (Bore Well)	Relationship
pH	Neutral	Neutral	Comparable
EC	Low to Moderate	Moderate to High	BW > IDW
SAR	Low to Moderate	Moderate to High	BW > IDW

- IDW wells generally have better water quality in terms of salinity (EC) and sodium hazard (SAR) compared to borewells.
- Borewells may access deeper, older, and more mineral-rich water tables, leading to higher EC and SAR.
- The improvement in doruvu wells is reflected in their lower salt and sodium content, making them more suitable for irrigation in terms of long-term soil health.

Influence of levels of nitrogen and *Azospirillum* doses on rice crop in saline soils (Bapatla)

Field experiment on studying effect of nitrogen levels and *Azospirillum* doses on rice crop in saline soils revealed that Leaching + green manure incorporation @ + 25 per cent extra RDN + *Azospirillum* @ 750 mL acre⁻¹ recorded the highest yield attributes and grain (6117 kg/ha) and straw yield (8663 kg/ha) of paddy (Table 10.3).

Nitrogen content both in rice grain and rice straw was significantly influenced by nitrogen levels and *azospirillum* doses. Significantly the highest nitrogen content in rice grain (1.27%) in rice straw (0.62%) nitrogen uptake both in rice grain (77.5 kg/ha) and in rice straw (53.8) was recorded with Leaching + green manure incorporation + 25% extra RDN + 750 mL/ac *Azospirillum* and the lowest was recorded with Leaching + green manure incorporation + RDN treatment.

Table 10.4 Influence of nitrogen levels and Azospirillum doses on yield, harvest index and test weight of rice

Treatments	Grain Yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)	Test weight (g)
T1- Leaching+ green manure incorporation + RDN	4067	5717	41.5	17.5
T2- Leaching+ green manure incorporation+RDN +500mL/ac Azospirillum	5283	7333	41.9	17.9
T3- Leaching+ green manure incorporation+RDN +750mL/ac Azospirillum	5367	7717	41.0	18.4
T4- Leaching+ green manure incorporation+RDN +1000mL/ac Azospirillum	5400	7633	41.4	18.3
T5- Leaching+ green manure incorporation+ 25% extra RDN	5583	7900	41.4	18.2
T6- Leaching+ green manure incorporation + 25% extra RDN+500mL/ac Azospirillum	5483	7683	41.6	18.9
T7- Leaching+ green manure incorporation + 25% extra RDN+750mL/ac Azospirillum	6117	8683	41.3	18.5
T8- Leaching+ green manure incorporation + 25% extra RDN+1000mL/ac Azospirillum	5867	8117	42.0	18.3
Sem +	301	437	0.3	0.96
CD (0.05)	913	1325	NS	NS
CV (%)	12.6	12.9	1.5	11.8

Effect of Saline Water Irrigation on Growth, Yield attributes and Yield of different varieties of Fennel through Drip (Bikaner)

A field experiment conducted during the rabi season of 2021–22 evaluated the effect of irrigation water salinity on fennel growth and yield. The study involved four salinity levels viz. ECiw 0.25 (BAW), 4, 6, and 8 dS/m and four fennel varieties (AF-1, RF-157, RF-281, and RF-290) in a split-plot design with five replications. Results of the study indicate that irrigation salinity significantly affected plant height, umbels per plant, umbellates per umbel, seeds per umbellate, test weight, and seed yield. Based on pooled data, the highest values for plant height (129.33 cm), umbels per plant (17.95), umbellates per umbel (23.32), seeds per umbellate (22.33), test weight (5.44 g), and seed yield (11.17 qha⁻¹) were obtained under BAW (ECiw 0.25 dS/m), closely followed by ECiw 4 and 6 dS/m. Salinity levels beyond ECiw 6 dS/m caused a marked decline in all growth and yield parameters. Among the tested varieties, RF-290 consistently exhibited superior performance, confirming its higher productivity and tolerance to moderate salinity conditions.

Effect of nitrogen fertigation utilizing good and saline water under drip irrigation system in vegetable crops (Hisar)

A two-year study (2022–23 and 2023–24) examined the impact of saline water irrigation under fertigation on garlic and onion yields. In 2022–23, garlic was grown under drip irrigation with varying nitrogen application levels (75%, 100%, and 125% of recommended dose of nitrogen-RDN) and irrigation water salinity (2.5 and 5.0 dS/m). At 75% RDN, yields declined by 10.43% and 27.08% at 2.5 and 5.0 dS/m, respectively, compared to canal water. At 100% RDN, reductions were 8.16% and 22.16%, and at 125% RDN, 7.67% and 20.04%. On average, garlic yield decreased by 8.62% at 2.5 dS/m and 22.78% at 5.0 dS/m. In 2023–24, onion exhibited similar trends: yield declines at 75%,

100%, and 125% RDN were 5.48%, 5.13%, and 4.59% at 2.5 dS/m, and 27.26%, 22.62%, and 20.68% at 5.0 dS/m. Mean reductions were 5.05% with 2.5 dS/m water and 23.36% with 5.0 dS/m water irrigation. Higher nitrogen application (125% RDN) marginally mitigated salinity-induced yield losses in both crops.

Performance of mycorrhizal (*Glomus mosseae*) inoculation in cotton-wheat under saline water irrigation (Hisar)

A two-year experiment (2022–23 and 2023–24) evaluated the impact of high salinity irrigation water (ECiw 8 dS/m) on cotton and wheat yields under varying nutrient management practices. In cotton, mean seed yield declined by 20.01% in 2022 and 21.53% in 2023 with saline irrigation as compared to canal water. The lowest yields occurred in the control (35.75 g/plant in 2022; 33.33 g/plant in 2023), while the highest yields were achieved under RDF + FYM + Mycorrhiza (64.18 and 63.05 g/plant), statistically at par with RDF + Mycorrhiza (63.06 and 62.05 g/plant) and RDF alone (62.71 and 61.37 g/plant). In wheat, mean yields decreased by 20.28% in 2022–23 and 28.76% in 2023–24 under saline irrigation. The lowest yields were in the control (25.92 g/pot; 24.65 g/pot), while the highest were in RDF + FYM + Mycorrhiza (51.86 and 52.27 g/pot), comparable to RDF + Mycorrhiza and RDF alone. The findings show that integrated nutrient management mitigates yield losses from saline irrigation.

Performance of vegetable guar with different doses of Sulphur and Potassium under different water quality (Bathinda)

An experiment was conducted to study the effect of three doses of sulphur (0, 30, and 45 kg/ha) and potassium (0, 30, and 45 kg/ha) on vegetable guar under two irrigation water qualities—canal water and saline tube well water. Canal water was of good quality ECiw < 2 dS/m; SARiw < 10 mmol/L; RSC < 2.5 meq/L, while tube well water was high-SAR saline (ECiw > 4 dS/m; SARiw > 10 mmol/L). Uniform nitrogen (22 kg/ha) and phosphorus (60 kg/ha) doses were maintained across treatments. Saline irrigation reduced germination, plant height, and green pod yield by 38.6%, 24.6%, and 15.1%, respectively, compared with canal water. However, saline water increased seed potassium and sulphur content by 8.1% and 2.1% and straw potassium and sulphur content by 15.7% and 7.5%, respectively.

Management of Wastewater

Effect of treated sewage water as a source of irrigation and nutrients supply for Marigold-Chrysanthemum rotation (Agra)

A field experiment was carried out in 2023–24 to study the effect of treated sewage water as a source of irrigation and nutrients supply for Marigold-Chrysanthemum rotation in sandy loam soil. Total eight treatment combinations of different water quality (sewage and tube well water) and varying dose of RDF were evaluated in a randomized block design. Results showed that crops irrigated with sewage water (SW) along with the recommended dose of fertilizer produced the highest flower yield compared to tube well water (TW). Treatments such as TW + 125% RDF, SW + 75% RDF, and 1SW:1TW + RDF recorded the second highest flower yields.

Effects of fluoride in irrigation water on yield and quality of brinjal (Bathinda)

An experiment was conducted under polyhouse with varying concentration (0.12, 2.0, 4.0, 6.0, 8.0 and 10.0 mg F/L) of fluoride in irrigation water in two brinjal varieties namely PBH-4 (Long Fruited) and PBHR-42 (Oblong fruited). The brinjal yield was significantly

reduced, whereas F content in leaf and fruits were significantly higher with increasing F concentration in irrigation water. PBHR-42 produced significantly higher yield as compared to PBHR-4, whereas PBH-4 contains significantly higher leaf and fruit fluoride content, but was found under safe limit (≤ 1.0 ppm).

2. MANAGEMENT OF IRRIGATION INDUCED SALINIZATION AND ALKALINIZATION

Management of Irrigation Induced Alkali Soils

Management of Sodic Vertisols through Conjunctive use of Gypsum and Gliricidia sepium under Paddy-Wheat Cropping System (Indore)

A field experiment on paddy (CSR-10) was conducted in sodic vertisols from 2023–2025 using three gypsum levels (0%, 50%, 75% GR) and three Gliricidia sepium leaf doses (0, 5, 10 t/ha) in a split-plot design. Application of 75% GR gypsum with 10 t/ha Gliricidia significantly reduced bulk density, pH, and EC while increasing organic carbon and available N, P, and K. Exchangeable Na^+ and ESP declined, improving soil health and reclamation. Results also revealed that though gypsum improves productivity, Gliricidia alone records the highest net returns and benefit–cost ratio, indicating it as a sustainable, cost-effective option for managing salt-affected soils.

Management of sodic Vertisols through resources conservation technologies (Indore)

A two-year study (2020–21 and 2021–22) was conducted on sodic Vertisols using wheat (HI 1544) and paddy (CSR-10) under three tillage systems viz. conventional, reduced, and zero tillage, with or without rice residue mulch. In wheat, the highest grain (3749 and 3969 kg/ha) and straw yields (5080 and 5698 kg/ha) were obtained under conventional tillage during both years, significantly higher than reduced and zero tillage. Application of rice residue mulch @ 5 t/ha enhanced straw yield (4792 and 5488 kg/ha) compared to no mulch (4506 and 5064 kg/ha). For paddy, conventional tillage produced the highest grain yields (3606 kg/ha in 2021 and 4002 kg/ha in 2022), with straw yield showing a similar trend. Soil analysis revealed the lowest exchangeable sodium percentage (ESP) under conventional tillage (21.8 in 2021 and 19.6 in 2022) and in mulch treatments (25.1 and 23.3) compared to no mulch (25.9 and 24.5), indicating significant improvement in soil health and productivity under conventional tillage combined with mulching.

Management of Irrigation Induced Waterlogged Saline Soils and Coastal Saline Soils

Enhancing water use efficiency in reclaimed waterlogged saline Vertisols by implementation of subsurface drainage system (Gangavathi)

A field investigation initiated to devise strategy for enhancing water use efficiency and minimizing nitrate-N losses from subsurface drainage installed field. The experiment consisted four treatments viz. conventional drainage with continuous flooding (CF, T1), conventional drainage with alternate wetting and drying (AWD, T2), CF with controlled subsurface drainage (CF-CDF, T3), and AWD with controlled subsurface drainage (AWD-CDF, T4). Across four Kharif and three Rabi seasons, CF had higher average drain discharge (1.22 mm d^{-1}) than AWD (0.93 mm d^{-1}). Drain water salinity maintained below 4.0 dS m^{-1} with little variation for different treatments. A greater salt and nitrogen losses were found with CF, while controlled drainage helped in minimize them. AWD saved 19.95 cm (kharif)

and 17.8 cm (rabi) irrigation water, maintaining a shallower water table. Paddy yields increased in all treatments, with CF giving about 3% higher yield, showing AWD with controlled drainage improves resource efficiency with minimal yield impact.

Feasibility of drip irrigation in puddled transplanted rice (PTR) under saline vertisols of TBP Command Area, Karnataka (Gangavathi)

A field experiment was conducted during kharif-2023 to study the feasibility of drip irrigation in puddled transplanted rice (PTR) under saline Vertisols. Two sorghum varieties (GNV-1801 and GVT-05-01) under four irrigation levels (1.2, 1.4, 1.6, and 1.8 ET) were evaluated using a split-plot design. Despite 39% lower rainfall (332 mm), drip irrigation effectively met crop water demand through 14 irrigations and saved 34.7%-45.2% water as compared to conventional methods. Soil salinity remained below 4 dS m⁻¹. GNV-1801 achieved higher grain (6165 kg ha⁻¹) and straw yields (6843 kg ha⁻¹) than GVT-05-01. The irrigation applied at 1.6 ET produced the highest yields (6592 and 7300 kg ha⁻¹) and water use efficiency (80.56 kg ha⁻¹ cm⁻¹), followed by 1.4 ET, while the lowest under 1.2 ET irrigation. Economic returns were the highest for 1.6 ET irrigation and with GNV-1801, recorded gross returns of ₹1,57,989 ha⁻¹, net returns of ₹78,264 ha⁻¹, and a B:C ratio of 1.99, though varietal and irrigation interactions were insignificant.

Comparative efficacy of nano and conventional urea on growth and yield of rice (*Oryza sativa* L.) under waterlogged saline soil in Tungabhadra Command Area, Karnataka (Gangavathi)

To assess efficacy of nano and conventional urea on rice growth and yield in waterlogged saline soils, a field experiment was conducted in kharif-2024 in the Tungabhadra Command Area, Karnataka. Total ten treatments in a randomized block design were tested. Initial soil pH and ECe ranged between 8.20–8.70 and 5.10–9.80 dS/m, respectively, and soil salinity declined at panicle initiation and rose slightly at harvest but remained within the safe root zone limits (<4.0 dS/m). Treatment T5 (125% RDN + foliar spray of 1% conventional urea at active tillering and panicle initiation) achieved the highest plant height (81.10 cm), tillers per hill (15.1), panicles per hill (13.2), grain yield (5995 kg/ha), and straw yield (6388 kg/ha), and the performance was at par with T2, T9, and T10. Findings suggest that combining higher RDN levels with foliar spray of conventional urea significantly boosts rice productivity while maintaining acceptable salinity under waterlogged saline conditions.

Effect of different levels of organic manures and mulching on vegetables (Brinjal, Chilli and Tomato) under drip irrigation (Panvel)

A field experiment was conducted during *rabi* season 2022-2023 to study the effect of different levels of organic manures and types of mulch on performance of selected vegetables (Brinjal, Chilli and Tomato) under drip irrigation. Results indicate that plastic mulch significantly reduced soil electrical conductivity and pH as compared to paddy straw mulch and no mulch. It also maintained higher soil moisture than paddy straw mulch no mulch. However, paddy straw mulch recorded the highest yields of brinjal, chilli, and tomato. Moreover, combining paddy straw mulch with farmyard manure (7.5 t ha⁻¹) and vermicompost (2.5 t ha⁻¹) produced the highest yields, indicating that organic amendments under paddy straw mulch enhance soil conditions and crop productivity effectively.

Effect of planting windows and irrigation on dibbling of wal (Field bean) grown under zero tillage in coastal saline soils of Konkan (Panvel)

A field experiment was conducted to evaluate the effects of sowing date and irrigation on the growth and yield of dibbling of wal (Field bean), as well as on changes in soil properties. The initial soil $EC_{(1:2.5)}$ was 2.89 dS/m. Three irrigation treatments (nil, one and two numbers) and three window of sowing (after harvest of Rice, 10 days and 20 days after harvest of rice) were evaluated. Results indicate two irrigations at flowering and pod formation reduced soil EC and pH while maintained higher moisture. Sowing field bean immediately after rice harvest further improved soil moisture, lowered EC, and raised pH. Though two irrigations enhanced soil properties, one irrigation also significantly increased yield, especially when combined with immediate post-rice sowing.

Management of Saline-Acidic Soils

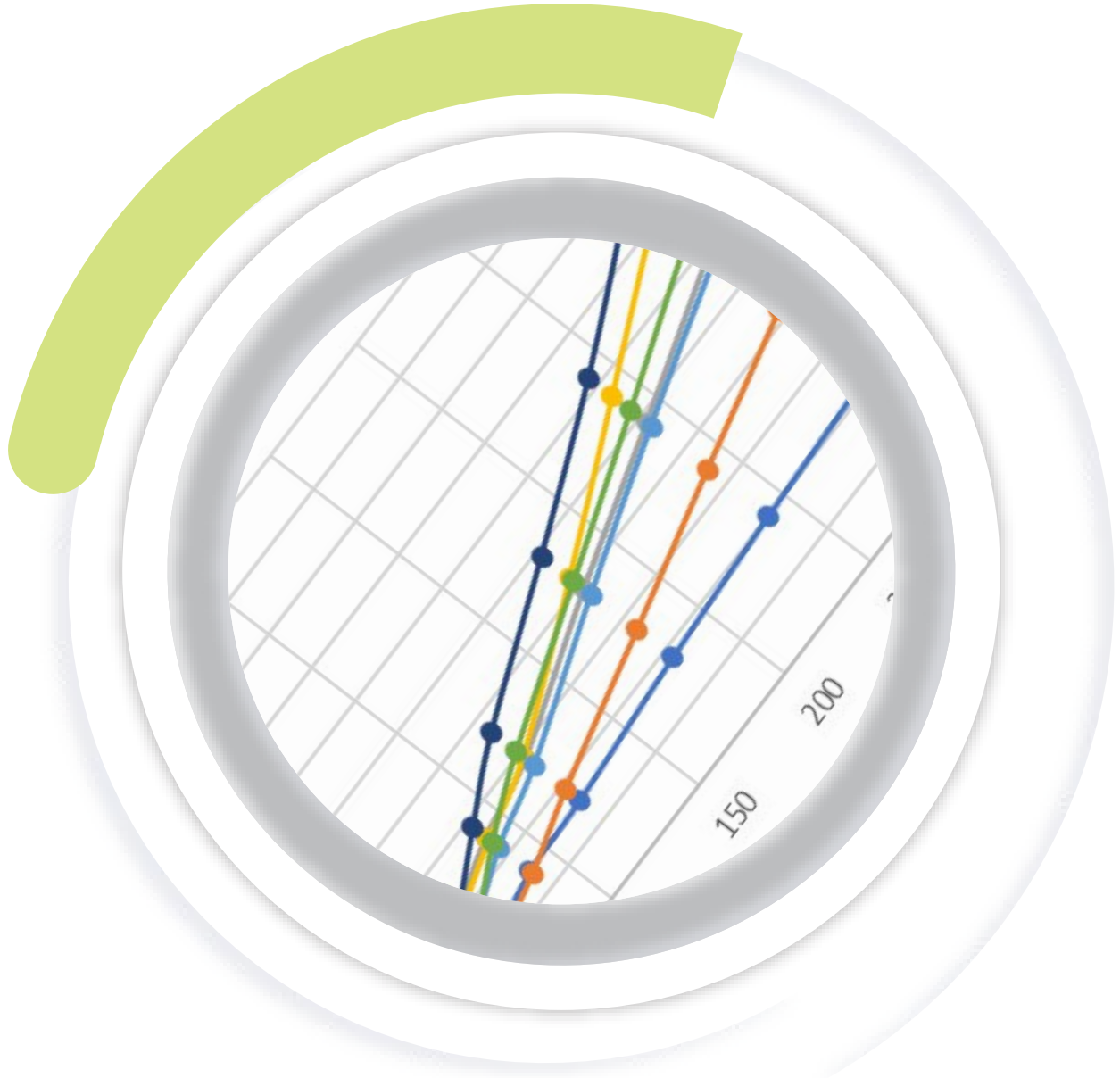
Management of salinity and acidity of Pokkali soils using suitable amendments (Vytila)

This study investigated the effectiveness of Calcium salts and silica on managing soil acidity and salinity and to find out a suitable ameliorant for economic yield in IFS in Pokkali ecosystem. Eight treatments were tested under randomized block design with three replications. Treatments consist of calcium salts (calcium nitrate, calcium chloride, calcium sulphate, rock phosphate, dolomite, lime) and rice husk ash @1000 kg ha⁻¹. The crop failed in 2023 due to flooding. Experiment repeated in 2024 with Vytila-11 variety. Results indicate that all calcium amendments raised soil pH from initial value of 4.57, while calcium nitrate (5.69) and dolomite (5.56) was found most effective. Treatments reduced salinity, improved nutrient availability (notably with rock phosphate and dolomite), and Al solubility found below undetectable levels. Dolomite treatment recorded the maximum plant height, while most tillers and most productive tillers were found under gypsum and calcium nitrate treatments, respectively. Rice husk ash gave the highest grain yield (27.49 q ha⁻¹) and improved pH (5.53) due to silica-enhanced stress resistance, followed by dolomite (26.51 q ha⁻¹ grain, 35.28 q ha⁻¹ straw). Rice husk ash and dolomite appear most promising for saline-acidic Pokkali soils.

3. ALTERNATE LAND USE

Development of Horticulture Based Agri-horti System under Saline Water Conditions (Bikaner)

An experiment was initiated to assess the suitability and economic viability of horticulture-based agri-horti systems under saline water conditions. Three irrigation water salinity levels (EC_{iw} 0.25, 2.4, and 6.0 dS/m) were tested using cluster bean as an intercrop in bael tree alleys during kharif, and mustard, taramira, oat, and barley during rabi. Results of kharif 2023 and 2024 revealed significant decreases in cluster bean seed and straw yields with increasing irrigation salinity. The pooled (2018–2023) data indicates yield reductions of 13.41% and 45.92% at EC_{iw} 2.4 and 6.0 dS/m, respectively. Yields of Rabi crops also declined under increased salinity, though reductions were mostly non-significant except in oat at 6.0 dS/m. Bael fruit yield, recorded from 2022 onward, was highest under BAW (0.25 dS/m), followed by 2.4 dS/m, and the lowest under 6.0 dS/m. Economic analysis found irrigation with BAW and 2.4 dS/m as most profitable, while 6.0 dS/m reduced profits. The Cluster bean–Bael–Mustard system proved most salinity-tolerant and economically viable, followed by barley, taramira, and oat.



Technology Assessed and Transferred

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) (Suresh Kumar and Anil Kumar)

Economic Impact of Salt-tolerant Wheat Varieties

Yield gains of STWVs over the prevailing wheat varieties in salt-affected soils

There is a negative association between soil pH and yield of all varieties including STWVs and non-STWVs (Figure 11.1). However, the yield gap between STWVs and non-STWVs widens with an increase in soil pH. At lower pH levels (7.50–8.5) non-STWVs perform better than STWVs in normal soils. The widening yield gap at higher pH levels (>8.5) indicated the superiority of STWVs over the prevailing cultivated varieties. Since, sodic soils have pH > 8.5; the yield advantage of STWVs in sodic soils is considered to be above this pH level. In this range of sodicity, the observations from the field show that the mean yield of STWVs is approximately 11.80% higher than that of non-STWVs. The yield advantage of STWVs in the saline soils (ECe > 4 dS/m) is estimated at approximately 24.30% (Figure 11.2).

or analytical purposes, we calculated the weighted average of the yield gains of the varieties grown in sodic and saline soils, with weights being the cultivated areas. Thus, the overall yield gain is 14.82%.

Adoption rate of STWVs

The adoption rate of STWVs was estimated based on the breeder seed supply by the ICAR-CSSRI. From 2012 to 2024, the adoption rate of STWVs reached 9.77% (Figure 11.3).

For *ex-ante* analysis, the adoption path of STWVs was traced using the logistic curve model up to 2030 under two cases: Business-As-Usual (BAU) and Optimistic Scenario (OS). The projected adoption rate may reach 18.5% under BAU and 25.0% under OS. The OS signifies a hypothetical scenario emphasizing the increasing demands of breeder seeds

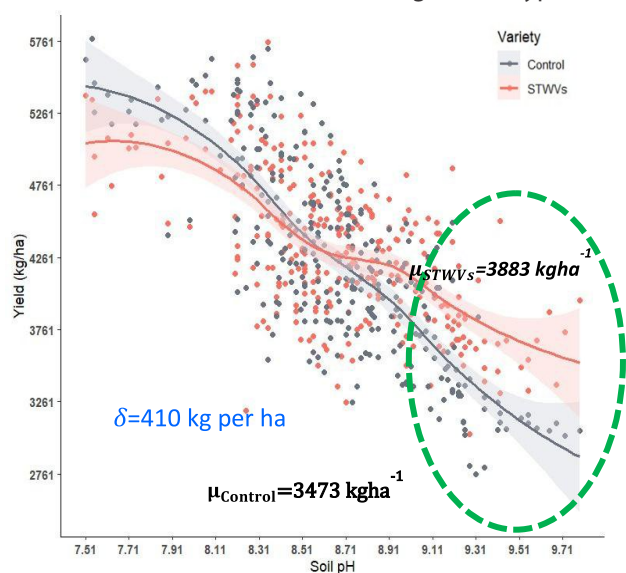


Fig 11.1 Yield response under increasing level of the soil sodicity

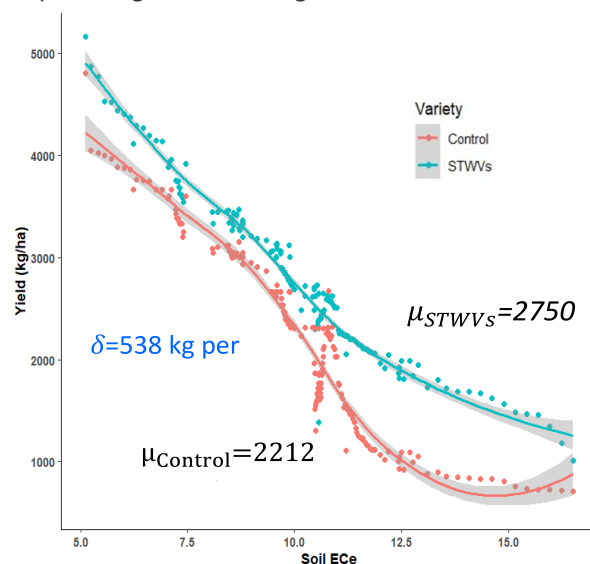


Fig 11.2 Yield response under increasing level of the soil salinity

Fig 11.3 Estimated adoption rate and projected adoption rate of STWVs in salt-affected lands

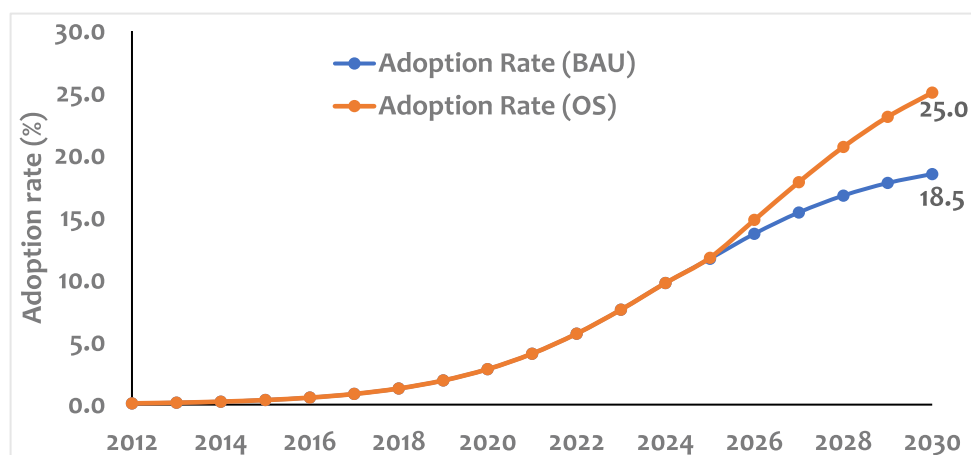


Table 11.1 Parameters of Economic Surplus model

Parameter	Symbol	Value	Sources
Production quantity in domain areas (mt, TE 2012)	Q_0	9.93	Authors' estimation based on the domain area and yield
Price (Rs /t, 2023-24)	P_0	23300	Gol (2025)8
Increase in yield (%)	$E(Y)$	14.82	Authors' estimation
Increase in variable cost per ha (%)	$E(C)$	4.64	Authors' estimation
Maximum adoption rate (%)	A_{max}	18.5 (BAU) & 25.0(OP)	Expert opinion and authors' estimation using the logistic model
Supply elasticity	ϵ_s	0.22	Kumar and Mittal (2022) 5
Demand elasticity	ϵ_d	-0.34	Kumar et al. (2011) 6
Exogenous growth rate	EGR	1.50%	Authors' estimation-based data Gol (2025) 7

of STWVs particularly by the private seed firms in the recent years, which is expected to increase further in future. To factor-in these developments, we assume that, in future, the demand for STWVs is likely to increase significantly. Therefore, the economic gains due to the adoption of STWVs were computed for the period 2012 to 2024 and, also estimated upto 2030. The values of the parameters used in the economic surplus model were estimated through primary survey and from available publications relevant to the economic impact assessment of salt-tolerant wheat varieties (Table 11.1).

Economic Impact of STWVs

For the period 2012–2024 under BAU, the consumer surplus is estimated at Rs. 22850 million, with an annual value of Rs. 1757.7 million. The producer surplus is Rs. 35320 million or Rs. 2716.9 million per annum. The total economic surplus amounts to Rs. 58170 million, with an annual value of Rs. 4474.6 million. For the period 2012–2030 under BAU, the consumer surplus may increase to Rs. 101750 million (annualized at Rs. 5355.3 million), and the producer surplus may rise to Rs. 157250 million, with an annual value of Rs. 8276.3 million. With this, the value of the total economic surplus is projected to reach Rs. 259000 million, with an annualized value of Rs. 13631.6 million. Similarly, under optimistic scenario, the estimated value of the total economic surplus may reach Rs. 278050 million, with an annual value of Rs. 14634.2 million (Table 11.2). These estimates highlight the potential of STWVs for enhanced economic benefits by ensuring the proper management of salt-affected lands, and the projected benefits highlight the need for proper policy support to realize these benefits in the future.

Table 11.2 Estimated value of economic surplus due to STWVs in India

Economic surplus	Value (Rs Million)		
	Business as usual		Optimistic scenario
	2012-2024	2012-2030	2012-2030
Consumer surplus	22850 (5355.3)	(1757.7) 109230	101750 (5748.9)
Producer surplus	35320 (8276.3)	(2716.9) 168810	157250 (8884.7)
Total economic surplus	58170 (13631.6)	(4474.6) 278050	259000 (14634.2)

Note: Figures in parentheses are the annual values of surplus

Policy Implications

Based on the interaction with stakeholders (e.g., farmers, KVKs, private firms, and extension field functionaries) and ground insights of experts, the following issues merit attention:

A. Accelerating the development of STWVs: Currently, only a limited number of STWVs are widely accepted. To address this limitation, it is recommended that future wheat breeding programs incorporate speed breeding techniques and gene editing tools.

B. Targeted and collaborative research: Gujarat encompasses a substantial area of salt-affected land dedicated to wheat cultivation, measuring 0.76 million hectares. Notably, to date, no STWV has been specifically released for Gujarat, nor has it been included in the state's seed rolling plan. This represents a significant gap in research and development efforts. Addressing this issue necessitates a targeted and collaborative approach involving State Agricultural Universities (SAUs) for seed multiplication and the establishment of seed delivery outlets in salt-affected regions.

C. Multiple stress tolerance with biofortification: In light of the growing emphasis on nutritional security and climate resilience, particularly concerning terminal heat stress in wheat, there is a need for a strategic shift in breeding programs. This shift should move from focusing solely on salt tolerance to encompassing multiple stress tolerances, including biofortification traits.

D. Physical and economic access to STWVs: Strategic initiatives involving public-private or public-public partnerships are essential for establishing robust seed supply chain systems that engage stakeholders and collaborate with farmers for the large-scale dissemination of STWVs. Furthermore, given the dispersed nature of salt-affected soils, there is a need to address the scattered and small-scale demand for STWVs seeds. To this end, the establishment of an "online portal for seed supply" is necessary to ensure timely and doorstep delivery of seeds to farmers. Collaboration with other ICAR institutes, particularly *Krishi Vigyan Kendras* (KVKs), could be transformative in facilitating the development, demonstration, and dissemination of STWVs seeds.

E. STWVs must be aligned with soil's nutrient status: It is important to acknowledge that farmers frequently prioritize high-yielding crops without adequately considering their soil conditions, even when dealing with salt-affected soils. In addition to soil health parameters, it is essential that recommendations for salt-tolerant crop varieties be communicated to farmers via soil health cards.

Agripreneurship for Sustainable Agricultural Development-Technological and Institutional Innovations and Strategies, NASF funded (Suresh Kumar, Rajkumar and SKSanwal)

The success of agri-entrepreneurs is a multidimensional concept, requiring a methodological framework that captures financial strength, business performance, social contribution, innovation capacity, and sustainability practices. This framework helps in evaluating the overall effectiveness of agri-enterprises and provides valuable insights for policymakers to promote rural entrepreneurship (Figure 11.4). Economic and financial indicators constitute the core dimensions of success measurement. These include annual income generated from the enterprise, profitability ratio, return on investment (ROI), business growth rate, and asset creation over time. Higher income and profitability reflect the entrepreneur's ability to generate financial returns, while asset creation indicates long-term stability and expansion potential. ROI is particularly useful for comparing performance across enterprises of different sizes. Business performance indicators reflect the operational and market strength of agri-enterprises. Key measures include sales turnover, market share expansion, customer base growth, product diversification, and employment generation.

An entrepreneur with increasing turnover and expanding market reach is considered more successful, as these factors reflect competitiveness and adaptability. Employment generation is also an important indicator, as it highlights the contribution of agri-entrepreneurs toward rural livelihood improvement. Social indicators capture the social impact of agri-entrepreneurship in terms of improvement in social recognition and status, contribution to rural development, networking and institutional linkages, and empowerment of women and youth. Strong social networking improves access to information, markets, and resources, while empowerment reflects inclusive development. Innovation and technology indicators measure the entrepreneur's ability to adopt modern practices. Adoption of improved technologies, use of ICT tools and digital marketing, product or process innovation, and branding or certification are key factors. These indicators show the entrepreneur's capacity to improve efficiency and gain market advantage. Finally, sustainability indicators assess environmental responsibility and resilience. Practices such as efficient resource use, climate-resilient farming, waste management, recycling, and eco-friendly production reflect long-term viability. Overall,

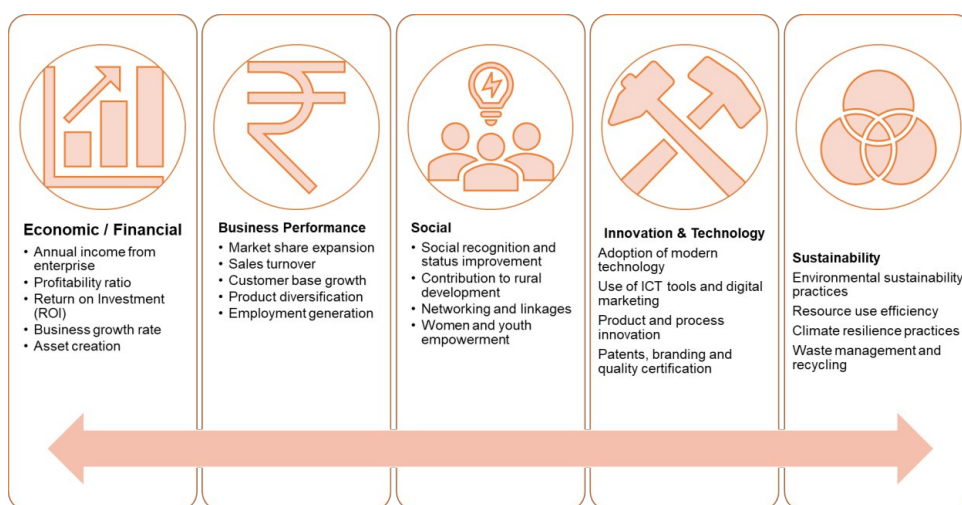


Fig 11.4 Methodological framework for assessing the success of agri-entrepreneurs

this framework provides a systematic and holistic approach to evaluate agri-entrepreneurial success.

Low Budget natural farming for sustainable crop production (R.K. Yadav, Kailash Prajapat, Ram Kishor Fagodiya, Awtar Singh, Madhu Choudhary, Arjun Singh, S.K. Jha, A.K. Dixit, D. Burman, U.K. Mandal, T.D. Lama, Anil R. Chinchmalatpure and Monika Shukla)

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 are made from locally available materials like cow dung and urine, pulse flour, buttermilk etc. 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. Many of the farmers reported they benefitted with the adoption of the LBNF in their crop fields but scientific validation of the claims needs to be explored with empirical data. Hence, a field experiment was formulated to compare the conventional farming (chemical inputs) system with LBNF treatments in order to evaluate the fulfilments of nutrient demand (macro and micro nutrients), yield gap and soil quality under different cropping systems of agroecological regions of India.

CSSRI, Karnal

A field experiment was conducted with seven treatments and three replications in RBD design 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) 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 dhaincha (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.

During *kharif* (2024), the rice grain yields ranged between 8.2 to 28.4 q ha⁻¹ under various scenarios. The significantly highest rice grain yield was obtained under improved management scenario (Sc-2) which was at with Sc-1 to Sc-5 scenarios. Interestingly the rice grain yield under TPR-LBNF (Sc5) was almost similar to conventional TPR (Sc-1) showing benefits of *dhaincha* green manuring and LBNF components on long term application (Figure 11.5A). However, the rice grain yield under DSR-LBNF rice suffered severe weed infestation which drastically reduced the yield while CA-based DSR (Sc-7) showed 20.6% yield penalty compared to TPR. The experimental results for wheat (2024-

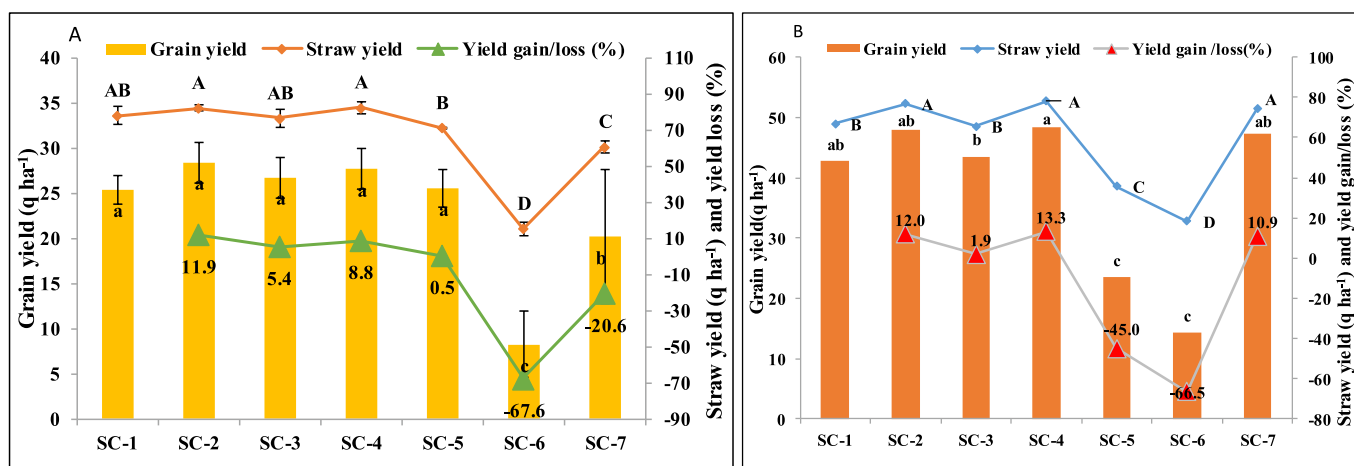
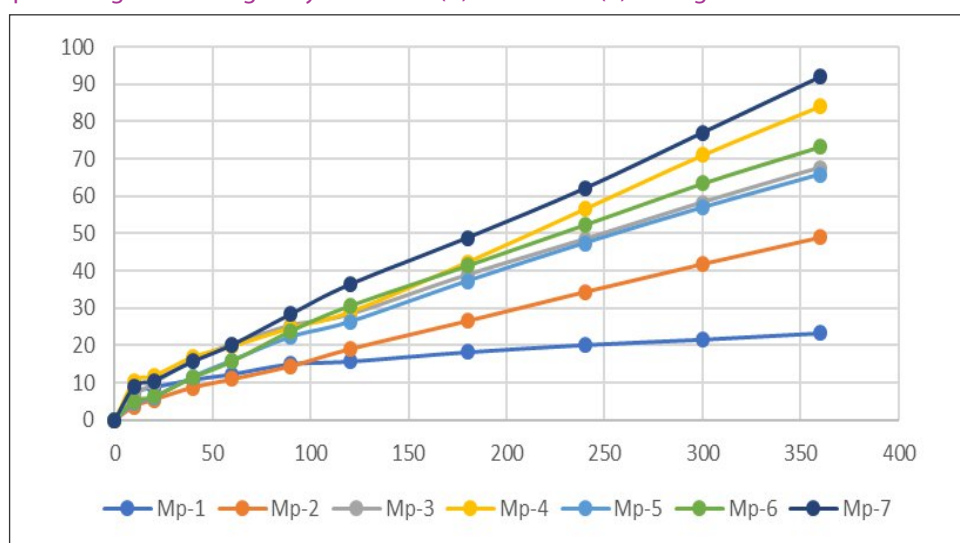


Fig 11.5 Grain yield, straw yield and per cent gain/loss in grain yield of rice (A) and wheat (B) during 2024-25

Fig 11.6 Effect of different scenarios on soil infiltration rate (mm/hr) after wheat 2025



25) showed that the wheat grain yield ranged between 14.3 to 48.4 q ha⁻¹ under different scenarios. The integrated scenario (Sc-4) recorded the significantly highest wheat grain yield (48.4 q ha⁻¹) followed by Sc-2 (47.8 q ha⁻¹) and Sc7 (47.4 q ha⁻¹). The organic system (Sc-3) also recorded statistically similar yield (43.6 q ha⁻¹) to that of obtained under conventional system (42.7 q ha⁻¹). While LBNF after transplanted rice (TPR, Sc-5) and after DSR (Sc-6) showed reduction in wheat grain yield by 45.0 and 66.5 per cent, respectively (Figure 11.5B).

After 5 cropping cycles, there was marked improvement in soil infiltration rate was seen in LBNF scenarios (Sc5 and Sc6) as compared to conventional practice (Figure 11.6). The soil organic carbon in surface soil layers (0-5) and (5-15 cm) also showed significant improvement under LBNF scenarios over chemical-based rice-wheat system. Soil enzymatic activities of dehydrogenase, alkaline phosphatase and acid phosphatase were significantly improved due to application of LBNF concoctions in Sc5 and Sc6 over Sc1.

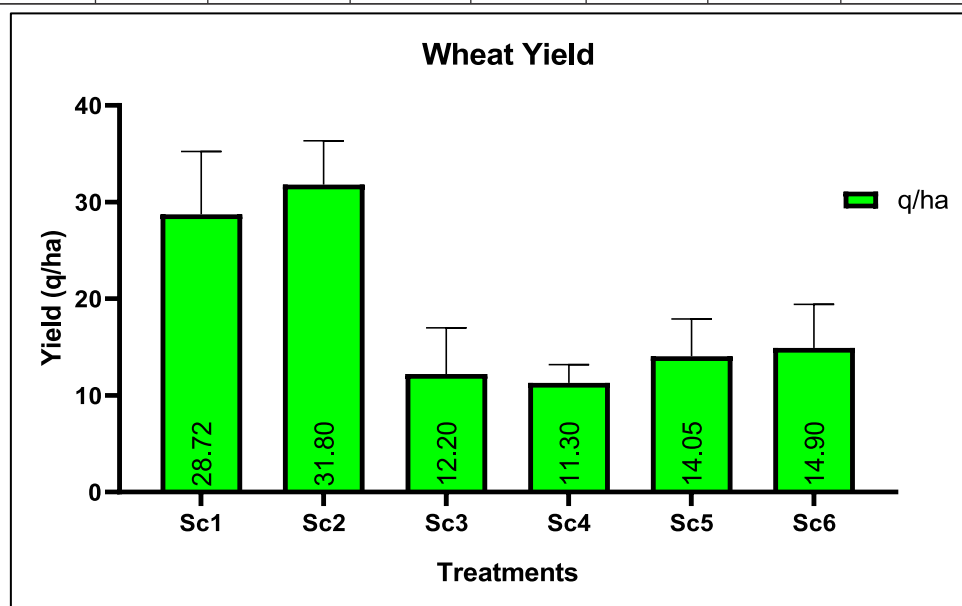
RRS Lucknow

In the sixth cropping cycle of the project, effect of the natural farming component was evaluated on growth and productivity of the wheat (var KRL283). Six treatments among which 2 treatments (viz; Sc-1 and Sc-2) were based on recommended chemical input-

Table 11.3 Changes in soil properties under wheat cultivation (var. KRL 283) following low budget natural farming as well as fertilizer based agronomic practices

Treatments	Organic Carbon (%)		Available Nitrogen (Kg/ ha)		Available Phosphorous (Kg/ ha)		Available Potassium (Kg/ha)		Dehydrogenase activity (µg/ml/hr)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Sc1	0.47	0.43	198.6	190.5	15.71	16.55	189.1	175.8	132.2	107.0
Sc2	0.46	0.48	196.6	200.8	15.40	15.94	189.3	192.4	110.9	125.1
Sc3	0.50	0.43	89.52	78.04	9.803	10.15	164.3	154.3	106.7	89.05
Sc4	0.42	0.46	113.3	107.0	10.08	11.80	165.7	162.4	121.2	94.26
Sc5	0.53	0.44	111.9	107.7	14.29	14.82	166.2	165.2	101.9	126.6
Sc6	0.50	0.43	114.7	105.4	14.45	15.69	167.0	163.7	118.2	126.4

Fig 11.7 Trends of yield under LBNF (Sc3, Sc4, Sc5, Sc6) as well as fertilized treatments (Sc1, Sc2) with wheat.



based farming practices whereas 4 treatments (viz; Sc-4, Sc-6, Sc-3 and Sc-5) were based on package and practices of LBNF components. There was drastic reduction in yield of wheat under the treatments receiving natural farming components, the plot yield ranged from 9.8 q ha⁻¹ to 13 q ha⁻¹ (Figure 11.5a). The results of the field experiments with wheat showed significant changes in the soil chemical as well as biological activity. With respect to the organic carbon (OC) data in wheat natural farming registered decrease in OC levels except for Sc4 (Table 11.3).

Under the NF treatments the reduction in availability of soil nitrogen was also observed as compared to control treatment, it was found that under NF treatments, available N ranged from 78 to 107 kg ha⁻¹ whereas the treatments receiving chemical inputs has available N to the range of 190-200 kg / ha. Changes in soil microbial biomass was estimated in terms of dehydrogenase activity. It was found that dehydrogenase activity also decreased in all the natural farming treatments, only Sc5 (LBNF + HaloMix + Residue) and Sc6 (LBNF + HaloMix + Residue+ Green Manuring) showed increase in dehydrogenase activity (Table 11.3). The yield response of the wheat was low under the application of natural farming components. It was found that maximum yield of 14.9 q/ha was obtained under natural farming whereas under conventional farming yield response was 31.8 q ha⁻¹ (Figure 11.7)

RRS Bharuch

To evaluate low budget natural farming (LBNF) concept in saline Vertisols, a field trial was initiated in 2020. Due to continuous failure of *kharif* crop (cotton), the experiment was modified in September 2022. The modified treatments comprised six combinations of nutrient management, tillage and spray of organic liquid fertilizer invented by Navsari Agricultural University from Banana pseudo stem (Novel plus) viz., 100% recommended dose of fertilizers through chemical fertilizers (RDF) + conventional tillage (CT) + No spray (T1); RDF + CT + Novel spray (T2); application of nutrients through LBNF components (LBNF) + CT+ No spray (T3); LBNF + CT + Novel spray (T4); LBNF + minimum tillage (MT) + No spray (T5) and LBNF + MT + Novel spray (T6) on different *kharif* (pigeon pea and cotton), semi-rabi (mung bean after pigeonpea) and wheat (after cotton) crops. In the control plots recommended dose of fertilizers, Cotton-80:40, Pigeon pea and green gram 20:40 and Wheat 120:60; N and P per hectare has been applied. In the LBNF plots application of Ghanamrut has been done prior to sowing which was made of specific proportion of desi cow dung, cow urine, Jaggry (Gur), pulse floor (besan) and fields soil. Beejamrit (made of specific proportion of desi cow dung, cow urine, choona, soil and water) treatment was applied to crop seed before sowing in LBNF plots and sown after drying the seeds in shade. Jeevamrit (made of specific proportion of desi cow dung, cow urine, Jaggry (Gur), pulse floor (besan), fields soil and water) was applied as spray in rainfed crops and with the first irrigation in irrigated crop to the LBNF plots. Jeevamrut was applied four times with each irrigation/spray as per recommendation.

In the *kharif* 2024 sowings of pigeon pea (GNP-2) crop was done in July 2024. According to the treatment conventional and minimum tillage practices, Novel spray and RDF and LBNF practices were followed. Various data for growth and yield parameter were recorded, however this year due to heavy attack of wild animal like monkey, we were not able to get final produce, seed yield. The highest number of pods per plant was recorded in T2 (243.33), which was at par or significantly superior to T1 (234.33). The results clearly indicate that RDF + CT + Novel Spray (T2) was the most effective treatment in improving plant height, branching, and pod formation.

In the *kharif* 2024 cotton (GN. Cot-25) was grown as second *kharif* crop. The maximum number of branches was recorded in T2 (32.47) followed by T1 (28.85) which was significantly superior to all other treatments. Cotton yield varied significantly among treatments. The highest yield was recorded in T2 (8.06 q/ha), which was significantly

Table 11.4 Performance of different crops under various treatments during 2024-25

Treatments		Pigeon pea (2024)		Cotton (2024)		Mustard (2024-25)	Wheat (2024-25)
		No. of Branches per plant	No. of pods per plant	No. of Branches per plant	Cotton Yield (q/ha)	Seed yield (q/ha)	Grain yield (q/ha)
T1	RDF+CT+No spray	27.67	234.33	28.85	7.50	6.17	22.43
T2	RDF+CT+Novel Spray	33.00	243.33	32.47	8.06	6.72	24.08
T3	LBNF+CT+No spray	20.00	183.67	24.73	5.37	3.65	5.78
T4	LBNF+CT+Novel Spray	23.67	195.00	25.87	6.09	4.15	6.13
T5	LBNF+MT+No Spray	16.67	161.00	21.87	4.60	3.49	5.17
T6	LBNF+MT+Novel Spray	18.33	174.67	23.80	5.22	3.71	5.54
LSD		5.46	23.80	3.12	1.38	0.99	1.32

superior to all other treatments and followed by T1 (7.50 q/ha). The higher cotton yield under RDF + CT + Novel Spray may be attributed to improved vegetative growth, greater branching, and efficient partitioning of assimilates towards reproductive structures. Cotton yield reduced up to 25 percent in LBNF treatment as compare to RDF treatments (Table 11.4).

Rabi season mustard crop (salt tolerant Var. CS-58) was sown in first week of December 2024 under different nutrient management treatments. The highest grain yield was recorded in T2 (6.7 q/ha respectively), followed by T1. The *rabi* season experiment was planned according to the treatments and salt tolerant wheat variety KRL 210 was sown in first week of December 2024. The highest grain yield of wheat yield was recorded in T2 (24.08 q/ha), followed by T1.

Enhancing farmers' livelihood through identified interventions in waterlogged saline agroecosystems of Haryana. FARMER FIRST, ICAR {Rajkumar, Suresh Kumar, Anil Kumar, Satyendra Kumar, Ashwani Kumar, Sohanvir Singh (NDRI)}

Impact of SSD (Sub Surface Drainage) installation on yield potential of salt tolerant wheat variety (KRL-210) under water-logged saline soils

Sub-surface drainage (SSD) installation significantly enhanced the yield potential and economic viability of salt-tolerant wheat varieties in waterlogged saline soils. Field demonstrations conducted across 6 sites totaling 1.5 ha showcased the performance of KRL 210 against the baseline variety HD 2967 (control). SSD reclamation alleviated dual stresses of salinity and waterlogging, enabling better root aeration, nutrient uptake, and photosynthetic efficiency, which translated into measurable agronomic and economic gains. KRL 210 achieved an average grain yield of 56.25 ± 2.1 q/ha under demo conditions with SSD, representing a 9.22% increase over the control yield of 51.50 ± 2.4 q/ha ($t=2.45$, $p<0.05$). This yield uplift aligns with SSD's role in reducing soil redox potential and bulk density, fostering an optimal rhizosphere for salt-tolerant genotypes. Economically, SSD-amended plots yielded net returns of ₹88,785 ha⁻¹ for KRL 210, a 13.13% improvement over ₹78,483 ha⁻¹ in controls. The benefit-cost (B:C) ratio rose from 1.70 to 1.93, indicating robust profitability even under saline constraints.

Impact of SSD (Sub Surface Drainage) installation on yield potential of various Rice varieties under water-logged saline soils

The installation of sub-surface drainage (SSD) in waterlogged saline soils significantly improved the yield and economic returns of all tested rice varieties compared to the local check, with PB 1692 showing the highest yields and PB 1121 giving the highest net return and B:C ratio. Under SSD-reclaimed waterlogged saline soils, all improved varieties out yielded the local check, with demo yields ranging from 50.20 to 57.20 q/ha compared to 42.50 q/ha in the local variety. PB 1692 recorded the highest grain yield (57.20 q/ha), followed by PB 1509 (56.30 q/ha), while PB 1121 had the lowest yield among the

Table 11.5 Yield and economic performance of KRL-210 Wheat variety under reclaimed waterlogged saline soils

Demonstrated variety	Demos (No.)	Area (ha)	Yield (q/ha)			Net return (₹)			B:C ratio	
			Demo	Control (HD 2967)	% Δ	Demos	Control	% Δ	Demos	Control
KRL 210	6	1.5	56.25	51.50	9.22	88785	78483	13.13	1.93	1.70

Note: Values are means $\pm$ SE; Statistical significance: yield ($p < 0.05$), net retur ns ($p < 0.01$).

Table 11.6 Yield and economic performance of rice varietal trial under reclaimed waterlogged saline soils

Variety	Yield (q/ha)		% increase in yield over local	Financial viability indicator			
				Net return (Rs./ha)		BC Ratio	
	Demo	Local		Demo	Local	Demo	Local
PB 1718	53.50	42.50	25.88	155772	113972	3.28	2.40
PB 1692	57.20		34.58	146952		3.09	
PB 1121	50.20		18.12	163312		3.44	
PB 1509	56.30		32.47	143892		3.03	

*Average Market selling price of different Paddy varieties: PB 1121 (Rs. 4200/-); PB 1718 (Rs. 3800/-); PB 1692 (Rs. 3400/-); PB 1509 (Rs. 3400/-)

improved varieties (50.20 q/ha). Compared to the local variety (42.50 q/ha), the yield increase in the demo plots varied from 18.12 % (PB 1121) to 34.58 % (PB 1692), indicating that SSD not only improved drainage but also enhanced the yield potential of high-yielding rice varieties in these problem soils. Economically, all improved varieties showed higher net returns and better benefit-cost (B:C) ratios than the local check (net return: ₹1,13,972/ha; B:C ratio: 2.40). PB 1121 gave the highest net return (₹1,63,312/ha; B:C ratio 3.44), followed by PB 1718 (₹1,55,772/ha; B:C 3.28). PB 1692 and PB 1509, though slightly lower in net return than PB 1718, still performed well with a B:C ratio of 3.28 and 3.03, respectively; confirming that SSD-based reclamation makes these high-yielding varieties more profitable under waterlogged saline conditions. The results clearly show that SSD installation in waterlogged saline soils not only improves drainage and root zone aeration but also substantially enhances the yield and profitability of modern rice varieties over the local check. Among the tested varieties, PB 1121 emerged as the most remunerative option, while PB 1692 were the highest yielding, making them suitable for cultivation in SSD-reclaimed saline waterlogged areas.

Development of sustainable production system for the date palm in salt affected soils of Haryana funded by RKVY-RAFTAAR (Rajkumar (Hort.), Ashwani Kumar, Suresh Kumar and R. K. Yadav)

The effects of sodicity and salinity stress on various morphological and physiological parameters of date palm were evaluated. The experiment included a control treatment (T_1 , pH 7.65) and eight stress treatments: four salinity levels (T_2 : ECe 9.6 dS/m; T_3 : ECe 13.1 dS/m; T_4 : ECe 16.9 dS/m; T_5 : ECe 18.5 dS/m) and four salinity levels (T_6 : pH 8.38; T_7 : pH 8.62; T_8 : pH 9.12; T_9 : pH 9.54). Data were analyzed for statistical significance using the critical difference (CD) at $p < 0.05$. The results are presented in Table 1, and key findings are detailed below, categorized by parameter for clarity. The experimental results demonstrate a clear gradient of declining growth and physiological performance in date palm plants with increasing sodicity and salinity stress relative to the non-stressed control (T_1 , pH 7.65), with most differences exceeding critical differences (CD at $p < 0.05$) to confirm statistical significance.

Vegetative Growth Traits

The growth parameters of the plants, including plant height, stem diameter, leaf length, leaf width, number of thorns, thorn-to-thorn distance, and thorn length, exhibited significant declines under both sodicity and salinity stresses at their maximum levels compared to the control (T_1). At the highest salinity level (T_5 , EC 18.5 dS/m), plant height significantly decreased from 139.17 cm in the control to 104.50 cm (24.9% reduction; $p <$

Table 11.7 Vegetative growth parameters under soil sodicity and salinity

Treatment		Plant height (cm)	Diameter (mm)	Leaf length (cm)	Leaf width (cm)	No. of thorns	T to T distance (cm)	Thorn length (cm)
Control	pH $\approx$ 7.65 (T1)	139.17	83.15	30.78	2.79	7	6.97	2.43
Salinity level	ECe $\approx$ 9.6dS/m (T2)	135.17	83.72	29.98	2.28	6.67	6.64	2.31
	ECe $\approx$ 13.1dS/m (T3)	129.67	78.26	29.38	2.18	6.5	5.98	2.21
	ECe $\approx$ 16.9dS/m (T4)	126.17	75.3	29.2	2.14	6.17	5.36	2.05
	ECe $\approx$ 18.5dS/m (T5)	104.5	67.82	25.82	2.04	5.5	4.49	1.93
Sodicity								
level	pH $\approx$ 8.38 (T6)	121.5	78.46	28.28	2.07	5.5	4.62	1.98
	pH $\approx$ 8.62 (T7)	114.67	73.23	24.52	2.00	5.17	4.46	1.85
	pH $\approx$ 9.12 (T8)	107.5	70.88	23.34	1.94	5	4.29	1.76
	pH $\approx$ 9.54 (T9)	102	68.06	22.12	1.83	4.67	4.05	1.62
CD (p<0.05)		15.999	N/A	3.283	0.303	1.038	1.211	0.063

0.05), stem diameter reduced from 83.15 mm to 67.82 mm (18.4% reduction), leaf length from 30.78 cm to 25.82 cm (16.1% reduction), leaf width from 2.79 cm to 2.04 cm (26.9% reduction), number of thorns from 7 to 5.50, thorn-to-thorn distance from 6.97 cm to 4.49 cm (35.6% reduction), and thorn length from 2.43 cm to 1.93 cm (20.6% reduction). Similarly, at the highest sodicity level (T₉, pH 9.54), reductions were generally more pronounced: plant height to 102.00 cm (26.7% reduction), stem diameter to 68.06 mm (18.1% reduction), leaf length to 22.12 cm (28.1% reduction), leaf width to 1.83 cm (34.4% reduction), number of thorns to 4.67, thorn-to-thorn distance to 4.05 cm (41.9% reduction), and thorn length to 1.62 cm (33.3% reduction). These significant reductions at maximum stress levels highlight that sodicity imposed greater adverse effects on structural development and defensive traits than salinity, likely due to combined osmotic and specific ion toxicity.

Physiological Traits

Physiological parameters, including photosynthetic rate, stomatal conductance, and transpiration rate, were significantly impaired at the maximum levels of sodicity and salinity compared to the control (T₁). At the highest salinity (T₅, EC 18.5 dS/m), photosynthetic rate decreased from 5.26 $\mu\text{mol}/\text{m}^2/\text{s}$ in the control to 4.89 $\mu\text{mol}/\text{m}^2/\text{s}$ (7.0% reduction; $p < 0.05$), stomatal conductance from 1.12 $\text{mol}/\text{m}^2/\text{s}$ to 0.87 $\text{mol}/\text{m}^2/\text{s}$ (22.3% reduction), and transpiration rate from 1.59 $\text{mmol}/\text{m}^2/\text{s}$ to 1.21 $\text{mmol}/\text{m}^2/\text{s}$ (23.9% reduction). At the highest sodicity level (T₉, pH 9.54), the declines were more severe: photosynthetic rate to 4.67 $\mu\text{mol}/\text{m}^2/\text{s}$ (11.2% reduction), stomatal conductance to 0.74 $\text{mol}/\text{m}^2/\text{s}$ (33.9% reduction), and transpiration rate to 0.91 $\text{mmol}/\text{m}^2/\text{s}$ (42.8% reduction). All differences at maximum stress levels were statistically significant ($p < 0.05$), indicating that sodicity caused greater disruption to gas exchange and water relations, primarily through enhanced stomatal closure and reduced CO₂ assimilation, compared to the relatively milder effects of severe salinity. Both sodicity and salinity stresses led to

Table 11.8 Physiological traits parameters under soil salinity and sodicity

Treatment		Photosynthetic rate ($\mu\text{mol}/\text{m}^2/\text{s}$)	Stomatal conductance ($\text{mol}/\text{m}^2/\text{s}$)	Transpiration rate ($\text{mmol}/\text{m}^2/\text{s}$)
Control	pH $\approx$ 7.65 (T1)	5.26	1.12	1.59
Salinity level	ECe $\approx$ 9.6 dS/m (T2)	5.18	1.07	1.49
	ECe $\approx$ 13.1 dS/m (T3)	5.1	0.99	1.41
	ECe $\approx$ 16.9 dS/m (T4)	5.02	0.91	1.33
	ECe $\approx$ 18.5 dS/m (T5)	4.89	0.87	1.21
Sodicity level	pH $\approx$ 8.38 (T6)	5.01	0.93	1.16
	pH $\approx$ 8.62 (T7)	4.93	0.86	1.07
	pH $\approx$ 9.12 (T8)	4.79	0.82	0.99
	pH $\approx$ 9.54 (T9)	4.67	0.74	0.91
CD (p<0.05)		0.158	0.061	0.057



ICAR-CSSRI Karnal (Sodicity)



ICAR IIWBR Experimental Farm, Hisar (Salinity)

significant deteriorations in plant morphology and physiology, with sodicity generally causing more severe impacts at equivalent stress intensities. The most affected parameters were those related to water relations (e.g., transpiration, stomatal conductance) and structural development (e.g., height, leaf dimensions, thorns).

MISCELLANEOUS





Training and Capacity Building

Name and	Subject/Training Program	Place/Organizer	Duration/Period
LokeshKumar BM	Hands-on training session on "BIOFLOW: Biometrical Genetic Workflow" by IRRI, South Asia-Hub, Hyderabad	ICRISAT Campus, Hyderabad	30 Apr 2025
Devika S.	Three-month FOCARS Training as part of the NAARM Training	ICAR-NAARM, Hyderabad	07 Jul - 16 Oct, 2025
Sonali Mallick	21 day online training programme on 'Advanced Statistical and Machine Learning Techniques for Data Analysis using Open Source Software for Abiotic Stress Management in Agriculture	ICAR-NIASM, Baramati	16 Jul – 05 Aug, 2025
LokeshKumar BM	Short training program on "Fundamentals of Genomic Predictions and Data-driven Crop Breeding" conducted by International Rice Research Institute, Philippines	ICAR-IIRR, Hyderabad	24 Nov - 28 Nov 2025

Deputation of Scientists Abroad

Name and	Subject/Training Program	Place/Organizer	Duration/Period
Anita Mann	Short-Term International Training in Genome Editing funded by ICAR	CIMMYT, Mexico	31 Mar – 27 Jun, 2025
Ajay Bhardwaj	Training on "Confirmation of Leymus racemosus chromosome N short arm in BNI-enabled wheat by Genomic in Situ-Hybridization" (Funding agency: JICA)	JIRCAS, Japan	24 May - 01 Jun, 2025



Awards and Recognitions

- Dr. S.K. Sanwal, Pr. Scientist & Head, Division of Crop Improvement conferred Fellow of Indian Academy of Horticultural Sciences-2025 in the field of Horticulture (Vegetable Science) and Fellow of Indian Society of Soil Salinity and Water Quality-2023-24.
- Dr. Kailash Prajapat-Awarded Young Scientist Award by Indian Society of Soil Salinity and Water Quality, Karnal in International Salinity Conference 3.0 (WE-CARE-2025) held during 29th October-1st November 2025 at ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa, India.
- Ajay Bhardwaj - Fellow, National Academy of Agricultural Sciences (NAAS), India, 2025 and Fellow, Society for Advancement of Wheat and Barley Research (SAWBAR; Indian Institute of Wheat & barley Research), 2025.
- Dr. Sanjay Arora - Conferred CSSRI Excellence Award for outstanding contribution in management of salt affected soils on March 12, 2025 at ICAR-CSSRI, Karnal.
- Dr. Sanjay Arora - Awarded Fellowship of British Ecological Society on December 2, 2025.
- Dr. Kailash Prajapat awarded with Best Oral Presentation for paper entitled "Quinoa for high saline environments: Evaluation of salinity tolerance and agronomic practices" in International Salinity Conference 3.0 (WE-CARE-2025): Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems during 29th October-1st November 2025 held at ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa, India.
- Dr. Suresh Kumar awarded with Best Oral Presentation for research paper entitled "where there will, there-a-way: Economic impact and overcoming barriers in reclaiming salt-affected soils by in International Salinity Conference 3.0 (WE-CARE-2025): Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems during 29th October-1st November 2025 held at ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa, India.
- Dr. Rajkumar awarded with best oral presentation award in International Conference on Technology Innovations & Sustainable Development of Date Palm-2025 (ICDP-2025) International Conference on Date Palm – 2025, 29 – 30 June, 2025 at Bhuj, Gujarat.
- Dr. Rajkumar awarded with Certificate of Excellence in Reviewing by the Journal of Advances in Biology & Biotechnology in recognition of an outstanding contribution to the quality of the journal on 28.02.2025.
- Dr. Rajkumar awarded with Certificate of Excellence in Reviewing by the Journal of Scientific Research and Reports in recognition of an outstanding contribution to the quality of the journal on 04.06.2025.
- Best Oral Presentation award: Kumar, J., Narjary, B., Vibhute, S., and Kumar, S. (2025). Performance Assessment of Soil Moisture Sensors under Saline Environment. International Salinity Conference 3.0 on "WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems," ICAR-Central Coastal Agricultural Research Institute, Ela, Old Goa, Goa, 29 October–1 November 2025, p. 121.
- Dr R. H. Rizvi Granted copyright for "Agroforestry Area Estimate Map of India" by Registrar of Copyright, Govt. of India for work on "Area under Agroforestry in India (State Wise)" on 19th Sept. 2025.
- Dr. Sanjay Arora - Received Best Poster Presentation Award for paper entitled "Isolation of Plant Growth Promoting Rhizobacteria from salt affected soil of Uttar Pradesh, India" during 13th International Science Congress, Dr RML University, Ayodhya, December 8-9, 2025.

- Dr. Sanjay Arora - Best Research Paper Award”for the article entitled “On-farm assessment of Halophilic Microbial Bio-formulation on Productivity of Mustard crop in sodic soils of Indo-Gangetic Plains” during the ISSSWQ International Salinity Conference 3.0 on 29th October 2025 held at CCARI, Goa.
- Dr Sanjay Arora has been was elected as Chief Editor, Journal of Soil and Water Conservation, India (2016- till date) [NAAS:5.51]
- Dr Sanjay Arora has been was nominated expert for development of the National Agriculture Code (NAC) Sectional Committee of India on “Soil health management” and “Plant health management” by Bureau of Indian Standards, New Delhi.
- Dr Sanjay Arora has been chaired a technical session in the 33rd National Conference on Soil, Water and Energy Management for Sustainable Agriculture and Livelihood Security organized by SCSi at PAU, Ludhiana during December 8-10, 2025.
- Anushandan National Research Foundation – International travel support by department of science and technology, Government of India for visiting Wageningen university and Research, The Netherlands from -6 sept, 2025 to Amresh Chaudhary
- Best oral presentation award for presenting paper on “Digital mapping of salt-affected soils of Uttar Pradesh in India at the International Salinity Conference 3.0 on WE-CARE: worldwide efforts on cutting edge approaches for restoring saline ecosystems. Amresh Chaudhary
- NESI Eminent Scientist (2025) by National Environmental Science Academy, New Delhi, India to Fagodiya, R.K.
- Young Scientist Award (2023) of Farming System Research and Development Association by FSRDA, Modipuram, India to Fagodiya, R.K.
- Ram Kishor Fagodiya*, Kailash Prajapat, Priyanka Chandra, Gargi Sharma, A. K. Rai, R. K. Yadav (2025). Partial Conservation Agriculture in Reclaimed Sodic Land: Ecosystem Service Gains and Trade-offs in the Rice–Wheat System, 33rd National Conference “Land and Water Management for Ecological Restoration and Agricultural Sustainability” held at Punjab Agricultural University, Ludhiana during 8-10 December, 2025 (Best oral presentation award)
- Ram Kishor Fagodiya*, Kailash Prajapat, Priyanka Chandra, Kamlesh Verma, Gargi Sharma, A. K. Rai, R. K. Yadav (2025). Ecosystem Service Gains from Partial Conservation Agriculture in Rice-Wheat System, in International Salinity Conference 3.0 “WE-CARE-2025: “Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline ecosystems” held at ICAR – Central Coastal Agricultural Research Institute, Goa during 28 October - 1 November, 2025 (Best oral presentation award)
- Ram Kishor Fagodiya*, Kamlesh Verma, Gargi Sharma, Kailash Prajapat, Priyanka Chandra, A. K. Rai, R. K. Yadav (2025). Greenhouse gases mitigation and carbon sequestration potential of rice-wheat system: An impact of long-term tillage and residue management experiment (LT&RE) in 1st International Farming Systems Conference (IFSC 2025) “Transforming Food, Land and Water Systems under Global Climate Change” held at ICAR- Indian Institute of Farming System Research, Modipuram during 7-9th March, 2025 (Best oral presentation award)
- Rakesh Banya was received best oral presentation award in International Salinity Conference (WE –CARE) at ICAR-CCARI, Goa by ISSS&WQ, Karnal Haryana
- Ajay Bhardwaj - Served as Chief Editor of the Journal of Natural Resources Conservation and Management, (ANRCM; <http://anrcm.org>).
- Ajay Bhardwaj - Served as Associate Editor in Scientific Reports (Nature), Journal of Cereal Research & journal 'Ecological Processes' (Springer-Nature).

- Ajay Bhardwaj - Served as Editorial Board Member in the journal 'Frontiers in Plant Science', 'Frontiers in Soil Science' & 'Frontiers in Environmental Science'.
- Awtar Singh received Best oral presentation award in 33rd National Conference on Land and Water Management for Ecological Restoration and Agricultural Sustainability" held at PAU, Ludhiana from 8-10 December 2025.
- Priyanka Chandra received Best Oral presentation entitled Fungal P-solubilizers improves growth and P nutrition of sorghum at variable salinity levels" in the Xth International Conference at MPUAT, Udaipur, Rajasthan, India.
- Dr. Uttam Kumar Mandal has been awarded the Best Poster Presentation for the Poster entitled 'Village-scale assessment of environmental hazards in the Ganges Delta of the Indian Sundarbans' Co-authored by Ghosh, A., Burman, D., Mallick, S., Lama, T.D., Bhutia, R.N., Raut, S., Mahanta, K.K., and Bhardwaj, A.K. at the International Salinity Conference 3.0. WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems. held at ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa India on 29 October to 01 November, 2025.
- Dr. S. Mallick received Best Oral Presentation Award for the paper 'Performance Analysis of Rice-Fallow Systems in the Indian Ganges Delta: Economic, Energy, and Environmental Perspectives' Co-authored by, Burman, D., Mandal, U. K., Kumar, S., Mahanta, K. K., Lama, T. D., Bhutia, R. N., Digar, S., Monjardino, M., & Mainuddin, M. 2025 in International Salinity Conference 3.0 WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems jointly organised by Indian Society of Soil Salinity and Water Quality (ISSSWQ), Karnal and also in collaboration with Association for Coastal Agricultural Research (ACAR), Old Goa during October 29-November 1, 2025.
- Dr. S. Mallick received Best oral presentation Award for the paper 'Efficiency of Cropping System Intensification in the Salt-Affected Coastal Zones of the Indian Ganges delta' co-authored by Burman, D., Mandal, U. K., Kumar, S., Mahanta, K. K., Lama, T. D., Digar, S., Bhutia, R. N., Digar, S., Burman, R. R., Monjardino, M., & Mainuddin, M. 2025 in Second International Extension Education Congress jointly organised by society of extension education S'O'A Bhubaneswar and CUO. Koraput, Odisha on "rethinking social ecology in a digital landscape during November 24-26, 2025.
- Dr. S. Mallick Received Young Scientist Award in Second International Extension Education Congress jointly organised by society of extension education S'O'A Bhubaneswar and CUO. Koraput, Odisha on "rethinking social ecology in a digital landscape during November 24-26, 2025.
- Dr. Devika. S. received Best oral presentation Award for the paper "Physiological and Morphological Mechanisms of Salinity Adaptation in Coastal Rice Genotypes" Co-authored by D. Burman, U. K. Mandal, T. D. Lama, N. R. Prakash, Lokesh B.M, K.T. Ravikiran and S. Mallick in International Salinity Conference 3.0 WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems jointly organised by Indian Society of Soil Salinity and Water Quality (ISSSWQ), Karnal and also in collaboration with Association for Coastal Agricultural Research (ACAR), Old Goa during October 29-November 1, 2025.



Linkages and Collaborations

International Collaboration

- Collaborative research with IRRI, Philippines, on advanced rice cultivation and salt tolerance.
- Joint projects with ICAR-CCAFS on climate-smart agriculture in South Asia.
- Partnership with JIRCAS, Japan, on sustainable resource management in water-stressed regions.
- Research with CIMMYT, Mexico, on improving nitrogen use efficiency using urease inhibitors.
- Collaboration with CSIRO, Murdoch University (Australia), and Bangladeshi institutes on cropping system intensification in coastal zones.
- Joint work with SAARC Agriculture Centre on cropping system modeling for food security.
- Academic exchange with Cairo University, Egypt, under the CV Raman Fellowship.
- Partnership with the National University of Singapore for wastewater remediation studies.
- Program with IRRI, Philippines, on breeding stress-tolerant rice varieties.
- Collaboration with IWMI, Sri Lanka, on water management.
- Research partnership with INIFTA, Argentina.
- HIROS project with DST-NWO on river rejuvenation and water balance modeling.

National Collaborations

ICAR-CSSRI has established academic collaborations with several prestigious institutions, including the Institute of Environmental Studies at Kurukshetra University, the Department of Biotechnology at Maharishi Markandeshwar University in Mullana, Deenbandhu Chhotu Ram University of Science & Technology in Murthal, and ICAR-NDRI, Karnal. These partnerships focus on postgraduate teaching and research. Further academic linkages exist with CCSHAU, Hisar; Banasthali Vidyapeeth, Rajasthan; BBAU, Lucknow; Bidhan Chandra Krishi Viswavidyalaya, Kalyani; Jaipur National University, Rajasthan; and Punjabi University, Patiala.

In addition, Institute has collaborations with various agricultural universities and research centers to support multi-location trials and capacity building. Notable partners include Anand Agricultural University (Anand), Junagadh Agricultural University (Junagadh), Navsari Agricultural University (Navsari), College of Agriculture (Bharuch), Cotton Research Stations (Bharuch and Surat), and Kerala Agricultural University (Trivandrum). Institute work closely with Krishi Vigyan Kendras across multiple districts, such as Chaswad, Dediapada, Surat, Dhoura, Unnao, Kaushambi, Pratapgarh, Sitapur, Auraiya, and Bhadohi.

ICAR-CSSRI have collaborations with various ICAR institutes which form a significant part of our research network. These include the ICAR-IIWBR (Karnal), CISR (Nagpur), CIFE (Mumbai), CIFA (Kolkata), CISH (Lucknow), IISR (Lucknow), IIWM (Bhubaneswar), NBSS&LUP (Nagpur) and NCIPM (New Delhi).

Institutes's involvement in national-level research projects includes the All India Coordinated Cotton Improvement Project (Coimbatore), the AMAAS project on application of micro-organisms in agriculture (ICAR funded), and enhancing nutrient use efficiency using nano-fertilizer in rice-wheat systems under salt stress with IFFCO, Chandigarh. Institute also collaborate in coastal salinity tolerant varietal trials (CSTVT), national salinity and alkalinity screening nursery (NSASN) with IIRR Hyderabad, and multi-locational evaluation of bread wheat germplasm with NBPGR, New Delhi.

ICAR-CSSRI maintain strong linkages with several government departments and agencies, such as the Departments of Agriculture of Haryana, West Bengal, and Uttar Pradesh; Department of Science and Technology, Government of India; Department of Soil Conservation, Government of West Bengal; Haryana State Forest Department; and the Water Conservation Department, Directorate of Irrigation Research & Development (Pune).

Institutes's collaborations also extended to prominent scientific and remote sensing institutions, including IIT Kanpur, the Indian National Academy of Engineering (INAE), Regional Remote Sensing Centre (East, Kolkata), National Remote Sensing Centre (NRSC, Hyderabad), State Remote Sensing Application Centres (Lucknow). We also work with the NCP, IGBP, IIRS, and NRSA under the Department of Space.

Institute have partnered with leading industry players and NGOs such as Reliance Industries Ltd., MAHYCO, Monsanto India Ltd., Gujarat Narmada Valley Fertilizer Company Ltd. (Bharuch), Rex Polyextrusion Pvt. Ltd. (Sangli), Astal Poly Technik Ltd. (Ahmedabad), Subham Seeds (Hyderabad), NTPC Ltd (New Delhi) FAGMIL (Jodhpur), ATAPI Seva Foundation (Jambusar), PRASARI (West Bengal), Tagore Society for Rural Development (West Bengal), VIKAS-NGO (Ahmedabad), Fondazione L'Albero della Vita (Kolkata), and NTPC Ltd. (New Delhi). These collaborations focus on technology transfer, outscaling innovations, and supporting large-scale agricultural projects.

Several partnerships of the institutes support specific research, demonstration, and technology transfer projects. These include technical guidance and monitoring for subsurface drainage projects in Haryana, promotion of SSD technology in Maharashtra, and strategies for sustainable management of degraded coastal lands with RAKVK (West Bengal), CIBA (Chennai), CARI (Port Blair), and BCKV (West Bengal). We also collaborate with ROCL Jaipur and the Horticulture Department of J&K for evaluating salt tolerance in olive germplasm.

Institutes's network further includes national funding agencies such as NABARD (Mumbai and Chandigarh) and the U.P. Council of Agricultural Research (UPCAR, Lucknow), and World Wide Fund (WWF), reflecting Institute's wide-ranging commitment to advancing agricultural research and development through collaborative efforts.

Publications

- Arora, Sanjay (2025) Advances in Assessment, Reclamation and Management of Salt affected Soils for Sustainable Crop Production. *Journal of the Indian Society of Soil Science* 72 (S): S106-S121.
- Ashwani Kumar, Sharma A, Kaushik S, Kundu A, Dhansu P, Verma K, Kumar R, Alsahli AA, Sheoran P. 2025. Temporal variations in morpho-physiology of sandalwood and gene expression analysis revealed Shisham as host preference under water deficit and salinity stress. *BMC Plant Biology*. 25(1):1280.
- Bhardwaj A.K., Malik K., Rani M., Kumar A., Devi S., Kumar N., Kumar R., Mann A., Sheoran P., Mandal U.K. and Yadav R.K. 2025. Transitioning from soil-based to soil-foliar hybrid application for nitrogen fertilizers offers energy-saving and use-efficiency benefits. *Food and Energy Security* 14 (5), e70109. <https://doi.org/10.1002/fes3.70109>
- Bhardwaj A.K., Malik K., Rani M., Kumar A., Devi S., Kumar N., Kumar R., Mann A., Sheoran P., Mandal U.K., Yadav R.K. (2025) Transitioning from Soil-Based to Soil-Foliar Hybrid Application for Nitrogen Fertilizers Offers Energy-Saving and Use-Efficiency Benefits. *Food and Energy Security* 14 (5), e70109. <https://doi.org/10.1002/fes3.70109>
- Bhardwaj AK, Malik K, Rani M, Ashwani Kumar, Devi S, Kumar N, Kumar R, Mann A, Sheoran P, Mandal UK, Yadav RK. 2025. Transitioning From Soil-Based to Soil-Foliar Hybrid Application for Nitrogen Fertilizers Offers Energy-Saving and Use-Efficiency Benefits. *Food and Energy Security*, 14(5):e70109.
- Bhatt, R., Arora, Sanjay, Sheoran, P. and Singh, B. (2025) Farmer response and awareness on soil health cards under Viksit Krishi Sankalp Abhiyan (VKSA) in Amritsar district of Punjab, India. *Journal of Soil and Water Conservation, India* 24(3): 298-306. (NAAS 5.51)
- Brijesh Kumar, Magan Singh, Deepak Kumar, BL Meena, Sandeep Kumar, Rekha Rana, Ajay Kumar and Avaneesh Kumar (2025) Productivity of fodder ryegrass and chinese cabbage inter-cropping as influenced by nutrient management. *Range Management and Agroforestry* 46 (2):301-310.
- Chand, G., Muthusamy, V., Allen, T., Gain, N., Singh, B., Dutta, S., Prakash, N.R., Singh, S., Sarika, K., Chawla, G., Zunjare, R.U., & Hossain, F. (2025). Dynamics of accumulation of lysine and tryptophan, and kernel modification in opaque2, opaque16, and double mutant (opaque2/opaque16) genotypes during kernel development in maize. *Journal of Applied Genetics*, 66, 871-882.
- Chaudhary, A., Maithani, D., Singh, R., Singh, S., Yadav, S., Kumar, D., Verma, P., Kumar, V., Fagodiya, R.K., Kumar, A., Malyan, S. K. (2025). Chlorpyrifos Pollutants in the Environment and Their Removal by Environmental-Based Remediation Approaches. *Environmental Claims Journal*, 1–41.
- Chaudhary, A., Rai, A. K., Yadav, G., Kumar, M., Kumar, J., Chandra, P., & Sundha, P. (2025). Emerging Perspectives in Cropping System-based Nutrient Management: A scientometric analysis of cropping system-based nutrient management. *Journal of Soil Salinity and Water Quality*; Vol. 17 No. 2 (2025): JSSWQ; 236-251, 0976-0806
- Chopra, M., Choudhary, M., Singh, M., Jat, H.S., Tureevna, Z.L., Sadykova, N. and Kumar, V., 2025. Biocontrol strategies in agricultural green development and soil health management to achieve sustainable growth in agriculture. *Discover Applied Sciences*, 7(10), p.1182.
- Choudhary, N., Kumar, S., Malik, D., & Kumar, J. (2025). Micro-irrigation and solar power: Unlocking India's agricultural potential. *Journal of Soil Salinity and Water Quality*, 17(2), 146–154.
- Dahiya A, Dahiya A, Kajala S and Singh N. (2025) Effect of Plant Growth Regulators on in vitro Micro Propagation of *Bacopa monnieri* and Expression of Secondary Metabolites. *Annals of Biology* 41(2):227-234.
- Dahiya A, Kumar A, Kaushik S, Devi S, Adhisha, Mann A, Kumar A and Sanwal SK. (2025) Neo-domestication of Crop Plants for Managing Unproductive Salt-affected Lands. *Journal of Soil Salinity and Water Quality* 17(1), 1-14. DOI: <https://doi.org/10.56093/jsswq.v17i1.163436>.
- David Camus D., N.S. Thakur, D.P. Patel, R.P. Gunaga, R.S. Chauhan and Y.A. Garde. (2025). *Melia dubia* Progenies from Satpura and Sahyadri Ranges of South Gujarat have Potential for Salinity Tolerance. *Indian Forester*, 151 (1): 1-7.
- Deb, P., Urfels, A., Kumar, V., Veettil, P. C., Srivastava, A. K., Dubey, S. K., Peramaiyan, P., Singh, S., Rawal, S., Kumar, S., Garg, R., Kamboj, B. R., Kumar, S., & Dhillon, B. S. (2025). Factors governing irrigation water productivity of rice in north-western India: Evidence from farmers' fields. *Journal of Environmental Management*, 394,

127428. <https://doi.org/10.1016/j.jenvman.2025.127428>
- Devika Sellathdurai, Dhiman Burman, Uttam Kumar Mandal, Tashi Dorjee Lama, NR Prakash, Lokeshkumar BM and Sukanta K Sarangi (2024). Crop Improvement Strategies for Addressing Waterlogging and Salinity in Coastal Ecosystems. *Journal of Soil Salinity and Water Quality* 16(2), 207-218. DOI: <https://doi.org/10.56093/jsswq.v16i2.157117>
- Dobhal, S., Binjola, R., Shikha, Kumar, R., Bali, R. S., Lal, P., Chaudhary, S., & Vasisth, A. (2025). Biomass production and carbon storage across slope aspects and altitudes in Western Himalaya: A case study of *Pinus roxburghii* forests in the fire-vulnerable region. *Journal of Environmental Management*, 395, 127884. <https://doi.org/10.1016/j.jenvman.2025.127884>
- Fagodiya, R.K.* Verma, K., Sharma, G., Rai, A.K., Prajapat, K., Singh, R., Sheoran, P., Basak, N., Chandra, P., Sharma, D.P., Yadav, R.K., and Biswas A.K. (2025). Assessing the soil organic carbon stability and greenhouse gases mitigation in rice-wheat system: Seventeen-years assessment of tillage and residue management. *Soil and Tillage Research*, 254, 106697.
- Fagodiya, R.K., Singh, A., Rai, A.K., and Yadav R.K. (2025). Crop Residue Management for Green Future. *Indian Journals of Fertilizers*, 21 (12) 1-12.
- Harisha, C. B., Boraiah, K. M., Basavaraj, P. S., Halli, H. M., Singh, R. N., Rane, J., Chaudhary, A. & Senthamil, E. (2025). Optimizing sowing time and weather conditions for enhanced growth and seed yield of chia (*Salvia hispanica* L.) in semi-arid regions. *PeerJ*, 13, e19210.
- Hossain, F., Prakash, N.R., Zunjare, R.U., Chhabra, R., Muthusamy, V., Kyada, A.D., Sharma, D., Mishra, S.J., Sarma, G.R., Duo, H., & Katral, A. (2025). An overview of maize landraces of the North-Eastern Himalayan region of India with special reference to 'Sikkim Primitive'-a unique landrace with extraordinary prolificacy. *Indian Journal of Genetics and Plant Breeding*, 85(04), 535-545. [NAAS Rating – 6.00]
- Islam, M. M., Roy, K., Goswami, R., Rahman, M. C., Begum, M. E. A., Mallick, S., Chowdhury, A., Mainuddin, M. & Monjardino, M. (2025). Farm diversification in the salt-affected coastal region of the Ganges Delta: Drivers and pathways to smallholder resilience. *Environmental and Sustainability Indicators*, 28, 100997.
- Ismail, A. M., Singh, P. K., Krishna, H., Kumar, A., Kulshreshtha, N., Mahendra, C., & Kumar, K. (2025). Physiological and molecular analysis of salt tolerance in wheat (*Triticum aestivum*) recombinant inbred lines population (HD2851 × Kharchia 65). *Indian Journal of Agricultural Sciences*, 95(1), 3–9.
- Ismail, A. M., Singh, P. K., Krishna, H., Kumar, A., Kulshreshtha, N., Mahendra, C., & Kumar, K. (2025). Physiological and molecular analysis of salt tolerance in wheat (*Triticum aestivum*) recombinant inbred lines population (HD2851 × Kharchia 65). *Indian Journal of Agricultural Sciences*, 95(1), 3–9.
- Jat, H.S., Khokhar, S., Prajapat, K., Choudhary, M., Kakraliya, M., Gora, M.K., Gathala, M.K., Sharma, P.C., McDonald, A., Ladha, J.K. and Jat, M.L., 2025. A decade of conservation agriculture in intensive cereal systems: Transitioning to soil resilience and stable yield trends in a climate crisis. *Journal of Environmental Management*, 373, p.123448.
- Jat, H.S., Prajapat, K., Khokhar, S., Choudhary, M., Kakraliya, M., Poonia, T., Kalwania, K.C., Sharma, P.C. and Jat, M.L., 2025. Achieving environmental stewardship through climate-smart agriculture practices in intensive cereal systems of North-western India: Effects on energy-water-carbon footprints. *Energy Nexus*, p.100509.
- Jat, R. A., Jinger, D., Kumawat, A., Kar, S. K., Rawat, I., Kumar, S., Paramesh, V., Meena, V. S., Kaushal, R., Kumar, K., Meena, H. S., Wani, S. P., Singh, R., & Madhu, M. (2025). Integrated watershed management for transforming dryland livelihoods: A climate-smart strategy for sustainable dryland agriculture in India. *Watershed Ecology and the Environment*, 7, 159–177. <https://doi.org/10.1016/j.wsee.2025.03.006>
- Jatana MS, Sheoran P, Fagodiya RK, Ashwani Kumar, Mann A, Kumar P, Mehla MK, Kumar A, Kumar S. 2025. Designing an ecologically sustainable and resource-efficient rice-wheat system in the western indo-gangetic plains of india: Integrating practices of pressurized irrigation, tillage and residue management. *Energy Nexus*. 13:100504.
- Jatana, M.S., Sheoran, P., Fagodiya, R.K., Kumar, A., Mann, A., Kumar, P., Mehla, M.K., Kumar, A. and Kumar, S., 2025. Designing an ecologically sustainable and resource-efficient rice-wheat system in the Western Indo-Gangetic Plains of India: Integrating practices of pressurized irrigation, tillage and residue management. *Energy Nexus*, p.100504.
- Jinger, D., Kakade, V.D., Kaushal, R., Bhatnagar, P.R., Ghosh, A., Mahawer, S.K., Dinesh, D., Singh, G., Akula, C., Paramesh, V., Meena, V.S., Roy, T., Islam, S., Kumar, D., Uthappa, A.R., Chavan, S.B., Pradhan, A., Kumar, R., Kaledhonkar, M. J., &

- Madhu, M. (2025). Nature-based solutions for enhancing CO₂ sequestration and rehabilitating degraded lands through silvo-aromatic system and soil moisture conservation techniques. *Journal of Environmental Management*, 380, 124904. <https://doi.org/10.1016/j.jenvman.2025.124904>
- Kakade, V. D., Morade, A. S., Salunkhe, V. N., Boraiah, K. M., Jinger, D., Singh, G., Chavan, S. B., Kumar, R., Pradhan, A., Jadhav, S., Magar, S., Patil, A., Doke, A., Jadhav, P., Nangare, D.D., & Reddy, K. S. (2025). Dragon fruit cultivation in new areas: Challenges, management strategies, and insights from India. *Discover Agriculture*, 3(168). <https://doi.org/10.1007/s44279-025-00243-2>
- Kakade, V.D., Kumar, R., Jinger, D., Amrut Morade, Dinesh D., Singh G, Chavan S. B., Salunkhe V, Pradhan A & Reddy K. S. 2025. Soil- and Moisture-Saving Techniques Improve Rain-Fed Sapota Tree Growth, Productivity, and Fruit Quality in Semi-Arid Degraded Ravine Lands. *Applied Fruit Science* 67, 230 (2025). <https://doi.org/10.1007/s10341-025-01445-0>
- Karegoudar AV, Jowkin Vishwanath, Naveen K, Kaledhonkar MJ, Meena RL and Meena BL (2025) Evaluating the Spacing in Free and Controlled Subsurface Drainage Systems in Saline Vertisols of the Tungabhadra Project Command Area, Karnataka, India. *Journal of Soil Salinity and Water Quality*, 17(2), 129-145.
- Kaur Amandeep, Satyavan, Yadav A.K., Ram Prakash and Singh Vikram. (2025). Optimum Nitrogen Dose and Malt Quality of Barley Varieties under Saline Water Irrigation. *Agricultural Science Digest*, 45(30)-429:434
- Kaur, G., Sanwal, S.K., Sehrawat, N., Kumar, A., Kumar, N., Mann, A., Dasila, H., Maithani, D., Jangra, S., Perveen, K. and Alfagham, A.T., 2025. Maintaining nitrogen balance under salt stress through enhanced nodule function and antioxidative defense in chickpea. *Scientific Reports*, 15(1), p.35718.
- Khobragade SS, Vanave PB, Wahane MR, Bhangare KB, Kaledhonkar ML, Borse DK, Meena RL, Meena BL, Dodake SB and Vaidya KP (2025) Effect of Manure and Mulching under Drip Irrigation on Salinity and Yield of Brinjal in Coastal Saline Soils: Effect of manure and mulching under drip irrigation. *Journal of Soil Salinity and Water Quality* 17(2), 288-296.
- Kumar M, Rai AK, Kumar R, Amresh C, Jitendra K, Gajender Y, Banyal R, Rajender KY (2025) Germination sensitivity and seedling quality of mahogany (*Swietenia macrophylla*) in response to saline irrigation. *Current Science* 129 :1081–1088. <https://doi.org/10.18520/cs/v129/i12/1081-1088>
- Kumar M, Ravula R, Reddy GC, Bodiga S, Reddy MC, Rajendra MP (2025) Life cycle assessment and carbon balance of eucalyptus and bamboo plantations in Semi-Arid, India. *Environmental Monitoring and Assessment* 198:67. <https://doi.org/10.1007/s10661-025-14861-2>
- Kumar S, Onte S, Boregowda YS, Angadi AP, Pyati PS, Naveena K, Garg K, Meena VK, Chandra R, Meena BL, Reddy MB, Kochewad SA, Kumar S, Om H, Karunakaran V, Chandersheker S, Azman EA, Mukherjee S, Hashim M and Meena R (2025) Organic farming for a sustainable future: soil and yield improvement through integrated nitrogen management. *Front. Sustain. Food Syst.* 9:1564945.
- Kumar S, P S Birthal, S Kumar and R K Yadav. 2025. Economic Impact of Subsurface Drainage Technology: Institutional and Policy Imperatives for Upscaling. Policy Paper 49, ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi.
- Kumar, J., Pandey, S. C., & Nath, S. (2025). Spring-cum-rainwater harvesting and water budgeting of farm tank for growing vegetable crops in terrace land. *Journal of Soil and Water Conservation*, 173–179. <https://doi.org/10.5958/2455-7145.2025.00020.8>
- Kumar, J., Pandey, S. C., Nath, S., Vibhute, S., & Kumar, S. (2025). Spring water quality assessment and its utilization through gravity and solar-based micro irrigation system for hilly region. *Journal of Soil Salinity and Water Quality*, 17(1), 76–82.
- Kumar, M., David, A.A. and Arora, Sanjay (2025) Impact of Paddy Straw and Bio-decomposer with Inorganic Fertilizers on Soil Health in Wheat (*Triticum aestivum* L.). *Journal of Soil and Water Conservation, India* 24 (3), 264-269 (NAAS 5.51)
- Kumar, M., David, A.A., Thomas, T. and Arora, Sanjay (2025) Economic evaluation of different treatment combination of paddy straw and Halo-CRD bio-decomposer with inorganic fertilizers of wheat (*Triticum aestivum* L.) crop. *Ecology, Environment & Conservation* 31(3), 972-976.
- Kumar, R., Sharma, N., Dubey A. K., Sharma, R. M., Sethi, S, Mathur, S., Mishra, G. P., Vittal H., Shivran, M and Sharma, N (2025). Fruit Quality Assessment of Novel Hybrid Pummelo × Sweet Orange and Its Molecular Characterization Using Acidity Specific Markers. *Food Technology and Biotechnology*,

<https://doi.org/10.17113/ftb.62.01.24.8349>. Pp 35-48.

Kumar, R., Kumar, A., Singh, A., Singh, N., Kumar, A., Poonia, P. and Kundu, A., 2025. Sodicty tolerance in Jamun (*Syzygium cumini* L. Skeels) genotypes based upon growth and physiological traits. *Plant Physiology Reports*, pp.1-10.

Kumar, R., Kumar, S., Fagodiya, R.K., Singh, A., Sheoran, P., Yadav, G., Singh, N., Mandal, S. and Yadav, R.K. 2025. A multi-dimensional analysis of integrated farming system in salt-affected ecologies. *The Indian Journal of Agricultural Sciences*, 95(3), pp.316-322.

Kumar, R., Singh, N., Kumar, A., Kumar, A., Barman, P., Haldhar, S. M. and Poonia, P. 2025. Sustainable management of fruit fly infestation in guava for quality fruit production: A review. *Indian Journal of Arid Horticulture*.7:19-16.

Kumar, R., Singh, N., Kumar, A., Kumar, S. and Poonia, P. 2025. Optimizing yield and quality in guava through crop regulation: comprehensive review. *Indian Journal of Arid Horticulture*, 7(2), 43-50.

Kumari, R., Fagodiya, R.K.*, Sharma, G., Verma, K., Kumar, R., Prajapat, K., Thakur, I.S., Rai, A.K. and Yadav, R.K., 2025. Diverse land use systems differentially affect soil quality index in reclaimed sodic soils of Western Indo-Gangetic plains of India. *Agroforestry Systems*, 99, 167.

Lee, G., Onishi, J., Kameoka, T., Matsui, K., Yadav, G., Kumar, S., Prasad, G., Kumar, S., & Yadav, R. K. (2025). The impact of cut-soiler technology on rice-wheat production in salt-affected areas of western Indo-Gangetic Plains of India. *PLoS ONE*, 20(4), e0320775. <https://doi.org/10.1371/journal.pone.0320775>.

Lokeshkumar BM, Krishanu, Anita Mann, Arvind Kumar, Ashwani Kumar, Satish Kumar Sanwal, Ravi Kiran KT, Sanchika Snehi, and Nitish Ranjan Prakash (2024). Maneuvering Crop Wild Relatives to Revamp Salt Tolerance in Crops. *Journal of Soil Salinity and Water Quality* 16(2), 219-233.

Machra, A., Kumar, R., Singh, A., Mishra, D.S., Patel, P.J., Singh, N., Kundu, A. and Kumar, A., 2025. Gypsum and press mud application alleviate the deleterious effects of sodic water irrigation in Guava (*Psidium Guajava* L. cv. Taiwan Pink). *BMC Plant Biology*, 25(1), p.1783.

Mahawer, A. K. · Sharma, R. M., Dubey, A. K., Awasthi, O. P, Singh, D., Kesharwani, A. K., Kashyap, A. S., Sharma, N., Kulshreshtha, A., Kumar, A., Yadav J., Goswami A. K. Morade A., Debnath D. (2025). Deciphering the Genetic Response: Differential Gene Expression Profiling in *Citrus aurantifolia* (Chrism.) and *Citrus limon* (L.) Burm Infected with *Xanthomonas citri* pv. *Citri*. *Tropical Plant Biology*, 18:22 <https://doi.org/10.1007/s12042-024-09388-8>.

Mandal, A.K., Arora, Sanjay, Sharma, P.C. and Yadav, R.K. (2025) Spatial assessment, mapping, and characterization of salt-affected soils in Uttar Pradesh state of the Gangetic plain (IGP), India, for planning reclamation and management *Environmental Monitoring and Assessment* 197 (7), 739

Mandal, U.K., Ghosh, A., Karim, F., Mallick, S., Nayak, D.B., Bhutia, R.N., Bhardwaj, A.K., Lama, T.D., Burman, D., Choudhury, P., Mahanta, K.K., Raut, S., Mandal, S. and Mainuddin, M. 2025. Land use change and soil salinization in the Sundarbans: a machine-learning based analysis of long-term transformation and

future projections. *Environmental Monitoring and Assessment*, 197:1380 <https://doi.org/10.1007/s10661-025-14829-2>.

Mandal, U.K., Ghosh, A., Karim, F., Mallick, S., Nayak, D.B., Bhutia, R.N., Bhardwaj, A.K., Lama, T.D., Burman, D., Choudhury, P., Mahanta, K.K., Raut, S., Mandal, S., Mainuddin, M. (2025) Land use change and soil salinization in the Sundarbans: a machine-learning based analysis of long-term transformation and future projections. *Environ Monit Assess* 197, 1380. <https://doi.org/10.1007/s10661-025-14829-2>

Manohara T, Saini Neha and Banyal R (2025) Differential Ion Partitioning and Salinity Tolerance in Willow (*Salix* spp.) Clones under Semi-Arid Conditions, *Phyto talks*, 2(3).

Meena, H.M., Mavi, M.S., Saini, T., Choudhary, O.P. and Arora, Sanjay (2025) Alleviation of sodic water irrigation induced sodicity through microbial bioformulations. *The Indian Journal of Agricultural Sciences* 95 (5), 509-515.

Monika Shukla, Sadhu, A.C., Patel, P. and Mevada, K.D. (2025). Effect of Inclusion of Legumes in Cropping System and Their Residue Incorporation on the Yield of Maize. *Legume Research*. 48(2): 292-298. doi:10.18805/LR-4868.

Morade, A.S., Sharma, R M., Dubey, A. K., , Lekshmy, S., S., Ekshmy, , Kadam, D. M., Awasthi, O P., Mahawer, A. K. and Deepak (2025). Leaf injury index: A quantitative approach for rapid screening of drought tolerance in citrus rootstocks, , *Indian J. Agric Sci*, 95 (4): 457–462, <https://doi.org/10.56093/ijas.v95i4.159082>

Mukhopadhyay, R., Saroha, D., Paul, R., Narjary, B., Barman, A., Bundela, D. S., Kumar, S., & Sarkar, B. (2025). Impact of subsurface drainage on

- soil solution chemistry, structural stability and clay mineralogy of waterlogged saline soils. *Pedosphere*. <https://doi.org/10.1016/j.pedsph.2025.10.003>
- Narjary, B., Mukhopadhyay, R., Barman, A., & Bundela, D. S. (2025). 3D mapping of soil salinity in sub-surface drainage project site using electromagnetic induction (EMI) and inversion modelling. *Journal of Soil Salinity and Water Quality*, 17(2), 119–128. <https://doi.org/10.56093/jsswq.v17i2.168350>
- Nayak, S. L., Sethi, S., Dubey, A. K. (2025). Retention of 'Dancy' Tangerine Quality Attributes with Chitosan Coating and Phytosanitary Irradiation Dose. *Applied Fruit Science* (2025) 67:206 <https://doi.org/10.1007/s10341-025-01443-2>
- Nayak, S. L., Sethi, S., Paul, V. Singh, B and Dubey, A. K. (2025) Citrus Granulation: an Unsolved Disorder with Physiological Intricacies. *Applied Fruit Science* (2025) 67:235 <https://doi.org/10.1007/s10341-025-01479-4>.
- Nowmika N, M Baskar, T Sherene Jenita Rajammal, S Rathika, M Selvamurugan, P K Karthikeyan and RL Meena. 2025, Reimagining conservation agriculture: The critical role of crop residue in soil health. *Plant Science Today*, Vol 10
- Onte S, Fiskey VV, Melavanki MS, Angadi AP, Pyati PS, Singh M, Kumar D, Kochewad SA, Kumar S, Om H, Meena VK, Garg K, Karunakaran V, Kanwat M, Meena BL, Boregowda YS, Bellagi R, Naveena K, Chandersheker S, Azman EA and Kumar S (2025) Optimizing fodder yield and quality through integrated organic nutrient amendments in multi-crop system. *Front. Plant Sci.* 16:1517399.
- Pandey, R. K., Denis, D.M., Verma, C. L. and Arora, Sanjay (2025) Hydrological responses on sodic soil against linearly increasing rainfall pattern. *Journal of Soil and Water Conservation, India* 24(1): 61-71.
- Pandey, R. K., Denis, D.M., Verma, C. L. and Arora, Sanjay (2025) Simulation of overland flow and associated sediment loads under low slope sodic soil conditions. *Journal of Soil and Water Conservation, India* 24(2): 165-172.
- Patil, L. M., Chinchmalatpure, A. R. and Valvi, V. I. (2025) Soil Characterization, Classification and Land Use Planning for Netrang Taluka in Bharuch District, Gujarat, India. *Asian Journal of Soil Science and Plant Nutrition* 11 (4):378-387
- Patil, L. M., Valvi, V. I., Patel, K.G. and Chinchmalatpure, A. R. (2025) Geospatial Assessment of Soil Fertility Status and Management Strategies in Tribal Blocks of Bharuch District, Gujarat, India. *Journal of Scientific Research and Reports*, 31 (10):931-949, 2025
- Pla Sentís, I. and Arora, Sanjay (2025) Advances in the prognosis of soil salinization and sodification for sustainable soil and water management. *Journal of Soil and Water Conservation, India* 24(1):1-16.
- Prakash, N.R., Zunjare, R.U., Kumar, K., Snehi, S., Muthusamy, V., & Hossain, F. (2025). Meta-QTL Analysis Explores Key Candidate Gene (s) for Ear Prolificacy in 'Sikkim Primitive': A Unique Maize Landrace of North Eastern Himalaya. *Journal of Plant Growth Regulation*, 1-14, <https://doi.org/10.1007/s00344-025-11874-6>.
- Priyanka Chandra, Arvind Kumar Rai, Nirmalendu Basak, Parul Sundha, Kailash Prajapat, Awtar Singh, Anita Mann and R. K. Yadav Phosphorus-solubilizing fungi improve growth and P nutrition in sorghum at variable salinity levels *Environmental Microbiome* <https://doi.org/10.1186/s40793-025-00716-3> RESEARCH (2025) 20:124 I.M.5.4
- Priyanka Chandra, Arvind Kumar Rai, Nirmalendu Basak, Kailash Prajapat, Rajender Kumar Yadav Mitigating Salinity Stress in Crops using *Talaromyces* sp.: Impacts on Phosphorus Solubilization, Growth and P Nutrition *Journal of Soil Science and Plant Nutrition* (2025) 25:4212–4224 I.M.3.1
- Rahman A, Schmidt E., Scobie M, Mali S.S., Kumar Ajay., Kumar Anuj, Upadhyaya A, Bhatt B.P. 2025. Array Sizing Pattern and Rated Power Operation of Solar Pumps in India. *Journal of AgriSearch*, 12 (1), pp. 23-26.
- Rahman A. 2025. A solar energy operated mechanism for mitigating heat stress in cattle barn. *International Journal of Veterinary Sciences and Animal Husbandry*, 10(10), pp. 181-186.
- Raiya, R., Yadav, H.K., Kumar, K., Prakash, N.R., Parida, S.K., Bharadwaj, C., Hegde, V., & Tripathi, S. (2025). Genome-wide association analysis using multi model approach identified novel associations for plant architectural traits in chickpea germplasm collection. *The Nucleus*, 1-15.
- Rajavarshini T, Baskar M, Sherene Jenita Rajammal T, Rathika S, Nagarajan M and Meena RL, 2025, Delineation and mapping of groundwater quality in Salem district: A comprehensive assessment of contaminant sources. *Plant Science Today*, Vol 12(1): 1-6, (P128)
- Rajput, J., Kushwaha, N. L., Srivastava, A., Vishwakarma, D. K., Mishra, A. K., Sahoo, P. K., Suna, T., Rana, L., Jatav, M. S., Kumar, J., & Bisht, H. (2025). Developing machine learning models for predicting daily relative humidity and solar radiation using

- lagged time series data inputs in a semi-arid climate. *Journal of Atmospheric and Solar-Terrestrial Physics*, 106619.
- Ram Prakash, Dhanda Ankush, Kumar Rakesh, Rani Sarita, and Kumar Shital. (2025). Effect of integrated nutrient management in pearl millet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) system under water saline irrigation. *Indian Journal of Agricultural Sciences* 95 (1):095–100.
- Ram Prakash, Rani Sarita, Meena R.L., Khatkar Jyoti and Sindhu Simran. (2025). Screening of mungbean (*vigna radiata* L. Wilczek) genotypes against salinity stress in semi-arid region of north-western Haryana. *Journal of plant development sciences*, 17(1): 23-28.
- Ram Prakash, Yadav Rajpaul, Rani Sarita, Kumar Sanjay, Meena B.L. and Kumar Satyendra. (2025). Survey and mapping of groundwater quality of Karnal block of Karnal district, Haryana, India. *The Journal of Rural and Agricultural Research*, 25(2):85-88.
- Rani Sarita, Ram Prakash, Meena R.L. and Rani Sonian. (2025). Study of soil and agronomic traits in mungbean genotypes under saline water irrigation in semi-arid regions of Haryana. *Journal of plant development sciences*, 17(1): 29-33.
- Ravikiran, K. T., Thribhuvan, R., Anilkumar, C., Kallugudi, J., Prakash, N.R., Adavi, S., Sunitha, N.C., & Abhijith, K. P. (2025). Harnessing the power of genomics to develop climate-smart crop varieties: A comprehensive review. *Journal of Environmental Management*, 373, 123461.
- Ravikiran, K.T., Arora, S., Khandelwal, V., Reddy, S.P., Dixit, A.K. and Yadav, R.K., (2025). Evaluation of pearl millet hybrids for salt tolerance: Na⁺ and K⁺ dynamics under normal and sodic conditions. *Discover Soil*, 2(1): 1-19.
- Rizvi, R.H., Arora, Sanjay, Verma, C.L. and Pandey, M. (2025) Assessment of waterlogged sodic soils using Sentinel-2 imageries for ecological restoration planning in Pratapgarh district, Uttar Pradesh, India. *Journal of Earth System Science* DOI: 10.1007/s12040-026-02737-z
- S. L. Krishnamurthy, B. M. Lokeshkumar, Suman Rathor, A. S. Warraich, N. M. Vinaykumar, and P. C. Sharma (2024). Additive main effects and multiplicative interaction for grain yield of rice (*Oryza sativa*) genotypes for general and specific adaptation to salt stress locations, " Crop and Pasture Science 75(12). <https://doi.org/10.1071/CP23219>
- S. S. Khobragade, P. B. Vanave, M. R. Wahane, K. B. Bhangare, M. J. Kaledhonkar, D. K. Borse, R. L. Meena, B. L. Meena, S. B. Dodake and K. P. Vaidya (2025). Effect of manure and mulching under drip irrigation on salinity and yield of brinjal in coastal saline soils. *Journal of Soil Salinity and Water Quality*, 17 (2): 288-296.
- Saini Neha, Manohara T, and Banyal R (2025) Physiological and Biochemical Responses of Willow (*Salix* spp.) Clones to Salinity Stress in Semi-Arid Conditions: Identifying Salt-Tolerant Genotypes for Sustainable Land Use, *Phyto talks*, 2(3), Q-3.
- Saini, S., Burman, R. R., Padaria, R. N., Mahra, G. S., Bishnoi, S., Padhan, S. R., Mallick, S. & Mukherjee, S. (2025). Agriculture driven rural-to-urban migration trends among farmers impacting urban policy development in Northern India. *Cities*, 162, 105960. (I.F.: 6.6)
- Sanchika, S., Ravi Kiran, K.T., Rathi, S., Upadhyay, S., Kota, S., Sanwal, S.K., Lokeshkumar, B.M., Arun, B., Prakash, N.R., Singh, P.K. (2025). Discerning Genes to Deliver Varieties: Enhancing Vegetative and Reproductive Stage Flooding Tolerance in Rice. *Rice Science*, 32(2), 160-176. <https://doi.org/10.1016/j.rsci.2025.01.002>
- Sanwal, S.K., Kesh, H., Kumar, A., Kumar, A., Rohila, N., Dahiya, A., Dahiya, A., Yadav, R.K., Kumari, A., Munjal, R. and Kumar, A., 2025. Linseed (*Linum usitatissimum* L.) germplasm characterization and traits sensitivity to salinity stress under multi-environment field conditions. *Industrial Crops and Products*, 226, p.120668.
- Sarooha, D., Jat, H.S., Fagodiya, R.K., Khokhar, K., Mukhopodhyay, R. (2025). Zinc adsorption and bioavailability: insights from long-term conservation agriculture and integrated nutrient management strategies. *Proc. Indian Natl. Sci. Acad.* 91, 1374–1391.
- Sarvade S, Bhardwaj DR, Gupta B, Prakash P, Kumar D, Sharma P, Thakur CL, Kumar M, Attri V (2025) Assessing Biomass Production and Carbon storage in Agroforestry Systems Located at Proximity Gradients to Gobind Sagar Reservoir. *Indian Journal of Ecology* 52 (5):1260–1267. <https://doi.org/10.55362/IJE/2025/4643>
- Sawant, C.P., Singh, K.P., Gupta, A., Meena, B.P., Fagodiya, R.K., Singh, A., Lakaria, B.L., Vishwakarma, A.K., Khadatkar, A., Magar, A.P., Chaudhary, V.P. (2026). Conservation Agricultural Practices Enhance Food-Water-Economics Nexus and Mitigate Greenhouse Gas Emissions in Maize (*Zea mays* L.) – Chickpea (*Cicer arietinum* L.) Cropping System in Central High Lands of India. *Int. J. Plant Prod.* 20, 1.
- Sehrawat, A., Chandra, P., Basak, N., Rai, A.K., Sundha, P., Dhuli, P.,

- Kumar, A. and Yadav, M. Synergistic Effect of Flue Gas Desulfurization (FGD) Gypsum and Arbuscular Mycorrhizal Fungi (AMF) inoculation Improving Wheat Yield in Sodic Soils *Annals of Biology* 41 (2): 206-213, 2025.
- Shah, S. S., van Dam, J., Fan, L., Kumar, S., Singh, A., Bundela, D. S., Yadav, R. K., Mohrmann, J. B., Geissen, V., & Ritsema, C. (2025). Understanding farmers' protective behaviour towards pesticide use in northern India: Application of the health belief model using PLS-SEM and fsQCA approaches. *Environmental Impact Assessment Review*, 117, 108193. <https://doi.org/10.1016/j.eiar.2025.108193>
- Shah, S. S., van Dam, J., Singh, A., Kumar, S., Kumar, S., Bundela, D. S., & Ritsema, C. J. (2025). Impact of irrigation, fertilizer, and pesticide management practices on ground-water and soil health in the rice-wheat cropping system-a comparison of conventional, resource conservation technologies and conservation agriculture. *Environmental Science and Pollution Research*, 32(2), 533–558. <https://doi.org/10.1007/s11356-024-35661-0>.
- Shekhawat P, Jakhar ML, Punia SS, Singh J, Ravi Kiran KT, and Singh V. (2025). Insights into the salt tolerance of Lentil (*Lens culinaris* Medik): Characterization of germplasm resource to accelerate crop improvement. *Journal of Agronomy and Crop Science*. <https://doi.org/10.1111/jac.70056>
- Sing, N., Sharma, R. M., Dubey, A. K., Sharma, N., Awasthi, O. P., Saha, S., Bharadwaj, C., Sevanthi, A.M., Shivran, M., Akshay, Kadam, D. M., and Kumar, A. (2025) Developing new interspecific citrus hybrids for improved fruit quality: physico-chemical and sensory characterization. *Journal of Agriculture and Food Research*, <https://doi.org/10.1016/j.jafr.2025.102453>.
- Singh A, Ashwani Kumar, Prakash J and Mishra DS. 2025. Physiological traits underlying sodicity tolerance in Jamun (*Syzygium cumini* L. Skeels) cultivars. *PeerJ*, 13, p.e19132.
- Singh G, Dhakshanamoorthy D, Jinger D, Kumar R, Kakade VD, Kar SK, Natrajan NK, Singh AK, Kaledhonkar MJ, Meena VS and Madhu M (2025) Enhancing climate resilience through resource conservation practices in watershed of Western India. *Front. Sustain. Food Syst.* 9:1612949. doi: 10.3389/fsufs.2025.1612949
- Singh G, Dinesh D., Jinger Dinesh, Kumar R, Kakade V.D., Rao B.K., Kar S. K., Natrajan N.K., Singh, A.K., Kaledhonkar, M.J., Madhu M. Sapota (*Achras zapota*) based bio-engineering measures for slope stabilization and sustainable productive utilization in Mahiravines, Gujarat. *Indian J. Soil Cons.*, 53(1): 36-43. DOI: 10.53550/ijsc.v53.i1.186
- Singh J, Singh V, KT Ravi Kiran, Kumar A, Khan MA, Khatik CL, Jakhar ML, Sheera A, Meena PD, Yadava DK and Sharma PC. (2024). Accelerated mustard [*Brassica juncea* (L.) Czern & Coss] improvement for salt tolerance: Photosynthetic traits and selection indices. *Agro-nomy Journal*. 116 (5): 2458–2469. <https://doi.org/10.1002/agj2.21663>
- Singh, Charan Prakash Ram , Kumar Rakesh, Kumari, Sachin, Kumari Gayatri. (2025). Impact of Farm Yard Manure, Sewage Sludge and Fertilizer Levels on Soil Fertility, Enzymatic Activity, Cotton-Wheat Nutrition and Heavy Metal Accumulation Under Saline Water Irrigation. *International Journal of Environmental Research*, 19:224
- Singh, N., Sharma, R. M., Bharadwaj, C., Sevanthi, A. M., 5 Kumar, V., Yadav, A. K., Shivran, M., Dubey, A. K., Saha, S., Awasthi, O. P., Kumar, A., Sharma, N., Kumar, R. Porat, R and Deepak (2025). Bioactive Compounds and Bitterness Properties of Newly Developed Interspecific Citrus Hybrids (*Citrus maxima* [Burm. f.] Osbeck × *Citrus sinensis* [L.] Osbeck). *Horticulturae*, <https://doi.org/10.3390/horticulturae11020208>.
- Singh, S.K., Tomar, S. P., Devi, R., Srivastava, D.S., Singh, A. and Arora, Sanjay (2025) Assessing soil testing awareness and practices among farmers in Sitapur: Implications for sustainable agriculture. *Journal of Soil and Water Conservation, India* 24(2): 212-215.
- Singh, Y.P., Arora, Sanjay, Mishra, V.K. and Gupta, R.K. (2025) Assessing the influence of changes in land use-land cover on soil properties of degraded sodic lands in Indo-Gangetic plains. *Scientific Reports* 16:1418
- Snehi, S., Kt, R. K., Rath, S., Upadhyay, S., Kota, S., Sanwal, S. K., Lokeshkumar, B.M., Arun, B., Prakash, N.R. & Singh, P. K. (2025). Discerning Genes to Deliver Varieties: Enhancing Vegetative and Reproductive Stage Flooding Tolerance in Rice. *Rice Science*. <https://doi.org/10.1016/j.rsci.2025.01.002>
- Snehi, S., Singh, P.K., Beena, R., Kota, S., Sanwal, S.K., Kiran, K.R., Anilkumar, C., Chattopadhyay, K., Prakash, N.R., & Sah, R.P. (2025). QTL-Meta-analysis and Candidate Gene (s) for Anaerobic Germination Potential in Rice. *Journal of Plant Growth Regulation*, 1-14. <https://doi.org/10.1007/s00344-024-11618-y>
- Suresh Kumar, S K Sanwal, Ankita Kandpal, Arvind Kumar, N Kulshreshtha and R K Yadav (2025) Economic Impact of Salt-tolerant

Wheat Varieties. Policy brief #72, ICAR – National Institute of Agricultural Economics and Policy Research, 4pp.

Tomar, J. M. S., Barh, A., Kumar, R., Singh, D., Singh, R., Jinger, D., Singh, R., Kaushal, R., Dobhal, S., & Madhu, M. (2025). Long-term ecological recovery of a minespoil watershed: Hydrological, vegetation, and carbon stock assessment. *Ecological Engineering*, 224, 107883. <https://doi.org/10.1016/j.ecoleng.2025.107883>

Tomar, S.P. Rao, P.S., Singh, S.K., Singh, S.K., Arora, Sanjay, Habib, K. and Siddiqui, S. (2025) Effect of Halophilic Bio-formulations on Soil Fertility and Productivity of Salt Tolerant Variety of Paddy in Sitapur District. *Indian Journal of Agricultural Research* 1, 7

Vadithya, A. S., Bindra, S., Sharma, N., Sanwal, S. K., PS, S., Singh, I., Bharadwaj, C., & Singh, M. 2025. Multi-model statistical approaches for assessing the stability of Cicer interspecific derivatives in the trans and upper gangetic regions of India. *Scientific Reports*, 15, 22230.

Vanitha S. M., Suresh Kumar, Rajni Jain, Dinesh Chand Meena, Pradeep Dogra, Ashok Kumar, Ravi Dupdal, Abimanyu Jhahhria, Hombegowda

H. C., Gaurav Singh, Sundarambal P., Indu Rawat, Dubey R. K., Yadav R. S., Rajesh Bishnoi, Mukesh Kumar Meena, Ramajayam D., Somasundaram J. Muruganandam M. and Madhu M., 2025. Economic Impact of Watershed Management: Insights and Policy Implications. Policy Paper No. 3, ICAR-Indian Institute of Soil and Water Conservation, 218, Kaulagarh Road, Dehradun- 248195, UK, Pp.72. ISBN:978-93-94687-37-0

Verma K., Kumar A., Kumar R., Bhardwaj A.K., Fagodiya R.K., Sharma P. (2025) Influence of host plant selection on salinity tolerance and antioxidative defence in Sandalwood (*Santalum album L.*). *Environmental Challenges*, 101206

Vibhute, S. D., Sarangi, A., Singh, D. K., Bandyopadhyay, K. K., Kumar, D., & Kumar, J. (2025). Simulation of rice yield under different cultivation methods and irrigation regimes using DSSAT model. *Journal of Agricultural Engineering*, 62(3), 124–136.

Wakchaure, G.C., Minhas, P.S., Biswas, A.K., Meena, K.K., Pradhan, A., Gawhale, B.J., Choudhary, R.L., Kumar, S., Fagodiya, R.K., Reddy, K.S. and Pathak, H. (2025). Assessment of gains in productivity and water-energy-carbon nexus with tillage, trash retention

and fertigation practices in drip irrigated sugarcane. *Renewable and Sustainable Energy Reviews*, 211, 115294.

Yadav, Rajpaul; Anuj; Rani, Sarita; Ramprakash; Kumar, Sanjay and Kumar, Pankaj. (2025). Ground water quality assessment, characterization and mapping for Dadri-1 block of Charkhi Dadri district for irrigation purpose. *Journal of Plant Development Sciences*. 17(12): 467-473.

Yadav, S., Kumar, K., Kumar, S., Arora, Sanjay, Singh, V., Singh, V., Kumar, Y., Yadav, K. K. and Shukla, J. (2025) Harnessing conservation and nutrient management practices to enhance water use efficiency and soil moisture estimation in finger millet (*E. coracana L.*) under the central plain zone of Uttar Pradesh. *International Journal of Research in Agronomy* 8(11):355-359.

Yadav, S., Kumar, K., Kumar, S., Arora, Sanjay, Singh, V., Singh, V., Kumar, Y., Yadav, K. K., Shukla, J. and Yadav, A. K. (2025) Mechanistic Elucidation of Protein Enrichment under Conservation Practices and Advanced Nutrient Management Regimes in Finger Millet (*Eleusine coracana L.*). *Progressive Research: An International Journal* 20 (S-1): 396-399

Conference/Seminar/Symposia/Workshop papers

Anil R. Chinchmalatpure (2025) Coastal Saline Soils of Gujarat : Current Status, reclamation measures and improved management strategies to restore productivity. Presented during 14th National Symposium on Coastal Agriculture: Harnessing Fragile Coastal Ecosystem for Food and Environmental Security from February 28th to March 3rd 2025 at ICAR-CRIJAF, Barrackpore, West Bengal

Anil R. Chinchmalatpure, Sagar Vibhute, Monika Shukla, Satyendra Kumar and R.K. Yadav (2025) Appraisal of Salinity Status in Black Soils of the Malarpura Farm of Sabarmati Ashram Gaushala for Sustained Production. In Abstract of: International Salinity Conference 3.0 on 'WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems' Organized at: ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa India from 29th Oct - 1st Nov 2025

Anil R. Chinchmalatpure, Sagar Vibhute, Shrvan Kumar, B. Gorain, Vineeth TV and AK Mandal (2025) Characterization and mapping of salt affected soils in different regions of Gujarat: revisiting the extent and probable causes for change. International Salinity Conference 3.0 WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems from Oct 29th to Nov 1st 2025 at ICARCCARI, Goa

Ashwani Kumar, Sharma A, Kaushik S and Kumar R. 2025. Temporal changes in morpho-physiology of

sandalwood and gene expression analysis under water deficit and salinity stress. In: XVII Agricultural Science Congress organized during February 20-22, 2025 at GBPUA&T, Pantnagar

Ashwani Kumar, Sharma A, Verma K, Kaushik S, Dahiya A, Banyal R and Kumar R. 2025. Preferential host selection based on physico-biochemical traits and gene expression profiling in sandalwood underwater and salt stress. In: International Salinity Conference 3.0 on WE-CARE-2025: Worldwide Efforts on Cutting Edge Approaches for Restoring Saline Ecosystems at ICAR – CCARI, Goa during 29th Oct to 01st Nov, 2025

Bisweswar Gorain, Anil R. Chinchmalatpure, Shrvan Kumar and Sagar Vibhute. Effect of crop residues and their incorporation methods on crack management and yield in pigeon pea-wheat cropping system in saline Vertisols of Gujarat. In Abstract of: International Salinity Conference 3.0 on 'WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems' Organized at: ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa India from 29th Oct - 1st Nov 2025

Bundela DS, Krishan Kanahiya, Wim Bastiaanssen, Bas Mohrmann, Singh Awtar, Yadav, R.K., Sharad K. Jain and D. Nagesh Kumar (2025). Application of IrriWatch tool for real-time monitoring of sugarcane crop health at farmer's fields using satellite thermal remote sensing,

modelling and mobile app for yield enhancement. Book of Abstracts of the International Salinity Conference 3.0 (WE-CARE-2025) on "Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems held at ICAR-CCARI, Goa during 29 Oct-1 Nov 2025, pp 10-11

Choudhary, N., Kumar, S., Malik, D.P., and Kumar, J. (2025). Micro-Irrigation and Solar Power: Unlocking India's Agricultural Potential. International Salinity Conference 3.0 on "WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems," ICAR-Central Coastal Agricultural Research Institute, Ela, Old Goa, Goa, 29 October–1 November 2025, p. 112.

David Camus D, Thakur N. S., Patel D. P., Gunaga R. P., Chauhan R. S. and Garde Y. A. Assessment of Salinity Tolerance in Melia dubia Progenies from Selected Candidate Plus Trees. In Abstract of: International Salinity Conference 3.0 on 'WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems' Organized at: ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa India from 29th October - 1st November 2025.

Devika. S, D. Burman, U. K. Mandal, T. D. Lama, N. R. Prakash, Lokesh B. M., K. T. Ravikiran, S. Mallick Physiological and Morphological Mechanisms of Salinity Adaptation in

- Coastal Rice Genotypes (2025). In International Salinity Conference 3.0 WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems jointly organised by Indian Society of Soil Salinity and Water Quality (ISSSWQ), Karnal and also in collaboration with Association for Coastal Agricultural Research (ACAR), Old Goa during Oct 29-Nov 01, 2025
- Dixit AK and Choudhary M (2025). Inclusion of perennial legumes as hedge row in existing cropping systems for assured fodder production under rainfed condition of Bundelkhand. In: International Salinity Conference 3.0 WE-CARE-2025: Worldwide Efforts on Cutting- Edge Approaches for Restoring Saline Ecosystems during Oct 29th to Nov 1st, 2025 at ICAR - Central Coastal Agricultural Research Institute, Goa
- Dixit AK, Palsaniya DR, Prasad M, Rai AK, Das SK, Singh HV and Srivastava MK. (2025). Long term nutrient management in guinea grass + (cowpea-berseem) cropping system for sustainable quality fodder production, enhanced farm income and improved soil health under semi arid tropics of India. In: Sixth International Agronomy Congress on Re-envisioning Agronomy for Smart Agri-food Systems and Environmental Stewardship during November 24–26, 2025 at New Delhi, India
- Javed, Ravikiran KT, Vimal SC, Neeraj Kulshreshtha, Arvind Kumar, Ashwani Kumar, Monika Shukla, Shambhoo Prasad, Vinod Kumar Singh, and Vikram Jeet Singh (2025) Assessment of Genetic Variability for Sodicity Tolerance in Wheat. In Abstract of: International Salinity Conference 3.0 on 'WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems' Organized at: ICAR-Central Coastal Agricultural Research Institute, Goa India from 29th Oct-1st Nov 2025
- Kumar, J., Narjary, B., Vibhute, S., and Kumar, S. (2025). Performance Assessment of Soil Moisture Sensors under Saline Environment. International Salinity Conference 3.0 on "WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems," ICAR–Central Coastal Agricultural Research Institute, Ela, Old Goa, Goa, 29 Oct –1 Nov 2025, p. 121
- Kumar, S., Mahajan, G.R., Kumar, J., Fagodiya, R.K., Yadav, G., Kumar, A., Narjary, B., Kumar, A., Datta, A., Chandra, P., Paramesha, V., Uthappa, A.R., Desai, S., Yadav, R.K., & Kumar, P. (Eds.). (2025). Book of Abstracts: International Conference 3.0 on Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems. Indian Society of Soil Salinity and Water Quality (ISSSWQ), Karnal, India. (Held at ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa, India, October 29–November 1, 2025.) ISBN: 9788199273078
- Lama, T.D., Naskar, S., Mandal, U.K., Burman, D., Mahanta, K.K., Sarangi, S.K. Mandal, A.K., Narjary, B., Chaudhary, A, Raut, S. and Reza, S.K. 2025. Mapping soil salinity in coastal West Bengal using Sentinel-2 data, environmental covariates and machine learning approaches. Paper presented during the International Salinity Conference 3.0 WE-CARE-2025: Worldwide efforts on cutting-edge approaches for restoring saline ecosystems, 29th Oct to 1st Nov, 2025, ICAR-CCARI, Goa, Indi.
- Mahanta, K. K., Sarangi, S. K., Digar, S., Mandal, U. K., Burman, D., Mainuddin, M., Lama, T.D., Mallick, S..2025. Tackling Saline Soil and Water Scarcity: Pitcher Irrigation in Coastal West Bengal Deltas", Indian Society of Soil Salinity and Water Quality (ISSSWQ), Karnal, India Association for Coastal Agricultural Research (ACAR), Goa, India, 29 Oct - 1 Nov 2025
- Mallick, S., Burman, D., Mandal, U. K., Kumar, S., Mahanta, K. K., Lama, T. D., Bhutia, R. N., Digar, S., Monjardino, M., & Mainuddin, M. (2025). Performance Analysis of Rice-Fallow Systems in the Indian Ganges Delta: Economic, Energy, and Environmental Perspectives. In International Salinity Conference 3.0 WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems jointly organised by Indian Society of Soil Salinity and Water Quality, Karnal and also in collaboration with Association for Coastal Agricultural Research, Goa during Oct 29-Nov 1, 2025
- Mallick, S., Burman, D., Mandal, U. K., Kumar, S., Mahanta, K. K., Lama, T. D., Digar, S., Bhutia, R.N., Digar, S., Burman, R.R., Monjardino, M., & Mainuddin, M. (2025). Efficiency of Cropping System Intensification in the Salt-Affected Coastal Zones of the Indian Ganges delta. In second international extension

education congress jointly organised by society of extension education S'O'A Bhubaneswar and CUO. Koraput, Odisha on "rethinking social ecology in a digital landscape during Nov 24-26, 2025

Mandal, U.K. 2025. A remote sensing assessment of spatio-temporal dynamics of coastal ecosystem: evidence from Indian Sundarbans. Presented as Invited Lead Lecture in International Salinity Conference 3.0. WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems. held at ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa India on 29 Oct to 01 Nov, 2025

Mandal, U.K., Ghosh, A., Burman, D., Mallick, S., Lama, T.D., Bhutia, R.N., Raut, S., Mahanta, K.K., and Bhardwaj, A.K. 2025. Village-scale assessment of environmental hazards in the Ganges Delta of the Indian Sundarbans. Paper presented in International Salinity Conference 3.0. WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems. held at ICAR-Central Coastal Agricultural Research Institute, Goa from 29 Oct to 01 Nov, 2025

Mann Anita, Nitish Ranjan Prakash, Ashwani Kumar, Arvind Kumar, Avni Dahiya, S. K. Sanwal and R. K. Yadav. (2025). Targeted primer design-based functional sequencing of TaTre1 gene in wheat for guide RNA designing. Oral presentation In: International Salinity Conference 3.0 (WE-CARE-2025): Worldwide Efforts on Cutting-Edge Approaches for

Restoring Saline Ecosystems, held at ICAR-Central Coastal Agricultural Research Institute, Goa, in association with Indian Society of Soil salinity and Water Quality from 29 Oct-01 Nov 2025

Mann Anita, Priti, Poonam, Harish, Sujata, Noyonika, Krishanu. (2025). Systematic Primer Design Facilitates Functional Sequencing of the Wheat Sal1 Gene Family. Oral presentation In: 6th International Conference on Plant Physiology on "Translational Genomics and Physiology For Sustainable Agriculture" organised at TNAU, Coimbatore, in association with Indian Society of Plant Physiologists from 15-18 December 2025, pp 36

Monika Shukla, Anil R. Chinchmalatpure and Vineeth T. V. (2025) Exploration for balance nutrition for salt tolerant mustard variety under Saline Vertisols of Gujarat. In Extended Summaries: 6th International Agronomy Congress, November 24-26, 2025, India

Monika Shukla, Vineeth T. V., Anil R. Chinchmalatpure, and Jogendra Singh. (2025) Agronomic Interventions to Boost Productivity and Quality of Salt Tolerant Mustard in Salt affected Vertisols of Gujarat. In Abstract of: International Salinity Conference 3.0 on 'WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems' Organized at: ICAR-Central Coastal Agricultural Research Institute, Goa India from 29th Oct- 1st Nov 2025

Mukhopadhyay, Raj, Narjary, Bhaskar, Bundela DS and Kumar Satyendra (2025). Impact of sub-surface drainage on soil solution chemistry, structural stability and clay

mineralogy of waterlogged saline soils. Book of Abstracts of the International Salinity Conference 3.0 (WE-CARE-2025) on "Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems held at ICAR-CCARI, Goa during 29 Oct-1 Nov 2025, pp 91

Narjary, B., Kumar, J., Vibhute, S., and Kumar, S. (2025). Proximal sensing approach for rapid detection and characterization of soil salinity in semi-arid region. International Salinity Conference 3.0 on "WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems," ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa, 29 Oct-1 Nov 2025, p. 132

Neeraj Kulshreshtha, Arvind Kumar, Ashwani Kumar, Ravikiran KT and Monika Shukla (2025) Waterlogging Tolerance in Sodic Soils: A Focus on Microelement Toxicities and Deficiencies in Wheat. In Abstract of: International Salinity Conference 3.0 on 'WE-CARE-2025: Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems' Organized at: ICAR-Central Coastal Agricultural Research Institute, Goa India from 29th October- 1st November 2025

R.H. Rizvi, Sanjay Arora, A. Rahman and S.K. Jha (2025). Mapping, reclamation and management of Waterlogged Sodic Soils in Gangetic Plains of UP, India. Lead paper in international salinity conference 3.0. WE-CARE-2025: Worldwide Effort on Cutting-Edge Approach for Restoring Saline Ecosystem. Held on 29th Oct-01 Nov 2025 at ICAR-CCARI, Goa

Rahman A. Sanjay Arora, A.K. Dixit, PR Bhatnagar, A.K. Singh, B. Narjari, A.K. Dubey and R.K. Yadav (2025). Effect of field slope on salt flushing and crop yield under surface flush irrigation in sodic soil" in National Seminar on "Green Energy for Clean Environment & Sustainable Agriculture" organized the Academy of Natural Resource Conservation and Management (ANRCM), Lucknow on 22 Apr 2025 at ICAR-NBFGR, Lucknow

Raut, Shishir, Burman, D. and Lama, T.D. (2025). Study of ground water in a coastal village using geo-electrical method. A research paper was presented in International Salinity Conference 3.0 "WE-CARE-2025" held during Oct-Nov., 2025 at CCARI, Goa

Rizvi, R.H. and Arora, Sanjay. 2025. Digital Mapping of Sodic Soils in Sharda Sahayak Canal Command of Jaunpur district by Sentinel-2 MSI data. In: International Salinity Conference 3.0 on WE-CARE-2025: World Wide Efforts on Cutting Edge Approaches for Saline Ecosystems organized by ISSS&WQ CSSRI, Karnal, Oct. 29-Nov. 1, 2025 at ICAR-CCARI, Goa

Rizvi, R.H., Arora, Sanjay, Verma, C.L. and Pal, A.S. 2025. Spectral analysis of Sentinel-2 multi-spectral images for mapping of sodic soils in Sharda Sahayak Canal Command of Raebareli

district. In: National Seminar on "Green Energy for Clean Environment and Sustainable Agriculture" organized by ANRCM on April 22, 2025 at ICAR-NBFGR, Lucknow

S. K. Sanwal (2025). Genetic resources for salinity tolerance in Linseed: trait-based evaluation of a global germplasm collection. Lead presentation In: International Salinity Conference 3.0 (WE-CARE-2025): Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems, held at ICAR-Central Coastal Agricultural Research Institute, Goa, in association with Indian Society of Soil salinity and Water Quality from 29 Oct-01 Nov 2025

S. K. Sanwal, participated in 11th Indian Horticulture Congress – 2025, International meet on Horticulture for Inclusive, Equitable and Sustainable Growth held at University of Agricultural Sciences, Bengaluru from Nov 06–09, 2025

Sagar D. Vibhute, Vineeth T. V., Monika Shukla, Anil R. Chinchmalatpure, David Camus D. and Satyendra Kumar (2025) Comparative Assessment of Different Irrigation Methods for Improving Water Productivity and Soil Sustainability of Wheat Under Saline Groundwater Irrigation. In Abstract of: International Salinity Conference 3.0 on 'WE-CARE-2025: Worldwide

Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems' Organized at: ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa India from 29th Oct-1st Nov 2025

Singh Awtar, Shailendra S. Shah, Suresh Kumar, Bundela DS, J. Bastiaan Mohrmann, Satyendra Kumar, Jos van Dam, Coen Ritsema, Madhu Choudhary, and RK Yadav (2025). Response of autumn planted sugarcane to different water-fertilizer-pesticides reduction practices in North India. Book of Abstracts of the International Salinity Conference 3.0 (WE-CARE-2025) on "Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems held at ICAR-CCARI, Goa during 29 Oct-1 Nov 2025, pp 136

Vibhute S. D., Vineeth T. V., Shukla M., Chinchmalatpure A. R., Camus D. D., and Kumar, S. (2025). Comparative Assessment of Different Irrigation Methods for Improving Water Productivity and Soil Sustainability of Wheat Under Saline Groundwater Irrigation. Book of Abstracts of the International Salinity Conference 3.0 (WE-CARE-2025) on "Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems held at ICAR-CCARI, Goa during 29 Oct-1 Nov 2025, pp 32

Technical Bulletin/Popular Article/Folder

Ajay Kumar Bhardwaj, Akash Saroha, Kapil Malik, Mohit Sharma, Shivani Chakad, Preeti Sharma, Raj Kumar, R. K. Yadav (2025). Soil and Irrigation Water Quality Testing and Measurement – A Guide for Farmers (Hindi). Technical Bulletin/ICAR-CSSRI/Karnal 2025/11

Arora, Sanjay, Singh, A.K. and Choudhary, Madhu (2024) Halo-CaRe: Fungal consortia bioformulation for in-situ and ex-situ crop residue decomposition and soil carbon recycler. *Salinity News* 30(2):5

Banyal R. and Saini Varun (2025) Nature-based solutions with ecosystem services gains for managing saline waterlogged landscapes in semi-arid regions, *Indian Farming*; Vol. 75 No. 11 (2025): Special Issue on International Salinity Conference 3.0 (WE-CARE-2025); 13-15, 0019-4786

Chaudhari S.K., Madhu, M., Islam A., Patra S., Singh D.V., Kumar S., Mishra, A. (2025) Circular Economy Perspective for Water Management in Agriculture: Technological, Institutional and Policy Imperatives, Report by National Committee, ICAR-Indian Institute of Soil and Water Conservation, Dehradun, Uttarakhand, ISBN 978-93-94687-71-4, 51p.

Chaudhary, A., Kumar, S., Basak, N., Sundha, P., Chandra, P., & Rai, A. K. (2025). Use of modern digital techniques for mapping and assessment of salt-affected soils. *Indian Farming*; Vol. 75 No. 11 (2025): Special Issue on International Salinity Conference 3.0 (WE-CARE-2025); 57-60, 0019-4786

Bhardwaj, A. K., Prajapat, K., Sundha, P., Yadav, G., Choudhary, M., Kumar, S., Kumar, A., & Kumar, J. (Eds.). (2025). Book of Abstracts: International Conference 3.0 on Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems. Indian Society of Soil Salinity and Water Quality (ISSSWQ), Karnal, India. (Held at ICAR-Central Coastal Agricultural Research Institute, Old Goa, Goa, India, October 29–November 1, 2025). ISBN 978-81-992730-7-8

Kumar, U., Singh, S., Nath, S., Kumar, J., Kant, L., and Pattanayak, A. (2025). Construction of VL Portable Polyhouse and importance of micro irrigation under protected cultivation. AICRP on PEASEM, ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora. Technical Bulletin Pp. 1-39.

Madhu Choudhary, Kailash Prajapat, Tanuja Poonia, Shivani Khokar, Mahesh Gathala, M.L. Jat, P.C. Sharma, H.S. Jat and R.K. Yadav 2024. Climate-smart intensification of cereal systems in IGP for agri-food systems' sustainability. Technical Bulletin: CSSRI/Karnal/2024/04. ICAR-Central Soil Salinity Research Institute, Karnal. 32 p.

Mann Anita, S. K. Sanwal, Ashwani Kumar, Nitish Ranjan Prakash, Avni Dahiya, Arvind Kumar and R. K. Yadav (2025). Harnessing genome editing for developing climate-resilient crops. Special Issue on International Salinity Conference 3.0. *Indian Farming* 75 (11):09-12.

Mann Anita, S. K. Sanwal, Ashwani Kumar, Nitish Ranjan Prakash, Avni Dahiya, Arvind Kumar and R. K. Yadav (2025). Harnessing genome

editing for developing climate-resilient crops. Special Issue on International Salinity Conference 3.0. *Indian Farming* 75 (11):09-12.

Mann, A., Sanwal, S.K., Kumar, A., Prakash, N.R., Dahiya, A., Kumar, A., & Yadav, R.K. (2025). Harnessing genome editing for developing climate-resilient crops. *Indian Farming*, 75(11), 09-12.

Meena R.L., Meena B.L., Chandra Priyanka, Sanwal S.K. and Narjary Bhaskar (2025) Commercial vegetable production under protected structures in saline environments: A promising strategy for livelihood security. *Indian Farming*, 75 (11):52-55

Meena RL, Meena BL and Chandra P (2025) Lavaneey jal se Polyhouse mein sabji utpadan (in Hindi). *Kheti*, 78 (7):34-37.

Mohit Singh, Rajkumar, Sanjay Arora, Arjun Singh and Akshay. 2025. Fostering natural farming: a path to Sustainable agriculture. *Vet Farm Frontier*, 2(11):1-6.

Parul Sundha, Nirmalendu Basak, Arvind Kumar Rai, Priyanka Chandra, Amresh Chaudhary and RK Yadav, An overview of emerging trends in sodicity reclamation and enhanced food production. *Indian Farming* 75 (11): 45-47; November 2025

Rajkumar, Kumar, S., Fagodia, R. K., Singh, A., & Singh, N. (2025). Integrated sustainable farming model for saline and sodic soils. *Indian Farming*, 75(11), 31-35.

Rajkumar, Suresh Kumar, Ashwani Kumar, Arvind Kumar, Nirmal Singh and RK Yadav. 2024. From

- salinity to sustainability: Building capacities for date palm cultivation in Haryana. *Salinity News*, Vol. 30, No.2 | July-December 2024
- Rajkumar, Suresh Kumar, Ram Kishor Fagodia, Awtar Singh and Nirmal Singh. 2025. Integrated sustainable farming model for saline and sodic soils. *Indian Farming*, 75 (11): 31-35
- Raman Jeet Singh and Suresh Kumar (2025) Synergizing soil conservation and livelihood enhancement in the Northwestern Himalayan regions of India. *WATER-SHED BULLETIN* No.9, pp 48-54.
- Rizvi, R.H., Arora, Sanjay, and Verma, C.L. (2025). Waterlogged sodic soils in Sharda Sahayak Canal Command of Uttar Pradesh: Mapping spatial extent for its reclamation and crop planning. *Salinity News*, Jan.- Jun., 32(1): 7-8.
- Rizvi, R.H., Arora, Sanjay, Verma, C.L. and Verma, S. (2024). Spatial analysis of waterlogged sodic soils in Sharda Sahayak canal command of Pratapgarh district using Sentinel-2 satellite images. *Salinity News* 30(2):4.
- Sagar D. Vibhute, Satyendra Kumar, D. S. Bundela, Suresh Kumar, Anil R. Chinchmalatpure, Jitendra Kumar, Bhaskar Narjary, Raj Mukhopadhyay and Aslam L. Pathan (2025) Subsurface drainage technology for restoring crop productivity in waterlogged saline soils. *Indian Farming* 75 (11): 48-51
- Sheoran, P., Kumar, R., Singh, R. K., Barman, A. Prajapat, K., Kumar, A., Kumar, S., Kumar, A., Kumar, S., Sanwal, S.K., Singh, S. and Yadav, R.K. 2025. Empowering Farmers through Selective Interventions in Salt-affected Agroecosystems of Ghaghar Plains. ICAR-Central Soil Salinity Research Institute, Karnal, Haryana, India. Pp: 80. ISBN 978-81-983602-9-8.
- Singh, M., Rajkumar, Arora, Sanjay, Singh, Arjun and Akshay (2025) Fostering Natural Farming: A path to Sustainable Agriculture. *Vet Farm Frontier* Vol. 2(Issue 11), 1-6. DOI: <https://doi.org/10.5281/zenodo.17582671>
- Snehi, S., Singh, P.K., Kota, S. & Prakash, N.R. (2025). Tiny but Mighty: Plant miRNAs and its Role in Abiotic Stress Tolerance. *Food and Scientific Reports*, 6(8), 49-54.
- Vibhute, S. D., Kumar S., Bundela D. S., et. al. (2025). Subsurface drainage technology for restoring crop productivity in waterlogged saline soils. *Indian Farming*, 75 (11), 48-51.
- राज कुमार, कमलेश वर्मा, अश्वनी कुमार, मनीष कुमार, राकेश बनयाल, अवनी, अवतार सिंह, राम किशोर फगोडिया और अजय कुमार भारद्वाज (2025) लवणीय मृदा में चंदन की खेती। खेती, 78(7): 30–33.
- राज कुमार, निर्मल सिंह, सुरेश कुमार, राम किशोर फगोडिया और अश्वनी कुमार (2025) सुधरी क्षारीय मृदा हेतु समेकित कृषि प्रणाली मॉडल। खेती, 78(7): 45–48.
- कैलाश प्रजापत, सतीश कुमार सनवाल, राम किशोर फगोडिया, सुरेश कुमार और अनिल कुमार ;2025— जलवायु स्मार्ट पोषक फसल किनोवा, खेती, 27.29.
- राज कुमार, कमलेश वर्मा, अश्वनी कुमार, मनीष कुमार, राकेश बन्याल, अवनी, अवतार सिंह, राम किशोर फगोडिया और अजय भारद्वाज 2025— लवणीय मृदा में चंदन की खेती, खेती, 30–33
- पारुल सुन्धा, निर्मलेंदु बसाक, अरविंद कुमार रॉय, प्रियंका चंद्रा, अमन कुमार, अमरेश चौधरी और राजेंद्र कुमार यादव खाद्य उत्पादन वृद्धि में मृदा सुधार विकल्पों की भूमिका खेती 38.41
- अनिता मान, सुजाता, पूनम, प्रीति, नोयोनिका, हरीश, अन्नु, कृशानु और नितीश रंजन 2025 जलवायु चुनौतियों के खिलाफ फसलों का सशक्तिकरण खेती – नवम्बर 2025
- जीतेन्द्र सिंह, विजयता सिंह, जोगेन्द्र सिंह, धीरज कुमार, गुरुदीन, अनुज चौधरी और गोविंद 2025 सरसों की खली के फायदे। खेती 49–51।
- चौधरी, अमरेशय सिंह, राम नारायणय वाकचौरे, गोरक्षय तथा हरिशा, सी.बी. (2025). पर्यावरण अनुकूल प्राकृतिक खेती। खेती, सितम्बर अंक, पृष्ठ 12–13।
- चौधरी, अमरेशय कुमार, संदीपय नर्जरी, भास्करय यादव, गजेंद्रय एवं राय, ए. के. (2025). लवणीय मृदा का डिजिटल मानचित्रण एवं मूल्यांकन खेती, नवम्बर 2025, पृष्ठ 5–7।
- रहमान ए. और ए.के. दुबे (2025). लवणीय क्षेत्रों में कृषि उत्पादकता में सुधार के लिए सौर –ऊर्जा का दृष्टिकोण, इक्षु –राजभाषा पत्रिका, 14(1), पेज 37–39
- पारुल सुन्धा प्रियंका चंद्रा गजेन्द्र यादव अरविन्द कुमार राय राजेन्द्र कुमार यादव – लवणीय पारिस्थितिकी तंत्र पुनःस्थापना हेतु प्रबंधन प्रौद्योगिकियाँ “खेत” पत्रिका के नवम्बर, 2025 विशेषांक

- Akshay, Rakesh Banyal, Rajkumar, Mukesh Kumar Mehla, Satish Sanwal, Ashwani Kumar, Anshuman Singh, Rajkumar (2025) Role of Farm Advisory and Resource Management for Fruit, Vegetable and Agroforestry Growers Under Saline-Sodic Agroecosystem, in Advisory services in horticulture, pub. By. NIPA® Genx Electronic Resources & Solutions P. Ltd. New Delhi-110 034, 181-496.
- Anil R. Chinchmalatpure (2025) Dry land Salinity Management for Sustainable Crop Production in Semiarid regions of India. Souvenir of International Salinity Conference 3.0 of the Indian Society of Soil Salinity and water Quality Karnal (Eds. A. K. Bhardwaj, Kailash Prajapat, Parul Sundha, Gajender Yadav, Suresh Kumar, Arvind Kumar, Jitendra Kumar, G.R. Mahajan, R. K. Yadav and Parveen Kumar) at ICAR-CCARI Goa, pp 20-33 29th October -1st November 2025
- Arora, Sanjay, Jha, S.K. and Singh, A. (2025) Training Manual on "Nature based solutions for soil health management and climate resilience. Central Soil Salinity Research Institute, Regional Research Station, Lucknow, pp. 215
- Arun Kumar, Ningdalli Mallikarjun, Sourabh Sherawat, Utpal Barua, Priyadarshini Sanjay Borale, Raj Kumar. Plant Propagation and Nursery Management in Vegetables, Flowers and Fruit Crops. Vol. 1, The Pustakalay, Lucknow, 2025, pp. 1-198.
- Ashvinkumar Katral, C. Anilkumar, B.M. Lokeshkumar, B. Jeevan, N.C. Sunitha, P.S. Basavaraj, Gowda G. Basana, S. Raghu, Shridhar Ragi, Vishvjeet S. Patel (2026). Accelerated Breeding Approaches for Enabling Sustainable Rice Farming. In: Gnanesh, B.N., & Kole, Next Generation Crop Improvement for Agricultural Sustainability and Food Security (1st ed.). CRC Press. <https://doi.org/10.1201/9781003584100>
- Bhardwaj, A.K. (2024) Revitalizing Agroecosystems: Unleashing the Power of Soil Health and Ecosystem Services. In: Caring for Soils Beyond Food Security- Volume II: Climate Resilience and Ecosystem Services (Eds. S.K. Chaudhari, D.R. Biswas, R. Bhattacharya, H. Pathak), Springer. (ISBN: 978-9819616626)
- Chandra, P., Fagodiya, R. K.*, Singh, A., Prajapat, K., Sundha, P., Basak, N., Verma, K., Sharma G., Rai, A. K., Yadav, R.K. (2025). Advancing Sustainable Agriculture Through Plant-Microbial Interactions Amid Climate Change. In: Mann, A., Kumar, N., Kumar, A., Chandra, P., Sanwal, S.K., Sheoran, P. (eds) Cutting Edge Technologies for Developing Future Crop Plants. Springer, Singapore.
- Devika S (2025). Arbuscular Mycorrhizal Fungi as plant biostimulants for sustainable agriculture. In Comprehensive assessment of ameliorative effects of AMF in alleviating abiotic stress in crops. (PP 281-295). Cambridge Scholar Publishing.
- Fagodiya, R.K., Verma, K., Sharma, G., Prajapat, K., Kumari, R., Mukhopadhyay, E., and Jha P. (2025). Conservation Agriculture Technologies for Salinity Management. In: Malyan, S.K., Fagodiya, R.K., Kumar, A., & Kumar, V. (Eds.) The Climate Change-Agricultural-Environmental Nexus. CRC Press.
- Gupta SK, Panwar P., Banyal R. and Ramanan SS (2025). Forest Soils, In Textbook of Forest Science. Springer, Singapore, 165-189.
- Gupta, M., Singh, A., Prakash, N.R., Jha, S.K., Choudhary, M., Pandey, P., Kumar, K., Halder, T., Kumar, H. (2025). Methods of Characterizing Genome-Edited Plants. In: Principles and Applications of Genome Editing in Field, Horticultural, and Forest Crops, Ed(s), Tribhuvan, K.U., Singh, B.K., Pandey, A., Limbalkar, O.M., pp110-126, ICAR-IIAB, Ranchi (ISBN:978-93-7020-910-7)
- Kamboj, P., Sukriti, Fagodiya, R.K., Sheoran, P. (2025). Greenhouse Gas Emission: Problems, Global Reality, and Future Perspectives. In: Mann, A., Kumar, N., Kumar, A., Chandra, P., Sanwal, S.K., Sheoran, P. (eds) Cutting Edge Technologies for Developing Future Crop Plants. Springer, Singapore.
- Kaul, N., Ranga, P., Yadav, S., Choudhary, P., Dahiya, A., Sehrawat, D. R., & Mann, A. (2025). CRISPR/Cas-based fungal genome engineering for secondary metabolite production: Progress and challenges. In Mann, A. et al. (Eds.), Cutting-edge technologies for developing future crop plants. Springer Nature. pp. 339-348.
- Krishnamurthy S L, Suman Rathor, Lokeshkumar B M, Warriach A S, Vinaykumar N M, Sharma P C, Gautam R K, and Singh R. K (2024) Genetic Improvement of Rice for Inland Saline and Alkaline Areas of

- North-Western India. In: Genetic Improvement of Rice for Salt Tolerance. Springer Nature Singapore Pte Ltd. ISBN 978-981-99-3829-2 ISBN 978-981-99-3830-8 (eBook) <https://doi.org/10.1007/978-981-99-3830-8>
- Kumar, M., Arora, Sanjay and Rajput, TBS (2025) Advanced approaches for climate resilient water resource management. Soil Conservation Society of India, New Delhi, pp 273 ISBN 978-81-996082-0-7
- Kumar, M., Kumar, R., Sarvade, S., Gautam, K., Yadav, G., Banyal, R., Mann, A., et al. (2025). Underlying survival mechanisms in model trees for enhanced abiotic stress tolerance. In Mann, A. et al. (Eds.), Cutting-edge technologies for developing future crop plants. Springer Nature. pp. 251-279.
- Kumar, R., Verma, K., Kumar, A., Kumar, M., Mann, A., Kumar, S., Dobhal, S., & Chaudhary, S. (2025). Challenges and Opportunities of Cultivating Sandalwood (*Santalum album*) Under Abiotic Stress Conditions. In Cutting Edge Technologies for Developing Future Crop Plants (pp. 419-435). https://doi.org/10.1007/978-981-96-2508-6_20
- Kumar, S., Fagodiya, R. K., Mandal, S., Prajapat, K., Rajkumar, Kumar, R. and Praveen, K. V. Impact of Agri-Based Technological Interventions for Managing Poor Soils and Policy Insights. In book: Cutting Edge Technologies for Developing Future Crop Plants by Mann et al., (Eds.) 2025; 65-79pp. Singapore: Springer Nature Singapore. ISBN-13: 978-9819625086
- Lokeshkumar, B. M., Snehi, S., Krishanu, Kumar, S., Ravikiran, K. T., Kumar, R., Choudhary, M., Kota, S., Kumar, A., Mann, A., Sanwal, S.K., & Prakash, N.R. (2025). Breeding Strategies for Improved Multistress-Resilient Crops. In Cutting Edge Technologies for Developing Future Crop Plants (pp. 125-154). Singapore: Springer Nature Singapore.
- Malyan S.K., Maithani, D., Fagodiya, R.K., Kumar, A., and Kumarn N., (2025). Biological Approaches for Reducing Greenhouse Gas Emissions from Agricultural Soils.
- Malyan, S.K., Fagodiya, R.K., Kumar, A., & Kumar, V. (Eds.). (2025). The Climate Change-Agricultural-Environmental Nexus (1st ed.). CRC Press.
- Mandal, U.K., Bhardwaj, A.K., Malik, K., Ghosh, A. and Yadav, R.K. 2025. Atlas of the arable saline soils of coastal India. ICAR-CSSRI, Karnal. (ISBN: 978-81-969698-7-5)
- Mandal, U.K., Ramesh, V., Mal, S., Lama, T.D., Sarangi, S.K., Mullick, S., Ghosh, A., Nayak, D.B. and Burman, D. 2025. Coastal region soil health: problems and perspectives from India. In: Soil Health and Sustainability in India, Editor: Bhattacharyya, R. ISBN: 978-0-891-18739-4; page: 161-188.
- Manish Kumar, Raj Kumar, S. Sarvade, Kamini Gautam, Gajender Yadav, R. Banyal, Anita Mann & Sneha Dobhal (2025) Underlying Survival Mechanisms in Model Trees for Enhanced Abiotic Stress Tolerance, In cutting edge technologies for developing future crop plants, Springer Nature, Singapore, 251-279.
- Mann A, Kumar N, Kumar A, Chandra P, Sanwal SK, Sheoran P. 2025. Cutting Edge Technologies for Developing Future Crop Plants. Springer Nature Singapore; 2025 Mar 26.
- Narjary, B., Basak, N., Kumar, S., & Rai, A. K. (2025). Advances in water management for productive utilization of salt-affected soils. In P. P. Maity, D. Bhaduri, K. K. Bandyopadhyay, J. Mukherjee, & S. N. Pillai (Eds.), Advances in monitoring soil health and plant growth for better agriculture (pp. 321-345). New India Publishing Agency.
- Prajapat, K., Sanwal, S.K., Fagodiya, R.K., Kumar, S., Saha, Anusmita and Choudhary, G.L. 2024. Quinoa: A New Climate-smart Nutritional Crop under Changing Environment. In: Climate Smart Agriculture (CSA) for Sustainable Resource Management, (Choudhary et al., eds.), SSPH, Delhi. pp. 219-232.
- Prakash N R, Lokeshkumar B M, Suman Rathor, Warriach A S, Satyendra Yadav, Vinaykumar N M, Krishnamurthy S L, and Sharma P C (2024) Mechanisms of Saline and Submergence Tolerance in Rice for Coastal Ecology. In: Genetic Improvement of Rice for Salt Tolerance. Springer Nature Singapore Pte Ltd. ISBN 978-981-99-3829-2 ISBN 978-981-99-3830-8 (eBook) <https://doi.org/10.1007/978-981-99-3830-8>
- Priyanka Chandra, Parul Sundha, Gajender Yadav, Arvind Kumar Rai and Rajender Kumar Yadav, Indian Farming Vol. 75 No. 11 (2025): Special Issue on International Salinity Conference 3.0 (WE-CARE-2025)
- Rahman, A. (2025). Scope of Solar Energy use in Agriculture and Allied field-In Training Manual "Nature Base Solution for climate Resilience and Soil Health Management, pp 167-173.
- Rai, A., Mishra, R., Chaudhary, A., Gangwar, A., Rajput, J., Srivastava, R. K., ... & Singh, N. K. (2025).

- Climate Resilient Agriculture Need of Future Food Production System and Green Resource Management. In *Blue-Green Land Management and Smart Ecosystem Services: Integrated Strategies for Planning and Development* (pp. 37-62). Singapore: Springer Nature Singapore.
- Rajkumar, Mukesh Kumar Mehla, Satish Sanwal, Ashwani Kumar, Anshuman Singh, Rajkumar, Akshay and Rakesh Banyal. Role of Farm Advisory and Resource Management for Fruit Vegetable and Agroforestry Growers Under Saline-Sodic Agroecosystem in Agro-Advisory Services in Horticulture: Strategies for climate- resilient and profitable production. Nipa® Genx Electronic Resources & Solutions P. Ltd. 101,103, Vikas Surya Plaza, CU Block L.S.C. Market, Pitam Pura, New Delhi-110 034 pp181-196 ISBN:978-93-58879-48-3
- Ranga, P., Choudhary, P., Kaul, N., Yadav, S., Dahiya, A., Kumar, A., & Mann, A. (2025). Gene editing prospective for engineering climate-smart plants. In Mann, A. et al. (Eds.), *Cutting-edge technologies for developing future crop plants*. Springer Nature. pp. 197-217.
- Ranga, P., Ranga, V., & Mann, A. (2025). CRISPR technology: Mechanisms and applications in genome editing and long non-coding RNA functional analysis. In *Long non-coding RNAs: Function, mechanisms, and applications*. (Tutar Y and Tutar L; eds) Genetics. IntechOpen. <http://dx.doi.org/10.5772/intechopen.1009307>.
- Rizvi, R.H., Arora, Sanjay, Rahman, A. and Jha, S.K. (2025) Mapping, reclamation and management of Waterlogged Sodic Soils in Gangetic Plains of Uttar Pradesh, India. In: *Souvenir International Salinity Conference 3.0 WE-CARE*, Goa, pp 82-94.
- Sehrawat, A., Sehrawat, D. R., & Mann, A. (2025). Crop for food security. In Mann, A. et al. (Eds.), *Cutting-edge technologies for developing future crop plants*. Springer Nature. p. 381.
- Sheoran, P., Kumar, P., Kumar, V., Kumar, A., & Mann, A. (2025). Farmer's perspective on climate change and agricultural production. In Mann, A. et al. (Eds.), *Cutting edge technologies for developing future crop plants*. Springer Nature. pp. 3–20.
- Singh Meena, Vijay, Ram Swaroop Bana, Ram Kishor Fagodiya, and Mohammad Hasanain, (Eds.). (2025). *Sustainable Agroecosystems - Principles and Practices*. IntechOpen.
- Singh, Y.P., Arora, Sanjay, Ravi Kiran KT and Yadav, R. K. (2025) Twenty years of Research Excellence in Reclamation and Management of Sodic Soils. ICAR-CSSRI, Karnal, pp 12
- Sundha, P., Basak, N., Rai, A. K., Chandra, P., Chaudhary, A., Bedwal, S., ... & Yadav, R. K. (2025). Improving Soil Properties Through Various Soil Amendments Under Changing Climate Scenario. In *Cutting Edge Technologies for Developing Future Crop Plants* (pp. 37-53). Singapore: Springer Nature Singapore.
- Uttam Kumar Mandal, Ajay Kumar Bhardwaj, Kapil Malik, Amit Ghosh, Rajender Kumar Yadav. 2025. *Atlas of the Arable Saline Soils of Coastal India*. ICAR-CSSRI, Karnal. (ISBN:978-81-969698-7-5)
- Veerabhadrapa, R.G., Nanoti, S.A., Vaikuntapu, P.R., Muppavarapu, K., Snehi, S., Prakash, N.R., Ravikiran, K.T., Shruthi, K., Divya, B., Kalyani, M.B., Saiprasad, S.V., Sundaram, R.M., & Kota, S. (2025). *Phytomelatonin Regulates Uptake, Transport, and Assimilation of Mineral Nutrients and Aquaporins to Attenuate Ionic and Osmotic Stability with Redox Modifications Under Environmental Stressors*. In *Phytomelatonin* (pp. 97-137). CRC Press.
- Yadav, R., Ajay, N.S., Kushwah, A., Kumar, J., Sudhishri, S. and Nageswar, B., 2025. *Advancements in Machine Learning for Water Quality Assessment. Artificial Intelligence and Computer Vision for Ecological Informatics*, pp.202-218.
- Yadav, S., Dahiya, A., Chandra, P., Kumar, A., Sheoran, P., & Mann, A. (2025). Arbuscular mycorrhizal fungi (AMF) for Salt affected soils: Improving Soil and plant health for sustainable agriculture. In: *Arbuscular Mycorrhizal Fungi as Plant Biostimulants for Sustainable Agriculture*. Cambridge Scholars Publishing, pg:296-321.



Participation in Conference/Seminar/Symposia/Workshop

Name and	Subject/Training Program	Place/Organizer	Duration/Period
Sanjay Arora	IAU Convention on Agrotourism	ANDUAT, Ayodhya	13 Feb, 2025
Ashwani Kumar	XVII Agricultural Science Congress	GBPUA&T, Pantnagar	20 Feb – 22 Feb, 2025
Lokeshkumar BM	Invited lecture on “Novel Breeding Approaches for Delivering Salt-Tolerant Rice Varieties” in ICAR-Sponsored Winter School on “Smart agriculture and way forward: New age technologies for management of salt affected agroecologies”	ICAR-CSSRI, Karnal	20 Feb – 12 Mar, 2025
Lokeshkumar BM Anil R. Chinchmalatpure D.S. Bundela Bhaskar Narjary A.K. Dubey S.K. Jha	14th National Symposium on Coastal Agriculture ‘Harnessing Fragile Coastal Ecosystem for Food and Environmental Security	ICAR-CRIJAF, Barrackpore	28 Feb – 03 Mar, 2025
Raj Kumar	1st International Farming Systems Conference on “Transforming Food, Land and Water Systems under Global Climate Change”	IIFSR, Meerut	07 Mar – 09 Mar, 2025
Amresh Chaudhary	National workshop on AAYAM 2025 – Empowering Geospatial Solutions: Future ready mapping & collaboration	Vivanta Taj, New Delhi	17 Mar, 2025
Amresh Chaudhary	National Workshop on “Mapping and Assessment of Land degradation and Groundwater quality in India	ICAR-NBSS & LUP, Nagpur	20 Mar – 21 Mar, 2025
Sanjay Arora	Samuday Rural Development Conference by HCL Foundation	Indira Gandhi Pratishthan, Lucknow	15 Apr – 16 Apr, 2025
A. Rahman Sanjay Arora R.H. Rizvi	National Seminar on “Green Energy for Clean Environment and Sustainable Agriculture” by ANRCM, Lucknow	ICAR-NBFG, Lucknow	22 Apr, 2025
Lokeshkumar BM	60th Annual Rice Research Group Meeting	ICAR-IIRR, Hyderabad	26 Apr – 28 Apr, 2025
Lokeshkumar BM	National workshop on “Stakeholder’s consultation on Basmati Rice–Way forward”	ICAR-IARI, New Delhi	16 May, 2025
Satyendra Kumar D.S. Bundela Sagar Vibhute	6th Meeting of BIS FAD34/P2 Panel (Irrigation and Drainage Systems)	BIS HQ, New Delhi	21 May, 2025
D.S. Bundela	8th Meeting of BIS FAD17/P3 panel to review Indian Standards on Water Quality and Drainage System	ICAR-IIWM, Bhubaneswar	27 May, 2025
All CSSRI Scientists	Vikshit Krishi Sankalp Abhiyan	ICAR, New Delhi	29 May - 12 Jun, 2025
Amresh Chaudhary	National Workshop on ISRO-ICAR joint collaboration on the theme “Space Technology-based Digital and Precision Agriculture for efficient agricultural resource management	ICAR, New Delhi	06 Jun, 2025
D.S. Bundela R.K. Yadav	Knowledge Sharing Technical Workshop on Haryana’s Second Green Revolution Agriculture for Sustainability Project	Panchkula	27 Jun, 2025
Raj Kumar	International Conference on Technology Innovations & Sustainable Development of Date Palm-2025	Bhuj, Gujarat	29 Jun – 30 Jun, 2025
D. Burman	Consultation on “Exploring the research and development roadmap for creating agriculture’s cross-sect oral impact in the Sundarbans	RKMVERI, Kolkata	18 Jul, 2025
Jogendra Singh	32nd Annual group meeting of AICRP on Rapeseed & Mustard	RVSKVV, Gwalior	06 Aug 2025
T.D. Lama	Multistakeholder Workshop on ‘Agro-farming Dialogues on Climate Preparedness and Practices in Coastal Agriculture of South Asia’	SAFE, Kolkata	06 Aug, 2025
Anil R. Chinchmalatpure	Workshop for State of Gujarat on “Transforming Food, Land, and Water (FLW) Systems to Combat the Climate Crisis”	ICAR-DMAPR, Anand	14 Aug 2025
Amresh Chaudhary	National workshop on National Space day	NASC Complex, delhi	23 Aug, 2025
Neeraj Kulshrestha	64th All India Wheat and Barley Workers’ Meet	RVSKVV, Gwalior	25 Aug – 27 Aug, 2025
Sanjay Arora	Brain storming Meeting on “Microbial Solutions for Soil and Plant Health: Aligning Science with Policy Imperatives” being jointly organized by ICAR–NBAIM and Crop Science Division, ICAR	NASC Complex, New Delhi	01 Sep, 2025
D.S. Bundela Sagar Vibhute	Esri India User Conference 2025 on GIS Integrating Everything Everywhere	Aerocity, New Delhi	03 Sep - 04 Sep, 2025

Name and	Subject/Training Program	Place/Organizer	Duration/Period
Sanjay Arora	4th Meeting of FAO-International Network on salt affected soils	Dunhuang, China	11 Sep – 13 Sep, 2025
Raj Kumar	Chairman of Hindi Pakhwada Celebration	ICAR-CSSRI, Karnal	14 Sep – 28 Sep, 2025
Satyendra Kumar	Global DSR Conclave on “DSR-based System for Food, Climate and Environmental Security: Driving Change through Science, Policy, and Partnerships	ISARC, Varansi	05 Oct - 07 Oct, 2025
All CSSRI Scientists	XXIX ICAR-AICRP Biennial Workshop 2023-2024 on Management of Saline Water and associated Salinization in Agriculture	ICAR-CCARI, Goa	27 Oct - 28 Oct, 2025
All CSSRI Scientists	International Salinity Conference 3.0 (WE-CARE-2025): Worldwide Efforts on Cutting-Edge Approaches for Restoring Saline Ecosystems in association with Indian Society of Soil Salinity and Water Quality	ICAR-CCARI, Goa	29 Oct – 01 Nov, 2025
S. Mallick	Second International Extension Education Congress on “Rethinking social ecology in a digital landscape” jointly organised by society of extension education S’O’A Bhubaneswar and CUO	Koraput, Odisha	24 Nov – 26 Nov, 2025
Monika Shukla Kailash Prajapat A.K. Dixit	Sixth International Agronomy Congress on “Re-envisioning Agronomy for Smart Agri-food Systems and Environmental Stewardship”	NASC, New Delhi	24 Nov – 26 Nov, 2025
D. Burman	Stakeholder Meet – Community-led horseshoe crab and mangrove restoration initiative in Indian Sundarban	SAFE, Gosaba, Sundarbans	25 Nov, 2025
Suresh Kumar	33rd Annual Conference of Agricultural Economics Research Association (India) “Innovation in Agribusiness, empowering women and climate resilient Agriculture”	ICAR-NAARM, Hyderabad	01 Dec – 03 Dec, 2025
Sanjay Arora	33rd National Conference on Soil, Water and Energy Management for Sustainable Agriculture and Livelihood Security by SCSI	PAU, Ludhiana	08 Dec – 10 Dec, 2025
Anita Mann	6th International Conference on Plant Physiology on “Translational Genomics and Physiology For Sustainable Agriculture” in association with ISPP from.	TNAU, Coimbatore	15 Dec -18 Dec, 2025

List of On-going Research Projects

Institute Funded Projects

Priority area - Data Base on Salt Affected Soils & Poor Quality Waters

1. NRMACSSRISIL202400501083 Rapid Characterization of salt-affected soils using Proximal spectroscopic techniques. (Amresh Chaudhary, Nirmalendu Basak, Gajender, A.K. Rai, R.K. Yadav, Nishat Kumar Sinha and Rahul Mishra from IISS, Bhopal)

Priority Area - Reclamation and Management of Alkali Soils

2. NRMACSSRISIL202001301004. Low budget natural farming for sustainable crop production. (Dr. RK Yadav -Team Leader; CSSRI-Kailash Prajapat (PI), Madhu Choudhary, RK Fagodiya, Awtar Singh; RRS, Lucknow: Arjun Singh (CC-PI), S.K. Jha; A.K. Dixit; RRS Bharuch: Anil R. Chinchmalatpure (CC-PI), Monika Shulkla, RRS Canning Town: D. Burman (CC-PI), U.K. Mandal, and T.D. Lama)
3. NRMACSSRISIL202100101022. Effect of residue management on soil microbial activities under salt affected soils in rice-wheat system. (Madhu Choudhary, Sanjay Arora, R.K. Yadav and Hardev Jatt)
4. NRMACSSRISIL202100901030. Farmer participatory integrated farming system model for improving livelihood security under reclaimed sodic land. (Rajkumar (Hort), Suresh Kumar, Awtar Singh, R.K. Fagodiya, R.N. Bhutia and J.K. Pundir (NDRI)
5. NRMACSSRISIL202200801055. Effect of rice straw retention, incorporation and residue decomposition on productivity, profitability, soil health and environment under RW system. (Awtar Singh and R.K. Fagodiya)
6. 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 Amresh Choudhary)
7. NRMACSSRISIL202201301060. Micronutrient biofortification in cereal-based systems using nano-micronutrient fertilizer forms. (A. K. Bhardwaj and R. K. Yadav)
8. NRMACSSRISIL202400601084. Development of Sensor and IoT based irrigation system for enhancing water productivity under salt affected environment. (Jitender Kumar, Bhaskar Narjary, Sagar Vibhut, Satyendra Kumar and Ashwani Kumar)
9. NRMACSSRISIL202401001088. Modelling soil salinization in irrigated agriculture under climate change scenarios. (Bhaskar Narjary, Jitender Kumar, Sagar Vibhute D. and Satyendra Kumar)

Priority Area - Management of Marginal Quality Waters

10. NRMACSSRISIL202002301014. Changes in seed quality development of rice-wheat irrigated with residual alkalinity water. (Gajender, R.K. Yadav, Anita Mann, Nirmalendu Basak,, Manish Kumar and Vanita Pandey (IIWBR))

11. NRMACSSRISIL202300701072. Regional salt balance modeling of Western Yamuna Canal command of Haryana. (Satyendra Kumar, B Narjary and Sagar Vibhute D.)
12. NRMACSSRISIL202402701105. Confirmation trial of tomato cultivation with saline water irrigation and plastic mulch under naturally ventilated polyhouse conditions. (RL Meena, BL Meena, SK Sanwal, Bhaskar Narjary and Jitendra Kumar)

Priority Area - Crop Improvement for Salinity, Alkalinity and Waterlogging Stresses

13. NRMACSSRISIL202001501006. Exploring the conventional and molecular breeding approaches to develop salt tolerant high yielding Indian Mustard (*Brassica juncea* L.) genotypes. (Jogendra Singh, Vijayata Singh, Ashwani Kumar, Kailash Prajapat and Ravi Kiran KT)
14. NRMACSSRISIL202001701008. Genetic approaches to improve wheat (*Triticum aestivum* L.) germplasm for salt tolerance. (Neeraj Kulshreshtha, Arvind Kumar, Ashwani Kumar, Monika Shukla and Ravi Kiran KT)
15. NRMACSSRISIL202001801009. Genetic improvement of rice genotypes for salt tolerance using conventional and molecular breeding methods. (Lokeshkumar BM, Ravi Kiran KT, Nitish Ranjan Prakash, Devika S and Dr. Devenna)
16. NRMACSSRISIL202002101012. Genetic improvement of Lentil (*Lens culinaris* Medikus) for salt tolerance using conventional and molecular breeding approaches. (Vijayata Singh, Jogendra Singh, Kailash Prajapat and Ravi Kiran KT)
17. NRMACSSRISIL202002401015. Exploring production potential of Quinoa (*chenopodium quinoa*) under saline Agro-ecosystems of India. (Kailash Prajapat, SK Sanwal, Monika Shukla, Nitish Rnjan Prakash and Ravi Kiran KT)
18. NRMACSSRISIL202101801039. Physiological and molecular dissection of root system architecture (RSA) in wheat under salt stress. (Anita Mann, Arvind Kumar, Ashwani Kumar Neeraj Kulshreshtha and Avni)
19. NRMACSSRISIL202200901056. Genetic improvement of chickpea for salt tolerance. (S.K. Sanwal, Jogendra Singh, Anita Mann and Avni)
20. NRMACSSRISIL202300501070 Performance evaluation of minor millets under salt affected land to regain food-nutri-livelihood security for resource poor farmer. (Vijayata Singh)
21. NRMACSSRISIL202401901097. Genetic improvement in barley for managing salt affected agro-ecosystems (Arvind Kumar, Anita Mann, Neeraj Kulshreshtha, Priyanka Chandra, Monika Shukla, Ravi Kiran KT and Devika S.)
22. NRMACSSRISIL202402001098. Metatranscriptomics and systems biology approach for deciphering the molecular basis of salt stress response in crop plants. (Avni Dahiya, Anita Mann and Nitish Ranjan Prakash)

Priority Area - Agroforestry in Salt Affected Soils

23. NRMACSSRISIL202101901040. Assessing the genetic diversity and deciphering the molecular mechanism for salinity tolerance in Sandalwood (*Santalum album* L.). (Raj Kumar (Forestry), Rakesh Banyal, Ashwani Kumar, Manish Kumar and Avani)

24. NRMACSSRISIL202301101076. Evaluation of Willow Mahogany genotypes for salt tolerance. (Manish Kumar, Raj Kumar (Agroforestry), Rakesh Banyal and A.K. Rai)
25. NRMACSSRISIL202401801096. Exploring the potential of salt tolerant genotypes of high value agroforestry tree species in diverse agro-ecological regions: A field evaluation. (R. Banyal, Raj Kumar, Manish Kumar, B.L. Meena A.K. dubey and David Camus D.)

Priority Area - Reclamation and Management of Coastal Saline Soils

26. NRMACSSRISIL202101201033. Development of better rice genotypes with tolerance to coastal salinity. (Nitish Ranjan Prakash, Lokesh Kumar B.M and Ravi Kiran KT)
27. NRMACSSRISIL202101301034. Assessment of Ichthyofaunal diversity, biology and stock assessment of selected species along the estuary of Sundarbans. (R.N. Bhutia and U.K. Mandal)
28. NRMACSSRISIL202200501052. Conjunctive use of poor quality water for Zero-tillage Potato under micro-irrigation system in coastal salt affected soil. (K. K. Mahanta, D. Burman, U.K. Mandal, T.D. Lama and Nitish Ranjan Prakash)
29. NRMACSSRISIL202300101066. Enhancing the production potentials and profitability of ponds through integration of small indigenous fishes in coastal region of West Bengal. (R. N. Bhutia, Uttam Kumar Mandal, D. Burman and Sonali Mallick)
30. NRMACSSRISIL202300401069. Assessment of ground water in sea water inundated locations of coastal West Bengal using geo-electrical method. (Shishir Raut, D. Burman & T.D. Lama)
31. NRMACSSRISIL202300801073. Impact of climate change on rice yield in the coastal deltaic region of West Bengal. (T.D. Lama, U.K. Mandal, D. Burman, S.K. Sarangi and K. K. Mahanta)
32. NRMACSSRISIL202400301081. Exploring livelihood resilience of agricultural households in coastal salt-affected region. (Sonali Mallick, T.D. Lama, Richen N. Bhutia, U.K. Mandal and D. Burman)
33. NRMACSSRISIL202400401082 Morpho-physiological responses and grain quality of rice genotypes under salinity stress. (Devika S., U.K. Mandal, T.D. Lama, Nitish Ranjan Prakash and Ravi Kiran KT.)

Priority Area - Reclamation and Management of Salt Affected Vertisols

34. NRMACSSRISIL202002201013. Performance of Indian mustard (Brassica juncea) under saline Vertisols. (Monika Shukla and Anil R. Chinchmalatpure)
35. 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).
36. NRMACSSRISIL202400701085. Improved agronomic practices for enhancing Indian Mustard (Brassica juncea L.) yield under saline vertisols of Gujarat. (Monika Shukla, Anil R. Chinchmalatpure and David Camus D)

37. NRMACSSRISIL202400801086 Enhancing productivity and Sustainability of saline vertisols through Drumstick agroforestry. (David Camus D, Monika Shukla and Anil R. Chinchmalatpure)
38. NRMACSSRISIL202400901087. Combined effects of salinity stress and biostimulators on growth, physiology and fruit quality of Dragon fruit. (David Camus D, Anil R. Chinchmalatpure and Monika Shukla)

Priority Area - Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains

39. NRMACSSRICIL202101501036. Harnessing productivity potential of calcareous salt affected soils of Bihar through improved reclamation technologies.(Sanjay Arora, Arjun Singh, S.K. Jha, SP Singh (RAU) and SS Prasad (CoA, Dholi))
40. NRMACSSRISIL202200301050. Spatial and temporal analysis of waterlogging and salt dynamics for crop planning in Sharda Sahayak Canal Command of Uttar Pradesh (Raza H. Rizvi and Sanjay Arora)
41. NRMACSSRISIL202201101058. Evaluation of multiple auger planting technique for fruit crops in partially reclaimed sodic soil. (A.K. Dubey and S. K. Jha)
42. NRMACSSRISIL202300201067. A genetic investigation on the prospect of pearl millet as alternative Kharif crop for sodic soils of Uttar Pradesh. (Ravikiran KT, Sanjay Arora, A.K. Dixit and R.K. Yadav)
43. NRMACSSRISIL202102301044. Feasibility of reclaiming salt affected soils through salt harvesting from high salinity lands using polythene lined pond and enhanced evaporation techniques. (A.R. Rahman, Sanjay Arora and A.K Dixit)
44. NRMACSSRISIL202401101089. Development of integrated farming system for resource poor farmers of sodic soil of Uttar Pradesh. (A.K Dubey, A.K. Dixit, S.K. Jha, Arjun Singh, Deepa Hansraj Dwivedi (BBAU, Lucknow) and Aditya Kumar (NBFGR).
45. NRMACSSRISIL202401201090. Exploring production potential of economically important fruit crops and development of sustainable fruit production systems for salt affected soils.(A.K Dubey, Arjun Singh, S.K. Jha)
46. NRMACSSRISIL202401301091. Characterization of heavy textured sodic soils of Uttar Pradesh by Vis-NIR spectroscopy for rapid and non-destructive estimation SAS parameters (A. Rahman, Sanjay Arora, Amresh Choudhary and R.H. Rizvi)
47. NRMACSSRISIL202401401092. Investigating role of bacterial endophytes for ameliorating salt stress in wheat. (Arjun Singh and S.K. Jha)
48. NRMACSSRISIL202401601094. Sulphamic acid based management of sub-soil sodicity in partially reclaimed sodic soils. (S.K. Jha, Sanjay Arora and A.K. Dixit)
49. NRMACSSRISIL202401701095. Development of resource efficient cropping systems for sodic environment. (Anoop Kumar Dixit, Anil Kumar Dubey, Sanjay Arora and Arjun Singh)

Foreign Funded Projects

1. NRMACSSRISOL201601500913. Strategic Research Platform on Climate Smart Agriculture “Developing and defining climate smart agricultural practices

- portfolios in South Asia” (Team Leader, R.K. Yadav, Madhu Chaudhary (PI), Kailash Prajapat) ICAR-CCAFS-TAFSSA
2. NRMACSSRICOP201602200920 (Phase-II). Mitigating risk and scaling out profitable cropping system intensification practices in the salt affected coastal zones of the Ganges delta. (D. Burman, U. K. Mandal, Suresh Kumar K.K. Mahanta, T.D Lama and Sonali Mallick)- ACIAR.
 3. NRMACSSRISOL201801300965. Development of sustainable resource management systems in water vulnerable regions of India. (Team Leader; Dr. R.K. Yadav, Gajender (PI), D.S. Bundela, Satyendra Kumar, Bhaskar Narjary, A.K. Rai, Amresh Kumar and Suresh Kumar) Funded by ICAR-JIRCAS, Japan
 4. 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. R.K. Yadav (Team leader), Madhu Choudhary (CCPI, Karnal and Coordinator of four Subproject), Kailash Prajapat and Raj Mukhopadhyay) CIMMYT
 5. NRMACSSRICOP202102501046. Hindon Roots Sensing HIROS River rejuvenation through scalable water- and solute balance modelling and informed farmers’ actions. R.K Yadav (Team leader) (WP1a: D.S Bundela (PI) Satyendra Kumar, Bhaskar Narjary. WP2c: Awtar Singh, Satyendra Kumar, Suresh Kumar and Madhu Choudhary) DST-NWO Hindon
 6. NRMACSSRISOL202201501062. NEXUS Gains: realizing multiple benefits across water-energy-food-forest-biodiversity systems. (Satyendra Kumar, Gajender and Bhaskar Narjary) (IRRI Funded)
 7. NRMACSSRISOL202201701064. Accelerate breeding: Meeting farmers’ needs with nutritious, climate resilient crops. (Lokeshkumar B.M) (IRRI Funded)
 8. NRMACSSRISOL202201801065. Securing the Asian mega-deltas from sea-level rise, flooding, salinization and water insecurity. (D. Burman, T.D. Lama, U.K Mandal, R.N. Bhutia and Nitish Ranjan Prakash) (CGIAR)
 9. NRMACSSRICOP202201601063. Establishment of nitrogen-efficient wheat production systems in Indo-Gangetic plains by the development of BNI-technology. (Ajay Kumar Bhardwaj, Awtar Singh, RK Yadav) (ICAR-BISA-JICA)
 10. NRMACSSRISOL202300901074. Integrated DSR system for India. (IRRI) (Satyender Kumar, Gajendra, Bhaskar Narjary and Jitendra Kumar)

Externally Funded Projects

1. NRMACSSRICOP201500400880. Climate change mitigation and adaptation strategies for salt affected soils (Phase-II). (Ajay Kumar Bhardwaj (PI), Bhaskar Narjary, Satyendra Kumar, Raj Kumar (Agroforestry), U.K. Mandal, K.K. Mahanta, Shishir Raut and Rinchen Nopu Bhutia) NICRA
2. NRMACSSRISOL201501600892. Molecular genetic analysis of resistance/tolerance in rice, wheat, chickpea and mustard including sheath blight complex genomics. [(Rice: component 1): Lokeshkumar BM (Chickpea: component 3): Satish Kumar Sanwal and Anita Mann (Mustard: component 4): Jogendra Singh 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, Priyanka Chandra and Kailash Prajapat)-ICAR
4. NRMACSSRICOL201702300947. Network project on Functional Genomics and genetic modification in crops (NPFGGM) salt tolerance in rice. (Lokeshkumar B.M.) – ICAR- NPTC, New Delhi
5. NRMACSSRISOL201802700978. Intellectual property management transfer/ commercialization of agricultural technologies renamed as NAIF. (Madhu Choudhary and Nirmalendu Basak) ICAR
6. NRMACSSRICOL202001001001. Pilot Project on Reclamation of Alkaline soils in Haryana and Punjab. (Team Leader R.K. Yadav) Alkaline Soil Reclamation: Gajender (PI), Kailash Prajapat (NABARD)
7. 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 Kulshershta) DBT Funded
8. NRMACSSRICOL202000800999. 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, Jogindra Singh, Avni and Ashwani Kumar) DBT Funded
9. NRMACSSRISOL202100701028. Characterization of Chickpea germplasm resource to accelerate genomics-assisted crop improvement. (Jogendra Singh and Vijayata Singh) DBT
10. NRMACSSRISOL202101601037. Development of integrated organic farming system in partially reclaimed sodic soil of Uttar Pradesh for livelihood security. (Arjun Singh, SK Jha, Sanjay Arora and A.K. Dubey) RKVY
11. NRMACSSRICOL202102101042. Enhancing farmer's livelihood through identified interventions in waterlogged saline agroecosystems of Haryana. (Rajkumar (Hort), Anil Kumar, Satyendra Kumar, Suresh Kumar Ashwani Kumar, Sohanvir Singh and K Ponnusamy (NDRI). FARMER FIRST, ICAR
12. NRMACSSRISOL202200101048. Development of Arbuscular 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.
13. 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) (Suresh Kumar and Anil Kumar)
14. NRMACSSRISOL202201201059. Morphological and molecular characterization of salt tolerant coastal rice landraces. (Nitish Ranjan Prakash) (DST-SERB)

15. NRMACSSRICOL202201401061. Exploring the potential use of the silicious chalk in agriculture: sodicity reclamation and nutrient source. Jodhpur, Rajasthan (Arvind Kumar Rai, Nirmalendu Basak, Parul Sundha, Priyanka Chandra, Avni and R.K. Yadav). Funding FCI Aravali Gypsum and Minerals India Ltd (FAGMIL).
16. NRMACSSRISOL202301001075. Characterization and standardization of agro-techniques for Millet varieties and land races in salt affected soils to boost productivity) UPCAR Funded (Ravikiran KT, Sanjay Arora and Arjun Singh)
17. NRMACSSRICOL202300601071. Agri-preneurship for sustainable Agricultural development: technological and institutional innovations and strategies. (Suresh Kumar (CC-PI), S.K. Sanwal and Rajkumar (Hort.) NASF
18. NRMACSSRICOP202401501093. Enhancing climate resilience and ensuring food security with genome editing tool- IARI-EFC project on "Genome Editing for Sustainable Food system".(Team leader ; RK Yadav, CCPI & PI Anita Mann) (Component–Wheat: Anita Mann, SK. Sanwal, Arvind Kumar, Ashwani Kumar, Avani Dahiya) (Component- Rice-: Nitish Ranjan Parkash, Lokeshkumar B.M.) (Component- Mustard: Jogendra Singh, Vijayata Singh and Neeraj Kulshreshtha) Funded by ICAR

Collaborative

1. NRMACSSRISL202102401045. Novel genetic approaches for development of climate smart rice varieties. (Nitish Ranjan Prakash (Co-PI) Collaboration with IIRR, Hyderabad
2. NRMACSSRICOL202400201080. Evaluation of soil testing kit "Dharti Ka Doctor". (Nirmalendu Basak, Parul Sundha, Priyanka Chandra, Arvind Kumar Rai, R.K. Yadav) Bharuwa Agri Science Private Limited, Haridwar, Uttarakhand.
3. Analysis and Assessment of soils and manure samples from Ladakh (Ajay Kumar, Bhardwaj) (DIHAR- DRDO (Defence Institute of High Altitude Research, (DRDO)) Leh.
4. Performance of reliance Bhoovedyam (Fermented organic manure, FOM) on rice-wheat cropping system. (Nirmalendu Basak, Arvind Kumar Rai, Priyanka Chandra, Parul Sundha, Kailash Prajapat and R,K, Yadav) Reliance Industries Ltd (RIL), Mumbai

Consultancy

- 1 NRMACSSRISCL202300301068. Assessment of Aniline-ETP treated effluent irrigation on growth and yield of wheat crop in black cotton soils. (R.K. Yadav –Team Leader, Anil R. Chinchmalatpure, Sagar Vibhute D, David Camus and Monika Shukla)
- 2 NRMACSSRICCL202301301078. Sodic soil management through farmers adaptable technological interventions for boosting productivity in Hardoi. (Sanjay Arora, A.K. Singh, C.L.Verma, S.K. Jha and A.K. Dubey)
- 3 NRMACSSRICCL202402501103.Sub-Surface Drainage (SSD) for reclamation of waterlogged and saline heavy soils of four states (Maharashtra, Gujarat, Karnataka and Haryana. (R.K.. Yadav (Team Leader), D.S. Bundela (PI), Sagar Vibhute, Anil R Chinchmalatpure, Satyendra Kumar and Suresh Kumar)

4. NRMACSSRICOL202402601104. Planning, Monitoring and evaluation of subsurface drainage project at the farm of Sabarmati Ashram Goshala. (R.K. Yadav, Anil R Chinchmalatpure, Sagar Vibhute, Monika Shukla and Satyendra Kumar) (National Dairy Development Board (NDDB, Anand, Gujarat)

Contract Research

1. NRMACSSRISOL202301201077. Developing Strategies for sustainable integration of Nano N and P for enhancing nutrient use efficiency under salt stress. (Ashwani Kumar, Ajay Bhardwaj Anita Mann, R.K. Yadav, and Parvender Sheoran (CCPI)) funded by IFFCO
2. NRMACSSRICOL202400101079. Soil salinity mapping of different landforms of mining lease area in coastal Gujarat. (Nirmalendu Basak, Bhaskar Narjary, Arvind Kumar Rai, Anil R. Chinchmalatpure, R.K. Yadav) Heidelberg Cement India Ltd, Gurugram, Haryana

INSTITUTE ACTIVITIES

Ms. Alka, Chief Guest, delivering the foundation day lecture



57th Foundation Day of the Institute

ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, celebrated its 57th Foundation Day on 12th March 2025 with the participation of distinguished dignitaries, scientists, farmers, students, and staff members. The event highlighted the institute's achievements in reclamation and management of salt-affected soils, sustainable agriculture, and food security. The Chief Guest, Ms. Alka Nangia Arora, emphasized soil health, natural resource management, and effective dissemination of scientific technologies, while Guest of Honour Prof. Pratap Singh BIRTHAL highlighted the role of CSSRI technologies in reclaiming salt-affected lands and addressing emerging challenges such as climate change. Former Directors and eminent scientists reflected on the institute's journey and landmark achievements, including the reclamation of over 2.2 million hectares of salt-affected land and the development of salinity management technologies and salt-tolerant crop varieties. Director Dr. R.K. Yadav presented the institute's major accomplishments and contributions to agricultural productivity. As part of the celebrations, a Kisan Gosthi and training programme for Scheduled Caste farmers was organized under the SCSP scheme, during which 100 Direct Seeded Rice (DSR) kits were distributed, and students from various schools visited the institute to learn about soil salinity management technologies. The celebration marked another milestone in CSSRI's commitment to scientific excellence and sustainable agricultural development.



Janjatiya Gaurav Varsh Pakhwada

Janjatiya Gaurav Varsh Pakhwada

In commemoration of the 150th birth anniversary of Bhagwan Birsa Munda, the Government of India celebrated the "Tribal Pride Year Fortnight" from November 1 to 15, 2025. Different programmes were organized for six days by ICAR CSSRI RRS, Bharuch at six different villages with ST population. The ST farmers were made aware about the programme and other aspects of life and farming.



Distribution of inputs

Training and distribution of inputs to SC farmers

One day training and distribution of Salt tolerant wheat variety seed and fertilizer package to 50 SC farmers of Bharuch district were organized under SCSP programme. The farmers were informed about the SCSP scheme and various aspect of farming under saline conditions by scientists of the station. The input of seed and fertilizes were provided for one acre area to each farmer.



Training Participants

Training and distribution of inputs under MGMG

One day training and distribution of salt tolerant wheat variety (KRL210) seed to 20 farmers of MGMG adopted villages in Bharuch district were organized. The farmers were informed about the MGMG and various aspect of farming under saline conditions by scientists of the station. The quantity of seed was provided for one acre area to each farmer.



Yoga Day at RRS Bharuch

Celebration of International Yog Day

ICAR-CSSRI and regional stations organized the 11th International Yoga Day 2025 on 21 June 2025 at 7.00 AM. Various types of yogasan and exercises were performed for benefit of health and mind.



Hindi Saptah at RRS Bharuch

Celebration of Hindi Saptah

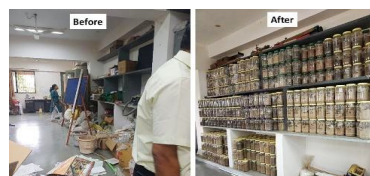
ICAR-CSSRI, RRS, Bharuch celebrated Hindi week during 09-15 September 2025 during which different events were organized and all the staff participated in these events. The winner in different events was given the prizes. Hindi rally was also organized.



Students visit

B. Sc. Agriculture RAWE student Visit

170 B. Sc. (Agri.) RAWE students from College of Agriculture, Navsari, Navsari Agricultural University were visited the station on 24th and 25th September 2025. They were informed about various activities undertaken by the Station.



Special Campaign 5.0

Special campaign 5.0 for disposal of pending matters

Cleanliness drive was conducted from 14.09.2025 to 02.10.2025 under the Special campaign 5.0 for disposal of pending matters at RRS, Bharuch. Under this programme various part of campus were cleaned and arranged. All the staff of station participated in the events

List of Scientific, Technical and Administrative Personnel

Rajender Kumar Yadav, Director

Division of Soil and Crop Management

A.K. Rai, Head
A.K. Bhardwaj, PS
Rakesh Banyal, PS
Gajender Yadav, PS
Aditya Kumar Singh, PS
Madhu Choudhary, SS
Raj Kumar (Agroforestry), SS
Ashim Datta, SS
R.K. Fagodiya, Sci.
Parul Sundha, Sci.
Awtar Singh, Sci.
Priyanka Chandra, Sci.
Manish Kumar, Sci.
Amresh Choudhary, Sci.
Manisha, Technical Officer
Brajesh Kumar, Sr. Tech. Astd.
Preeti Sharma, Sr. Tech. Astd.
Raghubir Singh, Sr. Technician
Girraj meena, Sr. Technician
Dheeraj Kumar, Sr. Technician
Vikas, Sr. Technician
Pradeep, Sr. Technician
Reena Devi, Sr. Technician
Amit Kumar, Technician
Gurinder Singh, Technician
Raj Kumar, Technician
Raveesh Kumar, Technician
Robin Yadav, Technician

Division of Crop Improvement

S.K. Sanwal, Head
Neeraj Kulshreshtha, PS
Anita Mann, PS
Jogendra Singh, SS
Arvind Kumar, SS
Ashwani Kumar, SS
Vijayata Singh, Sci.
Lokesh Kumar B.M., Sci.
Avni, Sci.
N.R. Prakash, Sci.

Ananya Baidya, Sci.
Sharanjeet Singh, Sr. Technician
Indra Pal Tomar, Sr. Technician
Anuj Choudhary, Sr. Technician
Zeetendra Singh, Sr. Technician
Gurudin, Sr. Technician
Jay Sharma, Technician
Kamal Tomar, Technician

Division of Social Science Research

Suresh Kumar, Head (A)
Anil Kumar, PS
Rajkumar (Horticulture), SS
Kailash Prajapat, Sci.
Neela Madhav Patnaik, Sci.
Vikas Khokhar, Sr. Technician
Alok Kumar, Technician
Azmat Ali, Technician

Division of Irrigation and Drainage Engineering

Satyendra Kumar, Head
D.S. Bundela, PS
Bhaskar Narjary, Sci.
Raj Mukhopadhyay, Sci.
Pathan Aslam Latif, Sci.
Jaffer Yousuf Dar, Sci.
Jitendra Kumar, Sci.
Vibhuti Sagar D., Sci.
Dharam Pal kansia, STO
Rahul Singh Pannu, STO
Rajinder Singh, Technical Officer
Dilbag singh, Technical Officer
Khushwant, Sr. Technician
Ankur Sharma, Sr. Technician
Mehul Sharma, Technician
Ravi Kaushik, Technician

AICRP (Saline Water)

Satyendra Kumar, PC
Babu Lal Meena, PS
Shashi Pal, Pr. Sec.
Ram Sewak, SSS

Regional Research Station, Canning Town

D. Burman, Head
U.K. Mandal, PS
T.D. Lama, PS
K.K. Mahanta, PS
Shishir Raut, Sci.
R.N. Bhutia, Sci.
Devika S., Sci.
S. Mallick, Sci.
Sivaji Roy, ACTO
B. Mondal, Sr. Technician
A. Barik, Technician
S. Kayal, Technician
Soumen Bag, Technician
Ramashankar Kumar, Technician

Regional Research Station, Bharuch

Anil R. Chinchmalatpure, Head
David Camus D., Sci.
Monika Shukla, Sci.
Bisweswar Gorain, Sci.
Vineeth TV, Sci.
A.V. Chaudhary, PS
P.K. Parekh, AAO
C.R. Taviyad, TO
B.G. Damor, TO
Dinesh Kumar Meena, STA
Pathan Murtujakhan, Technician
Akansha Vishwakarma, Technician
Manjulaben vasava, Technician
Naveen Kumar, LDC
D.R. Vaghela, SSS

Regional Research Station, Lucknow

A.K. Dubey, Head
Sanjay Arora, PS
S.K. Jha, PS
A. Rahman, PS
R.H. Rizvi, PS
A.K. Dixit, PS
Arjun Singh, Sci.

Ravi Kiran, Sci.
 Hari Mohan Verma, CTO
 Shyam Ji Mishra, STO
 Santosh Kunmar, STO
 Shailendra Verma, STO
 Manish Pandey, TO
 Anil Swaroop Pal, Technician
 Amit Kumar Singh, Technician

KVK, Hardoi

Pankaj Nautiyal, Head
 Trilok Nath Rai, ACTO
 Anjali Sahu, ACTO
 Traloki Singh, ACTO
 Mohit Singh, SMS
 Thanga Anusya S, SMS
 Sombir, Sr. Technician

Administration

Sumit Kumar jindal, CAO(SG)
 Amitabh singh, CFAO
 Mukul Rajsingh, SAO
 Lala Ram Sharma, FAO
 Rita, Pr. Sec.
 Veera Rani, AAO
 Avtar Singh, AAO
 Bhagesh Sharma, AAO
 Nitesh, Assistant
 Sweta Kaim, Assistant
 Sachin kumar, Assistant

Reema Nandal, Assistant
 Abhishek Bhardwaj, Assistant
 Vinod Singh, UDC
 Bhavya, UDC
 Govind, Sr. Technician
 Reena Rani, Sr. Technician
 Kawaljeet Singh, Technician
 Naresh Kumar, Technician
 Akashdeep, Technician
 Charan Singh Meena, LDC
 Dalip Singh, LDC
 Rinku Pal, LDC

Priortizing, Monitoring and Evaluation (PME)

Raj Kumar, OIC
 C.B. Singh, Technical Officer
 B.S. Bhagel, Sr. Technical Astt.
 Monika Singh, Sr. Technician

Publication and Supporting Services Unit (PSSU)

A.K Rai, OIC
 Y.S. Ahlawat, Sr. Technician

Public Relation Officer

R.K. Fagodiya, Sci.

Farm Section

Ganesh Patel, STO
 Raj Kumar, Technical Officer
 Devendra Kumar, Sr. Tech.Astt.

Neeraj Kumar, Technician
 Pankaj Sharma, Technician

Library

B.M. Meena

Estate Section

Akshay Kumar, STO
 Raj pal, Technical Officer
 Mohit , Assistant
 Krishan Pal, Technician

Director Cell

Sunita Malhotra, PS
 Narender Kumar, Technical Assistant
 Niranjan Singh, Technician

Workshop

Amit Kumar Singh, STO
 Anil Kumar, Technical Officer
 Dharambir, Technical Officer
 Joginder Singh, Technician

Health Care Center

Geeta Rani, STO
 Chanchal Rani, TO

Guest House and Security

B. M. Meena, STO
 Gourav Kaushik, Technician
 Mohan Lal, SSS

* 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 31.12.2025.

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	02	57	59	04	6.77	03	5.08
Lowest rung of Class-1	-	12	12	02	16.66	01	8.33
Class-II	-	29	29	02	6.89	03	10.34
Class-III	-	66	66	04	6.06	03	4.54
Class-IV (excluding sweepers)	-	-	-	-	-	-	-
Class-IV (only sweepers)	-	-	-	-	-	-	-
Total	02	164	166	12	7.22	10	6.02

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 31.12.2025.

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 2025

Main Institute, Karnal

During the year 2025, a total rainfall of 780.9 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 a normal rainfall year (105% of the long-term mean annual rainfall) whereas the year 2024 was also a deficient rainfall year (82%). The maximum monthly rainfall of 221.8 mm was recorded during August. During the monsoon season, the highest rainstorm of 118.0 mm was recorded on 25th May and the second highest of 55.6 mm on 12th August. During January and February, there was a low amount of rainfall of 20.1 mm in both months thus increased irrigation demand of wheat and other Rabi crops met either from canal water or groundwater tubewells or both. There was low amount of winter rainfall, 12.7 mm (March) as compared to winter rainfall last year (43.4). Low rainfall resulted in higher irrigation demands for different Rabi crops during March leading to bumper Rabi crop production. There were 51 rainy days same as during the last year.

The minimum and maximum air temperatures, 3.5 °C and 44.5°C were recorded on 27th January and 11th June, respectively. The air relative humidity was the lowest (17%) on 3rd April while the highest (100%) was recorded on several occasions during the year. The highest soil temperatures at 5 cm, 10 cm and 20 cm depth were 47.0°C, 42.0°C and 38.0°C on 9th June. The lowest values at same depths were recorded as 5.0°C, 8.0°C, and 11.0°C on 26th Jan (5, 10 and 20 cm depth). The total open pan evaporation during the year was 1431.0 mm, which was almost 183% higher than the current annual rainfall. The lowest evaporation of 0.1 mm was recorded on various days of January and the highest of 11.2 mm was on 8th June. The average sunshine hours per day were 6.2. The highest and lowest vapour pressure values were 30.4 and 5.9 mm on 12th July and 9th January, respectively. The highest average wind speed was 10.7 km per hour. The monthly weather parameters recorded at Agro-meteorological Observatory, ICAR-CSSRI, Karnal (Haryana) for the year 2025 are presented in Table W1.

Weather Report 2025 Bharuch

Agro-meteorological observations (Table W2) recorded at Regional Cotton Research Station, NAU, Bharuch Gujarat during the year 2025 revealed that this region received normal rainfall of 1019.4 mm spread over 43 days. Season's highest rainfall 317.4 mm was received during September followed by 251.0 mm and 146.2 mm in the month of June and July 2025, respectively. This year May, October and November months also received good amount of rainfall. Maximum air temperature ranged from 28.2°C (December) to 38.8°C (May) and minimum air temperature varied from 12.8°C (December) to 27.9°C (May). Pan evaporation varied from 1.7 mm day⁻¹ to 12.5 mm day⁻¹ during the year. The average bright sunshine hours varied from 2.5 to 9.6 hr/day. Mean relative humidity ranged from 44.7 to 82.7 per cent the year. The average wind speed varied from 1.2 kmph to 12 kmph during the year.

Weather Report 2025 Canning Town

The onset of the southwest monsoon in this region was recorded in advance on 18 May 2025. A total annual rainfall of 2301.2 mm was received during the year 2025, as recorded by the Meteorological Unit of the Centre. The highest monthly rainfall of 738.8 mm was

observed in July, which also recorded the maximum number of rainy days (19), along with August 2025. Rainfall during July was significantly higher than normal, leading to flooding in rice fields across the coastal areas of West Bengal. This adversely affected the early growth of transplanted rice during the initial phase of kharif season. In contrast, rainfall during the post-monsoon period was scanty, necessitating supplemental irrigation for the successful cultivation of rabi crops. A total of 91 rainy days were recorded during the year. The early onset of the monsoon, coupled with adequate annual rainfall, contributed positively to the farming system and resulted in a significant increase in agricultural production during 2025. The average daily sunshine hours remained moderate throughout the year. The maximum temperature of 39.4°C was recorded on 12 May and again on 9 June. During April, temperatures ranged between 31.0°C and 36.0°C,

Table W1. Mean monthly weather parameters for the year 2025 recorded at the Agro-meteorological Observatory, ICAR-CSSRI, Karnal

Latitude : 29° 43' N Longitude : 76° 58' E								Altitude : 245 m above the Mean Sea Level							
I Time : 0722/0830 hours IST II Time : 1422 hours IST															
Month	Temperature, °C							Vapour pressure (mm of Hg)		Relative Humidity (%)		Max. Temp, °C		Min. Temp, °C	
	Max.	Min.	Grass Min.	Dry bulb		Wet bulb						High/ date	Low/ date	High/ date	Low/ date
				I	II	I	II	I	II	I	II				
Jan.	18.5	7.2	-	8.6	17.9	8.2	14.5	8.0	10.5	94	69	23.2/31	11.5/5	11.4/12	3.5/27
Feb.	23.2	9.4	-	11.0	22.9	10.1	17.1	8.8	11.1	88	54	29.8/27	19.2/4	17.0/27	6.5/9
Mar.	28.8	12.2	-	14.7	28.6	13.3	20.0	10.9	12.5	85	43	34.0/28	23.6/2	8.0/3	17.0/27
Apr.	37.0	19.2	-	23.2	36.7	18.5	24.0	13.2	14.8	62	32	41.5/27	32.4/12	25.0/21	10.8/1
May	35.6	24.0	-	26.8	35.3	23.7	27.1	20.1	22.0	76	53	41.2/18	28.2/3	28.2/21	17.9/5
Jun.	36.1	26.3	-	28.7	35.1	26.0	28.5	23.8	25.2	80	62	44.5/11	29.0/26	30.6/13	21/5
Jul.	33.1	26.8	-	28.3	32.0	27.4	29.0	26.6	27.7	92	78	35.6/26	29.2/22	28.6/27	24.8/10
Aug.	31.6	26.2	-	27.5	30.9	26.5	27.6	25.3	25.7	91	77	35.2/23	28.6/1	27.5/11	24.0/23
Sept.	33.0	24.8	-	26.4	32.3	25.1	27.0	23.2	23.6	89	66	35.8/28	27.6/3	26.4/29	22.5/24
Oct.	31.8	19.3	-	20.5	31.1	19.2	22.7	16.1	15.5	89	47	35.0/6	29.0/30	23.6/3	16.0/23
Nov.	27.5	10.2	-	11.4	34.3	10.4	17.2	9.1	8.8	87	33	30.8/2	24.2/6	17.5/2	7.0/26
Dec.	21.3	7.9	-	9.4	20.7	8.7	15.1	8.1	9.7	91	55	26.0/9	14.5/21	11.0/18	5.0/1
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	29.79	17.79	-	19.71	29.82	18.09	42.81	16.10	17.26	85	55	-	-	-	-

Month	Soil Temperature, °C (Depth-wise)						Rainfall*			Evaporation		Sunshine (hr/day)	Wind Speed (km/hr)
	5 cm		10 cm		20 cm								
	I	II	I	II	I	II	Monthly (mm)	No of rainy days	Heavy/ date	mm/ day	mm/ month		
Jan.	9.4	20.7	10.6	17.0	12.6	15.4	4.1	3	1.6/12	0.9	27.4	4.1	1.8
Feb.	10.7	26.3	13.2	22.3	14.7	19.4	16.0	3	11.0/20	1.5	41.0	6.9	2.2
Mar.	15.4	33.1	17.1	29.4	19.0	25.6	12.7	2	7.2/15	3.3	101.0	8.2	2.4
Apr.	23.2	42.9	24.4	36.9	26.1	31.7	6.4	3	2.4/19	7.3	218.0	8.6	3.5
May	25.6	39.1	27.1	35.4	28.4	32.6	179.4	6	118/25	6.8	212.3	8.1	3.6
Jun.	28.8	40.6	30.1	37.1	31.3	34.4	97.2	5	40.8/25	7.7	230.3	6.4	6.1
Jul.	28.1	36.5	29.1	34.7	29.9	32.8	99.1	8	44.2/31	4.6	141.7	4.3	4.0
Aug.	26.9	33.0	27.8	31.4	28.5	29.8	221.8	12	55.6/12	2.9	90.0	3.4	1.1
Sept.	26.1	34.9	27.4	32.4	28.3	30.3	126.6	7	30.4/7	4.0	119.8	6.4	1.0
Oct.	21.0	34.1	23.1	29.5	24.0	27.7	17.6	2	14.8/7	3.5	109.2	6.6	*
Nov.	12.1	28.7	15.2	23.6	16.3	22.1	0.0	0	0.0/-	2.9	87.2	6.5	0.8
Dec.	9.9	23.1	12.0	18.4	13.1	17.2	0.0	0	0.0/-	1.7	53.1	4.5	0.6
Total	-	-	-	-	-	-	780.9	51	-	-	1431.0	-	-
Average	19.8	32.7	21.4	29.0	22.7	25.7	65.1	4.3	-	3.9	119.2	6.2	2.5

Table W2. Monthly average agro-meteorological parameters at Bharuch during 2025

Month	Air Temperature (°C)		Rainfall (mm)	Total rainy days	Mean Relative humidity (M+E) (%)	Vapour pressure(mm)		Wind speed (km/hr)	Sunshine (hr/day)	Epan (mmpd)
	Max	Min				M	E			
January	31.4	15.2	0.0	0.0	49.9	10.8	10.4	3.2	8.8	3.6
February	30.8	18.2	0.0	0.0	44.7	11.6	9.6	5.7	9.0	6.4
March	35.1	21.4	0.0	0.0	51.3	14.6	12.5	7.1	8.3	7.4
April	37.2	24.1	0.0	0.0	51.4	20.5	13.4	7.5	9.6	12.5
May	38.8	27.9	123.2	5.0	59.9	25.2	21.7	11.5	7.6	6.4
June	36.4	27.4	251.0	12.0	67.5	25.4	21.6	12.0	6.9	1.7
July	33.0	26.3	146.2	8.0	78.4	25.3	24.4	10.0	4.5	1.9
August	30.7	25.4	85.4	5.0	82.7	24.1	23.4	6.1	4.0	2.8
September	31.4	25.6	317.4	8.0	82.7	31.0	24.0	3.9	2.5	2.9
October	37.1	22.8	57.8	4.0	56.5	20.3	16.5	1.2	7.1	5.7
November	35.0	18.9	38.4	1.0	50.3	15.3	13.3	1.2	8.2	6.1
December	28.2	12.8	0.0	0.0	47.9	10.1	9.5	2.9	7.9	5.4
Total			1019.4	43.0						
Average	33.8	22.2			60.3	19.5	16.7	6.0	7.0	5.2

Table W3. Mean monthly weather parameters at Canning Town (Latitude 22°15' N, longitude 88°40' E, altitude (AMSL) 3.0 m) during the year-2025

Month	TEMPERATURE(°C)			RH (I) (%)	RH (II)(%)	Rainfall (mm)	Rainy Days (no.)	Evapora- tion (mm)	Av. WIND (km h ⁻¹)	BSSH (day ⁻¹)
	MAX.	MIN.	MEAN							
January	25.3	14.4	19.9	88	51	0.0	00	1.0	2.8	5.4
February	29.5	19.2	24.3	89	61	17.4	01	2.5	3.0	6.2
March	32.9	22.1	27.5	88	62	1.2	00	5.0	4.3	7.4
April	34.0	24.9	29.4	89	74	58.6	02	4.9	7.5	7.2
May	35.0	25.8	30.4	89	74	324.0	12	4.3	7.3	6.7
June	34.0	26.7	30.4	90	79	289.0	17	3.3	6.0	4.5
July	32.4	26.4	29.4	96	88	738.8	19	2.3	3.0	2.7
August	32.3	26.1	29.2	93	86	470.8	19	4.1	3.1	3.8
September	33.2	26.0	29.6	89	79	234.0	11	3.0	2.8	5.4
October	32.8	24.6	28.7	86	76	160.0	09	2.9	1.5	5.9
November	29.9	17.7	23.8	72	52	7.4	01	1.2	1.8	7.9
December	25.1	13.6	19.4	76	52	0.0	00	1.0	2.4	4.9
TOTAL	376.4	267.6	322.0	1046	835	2301.2	91	35.4	45.5	68.0
MEAN	31.4	22.7	27.04	82	60	-	-	3.3	5.5	6.3

Max. temperature: 39.4°C on 12.05.2025 and 9.06.2025

Moderate/Minimum temperature: 31.0°C to 36.0°C Month of April

Maximum average wind speed: 17.7 km h⁻¹ on 26.04.2025

Heavy rainfall: 106.4 mm on 31.07.2025

which were considered moderate. The mean monthly temperature increased sharply from 19.9°C in January to 29.4°C in April. Relative humidity remained consistently high throughout the year, creating favourable conditions for the incidence of pests and diseases. Notably, a single-day heavy rainfall event of 106.4 mm was recorded on 31 July 2025, and the highest average wind speed of 17.7 km h⁻¹ was observed on 26 April 2025. The mean monthly meteorological parameters recorded at RRS, Canning, are presented in Table W3.



संस्थान कार्यकलापों में राजभाषा हिन्दी

हिंदी के महत्व को बढ़ाने के लिए संस्थान में प्रति वर्ष अनेक गतिविधियाँ आयोजित की जाती हैं और प्रत्येक प्रतिभागी को पुरस्कार और प्रमाण पत्र प्रदान करके सम्मानित किया जाता है। संस्थान में प्रत्येक वर्ष चार तिमाही बैठकें और हिंदी कार्यशाला आयोजित की जाती हैं हिन्दी कार्यशाला का विषय वैज्ञानिकों द्वारा उपलब्ध कराया जाता है। कार्यशाला का आयोजन निर्धारित समय पर किया कराया जाता है। हिंदी समिति के सदस्य और संस्थान के निदेशक भी इस बैठक में उपस्थित रहते हैं। हिंदी का समस्त कार्य हिंदी राजभाषा के प्रत्येक प्रमुख सदस्य और प्रभारी हिंदी अधिकारी श्री धर्म पाल कांसिया को आवंटित किया जाता है। निर्धारित समय और कार्यक्रम के अनुसार हिंदी अधिकारी बैठक के विचारों और परिपत्र के अनुसार कार्य विवरण संस्थान स्तर पर प्रसारित करते हैं। पखवाड़ा प्रगति रिपोर्ट सूचना एवं आवश्यक कार्यवाही के लिए नराकास कार्यालय करनाल को प्रस्तुत की जाती है। सितंबर में हिंदी पखवाड़ा के आयोजन के लिए हिंदी पखवाड़ा समिति का गठन निदेशक महोदय द्वारा किया जाता है। वर्ष 2025 के दौरान हिंदी पखवाड़ा 14 से 28 सितम्बर 2025 तक मनाया गया जिसका विवरण इस प्रकार है—

हिन्दी पखवाड़े का आयोजन

विगत वर्षों की भांति इस वर्ष भी केन्द्रीय मृदा लवणता अनुसंधान संस्थान करनाल में 14 से 28 सितम्बर 2025 के मध्य हिन्दी पखवाड़े का आयोजन किया गया। हिन्दी पखवाड़े का आयोजन डॉ. राजकुमार (वरिष्ठ वैज्ञानिक), डॉ. पारुल सुन्धा (वरिष्ठ वैज्ञानिक), श्री लालाराम शर्मा (सहायक वित्त एवं लेखाधिकारी), श्री अमित कुमार सिंह (वरिष्ठ तकनीकी अधिकारी), श्रीमती अनीता मेहता (सहायक प्रशासनिक अधिकारी) एवं श्री बृज मोहन मीणा (वरिष्ठ तकनीकी अधिकारी) की समिति द्वारा किया गया। दिनांक 15 सितम्बर 2025 को हिन्दी पखवाड़े का शुभारम्भ मुख्य अतिथि डॉ. श्रवण कुमार दुबे, एमेरिटस वैज्ञानिक, केन्द्रीय मृदा लवणता अनुसंधान संस्थान, करनाल ने दीप प्रज्ज्वलित करके किया। हिन्दी पखवाड़ा समिति के अध्यक्ष डॉ. राजकुमार ने हिन्दी के महत्व को बताते हुए राजभाषा के नियमों व अधिनियमों की विस्तृत जानकारी दी तथा हिन्दी पखवाड़ा के दौरान आयोजित किए जाने वाले कार्यक्रमों व प्रतियोगिताओं का विस्तृत विवरण दिया।

संस्थान के निदेशक डॉ.राजेन्द्र कुमार यादव ने बताया कि स्वतंत्रता के प्राप्ति के पश्चात 14 सितम्बर, 1949 को यह निर्णय लिया गया था कि राज-काज में अंग्रेजी भाषा का प्रयोग 15 वर्ष तक होगा। आज गूगल व याहू आदि वेबसाइटों में हिन्दी का प्रयोग बढ़ रहा है। हिंदी को उसकी सही जगह दिलाने के लिए हमें हिंदी को केवल एक दिन मनाने तक सीमित नहीं होना चाहिए, बल्कि इसे अपने दैनिक जीवन का अभिन्न हिस्सा बनाना चाहिए। मुख्य अतिथि डॉ. श्रवण कुमार दुबे ने कहा कि सभी भाषाओं में हिंदी को एक विशेष स्थान प्राप्त है। यह न केवल देश के एक बड़े हिस्से में बोली जाती है, बल्कि यह हमारी राष्ट्रीय पहचान, एकता और गौरव का प्रतीक भी है। इसी महत्व को याद करने और हिंदी को सम्मान देने के लिए 14 सितंबर का दिन हमें याद दिलाता है कि हिंदी सिर्फ एक भाषा नहीं बल्कि हमारी सभ्यता, हमारी भावनाएँ और हमारे देश को एक साथ जोड़ने वाली एक मजबूत कड़ी है।



कविता पाठ प्रतियोगिता का दृश्य

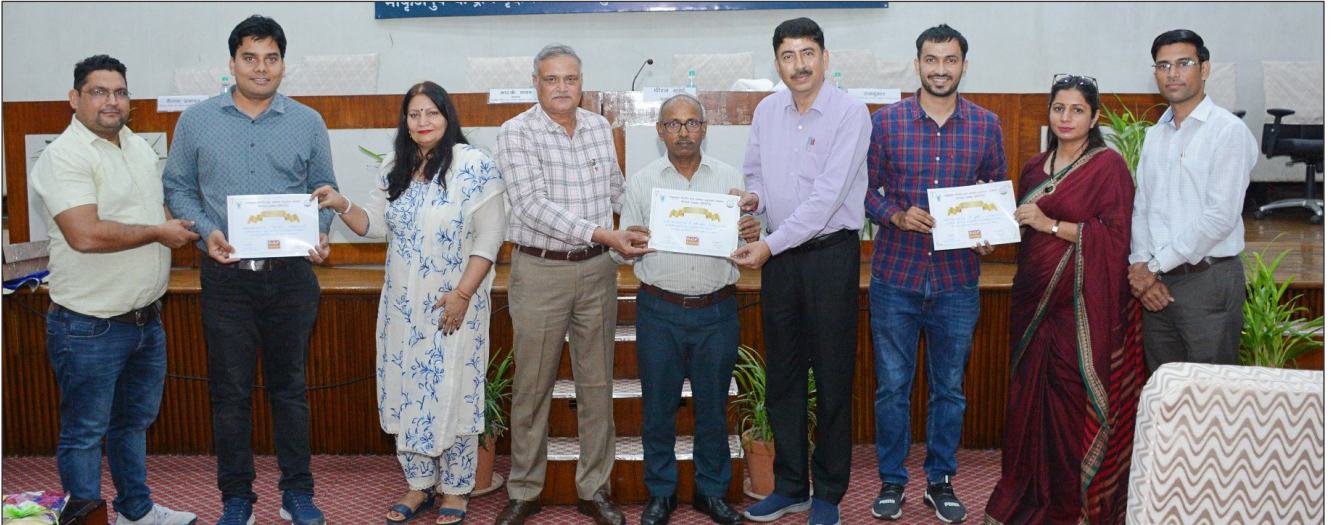


हिन्दी पोस्टर प्रतियोगिता (विद्यार्थियों के लिए)

हिन्दी पखवाड़े के अंतर्गत 12 प्रतियोगिताएं: कविता पाठ प्रतियोगिता, निबंध लेखन प्रतियोगिता, प्रश्नोत्तरी प्रतियोगिता, आवेदन-पत्र लेखन (कुशल सहायक कर्मचारियों के लिए), हिन्दी टंकण प्रतियोगिता, तत्काल भाषण प्रतियोगिता, नगर स्तरीय टिप्पणी एवं मसौदा लेखन, सरकारी कामकाज में मूल हिन्दी आलेखन, हिन्दी पोस्टर प्रतियोगिता (विद्यार्थीओं के लिए), हिन्दी गीत अन्ताक्षरी प्रतियोगिता, चल वैजयन्ती प्रतियोगिता एवं वाद-विवाद प्रतियोगिता आयोजित की गई। इन सभी प्रतियोगिताओं में संस्थान के अधिकारियों व कर्मचारियों ने उत्साहपूर्वक भाग लिया। हिन्दी पखवाड़े का समापन समारोह दिनांक 26 सितम्बर 2025 को आयोजित किया गया जिसके मुख्य अतिथि श्री धीरज शर्मा, उप निदेशक (राजभाषा), भा.कृ.अनु.प.-राष्ट्रीय डेरी अनुसंधान संस्थान, करनाल थे। उन्होंने अपने संबोधन में कहा कि देश की प्रगति एवं एकता के लिये मातृ भाषा में कार्य करना अति आवश्यक है। समस्त देशवासियों को एकता के सूत्र में पिरोने के लिये राजभाषा हिन्दी ही एक सर्वोच्च माध्यम है। समापन समारोह के दौरान विभिन्न प्रतियोगिताओं के विजेताओं को प्रमाण-पत्र देकर सम्मानित किया गया। संस्थान निदेशक ने संस्थान के सभी कर्मचारियों को अधिक से अधिक हिन्दी भाषा में कार्य करने के लिये आह्वान किया। इस अवसर पर सभी प्रभागाध्यक्ष, मुख्य प्रशासनिक अधिकारी, संस्थान के समस्त वैज्ञानिक, प्रशासनिक एवं तकनीकी अधिकारी व कर्मचारी उपस्थित रहे।

राजभाषा हिन्दी में किये गए अन्य कार्य

- संस्थान में सभी प्रशासनिक बैठकें हिन्दी में आयोजित की गई हैं तथा संस्थान की तिमाही रिपोर्ट हिन्दी में भेजी गई है।
- इस अवधि में संस्थान की पत्रिका 'कृषि किरण 2024-25' एवं 'वार्षिक प्रतिवेदन Annual Report 2024 (द्विभाषी)' प्रकाशित किए गए।
- हिन्दी समाचार पत्रों में संस्थान में सम्पन्न गतिविधियों संबंधी प्रेस विज्ञप्तियाँ हिन्दी में प्रकाशित हुई।
- अधिकारियों/कर्मचारियों की सेवा पुस्तिकाओं में प्रविष्टियाँ हिन्दी में की गई।
- कार्यालय के सभी अनुभागों में फाइलों में अधिकतर टिप्पणियाँ हिन्दी में लिखी गई।
- सभी निविदाएं तथा नीलामी सूचनाएं, विज्ञापन, प्रेस नोट आदि हिन्दी में प्रकाशित किये गये।
- सभी बिलों पर भुगतान आदेश हिन्दी में लगाये गये व रोकड़ बही भी हिन्दी में लिखी गई।



समापन समारोह के दौरान विभिन्न प्रतियोगिताओं के विजेताओं को प्रमाण-पत्र देते हुए



.....



.....



.....



.....





ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE

≡ Karnal, Haryana-132001 ≡