भाकृअनुप
ICAR

वार्षिक प्रतिवेदन 2024 ANNUAL REPORT

ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE

Karnal, Haryana-132001

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ICAR

वार्षिक प्रतिवेदन
Annual Report
2024

केन्द्रीय मृदा लवणता अनुसंधान संस्थान
CSSRI
1969

ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE
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Cover Photo

Front side: Salt tolerant rice variety CSR 101 & Eddy Covariance System for measuring vertical turbulent fluxes of carbon dioxide, methane and water from rice-wheat systems

Back side: ICAR-CSSRI Headquarters building (Karnal)

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प्रस्तावना

Preface

भारतीय कृषि अनुसंधान परिषद – केंद्रीय मृदा लवणता अनुसंधान संस्थान, करनाल, की स्थापना वर्ष 1969 में की गई थी। यह संस्थान भारत में लवण प्रभावित मृदाओं के सुधार और सतत प्रबंधन हेतु समर्पित एक प्रमुख संस्थान है। वर्षों में इसने उपसतही जल निकासी प्रणाली, लवण–सहिष्णु फसल किस्में, और जिप्सम–आधारित मृदा संशोधन जैसी परिवर्तनकारी तकनीकों का विकास किया है। इन तकनिकी के माध्यम से 22 लाख हेक्टेयर से अधिक लवणीय भूमि को सफलतापूर्वक सुधार कर 1.7 करोड़ टन वार्षिक खाद्यान्न उत्पादन में वृद्धि हुई है। हालाँकि, उच्च लागत, सीमित किसान जागरूकता, और स्थल–विशिष्ट मृदा भिन्नता जैसी चुनौतियाँ इन तकनीकों के व्यापक प्रसार में बाधक बनी हुई हैं। साथ ही, जलवायु परिवर्तन से उत्पन्न लवण संचयन, द्वितीयक लवणीयता और तकनीकी विस्तार की कठिनाइयाँ भी गंभीर चिंताएं बनी हुई हैं। भविष्य में संस्थान का लक्ष्य है कि वह नवीन संशोधन सामग्री, ट्रांसजेनिक फसलें, जैव उपचार तकनीकें और डिजिटल उपकरणों का विकास करे जिससे भूमि उत्पादकता में सुधार लाया जा सके और लवण प्रभावित क्षेत्रों को पुनर्स्थापित किया जा सके, साथ ही किसान–केंद्रित, जलवायु–लचीली कृषि पद्धतियों को बढ़ावा दिया जा सके।

वर्ष 2024 के दौरान, संस्थान ने लवण प्रभावित मृदा प्रबंधन और जलवायु–लचीली कृषि में उल्लेखनीय प्रगति की। जिप–रफस आधारित मिट्टी संशोधनों ने प्रभावी रूप से मृदा pH को कम किया, जबकि नैनो–सूक्ष्म पोषक तत्व अनुप्रयोगों से जिंक, आयरन और पोषक तत्व अवशोषण में सुधार हुआ। सोडिक भूमि में जिप्सम के विकल्प के रूप में सिलिशियस चॉक को संभावित विकल्प के रूप में चिन्हित किया गया, जिसमें हैलोफिलिक सूक्ष्मजीवों की मदद से घुलनशीलता बढ़ी। संस्थान ने लवण–सहिष्णु चंदन जर्मप्लाज्म की पहचान की और इसकी रोपण तकनीक विकसित की। भारत का तटीय लवणीयता मानचित्र

The ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI), Karnal, established in 1969, is a leading institute dedicated to the reclamation and sustainable management of salt-affected soils in India. Over the years, it has developed transformative technologies such as subsurface drainage systems, salt-tolerant crop varieties, and gypsum-based soil amendments. These innovations have successfully reclaimed over 2.2 million hectares of salt-affected land, boosting food grain production by more than 17 million tonnes annually. However, challenges such as high implementation costs, limited farmer awareness, and site-specific soil variations hinder their widespread adoption. Additionally, climate change-induced soil-salt build-up, secondary salinization, and technology scalability remain pressing concerns. In the future, ICAR-CSSRI aims to develop novel amendment materials, transgenic crops, bioremediation techniques, and digital tools to improve land productivity and restore salt-affected areas, while fostering farmer-centric climate-resilient agricultural practices.

During 2024, the ICAR-CSSRI made significant advancements in management of salt-affected soil management and climate-resilient agriculture. GYPRFS-based soil amendments effectively reduced soil pH, while nano-micronutrient applications improved Zn, Fe, and nutrient uptake. Siliceous chalk emerged as a potential alternative for gypsum in sodic soils, aided by halophilic microbes for better solubility. The institute identified salt-tolerant sandalwood germplasm and developed its cultivation technology. The coastal salinity map of India was generated for precision land-use planning. Technologies like cut-soiler based PSSD showed reclamation potential, while AGROTAIN-incorporated urea showed nitrogen saving potential. Multiple salt-tolerant crop varieties were released, including CSR 101, CSR 104, and CSR 105. Subsurface drainage systems, salt-tolerant crop varieties, and gypsum

सटीक भूमि उपयोग योजना के लिए तैयार किया गया। कट–सॉयलर आधारित PSSD तकनीक ने सुधार की संभावनाएं दर्शाई, जबकि AGROTAIN संलग्न यूरिया में नाइट्रोजन की बचत की संभावना पाई गई। CSR 101, CSR 104 और CSR 105 जैसी कई लवण–सहिष्णु फसल किस्में जारी की गईं। उपसतही जल निकासी प्रणाली, लवण–सहिष्णु फसल किस्में और जिप्सम तकनीकें अब भी लवणीय भूमि की उत्पादकता सुधारने में प्रमुख भूमिका निभा रही हैं।

क्षेत्रीय अनुसंधान केंद्रों पर भी उल्लेखनीय कार्य हुआः लखनऊ में सोडिक मृदाओं पर जैविक खेती, केनिंग टाउन (गंगा डेल्टा) में जलवायु–लचीली कृषि, और भरूच में लवण–सहिष्णु सरसों और गेहूँ के लिए कृषि विधियों का मानकीकरण किया गया। परियोजना समन्वयक इकाई ने देश के आठ जिलों में व्यापक भूजल सर्वेक्षण किए, जिससे सिंचाई जल की गुणवत्ता संबंधी महत्वपूर्ण जानकारियाँ प्राप्त हुईं। ये समग्र उपलब्धियाँ संस्थान की सतत मृदा प्रबंधन और लचीली कृषि में केंद्रीय भूमिका को रेखांकित करती हैं।

संस्थान की अनुसंधान समिति (IRC) की बैठकें जनवरी और मई माह में निदेशक की अध्यक्षता में आयोजित की गईं, जिनमें चल रहे अनुसंधान परियोजनाओं की प्रगति की समीक्षा की गई और नई परियोजनाओं का मूल्यांकन किया गया। कुल 87 परियोजनाएं समीक्षा के लिए प्रस्तुत की गईं, जिनमें से 49 संस्थान–निधि प्राप्त और 28 बाह्य–निधि प्राप्त परियोजनाएं थीं। इन बैठकों में सभी विभागाध्यक्षों, केंद्राध्यक्षों और वैज्ञानिकों ने भाग लिया।

इस वर्ष, संस्थान ने 1 मार्च को अपना 56वाँ स्थापना दिवस समारोह मनाया, जिसमें डॉ. एन.के. त्यागी मुख्य अतिथि के रूप में उपस्थित हुए। कार्यालय में हिन्दी के प्रचार–प्रसार हेतु हिन्दी पखवाड़ा तथा स्वच्छता के प्रति जागरूकता हेतु स्वच्छता पखवाड़ा जैसे कार्यक्रम आयोजित किए गए, जिनमें संस्थान के कर्मचारियों, विद्यार्थियों, किसानों और स्थानीय समुदाय ने सहभागिता की।

मैं डॉ. हिमांशु पाठक, सचिव, डेयर एवं महानिदेशक, भाकृअनुप तथा डॉ. एस. के. चौधरी, उप–महानिदेशक (NRM), भाकृअनुप के प्रति उनके मार्गदर्शन और निरंतर समर्थन हेतु हार्दिक आभार व्यक्त करता हूँ। विशेष धन्यवाद डॉ. राज कुमार, डॉ. ए.के. राय, डॉ. डी.एस. बुंदेला, डॉ. सुरेश कुमार, डॉ. अश्वनी कुमार और इं. वाई.एस. अहलावत को, जिन्होंने इस वार्षिक प्रतिवेदन के संकलन, संपादन और समय पर मुद्रण में सराहनीय योगदान दिया। मैं अपने सभी सहयोगियों का भी आभार प्रकट करता हूँ, जिनके अमूल्य सहयोग से यह प्रतिवेदन समय पर प्रकाशित हो सका।

मुझे विश्वास है कि यह वार्षिक प्रतिवेदन संस्थान के वर्तमान अनुसंधान एवं विकास प्रयासों, नवप्रवृत्तियों, और लवणीयता प्रबंधन से जुड़ी चुनौतियों की उपयोगी जानकारी प्रदान करेगा। हम अपने पाठकों से सुझाव एवं प्रतिक्रिया प्राप्त करने के लिए सदैव स्वागत करते हैं, ताकि भविष्य के प्रतिवेदनों की गुणवत्ता को और अधिक बेहतर बनाया जा सके।

राजेन्द्र कुमार

राजेन्द्र कुमार यादव

निदेशक

technology continued to play a key role in reclaiming and improving the productivity of the salt-affected lands. At regional research stations, progress was made in organic farming on sodic soils (Lucknow), climate-resilient agriculture in the Ganges Delta (Canning Town), and standardization of agronomic practices for salt-tolerant mustard and wheat (Bharuch). The Project Coordinator Unit conducted extensive groundwater surveys across eight districts of the country, providing critical insights into irrigation water quality for sustainable management. These collective achievements reinforce ICAR-CSSRI's pivotal role in advancing sustainable soil management and promoting resilient agriculture.

The Institute Research Committee (IRC) meetings were held during January and May under the chairmanship of the Director to review the progress of ongoing research projects and evaluate new proposals. A total of 87 projects were reviewed, comprising 49 institute-funded and 28 externally funded initiatives. The meetings were attended by all division heads, station heads, and institute scientists.

During this year, the institute celebrated its 56th Foundation Day on March 1st, with Dr. N.K. Tyagi gracing the occasion as Chief Guest. Activities such as Hindi Pakhwada were organized to promote the use of Hindi, and Swachhta 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. Himanshu Pathak, Secretary (DARE) and Director General (ICAR), and Dr. S.K. Chaudhary, Deputy Director General (NRM), ICAR, for their continued guidance and support. Special thanks are due to Dr. Raj Kumar, Dr. A.K. Rai, Dr. D.S. Bundela, Dr. Suresh Kumar, Dr. Ashwani Kumar, and Er. Y.S. Ahlawat for their commendable efforts in compiling, editing, and ensuring the timely printing of this Annual Report. 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 confident that the information presented in this annual report will provide valuable insights into the institute's current research and development efforts, emerging trends, and challenges in salinity management in agriculture. We welcome suggestions and feedback from our readers to further enhance the quality of our annual report.

Rajender Kumar Yadav

Director

कार्यकारी सारांश

आईसीएआर–सीएसएसआरआई ने वर्ष के दौरान लवणीय कृषि पारिस्थितिकी तंत्र से जुड़ी कई समस्याओं का समाधान करने के लिये एकीकृत अनुसंधान, विकास और प्रसार कार्यक्रमों के माध्यम से उल्लेखनीय प्रगति की। संस्थान की विभिन्न विभागों और क्षेत्रीय केंद्रों ने मृदा एवं जल प्रबंधन, लवण–सहिश्णु फसलों के विकास, टिकाऊ सिंचाई तकनीकों और आजीविका को सुरक्षित रखने वाले शोधो में महत्वपूर्ण योगदान दिया, जैसा कि नीचे वर्णित हैः

मृदा एवं फसल प्रबंधन विभाग ने कठिन परिस्थितियों में भी मृदा के स्वास्थ्य और फसल की पैदावार को बेहतर बनाने में महत्वपूर्ण कार्य किया। मृदा संशोधन की विभिन्न विधियों का मूल्यांकन किया गया, जिसमें GYPRFS ने pH को कम करने में कैलफिल्स और RAWSWC की तुलना में सबसे अच्छा परिणाम दिया। RSC3 सिंचाई उपचारों में सूक्ष्म जीवाणु जैवमंडल (MBC) और डिहाइड्रोजेनेज गतिविधि (DHA) सबसे अधिक पाई गई जिससे मृदा में सूक्ष्म जीवों का स्वास्थ्य बेहतर हुआ। CSSRI द्वारा विकसित नैनो–माइक्रोन्यूट्रिएंट फार्मूलेशन से जिंक, आयरन और कॉपर जैसे तत्वों की मात्रा में 25% तक वृद्धि हुई, जिससे 5-7% तक फसल उत्पादन में सुधार हुआ। क्षारीयता तनाव पर किए गए अध्ययनों में बीज की नमी और वजन में अन्तर देखा गया, जिससे गेहूँ और धान के अंकुरण पर असर पड़ा। लवण प्रभावित मृदा में चंदन, बबूल और मालाबार नीम के पौधों का खेत में प्रत्यारोपण परीक्षण किया गया, जिसमें चंदन की किस्में H-18, H-15, K4-12 और K4-11 सबसे बेहतर रही। संरक्षण कृषि पद्धतियों से मृदा की जलधारण क्षमता, जैविक कार्बन और सूक्ष्मजीव गतिविधि में सुधार हुआ। सोडिक मृदाओं के लिए सिलिकिस चाक एक प्रभावी सुधारक साबित हुआ और इससे फसल उत्पादन बेहतर हुआ। तटीय क्षेत्रों में लवणता का मानचित्रण किया गया और धान की फसल के अवशेशों को दोबारा खेत में डालने से कार्बन को संचित करने की दर 10–22 प्रतिशत तक बढ़ी। जैविक नाइट्रिफिकेशन रोकने वाली (BNI) गेहूँ की किस्म की जांच की गई, जिससे विभिन्न मृदा pH स्तरों में नाइट्रेट की मात्रा 5–15 प्रतिशत तक कम हुई। कम लागत वाली प्राथमिक उपसतही जलनिकासी तकनीक (PSSD) का सफल परीक्षण किया गया जिससे लवणता और जलभराव की समस्याओं का समाधान हुआ। हरियाणा और पंजाब में मृदा स्वास्थ्य प्रयासों ने यह दर्शाया कि जिप्सम का प्रभावी ढंग से प्रयोग मृदा का pH मान और ESP को घटाने में प्रभावी है, हालांकि समय के साथ कुछ पुनरावृत्ति प्रभाव देखे गए। जलवायु–स्मार्ट कृषि परीक्षणों ने बेबी कॉर्न–गाजर–गवार फसल प्रणाली को सबसे अधिक उत्पादक और लाभकारी पाया, जिसमें पारंपरिक चावल–गेहूं प्रणालियों की तुलना में 140 प्रतिशत उच्च प्रणाली उत्पादकता और 126 प्रतिशत अधिक शुद्ध लाभ मिला।

फसल सुधार विभाग ने लवणीय परिस्थितियों के लिये धान, गेहूँ, सरसों और चने की किस्मों के विकास में महत्वपूण प्रगति की है। धान की तीन किस्में, CSR 101, CSR 104 और CSR 105 को विभिन्न राज्यों के लवणीय क्षेत्रों के लिये जारी किया गया, जबकि CSR 64 और CSR 92 को उत्तर प्रदेश की क्षारीय मृदाओं के लिए उपयुक्त पाया गया। धान की कई नई किस्में अभी भी राष्ट्रीय परीक्षण में शामिल हैं। QTL मैपिंग से लवण सहिष्णुता और पैदावार से जुड़े प्रमुख जीन पहचाने गए हैं। साथ ही नए लवण सहनशीलजीन स्रोतों की पहचान कर उन्हें उननत किस्मों से मिलाया जा रहा है। गेहूँ में KRL 423 और KRL 1803 नामक किस्मों को उत्तर प्रदेश की सोडिक मृदा के लिए उपयुक्त पाया गया। इन किसमों के बीजों का उत्पादन कर किसानों को उपलब्ध कराया गया, जिससे इनकी खेती में काफी वृद्धि और आर्थिक लाभ हुआ। सरसों में कई नई किस्मों का विकास किया गया और उन्हें सोडिक परिस्थितियों परीक्षण किया गया। लवण सहनशीलता से जुड़े जीन भी पहचाने गय इसके अतिरिक्त, 1,000 इनब्रीड लाइनों को आनुवंशिक अनुसंधान के लिये संरक्षित किया गया है। चने में, CSG–20–6 और CSG–21–1 जैसी लवण–सहनशील किस्मों ने बेहतर उपज दी और राष्ट्रीय परीक्षणों में शामिल की गई। इसके अलावा, 330 इनब्रीड लाइनों को लवणीय और सोडिक परिस्थितियों में जांचा गया और कई आशाजनक किसमें सामने आई। फाइन मैपिंग और NIL पॉपुलेशन के विकास पर भी कार्य चल रहा है।

सिंचाई एवं जल निकासी अभियांत्रिकी विभाग ने जल के टिकाऊ उपयोग, मृदा लवणता प्रबंधन और जलवायु अनुकूल कृषि को लक्षित करने वाली कई परियोजनाओं में उल्लेखनीय प्रगति की है। DST–NWO HIROS परियोजना में गन्ने की सिंचाई के लिय सतही ड्रिप कम रासायनिक उपयोग के साथ फर्टिगेशन तकनीक (परिदृश्य 3 और 5) से जल और नाइट्रोजन की उपयोग दक्षता तथा फसल पैदावार में उल्लेखनीय सुधार देखा गया। "प्लांट डायरेक्ट" परियोजना में धान की सीधी बिजाई (डीएसआर) में रणनीतिक सिंचाई समय शेडयुलिंग से 35 प्रतिशत तक पानी की बचत हुई और उपज में कोई विशेश कमी नहीं आई, पीआर 126 कस्म को उच्च उपजदेने वाली किस्म के रूप में पहचाना गया। डीएसटी–पीएयू केंद्र द्वारा कैथल जिलें में जलवायु परिवर्तन के प्रभावों का अध्ययन किया किया गया जिसमें तापमान में वृद्धि और वर्शा में अनियमितता देखी गई। भूजल मॉडल ने सटीक परिणाम दिये। रोहतक जिले में मृदा की लवणता को मापने के लिये EMI डेटा और EM4Soil सॉफटवेयर का का उपयोग किया गया जिससे 1012 कि.मी. क्षेत्र को मध्यम और 313 कि.मी. क्षेत्र को अधिक लवणीय श्रेणी के रूप में पहचाना गया। मृदा की बनावट में भी भारी विविधता पाई गई। अंत में एक कम लागत वाला रीयल–टाइम सेंशर विकसित किया गया जो मृदा की नमी, तापमान और विद्युत चालकता को मापता है इसके परिणाम मानक तरीकों से मेल खाते हैं।

सामाजिक विज्ञान अनुसंधान प्रभाग ने कठिन कृषि–पारिस्थितियों में किसानों की आजीविका में सुधार के लिए कई तकनीकों और उपायों का मूल्यांकन किया। सबसे बड़ा अध्ययन उपसतही जल निकास (एसएसडी) तकनीक पर किया गया जिससे गेहूँ में 30.9 प्रतिशत, धान में 46.5 प्रतिशत और गन्ने में 62.4 प्रतिशत की वृद्धि हुई साथ ही मृदा स्वास्थ्य, उच्च जैविक कार्बन और लवणता में सुधार देखा गया। आर्थिक विश्लेषण के अनुसार इस तकनीक ने धान, गेहूँ और गन्ने के उत्पादन में वृद्धि से 84,780 करोड़ रुपये का लाभ उत्पन्न किया। हालाँकि, सीमित उपकरणों, वित्त पोषण, किसान जागरूकता और संस्थागत समर्थन की कमी के कारण एसएसडी को अपनाने की दर कम (प्रभावित भूमि का 2.57 प्रतिशत) बनी हुई है। कृषि उद्यमिता के अंतर्गत, 70 किसानों का सर्वेक्षण किया गया जिसमें मूल्य अस्थिरता, उच्च भंडारण शुल्क, खराब रोपण सामग्री और भूमि क्षरण को प्रमुख कठिनाइयों के रूप में पहचाना गया। फार्मर फर्स्ट परियोजना ने हरियाणा में लवणीय मृदा के लिए उच्च उपज देने वाली गेहूँ (डीबीडब्ल्यू 371, डीबीडब्ल्यू 303) और धान (पीबी 1509, पीबी 1692) की किस्मों की पहचान की। राज्य भर में छह लवण–प्रभावित स्थलों पर बाग लगाकर खजूर की टिकाऊ खेती शुरू की गई। किनोआ के परीक्षणों से पता चला है कि अक्टूबर की शुरुआत में बुवाई करने से अधिक उपज हुई, जबकि देर से बुवाई करने से कटाई में देरी के कारण उत्पादकता में कमी हो गई।

परियोजना समन्वयक इकाई ने लवणता, क्षारीयता और रासायनिक मापदंडों पर ध्यान केंद्रित करते हुए सिंचाई जल की गुणवत्ता का आकलन करने के लिए भारत के विभिन्न जिलों में व्यापक भूजल सर्वेक्षण किया। आंध्र प्रदेश के श्रीकाकुलम और विजयनगरम जिलों में 1,600 से अधिक पानी के नमूनों का विश्लेषण किया गया, राजस्थान के बाडमेर एवं जालौर जिलों में ही बहुत सारी भौगोलिक विभिन्नताएं पाई गई। बाड़मेर में, सिर्फ 26.32 प्रतिशत नमूनों को ही अच्छी गुणवत्ता वाला माना गया, जबकि जल की उच्च क्षारीयता और लवणता प्रमुख समस्या थी। जालौर ने 48.55 प्रतिशत अच्छी गुणवत्ता वाले पानी के साथ थोड़ी बेहतर तस्वीर पेश की, लेकिन लगभग 30 प्रतिशत नमूनों में लवणीयता और क्षारीयता की अधिकता पाई गई। हरियाणा के गुरुग्राम जिले में, 39.69 प्रतिशत नमूने अच्छे थे, जिनमें से लगभग 25 प्रतिशत लवणता या सोडिसिटी से प्रभावित थे। तमिलनाडु के सलेम जिले में, 66.5 प्रतिशत भूजल के नमूने अच्छे थे, हालांकि 20 प्रतिशत लवणीय और 13 प्रतिशत क्षारीय थे। पंजाब के संगरूर जिले ने अधिकांश नमूनों में सुरक्षित फ्लोराइड स्तर की मात्रा पाई गई, लेकिन 47 प्रतिशत नमूनों में नाइट्रेट संदूषण अधिक था। आगरा में फील्ड परीक्षणों ने अकेले क्षारीय जल की तुलना में नहर और मिश्रित (नहर–क्षारीय) सिंचाई के तहत बेहतर पैदावार और लाभप्रदता दिखाई बापटला और बीकानेर में, ड्रिप सिस्टम के तहत लवणीय पानी के वैकल्पिक उपयोग से क्रमशः मक्का और सौंफ की पैदावार बरकरार रही, जिससे यह संकेत मिलता है कि रणनीतिक जल सम्मिश्रण और ड्रिप फर्टिगेशन से लवणता के प्रभाव को कम किया जा सकता है। तटीय क्षेत्रों में भी सतत जल प्रबंधन के लिए दोरुवु तकनीक की क्षमता देखी गई।

आईसीएआर–सीएसएसआरआई, क्षेत्रीय केंद्र, लखनऊ में फसल सुधार, क्षारीय मृदा सुधार और सतत फल उत्पादन में उल्लेखनीय प्रगति हुई है। उत्तर प्रदेश के पंद्रह जिलों से 121 बाजरा जीनोटाइप के व्यापक संग्रह ने फसल विविधीकरण के उद्देश्य से आनुवंशिक मूल्यांकन को सुगम बनाया। आंशिक रूप से पुनः प्राप्त भूमि में उप–मृदा क्षारीयता के प्रबंधन के लिए, समुद्री जिप्सम और सल्फामिक अम्ल जैसे मृदा संशोधनों का मूल्यांकन किया गया, जहाँ समुद्री जिप्सम (T3: 50 GR) के सतही अनुप्रयोग से अनाज की उपज में उल्लेखनीय वृद्धि (4.62 टन/हेक्टेयर) हुई और मृदा pH कम हुआ। बिहार में, लवण–सहिष्णु धान की किस्म CSR 46 को हरी खाद, प्रेसमड और गोबर की खाद के साथ सूक्ष्मजीवों के मिश्रण से प्रयोग करने पर उपज में 44.7 प्रतिशत की वृद्धि हुई, जिससे उत्पादकता और मृदा की उर्वरता दोनों में सुधार हुआ। कार्बोनेट–विलयकारी जीवाणु पृथक्करणों की जाँच से एक तरल जैव सूत्रीकरण, "हेलो–मृदासुधारक" का विकास हुआ, जिसमें स्व–सुधार की क्षमता है। शारदा सहायक नहर कमान में सुदूर संवेदन और सांख्यिकीय मॉडलिंग ने बाराबंकी में 20,125 हेक्टेयर क्षारीय भूमि का चित्रण करने में मदद की। इसके समानांतर, प्राकृतिक खेती के परीक्षणों से मृदा सूक्ष्मजीवी गतिविधि में वृद्धि का पता चला। पॉलीथीन से ढके तालाबों का उपयोग करके लवण संचयन प्रभावी साबित हुआ, जिससे ढलान वाले भूखंडों में 2.27 टन/हेक्टेयर धान की उपज प्राप्त हुई। मछली–सब्जी–खजूर और मछली–बागवानी–डेयरी मॉडल जैसी एकीकृत कृषि प्रणालियों (आईएफएस) ने आय और संसाधन चक्रण के लिए आशाजनक परिणाम दिखाए। कृषि वानिकी परीक्षणों में, ऑगर प्लांटिंग, ओपन हाइड्रोपोनिक्स और सूक्ष्मजीवी इनपुट जैसी नवीन रोपण प्रणालियों ने सेब, खजूर, ड्रैगन फ्रूट और नींबू जैसे फलों की फसलों की उत्तरजीविता और वृद्धि में सुधार किया।

आईसीएआर–सीएसएसआरआई, क्षेत्रीय स्टेशन, कैनिंग टाउन (पश्चिम बंगाल) में, भारतीय सुंदरबन में तटीय लवणता, भूमि उपयोग की गतिशीलता और जलवायु के लचीलेपन पर व्यापक शोध किया गया। लैंडसैट डेटा (1973–2022) का उपयोग करके स्थानिक–कालिक विश्लेषण से 305.58 किमी^{2} का शुद्ध क्षरण और 269.12 किमी^{2} की अभिवृद्धि का पता चला। भूमि–उपयोग परिवर्तनों ने स्थिर मैंग्रोव वनों को दिखाया, जबकि जलीय कृषि, बस्तियों और दोहरी फसल वाली भूमि का विस्तार एकल फसल वाले क्षेत्रों की कीमत पर हुआ। भूमि की सतह के तापमान के रुझानों में बढ़ती परिवर्तनशीलता दिखाई दी, जिसमें एकल फसल वाली और परती भूमि में उच्च मूल्य दर्ज किए गए। एसएसपी 585 के तहत जलवायु मॉडलिंग ने 2060 तक तापमान में 1.3–2.1 डिग्री सेल्सियस और वर्षा में 212–292 मिमी की वृद्धि का अनुमान लगाया। जोखिम आकलन और एक निर्णय मैट्रिक्स ने हस्तक्षेप योजना को सूचित किया। ऊर्ध्वाधर विद्युत ध्वनि का उपयोग करके भूजल अध्ययन ने सिंचाई की गुणवत्ता को C2/3S1 के रूप में वर्गीकृत किया शून्य जुताई आलू, एकीकृत गृह कृशि और धान आधारित प्राकृतिक कृषि मॉडलों ने उत्पादकता और संसाधन उपयोग दक्षता में सुधार किया। नोना बोकरा और कैनिंग 7 जैसे लवण–सहिष्णु धान जीनोटाइप ने लचीलापन प्रदर्शित किया। मटला नदी के मुहाने के पारिस्थितिकी तंत्र मॉडलिंग ने जल गुणवत्ता से प्रभावित मछलियों और प्लवक की प्रचुरता में मौसमी परिवर्तन दिखाया। हेटेरोप्नेस्टेस फॉसिलिस के साथ जलीय कृषि परीक्षणों ने उच्च लाभ के लिए 60,000–80,000/हेक्टेयर के भंडारण घनत्व की सिफारिश की। भारतीय प्रमुख कार्प के साथ बहु–कृषि ने उच्चतम बी:सी अनुपात (3.24) प्राप्त किया।

आईसीएआर–सीएसएसआरआई क्षेत्रीय अनुसंधान केंद्र, भरूच (गुजरात), लवणीय वर्टिसोल पर फसल उत्पादकता में सुधार हेतु लवण–सहिष्णु तकनीकों के विकास में सक्रिय रूप से संलग्न है। कृषि अपशिष्टों का उपयोग करके दरार प्रबंधन पर किए गए एक अध्ययन से पता चला है कि 10 टन/हेक्टेयर की दर से जलकुंभी के प्रयोग से दरारों की मात्रा में उल्लेखनीय कमी आई और मृदा कार्बन स्तर में सुधार हुआ। सरसों के परीक्षणों में, 150 प्रतिशत आरडीएफ और पोटेशियम, सल्फर और जिंक के पोषक तत्वों के मिश्रण के प्रयोग से अधिकतम उपज में वृद्धि दर्ज की गई, जबकि सीएस–64 और सीएस–58 किस्मों ने विलंबित बुवाई के तहत बीज उत्पादन में सर्वश्रेष्ठ प्रदर्शन किया। केआरएल–2207 और एसपीएलएएसएन–10 सहित गेहूँ की प्रजनन प्रजातियों ने लवणता (ईसीई 6–7 डेसीलीटर/मी) के तहत उच्च उपज प्रदर्शित की। मक्के में, जीनोटाइप आईएमआर–15 ने तीन लवणता स्तरों पर बेहतर सहनशीलता दिखाई। जीएनएफसी के साथ एक परामर्श परियोजना ने प्रदर्शित किया कि 1:1 अनुपात में उपचारित

अपशिष्ट और अच्छी गुणवत्ता वाले पानी के साथ–साथ 120–160 किलोग्राम नाइट्रोजन/हेक्टेयर की सिंचाई से गेहूं की पैदावार प्रतिकूल मृदा प्रभावों के बिना 3.15 टन/हेक्टेयर हुई। सीएसएसआरआई ने लवण प्रभावित भूमि के लिए उपसतही जल निकासी डिजाइन करने में एनडीडीबी का भी समर्थन किया।

आईसीएआर–सीएसएसआरआई ने लवण प्रभावित कृषि–पारिस्थितिकी तंत्रों में जलवायु लचीलापन और स्थिरता बढ़ाने के उद्देश्य से कई नई पहल शुरू की हैं। एफएओ इंडिया के साथ एक सहयोगी परियोजना टिकाऊ खाद्य तकनीकों को बढ़ावा देने के लिए धान–गेहूं तकनीकों को बदलने पर केंद्रित है। जौ की लवणता के प्रति उच्च सहनशीलता को पहचानते हुए, जौ के आनुवंशिक सुधार पर एक नई पहल का उद्देश्य खाद्य सुरक्षा और निर्यात के लिए इसकी क्षमता का दोहन करना है। आरकेवीवाई–वित्त पोषित परियोजनाओं में हरियाणा में भूजल पुनर्भरण संरचनाएँ और लवण प्रभावित मृदा में खजूर की स्थायी कृशि शामिल है। बापटला में, धान की फसल में लवण सहनशीलता और जल उपयोग दक्षता बढ़ाने के लिए मल्चिंग तकनीकों और जीवाणु पहचान की खोज की जा रही है। बीकानेर केंद्र लवणीय सिंचाई के तहत ड्रैगन फ्रूट का मूल्यांकन कर रहा है। एसईआरबी–डीएसटी कृषि में सूक्ष्म प्लास्टिक संदूषकों पर एक अध्ययन को वित्तपोषित कर रहा है, जबकि एक अन्य परियोजना गेहूँ में लवणता की समस्या के न्यूनीकरण के लिए एंडोफाइटिक जीवाणुओं की जाँच कर रही है। एनडीडीबी आणंद के साथ एक परामर्श परियोजना और गुजरात के बारा क्षेत्र में सरसों के लिए परीक्षणों के एक पैकेज का विकास, इन प्रयासों को और आगे बढ़ाएगा। इसके अतिरिक्त, तटीय लवणता प्रबंधन के लिए बायोचार के अनुप्रयोग की खोज की जा रही है। ये प्रयास न केवल उत्पादकता और पर्यावरणीय स्थिरता में वृद्धि में योगदान करते हैं, बल्कि लवण प्रभावित कृषि–पारिस्थितिकी तंत्रों में आजीविका सुरक्षा, विविधीकरण, आय सृजन और दीर्घकालिक जलवायु के लचीलेपन को भी बढ़ावा देते हैं।

पुरस्कार और सम्मान

संस्थान के वैज्ञानिकों ने अपने उत्कृष्ट योगदान के लिए प्रतिष्ठित राष्ट्रीय सम्मान अर्जित किए हैं। डॉ. ए.के. भारद्वाज को एनएएएस फेलोशिप और डॉ. जेएसपी यादव मेमोरियल पुरस्कार सहित कई सम्मान प्राप्त हुए। डॉ. राम के. फगोडिया और नितीश रंजन प्रकाश को युवा वैज्ञानिक पुरस्कार प्रदान किए गए, जबकि डॉ. सुरेश कुमार और जोगेंद्र सिंह क्रमशः एनएएएस एसोसिएट और एफएसआरएमआर फेलो चुने गए। डॉ. ए.के. दुबे और डॉ. संजय अरोड़ा को बागवानी और कृषि विज्ञान में उत्कृष्टता के लिए भी सम्मानित किया गया।

सम्मेलन/कार्यशालाओं का आयोजन

- उत्तर प्रदेश में गन्ना किसानों और मिल कर्मचारियों के लिए इरीवॉच सलाहकार सेवाओं पर 28वीं द्विवार्षिक एआईसीआरपी कार्यशाला और व्यावहारिक प्रशिक्षण का आयोजन किया।
- हरियाणा में जलभराव वाले लवणीय क्षेत्रों के लिए ऊर्ध्वाधर जल निकासी और पुनर्ग्रहण रणनीतियों पर एचओपीपी परियोजना के अंतर्गत राज्य विभाग के अधिकारियों के साथ उच्च–स्तरीय बैठकें आयोजित की।
- सीजीआईएआर की एशियाई मेगा डेल्टा परियोजना के अंतर्गत कैनिंग टाउन में हितधारक और समीक्षा कार्यशालाओं का आयोजन किया गया, जिससे गंगा डेल्टा में जलवायु–अनुकूल कृषि को बढ़ावा मिला।
- सरदार सरोवर नहर कमान क्षेत्र में लवणता और लवणता की समस्या के समाधान हेतु नर्मदा नियंत्रण प्राधिकरण और गुजरात के इंजीनियरों के साथ सुव्यवस्थित चर्चा की गई।

प्रदर्शनी और क्षेत्रीय दौरे

2024 के दौरान, भारत और विदेश से 603 किसानों, 1590 छात्रों, 121 प्रशिक्षुओं, 17 विस्तार कार्यकर्ताओं और 12 वैज्ञानिकों सहित कुल 2333 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 2024 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 102 कृषि परामर्श प्रदान किए गए। इसके अलावा, संस्थान के साथ व्हाट्सएप समूहों के माध्यम से जुड़े 192 से अधिक किसानों को लवण प्रभावित क्षेत्रों के लिए फसल एवं मृदा प्रबंधन पर परामर्श दिए गए।

क्षमता निर्माण

आईसीएआर–सीएसएसआरआई ने 2024 में 23 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, भरूच 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 283 सीमांत किसानों और कृषक महिलाओं के लिए कुल 27 क्षमता निर्माण प्रशिक्षण, 4 प्रदर्शन और 3 गोष्ठियाँ आयोजित की गई।

अंतर्राष्ट्रीय सहयोग

- जलवायु परिवर्तन कृषि और खाद्य सुरक्षा (सीसीएएफएस) – (सीआईएमएमवाईटी द्वारा वित्त पोषित)
- उच्च जिंक 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 (जेआईआरसीएएस 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)

प्रौद्योगिकी विकास

आईसीएआर–सीएसएसआरआई ने 11 नई प्रौद्योगिकियाँ विकसित की गई जिन्हें आईसीएआर, नई दिल्ली द्वारा प्रमाणित किया गया है। इनमें जलभराव वाले धान के खेतों में अंतर–फसल के लिए धान सब्जी तकनीक, तीव्र अम्लीकृत खाद (RAM), समृद्ध नगरपालिका ठोस अपशिष्ट खाद, और क्षारीय मृदा प्रबंधन के लिए दीर्घकालिक संरक्षण कृषि पद्धतियाँ, आयन एक्सचेंज रेजिन तकनीक (IERT), मेलिया डूबिया का CSM 21 जर्मप्लाज्म, सल्फ्यूरिक अम्ल आधारित रासायनिक संशोधन, जिप्सम–CWC–आधारित सुधार प्रोटोकॉल, और तटीय क्षेत्रों की मृदा लवणता मानचित्रण शामिल हैं।

उद्योगों/स्टार्टअप्स/FPOs/अंतर्राष्ट्रीय संगठनों के साथ साझेदारी

ICAR&CSSRI ने उद्योगों, स्टार्टअप्स, FPOs और अंतर्राष्ट्रीय संगठनों के साथ समझौता ज्ञापनों के माध्यम से 31 साझेदारी स्थापित की हैं। प्रमुख सहयोगियों में GNFC, IFFCO, NABARD, NTPC, रिलायंस इंडस्ट्रीज और हीडलबर्ग सीमेंट शामिल हैं। अंतर्राष्ट्रीय सहयोगों में JIRCAS, JICA, CIMMYT, IRRI और AARDO शामिल हैं। साझेदारी हरियाणा सरकार जैसे सरकारी निकायों और पंजाब, हरियाणा, राजस्थान और उत्तर प्रदेश के विभिन्न FPOs और CHCs तक भी फैली हुई है।

प्रकाशन

संस्थान ने प्रतिष्ठित राष्ट्रीय और अंतर्राष्ट्रीय पत्रिकाओं में 107 शोध पत्र प्रकाशित किए हैं।

इसके अतिरिक्त, 38 पुस्तकें/मैनुअल/अध्याय और 50 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।

संसाधन सृजन बीज उत्पादन

वर्ष के दौरान, संस्थान ने कुल रु. 1.04 करोड़ का राजस्व अर्जित किया। मुख्य योगदान कृषि उपज और बीज बिक्री (रु. 91.6 लाख), विश्लेषणात्मक परीक्षण शुल्क रु. 5.35 लाख) और अनुबंध अनुसंधान (रु. 5.55 लाख) से आया। अतिरिक्त आय शुल्क और विविध स्रोतों से अर्जित की गई। संस्थान ने धान (CSR 30, CSR 56, CSR 60), गेहूँ (KRL 210, KRL 213, KRL 283), सरसों (CS 58, CS 60) और चना (करनाल चना–1) सहित लवण–सहिष्णु किस्मों के 109.36 क्विंटल प्रजनक बीज और 458.1 क्विंटल टीएल बीज का भी उत्पादन किया।

वित्तीय स्थिति

वित्तीय वर्ष 2024–25 के दौरान, संस्थान ने रु. 4955.10 लाख के अपने पूरे आवर्ती बजट का उपयोग किया। इसमें वेतन (रु. 2995.78 लाख), पेंशन (रु. 1059.50 लाख) और सामान्य व्यय (रु. 684.40 लाख) जैसे प्रमुख मद शामिल थे। गैर–आवर्ती घटक के अंतर्गत, 172.86 लाख रुपये मुख्य रूप से कार्यों, उपकरणों, आईटी और पुस्तकालय संसाधनों पर खर्च किए गए।

Executive Summary

ICAR-CSSRI made significant progress during the year in addressing the multifaceted challenges of salt-affected agro-ecosystems through integrated research, development, and outreach programmes. The institute's divisions and regional stations contributed critical advancements in soil and water management, development of salt-tolerant crops, sustainable irrigation practices, and livelihood security-oriented innovations across diverse agro-climatic zones, as highlighted below:

The Division of Soil and Crop Management has made significant strides in improving soil health and crop productivity under challenging conditions. Various soil amendment formulations were evaluated, with GYPRFS showing superior pH reduction effects compared to Calfils and RAWSWC. Microbial biomass carbon (MBC) and dehydrogenase activity (DHA) were highest in irrigation treatments with RSC 3, indicating improved soil microbial health. Nano-micronutrient formulations developed at CSSRI enhanced the biofortification of Zn, Fe, and Cu by up to 25%, leading to yield improvements of 5-7%. Studies on alkalinity stress revealed significant variations in seed moisture dynamics and seed weight reductions under different RSC treatments, impacting the germination ability of wheat and rice. Field out-planting trials of sandalwood, willow, and Malabar neem in saline soils provided critical insights into salinity tolerance, with sandalwood genotypes H-18, H-15, K4-12, and K4-11 performing best. Conservation agriculture practices showed enhancement in soil permeability, organic carbon, and microbial activity. Siliceous chalk emerged as a promising amendment for sodic soils, improving crop yields. A coastal salinity mapping initiative was undertaken, and rice residue recycling was found to boost carbon sequestration rates by 10-22%. The effectiveness of biological nitrification inhibition (BNI) wheat was assessed, revealing a 5-15% reduction in nitrate concentration across varying soil pH levels. Low-cost preferential subsurface drainage technology (PSSD) was successfully tested to manage salinity and waterlogging. Soil health monitoring efforts across Haryana and Punjab demonstrated effectiveness of gypsum in reducing soil pH and ESP, though some rebound effects were noted over time. Climate-smart agriculture trials identified the baby corn-carrot-cowpea cropping system as the most productive and profitable, yielding 140% higher system productivity and 126% greater net returns than conventional rice-wheat systems.

The Division of Crop Improvement made significant advancements in salt-tolerant rice, wheat, mustard, and chickpea breeding. Three rice varieties, CSR 101, CSR 104, and CSR 105, were released for salt-affected soils in different states, while CSR 64 and CSR 92 were identified for alkaline soils of Uttar Pradesh. Several promising advanced rice lines are in national varietal trials, and QTL mapping identified key genomic regions for salt tolerance and yield traits. Additionally, novel salt-tolerant donor genes were identified, and crossing with elite varieties were initiated for further improvement. In wheat, two salt-tolerant varieties, KRL 423 and KRL 1803, were identified for sodic soils of Uttar Pradesh, and multiple breeding lines progressed under salinity trials. Breeder and nucleus seed production ensured the widespread availability of salt-tolerant wheat varieties, with impact assessments revealing extensive adoption and economic benefits. In mustard, several genotypes were developed and advanced in trials under sodic conditions, while candidate genes associated with salt tolerance were identified for further molecular breeding. Additionally, 1,000 recombinant inbred lines were maintained for genetic studies. In chickpea, salt-tolerant lines such as CSG-20-6 and CSG-21-1 showed superior yields and progressed in national trials. Furthermore, 330 recombinant inbred lines were evaluated under saline and sodic stress, with promising lines identified for future breeding. Efforts in fine mapping and NIL population development are ongoing to enhance genetic improvement.

The Division of Irrigation and Drainage Engineering made notable progress across multiple projects targeting sustainable water use, soil salinity management, and climate resilient agriculture. Under the DST-NWO HIROS project, improved sugarcane cultivation practices such as surface drip irrigation and fertigation with reduced agrochemical doses (Scenarios 3 and 5) showed significant improvements in water and nitrogen use efficiencies and crop yields. IrriWatch-based monitoring provided critical insights on crop water use and nutrient status. In the "Plant Direct" project, strategic irrigation scheduling in Direct Seeded Rice (DSR) demonstrated up to 35% water savings with only marginal yield variations, and PR 126 emerged as a high-yielding variety. Under the NEXUS Gains project, DSR saved ~4 cm water but recorded yield losses (2–18 q/ha) compared to conventional rice. The DST-PAU Centre studied climate change impacts in Kaithal, projecting significant temperature rises under various SSPs and variable rainfall patterns; a groundwater model showed good calibration and validation accuracy. In the soil salinization modelling project for Rohtak, EMI data and EM4Soil software helped map soil salinity across depths, identifying 1012 km^2 under moderate and 313 km^2 under strong surface salinity, with high soil texture variability. Finally, a low-cost real-time sensor was developed to measure soil moisture, temperature, and electrical conductivity using capacitance and resistance principles, showing good correlation ($R^2 = 0.67$) with standard methods.

The Division of Social Science Research has evaluated several technologies and interventions for improving livelihoods in challenging agro-ecosystems. A major assessment of Subsurface Drainage (SSD) showed significant yield gains—30.9% in wheat, 46.5% in paddy, and 62.4% in sugarcane—along with better soil health, higher organic carbon, and reduced salinity. The economic analysis estimated that SSD technology generated a combined surplus of Rs 84,780 million from increased production of paddy, wheat, and sugarcane. However, SSD adoption remains low (2.57% of affected land) due to limited equipment, funding, farmer awareness, and weak institutional support. Under agripreneurship, a survey of 70 farmers identified price volatility, high storage charges, poor planting material, and land degradation as key challenges. The Farmer FIRST project identified high-yielding wheat (DBW 371, DBW 303) and rice (PB 1509, PB 1692) varieties for saline soils in Haryana. Sustainable date palm cultivation was initiated through orchard establishment at six salt-affected sites across the state. Quinoa trials showed that early October sowing led to higher yields, while late sowing reduced productivity due to delayed harvests.

The Project Coordinating Unit undertook extensive groundwater surveys across various districts in India to assess irrigation water quality, focusing on salinity, sodicity, and chemical parameters. In Srikakulam and Vizianagaram districts of Andhra Pradesh, over 1,600 water samples were analyzed, revealing that 79–90% of samples were suitable for irrigation, although areas with marginal salinity and alkalinity were identified. In Rajasthan's Barmer and Jalore districts, significant spatial variation was recorded; in Barmer, only 26.32% of samples were classified as good, with high SAR saline and marginally saline waters were the major concern. Jalore presented a slightly better picture with 48.55% good quality water, but around 30% samples showed saline and high SAR saline categories. In Haryana's Gurugram district, 39.69% of samples were good, with nearly 25% affected by salinity or sodicity. In Tamil Nadu's Salem district, 66.5% of groundwater samples were good, though 20% were saline and 13% alkaline. Punjab's Sangrur district reported safe fluoride levels in most samples, but nitrate contamination was high in 47% samples. Field trials in Agra showed better yields and profitability under canal and mixed (canal-alkali) irrigation compared to alkali water alone. In Bapatla and Bikaner, alternate use of saline water under drip systems maintained yields of maize and fennel, respectively, indicating that strategic water blending and drip fertigation can mitigate impact of salinity. The potential of doruvu technology for sustainable water management was also observed in coastal areas.

At ICAR-CSSRI, Regional Station, Lucknow, substantial progress was achieved in crop improvement, sodic soil reclamation, and sustainable fruit production. A comprehensive collection of 121 millet genotypes from fifteen districts of Uttar Pradesh facilitated genetic evaluation aimed at crop diversification. For managing subsoil sodicity in partially reclaimed lands, soil amendments such as marine gypsum and sulfamic acid were assessed, where the surface application of marine gypsum (T3: 50 GR) significantly enhanced grain yield (4.62 t/ha) and reduced soil pH. In Bihar, using the salt-tolerant rice variety CSR 46 along with green manuring, pressmud, and cow manure with added microbes resulted in a 44.7% increase in yield, boosting both productivity and soil health. The screening of carbonate-dissolving bacterial isolates led to the development of a liquid bioformulation, "Halo-MridaSudharak," which has the potential for self-reclamation. Remote sensing and statistical modeling in the Sharda Sahayak Canal Command helped delineate 20,125 ha of sodic land in Barabanki. In parallel, natural farming trials revealed enhanced soil microbial activity. Salt harvesting using polythene-lined ponds proved effective, yielding 2.27 t/ha rice in sloped plots. Integrated Farming Systems (IFS) such as fish-vegetable-date palm and fish-horticulture-dairy models showed promise for income and resource cycling. In agroforestry trials, innovative planting systems like auger planting, open hydroponics, and microbial inputs improved survival and growth in fruit crops like apple ber, date palm, dragon fruit, and citrus.

At ICAR-CSSRI, Regional Station, Canning Town (West Bengal), extensive research was undertaken to address coastal salinity, land use dynamics, and climate resilience in the Indian Sundarbans. Spatio-temporal analysis using Landsat data (1973–2022) revealed a net erosion of 305.58 km^2 and accretion of 269.12 km^2. Land-use changes showed stable mangrove forests, while aquaculture, settlements, and double-cropped lands expanded at the cost of mono-cropped areas. Land surface temperature trends showed increasing variability, with single-cropped and fallow lands recording higher values. Climate modeling under SSP585 projected a rise of 1.3–2.1°C in temperature and 212–292 mm in rainfall by 2060. Risk assessments and a decision matrix informed intervention planning. Groundwater studies using vertical electrical sounding classified irrigation quality as C2/3S1. Biochar from local biomass showed promise in salt leaching. Salinity management trials with potato, sunflower, and okra under drip irrigation highlighted varietal tolerance and the role of straw mulch. Zero tillage potato, integrated homestead farming, and rice-based natural farming models improved productivity and resource use efficiency. Salt-tolerant rice genotypes like Nona Bokra and Canning 7 exhibited resilience. Ecosystem modeling of Matla estuary showed seasonal variation in fish abundance and plankton influenced by water quality. Aquaculture trials with Heteropneustes fossilis recommended stocking densities of 60,000–80,000/ha for optimal returns. Polyculture with Indian major carps yielded the highest B:C ratio (3.24).

The ICAR-CSSRI Regional Research Station, Bharuch (Gujarat), has been actively engaged in developing salt-tolerant technologies for improving crop productivity on saline Vertisols. A study on crack management using agricultural wastes revealed that water hyacinth @10 t/ha significantly reduced crack volume and enhanced soil carbon status. In mustard trials, application of 150% RDF and a nutrient package of K, S, and Zn recorded maximum yield and growth, while varieties CS-64 and CS-58 performed best in seed production under delayed sowing. Wheat breeding lines including KRL-2207 and SPLASN-10 exhibited high yield under salinity (ECe 6–7 dS/m). In maize, genotype IMR-15 showed superior tolerance across three salinity levels. A consultancy project with GNFC demonstrated that wheat irrigated with a 1:1 ratio of treated effluent and good quality water, along with 120–160 kg N/ha, yielded 3.15 t/ha without adverse soil effects. CSSRI also supported NDDB in designing subsurface drainage for salt-affected lands.

ICAR-CSSRI has launched several new initiatives aimed at enhancing climate resilience and sustainability in salt-affected agro-ecosystems. A collaborative project with FAO India focuses on transforming rice-wheat systems to promote sustainable food systems. Recognizing barley's high tolerance to sodicity, a new initiative on genetic improvement of barley aims to harness its potential for food security and export. Another project funded under the WTI Call 2023 is being initiated to develop a framework for saline water use through drip irrigation in vegetables. A subsurface drainage (SSD) project in sugarcane-growing saline Vertisols of Kolhapur aims to optimize drain spacing. RKVY-funded projects include groundwater recharge structures in Haryana and sustainable date palm cultivation in salt-affected soils. At Bapatla, mulching techniques and bacterial identification are being explored to enhance salinity tolerance and water use efficiency in paddy. The Bikaner centre is evaluating dragon fruit under saline irrigation. SERB-DST is funding a study on microplastic contaminants in agriculture, while another project investigates endophytic bacteria for salt stress mitigation in wheat. A consultancy project with NDDB Anand and the development of a package of practices for mustard in Bara tract, Gujarat, further augment these efforts. Additionally, biochar application is being explored for coastal salinity management. These efforts not only contribute to enhanced productivity and environmental sustainability, but also support livelihood security, diversification, income generation, and long-term climate resilience in of salt affected agro-ecosysetms.

Awards and Recognitions

The institute's scientists have earned prestigious national recognitions for their outstanding contributions. Dr. A.K. Bhardwaj received multiple honors, including NAAS Fellowship and the Dr. JSP Yadav Memorial Award. Dr. Ram K. Fagodiya and Nitish Ranjan Prakash were conferred Young scientist awards, while Dr. Suresh Kumar and Jogendra Singh were elected NAAS Associate and FSRMR Fellow, respectively. Dr. A.K. Dubey and Dr. Sanjay Arora were also awarded for excellence in horticulture and agricultural science.

Conference/Workshops organized

- Conducted the 28th Biennial AICRP Workshop and hands-on training on IrriWatch advisory services for sugarcane farmers and mill staff in Uttar Pradesh.
- Held high-level meetings under the HOPP project on vertical drainage and reclamation strategies for waterlogged saline areas in Haryana with state department officials.
- Organized stakeholder and review workshops at Canning Town under CGIAR's Asian Mega Deltas project, promoting climate-resilient agriculture in the Ganges delta.
- Facilitated discussions with Narmada Control Authority and Gujarat engineers to address salinity and sodicity in the Sardar Sarovar Canal command area.

Exhibition and Field Visits

During 2024, a total of 2333 stakeholders including 603 farmers, 1590 students, 121 trainee, 17 extension workers and 12 scientists from India and abroad visited Institute Technology Information Centre and experimental farms to learn about the technologies commercialized and being developed.

Farmers' Advisory Services

During the year 2024, a total of 102 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 192 farmers associated through WhatsApp groups with the institute.

Capacity building

ICAR-CSSRI organized 23 diverse training programmes in 2024, 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 27 capacity building trainings, 4 demonstrations and 3 Goshthis were organized for 283 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)

Technologies development

ICAR-CSSRI developed 11 new technologies and were certified by The ICAR, New Delhi. These include Rice+Veg Technology for intercropping in waterlogged paddy fields, Rapid Acidulated Manure (RAM), enriched municipal solid waste compost, and long-term conservation agriculture practices for sodic soil management, Ion Exchange Resin Technique (IERT), CSM 21 germplasm of Melia dubia, Sulphuric acid based chemical amendments, gypsum-CWC-based reclamation protocol, and soil salinity mapping of coastal regions.

Partnerships with industries/startups/FPOs/International organizations

ICAR-CSSRI has established 31 partnerships through MoUs with industries, startups, FPOs, and international organizations. Key collaborators include GNFC, IFFCO, NABARD, NTPC, Reliance Industries, and Heidelberg Cement. International collaborations involve JIRCAS, JICA, CIMMYT, IRRI, and AARDO. Partnerships also extend to government bodies like the Govt. of Haryana and various FPOs and CHCs across Punjab, Haryana, Rajasthan, and Uttar Pradesh.

Publications

The Institute published 107 research papers in reputed national and international journals. Additionally, 38 books/manuals/chapters and 50 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.

Resource generation Seed Production

During the year, the institute generated a total revenue of ₹1.04 crore. Major contributions came from farm produce and seed sales (₹91.6 lakh), followed by analytical testing fees (₹5.35 lakh), and contract research (₹5.55 lakh). Additional income was earned through fees and miscellaneous sources. Institute also produced 109.36 q of breeder seed and 458.1 q of TL seed of salt-tolerant varieties including rice (CSR30, CSR56, CSR60), wheat (KRL210, KRL213, KRL283), mustard (CS58, CS60), and chickpea (Karnal Chana-1).

Financial Status

During the financial year 2024–25, the institute utilized its entire recurring budget of ₹4955.10 lakhs. This included major heads like salaries (₹2995.78 lakhs), pensions (₹1059.50 lakhs), and general expenses (₹684.40 lakhs). Under the non-recurring component, 172.86 lakhs were utilized, mainly towards works, equipment, IT, and library resources.

Introduction

Historical Perspective

ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) is a premier research institute dedicated to pursue interdisciplinary researche 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, Bapatala, Bikaner, Gangawati, Hisar, Indore, Kanpur and Tiruchirapalli). In 2014, four new voluntary centres have started functioning at Bathinda (Punjab), Panvel (Maharastra), Vytilla (Kerela) and Port Blair (Andaman & Nicobar Islands).

Over the years, Institute has grown into an internationally recognized 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.

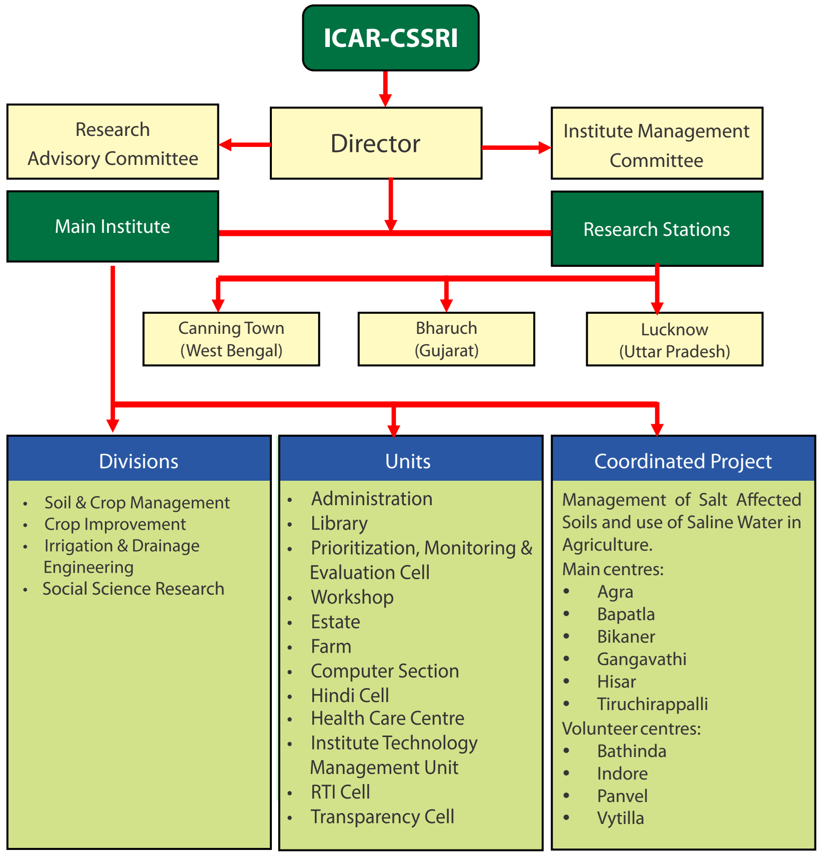
Mandate

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, laser leveler, tractors, hydraulic trolley, cleaner, shrub master, maize thresher, Straw bailer, Riper binder, Jet sprayer, Rotavator, bund maker and lawn mower etc. are available; most of farm operations are mechanized. To achieve the optimization of water and other inputs, all the plots are precisely leveled with laser leveler at regular intervals. Combination of different cropping system is being practiced to optimize the land use in the farm. Experimental crops are grown on 22.34 ha area, while general crops and orchards are grown in 20.8 ha, which also includes the 8.8 ha area under seed production mainly of salt tolerant varieties of rice and wheat. A seed processing plant is also installed

Productivity of crops at CSSRI farm

Crop	Variety	Average yield (t ha^{-1})
	Rabi 2023 - 24	
Wheat#	*KRL-210*	*5.21*
	KRL-213	*4.60*
	KRL-283	*4.47*
*Mustard**	*CS 58*	*1.38*
	CS 60	*1.86*
	CS 56	*1.30*
	CS 54	*1.02*
Chick Pea#	*Karnal chana 1*	*1.39*
	Kharif 2024	
Paddy#	CSR 30	2.82
	CSR 56	6.45
	CSR 60	3.38

*Breeder Seed Production

#TL Seed production

to provide quality of seed of salt tolerant varieties to the farmers. During the period under report, the farm unit generated revenue of Rs. 85 lakh. To reduce the emission of green house gases, most of area has been put under minimum tillage and residue burning is not practiced in the farm. Agro-forestry system is practiced on 6.2 ha area of the farm, where multipurpose tree species have been planted in combination with arable crops of the region. The area under fruit crops such as 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/CSSRIonline

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

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

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 2024-25 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)	215.22	-	-	215.22
Establishment Expenses (grant in aid-salaries)	2995.78	-	-	2995.78
Grant in aid general	1743.90	-	-	1743.90
Grand Total	4954.90	-	-	4954.90
Loan and advance	NIL	-	-	NIL

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	60	21	25.93
Technical	117	81	36	30.77
Administrative	55	26	29	52.73
Skilled Supporting Staff	48	9	39	81.25
Total	**301**	**176**	**125**	**41.53**

Library

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e-Services

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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

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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

Mapping and Characterization of Salt Affected Soils in Uttar Pradesh using Remote Sensing and GIS (A.K. Mandal, Arijit Burman, R.K. Yadav, P.C. Sharma, V.K. Mishra, Sanjay Arora, Sunil Jha and M.J. Kaledhonkar)

In the present study, to characterize, assess and map salt affected soils of Gujarat state using remote sensing and GIS, total number of soil samples were collected from 1579 geo-reference points in different districts of Gujarat using auger upto a soil depth of 120 cm with an interval of 0-15cm, 15-30 cm, 30-60 cm, 60-90 cm, and 90-120 cm. These soil samples were analysed for pH_2, EC_2, pHs and ECe, soluble cations (Ca, Mg, Na and K) and soluble anions (Cl, SO_4, CO_3 and HCO_3). SAR is estimated using standard formula to know the sodicity status of these soils. The data showed the predominance of subsurface salinity. Data on soil pHs analysis showed that large number of samples fall under 8.0 to 9.0 pH category and soil pH increased with depth. The data on soluble cation and anions revealed that among cations the dominance of Na^+ followed by Mg^{2+}, Ca^{2+}, and K^+ and among anions $Cl^- > SO_4^{2-} > CO_3^{2-} > HCO_3^-$. Among the soluble cations, sodium is dominant among all cations and chloride is dominant among anions. Geo-coordinated soil samples collected from the districts of Gujarat and its descriptive statistics are given (Table 1.1) to get an idea about degree and intensity of salinity and dominant nature of salts present. Zone-wise extent and distribution of salt affected soils in Gujarat and its relative status

Table 1.1 pH, EC and soluble cations and anions of soils of different districts of Gujarat

Number of samples		EC_2, dS/m	pH_2	EC_e, dS/m	pH_s	Ca (me/l)	Mg (me/l)	Na (me/l)	K (me/l)	CO_3 (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	SO_4^{2-} (me/l)
District Ahmedabad													
No of sample points 40	Mean	3.33	8.21	7.26	7.78	9.97	15.69	102.33	0.48	0.93	1.60	58.65	4.22
	Maximum	71.00	9.82	165.00	9.04	260.00	445.00	4683.04	21.82	2.50	11.25	985.00	35.14
	Minimum	0.06	6.63	0.23	6.46	0.00	0.50	0.20	0.01	0.00	0.00	2.50	0.00
	SD	8.87	0.60	19.67	0.50	29.07	48.51	414.52	2.01	0.49	1.89	158.04	5.61
District Amreli													
No of sample points 97	Mean	1.53	8.48	5.54	7.65	9.98	10.41	58.98	0.42	0.48	0.04	64.56	3.57
	Maximum	50.40	10.30	164.90	9.11	602.0	498.00	3216.96	22.60	0.50	0.75	2670.00	39.65
	Minimum	0.07	7.33	0.18	6.03	0.50	1.00	0.50	0.00	0.00	0.00	5.00	0.00
	SD	5.14	0.44	20.40	0.56	46.44	34.72	292.47	2.13	0.10	0.12	289.00	6.65
District Anand													
No of sample points 9	Mean	0.40	8.12	1.48	7.52	2.14	3.29	7.50	0.05	0.97	1.21	7.22	1.32
	Maximum	2.30	9.30	9.80	8.40	14.00	17.00	35.97	0.17	2.50	4.00	45.00	6.19
	Minimum	0.06	6.12	0.38	5.62	1.00	1.00	1.34	0.02	0.50	0.25	2.50	0.00
	SD	0.39	0.60	1.53	0.53	2.11	2.50	6.51	0.03	0.48	0.65	7.00	1.04
District Banaskantha													
No of sample points109	Mean	1.33	8.53	5.48	7.99	8.96	10.97	51.35	0.34	0.65	1.18	54.91	4.42
	Maximum	45.87	10.15	168.30	9.33	915.00	835.00	3503.91	15.84	3.00	5.50	2300.00	43.51
	Minimum	0.03	7.15	0.16	6.26	0.50	0.00	0.60	0.01	0.00	0.00	5.00	0.00
	SD	3.96	0.48	15.88	0.46	44.47	46.81	222.78	1.02	0.44	0.79	188.10	8.50
District Bharuch													
No of sample points 90	Mean	3.84	8.34	9.10	7.74	7.66	13.83	63.33	0.96	4.27	2.66	69.97	5.25
	Maximum	63.00	9.66	154.00	9.25	287.00	312.00	1509.13	46.67	21.00	14.00	1875.00	43.70
	Minimum	0.03	6.28	0.22	4.00	0.50	0.00	0.09	0.00	0.00	0.00	1.50	0.00
	SD	8.46	0.53	19.85	0.54	21.05	36.57	163.34	3.21	3.16	2.64	182.67	8.06
District Bhavnagar													
No of sample points 102	Mean	5.95	8.18	13.22	7.71	11.39	32.03	194.47	3.87	0.87	0.71	161.79	7.01
	Maximum	72.00	9.85	165.00	9.25	152.50	1080.00	4338.26	171.82	17.50	12.75	4200.00	63.19
	Minimum	0.07	6.96	0.18	6.36	0.50	1.00	0.50	0.00	0.00	0.00	2.50	0.00
	SD	13.65	0.46	28.45	0.40	21.89	93.61	594.52	19.71	1.18	1.35	437.87	11.03

Number of samples		EC_2, dS/m	pH_2	EC_e, dS/m	pH_s	Ca (me/l)	Mg (me/l)	Na (me/l)	K (me/l)	CO_3 (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	SO_4^{2-} (me/l)
District Jamnagar													
No of sample points 140	Mean	4.51	8.23	11.78	7.73	16.19	26.45	129.33	1.78	1.29	3.79	198.52	136.20
	Maximum	116.00	9.59	163.00	9.48	375.00	694.00	3886.96	109.18	9.00	163.25	5350.00	1236.04
	Minimum	0.09	7.00	0.28	6.24	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.13
	SD	12.50	0.43	24.80	0.40	41.62	76.39	440.20	10.03	1.12	8.85	640.66	248.77
District Junagadh													
No of sample points 59	Mean	1.76	8.37	5.30	7.47	11.10	11.19	49.06	0.20	0.39	0.09	57.41	4.08
	Maximum	35.79	9.02	157.00	9.60	602.00	214.00	3216.96	6.38	1.00	0.50	2335.00	42.79
	Minimum	0.09	7.51	0.14	6.12	0.50	0.50	0.04	0.00	0.00	0.00	5.00	0.00
	SD	4.42	0.28	14.75	0.70	43.99	29.71	233.91	0.66	0.27	0.15	200.58	6.19
District Kheda													
No of sample points 22	Mean	7.58	8.20	15.51	7.83	15.08	31.53	216.98	1.55	1.34	3.27	138.75	3.58
	Maximum	63.00	9.35	120.00	8.54	110.00	280.00	2139.57	19.28	4.00	21.25	947.50	20.25
	Minimum	0.13	6.83	0.39	6.90	0.50	1.00	0.69	0.02	0.50	0.00	2.50	0.60
	SD	14.05	0.43	27.13	0.37	25.24	62.84	455.45	3.54	0.65	4.89	250.18	3.71
District Kutch													
No of sample points 376	Mean	5.66	7.92	16.58	7.14	16.85	30.83	208.17	1.70	0.95	2.43	183.21	59.27
	Maximum	147.60	10.48	200.00	9.95	343.50	715.00	8178.26	162.23	11.00	32.75	4330.00	1091.63
	Minimum	0.01	6.70	0.20	6.03	0.50	-0.50	0.00	0.00	0.00	0.00	2.50	0.00
	SD	10.17	0.56	25.69	0.58	29.12	57.80	515.78	5.63	0.84	3.08	361.14	176.58
District Mehsana													
No of sample points 77	Mean	0.79	7.78	2.28	7.48	3.97	5.79	25.04	0.10	0.72	0.76	16.36	2.53
	Maximum	26.00	9.39	74.00	8.94	195.00	170.00	1438.26	2.41	2.50	15.00	580.00	20.08
	Minimum	0.02	6.06	0.17	6.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	SD	2.85	0.69	6.65	0.46	14.91	16.46	131.94	0.23	0.41	1.33	50.03	3.00
District Narmada													
No of sample point 1	Mean	0.28	7.94	0.97	7.76	1.67	3.33	2.16	0.06	4.67	0.67	6.00	1.13
	Maximum	0.33	8.06	1.37	7.83	2.00	4.50	2.95	0.08	6.00	1.00	7.50	1.30
	Minimum	0.21	7.84	0.71	7.68	1.00	2.50	1.73	0.04	4.00	0.50	5.00	1.03
	SD	0.05	0.09	0.29	0.06	0.47	0.85	0.56	0.02	0.94	0.24	1.08	0.12
District Navsari													
No of sample points3	Mean	10.35	8.15	22.59	7.56	16.65	34.35	105.20	4.02	0.98	1.12	165.25	37.92
	Maximum	42.00	8.40	92.00	7.74	84.00	176.00	367.83	11.31	2.00	7.45	580.00	98.08
	Minimum	0.47	7.73	0.96	7.04	1.00	2.00	1.00	0.03	0.00	0.00	5.00	1.84
	SD	13.34	0.19	29.16	0.19	23.90	50.00	137.14	5.02	0.87	1.89	207.79	42.75
District Patan													
No of sample points 94	Mean	5.23	8.29	16.52	7.63	19.01	44.55	309.39	0.48	0.67	1.46	236.03	10.65
	Maximum	82.00	9.72	184.50	9.03	475.00	830.00	7282.61	23.28	5.00	33.50	5000.00	59.17
	Minimum	0.03	6.36	0.25	6.18	0.50	0.50	0.31	0.00	0.00	0.00	2.50	0.00
	SD	10.79	0.66	33.64	0.57	46.60	111.74	902.13	1.58	0.55	1.88	601.78	14.12
District Porbander													
No of sample points28	Mean	2.45	8.11	7.41	7.47	14.81	12.12	46.05	0.21	0.21	0.57	76.73	11.22
	Maximum	18.84	10.13	69.96	9.64	281.50	54.00	662.61	1.52	4.00	5.50	825.00	67.12
	Minimum	0.15	7.00	0.40	6.65	0.50	1.00	0.89	0.00	0.00	0.00	10.00	0.38
	SD	3.33	0.53	11.11	0.49	30.80	13.68	89.05	0.25	0.57	0.75	116.99	13.26
District Rajkot													
No of sample points 74	Mean	2.91	8.18	7.67	7.65	9.62	16.10	60.01	0.41	1.60	5.42	92.28	20.94
	Maximum	117.00	9.21	175.00	8.76	186.50	262.00	3033.91	10.72	8.00	163.25	4515.00	994.43
	Minimum	0.02	7.24	0.25	6.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SD	9.69	0.37	18.79	0.34	19.30	30.82	234.33	1.53	1.34	12.61	369.94	95.27
District Surat													
No of sample points 68	Mean	4.33	8.12	8.12	7.45	8.83	11.71	84.40	0.79	1.63	1.59	80.72	2.64
	Maximum	62.00	9.32	139.00	8.68	169.00	265.50	1780.43	22.25	9.00	6.50	2025.00	31.40
	Minimum	0.06	6.60	0.09	5.95	0.50	0.00	0.37	0.00	0.00	0.00	1.00	0.00
	SD	11.36	0.47	20.31	0.44	19.36	27.88	254.60	2.26	1.22	1.24	227.83	4.02
District Surendranagar													
No of sample points 161	Mean	3.83	8.15	10.45	7.72	10.80	19.04	156.08	0.45	0.68	0.94	111.11	11.01
	Maximum	63.00	9.77	213.20	79.34	599.00	672.00	6365.22	30.28	7.00	8.50	3405.00	64.08
	Minimum	0.01	6.98	0.27	0.89	0.00	0.00	0.20	0.01	0.00	0.00	2.50	0.00
	SD	8.60	0.60	23.01	4.68	32.52	53.43	542.74	2.03	0.64	1.08	328.57	14.26

Number of samples		EC_2, dS/m	pH_2	EC_e, dS/m	pH_s	Ca (me/l)	Mg (me/l)	Na (me/l)	K (me/l)	CO_3 (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	SO_4^{2-} (me/l)
District Tapi													
No of sample points 9	Mean	0.26	7.71	0.55	6.79	1.10	1.81	1.76	0.03	1.07	1.17	3.53	8.31
	Maximum	0.50	8.48	1.13	7.58	2.00	3.50	5.03	0.20	3.00	4.50	7.50	12.34
	Minimum	0.08	6.48	0.24	5.36	0.50	1.00	0.33	0.01	0.00	0.00	2.50	4.52
	SD	0.13	0.53	0.24	0.61	0.47	0.69	1.08	0.03	0.92	1.07	1.57	1.56
District Vadodara													
No of sample points 20	Mean	0.38	8.11	0.85	7.51	1.42	2.40	3.66	0.06	1.66	1.53	8.58	1.72
	Maximum	1.23	9.26	8.90	8.15	6.00	15.00	26.10	0.39	7.00	4.50	40.00	9.18
	Minimum	0.05	6.55	0.12	6.38	0.00	0.50	0.41	0.01	0.00	0.00	2.50	0.00
	SD	0.24	0.45	0.98	0.30	0.83	1.81	3.78	0.05	1.16	1.12	5.80	2.3
District Valsad													
No of sample points 18	Mean	18.58	7.86	42.78	7.60	34.21	57.77	533.18	3.92	1.68	1.50	452.93	0.96
	Maximum	55.00	8.80	123.00	8.30	169.00	218.00	4203.91	11.93	6.50	7.25	1225.00	2.21
	Minimum	0.13	6.77	0.65	6.34	1.00	1.50	0.40	0.04	0.50	0.00	10.00	0.11
	SD	15.27	0.35	32.49	0.34	35.63	52.20	654.18	3.45	1.27	1.09	372.05	0.55

Table 1.2 District-wise extent (ha) of salt affected soils of Saurashtra Region of Gujarat

Sr. No	Saurashtra Gujarat	Saline Soils 2024(1996)	Sodic Soils 2024(1996)	Saline-Sodic Soils 2024(1996)	Total 2024 (1996)	Remarks
1	Devbhhomi Dwarka	189794.2	54346.8	45998.25	290139.28	Split from Jamnagar.
2	Jamnagar	436522.06 (82389)⇑	2028.2 (13389)⇓	87942.1	526492.36 (95778) ⇑	~5 times increase in salinity and total SAS. Need to check accuracy and also reason
3	Morbi	246450.6	4354.83	60684.82	311490.23	Split from parts of Rajkot and Surend ranagar districts.
4	Rajkot	258879.73 (57634)⇑	6827.92 (0)⇑	22796.16	288503.81 (57634) ⇑	~4 times increase in area. Need to check accuracy and also reason
5	Porbandar	165600.48	413.64	19655.13	185669.25	split from Junagadh
6	Junagadh	206171.19 (39800) ⇑	3961.3 (69358)⇓	9425.93	219558.42 (109158) ⇑	~5 time increase in saline area, ~17 times decrease in sodic area and ~2 times increase in total SAS-needs to be checked.
7	Gir Somnath	35238.63	2960.48	1305.57	39504.68	Split from Junagadh
8	Amreli	70026.01 (42952) ⇑	10712.63 (0) ⇑	1782.25	82520.89 (42952) ⇑	~2 times increase in saline and total salt affected area and sodicity formation is seen. Reason for the same may change in cropping pattern and use of injudicious use of irrigation water
9	Bhavnagar	65282.27 (78414) ⇑	8223.99 (21249) ⇓	11803.02	85309.68 (99663) ⇓	Split to Botad and decrease in seen in total salt affected area as compared to the data i the year 1996
10	Botad	29556.35	4704.81	1818.87	36080.03	Split from Bhavnagar and Ahmedabad
11	Surendranagar	186316.8 (135170) ⇑	34606.7 (98259) ⇓	23628.65	244552.22 (233429)⇑	Split to Morbi, Saline area increase and sodic area decreased, total SAS increase

Fig 1.1Regionwise extent ('000 ha) of salt affected soils in Gujarat

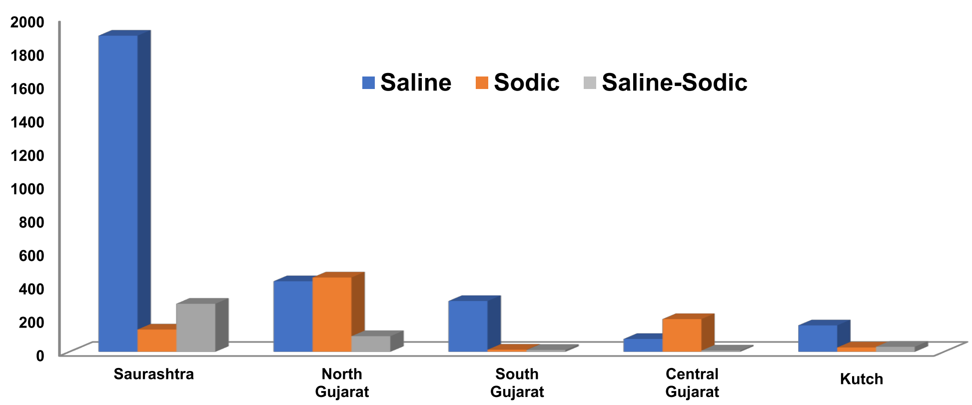


Table 1.3 District-wise extent (ha) of salt affected soils of North Region of Gujarat

Sr. No	North Gujarat	Saline Soils 2024 (1996)	Sodic Soils 2024 (1996)	Saline-Sodic Soils 2024 (1996)	Total 2024 (1996)	Remarks
1	Ahmedabad	110497.1 (161479)	15555.7 (116428)	15250.32	141303.14 (277907)	Extent of saline, sodic and total SAS is decreased as compared to the estimate in the year 1996.
2	Aravalli,	5476.87	55594.9	1086.16	62157.96	The reason for saline, sodic and saline-sodic area is due to increase in irrigated agriculture by using saline ground water and change of cropping pattern. Cultivation of vegetables is increased during last five to six years and also potato cultivation is also increased.
3	Banaskantha	139090.8 (211722)	213580.9 (83240)	35641.38	388313.1 (294962)	Saline area is decreased, sodic area is increased and overall total area is increased as compared to the data from the year 1996.
4	Gandhinagar	7168.18	27251.3	1043.36	35462.81	It was formed from parts of Ahmedabad and Mehsana
5	Patan	137508.1	43590.5	35813.76	216912.31	It was formed from parts of Banaskantha and Mehsana
6	Mahesana	8541.45 (117684)	25214.6 (126077)	948.95	34705.01 (243761)	Drastic reduction in extent of saline, sodic SAS. Part of this district goes to and total Patan disrict.
7	Sabarkantha	13185.74	63185.8	3302.24	79673.77	

Table 1.4 District-wise extent (ha) of salt affected soils of Central Region of Gujarat

Sr. No	Central Gujarat	Saline Soils 2024 (1996)	Sodic Soils 2024 (1996)	Saline-Sodic Soils 2024 (1996)	Total 2024 (1996)	Remarks
1	Anand	20725.25	32683.77	1973.11	55382.13	It was split from Kheda district. Sodic soils are more than saline soils. Reason for salt affected soils may be from injudicious use of canal water without proper drainage and other water management options.
2	Chhota Udaipur	4502.91	9074.29	359.56	13936.76	It was split from Vadodara district. Salinity and sodicity may be from saline ground water irrigation in the district
3	Dahod	2752.8	23352.97	512.01	26617.78	It was split from Panchmahal district. Salinity and sodicity from injudicious use of groundwater for irrigation
4	Kheda	16017.76 (37852)	77060.86 (0)	2452.93	95531.55 (37852)	Saline area decreased and sodic area increased as compared to the earlier estimate in the year 1996
5	Mahisagar	2602.23	22129.95	385.17	25117.35	It was created from parts of Kheda and Panchmahal districts. This district also exhibiting saline and sodic soils.
6	Panchmahal	6462.98	14691.35	663.47	21817.8	This district also exhibiting saline and sodic soils.
7	Vadodara	23376.26 (3863)	16284.88 (0)	798.57	40459.71 (3863)	Total extent increased as compared to the earlier estimate in the year 1996 and reason may be use of saline ground water and injudicious use of canal water for irrigation without scientific water management and without drainage.

Table 1.5 District-wise extent (ha) of salt affected soils of South Region of Gujarat

Sr. No	South Gujarat	Saline Soils 2024(1996)	Sodic Soils 2024(1996)	Saline-Sodic Soils 2024 (1996)	Total 2024 (1996)	Remarks
1	Surat	68349.21 (26287)	1498.34 (0)	844.02	70691.57 (26287)	SAS area increased. Coastal salinity may be reason
2	Bharuch	131642.8 (62561)	4793.06 (0)	8101.32	144537.18 (62561)	SAS area increased. Use injudicious use of canal water for irrigation.
3	Narmada	2819.13	2800.18	147.21	5766.52	Split from Bharuch district
4	Navsari	36980.85	221.6	391.92	37594.37	Split from Valsad district
5	Dang	11985.68	1100.87	16.54	13103.09	High rainfall area. District is declared as natural farming
6	Valsad	35049.94 (15427)	1275.26 (0)	605.02 (15427)	36930.22	All area increased. Sea coast salinity.
7	Tapi	16475.62	793.78	507.62	17777.02	Split from Surat district

Table 1.6 District-wise extent (ha) of salt affected soils of Kutch Region of Gujarat

Sr. No	Kutch Gujarat	Saline Soils 2024 (1996)	Sodic Soils 2024 (1996)	Saline-Sodic Soils Soils	Total 2024 (1996)	Remarks
1	Kutch	157578.47 (607336)	25697.8 (13430)	29725.15	213001.38 (620766)	~3 times decrease in saline as well as total SAS and sodic area increased 2 times as compared to the earlier estimate in the year 1996

Table 1.7 Extent and distribution of salt affected soils of Gujarat

SN	District	Saline area (ha)	Sodic area (ha)	Saline-Sodic area (ha)	Total SAS (lakh ha)
1.	Ahmadabad	110497	15555.7	15250.3	1.41
2.	Ameli	70026	10712.6	1782.25	0.83
3.	Anand	20725.3	32683.8	1973.11	0.55
4.	Bharuch	131643	4793.06	8101.32	1.45
5.	Junagadh	206171	3961.3	9425.93	2.2
6.	Kachchh	157578	25697.8	29725.2	2.13
7.	Navsari	36980.9	221.6	391.92	0.38
8.	Porbandar	165600	413.64	19655.1	1.86
9.	Rajkot	258880	6827.92	22796.2	2.89
10.	Surat	68349.2	1498.34	844.02	0.71
11.	Vadodara	23376.3	16284.9	798.57	0.4
12.	Valsad	35049.9	1275.26	605.02	0.37
13.	Jamnagar	436522	2028.2	87942.1	5.26
14.	Gir Somnath	35238.6	2960.48	1305.57	0.4
15.	Bhavnagar	65282.3	8223.99	11803	0.85
16.	Morbi	246451	4354.83	60684.8	3.11
17.	Devbhoomi Dwarka	189794	54346.8	45998.3	2.9
18.	Banas Kantha	139091	213581	35641.4	3.88
19.	Dohad	2752.8	23353	512.01	0.27
20.	Gandhinagar	7168.18	27251.3	1043.36	0.35
21.	Kheda	16017.8	77060.9	2452.93	0.96
22.	Mahesana	8541.45	25214.6	948.95	0.35
23.	Narmada	2819.13	2800.18	147.21	0.06
24.	Panch Mahals	6462.98	14691.4	663.47	0.22
25.	Patan	137508	43590.5	35813.8	2.17
26.	Sabar Kantha	13185.7	63185.8	3302.24	0.8
27.	Surendranagar	186317	34606.7	23628.7	2.45
28.	The Dangs	11985.7	1100.87	16.54	0.13
29.	Tapi	16475.6	793.78	507.62	0.18
30.	Chhota Udaipur	4502.91	9074.29	359.56	0.14
31.	Mahisagar	2602.23	22130	385.17	0.25
32.	Aravalli	5476.87	55594.9	1086.16	0.62
33.	Botad	29556.4	4704.81	1818.87	0.36
	Total	**2848629**	**810573.9**	**427410.5**	**40.89**
	Total (Mha)	**2.85**	**0.81**	**0.42**	**4.09**

with reference to its extent recorded in the year 1996 is given in the table 1.2 (for Saurashtra region), table 1.3 (for North region), table 1.4 (for Central region), table 1.5 (for South region) and table 1.6 (for Kutch district). Table 1.7 depicts the overall extent and distribution of salt affected soils in Gujarat. Region wise graphical presentation of salt affected soils is presented in figure 1.1.

Reclamation and Management of Alkali Soils

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

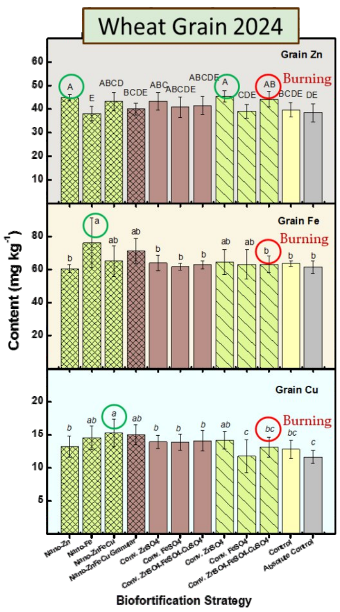


Fig 2.1 Effect of different bio-fortification strategies on the micro-nutrient concentrations in wheat grain during 2024

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. Four formulations of micronutrients for Zinc, Iron, and Copper have been 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 the particle size of 15-20 nm as confirmed with Litesizer 500 nanoparticle size analyzer and Transmission Electron Microscope. The objective of the project is to compare the performance of micronutrient fertilizer forms, conventional and nano, on the biofortification and to understand the effect of 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. FeSO4 + Conv. $CuSO_4$ (soil application of Conv. $ZnSO_4$ + Conv. $FeSO_4$ + Conv. $CuSO_4$ @30 kg acre^{-1}), 8) Foliar Conv. $ZnSO_4$ (foliar application of Conv. $ZnSO_4$ 0.5% solution), 9) Foliar Conv. $FeSO_4$ (foliar application of Conv. FeSO4 0.5% solution), 10) Foliar Conv. ZnSO4 + Conv. $FeSO_4$ + Conv. $CuSO_4$ (foliar application of Conv. $ZnSO_4$ + Conv. $FeSO_4$ + Conv. $CuSO_4$ 0.5% solution), 11) Control (no micronutrient fertilizers applied), and 12) Absolute Control (no macronutrient or micronutrient fertilizer applied). Foliar application of fertilizer materials was at 30, 45, and 60 days after rice transplanting and 60, 75, and 90 days after wheat sowing. The improvement in Zn, Fe, and Cu content in wheat grain was achieved in the foliar application of different nano fertilizers, compared to soil and foliar application of different convention fertilizers. Biofortification strategies using different forms of micronutrients

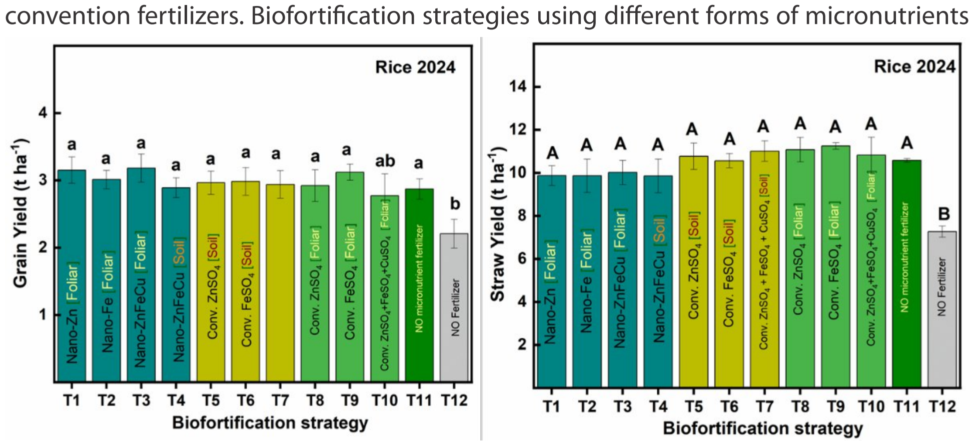


Fig 2.2 Effect of different biofortification strategies on the grain yield of rice during the 2024 season

improved the nutrient profile of the grain (Fig 2.1). Biofortification strategies using different forms of micronutrients improved the nutrient profile of the grain and straw with variable responses in rice and wheat. Nano-formulation can be efficient fortifiers of micronutrients. Favorable yield responses were noted yet varied with crop and season. Burning symptoms with foliar application of conventional sulphate forms was noted in wheat and reflected in yield loss (Fig 2.2).

Climate change mitigation and adaptation strategies for salt affected soils (Ajay Kumar Bhardwaj, Raj Kumar, Parvender Sheoran and Uttam Kumar Mandal)

Nitrogen (N) is a critical nutrient for plant growth, and its deficiency can significantly hinder crop development and reduce yields. To meet the nitrogen requirements of crops, farmers globally apply over 118 million metric tons of nitrogen fertilizers each year. Most agricultural soils and cropping systems worldwide face nitrogen deficiency, necessitating the use of supplemental fertilizers to maintain optimal productivity. However, more than half of the applied nitrogen is lost to the environment due to inefficiencies in application, often leading to excessive use to compensate for these losses, which may not always align with plant demand. The application of nitrogen fertilizers contributes to environmental concerns, including greenhouse gas emissions through nitrous oxide (N_2O) release and water contamination due to nitrate (NO_3^-) leaching into surface and groundwater sources. To mitigate these losses while improving nitrogen use efficiency (NUE), advanced fertilizers with controlled release mechanisms and precision application methods—such as foliar application—are gaining prominence. Among these innovations, nano-fertilizers, characterized by particle sizes below 100 nm, are emerging as a promising solution to enhance nutrient uptake, minimize losses, and reduce dependency on conventional fertilizers. Nano urea, a nanotechnology-based nitrogen fertilizer developed by the Indian Farmers Fertilizer Cooperative Limited (IFFCO), has been introduced for agricultural use in India and globally. Research indicates that nano urea improves nitrogen availability to crops by over 80%, leading to increased NUE. Its foliar application offers a more efficient alternative to conventional prilled urea, potentially reducing nitrogen losses from agricultural fields and minimizing environmental impact. By replacing or supplementing soil-applied nitrogen with foliar nano urea, crops can receive nitrogen more effectively, aligning with their growth demands. With these considerations in mind, field experiments have been initiated at the Central Soil Salinity Research Institute (CSSRI), Karnal, India. These trials aim to evaluate the effectiveness of nano urea in combination with prilled urea and precision application techniques, with the goal of formulating sustainable fertilizer management strategies for the rice-wheat cropping system. The experiment had ten treatments in total: four treatments with replacement of prilled urea by nano-urea, namely, 33 % replacement (R33), 50 % replacement (R50), 66 % replacement (R66), 100 % replacement (R100); two augmentation treatments namely, replacement to 50% augmented with micronutrient application (A-R50+µn), and replacement to 50% augmented with micronutrients, biofertilizer, and seaweed fertilizer (A-R50+µn+Bio); two precision-scheduling treatments namely, application of nano urea based on leaf color chart (LCC) values after two doses (1 basal and 1 top dress) of prilled urea (M-LCC), and application of nano-urea based on green seeker (GS) values after two doses (1 basal and 1 top dress) of prilled urea (M-GS). Two control treatments included '100% recommended N through prilled urea' (R0; no replacement), and 'no N fertilizer at all' (No-N) treatment.

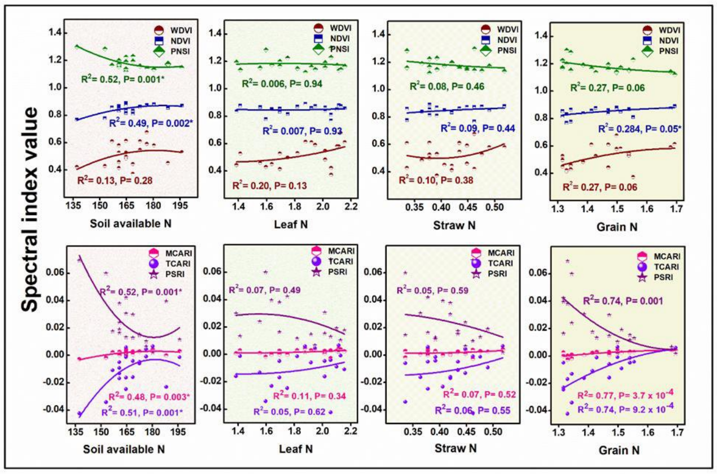


Fig 2.3 Relationship of different spectral indices with soil, leaf, straw and grain nitrogen

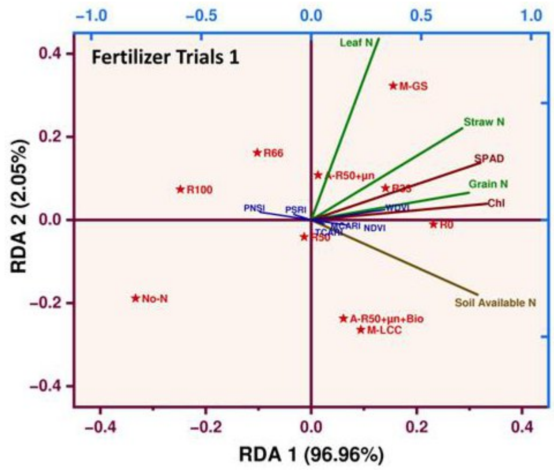


Fig 2.4 Redundancy Analysis (RDA) of the relationship between different variables

Studies were done to integrate canopy-spectra guided assessment into the development of soil-foliar hybrid fertilization strategies. the correlation between spectral reflectance indices, namely WDVI, NDVI, PNSI, MCARI, TCARI, and PSRI, calculated at specific wavelengths, with soil available N, leaf N, straw N and grain yield was tested. The soil available N varied from 135 to 195 kg ha^{-1} with respect to spectral index value varied from -0.04 to 1.4. The highly linearly correlation were recorded between spectral index value and vegetation index (PNSI, NDVI, MCARI, TCARI and PSRI), while non-linearly correlation was obtained with WDVI for soil available N. Among the vegetative index, PNSI (R^2=0.52, P= 0.001) and PSRI (R^2=0.52, P= 0.001) having highest correlation coefficient with respect to spectral index value. The sequence of correlation between spectral index value and vegetation index is, PNSI (R^2=0.52, P= 0.001) > PSRI (R^2=0.51, P= 0.001) > TCARI (R^2=0.51, P= 0.001) > NDVI (R^2=0.49, P= 0.002) > MCARI (R^2=0.48, P= 0.003) > WDVI (R^2=0.13, P= 0.28)

Redundancy Analysis (RDA) revealed the leaf N, straw N, grain N, Chlorophyll content and SPAD are positively correlated with the A-R50+un, M-GS and R33 treatment, while soil available N most significant affected by the R0, A-R50+un+Bio and M-LCC treatment. The leaf N, straw N, grain N, Chlorophyll content, SPAD and available N was not affected entirely by changing the treatment NO-N and R50.The vegetation index WDVI also directly proportional relationship with A-R50+un, M-GS and R33 treatment, however the vegetation index NDVI, MCARI and TCARI most significant affected by the RO, A-R50+un+Bio and M-LCC treatment. The vegetation index PNSI and PSRI also dependence on R100 and R66 treatment. The vegetation index (WDVI, NDVI, MCARI, TCARI, PNSI and PSRI) was not affected entirely by changing the N0-N and R50 treatment.

The project for establishment of nitrogen-efficient wheat production system in Indo-Gangetic plains by the deployment of BNI technology (Ajay Kumar Bhardwaj, Awtar Singh, Rajender Kumar 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-SMALYS Trials were initiated in 2021-22 wheat season, in small lysimeters filled with soils of two pH, 5.6 and 7.8. The soils were acquired from Palampur, Himachal Pradesh, and Karnal, Haryana, to conduct preliminary studies on pH and BNI function interactions. Six BNI elite lines and three local checks were planted under both soils (acidic and alkaline) during wheat season, in two replications. The experiment is expanded to six soil pH [5.6, 6.4, 7.2, 7.8, 8.5, and 9.3] in 2023 wheat season. Nitrate leaching, N speciation into NO_3^-, and NH_4^+ nitrogen in rhizosphere using Ion Exchange Resin [IER] strips, and crop and soil data were monitored to quantify different pools and fluxes of nitrogen as influenced by the BNI function. The BNI-LYS experiment was initiated in 2021, with six BNI elite lines and three local checks, in Karnal soils for monitoring the N_2O emissions and NO_3^- leaching as influenced by BNI function. The soil water samplers were installed at 1 m depth for collecting the NO_3^- leaching at weekly intervals. The experiments have been converted to BNI-Residue interaction trials in 2023 wheat season, wherein six BNI elite lines and three local checks were subjected to two treatments: Residue retention and No-residue retention to test the interaction of soil carbon with BNI. 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 fertility gradient trials at IIWBR, Karnal, were used to monitor N_2O emissions as affected by fertility gradient [0%, 50%, 70%, 100%] during 2022 wheat season. 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 data for plant and soil N dynamics as affected by BNI-function is also being collected and analyzed for the experiment at IIWBR, BISA and IARI, by CSSRI team. The soil and plant samples from different location trials were collected and analyzed for soil and plant N.

Grain yield for all elite lines/ check varieties increased with increase in fertilizer levels. BNI enabled lines compared to non-BNI parents, were noted to provide significant advantage in terms of grain yield at 100% fertilizer levels (Fig 2.5). For straw yield, there was

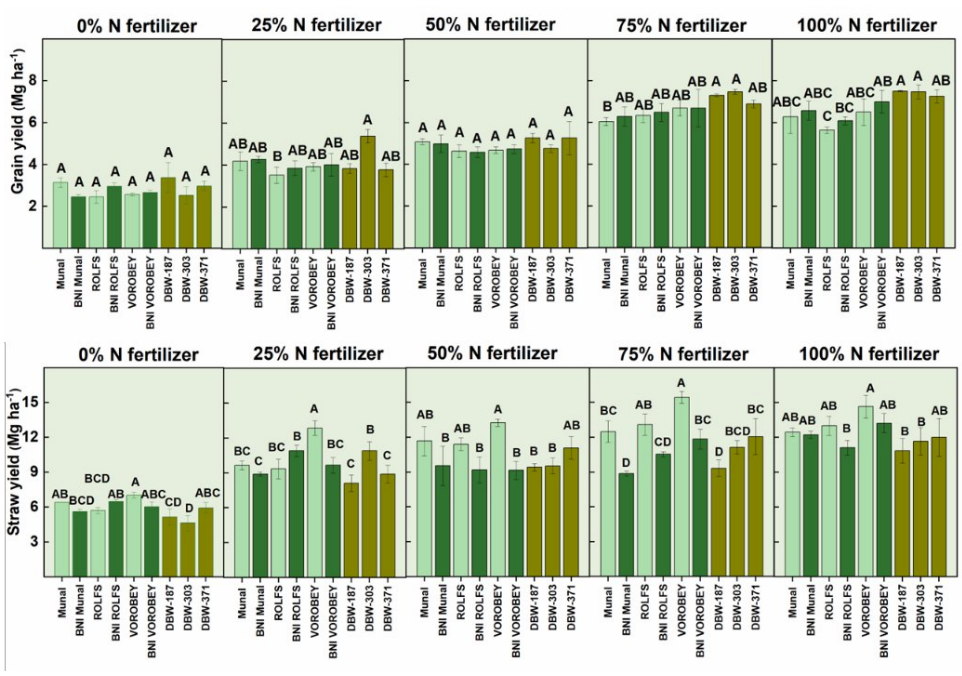


Fig 2.5 Effect of fertility gradient on the grain and straw yield of elite lines and three check varieties of wheat

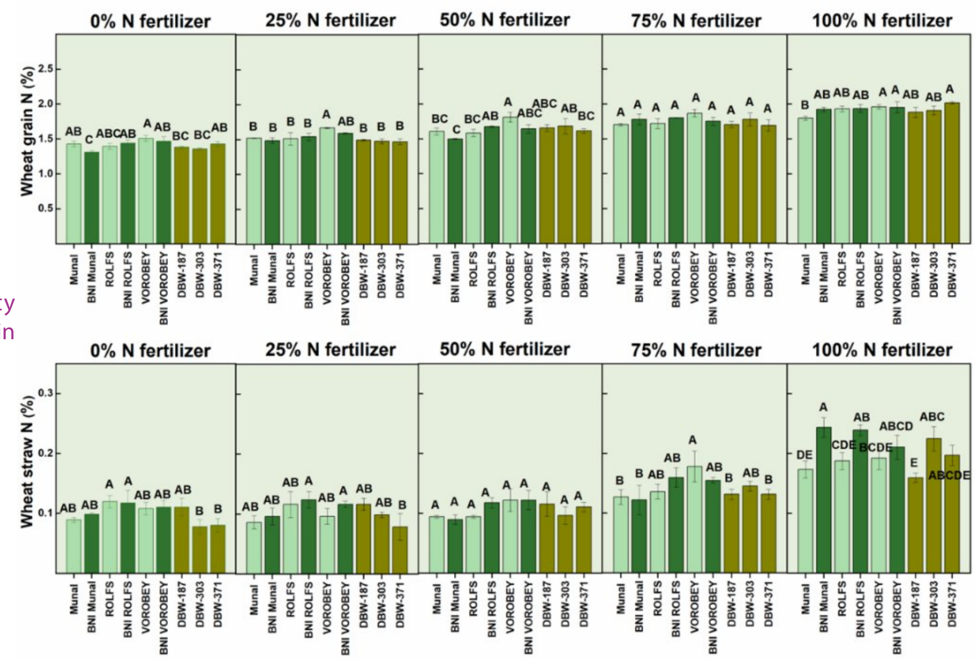


Fig 2.6 Effect of different fertility gradients on the grain and straw N in different elite lines/ check varieties

significantly lower straw yield for BNI enabled lines compared to parents. The maximum yields were obtained at neutral pH for all tested lines/ varieties. BNI-enabled lines had significantly higher yields, compared to the non-BNI parents in acidic to neutral range. BNI function effects were not very prominent, except in BNI Vorobey, in alkaline pH range.

The grain and straw N increased with increase in the fertilizer applied. Highly significant increase in the straw N content was noted in BNI enabled elite lines compared to parents, at the recommended doses of fertilizer, but not at the lower levels of fertilizer gradient. Significantly higher N yield (N harvested) was noted in case of BNI enabled elite lines at 100% fertilizer application levels (Fig 2.6).

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

Salt affected soils (SAS) is a pervasive problem that significantly undermines agricultural productivity, environmental health, and global food security. The presence of high levels of salts in the soil restricts the ability of plants to take up water, leading to reduced growth and, in severe cases, plant death, thereby diminishing crop yields and threatening the livelihoods of millions of farmers. One of the major hurdles in managing SAS is the lack of precise, scalable, and cost-effective mapping and characterization techniques. Traditional soil mapping methods and soil analysis are often labour-intensive, time-consuming, and may not accurately capture the spatial variability of soil salinity at the scale necessary for effective management. This limitation hinders the ability of land managers, policymakers, and farmers to make informed decisions regarding soil management practices, crop selection, and irrigation strategies to mitigate the impact of soil salinity. This project is aimed to used proximal spectroscopic technique particularly VNIR spectroradiometer and MIR spectroscopy is used for generating spectral libraries of soils from salt-affected regions of India. For this purpose, 292 soil samples from 0-15,15-30, 30-45 and 45-60 cm soil depths were collected from salt-affected regions of Uttar

Fig 2.7 SVC 1024i spectroradiometer setup for generating VNIR spectra of soil samples

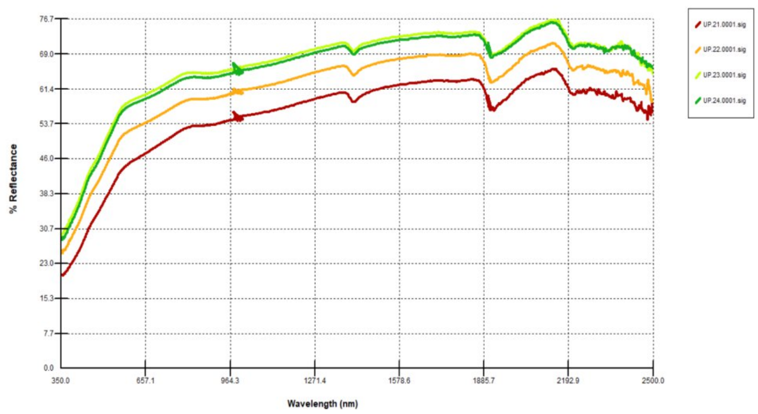


Fig 2.8 VNIR spectra of a representative soil sample from salt-affected soil of UP from four soil depths (presented in different colour as shown in the legends)

Table 2.1 Descriptive statistics of soil samples collected from 0-15,15-30, 30-45 and 45-60 cm soil depths from all the above location as given in the location map of soil sampling in UP

	Minimum	Maximum	Mean	Std. Deviation	Variance
pH_2	7.55	11.17	10.27	0.57	0.33
EC_2	0.34	20.75	2.75	2.27	5.15
pH_s	7.47	10.77	9.80	0.65	0.42
pH_e	7.12	10.65	9.40	0.72	0.52
EC_e	0.46	45.60	5.75	5.94	35.26
Ca	0.00	5.00	0.58	0.64	0.41
Mg	0.20	21.25	1.55	2.66	7.07
Na	0.60	346.40	43.63	43.15	1862.26
K	0.01	72.60	10.32	10.06	101.16
CO_3	0.20	74.60	9.42	10.32	106.57
HCO_3	2.40	178.04	29.78	26.91	724.20
Cl	0.00	111.85	2.17	8.86	78.57
SO_4	0.67	196.52	17.51	19.94	397.58
SOC	0.03	0.58	0.11	0.08	0.01
GR	0.85	66.66	20.70	8.87	78.71
$CaCO_3$%	0.20	51.50	3.86	7.09	50.33
sand %	22.22	82.95	56.74	10.28	105.73
Silt %	8.03	67.52	25.96	8.86	78.56
Clay %	1.61	37.89	17.31	6.52	42.55
ExCa	0.01	29.81	1.36	2.53	6.40
ExMg	0.01	9.72	1.24	1.65	2.71
ExNa	0.71	46.71	18.76	8.24	67.97
ExK	0.18	3.22	0.68	0.45	0.21
CEC	6.48	51.49	22.04	8.96	80.28
ESR	0.08	1480.51	35.96	96.73	9356.22
ESP	6.94	98.69	84.65	14.81	219.33
SAR_e	1.80	724.35	97.22	108.83	11844.73

Pradesh particularly from Azamgarh, Lucknow, Raebareli, Jaunpur, Mau, Etawah, Mathura, Agra, Budaun with three land use systems i.e. Barren, rice-fallow and rice-wheat. The soil properties analyzed were pH_2; EC_2; pH_s, pH_e, EC_e, Ca, Mg, Na, K, CO_3^-, HCO_3^-, Cl^-, SO_4^{2-} and SAR SOC, gypsum requirement, $CaCO_3$, sand, silt, clay, ExCa, ExMg, ExK, ExNa, ESP. besides this, we have also generated VNIR spectral library from SVC 1024i spectroradiometers of the samples (Fig. 2.7 & 2.8). The descriptive statistics of the samples are given in Table 2.1.

Exploring the potential use of the silicious chalk in agriculture: sodicity reclamation and nutrient source (Arvind Kumar Rai, Nirmalendu Basak, Parul Sundha, Priyanka Chandra, Avni Dahiya and Rajender Kumar Yadav)

Silicious–chalk contains about 8% Ca equivalent to about 34% gypsum. It can serve as the source of Ca for sodic soil reclamation as well as nutrient source for different crops. Gypsum replacement by silicious chalk showed impact on sodic soil pH. Grain and straw yield was also declined in proportion to increased replacement; however, 10-20 % replacement had similar grain yield. Siliciuos chalk was effective as Ca source as compared to silica in nutrition of rice crop. Residual effect of the silicious chalk was evident on the wheat crop. About 100-200 kg ha^{-1} application of silicious chalk recorded relatively greater grain yield of rice and wheat compared to recommended dose of the fertilizers under slightly sodic soil as well as acidic soil conditions. This trend of decline in soil pH_2 continued in second year. The pH_2 observed in second year after rice and wheat harvest was appreciably lower than the first year values. Similarly, EC_2 also declined in second year compared to first year (Table 2.2). In the second year also similar trend was observed the grain yield of rice and wheat were apparently greater in 50GR gypsum and 10% replacement of gypsum. With gradual increase in replacement of gypsum was commensurated with gradual decline in grain yield. Straw yield were almost similar in all the treatments. Chaffey grains were declined in second year compared first year in gypsum treated soils (Table 2.3). The grain yield of the rice and wheat were greater in silicious chalk treated soils. The yield observed were at par with the application of 150 kg/ha potassium silicate. The yield advantage was not greater at higher rate of chalk application compared to 100-200 kg/ha application. In second year chaffey grain were also reduced in rice. While in wheat, harvest index and grain to straw ratio were greater at 500 kg/ha application of silicious chalk (Table 2.4). The incubation study for value addition

Table 2.2 Effect of the gypsum replacement by silicious chalk in second year (2023-24); numbers followed by different letters in the column are significantly different using LSD ($p<0.05$)

Replacement of gypsum (%)	After Rice 2023		After Wheat 2024	
	PH_2	EC_2	PH_2	EC_2
Control	8.87[a]	0.98[b]	8.81[a]	0.71[b]
0 (50GR gypsum)	8.14[b]	1.26[ab]	8.42[b]	0.87[ab]
10	8.33[b]	1.04[ab]	8.46[b]	0.76[b]
20	8.48[a]	0.96[b]	8.53a[b]	0.91[ab]
30	8.53[a]	1.17[ab]	8.58[ab]	0.88[ab]
40	8.48[a]	1.49[a]	8.68[ab]	1.02[ab]
50	8.72[a]	0.99[ab]	8.71[ab]	1.26[a]
100	8.79[a]	1.05[ab]	8.78[a]	0.95[ab]

Table 2.3 Effect of gypsum replacement by silicious chalk on the performance of rice-wheat cropping system (2023-2024); numbers followed by different letters in the column are significantly different using LSD ($p<0.05$)

Replacement of gypsum (%)	**Rice**				**Wheat**		
	Grain yield (kg/m^2)	**Straw yield (kg/m^2)**	**Harvest Index**	**Chaffey grain (%)**	**Grain yield (kg/m^2)**	**Straw yield (kg/m^2)**	**Harvest Index**
Control	0.4^{b}	0.5^{b}	0.4^{ab}	15.0^{ab}	0.42^{b}	0.97^{ab}	0.3^{b}
0 (50GR gypsum)	1.1^{a}	1.3^{ab}	0.5^{ab}	6.6^{b}	0.76^{a}	1.08^{a}	0.41^{ab}
10	1.0^{a}	1.2^{ab}	0.5^{ab}	8.1^{b}	0.68^{ab}	0.89^{ab}	0.43^{ab}
20	0.9^{ab}	1.0^{ab}	0.5^{ab}	6.8^{b}	0.65^{ab}	0.93^{ab}	0.41^{ab}
30	0.9^{ab}	1.1^{ab}	0.5^{ab}	$8.6a^{b}$	0.59^{ab}	0.84^{b}	0.41^{ab}
40	0.8^{ab}	1.0^{ab}	0.4^{ab}	7.5^{b}	0.54^{b}	0.81^{b}	0.40^{ab}
50	0.8^{ab}	1.0^{ab}	0.4^{ab}	$9.0a^{b}$	0.51^{b}	0.64^{b}	0.44^{a}
100	0.5^{b}	1.0^{ab}	0.3^{b}	14.8^{ab}	0.50^{b}	0.90^{ab}	0.36^{b}

Table 2.4 Effect of silicious chalk on the performance of rice and wheat in second year (2023-2024); numbers followed by different letters in the column are significantly different using LSD ($p<0.05$)

Silicious chalk ($kg\ ha^{-1}$)	**Rice-2023**				**Wheat-2024**			
	Grain (kg/m^2)	**Straw (kg/m^2)**	**Chaffey grain (%)**	**HI**	**Grain (kg/m^2)**	**Straw (kg/m^2)**	**HI**	**Grain:straw ratio**
100	0.2b	0.89b	6.27a	0.18b	0.47b	1.22b	0.28	0.39b
200	0.27b	1.14ab	4.45c	0.19b	0.63a	1.39ab	0.31	0.45ab
300	0.30ab	1.16ab	6.03ab	0.20b	0.64a	1.45a	0.31	0.44ab
400	0.31a	1.12b	4.43c	0.22b	0.63a	1.46a	0.3	0.43ab
500	0.27b	1.19a	2.93d	0.19b	0.63a	1.18b	0.35	0.53a
K_2SiO_3 (150 $kg\ ha^{-1}$)	0.33a	0.89b	5.75b	0.27a	0.58ab	1.23b	0.32	0.47ab
Control	0.27b	0.96b	5.63b	0.22b	0.57ab	1.2b	0.32	0.47ab

Table 2.5 Effect of different haloalkaliphils on the solubilization of the silicious chalk incubated for 30 days; numbers followed by different letters in the column are significantly different using LSD ($p<0.05$)

Culture	**pH^{10}**	**EC^{10}**	**Ca^{2+} ($g\ kg^{-1}$)**	**Mg^{2+} ($g\ kg^{-1}$)**	**SO_4^{2-} ($g\ kg^{-1}$)**
Agrobacterium alinitolerans	6.91^{efg}	4.43^{bc}	5.65^{cdef}	3.00^{ab}	8.42^{efg}
Arthrobacter sedimenti	6.95^{def}	4.52^{abc}	6.65^{ab}	2.01^{cde}	8.38^{efg}
Priestia aryabhattai	6.97^{de}	4.42^{bc}	6.88^{a}	2.09^{cde}	8.04^{fg}
Priestia megaterium	6.88^{g}	4.58^{abc}	6.53^{ab}	2.13^{bcde}	9.00^{def}
Bacillus aerius	6.93^{defg}	4.28^{cd}	6.48^{abc}	1.73^{e}	8.26^{efg}
Stutzerimonas stutzeri	6.99^{d}	3.95^{de}	5.93^{bcdef}	1.86^{de}	7.55^{fg}
Rahnella aceris	$6.94d^{efg}$	4.19^{cd}	6.53^{ab}	1.91^{cde}	8.47^{efg}
Pseudomonas xtremaustralis	6.97^{de}	4.34^{cd}	5.95^{bcde}	$2.19b^{cde}$	8.59^{ef}
Pseudomonas veronii	$6.95d^{efg}$	4.54^{abc}	6.35^{abcd}	2.66^{abcd}	9.22^{def}
Stenotrophomonas pavanii	6.98^{d}	4.27^{cd}	6.60^{ab}	1.86^{de}	10.47^{bcd}
Exiguobacterium profundum	6.92^{defg}	4.79^{ab}	6.00^{bcde}	3.17^{a}	11.78^{ab}
Rhodococcus qingshengii	$6.93d^{efg}$	4.35^{cd}	5.58^{defg}	2.22^{bcde}	9.17^{def}
Micrococcus endophyticus	6.89^{fg}	4.91^{a}	6.10^{abcde}	3.24^{a}	12.72^{a}
Sphingomonas olei	7.27^{c}	$4.56a^{bc}$	5.10^{fg}	3.26^{a}	11.16^{abc}
P. chloritidismutans	7.32^{bc}	4.79^{ab}	5.45^{efg}	2.79^{abc}	11.46^{abc}
Control	7.38^{b}	3.67^{e}	4.75^{gh}	1.68^{e}	9.89^{cde}
silicious chalk	7.52^{a}	2.70^{f}	4.23^{h}	0.72^{f}	6.80^{g}

to the silicious chalk with the identified S oxidizers for increasing the effectiveness was found highly significant. Different halophilic microorganisms were incubated with suitable substrate to monitor the change in water soluble constituent of the siliceous chalk. Among the microbe's performance of the *Micrococcus endophyticus*, *Sphingomonas olei* and *Exiguobacterium profundum* were highly appreciable. (Table 2.5).

Implementation of a Pilot Project on Reclamation of Alkaline Soil in Haryana and Punjab (Gajender, R. K. Yadav and Kailash Prajapat)

This Pilot Project on reclamation of alkaline soils was implemented in two districts of each of Punjab and Haryana states. Alkali soil sites identified in two districts each in Haryana (Karnal and Kaithal) and Punjab (Patiala and Sangrur). Sites selected are villages clusters of Gunyana and Mundh in Karnal district; (village clusters Mundri, Kathwar in Kaithal district of Haryana; villages Budhmor, Bibipur, Kharabgarh, Pattijhungia, Dharmheri and Saasa Gujjran in Patiala district; villages Roshanwala, Bhullan, Maniana, Mandavi, and Moonak in Sangrur district of Punjab.

Initially 2660 soil samples from 629 farmers of Haryana and 2042 soil samples of 517 farmers of Punjab were collected from two soil depths i.e 0-15 cm and 15-30 cms. Samples were analysed for determine GR% (50) for gypsum application in individual farms. Production of wheat was recorded from respective identified and selected individual fields. Package of standard practices for reclamation of alkali soils using gypsum were adopted before transplanting of rice crop. In Kaithal (Haryana), the soil pH decreased from 8.92 in 2021 to 7.98 in 2023 due to gypsum application and then slightly increased to 8.50 in 2024 (Table 2.6). The ESP% dropped significantly from 29.42 in 2021 to 13.45 in 2023 due to gypsum application but increased to 16.3 in 2024. In Karnal (Haryana) results showed a reduction in soil initial pH from 8.80 in 2021 to 7.41 after one year of gypsum application in 2023, followed by a rise to 8.11 after second year of gypsum application in 2024, with ESP% decreasing from 26.82 in 2021 to 11.26 in 2023 and increasing to 13.2 in 2024. In Patiala (Punjab), soil pH reduced from 9.36 before gypsum application in 2021 to 7.91 in 2023 due to gypsum treatment. After two years of gypsum application soil pH again increased to 8.95 during 2024. The initial ESP percentage decreased from 31.30 in 2021 to 13.24 after one year of gypsum application in 2023 and increased to 14.8 in 2024. In Sangrur (Punjab), the soil pH decline from 9.67 in 2021 to 7.56 in 2023, followed by a rise to 8.63 in 2024, while ESP% dropped from 27.71 in 2021 to 11.80 in 2023 and increased to 13.1 in 2024. After one year of gypsum application, the increase in ESP and soil pH is primarily due to the continued use of sodic irrigation water.

After one year of gypsum application, average decrease in soil pH were 10.5% and 15.8% in Kaithal and Karnal, respectively. Whereas in distrcits of Punjab showed higher reduction in soil pH, a reduction in soil pH of 15.4% and 21.8% in Patiala and Sangrur, respectively were reported. After two years of gypsum application slight increment in soil pH and ESP were recorded as compared to the previous year.

Table 2.6 Change in soil pH and ESP (%) after gypsum application

Sites	Soil pH			ESP%		
	Before gypsum app.	After gypsum application		Before gypsum app.	After gypsum application	
	2021	2023	2024	2021	2023	2024
Haryana						
Kaithal	8.92	7.98	8.50	29.42	13.45	16.3
Karnal	8.80	7.41	8.11	26.82	11.26	13.2
Punjab						
Patiala	9.36	7.91	8.95	31.30	13.24	14.8
Sangrur	9.67	7.56	8.63	27.71	11.80	13.1

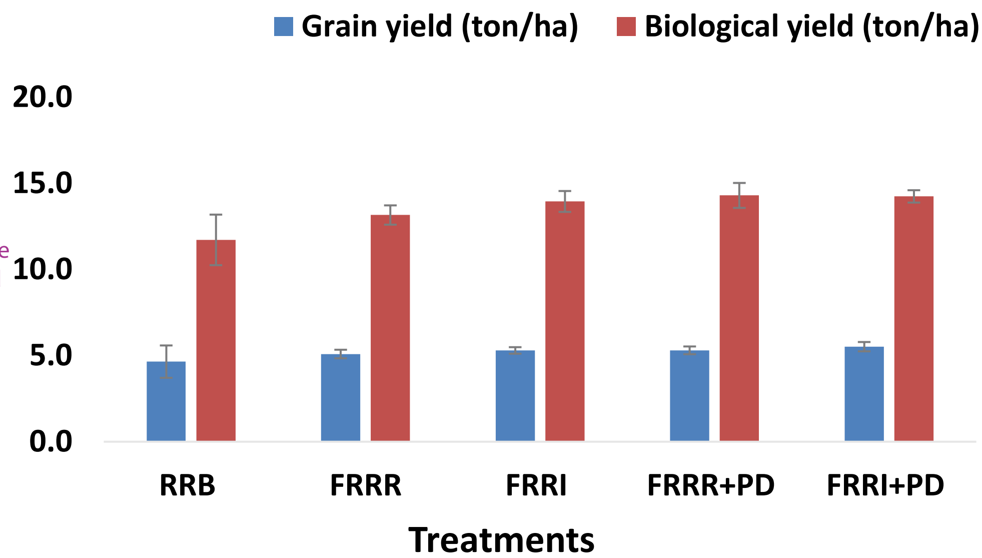


Fig 2.9 Effect of different residue management practices on wheat yield

View of field experiment

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

The long term sustainability of the rice–wheat cropping system is becoming challenging because of diminishing productivity, degrading soil quality, declining groundwater levels, rising greenhouse gas emissions, changing weed flora, evolving of herbicide-resistant weeds like *Phalaris minor* in wheat crop, and finally rice residues burning. Burning of stubble or crop residues is the most widespread practice for residue management. Despite of a number of benefits from surface retention of straw, uptake of happy seeder technology by the farmers is much slower than expected. Managing 8-10 Mg ha^{-1} residues efficiently and economically yet allow farmers to plant their wheat crop on time has been a daunting task. Therefore, an experiment was started in 2021-22, for the three years at the research farm of ICAR-CSSRI Karnal, for assessment of diverse cost-effective and farmer friendly residue management alternatives (residue retention, incorporation and use of residue decomposer etc.) under the rice-wheat system. Treatments include T1: Residue burning (RRB), T2: Full rice residue retention (FRRR), T3: Full rice residue incorporation (FRRI), T4: Full rice residue retention + Pusa decomposer spray on rice residues (FRRR+PD), T5: Full rice residue incorporation + Pusa decomposer spray on rice residues (FRRI+PD). The popular variety of rice (PR 126) and wheat (HD 2967) were used for the study. The rice was harvested with the help of combine harvester having super SMS. Rice was transplanted into all the plots and various treatments were imposed on the wheat crop. The 3rd years (2023-24) results showed that the grain as well as biological yield of wheat significantly decreased in residue burning plots compared to the residue retention as well as residue incorporated treatments (fig. 2.9).

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

A long-term field experiment was initiated in 2006 to evaluate the effects tillage and residue management practices on crop productivity and soil health. High-yielding rice

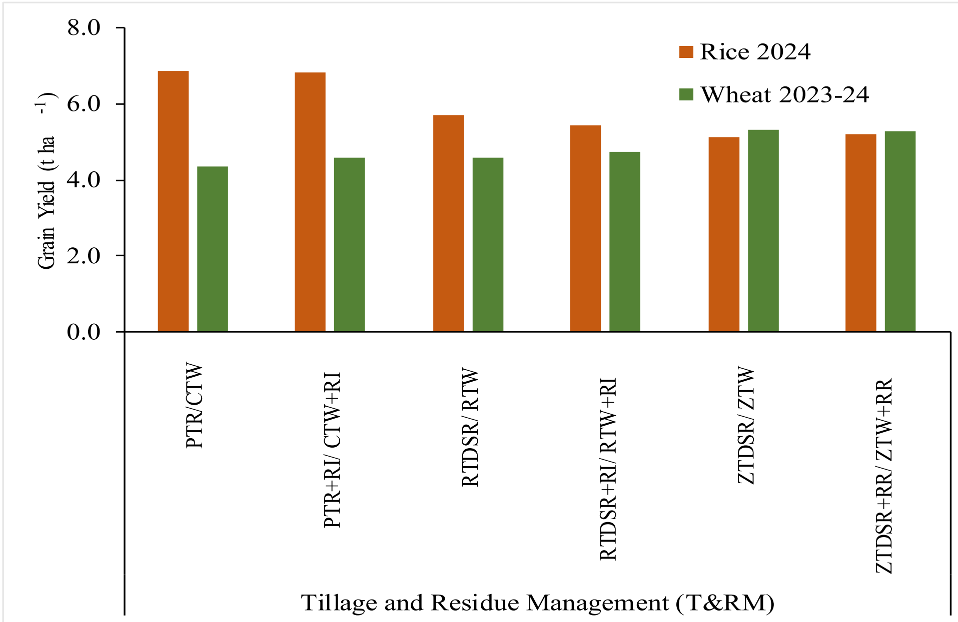


Fig 2.10 Effects of tillage and residue management practices, on grain yield of rice 2024 and wheat 2023-24

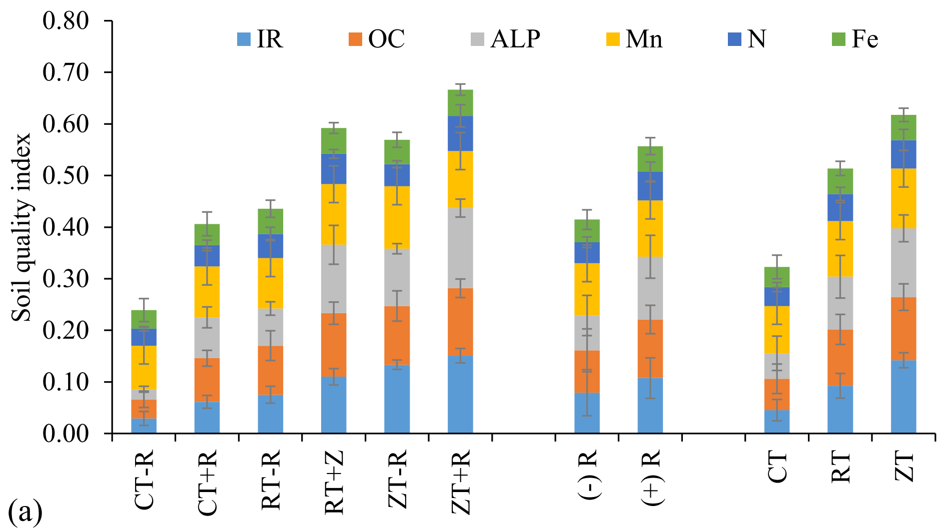


Fig 2.11 Soil quality indices at 0-15 cm soil layer after 15-years of tillage and residue management in rice-wheat system

Where, CT, RT and ZT represent conventional, reduced and zero tillage, respectively. -R and +R represent no crop residues and 1/3rd crop residue addition, respectively. IR: infiltration rate; OC: soil organic carbon: ALP: Alkaline phosphatase activity; N: nitrogen; Mn: manganese.

(*Arize 6129 Gold*) and wheat (*KRL 210*) varieties were used as test crops for the year 2024. The highest rice yield was recorded in puddled transplanted rice (PTR: 6.86 t ha^{-1}), followed by PTR with 1/3rd wheat residue incorporation (PTR+RI: 6.83 t ha^{-1}) (figure 2.10). The lowest rice yield was observed in zero-till direct-seeded rice (ZTDSR: 5.11 t ha^{-1}) followed by ZTDSR with one-third wheat residue retention (ZTDSR+RR: 5.20 t ha^{-1}). In contrast to rice highest wheat yield (5.33 t ha^{-1}) was observed in zero-till wheat (ZTW) followed by ZTW with 1/3rd rice residue retention (ZTW+RR: 5.27 tha^{-1}), and lowest yield was recorded in conventional tillage wheat (CTW: 4.35 tha^{-1}). From a system perspective, the highest system yield (11.43 t ha^{-1}) was achieved under PTR+RI/CTW+RI, which was 8.40% higher than ZTDSR+RR.

After completion of 15-years of the tillage and residue management practice, its impact on soil health was assessed and soil quality index (SQI) was computed. These practices significantly improved the soil fertility and health resulting higher SQI. The SQI at surface layer (0–15 cm) was significantly higher zero tillage (ZT) treatment with residue retention

(ZT + R; 0.67) followed by reduced tillage with residue incorporation (RT + R; 0.59), and ZT without residue (ZT-R; 0.57) (Fig. 2.11). The infiltration rate (IR), soil organic carbon (OC), Alkaline phosphatase activity (ALP), available Mn, available N, available Fe, are the main key quality indicators contributing to SQI at surface layer. The contrast results showed enhancement in SQI with residue addition irrespective of tillage practices by 34.30% surface depth. In without residue treatments, maximum contribution is by Mn, but on residue addition ALP (21.8%) and OC (20.4%) contributed the most to SQI at surface. SQI improved significantly with different tillage practices at surface soil and RT recorded 59.21% higher and ZT recorded 91.42% higher SQI in comparison to CT. Relatively higher soil quality with long term residue and tillage management practices indicates improvement in overall soil properties with residue addition and conservational tillage in long-run.

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

Arbuscular mycorrhizal fungi (AMF) can form symbiotic relationships with most terrestrial plants, modifying the inter-root microenvironment and promoting plant growth and development. Additionally, AMF offers various forms of support to plants, such as signaling, metabolic pathways, and recruitment of beneficial microorganisms. Notably, under salt stress conditions, AMF can improve plant tolerance by modulating osmotic stress and oxidative stress responses. Hence the efficacy of AMF in salt affected soils was evaluated in different vegetables crops. The vegetables inoculated with AMF exhibited significant ($p<0.05$) improved growth in comparison to control plants. Mycorrhizal application significantly increased yield over their respective control. The AMF responsiveness ranges from 3.7 % -19% (Fig. 2.12). The concentration of phosphorus was evaluated with Energy-dispersive X-ray spectroscopy (EDS) which revealed enhanced P content in the AMF inoculated roots. NS31–AM1 primer pair which is the one of the first primer pairs designed for the detection and identification of AMF. This primer targets the segment of the small subunit (SSU) rRNA gene and covers the detection of a broader spectrum mainly for phylum Glomeromycota. Amplification of NS31–AM1 primer pair was found in the AMF inoculated crops which indicate the validation of colonization of *F. mosseae* and *F. geosporum*. The abundance of lipids in spores and vesicles of colonized roots is a potentially useful biochemical character for taxonomic purposes and

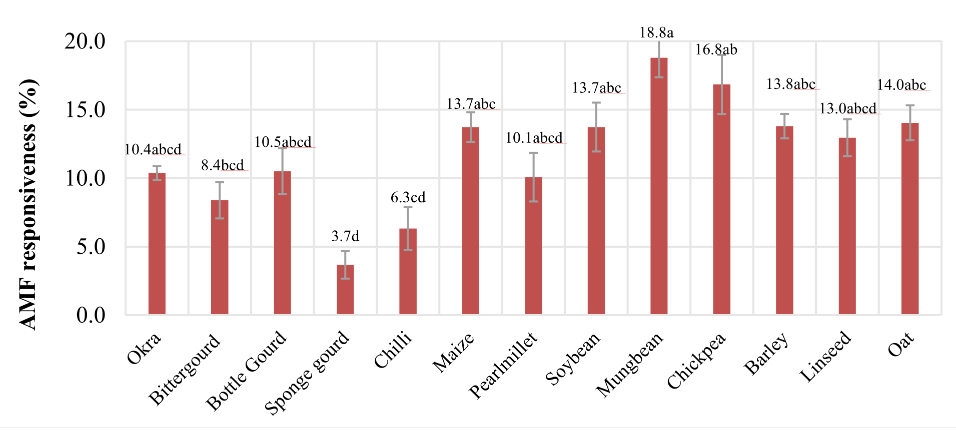
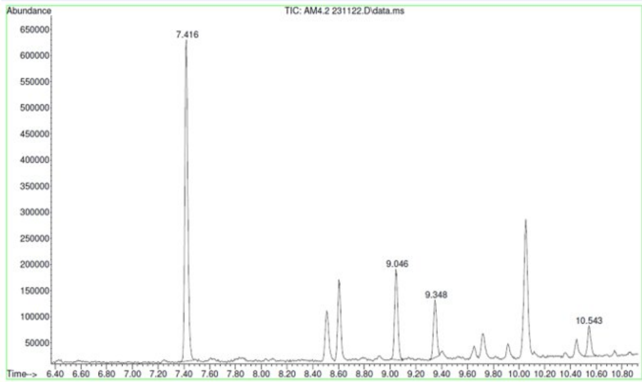


Fig 2.12 AMF responsiveness demonstrated after inoculation in different crops

Fatty Acid Methyl Ester (FAME) Profiles of AMF spores



Peak	Retention Time	C:D	Scientific name
1	7.416	C14:0	Tetradecanoic acid methyl ester
2	9.046	C16:0	Hexadecanoic acid, methyl ester
3	9.348	C16:1	cis-9-hexadecanoic acid, methyl ester
4	10.543	C18:0	Octadecanoic acid , methyl ester

C:D is the numerical symbol: total amount of carbon (C) atoms of the fatty acid, and the number of double (D) (*unsaturated*) bonds in it

Fig 2.13 Fatty Acid Methyl Ester (FAME) Profiles of AMF spores

quantification of glomalean fungi in host root tissue. The gas-liquid chromatography of lipids has generated widening interest in the use of fatty acid methyl ester (FAME) profiles for the purpose of identification and elucidation of relationships among organisms. The diversity of structure and quantity of fatty acids of 9 to 20 carbon atoms in length has provided characteristic profiles among genera of AMF. Tetradecanoic acid methyl ester, Hexadecanoic acid, methyl ester cis-9-hexadecanoic acid, methyl ester, Octadecanoic acid, methyl ester is the fatty acids presence in the AMF spores (Fig. 2.13).

Studies on AGROTAIN Incorporated Urea Produces with N-TEGRATIONTM Technology as an Enhanced Efficiency Fertilizer for use in Major Cropping Systems in India (Madhu Choudhary, Kailash Prajapat and R.K. Yadav)

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

The results from different cereal-based cropping systems (rice-wheat, rice-rice, sugarcane-sugarcane (ratoon) and wheat-maize) indicated that in maize-wheat system in North-western India, the application of 80% N through AIU (Agrotain incorporated Urea) produced similar system productivity with 10% higher Agronomic efficiency of N (AE_N) by 10 over 100% NCU, respectively. In sugarcane-sugarcane system at Maharashtra, the 80% AIU applied through drip system improved cane yield of sugarcane by 17% and AE_N by 60% without compromising the quality of sugarcane. Under rice-wheat cropping system at Bhopal, Madhya Pradesh, the system yield of rice-wheat was similar under 100% AIU and 100% NCU with improved AE_N over 100% NCU. The 100% AIU recorded higher amount of NH_4-N and NO_3-N after fertilization. In rice–rice cropping system at Bhubaneswar, Odisha, the system productivity was highest under 100% AIU (4% increase) with 8% improvement in AE_N over 100% NCU. The 20% reduction in dose with AIU, did not adversely affected the grain N content and soil N status in all the cropping systems across the sites.

At CSSRI- Karnal station, the three seasons (2021-22-2023-24) pooled grain yield of wheat was the highest with the application of 100% AIU (5.58 t/ha) and it was on par with 100% NCU (5.26 t/ha) and 80% AIU (5.15 t/ha) but significantly higher than 60% AIU) and control (1.43 t/ha) (Table 2.7). Furthermore, the 100% AIU showed 6.2% yield improvement over 100% NCU. The highest AE_N was reocrded with 60% AIU (33.2 kg grain/kg N) followed by 80% AIU (31.0 kg grain/kg N). The partial factor productivity of N (PFP_N) was the highest in the 60% AIU and followed by 80% AIU and 100% AIU. The 100% AIU and 80% AIU treatments improved the AE_N by 10.1 and 21.5%, while PFP_N improved 7.8% and 22.4% over 100% NCU, respectively. The highest grain yield of maize crop was recorded with the application of 100% AIU (8.84 t/ha) and it was on par with 80% AIU (8.62 t/ha) and 100% NCU (8.47 t/ha) but significantly higher than 60% AIU. The highest AE_N was found with the aplication of 60% AIU (37.7 kg grain/kg N) followed by 80% AIU (36.1 kg grain/kg N). The highest PFP_N was recorded with 60% AIU and followed by 80% AIU and 100% AIU.

On system basis (wheat+maize), the system productivity was the highest under 100% AIU (14.54 t/ha) followed by 80% NIU. The application of 100% AIU improved the system productivity by 6% over 100% NCU (Table 2.7). The system Agronomic Efficiency (AE_N) and Partial Factor Productivity (PFP_N) of nitrogen varied due to different sources and levels of N application. The values of AE_N were recorded highest with the application of 60% N through AIU (35.47 kg grain yield increased/kg N applied) followed by 80% AIU and 100% AIU application. The application of 100 and 80% AIU improved the AE_N by 10 and 26%,

Table 2.7 Effect of different N- doses on grain yield, system yield, agronomic efficiency of N (AE_N) and partial factor productivity of N (PFP_N) of maize–wheat system (2022-23) at Karnal

Treatment	Maize			Wheat			System (wheat equivalents)		
	Yield ($Mg\ ha^{-1}$)	AE_N (kg grain kg N^{-1})	PFP_N (kg grain kg N^{-1})	Yield ($Mg\ ha^{-1}$)	AE_N (kg grain kg N^{-1})	PFP_N(kg grain kg N^{-1})	Yield ($Mg\ ha^{-1}$)	AE_N(kg grain kg N^{-1})	PFP_N(kg grain kg N^{-1})
Control	4.29^c	-	-	1.43^c	-	-	5.71^d	-	–
100% NCU	8.47^a	27.9^c	56.4^d	5.26^a	25.5^c	35.1^c	13.72^b	26.69^d	45.75^b
100% AIU	8.84^a	31.0^b	59.9^c	5.58^a	28.1^b	35.3^c	14.54^a	29.42^c	48.48^b
80% AIU	8.62^a	36.1^a	71.8^b	5.15^a	31.0^a	42.9^b	13.77^b	33.55^b	52.72^b
60% AIU	7.68^b	37.7^a	85.3^a	4.42^b	33.2^a	49.1^a	12.10^c	35.47^a	67.24^a

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

respectively over 100% NCU, respectively. The 100% and 80%AIU showed an increase of 6 and15% in PFP_N over 100% NCU, respectively.

Developing and defining climate smart agriculture practices portfolios in South Asia (Madhu Choudhary, Kailash Prajapat and R.K. Yadav)

In South Asia, food security is achieved through Green Revolution by using high yielding varieties along with better irrigation facilities and fertilizer availability. The nutrition security is an emerging concern now-a-days because of malnutrition where more than 30% population suffers in the region. The Iron deficiency is also prevalent in more than 50% women in the northern region of India. In Northwest region of IGP, agricultural policies focus primarily on the production and related value chains of single crops in isolation, with less emphasis on developing an evidence base around the multisectoral

Table 2.8 Treatment details under different diversified scenarios

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

Table 2.9 System productivity (rice equivalent yield, REY), net returns and water productivity of diversified cropping systems scenarios

Scenarios	REY of kharif crops (Mg/ha)	REY of rabi crops (Mg/ha)	REY of spring crops (Mg/ha)	System REY (Mg/ha)	System net returns (INR/ha)	System irrigation water use (mm-ha)	System water productivity (kg REY/m^3)	Partial factor productivity of N (kg REY/kg N)
Rice-wheat –fallow	5.72[BC]	5.83[C] (4.34)*	Fallow	11.54E (10.06)*	167811D (134921)*	1920	2.02[F]	64.4
Rice-potato-spring pearl millet	5.54[BC]	7.23B (9.06)*	2.67[C] (2.80)*	15.44D (17.4)*	210012[C] (200315)	2096	3.96[E]	102.9
Rice-wheat–mung bean	6.15[B]	6.45BC (4.74)*	NA	12.6E (10.09)*	196881CD (159882)*	2003	2.55[F]	79.9
Maize-mustard -mung bean	10.29[A] (7.66)*	5.53[C] (5.95)*	4.22[B]	20.04B (17.83)*	348778A (305506)*	566	12.83[B]	351.4
Baby corn-carrot-cowpea	10.39[A]	15.51[A]	1.83[D]	27.73A	379525[A]	622	20.55[A]	404.9
Soybean-wheat-sorghum (fodder)	4.93[CD]	6.34[BC] (5.60)*	1.6[D]	12.87E (12.13)*	217789C (200949)*	892	5.11[D]	238.5
Pearl millet-pea-sunflower	3.88D (3.43)*	6.45[BC]	7.92[A]	18.25C (17.80)*	306429B (296654)*	743	8.06[C]	427.6

*with bio fortified variety. Means followed by similar uppercase letters within a column are not significantly different at 0.05 level of probability using DMRT.

farm, market, and policy interventions needed to sustainably intensify and diversify farming systems equitably without overstepping environmental boundaries. To address these challenges, a study was initiated during from kharif 2020-23 on conservation agriculture (CA)-based crop diversification options to ensure food and nutritional security while sustaining the natural resources. The experiment consisted seven treatments referred to as scenarios (Sc). The experiment details/scenarios (portfolios of practice) and management practices are presented in Table 2.8. The results of two cropping cycles indicated that the highest system yield in terms of rice equivalent yield (REY) was achieved in the diversified scenarios, as indicated by the baby corn-carrot-cowpea system (Sc5), followed by maize-mustard-mungbean (Sc4) and intermittently remaining systems proved significantly higher system REY over to business as usual rice-wheat system (Sc1). The higher system REY under Sc5 was attributed to the high potential of rabi carrot yields, which reflected a good market price and was further supplemented by additional yields from summer cowpeas as fodder (Table 2.9). The two years pooled data provided evidence that baby corn-carrot-cowpea (Sc5), resulted in a significant 140% increase in system yield pursued maize-mustard-mung bean (Sc4) by 73%, pearl millet-pea-sunflower (Sc7) by 58%, rice-potato-spring pearl millet (Sc2) by 34%, soybean-wheat-sorghum fodder (Sc6) by 11% and rice-wheat-mung bean (Sc3) by 9%, respectively. The highest net returns achieved under baby corn-carrot-cow pea system (Sc5) followed by maize-mustard-mung bean (Sc4); alternatingly remaining systems proved significantly higher net returns compared to business as usual (farmers' practice). The baby corn-carrot-cowpea (Sc5), resulted in a significant 126% increase in system net returns pursued maize-mustard-mung bean (Sc4) by 107%, pearl millet-pea-sunflower (Sc7) by 82%, soybean-wheat-sorghum fodder (Sc6) by 29%, rice-potato-spring pearl millet (Sc2) by 25%, and rice-wheat-mung bean (Sc3) by 17%, respectively. The system water productivity recorded higher in Sc5 (20.55 kg grain m^{-3}) followed by Sc4 (12.83 kg grain m^{-3}), Sc7 (8.06 kg grain m^{-3}), Sc6 (5.11 kg grain m^{-3}), Sc2 (3.96 kg grain m^{-3}) and Sc3 (2.55 kg grain m^{-3}), respectively compared to Sc1 (2.02 kg grain m^{-3}). The system irrigation water productivity under Sc5 was recorded 10 times higher, followed by Sc4 (534%) and Sc7 (298%) compared to Sc1. The nutrient use efficiency was expressed as partial factor productivity (PFP) of applied N among different scenarios/cropping systems. The system basis PFP of N was higher in Sc7, followed by Sc5, Sc4, Sc6, Sc2 and Sc3, respectively, compared to Sc1. The system PFP of N was six times higher under Sc7 and Sc5 than Sc1.

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

In the continuation of the project in the three experiments for Normal, saline and sodic soils, rice-wheat crop cycle was adopted. For rice crop variety CSR 46 and for wheat crop variety KRL 210 were taken. After harvesting of rice crop, straw was incorporated and placed on the surface. Spray of consortia of fungal (*Penicillium* spp. and *Alternaria* spp.) and bacterial was done twice. Wheat is grown after rice crop in all three types of soils. Residue was placed in litter bags and according to treatments they were placed on the surface and at 10-12 cm below surface. Under different treatments of microbial bioformulations the rice and wheat yield were recorded. The highest yield of wheat under normal soils was recorded in Residue+fungi+bac in both residue retention and incorporation treatments (Table 2.10). Followed by Residue+fungi and Residue+media. In saline soils in residue retention higher yields were recorded in Residue+fungi+bac-R and Residue+fungi-R and in residue incorporation treatment it was higher in Residue-I and Residue+Media-I. In sodic soils the highest yield was recorded in Residue+Halo+ fungi+bac-R in residue retention treatment where in residue incorporated treatments it was highest in Residue+fungi+bac-I and Residue-I. In all types of soils, the lowest yield was recorded in without residue treatment.

The weight of the residue was taken after 6 months of treatment to see the long-term effect of microbial consortia on residue decomposition. It can be seen in figure 2.14 and 2.15. that the decomposition was more in residue incorporation treatment than residue

Table 2.10 Yield (t/ha) of wheat under different type of soils

Treatments	Normal soil	Saline soil	Sodic soil
Without Residue	3.97b	3.99c	3.11bc
Residue-R	3.69c	4.17b	3.22b
Residue+Media-R	4.02b	4.33b	3.19b
Residue+fungi-R	4.19ab	4.71a	2.64c
Residue+fungi+bac-R	4.51a	4.66a	3.11bc
Residue+Halo+fungi+bac-R	-	-	3.75a
Residue+Halo-R	-	-	3.20b
Residue-I	3.46b	4.03a	3.54a
Residue+Media-I	3.62ab	3.91a	3.30b
Residue+fungi-I	3.64ab	3.47c	3.06c
Residue+fungi+bacteria-I	3.80a	3.63b	3.52a
Residue+Halo+fungi+bac-I	-	-	3.42ab
Residue+Halo-I	-	-	3.34b

Fig 2.14 Residue decomposition in incorporation after treatment with microbial formulation in saline soils

Fig 2.15 Residue decomposition in retention after treatment with microbial formulation in saline soils

CSR-Manage-R (पराली प्रबंधक) Bio-decomposer for Paddy Residue Management

retention treatment. This trend was observed in all three types of soils. Not only cellulose and hemicellulose but lignin was also found to decompose by the microbial treatment.

To use any microbial formulation in field, appropriate carrier is necessary for their sustainable use. In this study for the formulation, three C sources were selected 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 500mL "CSR-Manage-R" are prepared and will be distributed to the different agencies and farmers.

Intellectual property management transfer/commercialization of agricultural technologies-NAIF-ICAR (Madhu Choudhary and Nirmalendu Basak)

The intellectual property right (IPR) regime provides rights to the innovators/ inventors for their novel technology and also facilitates to transfer of IPR enabled technologies for commercialization through commercial, cooperative and public routes. To aware the scientists, project staff and students World Intellectual Property Day was celebrated by conducting a seminar on "Intellectual Property Rights in India and its Relation to Agricultural research" by Dr N. Kulshreshtha, PS, ICAR-CSSRI on April 30., 2024.

Lecture delivered by Dr N. Kulshreshtha, PS, ICAR-CSSRI on "Intellectual Property Rights in India and its Relation to Agricultural research"

Farmers in Training-cum-awareness programme' on "Plant Protection of Varieties and Farmers Right

Under this project a three days 'training-cum-awareness programme' on "*Plant Protection of Varieties and Farmers Right (PPV&FR)*" was organized from 9 to 11 October, 2024 in three villages, namely, Pundrak, Badarpur and Nadana of the Karnal district of Haryana. Key objective of the programme was to sensitize the farmers about different provisions of "the protection of plant varieties and farmers' rights Act, 2001". The role of this Act to provide an effective system for protection of plant varieties, the rights of farmers and plant breeders and to encourage the development of new varieties of plants.

Management of Waterlogged/Saline Soils

Layout of five experimental sugarcane scenarios and cane growth in Titawi AIP, Muzaffarnagar (Uttar Pradesh)

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)

Under three Agro-Innovation Platforms (AIPs) established for field scale sugarcane experimentation in the Hindon basin (Western UP), five sugarcane management scenarios comprising irrigation method (Flood/ drip), fertilizer and pesticide management (Farmers' practices, 70, 85 and 100% of the recommended dozes), and intercropping were imposed in three planting seasons- autumn (Oct 2022), spring (March 2023) and summer (May 2023) at Nandi Firozpur (Saharanpur district), Titawi (Muzaffarnagar) and Doula (Baghpat), respectively, (Table 3.1 and Fig 3.1). Each plot area (~0.5 acre) and total area at one AIP (~2.5 acres) were selected for the experimentation to study and improve crop and water productivity as well as to reduce groundwater abstraction using drip system, and fertilizer and pesticide loads by 15-30% with bio-control. The crop growth, biomass production and soil health data of five scenarios at 1, 3,

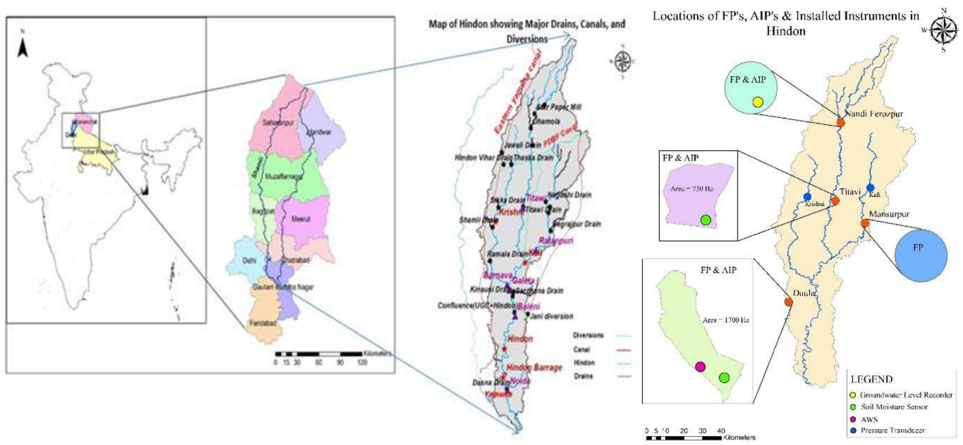


Fig 3.1 Location of 3 AIPs & 4 FPs in the Hindon Basin (Uttar Pradesh)

Table 3.1. Details of five experimental scenarios imposed for planted sugarcane at three AIPs

Scenario	Practices	Crop	Water Management	Fertilizer Management	Pesticide Management
S1	Farmers' practice (FP)	Sugarcane (Plant)	Flood Irrigation	FFP (NPK 200:60:60 kg/ha)	FPP
S2	Improved FP with the Recommended Dose	Sugarcane (Plant)	Flood Irrigation	RDF (NPK 150:60:60 kg/ha)	RDP
S3	Improved FP with 85% RDF via surface drip	Sugarcane (Plant)	Surface drip irrigation	85% of RDF	85% of RDP + Biological Control
S4	Improved FP with inter-cropping (No intercropping in summer cane)	Sugarcane (Plant) intercropped with mustard/ black gram	Flood Irrigation	85% of RDF	85% of RDP + Biological Control
S5	Improved FP with 70% Recommended dose via surface drip	Sugarcane (Plant)	Surface drip irrigation	70% of RDF	70% of RDP + Biological Control

FFP: Farmers' Fertilizer Practice; RDF: Recommended Dose of Fertilizers; FPP: Farmers' Pesticide Practice; RDP: Recommended Dose of Pesticide

Table 3.2 Sugarcane plant yield and sugarcane equivalent yield under different scenarios at three AIPs

Scenarios	Sugarcane yield (t/ha)	Percent Increase over S1 (Farmers practice)	Sugarcane equivalent yield (t/ha)	Percent Increase over S1
AIP-Nandi Firozpur*				
S1 (200:60:60)	51.78a	-	51.78b	-
S2 (150:60:60)	44.34a	-14.4	44.34b	-14.4
S3 (128:51:51)	50.68a	-2.1	76.94a	48.6
S4 (128:51:51)	52.90a	2.2	79.34a	53.2
S5 (105:42:42)	53.94a	4.2	80.49a	55.4
AIP-Titawi				
S1 (200:60:60)	113.16a		113.16a	
S2 (150:60:60)	89.39c	-21.0	89.39b	-21.0
S3 (128:51:51)	91.25c	-19.4	91.25b	-19.4
S4 (128:51:51)	103.31b	-8.7	114.19a	0.9
S5 (105:42:42)	108.37ab	-4.2	108.37a	-4.2
AIP-Daula				
S1 (200:60:60)	75.11ab	-	75.11ab	-
S2 (150:60:60)	89.77a	19.5	89.77a	19.5
S3 (128:51:51)	90.31a	20.2	90.31a	20.2
S4 (128:51:51)	69.67b	-7.2	69.67b	-7.2
S5 (105:42:42)	73.99ab	-1.5	73.99ab	-1.5

* Affected with monsoonal flooding in Aug 2023

6, 9 and 12 months for each treatment/plot were collected and analyzed. Harvesting of planted sugarcane started in mid-February 2024 and completed in the third week of March 2024.The cane yield data were also collected using crop cutting sampling and factory gate measurement methods.

The analysis of experimental results of AIP scenarios (Table 3.2) indicate that for the autumn and spring planted sugarcane with CoS 13235 variety, Scenario-5 (Improved FP with ~70% of recommended agro-chemical doses using surface drip and fertigation) is found promising for improving of 132% irrigation water productivity, 118% nitrogen productivity and 15% sugarcane yield over the FP practices (Scenario-1). Further, Scenario-4 (with Intercropping) is also found suitable for improving 17% irrigation water productivity, 83% nitrogen productivity and 17% sugarcane equivalent yield over the FP practices. For the summer season sugarcane with Co 0238 variety, Scenario-3 is found promising for improving 128% irrigation water productivity, 88% nitrogen productivity and 20% sugarcane yield over the FP practices (Scenario-1). Scenario-2 (FP with recommended dozes) is also found suitable for improving 18% irrigation water productivity, 59% nitrogen productivity and 20% sugarcane yield over FP practices (Scenario-1).

Ratoon cane crop was taken up in all AIP fields during Feb-Dec 2024 after harvesting of planted sugarcane. Ratoon cane growth and yield data were recorded at 6, 9 and 12 months and at harvesting in all scenarios of three AIPs during crushing season 2024-25. The analysis of preliminary results of sugarcane ratoon yields (Fig. 3.2 and 3.3) indicates that the highest cane yield was recorded in Scenario-5 and the lowest cane yield in Scenario-1 at Titawi and Nandi Firozpur AIP experimental sites, respectively. The second highest cane yield was recorded in Scenario-3 at Titawi AIP site. However, at Nandi Firozpur experimental site, the second highest yield was recorded in Scenario-4. Overall, cane yield at Titawi AIP sites was higher as compared to the Nandi Firozpur AIP site.

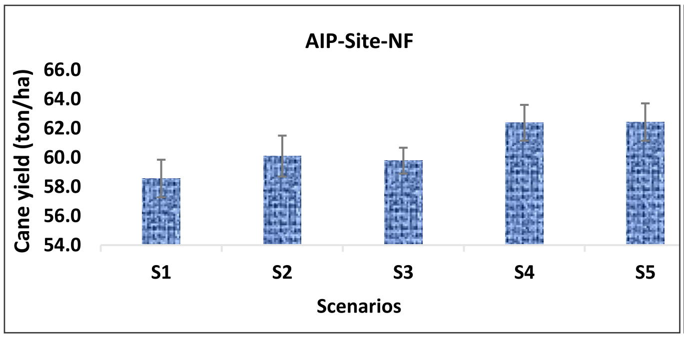


Fig 3.2 Effect of different scenarios on ratoon yield on Nandi Firozpur AIP, Saharanpur

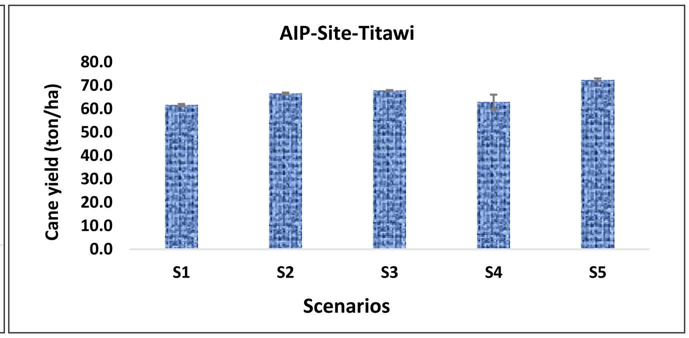


Fig 3.3 Effect of different experimental scenarios on ratoon cane yield at Titawi AIP, Muzaffarnagar

IrriWatch data for 15 experimental fields under three AIPs for the plant season (Feb 2023 to March 2024) and 156 cane fields (101 ha area) under 4 FPs were analyzed for daily and accumulated vegetation cover, dry matter production (DMP), soil moisture, ET, irrigation applied, leaf nitrogen, etc. at 10 m x 10 m pixel data and entire field levels. Four Farmer's Platforms (FPs) established at Nandi Firozpur, Titawi, Mansurpur and Doula in the Hindon basin were studied for understanding the prevailing dominant sugarcane cultivation, irrigation, fertilizers, pesticide and other inputs application practices; analyzing the relative performance of selected farmer's fields within a farmer's platform and comparing with other platforms by applying thermal remote sensing technology and farmer surveys, and evaluating eco-hydrological impact of sugarcane cultivation in the Hindon basin. The IrriWatch based projected cane yield of each field of three AIPs was correlated with the measured cane yield data collected from field sampling and factory measurement and was found within the reasonable accuracy (Fig. 3.4). Three progressive farmers of Titawi sugar mill (Field ID-TF 24, 68 & 10) outperformed in DMP and projected cane yield. The remote sensing derived ratoon cane yield data are being validated from the cane harvest data. Trainings to IPL-Titawi and DBO-Mansurpur sugar mill staff and progressive cane farmers were provided on web based IrriWatch advisory service- crop growth and soil moisture alerts for optimizing irrigation and fertilizer applications and cane productivity.

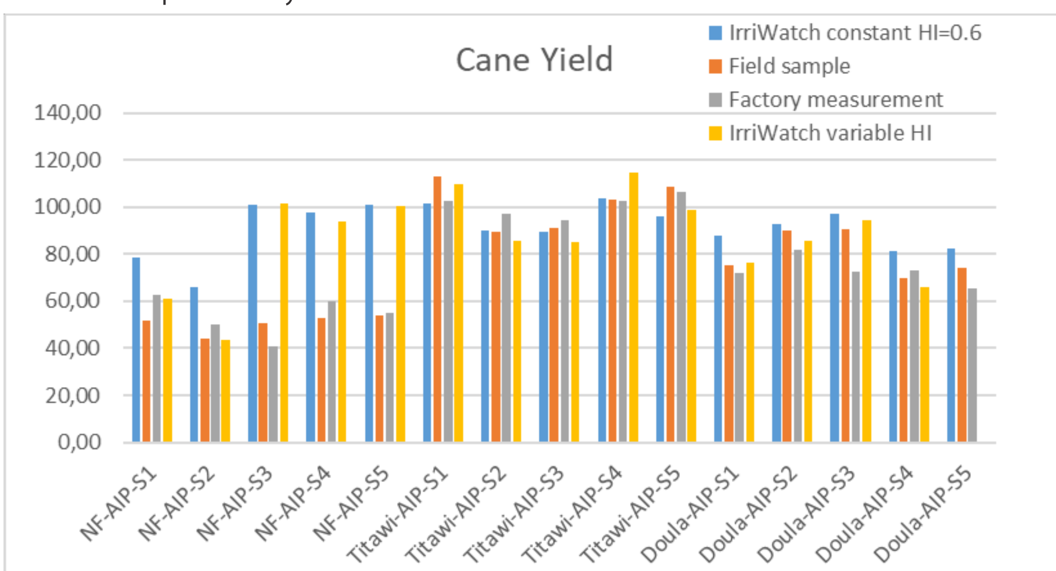


Fig 3.4 Validation of AIP cane yield results with IrriWatch thermal remote sensing data

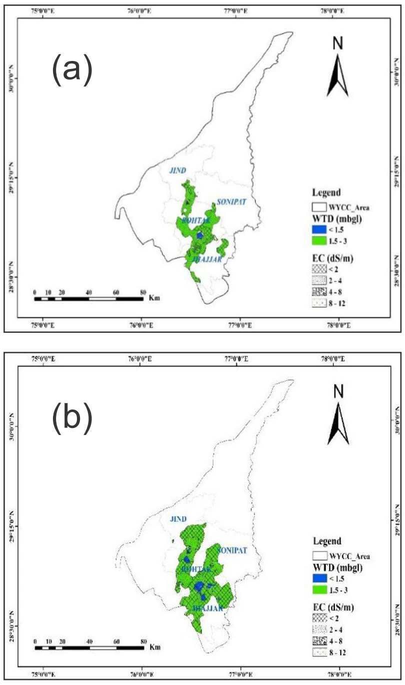


Fig. 3.5 Extent and distribution of critical and potential area based on
a) pre-monsoon and
b) post-monsoon data in WJC

Regional Salt Balance Modelling of Western Yamuna Canal command of Haryana

(Satyendra Kumar, Bhaskar Narjary and Sagar Vibhute)

The Western Yamuna Canal Command (WJC) covers part of the Upper Yamuna Basin and the inland alluvial basin in Haryana. With introduction of the irrigation project, in addition to enhance agricultural production, secondary salinization issue has also emerged due to injudicious and unscientific use of canal water. The farming is in some parts of WJC is about to abandoned due to high water table and soil salinization due to poor quality groundwater. To restore crop production in these area, salt leaching and controlling groundwater table to a certain depth (1.5m bgl) is needed. For this purpose, sub-surface drainage (SSD) technology is very effective and being implemented with the state government support. However, safe disposal of salt removed by the SSD holds the key for long term success of the technology and to achieve sustainable crop production in the region. The drainage effluent pumped from the SSD project site should not create any problem to crops of downstream. Therefore, implementation of SSD in affected area needs spatio-temporal information on salt and water dynamics to avoid any adverse environmental effects. In order to quantify the drainage effluent generated by the SSD, assessment and distribution of affected area which needs SSD intervention, has to be delineated. To characterize the critical and potential waterlogged area for SSD projects, groundwater level and its salinity were analysed in geographical information system environment. The spatial map of groundwater level and salinity data of consecutive three years i.e. 2019-21, was prepared and the area falls under critical (WTD < 1.5m, EC > 2 dS/m) and potential area (WTD - 1.5-3m and EC >2 dS/m) categories consecutively for three years were delineated. The categorization was done for pre and post monsoon period. The extent and distribution of groundwater level and salinity in western Yamuna canal command is presented in Fig 3.5. Based on pre-monsoon data, the most critical area which need immediate implementation of SSD to restore agriculture productivity and ensure livelihood security of the farming community was delineated as ~ 3000 ha, which increases to ~15000 ha in post-monsoon. The potential area for SSD was characterized as ~121000 ha (pre-monsoon) and ~224000 ha (post-monsoon).

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

Soil salinization in irrigated agriculture is a complex process that depends upon irrigation water, soil salinity, climatic variables, and groundwater interactions. Rohtak, district of Haryana, which represents an irrigated agricultural region and is affected by water logging and salinity, was selected to study the effect of climate change on soil salinization. An EMI (EM38) survey was conducted at 262 locations all over the Rohtak district to characterize root zone soil salinity. Quasi-3-dimensional inversion algorithm (EM4Soil-V302) was used to invert EMI (EC_a) data to get depth-specific true apparent electrical conductivity (σ). This true electrical conductivity (σ) was correlated with measured soil salinity (EC_e) in the topsoil (0–0.15 m), subsurface (0.15-0.3 and 0.3–0.6 m), and (0.6–0.9 m) subsoil layers. The regression coefficient of 0.65, 0.66, 0.66, and 0.65 was observed respectively, in topsoil (0-0.15 m), subsurface (0.15-0.3 and 0.3-0.6 m), and (0.6-0.9 m) subsoil layer between soil salinity (EC_e) and true apparent electrical conductivity (σ) and mapping was done with estimated soil salinity data (Fig 3.6). The textural analysis of soil showed that soil texture of the study region is highly variable. Soil of Rohtak district

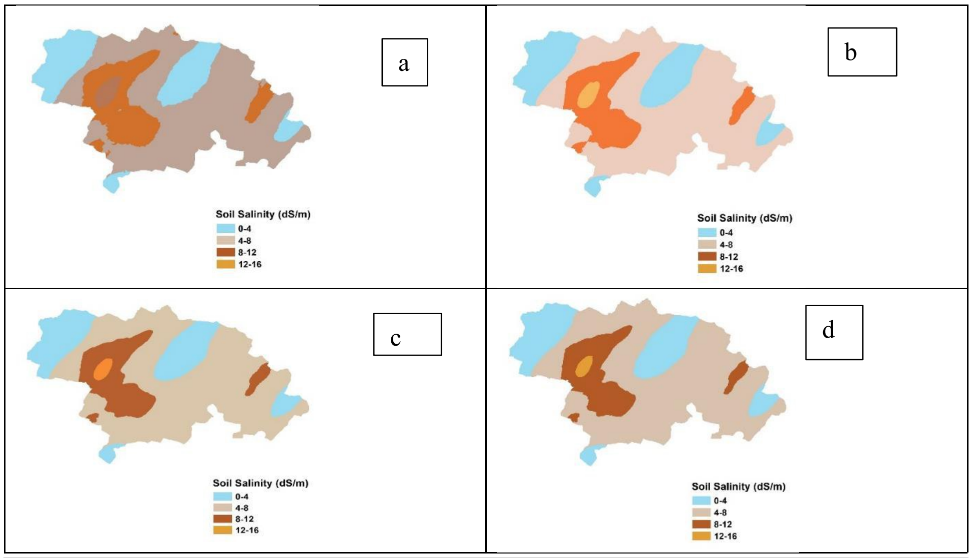


Fig. 3.6 Soil salinity
a) 0-15 cm
b) 15-30 cm
c) 30-60 cm
d) 60-90 cm soil layer

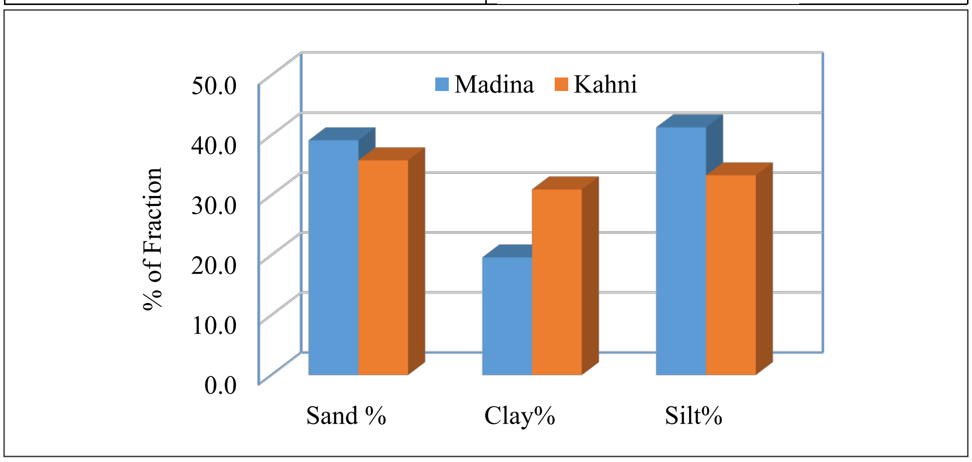


Fig. 3.7 Soil texture of two sites used for lysimeter study

was characterized as clay loam to sandy clay loam in texture with sand percentage varying from 60-88 %. Soil from two places namely Kahni and Madina village, representing heavy (Clay loam) and light (Loam) texture, were collected for lysimeter study at Karnal (Fig 3.7). In lysimeter, soil salinity and shallow saline groundwater table condition were created for generating data on salt and water dynamics in controlled condition to use in simulation study.

Evaluation of developed sensor in the field

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 Ashwini Kumar)

The automation of irrigation in country is very limited and not much popularize among the farmers due to high cost and required technical skills for its monitoring in Indian conditions. This research work has aimed to design and develop low cost sensor based automated irrigation system to bridge the gap between conventional irrigation and need base irrigation under salt affected environment. The developed IoT based automated irrigation system will switch on the irrigation, when soil solution salinity and moisture content reached to threshold level. To achieve the objective, effort has been made to developed a soil moisture sensor for measurement of soil moisture, temperature and electrical conductivity on real time basis. The design and development of soil moisture sensor was based on to measure the property of electrical resistance of the soil. The

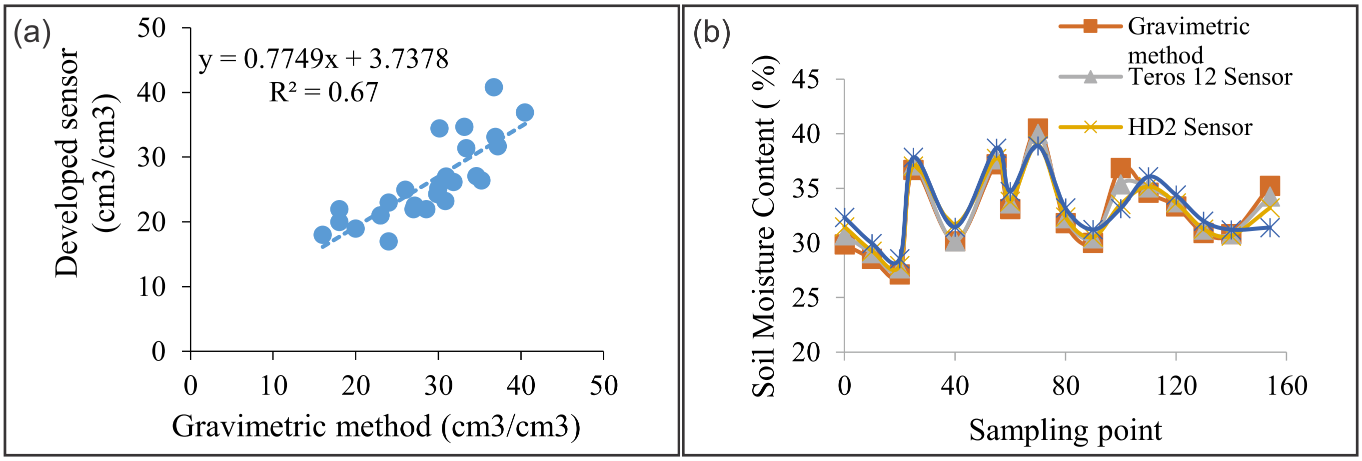


Fig 3.8 Comparison of soil moisture content measured with a) developed sensor and gravimetric method b) developed sensor with different commercially available sensors

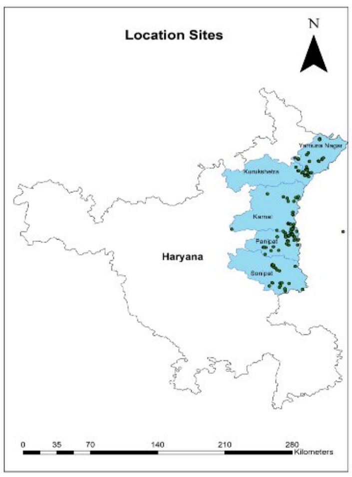


Fig 3.9 Study area and location of sites

electrical resistance of soil increases as the water content of the soil decreases. The coefficient of determination (R^2) for soil moisture measurement was found 0.67 against gravimetric and standard method (Fig 3.8). The electrical resistance of soil increases as the water content of the soil decreases. The performance of developed sensor was also compared with Teros 12 and HD2 sensor and satisfactory results were found. The performance of sensor was also evaluated in different soil salinity (EC_2 -2 to 20 dS/m) and coefficient of determination (R^2) was found as 0.63-0.65 against standard laboratory method.

NEXUS Gains: Realizing Multiple Benefits across Water-Energy-Food-Forest-Biodiversity Systems (Satyendra Kumar, Gajender and Bhaskar Narjary)

The groundwater table in rice-wheat dominant cropping system of north-west India is depleting at faster rate @33-88 cm per year, in last two decades. The effort has been made to divert prevailing conventionally grown (transplanted) rice area to direct seeded rice (DSR) with the hypothesis that groundwater pumping for irrigation will reduce by utilizing rainwater more efficiently under DSR. To gather evidence of actual irrigation application to rice systems (conventionally grown as well as DSR) by the farmers, a collaborative project of ICAR–Central Soil Salinity Research Institute Karnal and International Rice Research Institute (IRRI), Philippines was initiated in rice-wheat dominant Ganga basin of Haryana, covering parts of Sonipat, Panipat, Karnal and Yamunanagar districts (Fig 3.9). In order to quantify the actual water applied to rice field, a separate pipe line from the tube well was provided and fixed a water meter at the head of each field (photo). Total 153 water flow meters were installed at farmer's field, out of which approximately 62 water flow meters were installed in DSR fields.

View of installed water meter at farmers field

Irrigation applied by the farmers varied between 70-82 cm in DSR, while in conventionally grown transplanted puddled field, irrigation varied between 72 – 87 cm in the study region. The medium duration rice variety of 115-120 days was adopted for the study. Further, in DSR, farmers of Karnal district applied the least water while the maximum irrigation was recorded for farmers of Panipat district. However, the highest irrigation in TPR farmers was recorded in Sonipat. It is also found that TPR produced ~13% higher yield than DSR. The irrigation water productivity was recorded as 0.67 and 0.69 kg/m³ for DSR and TPR, respectively.

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

The Rice-Wheat dominant area of Haryana state, India, covering Karnal, Kaithal, Panipat, and Kurukshetra districts (29° 9' 46.8'' to 30° 14' 52.8'' latitude and 76° 10' 33.6'' to 77° 13' 22.8'' longitude) and having area of 7736.185 sq.km, is mainly dependent on groundwater resources. The continuous use of water for crop production has led to decline in groundwater table and the declining rate may further increase in future under changing climate. Therefore, sustainable management of groundwater resources needs reduction in irrigation. With the aim of developing strategies to reduce groundwater pumping, the study was proposed to simulate the effects of agronomic interventions on groundwater behavior of the study region. The study was conducted with the observed daily weather data (rainfall, maximum and minimum temperature, relative humidity, sunshine hours, and wind speed) for the period of 2013-2021 and prevailing cropping pattern. For simulating groundwater behavior, net flux from different land uses was estimated and used as input parameters in groundwater flow model. To estimate net flux, upward and downward water flux (draft-return flow) for different land uses were estimated by using modeling approach and standard procedures. The groundwater pumping was considered as upward flux i.e. draft and the downward flux (water passed beyond crop root zone in agriculture land), seepage from canal and water body were taken as return flow (return) components. The different land uses such as cropped area, forest land, residential area, water bodies including canal network and other land uses (barren, pasture and waste land) were taken into consideration while calculating groundwater recharge and draft component. The methodological approach used for simulating groundwater behavior is presented in Fig. 3.10.

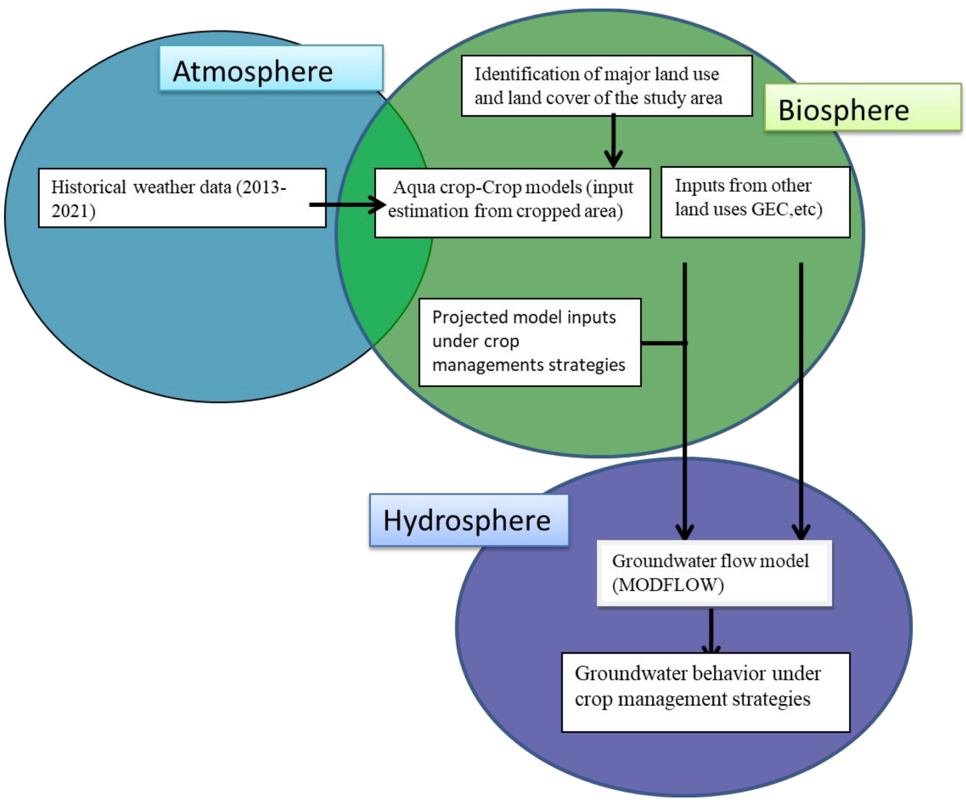


Fig 3.10 Methodological approach depicting interaction of atmosphere, biosphere, and hydrosphere for estimating fluxes for simulating groundwater behaviour of the study area

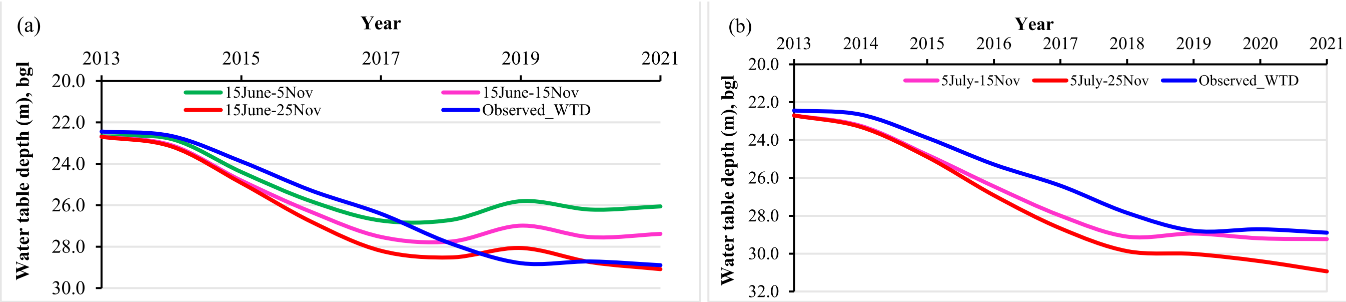


Fig 3.11 Groundwater level fluctuation as influenced by a) 15 June b) 05 July of rice transplanting with the combination of wheat sowing dates of 05 Nov (early), 15 Nov (mid) and 25 Nov (late)

With the aim of maximizing beneficial use of rain to reduce groundwater pumping for irrigation, effects of different transplanting dates of rice on groundwater fluctuation were simulated. It was assumed that variation in crop evapotranspiration, which is influenced by weather condition, affects the groundwater water pumping. The date of transplanting for simulation study was adopted as 15 June (prevailing practice), and delayed by 20 days (05 July). The groundwater table was 23.5 m below ground level (bgl) during the initial simulation period (2013). Simulation results show that prevailing rice transplanting date 15 June and wheat sowing on 25 November, could have been registered more decline in ground water. (Fig. 3.11a). However, if rice transplanting was 05 July with prevailing date of wheat (15 June), the groundwater table decline might have more than the actual (Fig 3.11b). The variations in groundwater fluctuation may be attributed to variable net draft under different combination of dates of rice transplanting and wheat sowing. It is also found that if rice is transplanted in last fortnight of June and wheat sowing date also shifts to first week of Nov, groundwater table decline might have lesser than the actual. Thus, simulation study reveals that to manage declining groundwater in the study area, transplanting of rice during last fortnight of June and wheat sowing in first week of November could be the best combination of dates of rice transplanting and wheat sowing.

Scaling groundwater recharge structure for climate resilience and groundwater augmentation at farmers' field in pilot villages of Haryana (Satyendra Kumar, Bhaskar Narjary, Aslam Pathan and Suresh Kumar)

View of recharge arm at the bottom of filter chamber and covered with bolder

The sustainability of agriculture in Haryana is threatened due to alarming rate of decline of water table, increase in pumping cost and deterioration in groundwater quality. The groundwater decline can be deferred to some extent by enhancing groundwater recharge using rain and excess canal water through adopting artificial groundwater recharge techniques. It helps in utilizing runoff water that otherwise goes waste or causes damage to standing crops and also in improving groundwater quality. Further, there is an urgent need to gradually diversify from rice to other less water requiring crops to reduce burden on groundwater resources. Maize, having about one quarter irrigation requirement as of paddy, is emerging as a viable alternative in Haryana except for its vulnerability to water submergence caused due to occasional heavy rains. Occurrence of high intensity rainfall over a small period is likely to increase with impending climate change. In addition, there is indication of larges shifts in temporal distribution of rainfall during monsoon months. Hence, a suitable structure provides localized drainage option could help in sustainable crop production under climate change. Such structure not only

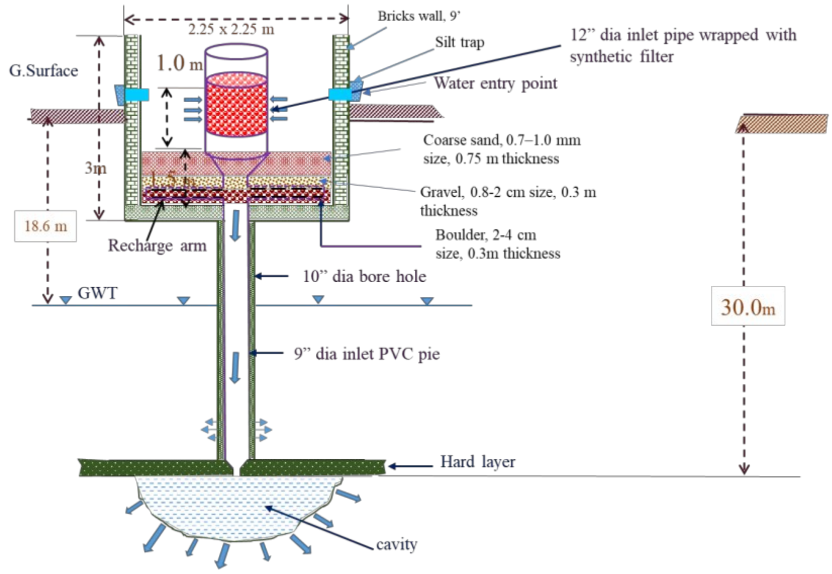


Fig 3.12 Sketch diagram of design of recharge structure installed in the field

View of two stage filtration unit

provides adoptive measure against extreme rainfall event for crop production but also good quality recharged rain water improves groundwater availability and quality. In view of these facts, this project was initiated under the umbrella of *Rashtriya Krishi Vikas Yojana*. The main aim of the project was to design and develop small groundwater recharge structure, evaluate at farmer's field and create awareness among farmers about the location specific drainage option as adoptive strategies for crop production under climate change. The total 14 recharge structures were installed at different locations (villages) in Karnal, Kaithal and Kurukchetra districts of Haryana. Two types of filtering unit viz. i) two stage filtration unit with radial filter and ii) vertical sand base coupled with silt trap, were designed and installed. The sketch diagram of installed structure is presented in Fig 3.12. The field level evaluation will be undertaken in coming monsoon season.

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

Under this project, two sub experiments namely i) Effect of water stress regime on performance of rice under direct seeded rice and ii) Varietal evaluation to identify varieties better suited to DSR conditions, were conducted. The paddy crop was sown on 18th June, 2024 to evaluate performance of direct seeded rice under different water stress regimes. Two varieties namely i) PR126-water sensitive and ii) DRR42-moderatly sensitive to waters stress were sown with row spacing of 20 cm. The water stress regime was taken as main plot treatment and variety was considered sub-treatment, and accordingly experiment was laid out. The plot size was 13 x 10m, in which each variety was sown in a sub plot of 6 x 10 m and 1m buffer was left in the middle. Each treatment was replicated thrice. To quantify the amount of water applied to each plot, a pipe network was laid which had independent water meter and out let for each plot. The treatments of water regimes was based on soil matric potential viz. i) T1- Near-saturation; no stress as check, T2-10 kPa throughout crop growing period, iii) T3-20 kPa between 3 weeks to flowering and rest period near saturation iv) T4-20 kPa between 3 week to panicle initiation (PI) and rest period near- saturation v) 30 kPa between 3 week to PI and rest period near-saturation vi) T6- 40 kPa between 3 week to PI and rest period near- saturation, vii) T7- 20

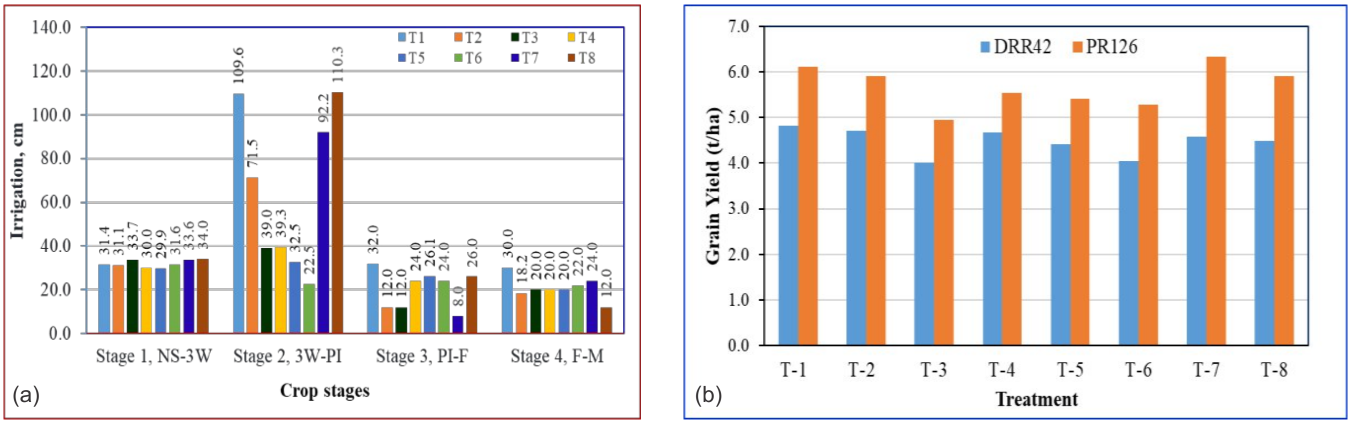


Fig 3.13 (a) Irrigation applied under different treatments during different growth stages and (b) Grain yield of both varieties recorded under different water stress regimes

View of crop in the field

kPa between PI to flowering and rest period near- saturation and viii) T8-20 kPa between grain filling to plant maturity (PM) and rest period near- saturation. Results reveal that during the crop growth stage 2 i.e. 3 weeks after sowing to panicle initiation period, a lot of variation in irrigation was recorded for different treatments and it varied from 22.5 cm to 109.0 cm (Fig. 3.13a). The variation in irrigation under different treatments was due to the variation in irrigation interval associated with varing soil matric potential for different treatments. The maximum irrigation (~203.0 cm) in T-1 and the minimum (~101 cm) was recorded for T-6 during entire crop growing season. T-2 saved ~35% irrigation as compared to treatment T-1. The crop yield was found better in PR126 as compared to DRR 42. Among the different water stress treatments, the highest yield was recorded in T1 (4.82 t/ha) and T7 (6.34 t/ha) for DRR 42 and PR126, respectively. The lowest yield among all treatments was recorded under T-3 treatment (-20 kPa throughout the growing season). Irrigation water productivity (IWP) for PR 126 variety was found higher than DRR42. Interestingly, T3 recorded the highest IWP at par with T4, T5 & T6 treatments. The lowest IWP in T-1 amongst all treatments despite of the highest yield level shows that yield improvement was not in the same proportion as of irrigation amount.

The results of trail on evaluation of varieties/advance lines suited to DSR conditions, reveal that the basmati varieties PB-1847 (43.6 q ha^{-1}), CSR-301-16-153 (38.4 q ha^{-1}), HKR-17-422 (38.3 q ha^{-1}) and CSR-PET-27 (37.9 q ha^{-1}) produced significantly higher grain yield as compared to PB-1885 (29.2 q ha^{-1}), PB-5 (24.2 q ha^{-1}) and HB-2 (20.6 q ha^{-1}) (Fig 3.14). However, performance of SAVA 134 (64.3 q ha^{-1}) was found the best among varieties / advance lines of coarse grain type paddy evaluated for DSR.

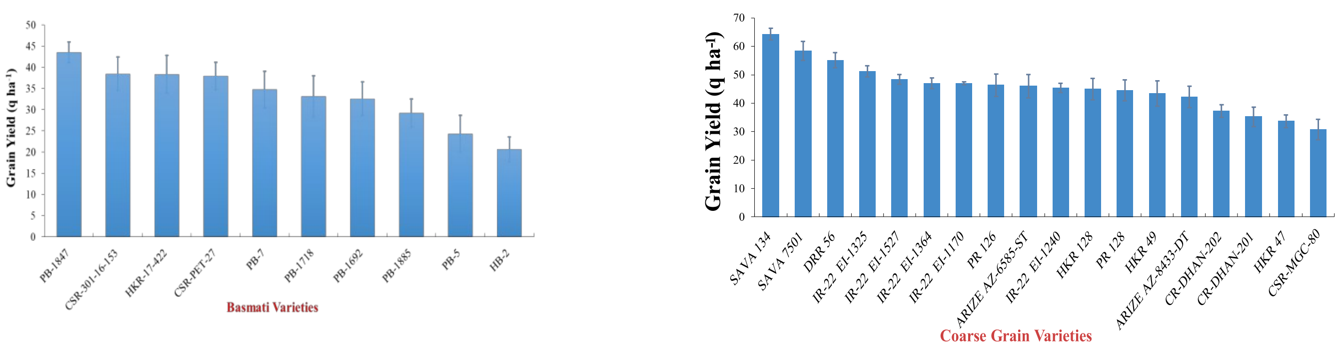


Fig 3.14 Performance of different varieties/advance lines under DSR condition

Management of Marginal Quality Water

Development of reclamation materials with high gypsum equivalent for productive utilization of alkali soil and water (Arvind Kumar Rai, Nirmalendu Basak, Parul Sundha, Rajender Kumar Yadav, Parbodh Chander Sharma**)**

Different combinations of the high gypsum equivalent materials were developed as an alternative to gypsum using granulation machines for reclamation of soil and water sodicity. Neutralizing of RSC of alkali water had lower soil $pH_{1:2}$ than unamended alkali irrigation. A single application of GYPRFS () and Calfils (two years before starting of the experiment at rice transplantation) and once a year application of RAMSWC at rice transplantation had lower values of soil $pH_{1:2}$. However, among the soil amendments, a single application of GYPRFS presented lower values of $pH_{1:2}$ than the Calfils and RAMSWC

Table 4.1 Soil amendments (SA) effect on soil pH and electrical conductivity (dS m^{-1})

Treatments	$pH_{1:2}$	pH_s	pH_e	EC_2	EC_e
	Water Quality				
RSC 3	8.22^b	7.98^b	8.16^a	1.62^a	3.70^a
RSC 6	8.45^a	8.09^a	8.18^a	1.53^a	4.24^a
RSC 7.5	8.45^a	8.05^a	8.17^a	1.62^a	4.31^a
NTW	8.40^a	8.06^a	8.19^a	0.88^b	2.28^b
	SoAmd				
GYPRFS	8.13^C	7.86^C	8.07^D	1.75^A	4.20^A
RAMSWC	8.42^B	8.08^B	8.22^B	1.41^B	3.75^A
Calfil	8.33^B	8.03^B	8.13^C	1.40^B	3.62^{AB}
Control	8.64^A	8.20^A	8.27^A	1.08^C	2.95^B

Table 4.2 Water quality (WQ) and soil amendments (SA) affect the ionic concentration (me L^{-1}) of soil water saturation paste extract; carbonate (CO_3^{2-}) was non-detectable; SAR: sodium adsorption ratio; CROSS: cation ratio of soil structure stability

Treatments		Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO^{3-}	Cl^-	SO_4^{2-}	Total alkalinity	SAR	CROSS
WQ	3	9.01^a	8.56^a	22.89^a	0.048^a	2.40^b	14.33^a	23.93^a	2.81^b	8.75^b	9.01^a
	6	6.44^b	7.00^b	27.56^a	0.019^b	2.92^a	12.65^a	27.15^a	3.34^a	12.52^a	6.44^b
	7.5	6.94^b	9.13^a	27.99^a	0.034^a	2.50^b	11.54^a	29.60^a	2.88^b	11.63^a	6.94^b
	NTW	$7.76a^b$	6.09^b	10.64^b	0.015^b	2.34^b	4.38^b	17.47^b	$3.00a^b$	4.81^c	7.76^{ab}
SA	GYPRFS	10.16^A	12.75^A	21.94^A	0.036^A	2.27^B	12.52^A	28.20^A	2.69^C	7.34^B	10.16^A
	RAMSWC	8.53^B	6.00^C	23.29^A	0.032^{AB}	2.69^A	10.52^{AB}	26.76^A	3.10^B	$9.95A^B$	8.53^B
	Calfil	6.43^C	7.84^B	22.10^A	0.019^B	2.21^B	9.17^B	24.44^{AB}	2.63^C	$9.41A^B$	6.43^C
	Control	5.03^C	4.19^D	21.74^A	0.031^{AB}	2.98^A	10.69^{AB}	18.74^B	3.63^A	11.02^A	5.03^C

Table 4.3 Water quality (WQ) and soil amendments (SA) effect on different plant parameters of rice in lysimeters

Water quality	Grain yield	Straw yield	Grain; straw ratio	Harvest index	Chaffy grain percent
3	0.68^b	1.50^{ab}	0.47^b	0.31^b	10.41^c
6	0.59^c	1.37^b	0.45^b	0.30^b	11.82^b
7.5	0.65^b	1.55^a	0.43^b	0.29^b	14.45^a
NTW	0.82^a	1.50^{ab}	0.55^a	0.35^a	9.26^d
LSD					
SoAmd					
GYPRFS	0.68^C	1.42^A	0.48^B	0.32^B	10.52^B
RAMSWC	0.73^B	1.48^A	0.51^B	0.33^{AB}	10.32^B
Calfil	0.82^A	1.48^A	0.57^A	0.36^A	10.32^B
Control	0.50^D	1.53^A	0.33^C	0.25^C	14.78^A

In above tables: The lower-case (a–b) and upper-case (A–D) letters followed by numeric at column shows are significantly different (P< 0.05); ns, *, **, *** are <0.05; <0.01 and <0.001, respectively.

application ($P < 0.05$). Alkaline irrigation developed soil salinity with higher values of $EC_{1:2}$ than irrigation with the best available water (BAW) (Table 4.1). Alkali irrigation showed higher values of SAR (11.21 and 10.27) in RSC 6 and 7.5 than RSC 3, and BAW (Table 4.2). Continuous alkali irrigation (RSC) for two crop cycles of rice–wheat system affected wheat straw yield and the presented data showed the values of wheat yield 2023 (Table 4.3). Irrigation with RSC 3 showed higher values of microbial biomass C (MBC) (385.68 mg kg^{-1}), followed by RSC 6 (355.43), BAW (342.52), RSC 7.5 (331.43). RSC 3 presented higher values of dehydrogenase activity (DHA, 47.58 mg TPF g^{-1} soil day^{-1}), followed by BAW (45.52), RSC 6 (45.11) than RSC 7.5 (40.01), ($p < 0.05$). Similarly, soil amendment application for alkali neutralization, DHA activities was higher in once in a year application of RAWSWC treated soil before rice transplantation (47.66) followed by single application of GYPRFS (44.54), unamended control (44.14), and Calfil (41.86).

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

The excessive extraction of groundwater has exacerbated soil and groundwater salinization, even in regions where water quality was initially good. SAS plays a crucial role in the ecological balance of arid and semi-arid regions, but soil salinization severely limits agricultural productivity, making it a significant obstacle to sustainable agricultural development. A global economic assessment estimates that soil salinization results in annual losses of approximately $27.3 billion, emphasizing the urgent need for effective management strategies. Traditional salinity management techniques, such as drainage systems, require high initial investments and struggle to keep pace with the rapidly increasing spread of soil salinization. Recognizing the urgency of this issue, ICAR-CSSRI is conducting a collaborative research project with JIRCAS, Japan, titled "Sustainable Resource Management System for Waterlogged and Saline Arid Regions of India." This project focuses on developing cost-effective and sustainable techniques to improve soil drainage, manage soil salinity, and enhance crop productivity. One of the key components of this initiative is the evaluation of the Cut-soiler–constructed Preferential Shallow Subsurface Drainage (PSSD) system. The Cut-soiler is a tractor-mounted farm implement designed to create residue-filled subsurface drains using surface crop residues. By incorporating this system with efficient trickle irrigation technologies such as the Water Drop Tube, researchers aim to develop a low-cost desalinization solution for different soil types. The field experiments are being conducted in salt-affected areas of Hisar, Haryana, and ICAR-CSSRI Karnal, where the effectiveness of this combined approach is being rigorously tested. To support the research, infrastructure for controlled irrigation using different salinity levels was constructed at ICAR-CSSRI, Karnal, and the IIWBR research farm, Hisar. Water drop tubes were installed at a depth of 20 cm for subsurface irrigation. In addition, advanced monitoring systems, including 5TE sensors (for volumetric water content, EC, and temperature) and observation wells for groundwater level monitoring, were set up to assess the long-term impact of these interventions. The Cut-soiler and water drop tube sub surface irrigation was installed in semi controlled Lysimeter at ICAR-CSSRI, Karnal. Border irrigation (BI) and Sub-surface saline (4 d Sm^{-1}) irrigation (20cm depth by Water drop tube) was applied to sandy loam saline soil and silty clay heavy soil with Cut-soiler and without Cut-soiler. The layout of treatment plan is given in figure 4.1.

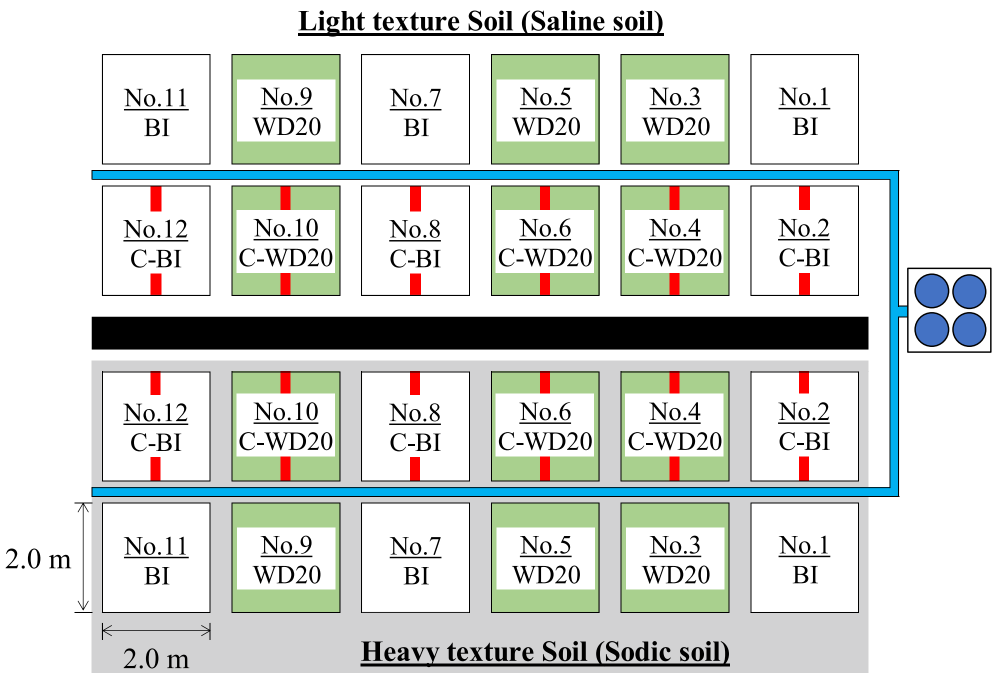


Fig 4.1 Layout of Cut-soiler anc water drop tube experiment in sem controlled Lysimeter at ICAR-CSSRI Karnal

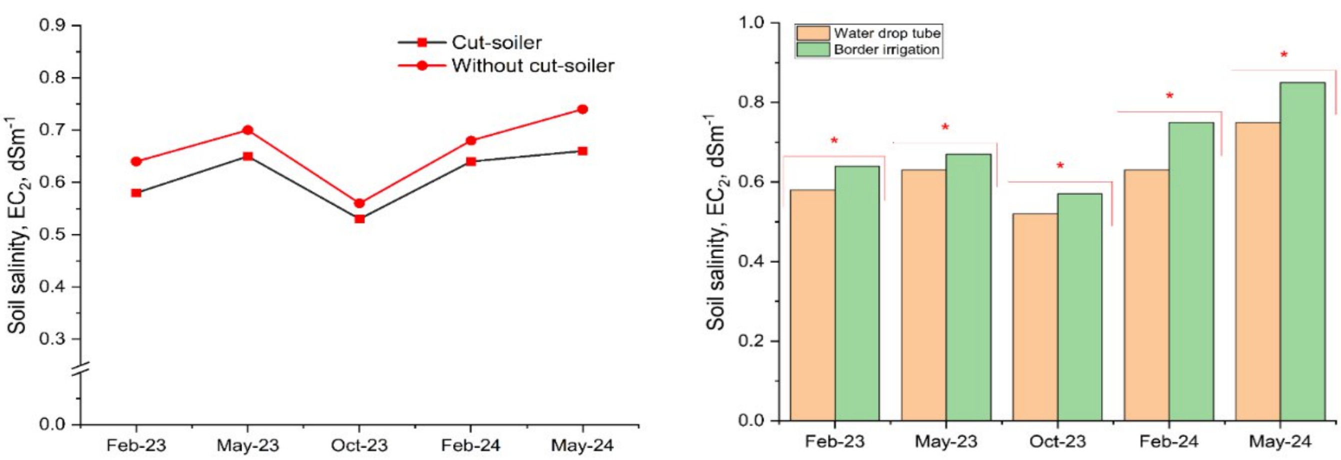


Fig 4.2 Soil salinity reduction due to cut-soiler and water drop tube under Lysimeter condition at ICAR-CSSRI, Karnal

The field experiment is currently in progress at ICAR-CSSRI, Karnal, utilizing a semi-controlled Lysimeter setup to study the effects of cut-soiler drainage and subsurface irrigation via water drop tube on pearl millet growth, soil salinity management, and water use efficiency. This experiment aims to assess how different soil and irrigation management strategies influence salinity dynamics, particularly under saline irrigation conditions. One of the significant findings so far is that there was no salinity buildup in the cut-soiler-treated plots where pearl millet was irrigated with water having an electrical conductivity (EC) of 4 dS m^{-1}. This suggests that the use of a cut-soiler can effectively disrupt compacted soil layers, improving water infiltration and reducing salt accumulation in the root zone (figure 4.2). 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.

The experiment also recorded seasonal variations in soil salinity accumulation, with notable increases observed during the May sampling period. Higher salinity levels were particularly pronounced in the surface soil layers, which is likely due to increased evaporative demand in the summer months. Surface soil salinity was found to be 15% higher than subsurface salinity during May, emphasizing the impact of seasonal climatic variations on salt distribution within the soil profile. A key comparison was made between different irrigation methods, and the results indicated that saline water irrigation through the water drop tube resulted in a 13.3% lower salinity buildup compared to the traditional border irrigation method. This reduction highlights the efficiency of subsurface water application in minimizing salt accumulation in the root zone, thereby improving soil health and crop productivity. Regarding crop performance, pearl millet yield showed significant improvements under various treatments. The grain yield was 20.6% higher in cut-soiler-treated plots, 18.1% higher in heavy-textured soil, and 26.3% higher in water drop tube-irrigated plots, compared to their respective control treatments (figure 4.3). These findings reinforce the effectiveness of cut-soiler and subsurface irrigation techniques in enhancing crop productivity under saline conditions. The results from this Lysimeter experiment suggest that combining cut-soiler drainage with water drop tube irrigation can be a promising strategy for managing soil salinity, improving water use efficiency, and increasing crop yield in salt-affected regions. This approach offers a sustainable solution for maintaining agricultural productivity in areas facing challenges due to high salinity and fluctuating groundwater levels.

A field experiment was 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 GS3 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

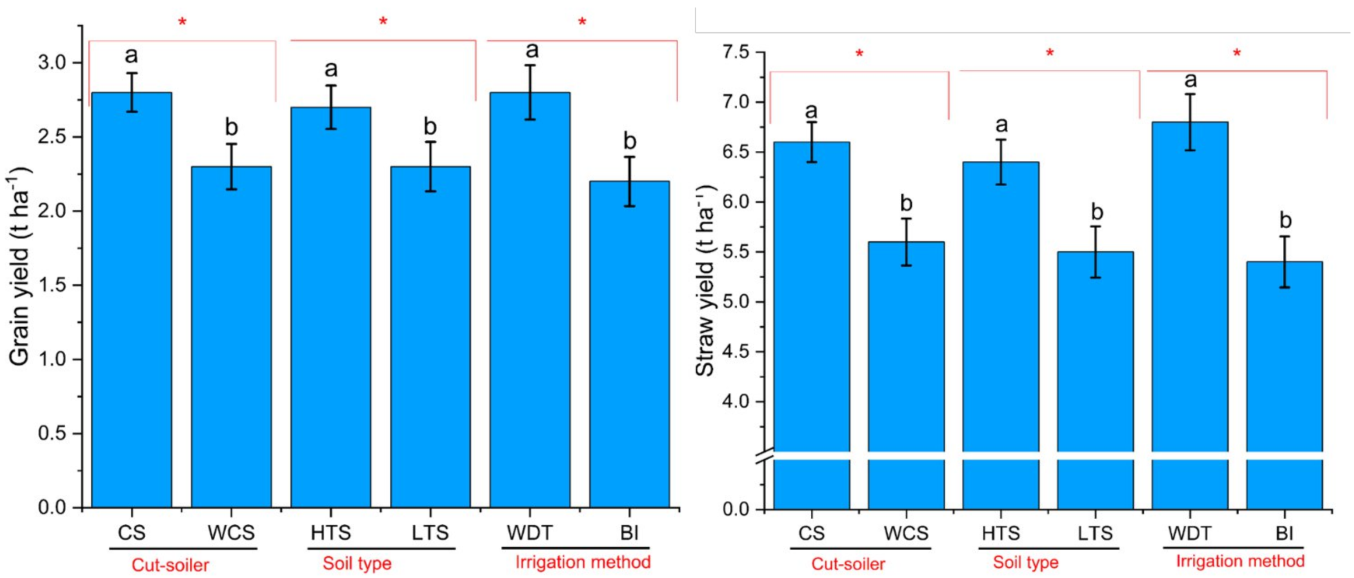


Fig 4.3 Grain yield and straw yield of pearlmillet under Lysimeter condition at Karnal site

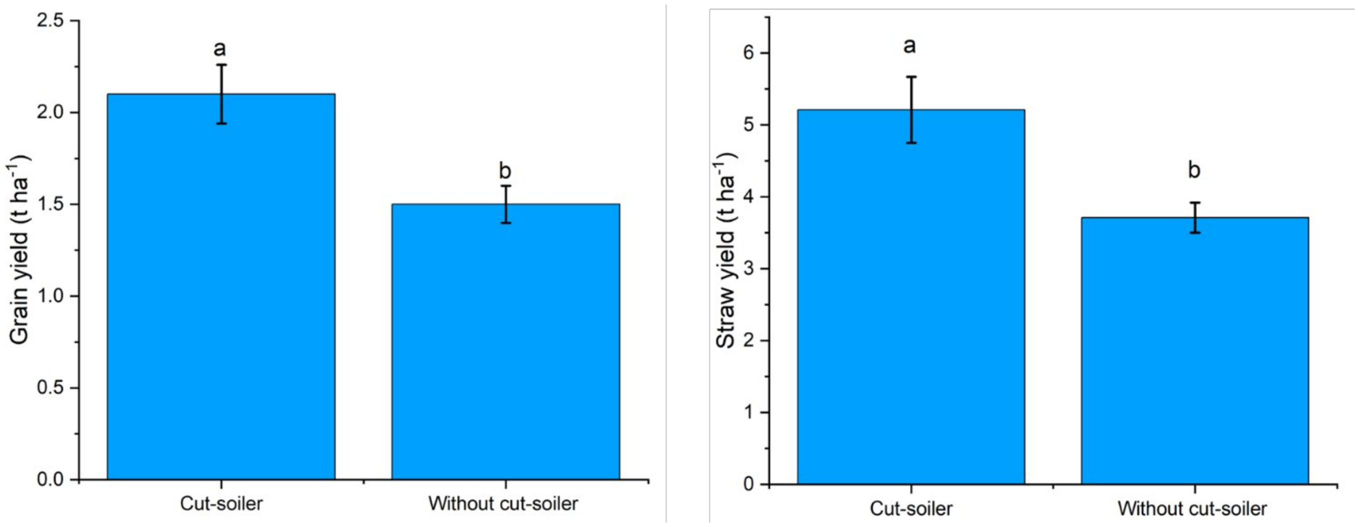


Fig 4.4 Effect of cut-soiler on grain and straw yield of pearlmillet at Hisar

following year. This seasonal fluctuation posed a risk of waterlogging and salt accumulation in the soil, negatively impacting crop growth.

However, the implementation of cut-soiler construction after dry-season crops proved to be an effective strategy for controlling groundwater rise and enhancing leaching efficiency. By breaking the compacted soil layers, the cut-soiler helped in improving water infiltration and preventing excessive salt buildup in the root zone. Results from the field experiment further demonstrated that soil salinity remained lower in the cut-soiler plots compared to the control plots. The positive impact of cut-soiler operations was reflected in crop yield, as the grain and straw yield of pearl millet increased by 42% and 39%, respectively, in cut-soiler plots compared to plots where the cut-soiler was not used (figure 4.4). This significant improvement in yield highlights the role of soil structural modifications in enhancing crop productivity under challenging saline conditions. Another key finding was the increment in soil salt buildup with depth, which is a common issue in saline-prone areas. However, the cut-soiler operation effectively reduced salinity even at lower depths, mitigating the risk of salt accumulation in the root zone. Quantitative analysis showed that the cut-soiler treatment resulted in a 34% reduction in soil salinity compared to the control plots. This reduction in salinity can be attributed to the improved leaching of salts facilitated by enhanced water movement in the soil profile. These findings hold significant implications for sustainable agricultural practices, particularly in areas where salinity and waterlogging pose major challenges to crop productivity.

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)

This study investigates the impact of differential alkalinity induced by residual sodium carbonate (RSC) in irrigation water on crop growth, seed development, and seed quality in rice and wheat. The study also examines the subsequent germination potential of these seeds. A long-term experiment is being conducted in lysimeters (2 m × 2 m × 2 m in size, equipped with drainage outlets connected to a common gallery) at the experimental farm of ICAR-Central Soil Salinity Research Institute, Karnal, India. The SW1

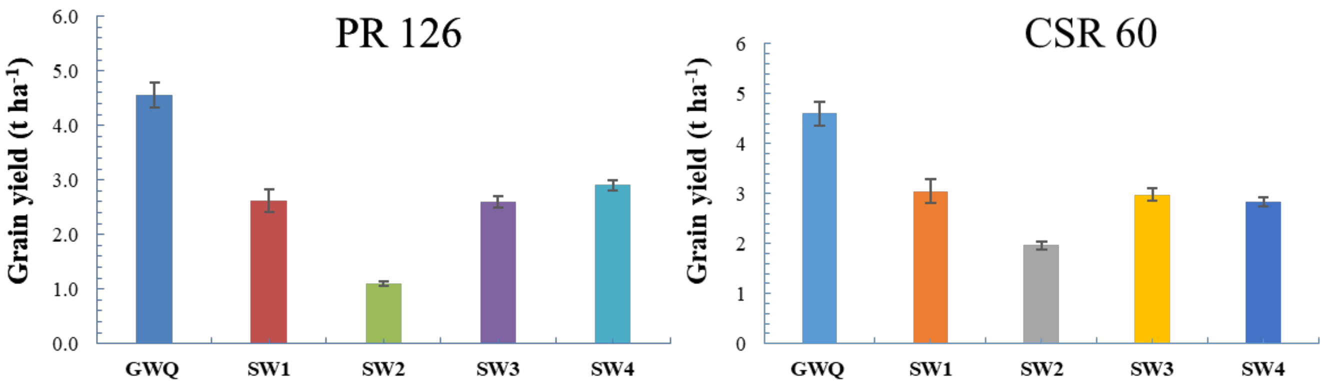


Fig 4.5 Effect of residual alkalinity water on yield of Rice-Wheat

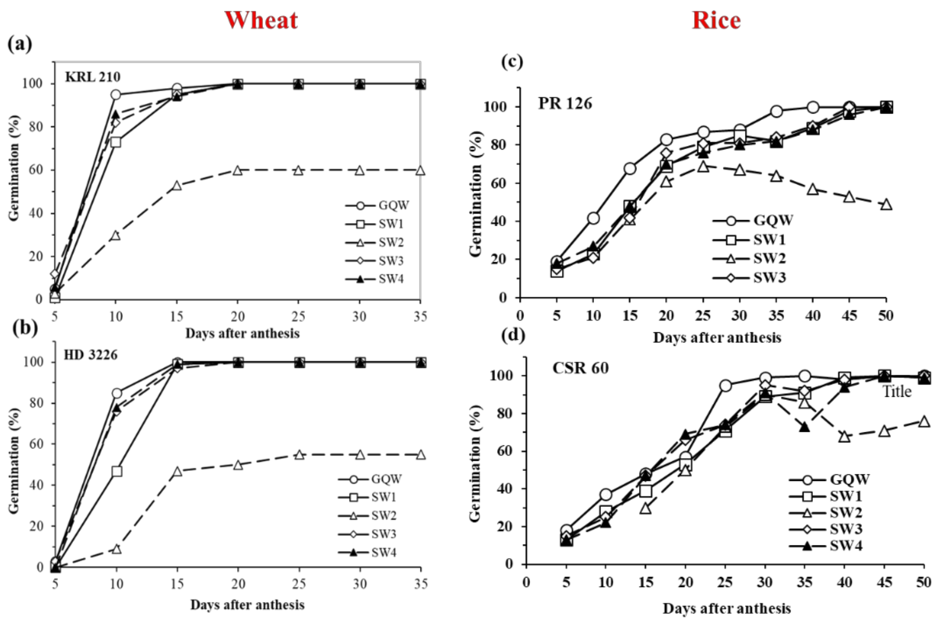


Fig 4.6 Effect of residual alkalinity water on germination of Rice-Wheat cultivars

and SW2 types had similar amounts of total salts (total electrolyte concentration 30 meq L^{-1}), but differed in residual sodium carbonate (RSC) (5 meq L^{-1} in SW1 and 10 meq L^{-1} in SW2), and SW2 was treated to neutralize RSC equivalent to 5 meq L^{-1} using gypsum (SW2 + Gypsum) in SW3 and sulphuric acid (SW2 + H_2SO_4) 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 wheat cvs KRL 210 and HD 3226 and for rice cvs PR 126 and CSR 60.

The experiment was conducted with wheat cvs KRL 210 and HD 3226. The reduction in wheat grain yield was higher in var. HD 3226 and reduction was more with increase in residual alkalinity irrigation water. In wheat var. HD 3226, yield was reduced under RSC 5 that was further reduced in RSC 10 compared to control. In var. KRL 210 the reduction was less as compared to HD 3226. Similary in rice CSR 60 showed the resistance to alkalinity and yielded higher under induced sodicity, whereas under control treatment PR 126 cultivar of rice yielded higher (figure 4.5).

Time to achieve highest germination (%) increase with residual alkalinity of irrigation water. The germination (%) was significantly lower at RSC 10 (SW2), this trend of germination was reported both rice and wheat cultivars (figure 4.6).

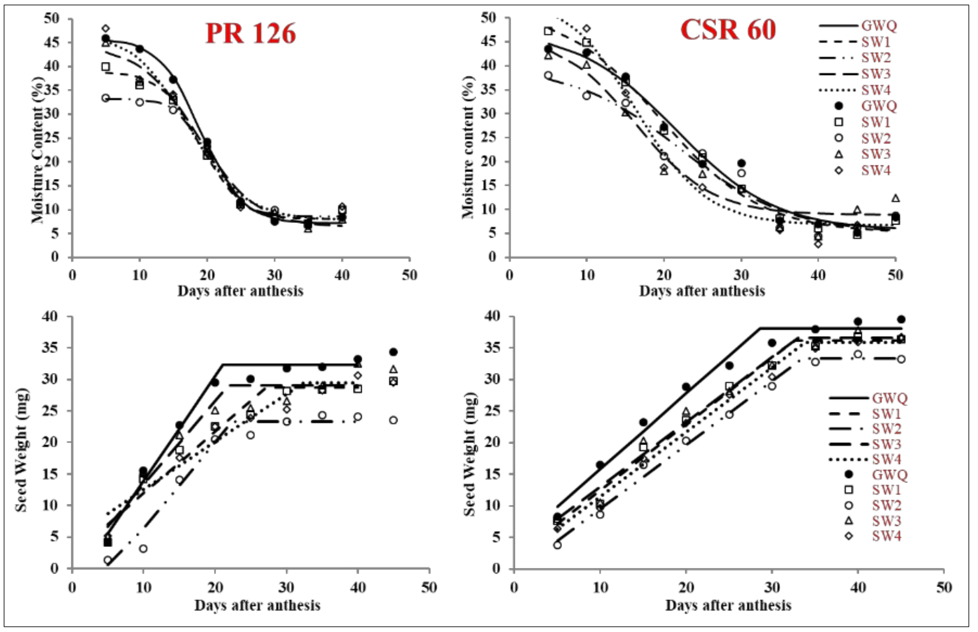


Fig 4.7 Changes in moisture content of fresh seeds and seed weight (g) of rice cv. PR 126 and CSR 60 in differential RSC induced alkali water irrigation regimes

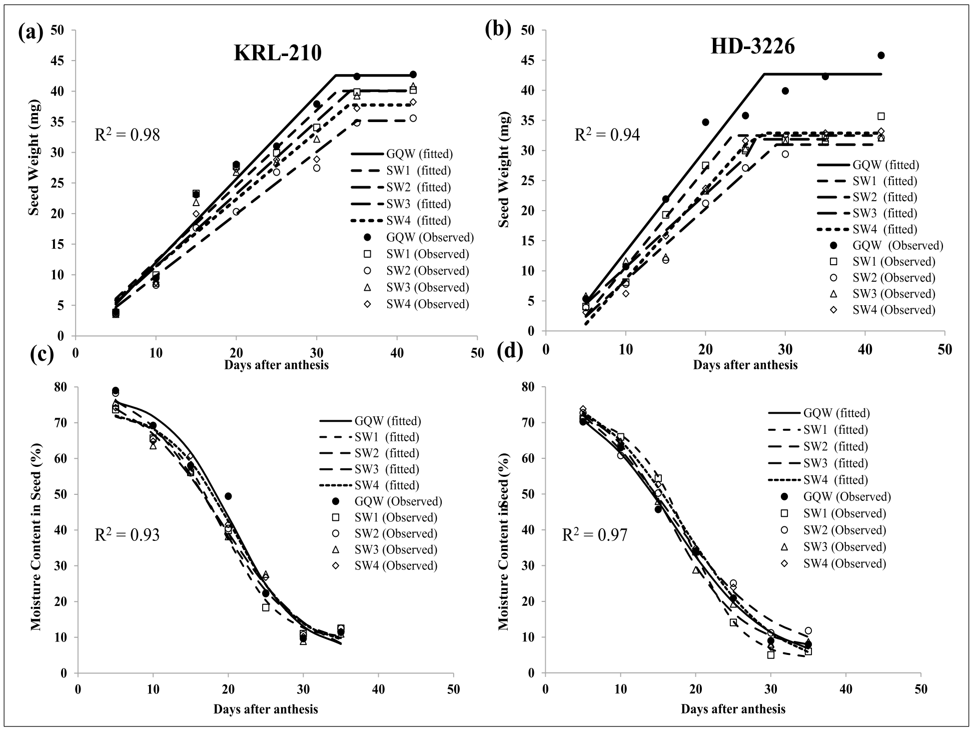


Fig 4.8 Changes in moisture content of fresh seeds and seed weight (g) of Wheat cv. KRL 210 and HD 3226 in differential RSC induced alkali water irrigation regimes

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. 4.7). The average seed weight (mg) was reduced significantly at RSC 5 (SW2) and further at RSC 10 (SW2). The seed weight was higher in Var CSR 60. RSC 5 neutralized with Gypsum or H_2SO_4(SW 3 and SW 4) slightly increased the seed filling period.

Seed moisture content was estimated on the fresh weight basis using the high-constant-temperature-oven method with ground seed. The seed moisture of wheat dries down trend was similar across the alkali treatments, but the rate was faster in Var. HD 3226 than

KRL 210 (Fig. 4.8). The average seed weight (mg) was reduced significantly at RSC 5 (SW2) and further at RSC 10 (SW2) in both the wheat cultivars. The seed weight was higher in Var KRL 210. RSC 5 neutralized with Gypsum or H_2SO_4 (SW 3 and SW 4) slightly increased the seed filling period in both the varieties of wheat.

Crop Improvement for Salinity, Alkalinity and Waterlogged Stresses

Genetic improvement of rice genotypes for salt tolerance using conventional and molecular breeding methods (B. M. Lokeshkumar, Ravi Kiran K.T., Nitish Ranjan Prakash and Devika S)

This project aims at identification of salt tolerant donors from different backgrounds, utilising it for the development, evaluation and dissemination of better salt tolerant rice genotypes through station trails and AICRP trails. To achieve the objectives, following trials were conducted and the breeding material was advanced during *Kharif* 2024.

A. National trail

a) IVT-Alkaline and Inland Saline Tolerant Variety Trial-2024

The IVT-Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL&ISTVT) comprised of 23 entries including check varieties (CSR 36, CSR 10, Pusa 44 and FL-478) and one local check (LC) which were evaluated across four sodic (pH ~9.7-10) and three saline (8-10 dS/m) stress locations including micro plots in Random Block Design with three replications. The grain yield ranged between 1935 to 4530 kg/ha with a mean grain yield of 3441 kg/ha. The entries namely 4804, 4810, 4801 and 4822 were the ideal genotypes with highest mean values under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36 across 7 locations.

b) AVT-Alkaline and Inland Saline Tolerant Variety Trial-2024

The AVT-Alkaline and Inland Saline Tolerant Variety Trial (AVT-AL&ISTVT) comprising of 28 entries including check varieties (CSR 36, CSR 10, Pusa 44 and FL-478) and one local check were evaluated across four sodic (pH ~9.7-10) and three saline (8-10 dS/m) stress locations including micro plots in Random Block Design with three replications. The grain yield ranged between 2035 to 4611 kg/ha with a mean grain yield of 3383 kg/ha. The three entries namely 4725, 4728, 4705, 4708 and 4722 has performed very well under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36.

c) IVT and AVT Basmati Varietal Trial-2024

The IVT-BT trail comprising of 24 entries including check varieties (Pusa Basmati 1, Taroari Basmati, Pusa Basmati 1121) and Basmati CSR30 (Local check) were tested in Random Block Design with two replications in CSSRI Karnal. The grain yield was ranged from 3003 to 5434 kg/ha with a mean grain yield of 4091 kg/ha. The entries namely, 1812, 1810, 1821 and 1822 were top performing entries with a yield of 5434, 5296, 5274 and 5202 kg/ha respectively.

Similarly the AVT-BT trail comprising of 28 entries including check varieties (Pusa Basmati 1, Taroari Basmati, Pusa Basmati 1121) and Basmati CSR30 (Local check) were tested in Random Block Design with two replications in CSSRI Karnal. The grain yield was ranged from 3370 to 6008 kg/ha with a mean grain yield of 4515 kg/ha. The entries namely, 1918, 1919, 1904 and 1910 were top performing entries with a yield of 6008, 5950, 5707 and 5654 kg/ha respectively.

d) IVT and AVT - Aerobic trial and Direct Seeded Rice trail 2024

The IVT-Aerobic trial 2024 comprised 64 entries tested in Random Block Design with two replications in CSSRI Karnal. Grain yield of 64 genotypes ranged from 887 to 5410 Kg/ha. The three entries namely 4214, 4213 and 4241 were top performing entries with highest grain yield above 5300 kg/ha with an average 3309 kg/ha. On the other hand AVT-Aerobic trial has 13 entries with grain yield ranged from 3220 to 5850 kg/ha with a mean grain yield of 4350 kg/ha. In addition, new trails on IVT –DSR was also conducted during *kharif* 2024. The DSR trail comprised of 57 genotypes with grain yield ranged from 1670 to 5553 kg/ha with a mean grain yield of 3427 kg/ha was recorded.

e) NILs trails 2024

During 2024, we have received 11 NILs –CSTVT, 9 -NILs -AL&ISTVT and genome edited lines were received from IIRR Hyderabad. We have evaluated these lines under normal condition. The yield distribution of NILs –CSTVT ranged between 3110 to 5300 kg/ha with an average grain yield of 4432 kg/ha. The yield distribution of NILs -AL&ISTVT and genome edited lines ranged from 4530 to 6280 kg/ha with an average of 5423 kg/ha.

B. Station Trials

Monitoring, maintenance and development of breeding materials and genetic stocks

Important salt tolerant lines were used in hybridization with high yielding varieties to enhance the genetic variation and to transfer the salt tolerance. Numbers of segregating populations around 20 crosses F_1, 25 crosses F_2, F_3-F_5 of 30 crosses and 250 fixed lines were maintained and used 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.

Evaluation of fixed lines for saline stress (ECe ~10 dS/m) condition

A total of 236 non segregated selected lines (F_8-F_{13}) from various crosses were tested at ECe ~10 dS/m. The grain yield of 236 genotypes ranged from 196 to 3408 kg/ha with a mean grain yield of 1466 kg/ha. The lines G168, G135, G176, G 110, G233 and G216 were showing highest grain yield of more than 3000 kg/ha under saline stress condition. The list of top performing lines over the check CSR 27 was presented in Figure 5.1.

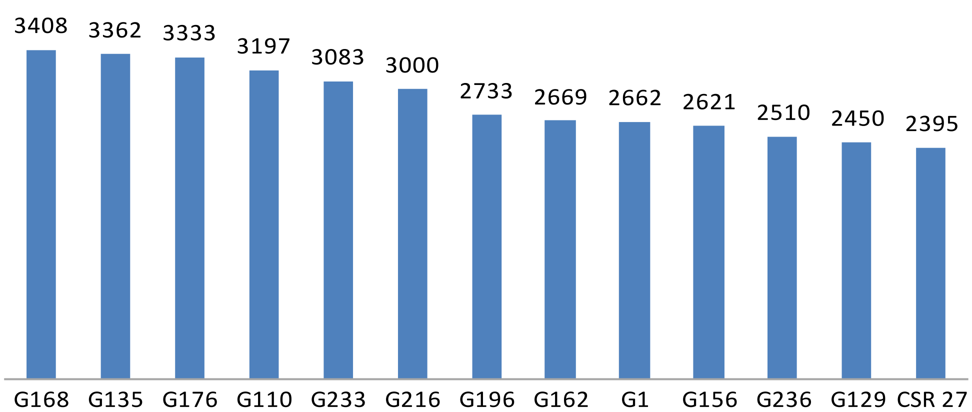


Fig 5.1. Graphical representation of top performing genotypes over CSR 27 under Saline stress condition (ECe ~10 dS/m)

Evaluation of IRRI lines for sodicity stress tolerance (pH ~9.2-9.5)

A total of 280 lines from IRRI were evaluated under pH~9.2-9.5 and noted that grain yield ranged from 267 to 5366 kg/ha with a mean yield of 2200 kg/ha. The genotypes IR 96080-25-3-2-2, IR 96067-14-2-1-3, IR 116709-B-B-53-3-B-B and IR 97432-36-3-2-2 with grain yield more than 5000 kg/ha.

Rice entries nominated to AICRP during 2024

Based on the performance of rice lines across the locations, stresses and season, the following entries nominated for testing under AICRP rice:

IVT – ETP: CSR2021-E-2-94-218

IVT Aerobic: CSR2021-2-94-181 & CSR -MGC-80

IVT- MS: CSR-MGC-63

IVT-AL&ISTVT: CSR 2022 BR-41-4-64, CSR 2022 ABC-165 and CSR2021-AL-29-485

IVT BT: CSR TPB 252-208 and CSR BT 252-179

Table 5.1 Rice entries promoted from IVT to AVT 1

Trial	IET	Name
AVT-1AL&ISTVT	31861	CSR2021-AL-2-94-112
	31862	CSR2021-AL-294-72
	31858	CSR2021-ST-294-168
AVT- 1Aerobic	31790	CSR2021-DSR-2-94-134
AVT-1 ETP	30653	CSR M1- 5
	30640	CSR M1-4
AVT-1 BT	31302	CSR 301-16-ST-153
	31292	CSR 301-16-BT-208
	31300	CSR – YET 73
AVT1-CSTVT	31075	CSR 2018-43-16

Table 5.2 Rice entries promoted from AVT1 to AVT 2

Trial	IET	Name
AVT-1 BT	30535	CSR BT-252-19
AVT2-AL&ISTVT	31055	CSR 141-11-112
	31044	CSR 103-10-2
	31050	CSR 104-10-2
	31048	CSR 116-10-2
NILs (SalTol+BLB Xa 13+ Xa21)	32052	CSR 389-16-19-15
	32053	CSR 389-16-23-42

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 (2.5 Q), CSR36 (0.5 Q), CSR 43 (0.5 Q), CSR 46 (2.0 Q), CSR49 (0.25 Q), CSR52 (0.25 Q), CSR56 (2.0 Q), CSR60(2.0 Q), CSR 76 (2.0 Q) the newly release varieties namely CSR 101(1.5Q), CSR 104 (1.5Q) and CSR 105 (1.5Q) was produced to meet the demand of seed producing agencies as per DAC (Department of Agriculture and Cooperation) during 2024.

Rice varieties

In 2024, two salt-tolerant rice varieties (CSR 101 and CSR 104) and one aerobic variety (CSR 105) were notified and released through CVRC. The details are given on next page.

CSR 101

CSR 101 Field View

- **Description**: CSR 101 is an improved version of Pusa 44, incorporating the Saltol QTL for enhanced salt tolerance and resistance to bacterial leaf blight, making it suitable for salt-affected areas.
- Notified and Released from CVRC in 2024 (Ref: Gazette Notification [PART II—SEC. 3(ii)] No. CG-DL-E-141022024-257835. S.O. No. 4388 (E) dated on the 9th October, 2024)
- **Release and Recommendation**: This variety was released and recommended for the salt-affected soils of **Kerala**, **Karnataka**, and **Tamil Nadu** in 2024.
- **Yield Potential**: Under normal conditions: Up to **6.0–6.5 t/ha**. Under saline conditions (EC < 8.0 dS/m) and sodic stress (pH < 9.5): Up to **4.0 t/ha**.

CSR 104

CSR 104 Field View

- **Description**: CSR 104 is an early-maturing, salt-tolerant rice variety suited for regions with limited water or short cropping windows, ensuring good yields under suboptimal conditions.
- Notified and Released from CVRC in 2024 (Ref: Gazette Notification [PART II—SEC. 3(ii)] No. CG-DL-E-141022024-257835. S.O. No. 4388 (E) dated on the 9th October, 2024).
- **Release and Recommendation**: CSR 104 was released and recommended for the salt-affected soils of **Uttar Pradesh** and **Haryana** in 2024.
- **Yield Potential**: Under normal conditions: Up to **7.0–7.5 t/ha**. Under sodic stress conditions (pH < 9.5): Up to **4.5 t/ha**.

CSR 105

CSR 105 Field View

- **Description**: CSR 105 is a rice variety developed for aerobic and direct-seeded (DSR) conditions, showing strong adaptability to water-saving cultivation systems.
- Notified and Released from CVRC in 2024 (Ref: Gazette Notification [PART II—SEC. 3(ii)] No. CG-DL-E-141022024-257835. S.O. No. 4388 (E) dated on the 9th October, 2024)
- **Release and Recommendation**: This variety was released in 2024 for aerobic conditions in the states of **Haryana** and **Gujarat**.
- **Yield Potential**: Under normal conditions: Up to **7.5–8.0 t/ha**. Under aerobic or DSR conditions: Up to **5.0–5.5 t/ha**

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

The main objective of this project is to map key genomic regions/QTLs controlling salt tolerance in rice, through collaboration between CSSRI (phenotyping) and NRC on Plant Biotechnology, New Delhi (genotyping). A total of 140 RILs, developed from a cross between MTU 1001 and Kalanamak, were evaluated under saline (ECe ~8 dS/m) and sodic (pH ~9.9) conditions during Kharif 2024. Grain yield under saline conditions ranged from 14.27 kg/ha (RIL19) to 4668.35 kg/ha (RIL56), with a mean of 2562.55 kg/ha. Under sodic stress, yield ranged from 150.77 kg/ha (RIL195) to 4773.77 kg/ha, with an average of 2552 kg/ha. RIL-129, RIL-15, RIL-141, and RIL-144 consistently performed well under salt stress and may be nominated for AICRP trials. Descriptive statistics under saline and sodic

Table 5.3 Mean and range of grain yield and yield contributing traits under saline (ECe ~ 8 dS/m) stress condition during 2024

Parameter	Plant height (cm)	Total tiller	Productive tiller	Panicle length (cm)	Yield (Kg/ha)
Average	121.39	3.43	2.55	21.30	2562.55
Maximum	168.16 (RIL84)	4.66 (RIL32)	3.50 (RIL27)	30.50 (RIL66)	4668.35 (RIL56)
Minimum	77.16 (RIL173)	2.33 (RIL173)	0.00 (RIL161)	9.16 (RIL165)	14.27 (RIL19)
MTU1001	116.17	3.50	3.00	20.83	890.26
Kalanamak	114.00	2.83	2.33	20.33	2350.52

Table 5.4 Mean and range of grain yield and yield contributing traits under sodic stress condition (pH~ 9.9) during 2024

Parameter	Plant height (cm)	Total tiller	Productive tiller	Panicle length (cm)	Yield (Kg/ha)
Average	117.68	5.13	5.05	25.43	2552
Maximum	176 (177)	11.5 (MTU1001)	10 (MTU1001)	16.50 (123)	4773.77 (61)
Minimum	75 (123)	2.5 (50)	2 (116)	37 (139)	150.77 (195)
MTU1001	100.00	11.50	10.00	26.00	1107.83
Kalanamak	117.50	9.00	9.00	21.00	2721.16

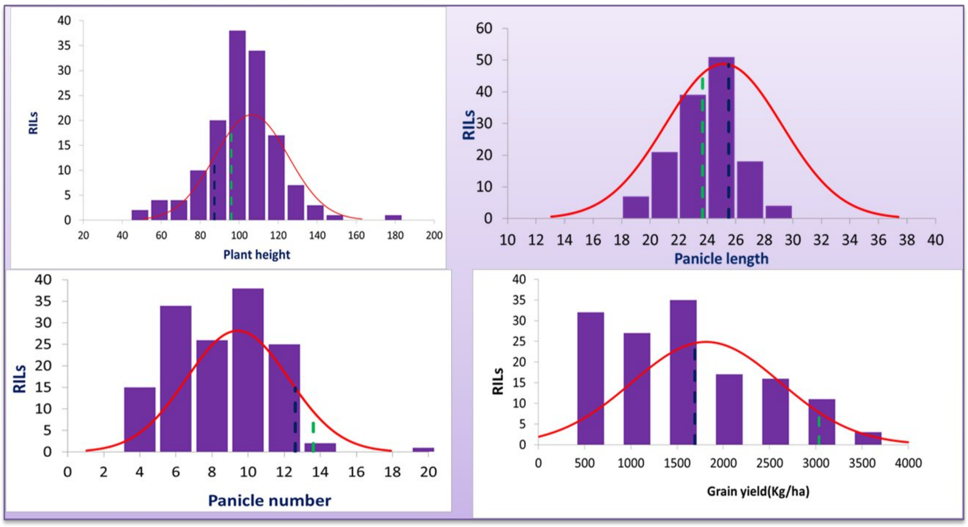


Fig 5.2 Frequency distribution of RIL population for different traits across the year (2021-2024)

conditions are provided in Tables 5.3 and 5.4, respectively. Frequency distributions of four years' data (2021–2024) illustrate variation in plant height, panicle length, panicle number, and grain yield under sodic conditions (Figure 5.2).

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

Phenotyping of mapping population (Pusa44/Bhurarata) for salinity tolerance

The salient findings of the systematic phenotyping of 190 recombinant inbred lines (RILs) derived from Pusa44 x Bhurarata cross are presented, 190 RILs along with two parents were evaluated under saline stress (ECe ~ 8dS/m) with two replication. Grain yield (Kg/ha) ranged from 567.42 (RIL298) to 4377.18 (RIL 280), while spikelet fertility (%) ranged from 5.13 (RIL281) to 93.25 (RIL290). The genotype RIL280 (4377.2 kg/ha) showed the highest grain yield followed by RIL246 (3978.8 kg/ha), RIL324 (3925.88 kg/ha), RIL299 (3837.3 kg/ha), RIL226 (3789.12 kg/ha), RIL227 (3633.8 kg/ha), RIL350 (3553.57 kg/ha), RIL301 (3532.6 kg/ha), RIL391 (3454.4 kg/ha) and RIL215 (3414.2 kg/ha) under saline stress.

Table 5.5 List of QTLs identified in the RILs of Pusa44/Burarata under saline stress

Trait Name	QTL name	Chr	Left Marker	Right Marker	LOD	PVE (%)	Add
Days to flowering	qDFF1	7	7:1221882	7:21930141	12.1602	18.2986	6.1833
Days to flowering	qDFF2	8	8:3742236	8:3969555	8.9167	12.0014	-4.9988
Plant Height	qPH1	10	10:13857630	10:19848442	3.1451	12.0918	-4.0243
Panicle Length	qPL1	3	3:29402224	3:29421146	4.2377	10.2681	-1.0057
Total Tiller	qTT1	9	9:5186651	9:5176308	3.0485	3.2441	-0.6812
Spiklet fertility	qSF1	1	1:24334487	1:24408874	4.7122	13.5631	-7.7764
Grain kg/ha	qGY1	8	8:17666281	8:19874140	3.0372	9.8645	226.4288
Leaf Na Content	qNa1	3	3:966332	3:966328	5.5243	12.5363	-3.0517
Leaf Na content	qNa2	8	8:21466980	8:21725643	3.1121	7.1906	2.293
Leaf Na content	qNa3	8	8:476843	8:579774	3.6149	8.2767	2.4476
Na/K ratio	qNa/K1	8	8:22281006	8:22110691	27.8286	22.3005	0.9847
Na/K ratio	qNa/K 2	8	8:476843	8:579774	6.3325	3.3043	0.3789

Identification of QTLs for yield and yield related traits

Table 5.5 provides a list of QTLs for key physio-morphological traits in the RIL population derived from a cross between *Pusa44* and *Bhurarata* under saline conditions. Two significant QTLs, *qDFF1* and *qDFF2*, were identified for days to flowering. *qDFF1*, located on chromosome 7 with a LOD score of 12.16, explained 18.29% of the phenotypic variance, while *qDFF2*, on chromosome 8 with a LOD score of 8.91, accounted for 12.0% of the phenotypic variance (PVE). For plant height, a single QTL, *qPH1*, was identified on chromosome 10 with a LOD score of 3.15 and a PVE of 12.09%. The QTL for panicle length, *qPL1*, located on chromosome 3, had a LOD score of 4.23 and explained 10.27% of the phenotypic variance. For the trait Total tiller *qTT1*, located on chromosome 9, had a LOD

Table 5.6 Salt responsive genes Associated with the QTLs identified from RILs of Pusa44/Bhurarata under saline stress

QTL	Salt responsive gene	Gene Symbol
qDFF1	LOC_Os07g05640	OsINT2
	LOC_Os07g06980	HDA704
	LOC_Os07g13100	OsAHL13
	LOC_Os07g17120	
	LOC_Os07g25390	OsCHR736, CHR736
	LOC_Os07g25680	
	LOC_Os07g31340	OsDNA2_4
	LOC_Os07g31770	OsCHS12
	LOC_Os07g32730	OsCHR731, CHR731
	LOC_Os07g34589	Os-eIF-1, eIF-1, OseIF1
qPH 1	LOC_Os10g28000	OsGR3, GR3
	LOC_Os10g28040	OsHAG702, OsGCN5
	LOC_Os10g29560	OsPQT3
	LOC_Os10g31850	DCA1
	LOC_Os10g31970	OsCHR717, CHR717
	LOC_Os10g33855	OsNBL1
	LOC_Os10g35060	PC1
qSF1	LOC_Os01g42860	OCPI2
qGy1	LOC_Os08g31560	SRWD4, OsWD40-160
	LOC_Os08g31580	OsERF48, OsDRAP1
	LOC_Os08g31870	OsSTL2
qNa2	LOC_Os08g34460	OsTET12

score of 3.04, accounting for 3.24% of the phenotypic variance. The spikelet fertility qtl *qSF1* found on chromosome 1 between positions 24,334,487 and 24,408,874, had a LOD score of 4.71 and a PVE of 13.56%, indicating significant genetic influence. For grain yield, *qGY1*, located on chromosome 8, had a LOD score of 3.04 and explained 9.86% of the phenotypic variance. Three significant QTLs associated with leaf sodium (Na) content were identified. The first QTL, *qNa1*, located on chromosome 3, had a LOD score of 5.52 and explained 12.53% of the PVE. The second, *qNa2*, located on chromosome 8, had a LOD score of 3.11 and accounted for 7.19% of the PVE.

The third QTL, *qNa3*, also located on chromosome 8, had a LOD score of 3.61 and explained 8.27% of the PVE. The QTLs *qNa/K1* and *qNa/K2* on chromosome 8 reveals key loci controlling the Na/K ratio, which is essential for maintaining ion homeostasis and improving stress tolerance in rice under saline conditions. *qNa/K1* (Chr 8: 22,281,006–22,110,691) had a high LOD score of 27.82, indicating a highly significant QTL with a major impact on Na/K balance. Its PVE of 22.30% highlights its strong contribution to this trait. In contrast, *qNa/K2*, also on chromosome 8, had a LOD score of 6.33 and explained just 3.30% of the phenotypic variance. The key QTLs are linked to yield, spikelet fertility, sodium (Na) content, and the sodium-to-potassium (Na/K) ratio. Table 5.6 depicts QTLs that harbor key genes associated with salinity tolerance mechanisms, including ion homeostasis, osmotic balance, oxidative stress management and hormonal signaling. Salt-responsive genes within these QTLs regulate physiological and molecular responses to salinity. Identifying these genes is crucial for marker-assisted breeding of salt tolerant rice.

Accelerated Breeding: Meeting farmers needs with nutritious, Climate resilient crops (*Lokeshkumar B M*)

Based on the previous year results, genotypes such as IR14L440, IR14L297, IR18R1165, IR15A4029, and IR16A2094 performed very well under normal and sodic stress conditions (pH ~9.5). These lines were multiplied for AICRP trial. The lines IR 97199-59-3-3-2, IR 132084-B-1327-2-1-B-17, IR13C222, IR 97184-84-1-2-3, and IR 132084-B-224-1-1-B-7, which performed well under normal conditions, can be evaluated under salt stress conditions. However, due to a lack of funding and the absence of new materials from IRRI the project may be discontinued.

Morphological and molecular characterization of salt-tolerant coastal rice landraces (*NR Prakash***)**

An association mapping panel of 243 genotypes were evaluated under low and high salinity conditions during Rabi 2022-23, 2023-24 at Canning and Kharif - 2023 at Canning, Lucknow, Machhilipattnam, and Dandi. The evaluation of genotypes for reproductive stage salinity tolerance during Rabi, identified landraces such as Pokkali, Dudheswar, Sitapi, Nona Bokra, Kakua, Okhadjama, Khaskal, Lathisal, Sonalu, Gilijite, Adanshilpa, Baduma, Khandagiri, Paaru, Kalajeera, Black, R.J.N., Sainthia, Radhuni Pagal, Kanakchur, Siuli, Hormanona, Talmugur, Sundari, Kuzhiadichan as salt tolerant. Based on SES score Dharansal, Bakulphool, Verisal, Tripura Khowai, Karma Mahsuri, Trichy 4, VTL06, Baspata, Jhumur, Nona Bokra, Sarala, Gosaba-5, Jhulur, Sitapi, and Murkimala were identified as salt tolerant for seedling stage salt tolerance. Across locations, Neta, Vasamanik, Baktulsi-1, Hormanona, Dudhkalam, and Raghusal performed better in terms of yield per plot across Canning and Dandi. At Dandi, Rupsal, Nazrabad, Chamarmani, Adanshilpa, Panvel-

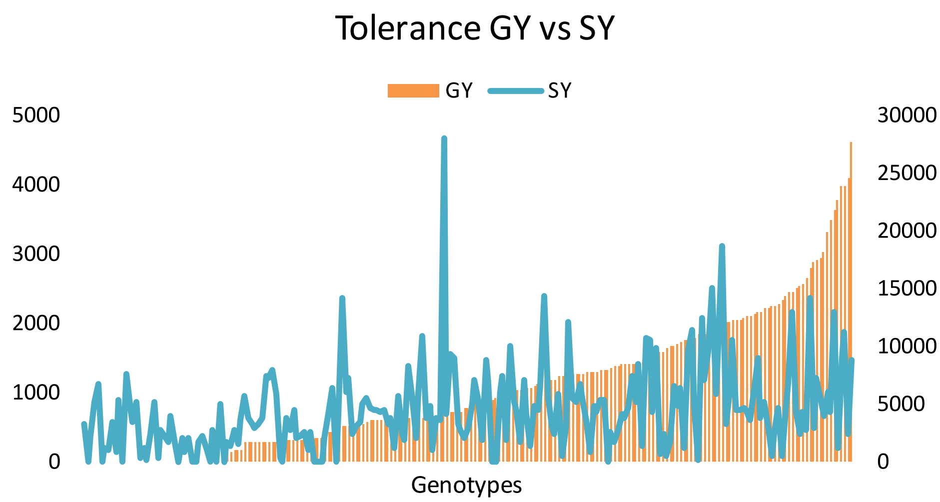


Fig 5.3 Variations in grain and straw yield of association mapping panel evaluated under saline conditions during Rabi 2023-24

1, Dharansal, Muktashree, Sonalu, Asanliya, SwarnaKanti, Sabita, Chitu-chamela, Panvel-3, Lunishree, VTL11, TripuraHakuchuk-2, Canning7 had robust seedling stage salt tolerance while Rupsal, Nazrabad, Chamarmani, Adanshilpa, and Panvel-1 exhibited both seedling and reproductive stage salt tolerance.

Based on the evaluation of 220 genotypes + 5 checks of association panel under high salinity (ECe >8.0 dS/m after vegetative stage) during Rabi 2023-24, 41 genotypes failed to flower, and highest yield were observed in genotypes Chandrakanti, Khaskal, Fulkhar, Muktashree, Rupsal, Gangajali, Murkimala, Verisal, Bhurisal, Medhi, Asanliya, Panvel-1, and Jhulur.

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 aimed to develop salt tolerant lines for different stress situations with reference to grain yield, grain colour, disease resistance and other morpho-physiological characters.

Varietal development

Two salt tolerant varieties KRL 423 and KRL 1803 were identified for released in UP state for their superior performance consistently over three years in salt affected soils. Two salt tolerant varieties KRL 370 and KRL 386 were recommended for release in Uttar Pradesh by the State Level Research Advisory Committee Meeting. Both varieties have multiple stress resistance to biotic stresses (Stripe Rust, Brown Rust, Karnal bunt, loose smut, flag smut, powdery mildew, leaf blight, foot root) and abiotic stresses (salinity and sodicity). KRL 370 has additional resistance to moisture stress.

Hybridization and generation advancement

To transfer the salt tolerance KRL 370, KRL 386, KRL 3-4, KRL 99, KRL 210, KRL 213, KRL 283, KRL 2002, KRL 2009, KRL 2202, KRL 2205, KRL 2207, KRL 2213, KRL 2302, KRL 2309, KRL 2305, KRL 2306 developed at CSSRI, Karnal in elite, 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) which are carrying the high yielding genes as well as gene pyramids for resistance to rust and other major diseases, quality

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

S.No.	Normal	Saline (EC_{iw}:10 dS/m)	TI	Sodic (pH_2: 9.3)	TI	S+WL (pH_2: 9.3)	TI
1	KRL 2302	KRL 2214	0.96	KRL 99	1.08	KRL 3-4	0.99
2	HD 3226	Kh 65	0.94	KRL 3-4	1.03	KRL 99	0.90
3	KRL 2014	KRL 2009	0.93	Kh 65	0.99	Kh 65	0.87
4	DBW 187	KRL 3-4	0.90	KRL 2101	0.96	KRL 2307	0.78
5	KRL 2301	KRL 2310	0.88	KRL 2308	0.96	KRL 210	0.77
6	KRL 2307	KRL 2303	0.86	KRL 2203	0.91	KRL 2308	0.76
7	KRL 2207	KRL 2215	0.86	KRL 2307	0.81	KRL 2203	0.74
8	Brookton	KRL 2308	0.83	KRL 210	0.80	KRL 2304	0.72
9	HD 2009	KRL 99	0.83	KRL 283	0.77	KRL 2303	0.70
10	PBW 343	KRL 2203	0.82	KRL 370	0.77	KRL 283	0.69
11	KRL 2202	KRL 386	0.79	KRL 2304	0.76	KRL 370	0.68
12	KRL 423	KRL 2205	0.78	KRL 2303	0.73	KRL 2306	0.67
13	KRL 2215	KRL 2301	0.78	KRL 2305	0.73	KRL 2305	0.64
14	KRL 2305	KRL 2307	0.77	KRL 2306	0.71	KRL 2309	0.60
15	KRL 3-4	KRL 2304	0.76	KRL 386	0.70	KRL 2101	0.59

characteristics, high Zn uptake, 368 new cross combinations were attempted. During the year 2023-24, 70 new cross combinations was advanced to diversify base, improve tolerance to disease resistance, waterlogging tolerance and salt tolerance. Under advanced/segregation generation F_1 (70 crosses), F_2 (402 Crosses), F_3 (1020 Crosses), F_4 (180 Crosses), F_5 (54 Crosses), F_6 and higher generations (80 Crosses) were advanced. Selections were made based on salt tolerance, disease resistance and agro-morphological traits during *rabi* season 2023-24.

Evaluation of wheat varieties for salt stress in Microplots

During the cropping season 2023-24, forty two wheat genotypes including 28 advanced lines were evaluated under four environments (Control, Saline; EC_{iw} 10 dS/m, Sodic; pH_2 9.3±0.11 and Sodic waterlogged: pH_2 9.3±0.19) for their *per se* performance in micro plots. Genotypes were evaluated in CRBD with three replications.

- Normal microplots - top performing genotypes were KRL 2302 followed by HD 3226, KRL 2014, DBW 187, KRL 2301, KRL 2307, KRL 2207, Brookton, HD 2009, PBW 343, KRL 2202, KRL 423, KRL 2215 and KRL 2305.
- Saline microplots – KRL 2214, Kharchia 65, KRL 2009 and KRL 3-4 were the top performer followed by KRL 2310, KRL 2303, KRL 2215, KRL 2308, KRL 99, KRL 2203, KRL 386, KRL 2205, KRL 2301, KRL 2307 and KRL 2304 based on tolerance indices.
- Sodic microplots – KRL 99, KRL 3-4, Kharchia 65, KRL 2101, KRL 2308, KRL 2203, KRL 2307, KRL 210, KRL 283, KRL 370, KRL 2304, KRL 2303, KRL 2305, KRL 2306 and KRL 386.
- Sodic waterlogged microplots - KRL 3-4 was the top performer followed by KRL 99, Kharchia 65, KRL 2307, KRL 210, KRL 2308, KRL 2203, KRL 2304, KRL 2303, KRL 283, KRL 370. KRL 2306, KRL 2305, KRL 2309 and KRL 2101 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 Nursery (15^{th} HZAN) was evaluated under control as well as waterlogged microplots (pH_2: 9.3) in augmented design. Each set was comprised of 10 entries and 3 checks. Entries HZAN128, HZAN177, HZAN41, HZAN171, HZAN113, HZAN170, HZAN212, HZAN103, HZAN64 and HZAN55 showed high tolerance index and yield in control plots. These entries are being evaluated in larger field trials and some have undergone introgression with salt-tolerant/high-yielding genotypes to potentially further improve performance.

Evaluation of advanced breeding lines for salt stress

Experiment 1: Thirty-one advanced wheat lines, including four checks, were evaluated at ICAR-CSSRI Karnal during the 2023-24 in complete randomized block design (CRBD) with three replications under four environments: control (normal soil), normal soil waterlogged, sodic soil (pH_2: 9.2), and sodic waterlogged soil (pH_2: 9.2). Waterlogging was imposed for 15 days, starting from 25 days after sowing. Among the top performers, KRL 2213, KRL 2215, KRL 2302, and KRL 2301 showed promise in normal, normal waterlogged and sodic conditions, while KRL 370 and KRL 386 performed well across control, normal waterlogged as well as sodic waterlogged conditions (Table 5.8).

Experiment 2: During 2023-24, the performance of 110 advanced wheat lines was evaluated for sodicity alongwith waterlogging at ICAR-CSSRI Karnal, Lucknow, and Bharuch in augmented design with five blocks, each comprising 22 test entries and five checks. The top 10 performing lines identified in each environment are presented in table 5.9.

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

NORMAL	GY g/plot	SE	Sodic (pH_2: 9.2)	GY g/plot	SE	TI	SWL (pH_2: 9.2)	GY g/plot	SE	TI
Genotypes										
KRL 2213	820	29	KRL 2020	414	12	0.65	KRL 370	241	10	0.32
KRL 2309	788	19	KRL 2207	395	29	0.56	KRL 2020	240	12	0.38
KRL 2215	785	30	KRL 2213	384	13	0.47	KRL 386	239	18	0.31
KRL 2302	785	27	KRL 2302	379	16	0.48	KRL 1803	231	5	0.32
DBW 222	783	18	KRL 2214	376	28	0.51	KRL 423	218	15	0.36
KRL 386	773	34	KRL 2215	373	21	0.47	KRL 2114	212	14	0.32
DBW 187	771	14	KRL 2301	373	19	0.49	KRL 2309	206	2	0.26
KRL 2301	761	20	KRL 2306	349	20	0.47	KRL 2207	203	20	0.29
KRL 370	755	30	KRL 2304	327	14	0.45	KRL 283	196	7	0.32
KRL 2306	749	23	KRL 2212	312	16	0.51	KRL 2310	195	9	0.28
Checks										
KRL 210	679	8	KRL 210	310	13	0.46	KRL 210	232	14	0.34
KRL 99	468	10	KRL 99	356	20	0.76	KRL 99	237	20	0.51
HD 2009	461	14	HD 2009	152	8	0.33	HD 2009	139	2	0.30
Kh.65	281	7	Kh.65	278	6	0.99	Kh.65	203	9	0.72

Table 5.9 Top 10 genotypes among advanced breeding lines with respect to grain yield/plot (g) in different environments at Karnal, Lucknow and Bharuch centers

S.No.	Normal	N+WL	Sodic (pH_2: 9.2)	S+WL (pH_2: 9.2)	Sodic MP (pH_2: 9.3)	Bharuch (EC_{iw} 6-7 dS/m)	Lucknow (pH_2: 9.1)
1	KRS 23109	KRS 23083	KRS 23082	KRS 23027	KRS 23059	KRS 23029	KRS 23059
2	KRS 23107	KRS 23090	KRS 23025	KRS 23028	KRS 23056	KRS 21053	KRS 23031
3	KRS 23001	KRS 23045	KRS 23001	KRS 23023	KRS 23053	KRS 21001	KRS 23069
4	KRS 23002	KRS 23079	KRS 23027	KRS 23025	KRS 23109	KRS 23032	KRS 23033
5	KRS 23044	KRS 23059	KRS 23024	KRS 23087	KRS 23087	KRS 23034	KRS 23032
6	KRS 23106	KRS 21050	KRS 23066	KRS 23024	KRS 23037	KRS 23035	KRS 23030
7	KRS 23110	KRS 23056	KRS 21138	KRS 23096	KRS 23030	KRS 21061	KRS 23038
8	KRS 23100	KRS 23061	KRS 23002	KRS 23052	KRS 23041	KRS 23026	KRS 23103
9	KRS 23084	KRS 23082	KRS 23057	KRS 23095	KRS 23078	KRS 23033	KRS 23060
10	KRS 23105	KRS 23080	KRS 23028	KRS 23100	KRS 23034	KRS 23057	KRS 23062

Salinity Alkalinity Tolerance Screening Nursery 2023-24

In 2023-24 for Special Variety Evaluation Trial under AICW&BIP, the nurseries were coordinated at ICAR-CSSRI and were conducted at 9 centers. Data from Karnal (pH_2 9.1), Hisar (EC_e 6.4 dSm^{-1}), Bathinda (EC_e 6.3 dSm^{-1}), Muktsar (EC_e 5.7 dSm^{-1}), Kanpur (pH_2 9.25), Pali (EC_{iw} 4 dSm^{-1}) and Bharuch (EC_{iw} 6-7 dSm^{-1}) was pooled for mean values. The nursery consisted of 24 test entries and five checks (KRL 210, Kharchia 65, DBW 187, KRL 19 and GW 322) in an augmented design with 3 blocks of eight test entries and five checks. Superior lines were identified based on grain yield and comparison with pooled values. Out of 24 test entries, 4 entries were found promising based on mean yield and resistance to all the three rusts (stem leaf and yellow rust) as evident from IPPSN 2023-24. On the basis of yield and disease resistance data, the entry KRL 2301 was promoted to Salinity alkalinity trial 2024-25.

Entries contributed for IPPSN 2024-25

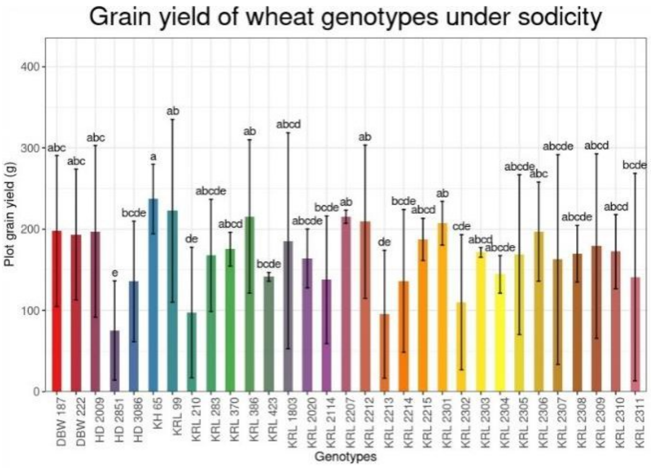
During the cropping season, eight promising wheat entries were sent for evaluation against rust diseases in Initial Plant Pathological Screening Nursery (IPPSN).

Entries Promoted/nominated

- KRL 2301 was promoted from Salinity/Alkalinity Tolerance Screening Nursery 2023-24 to Salinity alkalinity trial 2024-25 as the entry was found significantly superior to the best check KRL 210 along with resistance to stem, leaf and stripe rusts.
- KRL 2203 was promoted from NIVT 5A (2023-24) to AVT-RI-TS, NWPZ (2024-25) as it was found at par with all the checks along with resistance to stem, leaf and stripe rusts.
- KRL 2214 was nominated to NIVT 1A from SATSN 2023-24.
- Salt tolerant entries KRL 2020 and KRL 2114 were promoted for the Uttar Pradesh Salinity trial 2024-25 whereas KRL 2202 and KRL 2214 were nominated as new entries for sodicity trial of UP state whereas KRL 2002 was promoted for normal and irrigated timely sown trial.
- Entries submitted to SATSN 2024-25: KRL 2401, KRL 2402, KRL 2403, KRL 2404, KRL 2405, KRL 2406, KRL 2305, KRL 2307, KRL 2308 and KRL 2311
- IPPSN 2022-23: KRL 2407, KRL 2408, KRL 2409, KRL 2410, KRL 2411, KRL 2412, KRL 2413, KRL 2414.

Station Trial conducted at Lucknow and Bharuch

A station trial comprised 31 wheat genotypes including checks such as KRL 210, KRL 283 and Kharchia 65 which were tested under sodicity (pH_2 9.1) in RCBD with three replications. Observations were recorded on grain yield (plot basis) and its traits including biomass, test weight, days to heading and maturity, spike length and number of grains per spike. Based on grain yield, KRL 386, KRL 2007, KRL 2212, and KRL 2301 were superior and comparable to KRL 99. In second trial, sodicity was combined with 15 days waterlogging at 30 days. Compared to sodicity alone, dual stress i.e., sodicity + waterlogging further decreased the grain yields of all the tested genotypes. Promising genotypes on plot yield basis were KRL 2215, KRL 2309, KRL 2020, KRL 2301, and KRL 2310. KRL 210 outperformed all the tested entries. In Bharuch, the experiment was conducted on salt affected Vertisols (ECe 6-7dS m^{-1}). Grain yield ranged from 159 g (KRL-2213) to 396 g (KRL 2207). Top five high yielding varieties at Bharuch were KRL 2207, KRL 2302, KRL 1803, KRL 283 and KRL 210.



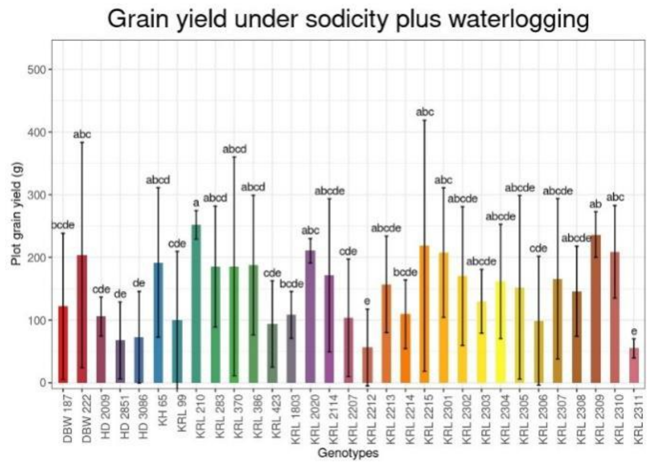


Fig 5.4 Performance of 31 wheat genotypes in terms of grain yield (plot basis in g) under sodicity and sodicity + waterlogging

Development and advancement of mapping populations for salt tolerance

Three mapping populations namely IC564103-A/Kharchia 65 (population size 290 in F_8 generation), HD2985/Kharchia Local (population size 360 in F_7 generation) and KRL 283/IC 401976 (size 120 in F_9 generation) were advanced.

Breeder/nucleus seed production

Breeder seed of KRL 210 (14 qt), KRL 213 (0.5 qt), KRL 283 (5 qt) was distributed to public and private agencies and KRL 210 (5.5 qt), KRL 213 (0.5 qt), KRL 283 (1.5 qt) was given to seed production unit for TL 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.

Impact assessment of institute wheat varieties

An impact assessment of institute wheat varieties from 2012-2024, based on breeder and truthful labeled (TL) seed sales, demonstrates substantial adoption of salt-tolerant varieties KRL 210, KRL 213, and KRL 283. Key data is in the table. Notably, KRL 210, with 265 quintals of breeder seed and 2,277 quintals of labeled seed distributed, impacted an estimated 167,996 hectares, producing 839,980 tonnes of wheat. Its success is due to wide adaptability across saline, sodic, saline vertisols, dryland salinity, and waterlogged ecosystems, combined with non-lodging behavior and high yields. KRL 213 and KRL 283 have impacted 122,634 hectares and 23,661 hectares, respectively. The combined impact of these varieties is estimated at 314,291 hectares, generating an estimated 1,571,455 tonnes of produce worth Rs. 2,569 crore (based on an MSP of Rs. 1,635/quintal and a yield of 5 t/ha).

Table 5.10 Estimated impact of salt tolerant wheat varieties KRL 210, KRL 213 and KRL 283

Wheat Varieties	Breeder Seed (q)	Certified Seed (q)	Seed already Sold (q) as certified/ TL seed	Total Seed (q) [E+F]	Estimated area coverage (ha)[@Seed rate: 100 kg/ha]	Estimated produce (@5t/ha) t	Estimated value of produce (crore Rs) (MSP for estimation =Rs 1635/qt)
KRL 210	265	165719	2277	167996	167996	839980	1373
KRL 213	196	122313	321	122634	122634	613170	1003
KRL 283	37	23313	349	23661	23661	118306	193
Total	498	311344	2947	314291	314291	1571455	2569

Table 5.11 Significance of % Change in yield and yield contributing traits in wheat under sodicity stress

Attributes	Control	Sodicity	Magnitude of change (%)		t value	Pr(>|t|)
			Increase	Decrease		
Days to 50% Heading	100± 0.55	104±0.62	3.2		-4.06	0.000
Harvest Index	0.27±0.01	0.28±0.01	3.6		-1.28	0.203
Seed Weight Per Spike (g)	1.8±0.04	2.01±0.05	10.4		-3.25	0.001
Spike Weight (g)	2.42±0.06	2.82±0.07	14.2		-4.52	0.000
Spike filling Rate (%)	0.74±0.01	0.72±0.01		-2.8	2.03	0.043
Days to Maturity	147±0.35	141±0.27		-4.6	14.93	0.000
Spike length	10.44±0.013	9.71±0.14		-7.5	3.82	0.000
Spikelet's/spike	19±0.16	17.34±0.17		-9.6	7.07	0.000
Plant Height (cm)	105±0.92	86.02±0.92		-21.6	14.32	0.000
Grain filling duration	47±0.49	37±0.43		-26.6	15.21	0.000
Grain yield (g)	401.71±9.99	146.78±4.16		-173.7	23.55	0.000
Above Ground Biomass (g)	1535.66±26.98	518.66±12.16		-196.1	34.37	0.000

DBT Project: Germplasm Characterization and Trait Discovery in Wheat using Genomics Approaches and its Integration for Improving Climate Resilience, Productivity and Nutritional quality (Arvind Kumar and Neeraj Kulshreshtha**)**

In the 2023-24, 180 bread wheat accessions were assessed using an Augmented Randomized Block Design with six blocks, under two conditions: normal soil (pH 7.9±0.21) and sodicity stress (pH 9.2±0.39). Each block contained 33 entries, including three checks i.e. Kharchia 65, KRL 210, HD2851 and HD2985. Three irrigations with good quality tube well water were provided in both environments. Data were collected for 10 traits, 4 traits were higher under sodicity stress, while 6 traits showed a decreasing trend under sodicity stress. The table 5.11 illustrates the intensity of these changes. The greatest positive changes occurred in spike weight (14.2%), seed weight per spike (10.4%), and harvest index (3.6%), while the largest negative changes were observed in above ground biomass (196%), grain yield (174%), grain filling duration (26.6%), and plant height (cm) (21.6%).

Sodicity tolerant lines were selected based on average STI of the trial (>0.40) along with grain yield of individuals Based on these selection criteria, 8 germplasm (IC279316, IC0128201, IC273982, IC384555, IC416168, IC416408, IC534974 and IC324561) were seemed as tolerant (Table 5.12).

5.12 List of promising salt tolerant lines

Accession Name	Grain yield (g/plot) Under normal conditions	Grain yield (g/plot) Under sodicity stress	Salt tolerant index (STI)
IC279316	599.6	324.2	0.541
IC0128201	459.4	297.8	0.648
IC273982	664.0	292.0	0.440
IC384555	497.6	285.8	0.574
IC416168	603.2	276.0	0.458
IC416408	516.4	275.4	0.533
IC534974	410.6	254.2	0.619
IC324561	451.6	250.2	0.554
Mean grain yield of trial	415.7	147.3	-
Average STI of trial	-	-	0.398
Standard deviation in grain yield of trial (SD)	131.23	59.0	0.17

Genetic improvement in barley for managing salt affected agro-ecosystems (Arvind Kumar, Anita Mann, Neeraj Kulshrestha, Priyanka Chandra, Monika Shukla, Ravi Kiran, KT and Devika S.)

A field view of exotic salt tolerant barely germplasm "Etu" and "Seco" for seed multiplication

To establish a genetic resource base, a diverse set of barley accessions (~620) was collected during the year 2023-24 from national land international research organization to initiate the breeding program at CSSRI, Karnal. It included advanced breeding lines, modern and old cultivars, landraces, elite lines and well recognized salt tolerant barely germplasm. A summary of collected barely genetic resources is given in Table 5.13.

Over the past sixty years, a significant amount of indigenous barley germplasm has been assessed for salinity tolerance, but only 14 salt-tolerant six-row feed barley cultivars have been released, owing to the limited availability of salt-tolerant barley germplasm. To expand the genetic pool, extensive searches were conducted on Springer, Science Direct, and Taylor & Francis databases for salt-tolerant barley lines and cultivars, along with their sources. As a result, a list of 68 salt-tolerant barley germplasm was compiled and imported into India. Notably, these 68 germplasm were sourced from 18 countries, including the United States, Afghanistan, Algeria, China, Pakistan, Mongolia, Iraq, Sweden, Ancient Palestine, Jordan, Spain, Finland, Japan, Canada, Sudan, Peru, Romania, and Venezuela (Table 5.14). In the Rabi season of 2023-24, seed multiplication was done for all the germplasm. Furthermore, 120 selected germplasm with adequate seed were evaluated for sodicity tolerance to identify the best potential parental lines.The selected barley germplasm was evaluated using an Augmented Randomized Block Design with 5 blocks, under both normal soil conditions and sodicity stress (pH_2 9.3±0.72), with each plot

5.13 Barely genetic resource at ICAR-CSSRI, Karnal

S.No.	Genetic resource	Numbers	Collected from
1.	Released cultivars and elite lines	133	ICAR- IIWBR, Karnal
2.	Advanced breeding lines	236	ICARDA, Morocco
3.	Advanced breeding lines	82	CSSRI, Karnal
4.	Salt tolerant germplasm (Exotic)	68	USDA, Washington DC
5.	Salt tolerant cultivars (Indigenous)	14	ICAR- IIWBR, Karnal
6.	Elite Lines	87	ICARDA India Research Platform, Amlaha, Sehore, MP
	Total	620	

5.14 List of Exotic Salt Tolerant Germplasm

S.No.	Name	Country	S.No.	Name	Country	S.No.	Name	Country
1.	Nepal	Colorado, United States	24.	CIho 6587	Fāryāb, Afghanistan	47.	1937	Al Buḩayrah, Egypt
2.	Spain	Castilla y León, Spain	25.	CIho 6591	Kābul, Afghanistan	48.	1968	Egypt
3.	Felix	Diyālá, Iraq	26.	Kaljao	Afghanistan	49.	2019	Egypt
4.	Purple Nudum	Punjab, Pakistan	27.	89	Puno, Peru	50.	2055	Al Buḩayrah, Egypt
5.	Yane-Hadake	Japan	28.	3	Al Balqā', Jordan	51.	2108	Al Buḩayrah, Egypt
6.	Black Hull-less	Gansu Sheng, China	29.	B158	Al Jīzah, Egypt	52.	2124	Al Buḩayrah, Egypt
7.	3981	Govi-Altay, Mongolia	30.	CPI 11083	Algeria	53.	2133	Al Buḩayrah, Egypt
8.	Kaljou	Parwān, Afghanistan	31.	Arizona 8501	Arizona, United States	54.	2158	Al Minūfīyah, Egypt
9.	5983	Bāmyān, Afghanistan	32.	'Seco'	Arizona, United States	55.	2721	Egypt
10.	Orge Palestine Nuda	Ancient Palestine	33.	'Etu'	Finland	56.	2726	Egypt
11.	CI 13507	Romania	34.	131	Egypt	57.	2731	Egypt
12.	4062	Mongolia	35.	334	Egypt	58.	2741	Egypt
13.	CI 14281	Táchira, Venezuela	36.	444	Egypt	59.	2751	Egypt
14.	Freak	Idaho, United States	37.	452	Egypt	60.	2847	Egypt
15.	Purple Hull-less	Manitoba, Canada	38.	538	Egypt	61.	2877	Egypt
16.	Beldi Dwarf	Biskra, Algeria	39.	1245	Egypt	62.	2897	Egypt
17.	Telli	Biskra, Algeria	40.	1271	Egypt	63.	2928	Egypt
18.	Chilga Arpa	China	41.	1532	Kafr ash Shaykh, Egypt	64.	'Arizona 8501'	Arizona, United States
19.	Saggia	Khartoum, Sudan	42.	1693	Kafr ash Shaykh, Egypt	65.	GSM-11	Iraq
20.	Gujar Khan	Punjab, Pakistan	43.	1865	Egypt	66.	'Birgitta'	Skåne län, Sweden
21.	3995	Mongolia	44.	1898	Dumyāţ, Egypt	67.	'Giza 132'	Al Jīzah, Egypt
22.	8286	Jilin Sheng, China	45.	1919	Egypt	68.	ari-e.1	Skåne län, Sweden
23.	Afangma	Gilgit-Baltistan, Pakistan	46.	1927	Al Buḩayrah, Egypt			

Table 5.15 Significance of % Change in yield and yield contributing traits in wheat under sodicity stress

Attributes	Control	Sodicity	Magnitude of change (%)		t value	Pr(>|t|)
			Increase	Decrease		
Days to heading (days)	89.70	94.02	4.82		-7.72	0.0000
Flavonoid content	0.66	0.72	10.24		-3.81	0.0002
leaf area (cm^2)	19.11	21.13	10.55		-3.12	0.0020
Vapor pressure deficit (kPa)	2.77	3.66	32.08		-14.07	0.0000
Sodium content (mg/g)	28.50	195.50	585.96		-26.77	0.0000
Na^+/ K^+	0.05	0.45	744.43		22.5	0.0000
Days to maturity (days)	129.81	126.88		-2.26	5.29	0.0000
Intercellular CO_2 (μmol mol^{-1})	193.57	186.57		-3.61	3.95	0.0001
Chlorophyll content	28.21	26.55		-5.91	2.69	0.0076
Nitrogen Balance Index	43.69	38.97		-10.80	3.34	0.0010
Seed weight per spike (g)	2.31	2.03		-12.26	4.02	0.0001
Ear weight (g)	2.79	2.43		-12.85	4.56	0.0000
NDVI value (index)	0.75	0.65		-14.32	13.09	0.0000
Potassium content (mg/g)	539.80	438.50		-18.77	5.7	0.0002
Spike length (cm)	9.02	7.52		-16.63	9.27	0.0000
Grain Filling Days (days)	40.14	32.86		-18.15	12.66	0.0000
SPAD value	42.21	33.94		-19.58	12.55	0.0000
Spikelets/spike (nos)	64.46	50.81		-21.17	7.41	0.0000
Average seed perimeter (mm)	47.75	34.39		-27.99	22.50	0.0000
Average seed length (mm)	15.03	10.70		-28.77	15.51	0.0000
Average seed breadth (mm)	5.85	4.04		-30.88	17.03	0.0000
Plant Height (cm)	121.78	77.68		-36.22	29.91	0.0000
Seed number per spike (nos)	49.36	30.76		-37.68	12.87	0.0000
Transpiration rate (mol m^{-2} s^{-1})	0.01	0.00		-39.61	13.35	0.0000
Grain yield (g)	724.50	385.32		-46.82	12.33	0.0000
Assimilation rate (μmol m^{-2} s^{-1})	9.14	4.71		-48.53	17.00	0.0000
Average seed area (mm^2)	72.68	37.14		-48.89	19.84	0.0000
Biomass (g)	2.53	1.19		-53.05	11.48	0.0000
Stomatal conductance (mol m^{-2} s^{-1})	0.30	0.13		-56.72	17.24	0.0000000

measuring 1.8 m^2 (3 rows of 3 meters, with a 20 cm spacing between rows). Four checks - NDB1173, RD-2907, KB-2031, and RD-2794 were arranged in each block. Standard wheat practices were followed. Three irrigations with best quality available water were applied in both environments. Data were recorded for 29 traits; 5 traits showed increased magnitude under sodicity stress, while 24 traits exhibited a decrease, with the extent of change detailed in Table 3. The greatest increase was observed in the Na/K ratio (744%), followed by Na^+ content (585%), VPD (32.08%), leaf area (10.55%), flavonoid content (10.24%), and days to heading (4.82%). On the other hand, the largest negative changes were seen in stomatal conductance (56.72%), followed by biomass (53.05%), average seed area (48.89%), assimilation rate (48.53%), grain yield (46.82%), and transpiration rate (39.61%). Statistical analysis revealed that the adjusted grain yields of the cultivars VLB-56, RD-57, C-84, NB-2, Sonu, RD-103, Azad, RD-2899, HUB-113, and UPB-1008 were significantly higher than the check variety RD2967 (best check). Based on visual scores and classical selection indices (Smith 1936), the genotypes RD57, K24, JB58, NB5, NB3, VLB58, RATNA, RS56, NDB11723, K603, RD2907, and DL88 have been selected as potential candidate parental lines for sodicity stress tolerance.

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)

Germplasm collection, documentation and conservation-2023-24

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 614-1-100-13 x CS 56; (2) CS 245-2-80-7 x CS 56; (3) CS 245-2-80-7 x Varuna; and (4) CS 614-1-100-13 x Varuna], 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-2023-24

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 (*p*H_2 9.3) at Karnal. Seed yield ranged from 1.65 to 2.90 t ha^{-1} (Mean 2.06 t ha^{-1}, $CD_{(0.05\%)}$ 0.30 t) under normal conditions while it ranged from 1.26 to 2.12 t ha^{-1} (Mean 1.49 t ha^{-1}, $CD_{(0.05\%)}$ 0.78 t) under alkali condition. One genotype CS 2009-215 (2.90 t ha^{-1}) gave significantly higher yield over the best check CS 60 (2.61 t ha^{-1}) under normal conditions, while CS 2009-245 (2.12 t ha^{-1}) and CS 2020-31 (2.00 t ha^{-1}) gave significantly higher yield over the best check CS 60 (1.71 t ha^{-1}) under alkali conditions.

Development and Evaluation of advanced breeding lines (YET) in semi–reclaimed alkali soils-2023-24

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 (*p*H_2 9.3) at Karnal. Seed yield ranged from 1.47 to 1.99 t ha^{-1} (Mean 1.25 t ha^{-1}, CD $_{(0.05\%)}$ 0.19 t) under normal conditions while it ranged from 1.71 to 2.79 t ha^{-1} (Mean 2.15 t ha^{-1}, CD $_{(0.05\%)}$ 0.20 t) under alkali condition. CS 17000-2-3 (2.79 t ha^{-1}) and CS 2009-219 (2.68 t ha^{-1}) gave significantly higher yield over the best check CS 60 (2.61 t ha^{-1}) under normal condition, while CS 2009-219 (1.99 t ha^{-1}), RIL199 (1.81 t ha^{-1}) and CS 2013-5 (1.73 t ha^{-1}) gave significantly higher yield over the best check CS 60 (1.71 t ha^{-1}) under alkali condition.

Development and Evaluation of Multi-stress tolerance advanced breeding line (drought, frost, heat and salt stresses) conditions-2023-24

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 ºC) and heat stresses along with sodic soils pH_2 9.78) at SKN Agriculture University, Agricultural

Table 5.16 Development of multi stress tolerance advanced breeding line- 2023-24

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			

Table 5.17 Performance of mustard strains in AVT (saline/alkaline conditions)-2023-24

S.No.	Code	Strain	Seed yield (t/ha)	1000-Seed wt. (g)	Oil Content (%)
1	CSCN-23-1	Kranti (NC)	1.49	4.17	37.94
2	CSCN-23-2	CS2020-10	2.28	5.20	40.17
3	CSCN-23-3	CS 60 (Filler)	2.00	5.16	39.75
4	CSCN-23-4	CS 54 (Check)	1.82	5.21	38.14
5	CSCN-23-5	CS 60 (LR)	1.99	5.13	39.30
GM			1.92		
CD (5%)			0.27		
DOS			23/10/2023		
CV (%)			9.20		
ECe (dS/m)/ pH			pH 9.3		

Research Station, Fatehpur-Shekhawati, Sikar (Rajasthan). Under drought, heat, salt and frost stresses, seed yield ranged from 0.69 to 2.59 t ha^{-1} (Mean 1.60 t ha^{-1}, CD $_{(0.05\%)}$ 0.22 t). Twenty lines CS 60 (1.40 t ha^{-1}) with CS2020-10 (2.60 t ha^{-1}) followed by CS2020-6 (2.5 t ha^{-1}) recorded maximum seed yield (Table 5.16). Further, Seed yield ranged from 0.89 to 2.6 t ha^{-1} (Mean 1.75 t ha^{-1}, CD $_{(0.05\%)}$ 0.65 t) under salt stress environment at Karnal (pH_2 9.3). Five lines surpassed CS 60 (2.00 t ha^{-1}) with CS2020-17 (2.47 t ha^{-1}) followed by CS2020-13 (2.45 t ha^{-1}) recorded maximum seed yield (Table 5.16).

Monitoring and Evaluation of promising salt tolerant strains of Indian Mustard (Brassica juncea) in AICRP on Rapeseed Mustard Salinity/Alkalinity Trial-2023-24

Five entries were evaluated in AVT-I under the alkali condition (*p*H 9.3) at Karnal. Seed yield ranged from 1.49 to 2.58 t ha^{-1} (Mean 1.92 t ha^{-1}, CD $_{(0.05\%)}$ 0.27 t). Entry CSCN-23-2 (2.28 t ha^{-1}) followed by CSCN-23-3 (2.00 t ha^{-1}) showed highest seed yield under the salt stress condition (Table 5.17).

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

In 2023-24, breeder seed (1.50 tonnes graded) of Indian mustard varieties produced ; CS 52 (0.05 t), CS 54 (0.05 t), CS 56 (0.20 t), CS 58 (0.40 t), CS 60 (0.60 t), CS 61 (0.20 t) while 0.3 tonnes of TL seed of CS 62 (0.1t) and CS 64 (0.2t) and distributed to stakeholders, central and state govt. agencies.

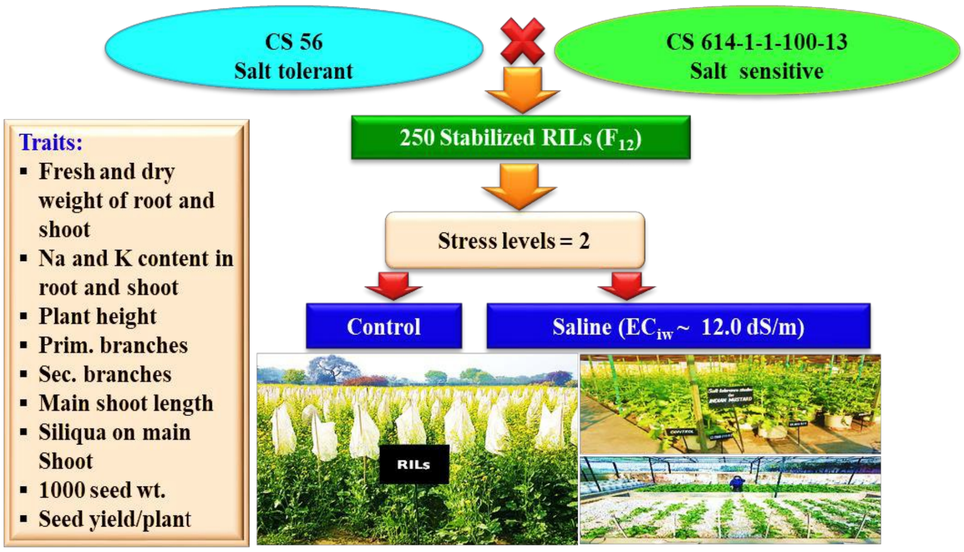


Fig 5.5 Phenotyping of mapping populations

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)

Two new RILs populations (F_5) developed using recently identified donors

1. CS 245-2-80-7 x CS 60 (Salt tolerant)-252 lines
2. CS 245-2-80-7 x CS 52-SPS-1-2012 (Salt tolerant)-250 line

Phenotyping of RILs (F_{12}) and parents under normal and saline (EC_{iw}12 dS/m) conditions

Advancement of RILs using single siliqua decent method

Two hundred fifty-two Recombinant Inbred Lines (RILs) including their parents (CS 56 and CS 614-1-1-100-13) were sown under normal and salinity (ECiw 12 dS/m) conditions for phenotyping in October 2023 and advanced F_{12} generation in to F_{13} using single siliqua decent method (Fig 5.5).

Shoot Na content of the RILs ranged from 2.82 to 21.66 mg/kg dry wt. and 6.25 to 26.88 mg/kg dry wt. under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed shoot Na content of 2.4 and 5.6 mg/kg dry wt. under normal and 8.9 and 16.7 mg/kg dry wt. in saline conditions. Shoot K content of the RILs ranged from 11.09 to 80.54 mg/kg dry wt. and 19.15 to 100.33 mg/kg dry wt. under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed shoot K content of 57.0 and 26.2 mg/kg dry wt. under normal and 56.4 and 49.4 mg/kg dry wt. in saline conditions. Root Na content of the RILs ranged from 6.82 to 40.79 mg/kg dry wt. and 7.30 to 43.15 mg/kg dry wt. under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed root Na content of 0.8 and 9.2 mg/kg dry wt. under normal and 9.4 and 10.6 mg/kg dry wt. in saline conditions. Root K content of the RILs ranged from 18.6 to 73.51 mg/kg dry wt. and 10.9 to 78.35 mg/kg dry wt. under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed root K content of 44.5 and 36.1 mg/kg dry wt. under normal and 32.8 and 17.63 mg/kg dry wt. in saline conditions. The plant height of the parental lines CS 614-1-1-100-13 and CS 56 was 186.7 and 194.5 cm respectively under normal and 166.7 and 174.0 cm saline (EC_{iw} 12 dS/m) conditions. The height of RILs ranged from 161-248 cm under normal and 134.5-207.3 cm under saline soils, respectively. The main shoot length of RILs ranged from 62.1- 100.2 cm under normal and 45.0- 81.3 cm under saline conditions, respectively. The main shoot length of the parental lines CS 56 and CS 614-1-1-100-13 was 87.0 and 77.5 cm under normal and 68.0 and 33.7 cm in saline conditions. The number of siliquae on main shoot of RILs ranged from 42.0-78.0 under normal and 36.0-59.0 under saline conditions, respectively. The number of siliquae on main shoot of the parental lines CS 56 and CS 614-1-1-100-13 was 58.0 and 57.0 under normal and 47.0 and 23.7 in saline conditions. The test weight of RILs range varied from 3.55-7.30g and 3.10-5.3g under normal and saline conditions. The parental lines CS 56 and CS 614-1-1-100-13 displayed test weight of 5.2 and 5.0g under normal and 4.9 and 3.9g in saline conditions. The yield/plant of RIL ranged from 33.7 to 139.0g and 3.73 to 109.50g under normal and saline conditions. The parental lines CS 56 and CS 614-1-1-100-13 displayed yield of 131.30 and 107.70 31.2g under normal and 98.20 and 15.20g under saline.

Validation of identified candidate genes

For in silico investigation of QTLs revealed using GWAS data. To begin, enter the reference SNPs ID into NCBI (https://www.ncbi.nih.gov) so that the NCBI SNP database can be located in the assembly/molecule. The FASTA sequence was then entered into the *UniProt* database (http://www.uniprot.org). These protein sequences were then utilized as queries in a blast search against the *Arabidopsis thaliana* genome database using *Ensembl Plants* which assisted in the discovery of the biological process, cellular component, and molecular function of the anticipated salt responsive genomic region.

a. RNA-based validation (Expression validation): Candidate primers for RT PCR were developed from SNPs of the flanking region of QTLs. Candidate genes expression was significantly higher under salt stress in tolerant than sensitive genotypes, compared to the constitutively expressed housekeeping gene.

b. Functional validation: Two candidate genes (BjuA014968 & BjuB041359) were important in the main shoot's salt tolerance for yield and siliqua density. Both genes were also overexpressed under control and salt stress conditions, while third gene BjuA027369 controlling seeds per siliqua was over-expressed under higher salinity in the tolerant genotype. *BjuA*014968 on chromosome A04 controlling yield per plant under salt stress conditions that regulates scavenging of ROS/ionic/osmotic stress stimulus, indicating cellular salt concentration changes. *BjuA*027369 on chromosome A07 controlling Seed/siliqua under salt stress condition that protects against hypo-osmotic shock by responding to membrane stretching, depolarization and mediating ATP-coupled ion transport. *BjuB*041359 on chromosome B08 controlling Siliqua density on the main shoot under salt stress conditions that encodes a CP43-like protein binding chlorophyll, facilitating light-driven photochemical reactions in PSII for ATP generation and energy balance.

Identifying allelic variation within a QTL region and CO-Localization with QTLs for salt tolerance through fragment analysis

The detection of allelic variations through fragment analysis and SSR markers situated near significant QTLs has yielded crucial insights into the genetic diversity that underpins salinity tolerance in *B. juncea*. SSR_52 emerged as a size polymorphic marker specific to a

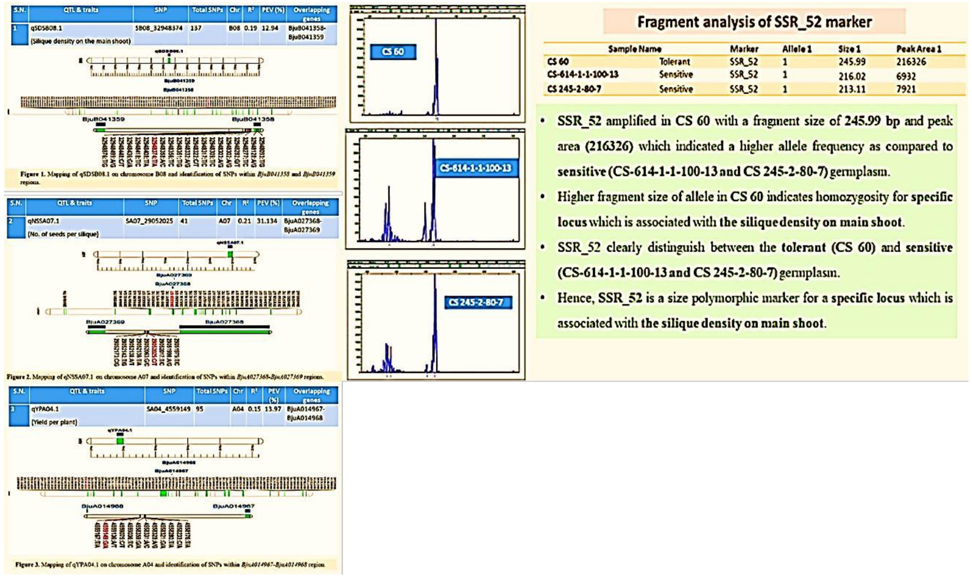


Fig 5.6 Fragment analysis

homozygous locus, demonstrating its crucial role in inheriting silique density on the main shoot under conditions of salt stress as compared to SSR_51, SSR_174, SSR_175 and SSR_312. The SSR_52 was successfully amplified in the CS 60 variety, producing a fragment size of 245.99 bp and peak area (216326). A comprehensive study identified 13 bands, with each displaying polymorphism, further affirming the genetic variability present. In total, SSR markers revealed 14 highly polymorphic alleles, while genetic similarity across genotypes varied significantly, ranging from 0.33 to 0.95. Co-localization is used to investigate association between quantitative trait loci (QTLs) and candidate genes. By mapping QTLs and candidate genes to the same chromosomal region, researchers can identify genes possibly controlling specific traits of interest. In this study, QTL analysis identify loci linked to key agronomic traits in *B. juncea*, silique density on the main shoot, number of seeds per silique, and yield per plant (Fig. 5.6).

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

Phenotypic of Chickpea germplasm

A total 1000 diverse panel of chickpea pan-gene germplasm and 2550 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 dS m^{-1}) conditions for phenotypic screening (Fig. 5.7).

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. The results indicate that checks are superior for all the traits studied except for yield/plant and filled pods under normal conditions. However, test entries are superior for remaining traits. The checks recorded more productive branches, filled pods, 100 seed weight and yield/plant under saline conditions due to better adaptation. However, some accessions outperformed checks in specific traits. Of these, the accessions for Yield/plant: ICC10386, ICC11007; Filled pods: ICC8769, ICC10386; Productive branches: ICC6874; 100 seed

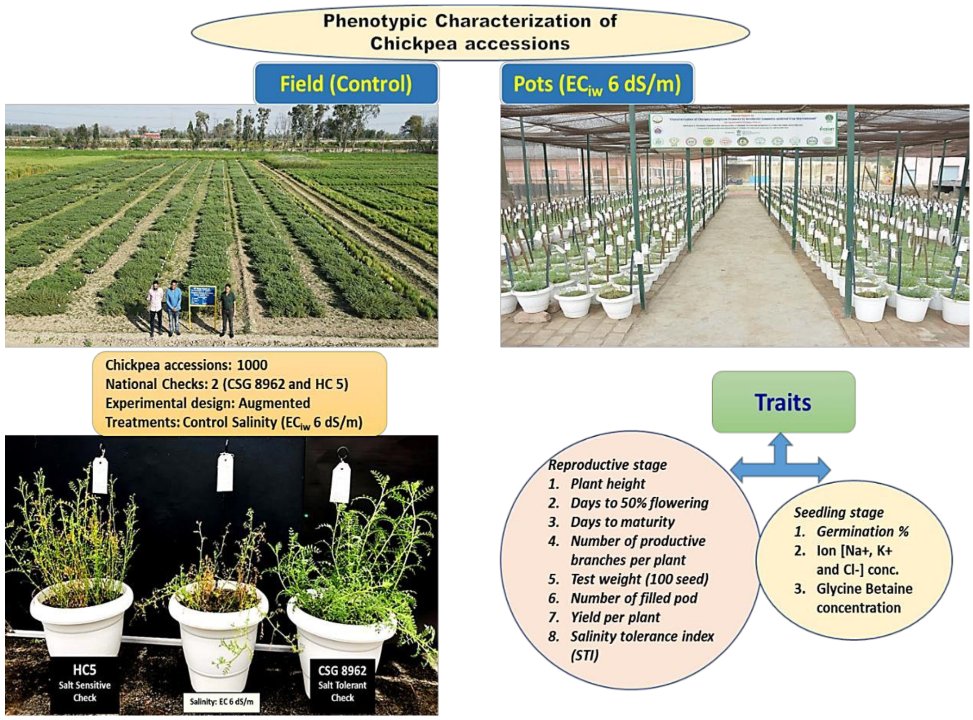


Fig 5.7 Phenotypic screening of Chickpea germplasm (A) Drone image of chickpea field (control), (B) Salinity evaluation of chickpea germplasm grown in pots supplemented with water of ECiw 6 dS/m, (C) Comparison of genotype with national checks.

weight: ICC6226 and ICC6433 were found better than checks under the normal condition. However, under saline environment Yield/plant: ICC13185, ICC12440; Filled pods: ICC13185, ICC12440; Productive branches: ICC13185, ICC12440, ICC12460; 100 seed weight: ICC8261, ICC11152, ICC13185; Highest shoot K conc.: ICC8950, ICC13185, ICC6875; Least Cl^- conc. in shoot: ICC12435, ICC12440, ICC6892; Least Cl^- conc. in root: ICC124790, ICC12440 and ICC14002 were found better than checks. Hence, these genotypes could be useful in hybridization to develop superior genotypes.

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 was non-significant for all traits under the normal and salinity conditions, indicating homogeneity of evaluation blocks. The treatment effects 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 conditions, indicating variability among chickpea accessions. Similarly, the effects due to checks and varieties were significant. Mean squares for checks and checks vs. varieties were significant, showing differential responses between checks and test entries under both environments.

Standard errors of mean and LSI for comparison of adjusted means

The standard errors of difference (Table 5.18) were computed for all traits to compare two check varieties (Sc), two test entries in the same block (Sb), test entries in different blocks (Sv) and 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 4 (yield/plant), 18 (plant height), 274 (productive branches), 935 (no. of filled pods), 464 (100 seed weight), 860 (K^+ conc. shoot), 191 (Cl^- conc. shoot) and 7 (Cl^- conc. root). However, accessions that surpassed the best check were 1 (yield/plant), 1

Table 5.18 SE of mean and LSI for comparison of adjusted means for traits of 1000 accessions of Chickpea under normal and saline conditions

Traits 2023-24	Difference between two check varieties (Sc): √2MSE/R		Difference between adjusted means of two test entries in the same block (Sb): √2MSE		Difference between adjusted means of two test entries in different blocks (Sv): √2 (C + 1) MSE/C		Difference between adjusted test entry and check mean (Svc): √{(R +1) (C + 1) MSE}/R.C		Least sig. increase (LSI): tα (1.833).Svc		Test entries Mean value		Critical value for traits = Check mean ± LSI		No. of entries desired for trait	
	Normal	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**	**Normal**	**Salinity**
Days to 50% flowering	2.90	1.06	9.10	3.30	11.10	4.10	8.20	3.03	15.03	5.55	101.1	87.90	86.07	82.35	1	1
Days to maturity	1.90	8.80	6.10	5.90	7.40	7.70	5.50	4.80	10.08	8.80	145.7	128.6	135.6	119.8	0	1
Plant height (cm)	7.50	3.10	23.70	9.60	29.00	11.80	11.50	8.70	21.08	15.95	49.93	41.09	71.01	57.04	8	3
Productive branches	1.10	1.00	3.50	3.40	4.30	1.20	3.20	3.10	5.87	5.68	8.13	3.98	14.00	9.66	0	1
No. of filled pods	30.6	2.40	96.60	7.70	118.3	9.40	87.80	6.90	160.9	12.65	116.2	17.27	277.2	29.92	15	1
Yield/plant (g)	10.6	3.10	33.60	9.80	41.10	12.10	30.50	7.80	55.91	14.30	51.96	12.76	107.9	27.05	0	2
100 Seed weight (g)	5.80	0.90	18.40	3.10	12.60	3.80	6.80	2.80	12.46	5.13	16.96	6.40	29.42	11.53	17	5
Na^+ conc. shoot (mg/g dw)	26.8	24.80	84.80	78.70	103.8	96.30	6.90	11.50	12.65	21.08	21.02	66.79	8.37	45.71	2	36
K^+ conc. shoot (mg/g dw)	26.4	18.70	83.40	59.10	102.1	72.40	29.80	23.70	54.62	43.44	32.18	19.66	86.80	63.10	66	0
Cl^- conc. shoot (mg/g dw)	0.57	1.20	1.81	3.70	2.21	4.50	0.94	1.40	1.72	2.57	2.27	3.28	0.54	0.71	2	0
Na^+ conc. root (mg/g dw)	21.4	18.60	67.60	58.90	82.80	72.10	8.40	10.50	15.40	19.25	21.05	70.67	5.65	51.43	0	30
K^+ conc. root (mg/g dw)	24.4	26.60	77.20	84.10	94.50	62.90	29.10	26.40	53.34	48.39	37.20	19.56	90.54	67.95	29	0
Cl^- conc. root (mg/g dw)	0.36	0.87	1.13	2.77	1.39	3.39	2.03	1.50	1.89	2.75	1.91	2.89	0.02	0.14	0	0

(productive branches), 3 (100 seed weight), 3 (K^+ conc. shoot), 197 (Cl^- conc. shoot), 1 (Cl^- conc. root) and 1036 (Days to maturity) under the salinity. The genotype CSG 8962 was the best check for all traits than HC 5 except days to maturity.

Association between traits

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: $\mathbf{STI = (Y_N \times Y_s) / (M_N)^2}$

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 - 0.03), and tolerant (STI= >0.30). We found 2 accessions ICC 13185 (STI=1.02) and ICC 12440 (STI=0.84) as highly tolerant, and 998 salt sensitive from 1000 chickpea accessions.

Genetic improvement of chickpea for salt tolerance through conventional and molecular breeding approache (SK Sanwal, Avni Dahiya, Anita Mann)

Phenotyping of chickpea RILs for salinity tolerance

During the rabi season 2023-24, 323 chickpea RILs along with their salt tolerant parent (CSG-8962) and salt susceptible parent (BG1103) were tested in micro plot (EC_{iw} 6 dS/m) and under control condition. Salt stress was imposed by irrigating three times (30, 60, and 90 DAS) with EC_{iw} 6 dS/m water. Quantitative data on days to 50% flowering (DFF), number of pods/plant, grain yield per plant, ionic analysis of root and shoot (Na^+ and K^+) were recorded to find out the effect of salinity stress in both conditions.

The days to 50% flowering was early in saline condition compared to control (Table 1). STI in tolerant group of genotypes was greater than 0.1, while in the susceptible group it was <0.1 (Table 5.19). The number of pods per plant was notably higher in salinity-tolerant

Table 5.19 Performance of best RILs along with checks

RILs	Days to 50% flowering		Number of pods/plant		Grain yield/plant (g)		STI_GY	Group
	Control	Salinity	Control	Salinity	Control	Salinity		
BG-1103 × 8962-266	117	89	67	14	26.00	17.09	0.45	Tolerant
BG-1103 × 8962-96	118	93	156	17	53.38	7.77	0.42	Tolerant
BG-1103 × 8962-143	116	93	187	16	46.25	8.51	0.40	Tolerant
BG-1103 × 8962-293	115	93	154	30	39.78	9.80	0.40	Tolerant
BG-1103 × 8962-76	112	94	154	31	39.79	8.91	0.36	Tolerant
BG-1103 × 8962-75	113	97	167	19	44.95	7.80	0.36	Tolerant
BG-1103 × 8962-67	122	93	156	23	39.37	8.87	0.36	Tolerant
BG-1103 × 8962-206	112	86	142	28	41.89	8.26	0.35	Tolerant
BG-1103 × 8962-77	112	93	168	23	42.09	8.09	0.35	Tolerant
BG-1103 × 8962-149	119	93	149	19	36.83	9.21	0.35	Tolerant
CSG-8962 CH	115	97	88	18	31.38	6.08	0.19	Tolerant
BG-1103 CH	119	94	111	6	31.27	3.04	0.10	Susceptible
BG-1103 × 8962-328	114	90	132	8	35.35	1.78	0.06	Susceptible
BG-1103 × 8962-330	115	86	141	9	35.93	1.57	0.06	Susceptible
BG-1103 × 8962-41	112	98	142	8	35.35	1.52	0.05	Susceptible
BG-1103 × 8962-321	116	87	95	7	26.38	2.02	0.05	Susceptible
BG-1103 × 8962-48	122	99	72	5	30.01	1.68	0.05	Susceptible
BG-1103 × 8962-115	122	99	107	3	31.83	1.51	0.05	Susceptible
BG-1103 × 8962-320	115	87	136	3	33.49	1.39	0.05	Susceptible
BG-1103 × 8962-118	116	93	133	5	28.25	1.59	0.05	Susceptible
BG-1103 × 8962-114	115	100	77	4	25.27	1.29	0.03	Susceptible
BG-1103 × 8962-329	113	92	129	3	39.07	0.60	0.02	Susceptible

genotypes than in susceptible ones, especially under salinity stress. Among the genotypes, BG-1103 × 8962-143 recorded the highest pod number under control conditions, while BG-1103 × 8962-76 exhibited the highest pod count under salinity stress (143 and 31 pods, respectively). These pod number variations aligned with grain yield differences, emphasizing pods/plant as a key trait for salinity tolerance and yield stability. Based on performance and STI-GY, 10 RILs outperformed the tolerant check CSG 8962 under ECiw 6 dS/m salinity stress.

Variability in the RIL population for salinity tolerance

The RIL population comprising 323 lines exhibited significant variability for salinity stress tolerance in traits such as days to 50% flowering (DF), number of pods per plant, and grain yield per plant. Mean, SD, range, and CV for all traits are presented in Table 5.20. The coefficient of variation (CV) was higher under salinity stress compared to control conditions, with values of 4.42% for DF, 34.29% for pods per plant, and 35.19% for grain yield per plant under salinity stress. In contrast, under control conditions, the CV values

Table 5.20 Basic statistics depicting variability in population of 330 RILs

Traits	Mean	Range	SD	CV(%)
DF-Control	117	110-128	3.87	3.31
DF-Salinity	92	83-100	4.08	4.42
NPP-Control	118.49	19.33-270.00	29.67	25.08
NPP-Salinity	15.80	0.63-38.33	5.47	34.29
GY-Control	31.66	1.96-67.53	7.35	23.23
GY-Salinity	5.89	0.12-18.75	2.07	35.19
STI-GY	0.19	0.02-0.45	0.07	38.80

DF: Days to 50% flowering; NPP: Number of pods/plant in control; GY : Grain yield/plant (g); STI- GY: Salinity tolerance Index based on grain yield

Table 5.21 List of breeding materials in different generation

BC1F1	F3	F4
(C 95× C 79) × C95; (L 200 × L 195) × L 200; (GNG 14581 × CSG 8962) × GNG 14581; (ICC 6679 × ICCV 10) × ICC 6679; (ICC 6558 × ICCV10) × ICC 6558; (JG 315 × ICCV 10) × JG 315	GNG 14581, HC 5, IPCL 4-14 × ICCV 10 & CSG 8962	JG-11, Vijay, JG 16, BG 1103 × ICCV 10; HC-5 × GG 4, GG 2

were 3.31% for DF, 25.08% for pods per plant, and 23.23% for grain yield per plant. This indicates substantial genetic variation for these traits under stress. These details are in Table 5.20. This genetic variability highlights the potential of this RIL population for selecting salinity-tolerant genotypes.

Introgression of Salinity tolerance traits into elite chickpea cultivars

High-yielding yet salinity-susceptible chickpea varieties were strategically crossed with salinity-tolerant genotypes ICCV-10 and CSG-8962 to incorporate salinity tolerance while retaining high yield potential. F2 progenies were advanced to F3, and F3 to F4 generations, with selection for salinity tolerance. Backcrossing was employed in targeted crosses to recover the genotypic background of high-yielding parental lines while maintaining salinity tolerance. This approach ensures the development of elite lines that combine stress resilience with productivity (Table 5.21).

Evaluation of salinity tolerant genotypes in micro-plots

In a microplot study, 62 chickpea lines, along with sensitive (IPCL-4-14) and tolerant (CSG 8962) checks, were evaluated under salinity stress (EC 6 dS m^{-1}). The performance of high-yielding lines compared to the salinity-tolerant check CSG 8962 is detailed in Table 5.22.

Days to 50% flowering was longest in the tolerant genotypes and the salinity-tolerant check (107 DAS), while the sensitive check IPCL-4-14 flowered at 101 DAS. Plant height ranged from 19 cm to 60 cm, with CSG 8962 measuring 36.33 cm. The highest 100-seed weight was observed in genotype BG 315 (18.86 g), followed by CSG 8962 (17.01 g). Grain yield per plant varied from 0.16 to 19.24 g, with CSG 8962 yielding 12.95 g. BG 315, the highest yielder, recorded a grain yield of 19.24 g per plant (Table 4). IPCL-4-14 exhibited the highest transpiration rate, negatively impacting its yield. CSG 8962 showed moderate internal CO_2 concentration (338.08 µmol mol^{-1}) and a high photosynthetic rate (2.264 µmol m^{-2} s^{-1}), contributing to its superior yield under salinity stress. BG 315, the top

Table 5.22 Performance of different genotypes under salinity environment (EC 6 dS m^{-1})

Genotype	DF	PH (cm)	HSW (g)	GY/plant(g)	E (mol m^{-2} s^{-1})	A (µmol m^{-2} s^{-1})	Ci (µmol mol^{-1})	Gsw (mol m^{-2} s^{-1})
BG315	106	39.35	18.86	19.24	0.0025	1.620	355.984	0.060
L-166	107	45.17	12.40	16.98	0.0023	2.107	342.023	0.059
IPCO4-52	106	56.00	18.75	12.50	0.0014	0.949	352.973	0.033
L-169	107	39.75	11.06	11.94	0.0023	1.247	365.192	0.057
CSG8962 (tolerant check)	107	36.33	17.01	12.95	0.0019	2.264	338.080	0.048
IPCL-4-14 (sensitive check)	101	41.11	14.16	3.69	0.0018	2.161	364.526	0.042

DF: Days to 50% flowering; PH: Plant height; HSW: Hundred seed weight; GY/plant: Grain yield/ plant; E: Transpiration rate; A: Photosynthetic rate; Ci: Internal CO_2 concentration; gsw: Stomatal conductance performer, had the highest stomatal conductance (0.060 mol m^{-2} s^{-1}), suggesting an efficient balance between CO_2 uptake and water regulation, essential for productivity in saline conditions.

Maintenance of germplasm and parental lines: A total of 378 germplasm lines and 64 parental lines were maintained for their use in future breeding programme.

Breeder seed production: During 2023-24, 5.1 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)

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

Introgression of Salt tolerant QTLs into mega chickpea varieties: The mega varieties high yielding and higher in demand but susceptible to salinity were used for introgression of salt tolerant genes from tolerant varieties/genotypes ICCV 10 and CSG 8962. The ICCV 92944 and Vijay were used. The hybridity of all the F_1s sown were checked by polymorphic SSR markers.

Table 5.23 List of breeding materials in different generation

F1	BC1 F1	BC2F1	BC3F1
ICCV 92944, Vijay × CSG 8962 & ICCV 10	GG-6, JG-16 × CSG 8962 & ICCV 10	BG 1103, HC5, JG16, Vijay, × CSG 8962 & ICCV 10	Vijay, HC5, JG11 × CSG 8962 & ICCV 10

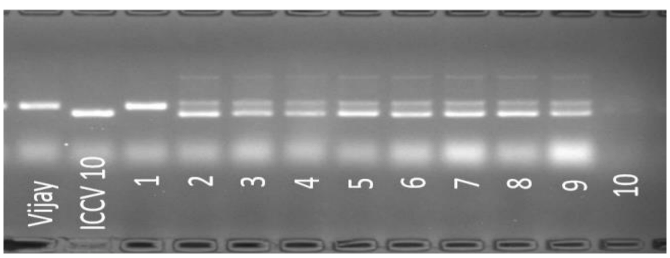


Fig 5.8 Conformation of true hybrids by using SSR marker TA-22-7 and CAGMS-13 Plant no. 2 to 10 are true hybrids

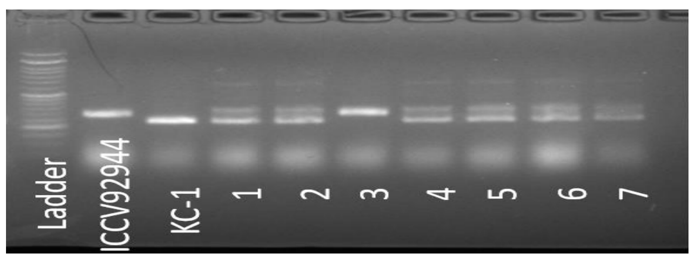


Fig 5.9 Conformation of true hybrids by using SSR marker TA-22-7 and CAGMS-13 Plant nos. 1,2,4,5, 6, 7 are true hybrids

QTL confirmation through gene based marker for salinity tolerance

BC_3F_1 population JG 11 x JG 11 x JG 11 x (JG 11x ICCV10) was grown in 2023-24 and foreground selection was done with ERF-3 and ERF- 6 SSR marker for confirmation of QTL and non-confirming plants were discarded.

Development of NIL population: For development of NIL population, extreme RILs were identified, crossed and seeds harvested. These F_1 seeds were advanced after confirming hybridity using molecular marker. The true F_1s were selfed and F2 population seeds were handed over to PI, Chickpea, IARI, New Delhi for genotyping. The extreme RILs used in crosses were RIL 63× RIL 172, RIL51 × RIL84, B200 × B195, and A132 × A63

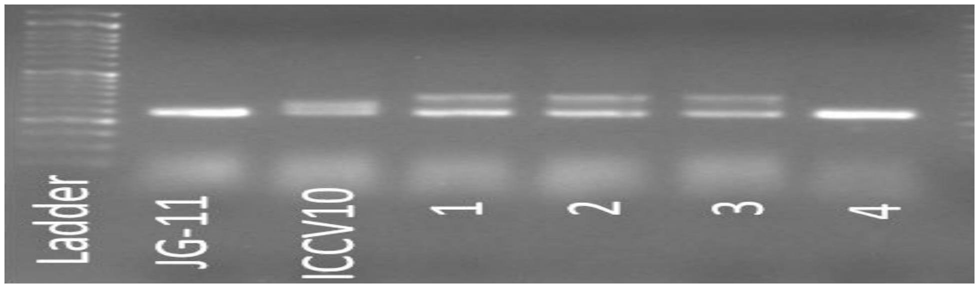


Fig 5.10 Fig 3.BC3F1 = JG 11 x JG 11 x JG 11 x (JG 11x ICCV10)

L-100bp Ladder, 1 to 4= single plant no. of JG 11 x JG 11 x JG 11 x (JG 11x ICCV10)

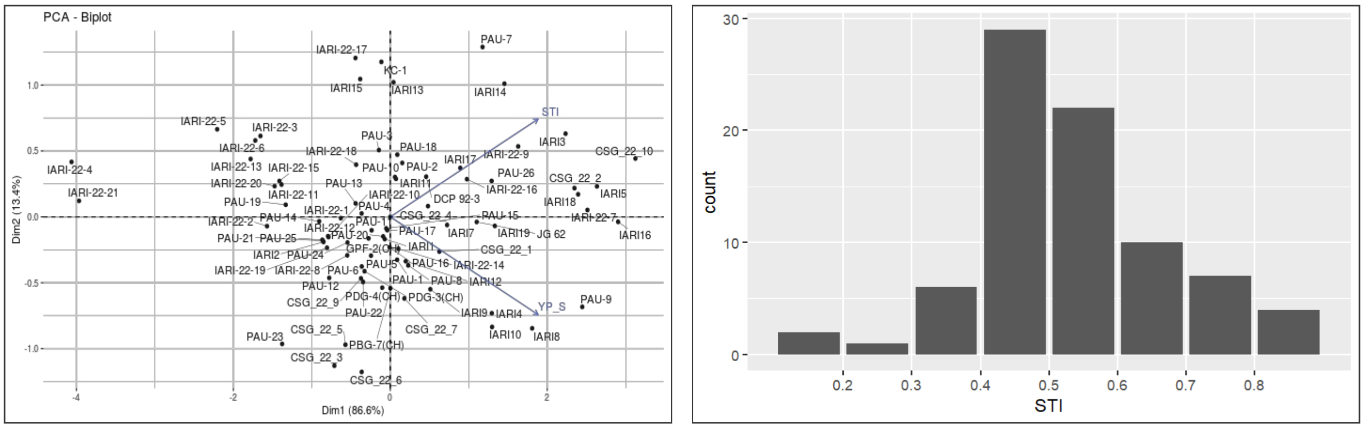


Fig 5.11 (A - Left) PCA (B-Right) Histogram showing the frequency distribution and classes (based on STI)

Table 5.24 Top five lines along with check based on salt tolerant index

Genotypes	Grain yield/plant in salinity (g)	STI
CSG-22-10	17.90	0.89
IARI 5	17.28	0.82
IARI 16	18.48	0.82
IARI 3	15.50	0.82
CSG-22-2	16.67	0.79
CSG-8962 (C)	14.46	0.64

Coordinated evaluation of advance material for salinity tolerance

Eighty-one chickpea genotypes including advance breeding lines, interspecific crosses, backcross inbred lines of CSSRI, IARI and PAU, Ludhiana along with salt tolerant checks (KC-1 and ICCV 10) were tested under saline (EC_{iw} 6 dS/m) and control conditions. Quantitative data on days to 50% flowering (DFF), pods per plant, yield per plant, and 100 seed weight were recorded to assess salinity impact.

Stress tolerance index (STI) was calculated from grain yield/plant data. The panel's frequency distribution showed wide variation and indicated the presence of salinity tolerance with four lines having STI > 0.80. Higher STI values reflect better yield and greater tolerance to soil salinity.

Physio-biochemical basis of salt tolerance

Based on the results of the above study, we selected five most tolerant (CSG-22-10, IARI 5, IARI 16, IARI 3, CSG-8962) and five most susceptible genotypes (IARI-22-3, IARI-22-6, IARI-22-5, IARI-22-21 & PAU-25) for detailed analysis of physio-biochemical traits. Tolerant group of genotypes exhibited higher ionic and biochemical efficiency in terms of water and osmotic potential, RWC, higher Membrane stability, proline accumulation and all anti-oxidant enzymes activity than sensitive ones. Tolerant genotypes had low Na^+/K^+ and

Cl^- ions in shoot and higher in roots conferring salt tolerance. Malondialdehyde (MDA), a marker of oxidative stress from ROS-damaged membranes, was lower in tolerant genotypes (Figure2b boxplot), indicating reduced membrane damage and capacity to withstand soil-salinity stress.

Correlation analysis indicated significant relationships between the traits of interest. Overall proline (0.94), NR (0.88), SOD (0.91), catalase (0.96), APX (0.95), GR (0.97), POX (0.91), OP (0.88), WP (0.83), RWC (0.92) and MS (0.87) were highly positively correlated with yield/plant under soil salinity. In tolerant group of genotypes catalase, APX, GR and osmotic potential were highly positively correlated (0.52, 0.89, 0.30, 0.40 respectively) and MDA content was highly negatively correlated (-0.46) with yield per plant under salinity condition. Na^+/K^+ ratio in shoot of the plants showed highly negative correlation (-0.79) in tolerant group and non-significant interaction in the susceptible group. Overall, MDA, catalase, APX, GR and osmotic potential effectively distinguished tolerant and susceptible groups. Thus, these traits might have contributed in maintaining the yield in the tolerant genotypes under saline conditions.

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

A core set of 304 and 401 lines including 5 high yielding and salt tolerant checks selected from 2657 accessions received from NBPGR, New Delhi were sown on 10.11.2023 and 13.11.2023 in experimental fields for evaluation under alkaline and saline conditions, at CSSRI, Karnal and ICAR-IIWBR research Farm, Hisar. The lines were assessed for seed yield, yield contributing, physiological and biochemical traits. During the reporting period the data was recorded on seedling vigor index (NDVI), total chlorophyll (SPAD), leaf area index (LAI), days to 50% flowering (DF), plant height (PH), days to physiological maturity (DM), number of seed per capsule (NSC), thousand seed weight (TSW), number of capsules per plant (NCP) and seed yield per plant (SYP).

Under stress condition, flowering was late in alkaline condition and early in saline condition showing 9.20% and 1.15% in alkaline and saline condition, respectively. A 29.65% reduction in plant height under alkaline conditions, while reduction was non-significant under saline stress. Days to physiological maturity was measured when more than 80% of the capsules turned into golden yellow. Maturity took longer under alkaline condition and lesser in saline condition.

Data of number of seed per capsule, thousand seed weight, number of capsules per plant and seed yield per plant were taken at harvesting stage. Under saline stress, number of seed per capsule reduced by 4.65%. However, under alkaline it was 2.60% higher than control. Thousand seed weight reduced by 1.27% (saline) and 0.39% (alkaline). Number of capsules per plant reduced by13.95% and 16.63% less in saline and alkaline stress (Table 5.25). Seed yield per plant showed a 19.46% (saline) and 14.54% (alkaline) reduction compared to control.

Mean performance of Tolerant and susceptible groups under control and saline conditions

The morphological, physiological and biochemical parameters studied separately of tolerant and susceptible genotypes. NDVI, SPAD, days to flowering, days to maturity have

Table 5.25 Performance of reference set under control, saline and alkaline condition

Traits	Mean			Range			% reduction over control	
	Control	Saline	Alkaline	Control	Saline	Alkaline	Saline	Alkaline
NDVI	0.66	0.49	0.33	0.54–0.74	0.53-0.76	0.16-0.54	25.76	50.00
SPAD	55.84	51.23	49.42	45.63-65.42	38.01-61.30	28.99-63.21	8.26	11.50
LAI	2.90	1.65	0.45	1.30-4.20	0.20-3.20	0.10-1.15	43.10	84.48
MI (%)	16.09	45.82	40.20	4.40-25.96	20.55-62.36	44.71-92.89	-184.77	-149.84
RWC (%)	79.64	63.09	63.74	66.01-90.46	49.92-81.51	43.41-81.47	20.78	19.96
Proline (µg/g DW)	123.29	226.21	302.56	40.72-167.32	85.18-365.60	107.30-408.50	-83.47	-145.40
DF	87	86	95	73-103	81-102	80-108	1.15	-9.20
PH (cm)	70.71	60.26	49.74	47.13-162.89	53.27-97.11	35.98-87.67	14.77	29.65
DM	133	130	138	125-142	122-150	130-148	2.26	-3.76
NSC	8.28	7.89	8.09	4.57-10.37	4.78-9.97	6.17-9.87	4.65	2.29
TSW (g)	6.14	6.07	6.12	3.39-11.10	3.32-11.76	3.98-10.88	1.27	0.39
NCP	152.13	130.91	126.82	70.39-318.38	57.34-279.75	46.31-327.34	13.95	16.63
SYP (g)	7.45	6.00	6.37	3.30-14.26	1.84-12.36	2.37-16.17	19.46	14.54

Table 5.26 Morphological parameters of tolerant and susceptible genotypes

Tolerance	NDVI		SPAD		LAI		DF		PH		DM	
	Control	Saline	Control	Saline	Control	Saline	Control	Saline	Control	Saline	Control	Saline
T	0.66	0.68	56.42	51.64	2.98	2.19	87.33	87.09	73.24	70.10	135	131
S	0.65	0.65	55.54	50.82	2.70	1.59	86.09	85.30	67.10	62.61	133	128
HSD @ 5%	NS	NS	NS	NS	NS	0.24	NS	NS	4.85	5.12	NS	NS

Table 5.27 Physiological and biochemical parameters of tolerant and susceptible genotypes

Tolerance	Chlorophyll content (mg/g FW)		Proline content (µg/g FW)		Soluble sugars content (mg/g FW)		Soluble Protein content (mg/g FW)		Root Na^+/K^+		Shoot Na^+/K^+	
	Control	Saline	Control	Saline	Control	Saline	Control	Saline	Control	Saline	Control	Saline
T	0.61	0.34	40.83	210.6	2.589	2.12	2.43	7.37	1.54	3.54	0.98	1.24
S	0.53	0.21	34.31	98.98	2.105	1.71	2.38	6.29	1.57	2.78	0.93	2.18
HSD @ 5%	NS	0.11	9.90	94.01	NS	0.34	1.22	0.68	NS	0.46	NS	0.56

non-significant differences between tolerant and susceptible genotypes. Plant height was only parameter with significant differences between tolerant and susceptible genotypes in control and saline conditions (Table 5.26). The other parameters- chlorophyll, proline, soluble sugars, root & shoot Na^+/K^+ ratio played a significant role in plants under stress environments. Tolerant genotypes had higher amount of chlorophyll, proline, soluble sugars, and low shoot Na^+/K^+ (Table 5.27). Hence, these parameters should be considered for selection of tolerant genotypes.

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

The project aims to development salt tolerant lentil genotypes, identifying donors for salt tolerance to introgress into high yielding cultivars and developing a mapping population from the most contrasting parental line for salt tolerance QTL identification. Advanced breeding line (germplasm, cultivars, segregating generations and elite line) were screened under control, salinity (ECe 7dS/m) and Alkali (pH_2 9.3) to assess target traits and seed yield during 2023-24.

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

We collected 725 accessions (released varieties, elite line, and wild accession) from PAU, Ludhiana and ICAR-NBPGR, New Delhi. We evaluated these 725 accessions under control, salinity (ECe 7dS/m) and Alkali (pH_2 9.3).

Table 5.28 Categorization of genotypes based on STI

Category	STI- Salinity	Total genotypes	STI - Alkali	Total genotypes
Salt sensitive	0-0.69	360	0-0.07	388
Tolerant	>0.69	140	>0.07	112

We reported 140 accessions as highly salinity tolerant, 112 accessions as alkali tolerant, 360 were salt sensitive and 388 were alkali sensitive on the basis of Salt tolerant Index (STI) (Table 5.28)

Among the studied genotypes, IC586784 (V306) exhibited the highest STI of 4.90, making it the most salt-tolerant genotype. Similarly, IC267104 (V50) recorded the highest alkali tolerance index (ATI) of 1.44, indicating its superior tolerance to alkaline conditions. The data also includes three check varieties (PDL-1, PSL-9, IPL 526), which showed lower tolerance levels to salinity and alkalinity.

Under saline and alkali stress, a significant reduction was observed in plant growth and yield-related traits compared to normal conditions. Days to 50% flowering and maturity were shorter under stress. Plant height, number of branches, and number of pods per plant were significantly lower, with the most severe reductions in alkali conditions. 100-seed weight and yield per plant also declined sharply with alkali stress. Overall, the study highlights the substantial negative impact of salinity and alkalinity on Lentil, emphasizing the need for stress-tolerant genotypes.

Several crosses were evaluated based on 100 seed weight (100 SW) and yield parameters. Among these, the cross IPL-220 × PDL-1 had the highest number of lines maintained

Table 5.29 Alkali and salinity tolerant indexes of different trials

S.N.	Trial Sr. No.	Accession number	Salinity Tolerance Index	Trial Sr. No.	Accession number	Alkali Tolerance Index
1	V306	IC586784	4.90	V50	IC267104	1.44
2	V172	IC342716	4.58	V19	IC248963	1.08
3	V369	EC223202	3.36	V313	IC614827	1.06
4	V21	IC248965	3.19	V13	IC248956	0.86
5	V176	IC342721	2.86	V32	IC267074	0.84
6	V22	IC248966	2.84	V83	IC268240	0.74
7	V311	IC610426	2.79	V66	IC267658	0.71
8	V301	IC565304	2.75	V65	IC267657	0.69
9	V373	EC223231	2.71	V34	IC267076	0.61
10	V50	IC267104	2.68	V18	IC248964	0.57
11	Check 1	PDL-1	0.88	Check 1	PDL-1	0.12
12	Check 2	PSL-9	1.26	Check 2	PSL-9	0.17
13	Check 3	IPL 526	0.69	Check 3	IPL 526	0.07

Table 5.30 Summary of development genetic resources under Lentil Breeding Programme for salt tolerance

Sr. No.	Crosses	Total no. of lines maintained	Selected on the basis of 100 SW & Yield			Total no. of lines Rejected
			100 Seed Weight	Yield/ Plant	Yield	
1	IPL- 220 × PDL- 1	267	1.68-3.15	16-42	46-127	97
2	IPL- 316 × ZS- 3	250	2.16-2.83	32-50	35-87	54
3	IPL- 526 × PSL- 9	37	2.48-2.86	13-20	18-39	15
4	IPL- 526 × ZS- 2	21	1.53-2.86	13-23	24-93	14
5	IPL- 526 × PDL- 1	18	1.63-2.96	13-22	17-50	14
6	PL-8 (Pant L-063) × PSL- 9	14	1.42-3.6	14-37	24-62	NIL

(267), with a 100 SW range of 3.15–1.68 g and yield per plant ranging from 16 to 42 g, leading to the rejection of 97 lines. The cross IPL-316 × ZS-3 consisted of 250 lines, with a 100 SW of 2.83–2.16 g and a yield range of 32–50 g, 54 lines being rejected. The IPL-526 × PSL-9 cross had 37 lines, showing 100 SW range of 2.86–2.48 g and a yield of 13–20 g, with 15 lines rejected. Similarly, the IPL-526 × ZS-2 cross maintained 21 lines with a 100 SW range of 1.53 –2.86g and a yield range of 13–23 g, leading to the rejection of 14 lines. The IPL-526 × PDL-1 cross included 18 lines, with a 100 SW range of 1.63–2.96g and a yield range of 13–22g, and 14 lines were rejected. Notably, the PL-8 (Pant L-063) × PSL-9 cross maintained 14 lines, with a 100 SW of 1.42–3.6 g and a yield range of 14–37 g, with no rejections.

Performance evaluation of minor millets under salt affected land to regain food-nutri-livelihood security for resource poor farmer (Vijayata Singh)

Foxtail Millet showed poor germination under salinity, making it unsuitable for highly saline regions. Finger Millet showed sensitive accessions ER 41, SEA 11, and SEJ 88 performed well under control conditions, suffered 70–90% yield reduction under salinity. Proso Millet showed SEA 3 and EN 76 (tolerant) yielded 1.57 and 3.73 g under control, but decreased to 1.27, 1.73, and 2.48 g under EC 6 and 8 EC. ER 98 and EN 75 Sensitive accessions recorded significant yield losses under salinity stress. Browntop Millet showed Browntop-4, Browntop-12, and Browntop-15 showed better adaptability for mean yield (7.87 g under control, 2.54 g under EC 6 and 1.64 g under EC 8) under saline conditions despite yield reduction. Barnyard Millet showed EUK 26 is best performing accession: with a 20–30% reduction in yield under salinity. Highly sensitive accessions (ESD 54, ELB 32, and E 274) failed to survive under salinity.

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

New project initiated during November, 2023. The field experiment comprising eleven treatments of integration of nano N and P in three replications having plot size of 68.75 m^2 (11.0 m x 6.2 m) and applied on KRL-210 wheat variety. The detailed treatments were given below:

1. Control (No N & P) (T1)
2. Urea (20-25 DAS) + ⅓ Urea (35-40 DAS) + ⅓ Urea (50-55 DAS) (T2)
3. DAP (Broadcast) +⅓ Urea + ⅓ Urea + ⅓ Urea (T3 - Farmer practice)
4. DAP (Broadcast) + ⅓ Urea + ⅓ Urea + ⅓ Nano-N (Spray) (T4)
5. Nano DAP (Seed priming) + ⅓ Urea + ⅓ Urea + ⅓ Nano-N (Spray) (T5)
6. Nano DAP (Seed priming) & 50% DAP (Broadcast) + ⅓ Urea + ⅓ Urea + ⅓ Nano-N (Spray) (T6)
7. Nano DAP (Seed priming) + ⅓ Urea + ⅓ Urea & Nano-DAP(Spray) + ⅓ Nano-N (Spray) (T7)
8. Nano DAP (Seed priming) +⅓ Urea + ⅓ Urea + ⅓ Nano-N & Nano-DAP (Spray) (T8)
9. Nano DAP (Seed priming) +⅓ Urea + ⅓ Urea & Nano-DAP (Spray) + ⅓ Nano-N & Nano-DAP (Spray) (T9)
10. Nano DAP (Seed priming) & DAP (basal) +⅓ Urea + ⅓ Urea & Nano-DAP (Spray) + ⅓ Nano-N (Spray) (T10)
11. Nano DAP (Seed priming) +⅓ Nano-N & DAP (Spray) + ⅓ Nano-N & DAP (Spray) + ⅓ Nano-N (Spray) (T11)

Significant difference was observed among all the studied morpho-Physiological parameters under different treatments. Chlorophyll reading (SPAD reading) was statistically same in all the studied treatments except T1 and T11. Pn values were found to be higher under treatment T3 (17.98 µmol $CO_2/m^2/s$) closely followed in T8 (17.95 µmol $CO_2/m^2/s$). Similar observations were also noted for Stomatal conductance and transpiration rate. AGR (Absolute growth rate) was maximum growth rate with 1.96 cm day^{-1} was observed in T6 treatment which is closely followed by T4 (1.93 cm day^{-1}) and T3 (1.74 cm day^{-1}). The data revealed that crop growth rate was maximum in T10 (22.29 mg m^{-2} day^{-1}) followed by T4 (21.08 mg m^{-2} day^{-1}) and T3 (19.08 mg m^{-2} day^{-1}) treatment. Relative growth rate (RGR) was also influenced significantly by different treatment. Higher RGR of 15.42 mg g^{-1} day^{-1} was reported in T4 treatment followed by 13.78 mg g^{-1} day^{-1} in T3. Overall result predicted that treatment (T4) with DAP (Broadcast) + ⅓ Urea + ⅓ Urea + ⅓ Nano-N (Spray) provided an increase in absolute growth rate with 10.9%, crop growth rate with 10.88% and relative growth rate with 11.90% compared to T3. Effective tillers showed variability with higher effective tillers in T3 (66.16/mrl) followed by T4 (66.0/mrl) and T8 (64.33/mrl). Non-significant differences were noted from T2 to T10 treatments for spike length, but maximum spike length of 10 cm was obtained in treatment T3 closely followed by T4 (9.84 cm) and T9 (9.83 cm) treatments. The data shown in Table 5.31 demonstrated that similar results for spike weight while number of grains/spike showed statistical variations, being maximum in T3 and T4 (50.5 grains/spike) closely followed by T8 (49.83 grains/spike) and T10 (49.33 grains/spike). Higher seed weight of 2.15 g/spike was noted in T3 followed by T4, T8 and T2 (Table 5.31). Test weight was 5.04 g, 4.99 g and 4.99 g in T3, T4 and T8, respectively. These studied yield attributes responsible for the final yield and noted that grain and biological yield was highest in T3 which was statistically same to T4 (Table 5.31). Biological yield was maximum under T3 (12.24 t/ha) followed by T4 (12.02 t/ha) and T8 (11.82 t/ha). Though grain yield was statistically same in treatments T2 to T10, but the values were numerically higher in T4 followed by T3, T2 and T8.

In addition, pot experiment was conducted in 20 Kg capacity porcelain pots during the Rabi season of 2023-24 to evaluate the efficacy of nano-DAP and nano-Urea under both control and saline conditions (EC_{iw} ~ 10 dS/m) in five replications, utilizing the salt-tolerant mustard variety CS 60. Relative water content (RWC) was highest in T3 (74.2%), followed by T2 (73.0%) and T4 (70.9%), with T8 also showing a high RWC of 71.7%. Salinity stress

Table 5.31 Yield and yield attributes of wheat with different fertilizers applications

Treatment	NET/mrl	SL (cm)	SW (g)	NG/S	SW/S (g)	TW	BY	GY
T1	43.50^{f}	6.16^{b}	1.41^{b}	31.83^{d}	1.19^{f}	3.09^{d}	5.42^{d}	1.49^{c}
T2	65.00^{ab}	9.16^{a}	2.68^{a}	46.83^{a}	2.02^{abc}	4.82^{ab}	10.53^{b}	3.42^{a}
T3	66.16^{a}	10.00^{a}	2.76^{a}	50.50^{a}	2.15^{a}	5.04^{a}	12.24^{a}	3.43^{a}
T4	66.00^{a}	9.83^{a}	2.80^{a}	50.50^{a}	2.07^{ab}	4.99^{a}	12.02^{a}	3.46^{a}
T5	64.00^{ab}	9.50^{a}	2.56^{a}	46.00^{ab}	1.82^{bcd}	4.87^{ab}	10.60^{b}	3.42^{a}
T6	62.83^{bc}	9.33^{a}	2.53^{a}	48.00^{a}	1.78^{cd}	4.89^{ab}	10.55^{b}	3.34^{a}
T7	60.33^{cd}	9.00^{a}	2.53^{a}	40.83^{bc}	1.86^{bc}	4.60^{b}	10.350^{b}	3.33^{a}
T8	64.33^{ab}	9.50^{a}	2.75^{a}	49.83^{a}	2.03^{abc}	4.99^{a}	11.82^{a}	3.41^{a}
T9	62.50^{bcd}	9.83^{a}	2.72^{a}	48.50^{a}	1.31^{ef}	4.84^{ab}	10.42^{b}	3.27^{a}
T10	59.66^{d}	9.86^{a}	2.83^{a}	49.33^{a}	1.87^{bc}	4.91^{ab}	10.45^{b}	3.26^{a}
T11	53.3^{e}	7.0^{b}	1.72^{b}	36.00^{cd}	1.55^{de}	3.77^{c}	7.12^{c}	1.82^{a}

Means with at least one letter common are not statistically significant ($p < 0.05$) using DUNCAN's Multiple Range Test. NET/mrl – number of effective tiller/meter row length; SL – Spike length; SW – Spike weight; NG/S – number of grains per spike; SW/S – seed weight per spike; TW – Test weight; BY – Biological yield; GY – grain yield.

reduced RWC, with the highest reduction (13.5%) in T10, while T4 showed the minimum reduction (5.9%), indicating its adaptability under salinity stress. T4 treatment exhibited the highest chlorophyll content (41.6 µg/cm^2), photosynthetic rate (15.28 µmol m^{-2} s^{-1}), stomatal conductance (0.27 mol m^{-2} s^{-1}), and transpiration rate (3.68 mmol m^{-2} s^{-1}), which was statistically at par with T3. Under saline stress, photosynthetic rate, stomatal conductance, and transpiration rate showed significant reductions, with mean reductions observed as 33.73-34.81% in photosynthetic rate, 32.0-62.16% in stomatal conductance, and 58.96-62.77% in transpiration rate in T4, T3, T2, and T8 compared to the control. Yield attributes and yield data were not recorded due to heavy infestation of aphids and powdery mildew.

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

Diverse wheat germplasm of 180 lines were study under control and salinity level of EC 10 dS/m with four checks including two tolerant (KRL3-4 & KRL 210) and two sensitive (HD 3226 & HD 2851) lines in Augmented Randomized Block Design. For second objective of the project to identify the genetic basis of root traits and interaction with plant development, GWAS data was conducted using phenotypic data of 22-root-shoot traits. GWAS analysis was done on 35K SNP array using six different ML-GWAS models, FASTmrMLM, FASTmrEMMA, pLARmEB, ISIS EM-BLASSO, pLARmEB and pKWmEB implemented in mrMLM v4.0 package (https://cran.r-project. org/package=mrMLM). These six ML-GWAS models broadly function on the same principle but differ in statistical power and the accuracy for estimating QTN effects. Significant QTNs associated with the traits were identified based on logarithm of odds (LOD) threshold of ≥3 and genomic region/QTNs repeatedly detected in two or more models were considered reliable for the trait. Trait variation was associated with significant reductions in mean value (BLUPs) of all the phenotypic traits under salinity stress compared to control conditions. Using six multi-locus GWAS models, a total of 466 significant QTNs with 241 in control and 225 in saline conditions were identified for 22 root and shoot traits at LOD ≥ 3. These QTNs explained 2-46.98% of the phenotypic variation. Manhattan plots and QQ plots depicted significant associated QTNs for respective traits (figure 5.12).

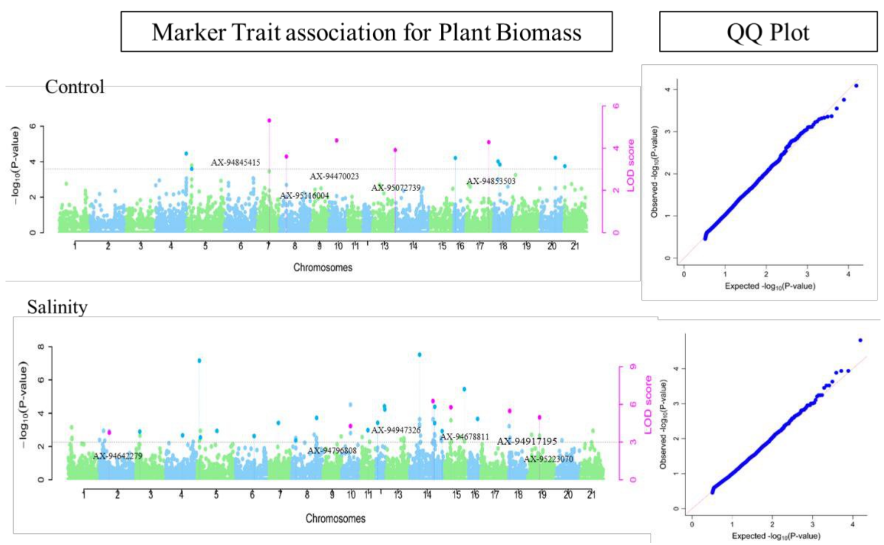


Fig 5.12 Manhattan plots and Quantile-quantile (QQ) showing significantly associated QTNs for Plant biomass of wheat using six multi-locus GWAS models. Horizontal lines show thresholds for significance (LOD score = 3). The QTNs repeatedly identified by two or more GWAS models with LOD scores ≥3 are represented with purple dots.

Genetic dissection of the root system architecture traits: Highest QTNs were identified for RK (18) followed by Root diameter (11) and root angle (10) in control conditions. Highest QTNs were identified for RFW (15) followed by RDW (14), RV (11), RSA (11) and RL (10), RK (10) in saline conditions. Trait specific candidate genes and protein markers will be identified from these associated genomic regions to identify the trait responsive gene with their function in salt tolerance.

Enhancing climate resilience and ensuring food security with genome editing Tools

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

Wheat Component

This project was initiated during March 2024 for developing SDN1-category gene-edited wheat plants with improved tolerance to salt stress. Two genes *TaTre1* and *TaSal1* were selected for editing using CRISPR-Cas9 system. These genes, involved in trehalose pathway, enhance osmoltyes production and promote the stay-green trait under stress. *Sal1* acts as a negative regulator of drought tolerance. Its inactivation results to altered osmoprotectants, higher leaf relative water content and sustained viable tissues during prolonged water stress in wheat. Gene data were retrieved from Plant Ensemble using BLAST to confirm the sequence identity and annotation within the wheat genome. Three copies of *Tre1* gene are present on 1A, 1B, 1D while seven copies of *Sal1* are present on 4A, 2 copies on 5A, 3 copies on 5B. Gene-specific primers were designed and synthesized for the accurate amplification and validation of *TaTre1* and *TaSal1* in twelve wheat varieties, namely, HD3406, HD3226, HD3386, HD3059, HD3090, HD2967, PBW826, PBW771, DBW187, DBW222, DBW303 and Bob white. Conserved domain identification, exon alignment and sequencing was performed for chromosome specific functional annotation of respective gene copies in three genomes, A, B and D of wheat (table 5.32). Optimization of these target genes across all wheat varieties was completed and amplified target gene sequences have been sent for sequencing.This sequencing data will be used to precisely design specific guide RNAs (sgRNAs) for targeting *TaTre1* and *TaSal1*. Four gene constructs have been designed as *TaSal1-CRISPR-Cas9-TaHD3406; TaSal1-CRISPR-Cas9-TaHD3226; TaTre1-CRISPR-Cas9-TaHD3406; TaTre1-CRISPR-Cas9-TaHD3226*. Vector Construct for these gene constructs have been designed as *HPTII::P35S-*

Table 5.32 Identification of functional domain of *Sal1* gene in wheat genome.

Gene	Trans cripts	Transcript id	Chromo some	Chr. Location & gene position	Exons	Domains	Name	Description	Interval	E-value
4A-1	1	>TraesCS4A02G400200.1	4A-1	Chromosome 4A: 674,601,837-674,604,971 forward strand.	8	15	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	149-1180	1.64E-133
4A-2	1	Pseudogene	4A-2	Chromosome 4A: 674601402: 674605282:1	8	15	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	2-217	1.57E-22
5A	2	>TraesCS5A02G119800.2	5A	Chromosome 5A: 253,598,647-253,602,446 forward strand.	8	14	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	256-1221	2.64E-140
		>TraesCS5A02G119800.1	5A	Chromosome 5A: 253,592,930-253,602,446 forward strand.	8	14	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	341-1321	9.43E-144
5B	3	>TraesCS5B02G121500.3	5B	Chromosome 5B: 216,653,222-216,659,535 reverse strand	8	15	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	149-1180	1.64E-133
		>TraesCS5B02G121500.2	5B	Chromosome 5B: 216,653,222-216,659,535 reverse strand	7	12	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	318-1199	2.10E-122
		>TraesCS5B02G121500.1	5B	Chromosome 5B: 216,653,222-216,659,057 reverse strand	8	13	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	115-1080	1.59E-140
5D	3	>TraesCS5D02G126800.3	5D	Chromosome 5D: 193,633,430-193,637,610 reverse strand	8	14	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	278-1267	7.41E-142
		>TraesCS5D02G126800.2	5D	Chromosome 5D: 193,633,238-193,637,610 reverse strand	9	14	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	278-1258	5.17E-145
		>TraesCS5D02G126800.1	5D	Chromosome 5D: 193,633,430-193,636,408 reverse strand	5	11	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	28-762	7.43E-104
7A	1	>TraesCS7A02G101500.1	7A	Chromosome 7A: 62,526,283-62,529,692 forward strand	8	15	FIG super family	FIG, FBPase/IMPase/glpX-like domain.	207-1235	3.76e-133
7D	1	>TraesCS7D02G287300.1	7D	Chromosome 7D: 311,852,312-311,895,509 reverse strand			no information found			

PTaU6:sgRNA-PUBI::SpCas9. CRISPR/Cas 9 plasmids for target genes have been ordered. Cloning work will be initiated as and when GE lab becomes functional. All the required instruments as proposed in the wheat component has been purchased for approximately Rs 40 lakh. Genome editing lab with complete experimental facilities has been developed for approximately Rs 41 lakh. Development of Speed breeding facility is also in process.

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

This project aims to establish 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 to improve 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 β-ketoacyl-CoA synthase (KCS), catalyzes the rate-limiting step in the elongation of long-chain fatty acids. These VLCFAs are crucial for seed oil biosynthesis, influencing oil composition in plants like *Brassica juncea* (Fig. 5.13).

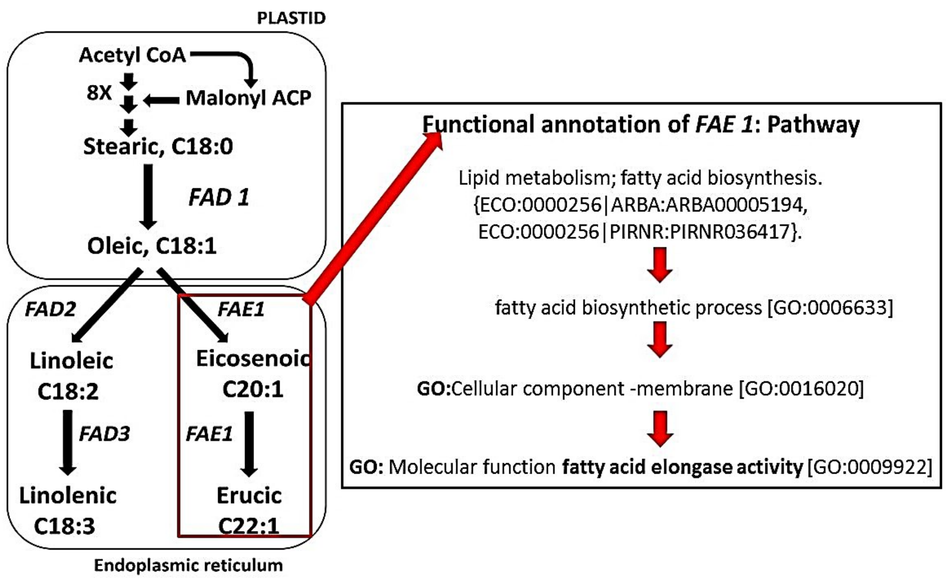


Fig 5.13 A simplified pathway of biosynthesis of fatty acids

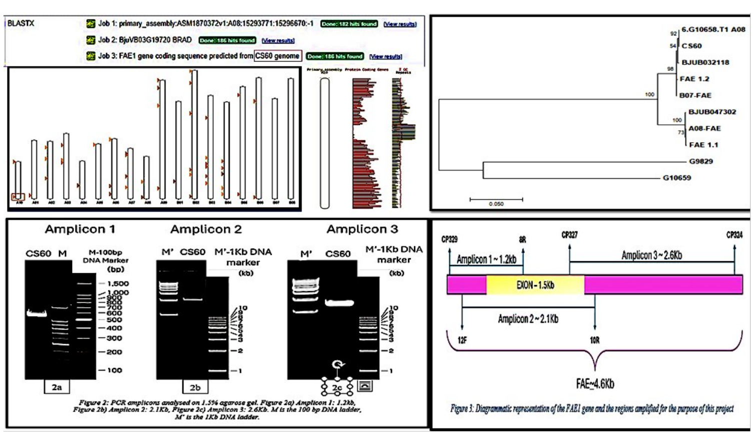


Fig 5.14 Baseline and Phylogenic analysis

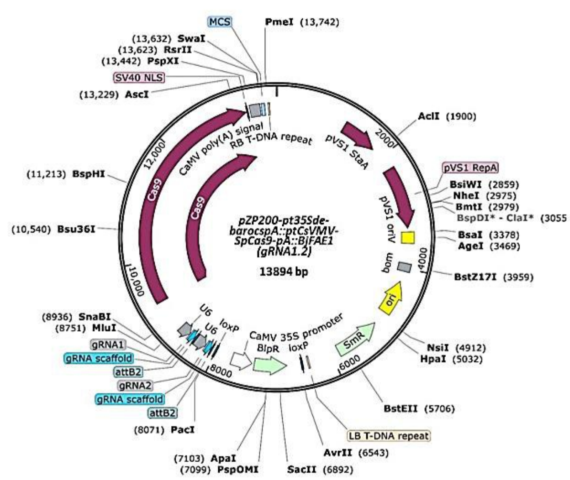


Fig 5.15 Vector Map with FAE 1 constructs

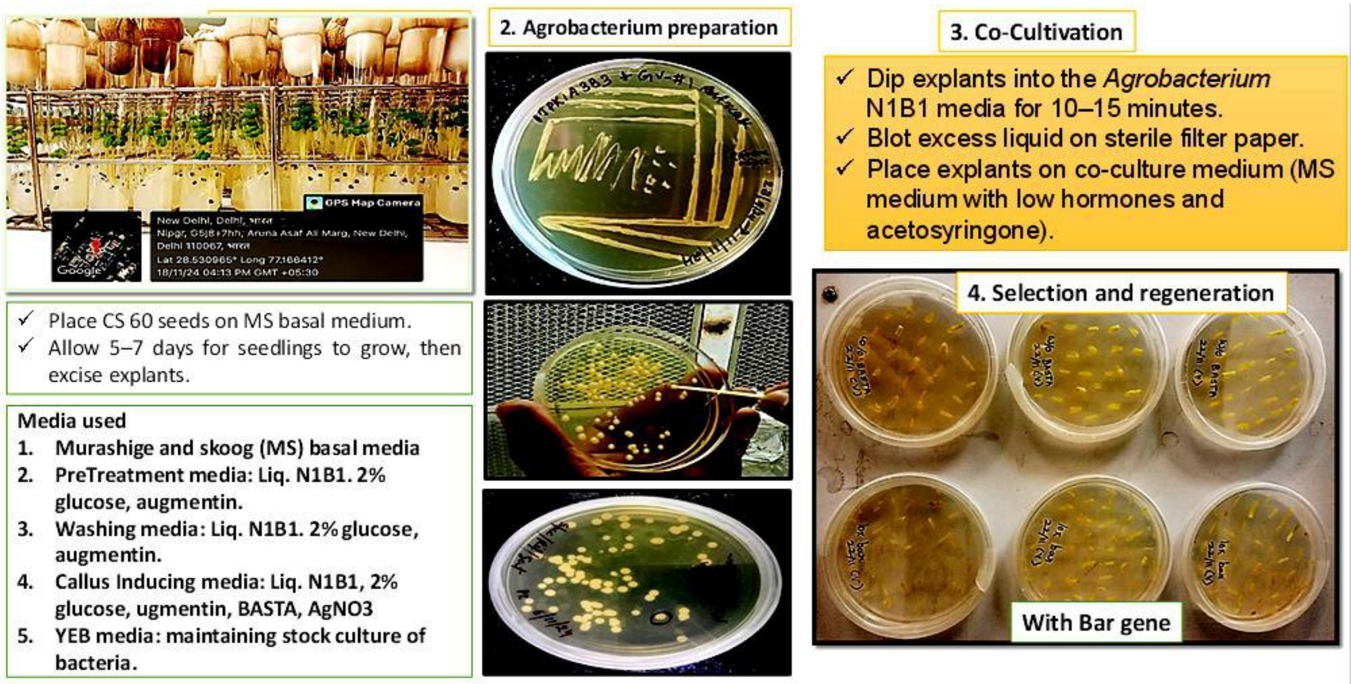


Fig 5.16 Standardization of protocol for *Agrobacterium tumefaciens* -mediated transformation and regeneration in CS 60

In *Brassica* species, FAE1 gene converts C18 fatty acids (oleic acid) into C20 and C22 fatty acids, primarily erucic acid. Erucic acid is a major component with industrial applications, but undesirable for human consumption. Knocking out FAE1 helps produce low-erucic acid (canola-quality) oils. Baseline analysis identified the genomic location of FAE 1 on CS 60. Sequence labelled "6.g10658.t1" aligns closely with the KY356811.1 FAE1 gene. The gene is located on chr. no CM031937.1 of CS60 genome. Phylogenic analysis was done to construct a phylogenetic tree to study evolutionary relationships among *Brassica* species and related genes. Blasts verified the sequence identity and confirm species – specific details (Fig. 5.14).

Empty vector pZP200 was obtained from NIPGR, New Delhi by MTA. Designed gRNAs and developed CRISPR based FAE constructs for editing of FAE 1 genes as under (Fig. 5.15). Standardization of protocol for Agrobacterium tumefaciens mediated transformation in CS 60 was done at NIPGR, New Delhi (Fig. 5.16).

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

Under EFC-funded scheme, gene editing work in rice was initiated at ICAR-CSSRI. *OsARF18* or *RST1* gene was selected with the following proposed outcomes; 1) Enhancing Salinity Tolerance – Editing *OsARF18* gene to improve root architecture, ion homeostasis, and osmotic regulation, enabling rice to withstand high salinity conditions; 2) Develop Herbicide Resistance: Modifying *OsARF18* to reduce auxin-mediated herbicide sensitivity, allowing tolerance to commonly used herbicides; & 3) Validate and Field-Test Edited Lines of *OsARF18*: Conducting molecular, physiological, and agronomic evaluations of genome-edited rice lines to assess their stress resilience, growth performance, and commercial viability. A length 4714 kb (3714 annotated gene length of *OsARF18* ~ chr06:28586493.28590206) was taken and 14 overlapping PCR primers were designed. Amplified sequences of target variety BPT5204 were sent for pair-end Sanger sequencing. Guide-RNAs were designed from 3rd exon of the gene to generate knock-out mutants. Binary vectors such as pRGEB32, pYLCRISPR/Cas9Pubi-H, pRGEB31, pDIRECT_22C, pYPQ150, and pBUN411 were obtained from different research institutes worldwide through *addgene* after proper material transfer agreement (MTAs).

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

This project was initiated in May 2024, aim to investigate the genetic basis of salinity tolerance in rice, wheat, and chickpea using a meta-transcriptomics and systems biology approach. Work on first project objective, aimed at identifying differentially expressed salt stress-responsive genes through meta-analysis, was initiated with rice as the model crop. Publicly available RNA-Seq datasets were systematically retrieved from NCBI GEO and EBI BioStudies using targeted search queries. A rigorous curation process was implemented to ensure data reliability and relevance, applying stringent selection criteria. Only datasets with at least two biological replicates per treatment, appropriate untreated controls, non-transgenic and non-mutant varieties, and well-documented experimental conditions were considered. After comprehensive screening, 128 RNA-Seq samples were finalized, encompassing four salt-tolerant and three salt-sensitive rice cultivars across different tissues and growth stages. The datasets were categorized into two groups based on phenotype: salt-tolerant and salt-sensitive. This curated dataset establishes a robust foundation for downstream transcriptomic analyses, facilitating the identification of key molecular responses to salt stress in rice.

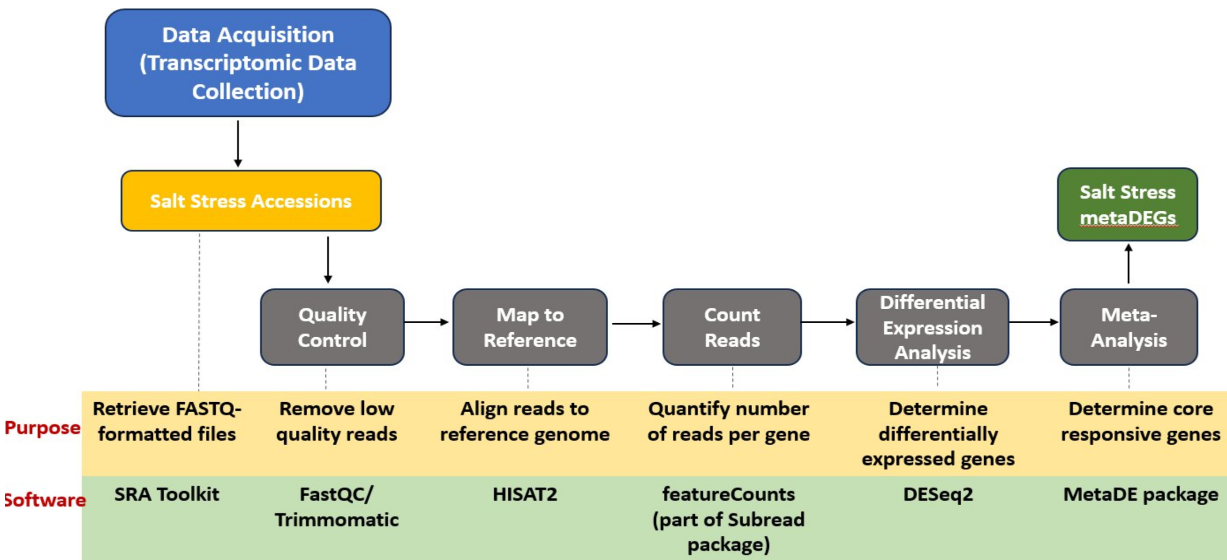


Fig 5.17 Summary of Selected RNA-Seq Datasets for Salt Stress Analysis in Rice

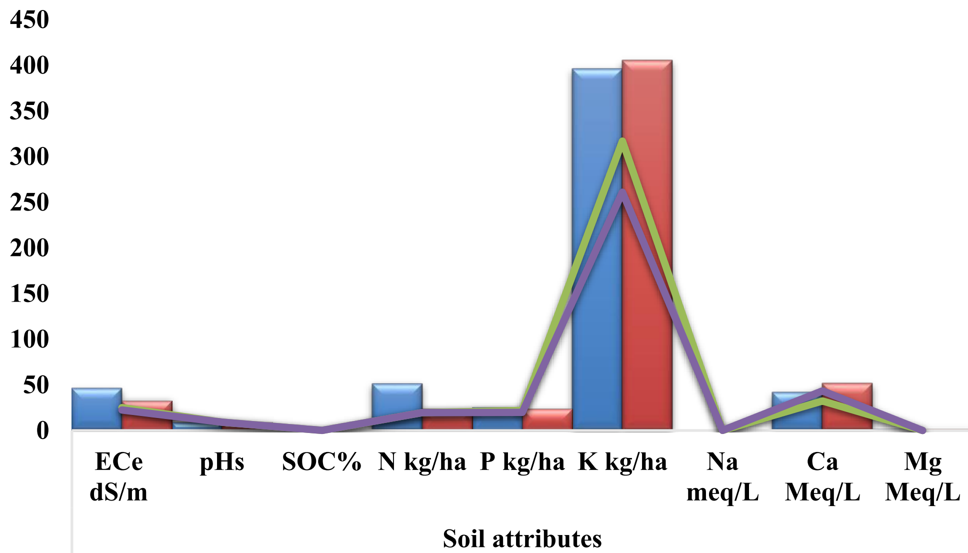
Alternate Land Use

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.)

Salt affected soils are unsuitable for traditional agriculture but offer great potential for tree plantations. Plantation on these soils is the viable option to combat the increasing demand of tree and allied products along with climate moderations. Agroforestry is an efficient land management option to enhance soil quality besides productivity as revealed from the research studies that physico-chemical and biological properties were significantly enhanced with agroforestry practices in degraded ecologies especially salt affected. Tree plantations have been known to restore salt affected soils and enhance productivity through commercial tree planting and potential hydrological impacts on groundwater conditions in irrigated areas. Most of the previous studies on agroforestry in salt affected soils were conducted on evaluation and reclamation aspects of few tree species in general without any focus on high value agroforestry trees. Salinity causes soils degradation which turns fertile lands into unproductive, resulting in the low returns from the agriculture and put the farming community in distress. In order to protect farmers from price/return related distress, a permanent and long term solution is urgently required. For this, one of the alternatives is to grow low input-high output crops such as *Salix*, *Moringa*, Sandalwood, *Melia*, etc. Recently, some of the high value trees were evaluated in induced salinity and sodicity environment under nursery conditions and have shown potential to grow in salt affected land masses. So, there is need to evaluate some potential tolerant genotypes of high value agroforestry tree species in real field situations engrossed with salinity and/or sodicity. With this background, a proposal has been conceived to evaluate the already tested high value agroforestry tree species in quasi-controlled conditions in real time field situations engraved with salinity. About, 1.50 acres of land area was marked at Seed Farm, ICAR-IIWBR, Hisar, Haryana and prepared for doing the plantation work of four high value agroforestry tree species to have the potential genotypes suitable to naturally salt laden landmasses. Before, initiation of the plantation work soil sampling was done in the month of November, 2024. The soil ECe ranged from 45.7 to 22.5 dSm^{-1}, pHs from 9.0-9.62, soil organic matter (SOC) from 0.32-0.21 per cent, Nitrogen (N) from 51.0-19.6 kg/ha, Phosphorus (P) from 25.3-19.9 kg/ha,

Glimpses of planttaion activities

Fig 6.1 Soil chemical parameters



Potassium (K) from 396.0-261.0 kg/ha, Sodium (Na^{+}) from 0.32-0.21 Meq/L, Calcium (Ca^{++}) from 51.2-32.2 Meq/L and Magnesium (Mg^{++}) from 0.00-2.00 Meq/L across the varying depths of soil profile from 0-90 cm (Fig 6.1). The nature of the soil was identified as highly saline and sodic in nature. However, the available nutrients (N and P) are in low range except potassium which is in higher range. Waterlogging problem was also observed. The plantation was done in furrows of 1.0 m wide and 15-20 cm deep from surface soil in the block pattern. Auger hole pit of 45 cm^3 was made in the sill of the furrow. Pits were filled with good soil, sand and FYM before planting the sapling.

In *Salix spp*. (Willow) four (J799, SI-64-017, 131/25 and UHFS62) out of five identified genotypes were planted in block design. In each genotypes, sixty saplings were planted in December, 2024 under 2.0x6.0 m spacing, making total of 240 saplings of four clones. Similarly, 30 saplings of each *Melia dubia* and *Santalum album* genotypes were planted under 3.0x6.0 and 5.0x6.0 m spacing. The rest of the genotypes of high value agroforestry tree species shall be planted in the coming planting season (July, 2025).

Development of *Prosopis* germplasm bank (R Banyal)

Prosopis genotypes planted in germplasm bank were managed and evaluated during 2024-25 for their establishment and growth performance (Table 6.1). The survival percentage ranged from 75.0 to 91.7 per cent across the genotypes. Genotypes PG_6, PG_7 and PG_8 showed highest survival of 91.7 per cent and lowest in PG_1, PG_3 and PG_4 of 75.0

Fig 6.2 Growth performance rating of *Prosopis* genotypes

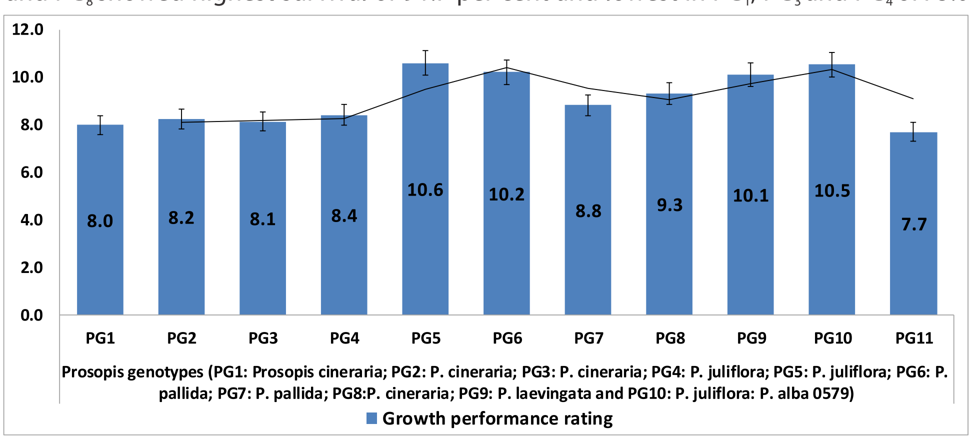


Table 6.1 Survival and growth of Prosopis genotypes

Prosopis genotype(s)*	Survival %	Plant height (m)	Stem dia. (cm)	Crown spread (m2)
PG1	75.0 (+0.26)	4.98 (+0.06)	11.2 (+0.04)	11.5 (+0.11)
PG2	77.8 (+1.00)	5.81 (+0.01)	10.9 (+0.03)	11.6 (+0.09)
PG3	75.0 (+0.26)	5.18 (+0.02)	13.1 (+0.11)	11.4 (+0.07)
PG4	75.0 (+0.28)	6.23 (+0.05)	16.1 (+0.20)	10.9 (+0.14)
PG5	75.0 (+0.87)	7.20 (+0.09)	16.4 (+0.19)	37.3 (+0.01)
PG6	91.7 (+1.06)	5.76 (+0.03)	11.4 (+0.10)	22.5 (+0.15)
PG7	91.7 (+0.87)	3.99 (+0.00)	05.8 (+0.07)	11.9 (+0.05)
PG8	91.7 (+0.05)	6.26 (+0.06)	12.5 (+0.16)	9.40 (+0.00)
PG9	83.3 (+0.88)	6.68 (+0.07)	12.6 (+0.01)	27.5 (+0.06)
PG10	91.7 (+1.18)	6.05 (+0.02)	11.2 (+0.13)	26.4 (+0.03)
PG11	91.7 (+0.68)	3.09 (+0.00)	2.30 (+0.02)	1.90 (+0.01)

Values in parenthesis are SEm

***PG_1:** Prosopis cineraria*; **PG_2:** *P. cineraria*; **PG_3**: *P. cineraria*; **PG_4**: P. *juliflora*; **PG_5**: *P. juliflora*; **PG_6**: *P. pallida*; **PG_7**: *P. pallida*; **PG_8**:*P. cineraria;* **PG_9**: *P. laevingata* and **PG_{10}**: *P. juliflora:* **PG_{11}**: *P. alba* 0579

percent, respectively. Plant height was maximum (7.20 m) in PG_5 and minimum (3.09 m) in PG_{11} genotype. PG_5 gave highest values of stem diameter (16.4 cm) and crown spread (37.3 m^2) compared to rest of the genotypes under evaluation. The overall growth performance rating ranking order of *Prosopis* genotypes based on survival and growth traits (plant height, diameter and crown spread area) was in the order of *P. juliflora* (PG_5)> *P. juliflora* (PG_{10})> *P. pallida* (PG_6)> *P. laevingata* (PG_9)> *P. cineraria* (PG_8)> *P. pallida* (PG_7)> *P. juliflora* (PG_4)> *P. cineraria* (PG_2)> *P. cineraria* (PG_3)> *P. cineraria* (PG_1)> *P. alba 0579* (PG_{11}) in seven years old germplasm bank (Fig. 6.2).

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

This project was initiated during October 2021 with the aim to assess genetic diversity, identify germplasm, and understand molecular mechanism for salinity tolerance in the sandalwood. Thus, 122 Sandalwood genotypes collected from across the country were examined at EC_{iw} 8 to determine salinity tolerance mechanisms and identify superior genotypes (photos). Experimental data demonstrated significant genetic diversity and relationships in genotypes for salinity-induced morphological and physiological traits. The findings revealed that mean plant height and collar diameter of sandalwood genotypes decreased by 26.40% and 21.57 %, respectively, under salinity stress. Similarly, the mean number of leaves, number of branches, shoot biomass, root biomass and number of haustoria of sandalwood genotypes declined by 48.40%, 44.80%, 37.78%, 8.70% and 37.84%, respectively, under saline conditions. The comparative hierarchical cluster analysis (HCA) was performed for sandalwood genotypes to classify sandalwood genotypes into different groups based on their similarity. Under control conditions, the sandalwood genotypes were grouped into four clusters: Cluster 1 (27 genotypes), Cluster 11 (14 genotypes), Cluster 111 (21 genotypes), and Cluster IV (63 genotypes). Under salinity stress (EC_{iw} 8), the genotypes were classified into four distinct groups: Sensitive (14 genotypes), Moderately Tolerant (43 genotypes), Tolerant (50 genotypes), and Highly Tolerant (16 genotypes). The plant height and collar diameter of each group of sandalwood genotypes (Sensitive, Tolerant, and Highly Tolerant groups) were analyzed. Under salinity stress (EC_{iw} 8), the sensitive group showed the highest reduction in plant

Plantation of sandalwood with different host species

height (27.25%) and collar diameter (22.50%). The Tolerant group exhibited a moderate decline, with plant height reducing by 11.85% and collar diameter by 9.50%. The highly tolerant group showed the least reduction, with plant height decreasing by 6.50% and collar diameter by 4.50%. The molecular mechanisms of sandalwood when planted with host *Dalbergia sissoo* under salinity stress were analyzed. The genes related to salinity tolerance (SOS1, NHX1, NHX2) showed increased expression under salinity stress, regulating ion homeostasis for sodium and potassium balance. Proline biosynthesis genes (P5CS, P5CR) were also highly upregulated, aiding osmotic adjustment and oxidative stress protection. Additionally, antioxidant enzyme genes (SOD, CAT, APX, POX) exhibited significant upregulation, with CAT reaching up to a 6.37-fold increase, effectively mitigating oxidative damage caused by reactive oxygen species (ROS). However, nitrogen metabolism genes (NR, NIR, GS, GDH) showed the decreased expression under salinity stress, suggesting reduced nitrogen assimilation. These findings emphasize the critical role of *Dalbergia sissoo* in enhancing resilience of sandalwood to salinity stress at the molecular level. Among the tested genotypes, H-18, H-15, K4-12, and K4-11 exhibited superior growth potential under salinity stress. Overall, results showed the presence of a high genetic diversity for salt tolerance in Sandalwood, and the identified genotypes can be considered for strengthening the breeding programs aiming at improving the salinity tolerance of the species.

Another study is being undertaken to identify suitable host species, standardize spacing, devise nutrient and water management techniques, and assess appropriate crop

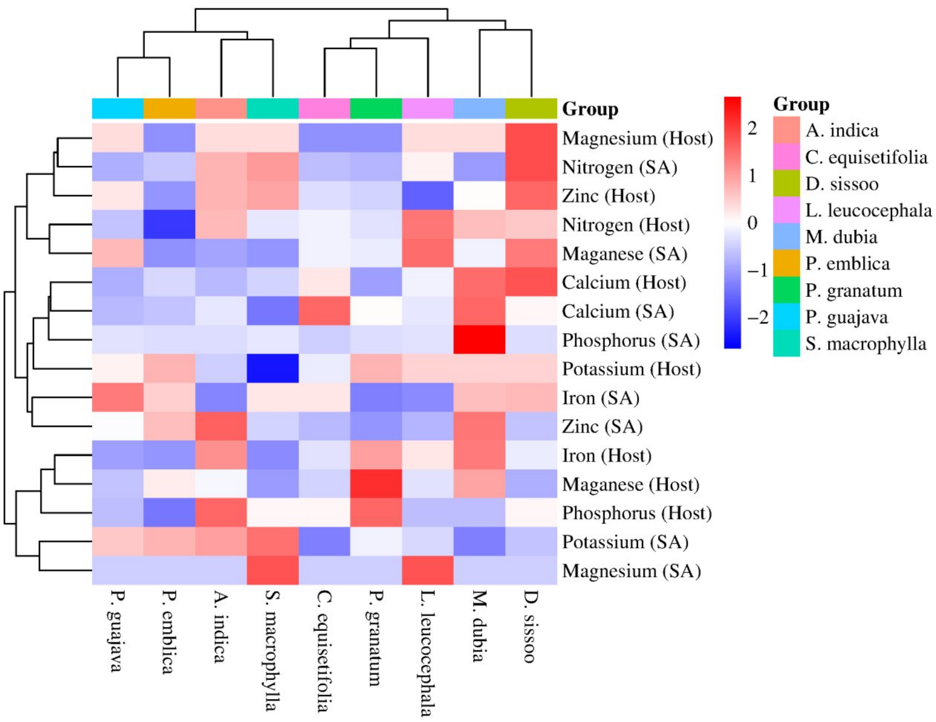


Fig 6.3 Clustering of host species of Sandalwood based on nutrient contents

combination to develop a successful Sandalwood based agro forestry model. Ten different host species (*Melia dubia, Dalbergia sissoo, Azadirachta indica, Casuarina equisetifolia, Acacia ampliceps, Citrus aurantium, Punica granatum, Syzygium cumini, Phyllanthus emblica, and Leucaena leucocephala*) is being considered for the present study. Findings showed that the host plants played a crucial role in modulating growth processes in sandalwood. Among different host species, *D. sissoo* emerged as the best host for improving plant height and DBH, while *C. equisetifolia* enhanced total tree biomass. Additionally, *A. indica* and *M. dubia* contributed significantly to sandalwood growth and physiological adaptation. The effect of host species on nutrient uptake in sandalwood was assessed. Results indicated that the nutrient content in sandalwood found to be host-dependent. The analyses showed that the *M. dubia* enhanced phosphorus content, *D. sissoo* increased nitrogen content, *S. macrophylla* contributed to potassium uptake, *P. guajava* improved iron levels, *A. indica* facilitated zinc uptake, *L. leucocephala* promoted manganese accumulation, and *C. equisetifolia* contributed to calcium absorption. Magnesium content remained relatively unchanged across all host species. Based on PCA clustering (Fig. 6.3), host species were grouped into four distinct categories, (1) *P. guajava* and *P. emblica*, (2) *A. indica* and *S. macrophylla*, (3) *C. equisetifolia, L. leucocephala,* and *P. granatum,* (4) *D. sissoo* and *M. dubia*. These findings underscore the significant role of host plants in optimizing sandalwood cultivation, particularly in saline environments.

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

Mahogany (*Swietenia macrophylla*) and willow (*Salix* spp.) are economically valuable timber species. This study aims to identify salinity-tolerant genotypes by investigating their tolerance mechanisms. Mahogany seeds were collected from seven regions across Karnataka, Kerala, Tamil Nadu, and West Bengal to capture genetic diversity. Over 500

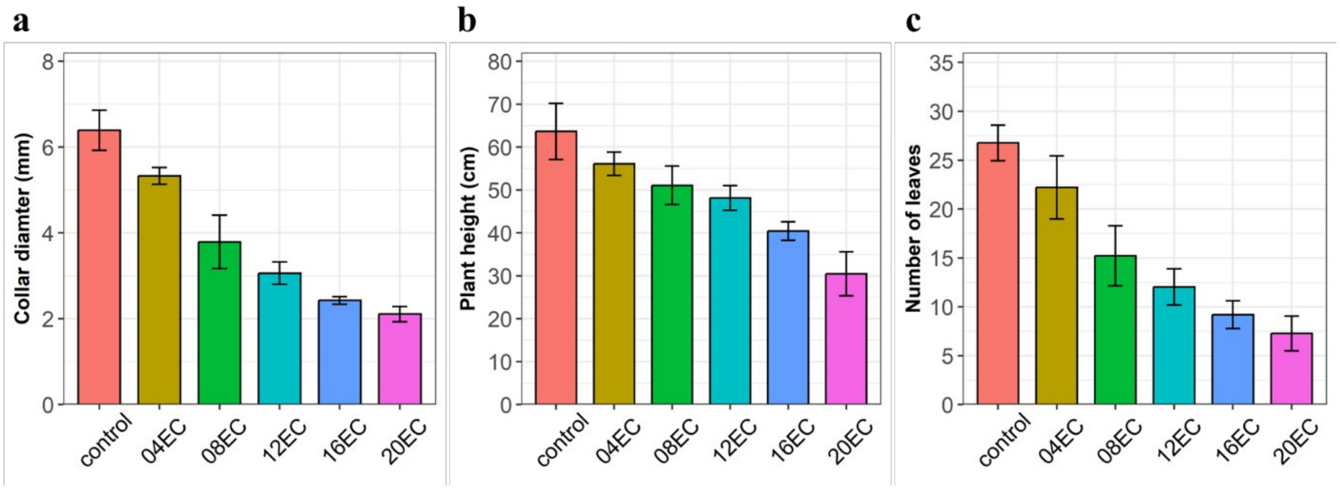


Fig 6.4 Barplot of growth-related traits of the Mahogany under the influence of different salinity treatment. Presented are (a) collar diameter, (b) plant height, and (c) number of leaves counted. Vertical lines represent standard errors (SE).

seedlings were raised using different pre-sowing treatments. An investigated conducted on optimal germination and seedling emergence in Mahogany using a split-plot design. Pre-sowing treatments (cold/hot water, GA_3, ethylene, KNO_3) and seed orientations (flat, wing down/up) were tested. KNO_3 + ethylene yielded the highest germination, with wing-down sowing performing best. Additionally, a salinity experiment (0–20 dS m^{-1}) was performed to assess salinity tolerance thresholds. For this, 9–10-month-old saplings were subjected to saline irrigation treatments (4–20 dS m^{-1}) in sand culture to determine salt tolerance thresholds.

Initial results revealed significant reductions across all measured growth parameters. Saplings irrigated with non-saline water (0 dS m^{-1}) exhibited superior performance in terms of collar diameter, height, and leaf count. Progressive declines in growth metrics were observed with increasing salinity levels (Fig. 6.4). Specifically, collar diameter decreased by 16–67%, plant height by 18–60%, and leaf count by 17–72%, relative to the control (normal irrigation). Comprehensive data analyses will be carried out which encompass growth dynamics, morphological adaptations, leaf functional traits (e.g., specific leaf area), root architecture, and biochemical indicators, including ion homeostasis (Na^+/K^+ ratio, Ca^{2+}, Mg^{2+}), macro-/micronutrient uptake, photosynthetic efficiency (chlorophyll *a*, *b*, and total chlorophyll), and membrane stability indices.

Salix (Willow) Screening for Salt Tolerance Using Hydroponics (Manish Kumar, Raj Kumar, Rakesh Banyal, A.K. Rai)

For willow, twenty specific clones of willow have been selected for the screening of salt-tolerant varieties and to deepen our understanding of salt tolerance mechanisms. These 20 Salix clones were acquired from UHF, Nauni, and subsequently propagated in the nursery for experimental purposes aimed at screening the most suitable clones for salinity tolerance. Hydroponics experiment using saline water (4–12 dS m^{-1}) is established to identify rootstocks with enhanced salinity tolerance, as illustrated in photo. We expect to gain valuable insights into the physiological responses of willow to salinity stress.

Twenty *Salix* spp. clones were procured from the University of Horticulture and Forestry (UHF), Nauni, in February 2024 for the experimental purpose to screen out salinity

Planting of Salix clones for germplasm establishment and maintenance at the ICAR-CSSRI, Karnal

Planting of Salix clones for germplasm establishment and maintenance at the ICAR-CSSRI, Karnal

tolerance germplasm. A mother block plantation was subsequently established to facilitate the large-scale multiplication of these clones. The collected germplasm has been maintained through systematic management practices, including scheduled irrigation, weed control, soil cultivation (hoeing), and the application of agronomic protocols such as fertilizer supplementation and targeted pesticide/insecticide sprays.

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

Application of amendment at sub-surface

Ponding of irrigation water for reaction

Placement of amendments at sub-surface using M.B. Plough and subsequent ponding of irrigation water

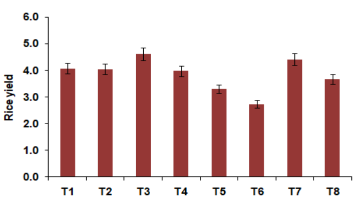


Fig 7.1 Yield of rice, t ha^{-1}

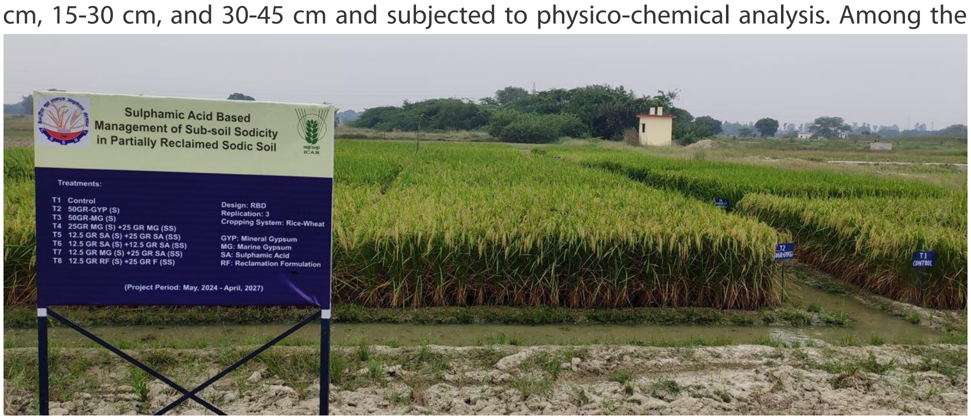
T1– Control; T2 – 50 GR gypsum (GYP) (S); T3 – 50 GR MG (S); T4 – 25 GR MG (S)+25 GR MG (SS); T5 – 12.5 GR SA (S)+25 GR SA (SS); T6 – 12.5 GR SA (S)+12.5 GR SA (SS); T7–12.5 GR MG (S)+25 GR SA (SS); T8 – 12.5 GR (F) (S)+25 GR F (SS)

Sulphamic acid based management of sub-soil sodicity in partially reclaimed sodic soil (S.K. Jha, Sanjay Arora and A.K. Dixit)

The soil samples were collected from 0-15 cm, 15-30 cm and 30-45 cm depth from five different points, from the selected a composite sample were prepared for each depth in the month of May, 2024. The collected soil samples were analyzed in the laboratory whose pH was found to be 8.89, 9.56 and 9.65 for 0-15, 15-30, and 30-45 cm, respectively. On the other hand, exchangeable sodium percentage (ESP) was 30.3, 49.1 and 65.4 mol_c kg^{-1} for 0-15, 15-30, and 30-45 cm, respectively. For application of amendments in sub-surface soil, tractor mounted mould bold plough was used as shown in photo. The amendments gypsum, marine gypsum and formulation were applied in the plots on the basis of gypsum requirement of the soil and as per the treatment design which involved eight treatment and three replications on plot size of 30 m^2 (6 m X 5 m), using a randomized block design. The treatments were: 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 (F) at surface (S)+25 GR F (SS).

The irrigation water was applied to each plots after amendment application and ponding of water was maintained for about 20 days. After 20 days of reaction time, 30 days old rice seedlings (cv CSR-36) were transplanted as a first crop at 20 cm and 15 cm between rows and hills, respectively. The required fertilizer (N:P:K,150:60:40 kg/ha) was applied through NPK fertilizer and urea. The full dose of P (60 kg P_2O_5) and 50 % of recommended doses of N (75 kg N) ha^{-1} were applied as basal. The remaining amount of N was applied at the time of tillering (30 days after transplanting) and panicle initiation (75 days after transplanting) in equal proportions. The performance of the crop is shown in photo. The rice was harvested and the grain yield was recorded. Maximum grain yield of 4.62 t ha^{-1} was recorded in the treatment T_3 where 50 GR marine gypsum was applied at the surface (50 GR MG surface) followed by treatment T_7 where 12.5 GR marine gypsum was applied at surface and 25 GR sulfamic acid applied on sub-surface layer using M.B. Plough (12.5 GR MG (S)+25 GR SA (SS) (Fig. 7.1)

The soil samples (augur hole) were collected after rice harvest from three depths viz 0-15 cm, 15-30 cm, and 30-45 cm and subjected to physico-chemical analysis. Among the



Performance of rice crop

Table 7.1 Changes in pH, Electrical conductivity, and Organic carbon under different treatments

TRT	pH (1:2)(dS m^{-1})			EC(1:2)(dS m^{-1})			Organic Carbon, OC%
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm
T1	8.73^{e}	9.50^{b}	9.54	0.58	0.81	1.07	0.36
T2	8.65^{d}	9.37^{b}	9.55	1.13	1.03	1.13	0.41
T3	8.02^{a}	8.98^{a}	9.54	1.32	1.27	1.32	0.32
T4	8.16^{ab}	9.11^{a}	9.53	0.94	0.93	1.08	0.34
T5	8.59^{bc}	9.02^{a}	9.48	0.76	1.01	1.39	0.31
T6	8.56^{bc}	9.01^{a}	9.41	0.89	1.06	0.88	0.31
T7	8.47^{abc}	9.02^{a}	9.48	0.79	0.98	1.26	0.36
T8	8.44^{abc}	9.08^{a}	9.55	0.91	1.03	1.33	0.32

treatments, the average pH (1:2) varied from 8.02 to 8.73 in 0-15 cm depth with maximum reduction in T_3 treatment (pH 8.02) where 50 GR MG was applied on the surface. This was followed by T_4 where 25 GR MG was applied on surface and 25 GR MG on subsurface. The treatment T7 where 12.5 GR MG applied on surface and 25 GR SA applied on sub-surface was found to be statistically similar to T_8 treatment where 12.5 GR formulation (F) applied on surface and 25 GR F applied on sub-surface (Table 7.1). On the other hand, in 15-30 cm depth, a maximum reduction (5.47%) in pH (1:2) was observed in T_3 followed by 5.16% in T_6 and 5.05% in T_7 and was statistically similar to treatments T_4, T_5, T_6, T_7, and T_8 with respect to control. In 30-45 cm depth, there was no significant change in pH was observed after the first crop harvest. The electrical conductivity, EC (1:2) varied from 0.58 to 1.32 dS m^{-1} in 0-15 cm soil depth whereas in 15-30 cm and 30-45 cm depths, the EC (1:2) varied from 0.81 to 1.27 dS m^{-1} and 0.88 to 1.33 dS m^{-1}, respectively. The organic carbon, OC % varied from 0.31 to 0.41% but among the treatments, there were no significant difference in OC was found.

As this is the first year the experiment and only one crop has been harvested so far, the subsequent changes in the soil characteristics will be monitored in coming crop seasons.

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

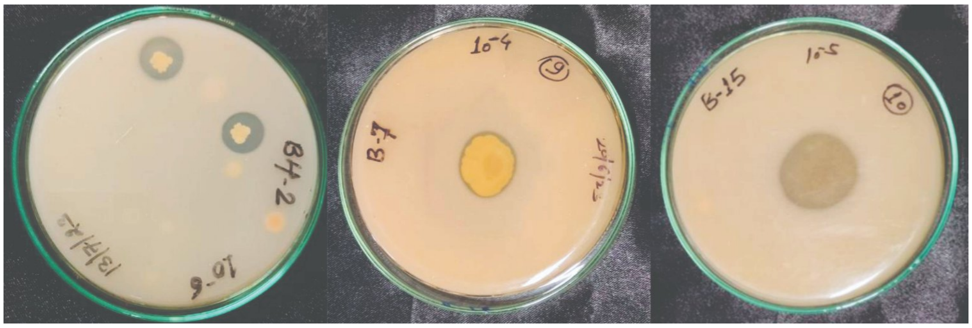
Effect of interventions on performance of salt tolerant variety grown on calcareous sodic soil

In Samastipur and Muzaffarpur district of Bihar, on-farm demonstrations of different interventions for ameliorating calcareous sodic soils were continued. On 12 sites, observations were recorded for the paddy where interventions *viz*. green manuring, cow manure and pressmud as soil amendment and salt tolerant variety (CSR 46) were evaluated with microbial formulations. It was observed that salt tolerant rice variety (STV) performed better over the traditional variety at all the locations. There was maximum increase in grain yield of salt tolerant variety to the tune of 44.7% and traditional variety to the extent of 38.5% with green manuring coupled with use of microbial enriched cow manure (enriched with halophilic PGP microbes) and pressmud as soil amendment over of no amendment or farmers practice (Table 7.2).

It was evident from the after harvest soil analysis that application of microbial enriched cow manure (MECM) and pressmud (PM), the soil pH declined substantially. Also, there was dissolution of free $CaCO_3$ content in soils amended with MECM, PM and green manuring. Soil organic C content improved to the extent of 0.14% surface layers in 2 years where the interventions were adopted compared to farmers practice and traditional

Table 7.2 Effect of technical interventions in calcareous sodic soils on rice growth and yield (average of 12 sites)

S. No.	Interventions	Plant height (cm)		Grain yield (q/ha)		Straw yield (q/ha)	
		STV	TV	STV	TV	STV	TV
I_0	No amendment/FP	107.4	103.5	34.8	28.5	41.8	40.1
I_1	With GM (Dhaincha)	113.2	109.4	35.7	29.4	44.3	42.7
I_2	With Cow Manure @ 10t/ha	118.7	111.3	36.2	30.4	49.2	46.7
I_3	With Pressmud @ 5t/ha*	122.5	113.6	36.7	32.7	54.7	52.3
I_4	With GM+ Cow Manure	127.3	115.2	39.3	34.2	58.3	56.8
I_5	With GM+ M Enriched Cow Manure (Halo-Mix)	129.5	115.7	41.2	35.5	60.6	57.3
I_6	With GM+ M Enriched Cow Manure+ ME Pressmud	132.4	118.5	42.3	37.1	62.8	59.1



Zone formation indicating $CaCO_3$ dissolution by bacterial isolates

Table 7.3 Characterization of calcite dissolving bacterial isolates

S. No.	Bacterial isolate	Zone Size (mm)	Titratable Acidity
1	CDHB-1	2	0.8
2	CDHB-2	6	0.8
3	CDHB-3	4	0.9
4	CDHB-4	1	0.7
5	CDHB-5	1	0.7
6	CDHB-6	4	0.9
7	CDHB-7	3	0.7
8	CDHB-8	4	0.8
9	CDHB-9	3	0.6
10	CDHB-10	3	0.9
11	CDHB-11	4	0.7
12	CDHB-12	5	0.6

variety. Microbial properties of calcareous sodic soil including microbial biomass C and enzymatic activities viz dehydrogenase and phosphatase activity improved when the soil amendment green manuring was done and cow manure and/or pressmud was applied. The soil MBC was 12.8% and 15.1% higher in soil under I_5 and I_6 compared to I_0. Similarly, dehydrogenase and phosphatase enzyme activity was maximum in I_6 followed by I_5 intervention sites.

Characterization and screening of carbonate dissolution potential bacterial isolates

Bio-chemical characterization of potential calcium carbonate dissolving bacteria (CCDB) was done. It was observed that out of the 12 bacterial isolates, 6 were able to form zone size above 4mm on specific media with titrable acidity of 0.6 to 0.9 (Table 7.3). It was recorded that four potential isolates tolerated high salt concentration and pH and from the incubation study it indicates self-reclamation utility for calcareous sodic soils of Bihar (Table 7.4).

Table 7.4 Characterization of $CaCO_3$ isolates

S. No.	Strain ID	IAA (µg/ml)	Salt Tolerance		pH tolerance		Thermal death point @ 70 oC (cfu/ml)
			5% Na_2CO_3	5% $NaHCO_3$	pH: 9.0	pH: 11.0	
1	CDHB-1	18.453	+	-	+++	+	304
2	CDHB-2	9.616	+	-	+++	++	266
3	CDHB-3	11.477	-	+	+++	++	241
4	CDHB-4	17.640	+	-	+++	+++	326
5	CDHB-5	7.988	-	-	+++	+++	313
6	CDHB-6	16.709	+	-	+++	++	357
7	CDHB-7	22.756	+	-	+++	+++	339
8	CDHB-8	13.570	-	-	+++	+++	288
9	CDHB-9	13.337	-	+	+++	+++	274
10	CDHB-10	16.471	-	+	+++	+++	296
11	CDHB-11	18.570	-	+	+++	+++	226
12	CDHB-12	12.988	+	-	+++	++	282

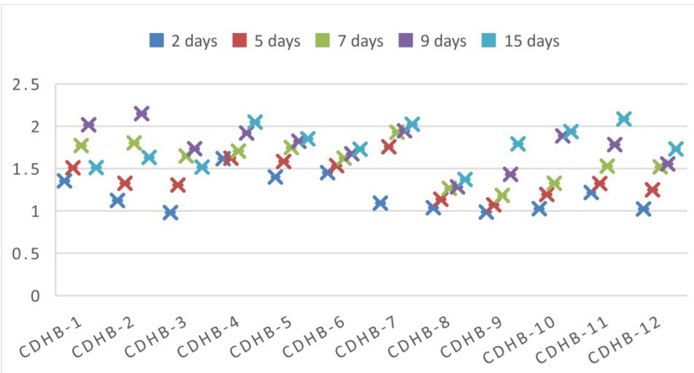


Fig 7.2 Growth pattern of calcite dissolving bacterial isolates

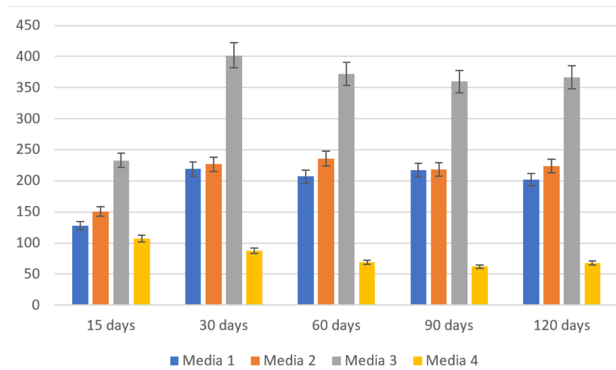


Fig 7.3 Liquid carrier media standardization and shelf life

Halo-Mrida Sudharak

Standardization of media and bioformulation development

The potential calcite dissolving bacteria were ascertain for their growth pattern in the liquid media. It was observed that 5 isolates were having good growth pattern throughout the fifteen days of incubation (Fig 7.2). Based on the traits and growth pattern, three potential isolates were tested for their compatibility to form consortia. Liquid based formulation prepared "Halo-Mrida Sudharak" Liquid carrier media was tested along with their shelf life. The standardized media showed satisfactory shelf life and ready for mass multiplication for widespread testing in different locations for promoting in-situ dissolution of native $CaCO_3$ in calcareous sodic soils for self-reclamation and plant growth promotion under these stress condition (Fig 7.3). The molecular identification is being done for registering the potential strains.

Development of resource efficient cropping systems for sodic environment (A.K. Dixit, A.K. Dubey, Sanjay Arora and Arjun Singh)

Rice-wheat is the predominant cropping system in the reclaimed sodic soils occupying about 60–70% area. High crop response to N in sodic soil under rice-wheat cropping system further reduces the nitrogen pool of the soil. Continuous growing of cereal-cereal cropping system in sodic environment and using inorganic fertilizer without recycling of residues over years has caused loss of organic matter and soil productivity, thereby had adversely affected the sustainability of crop productivity. Crop diversification is an

Table 7.5 Depth wise initial soil physico-chemical properties

Soil Depth	pH, 1:2 EC (dS)		OC, %	Avail. N kg/ha	Avail. P kg/ha	Avail. K kg/ha	Na, kg/ha	Ca, meq/lit	Ca+Mg, meq/lit	Mg, meq/lit
0-15 cm	9.08	0.52	0.19	120.7	107.1	218.1	3386	20.9	31.5	10.6
15-30 cm	9.47	0.64	0.13	115.8	95.4	209.4	4856	15.0	21.3	6.3


Raised bed and shunken bed layout


Performance of fodder sorghum on raised bed and rice in shunken bed


Performance of various kharif crops

important option for farming community. Crop diversifications by addition of new crop/cropping system and inclusion of the new varieties can be one of the important technologies in increasing the productivity and improving the health of sodic soils. The efficient and diversified cropping system should provide enough food for the family, fodder for cattle and generate sufficient cash income. This objective could be achieved by adopting diversified crops and other management practices.

Keeping above facts in mind, a field experiment was initiated at Research farm of CSSRI-Regional Research Station, Lucknow to explore the possibility of developing highly remunerative alternate cropping system to traditional rice-wheat system in sodic environment during *kharif* 2024. To study the initial fertility status of soil, samples from 0-15 cm and 15-30 cm soil depth have been taken and analysed. Dehydrogenase activity of initial soil sample from 0-15 cm soil depth was 51.44 ug/ml/hr. Depth wise initial soil physico-chemical properties are presented in table 7.5.

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 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 are made by cutting of 7.5 cm soil form shunken bed area and put that soil on raised bed area (photo). All the kharif season crops were sown/transplanted during first week of July, 2024. Recommended package of practices were used to grow different crops under various cropping systems (photos).

Yield of various kharif season crops have been recorded and to compare it among different cropping system, yield of different crops have converted into rice equivalent yield (Table 7.6 & figure 7.4). From the rice equivalent yield data it was envisaged that REY significantly influenced under different cropping systems (Table 7.5). Highest REY (3471.1 kg/ha) was recorded under CS4: Rice – Berseem cropping system however it was at par with CS1: Rice – Wheat (3442.8 kg/ha), CS2: Rice – Wheat – Dhaincha as green manure (3400.1 kg/ha), CS3: Rice-Barley-Dhaincha as green manure (3301.4 kg/ha), CS9: Fodder sorghum (Raised bed) + Rice (Sunken bed) – Lentil (Raised bed) + Barley (Sunken bed) - Dhaincha as green manure (3244.7 kg/ha) and CS5: Rice (Early variety) – Lentil + Mustard (6:1) - Dhaincha as green manure (2932.8 kg/ha) whereas lowest REY was recorded under CS8: Pearl millet (Line) + Dhaincha (Broadcasting) as brown manure – Toria – Sunflower (1141.4 kg/ha) cropping system.

After the harvest of kharif season crop, soil samples from 0-15 cm soil depth have taken and analysed for dehydrogenase activity (Fig. 7.5) and it was observed that the soil of

Table 7.6 Crop wise yield (kg/ha) and rice equivalent yield, REY (kg/ha) of different kharif season crops under various cropping systems during kharif, 2024.

Cropping systems	Rice		Pearl millet/ dhaincha		Fodder sorghum	REY
	Grain	Straw	Grain/seed	Stover		
CS1: R-W (FP)	3113	7596	-	-	-	3442.8
CS2: R-W-DGM	3171	5273	-	-	-	3400.1
CS3: R-Ba- DGM	3092	4824	-	-	-	3301.4
CS4: R-Be	3246	5181	-	-	-	3471.1
CS5: RE-L+M- DGM	2829	2384	-	-	-	2932.8
CS6: DSP-Ba	-	-	241	4989	-	1243.0
CS7: PMR+DBM-T-S	-	-	785	3449	-	1271.1
CS8: PMF+ DBM -T-S	-	-	719	2956	-	1141.4
CS9: FS(RB) +R(SB) - L(RB)+Ba(SB) - DGM	2010	3441	-		9983	3244.7
CD at 5%						862.1
CV (%)						19.5

Note: Prices of different component crops considered for conversion of individual crop yield into rice equivalent yield (REY) are Paddy grain @ Rs 23/kg, paddy straw @ Rs 1/kg, green fodder @ Rs 2.5/kg, pearl millet grain @ Rs 26.25/kg, pearl millet stover @ Rs 2.5/kg, dhaincha seed @ Rs 90/kg and dhaincha stover @ Rs 1.5/kg.

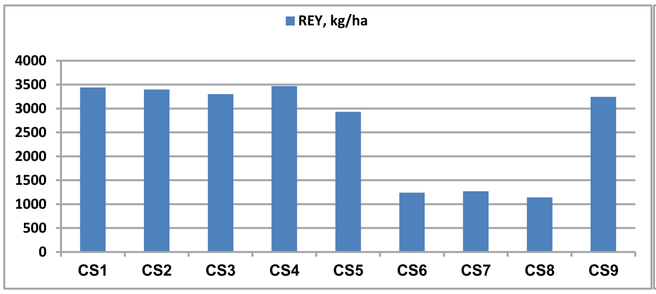


Fig 7.4 Rice equivalent yield from different cropping systems during kharif, 2024.

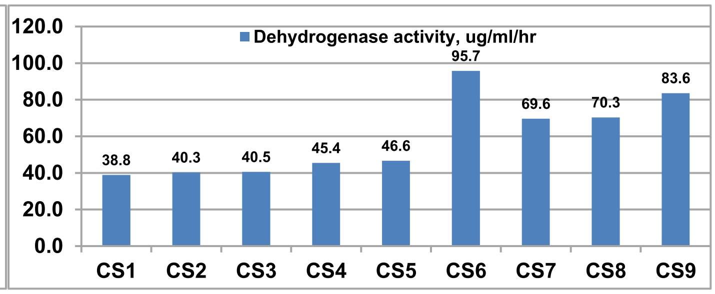


Fig 7.5 Dehydrogenase activity after harvesting of kharif season, 2024 crop

Performance of various rabi season crops | Toria during rabi season | Lentil on raised bed and barley in shunken bed

Performance of toria, berseem, lentil, mustard, barley and wheat.

dhaincha seed production plot (CS6) have significantly higher dehydrogenase activity (95.7 ug/ml/hr) than other cropping systems but was at par with CS9 (83.6 ug/ml/hr), CS8 (70.3 ug/ml/hr) and CS7 (69.6 ug/ml/hr). Soil samples from 0-15 cm and 15-30 cm soil were also taken and processed for soil physic-chemical properties. After the harvest of kharif season crop, treatment wise rabi crops viz., toria, berseem, lentil, mustard, barley and wheat are sown and the performance of almost all the crops is good (photos).

Table 7.7 Soil samples categories by pH and EC

pH class	Category	No. of samples	EC class	No. of samples
< 8.5	Non-sodic	2	Non-saline (EC<=4)	9
8.5 – 9.0	Slightly sodic	1	Saline (EC >4)	6
9.0 – 9.5	Moderately	1		
9.5 – 10.0	Sodic	4		
> 10	Highly sodic	7		

Spatial and temporal analysis of waterlogging and salt dynamics for crop planning in Sharda Sahayak Canal Command of Uttar Pradesh (RH Rizvi, S Arora and CL Verma)

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 km^2. 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 Pratapgarh district of Uttar Pradesh and 60 geo-referenced soil samples (at 4 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.

Soil analysis

The geo-referenced soil samples from 15 sites each (4 depths) were collected from Pratapgarh district in Sharda Sahayak Canal Command of Uttar Pradesh. These soil samples were analysed in laboratory for assessment of sodicity by standard methods. It was observed that in surface soil, the pH ranged from 7.58 to 10.73 (0-15 cm) and 7.89 to 10.69 (15-30 cm). The pH generally showed decreasing trend soil depth with some exceptions. pH value of about 50 percent of the samples is more than 10 indicating that soils as highly sodic. Soil EC varied from 0.478 to 12.89 dS /m (0-15 cm) and 0.458 to 11.12 dS /m (15-30 cm). About 60% samples having EC less than 4 dS /m indicating that soils to be non-saline in Pratapgarh district (Table 7.7). Sodium in surface soils was found higher than sub-surface soil and ranged from 7.30 – 716.52 meq/l at 0-15 cm depth.

Remote sensing analysis

Land use and land cover (LULC) analysis

Both supervised (maximum likelihood and spectral angle mapper) and unsupervised (ISODATA) methods of classification were applied on Sentinel-2B images of May 2022.

Table 7.8 Summary statistics of samples analysed for soil parameters

Depth		pH	EC (dS/m)	Na (meq/l)	K (meq/l)	pHe	ECe (dS/m)
0-15 cm	Min.	7.58	0.478	7.304	0.187	7.65	1.46
	Max.	10.73	12.89	716.522	18.372	10.06	19.69
	Mean	9.82	5.117	179.545	4.604	9.00	9.269
15-30 cm	Min.	7.89	0.458	5.43	0.139	7.95	1.218
	Max.	10.69	11.21	373.35	9.573	9.79	18.060
	Mean	9.875	3.646	84.80	2.174	8.96	7.419
30-45 cm	Min.	7.81	0.338	6.130	0.157	7.68	1.616
	Max.	10.54	8.195	152.391	3.907	9.52	17.59
	Mean	9.86	2.730	45.478	1.166	8.83	5.73
45-60 cm	Min.	8.13	0.327	5.435	0.139	7.66	1.126
	Max.	10.44	5.768	176.348	4.522	9.55	16.14
	Mean	9.909	2.390	41.220	1.057	7.75	4.655

Table 7.9 LULC statistics of Pratapgarh in Sharda Canal Command (May 2023)

Class# (%)	LULC Class	Area (ha)	Area
1	Sodic soils	11298.54	3.05
2	Water/ W' bodies	6521.19	1.76
3	Builtups/ sandy areas	130469.17	35.14
4	Bareland / fallow land	142646.67	38.46
5	Vegetation/ plantations	80118.45	21.60
		371054.11	

Supervised methods did not yield correct results as in case of maximum likelihood classifier (MLC), district area was not the actual one. Spectral angle mapper (SAM) method also gave wrong estimate of area under sodic soils (22.3%), which is quite high. Thus both the methods of supervised classification (SAM & MLC) failed to give correct area estimates. On the other hand, ISODATA method could provide correct classification, according to which are a under sodic soils was 5386.57 ha in the district.

Three methods of classification viz. ISODATA, spectral angle mapper and random forest (RF) were applied on Sentinel-2 images of May 2023. SAM method could not classify images properly as it gave more than 50% district's area as unclassified even if the signatures were generated for five LULC classes. Random forest classification has also given wrong results, according to which vegetation area is quite high (58.2%) and some district area was unclassified. ISODATA method did reasonably correct classification of Pratapgarh district (Table 7.9). Highest area was found under bare land/ fallow land (38.5%) in May 2023. By this method, area under sodic soils was estimated to be 11298.54 ha (3.05%) in the district.

Accuracy assessment of the LULC for period May 2023 was done with the help of ground check points (15 no's) collected during soil sampling. It is observed that both SAM and RF methods did not give much accurate results as their accuracy was less than 70 percent. Whereas accuracy of ISODATA method was reasonably good (80%) and hence may be used for mapping of sodic soils.

Spectral signatures of sodic soils

Spectral signatures for different land uses land covers (LULC) were generated from Sentinel-2 images of Pratapgarh district (Figure). Signature line for sodic soils is on the top indicating the highest reflectance in all spectral bands (B2 to B8). Further, signature line

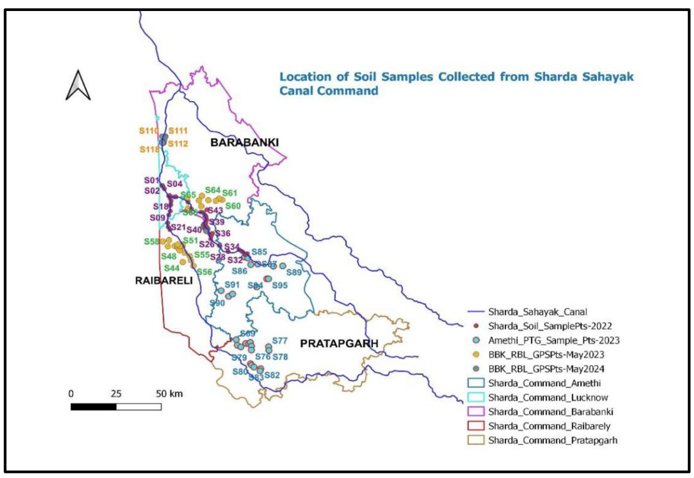


Fig 7.6 Location of soil samples collected from selected districts

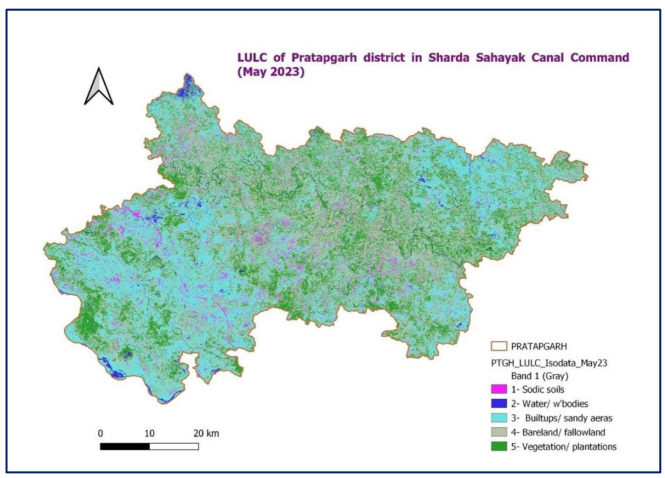


Fig 7.7 LULC of Pratapgarh district for May 2023 by Isodata method

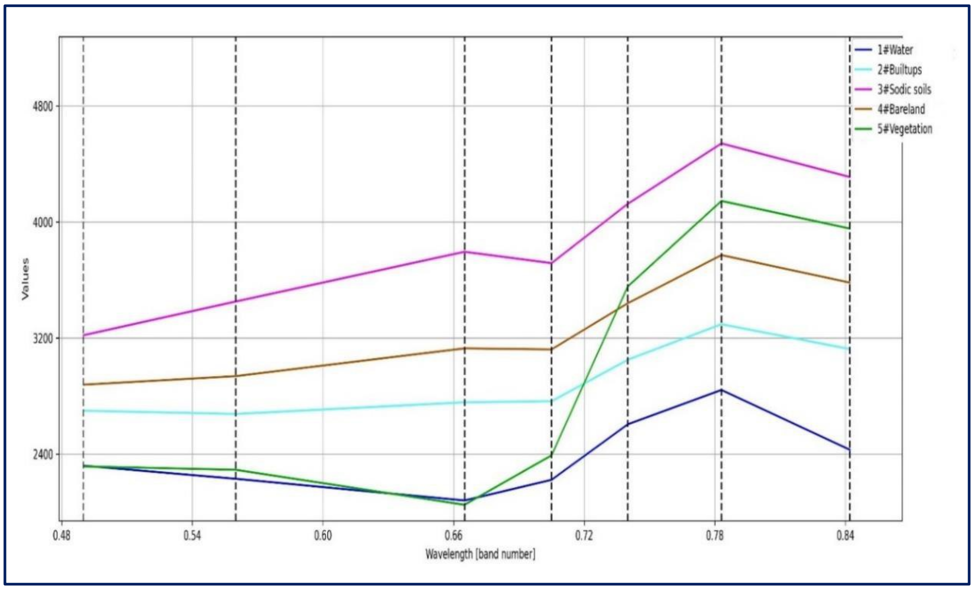


Fig 7.8 Spectral signatures of land uses and land covers generated from Sentinel-2 data

Table 7.10 Correlation matrix between soil parameters and spectral indices

Characters	SI1	SI3	SI5	SI7	SI8
pH	0.510	0.434	0.433	0.495	0.413
EC	0.387	0.377	0.398	0.368	0.299
Na	0.525	0.511	0.543	0.511	0.442
K	0.525	0.511	0.543	0.511	0.442
pHe	0.476	0.425	0.427	0.440	0.429
ECe	0.370	0.336	0.366	0.342	0.323
CEC	-0.301	-0.428	-0.444	-0.266	-0.308
ESP	0.672	0.647	0.691	0.676	0.600

for bare / fallow land was below to that of sodic soils indicating clear cut demarcation of two classes, although their signature pattern is almost same. Thus there is no mix up of sodic soils with any other LULC class and may be accurately mapped by Sentinel-2 images.

Correlation analysis

Correlation analysis was done to find relationship between soil parameters and some spectral indices (Table 7.10). It can be observed from the table that no good correlation was found except between ESP and SI5 (r = 0.691). So an equation given below was fitted between ESP and SI5 using statistical software:

ESP = 830.855 – 94.488 x SI5 (R^2 = 0.744)

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 revised objectives of assessing salt flushing under bordered surface flush irrigation with good quality of water and assessing the effect of treatments on crop yield parameters under rice-wheat cropping system. The adopted treatments were: T_1: level field- no gypsum, T_2: level field+ gypsum@50GR, T_3: 1% Land slope + no gypsum and T_4: 1% land slope + gypsum @ 50GR. Rice variety CSR-36 was transplanted @ 2 seedlings per hill during second fortnight of July. Rice was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare. Half dose of nitrogen and full dose of phosphorous and potassium was applied as basal. The remaining amount of nitrogen was applied at the time of tillering (30 days after transplanting) and panicle initiation (75

Standing rice crop in experimental plots (kharif 2024)

days after transplanting) in equal proportions. The measurement of salts flushing into the soil was done up to two levels, 0-15 cm and 15-30 cm, and for connected ponds' soil and water. The standing rice crops in experimental plots are shown in photo. The soil parameters of different plots *before* rice transplantation and flushed out salt parameters in pondwater during onset and recession of monsoonal rainfallare reported in table 7.11 and table 7.12, respectively.

From Table 7.11 it was found that the rice seed yield, biomass and the harvest index were the highest, 2.27 t/ha, 5.49 t/ha and 0.414, respectively in treatment T_3 (1% Land slope + no gypsum) followed by T_4 (1% land slope + gypsum), 1.84 t/ha, 4.46 t/ha and 0.412, respectively. A minimum seed yield, biomass of harvest index of 0.52 t/ha, 2.91 t/ha and 0.179 were observed in T_2 (level field + gypsum). The possible reason for the highest yield in T_3 might be due to a relatively low pH value and a low Na^+ ion concentration in both 0-15 cm and 15-30 cm, layers of soil. In treatment T_4 (1% land slope + gypsum) yield was slightly less compared to T_3 due to relatively high sodium Na^+ ions concentration in the deeper soil layer. i.e., 15-30 cm. This very trend suggests that, though gypsum applications freed more Na^+ ions but simultaneously it triggers a high tendency to leach out Na^+ ions vertically down into the soil compared to non-gypsum treated plot. This is also corroborated from the fact that Na^+ ions concentration in 15-30 cm soil layer in treatment T_2 (Level field + gypsum) was more compared to T_1 (Level field+ no gypsum).

Further, the concentration of Na^+ ions in ponds showed that the horizontal flushing of Na^+ ions comparably same in both gypsum-treated-slopy field and without-gypsum-treated-slopy field. Therefore, it is further inferred that, for a shallow rooted crop gypsum

Table 7.11 Impact of field slope and gypsum treatment on salt flushing and crop yield

Attributes	pH	EC	pHe	ECe	Na	K	Ca	Mg	CO3	HCO_3	Cl-	OC	Y(t/ha)	BY(t/ha)	HI
T1: Level field+ no gypsum															
0-15 cm	9.23	0.77	8.95	2.07	18.22	0.15	1.83	1.50	4.00	7.00	7.67	0.40	**1.99**	**5.41**	**0.368**
15-30 cm	9.70	0.83	8.55	1.30	9.17	0.06	1.67	0.67	2.00	6.33	5.67	0.19			
Pond	9.26	1.48	8.61	2.43	18.75	0.16	2.00	1.50	1.00	5.00	10.00	0.35			
T2: Level field + gypsum 50 GR															
0-15 cm	9.24	1.16	8.57	2.26	18.24	0.10	2.50	1.33	2.00	4.92	5.67	0.26	**0.52**	**2.91**	**0.179**
15-30 cm	9.55	1.00	8.39	1.71	14.34	0.07	1.33	0.83	1.83	6.17	4.83	0.16			
Pond	8.90	1.38	8.66	2.55	20.57	0.11	2.50	1.25	2.00	5.25	7.50	0.28			
T3: 1% Land slope + no gypsum															
0-15 cm	9.17	1.03	8.80	1.86	16.60	0.10	2.08	0.58	3.00	5.25	7.00	0.34	**2.27**	**5.49**	**0.414**
15-30 cm	9.61	1.04	8.30	1.64	11.00	0.07	1.67	0.58	2.33	5.50	5.08	0.15			
Pond	9.12	1.51	8.72	3.21	27.13	0.13	2.75	1.00	2.00	6.75	8.50	0.31			
T4: 1% Land slope + gypsum 50 GR															
0-15 cm	9.02	1.29	8.43	2.26	16.41	0.10	2.50	0.92	1.67	4.92	5.67	0.41	**1.84**	**4.46**	**0.412**
15-30 cm	9.52	0.77	8.47	1.56	13.90	0.21	1.42	0.58	2.33	6.67	4.83	0.21			
Pond	9.19	0.91	8.75	3.18	28.08	0.11	2.75	1.00	3.00	7.25	8.50	2.14			

Table 7.12 Flush out pondwater quality during onset and cessation of rainfall

Treatment	Sample duration	pH	EC	Na	Silt (mg/ml)
T1: Level field + No gypsum	Onset of rainfall	7.90	0.81	6.47	8.50
	Cessation of rainfall	8.39	2.22	14.55	11.48
T2: Level field+ gyp @50GR	Onset of rainfall	7.99	0.91	13.29	11.07
	Cessation of rainfall	8.48	3.10	20.34	11.48
T3: 1% slop field + No gypsum	Onset of rainfall	7.95	0.88	08.48	15.69
	Cessation of rainfall	8.53	3.04	19.60	17.42
T4: 1% slope field + gyp @50GR	Onset of rainfall	8.15	0.85	09.07	10.48
	Cessation of rainfall	8.55	3.15	19.30	20.70

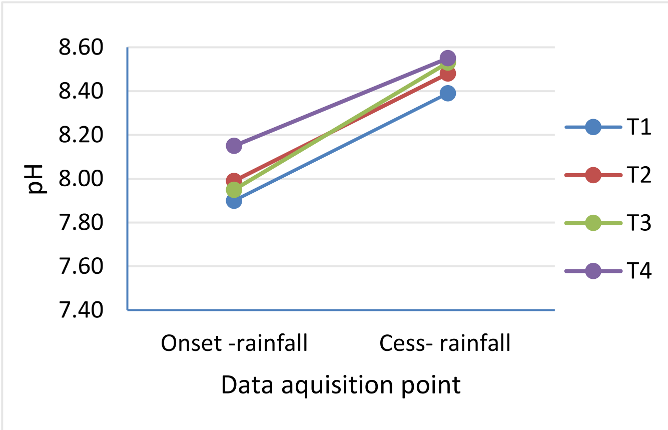


Fig 7.9a Change in pH of pondwater over rainfall season

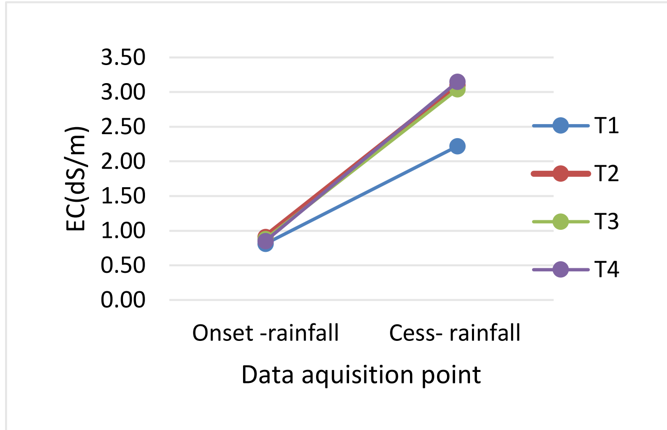


Fig 7.9b Change in EC of pondwater during rainfall season

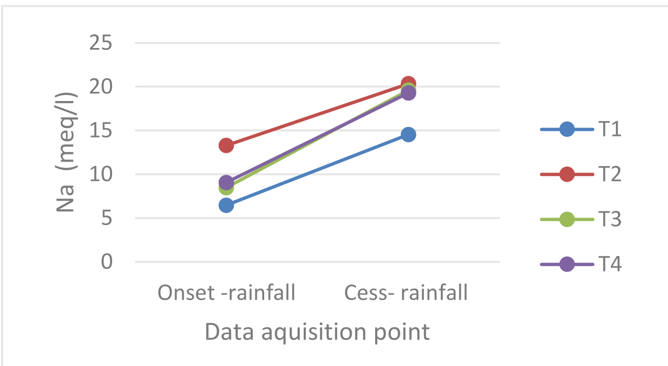


Fig 7.9c Change in Na of pondwater over rainfall season

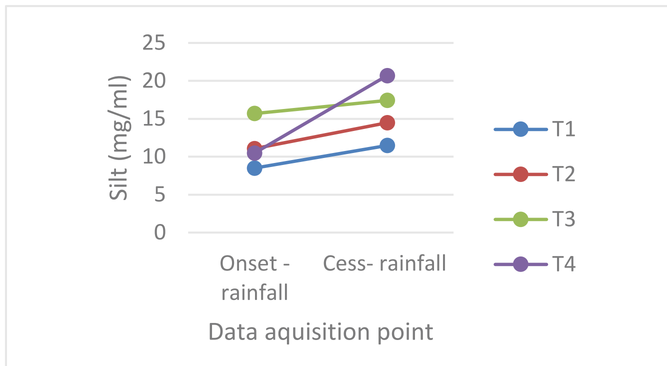


Fig 7.9d Change in Silt of pondwater over rainfall season

treatment is more effective than compared to relatively deep-rooted crops, as gypsum treatment also facilitates accumulation of Na^+ ions in the relatively deeper layer. The soil samples after the harvest of rice crops were collected and are under chemical analysis in the laboratory for further investigation.

The pondwater samples during onset and cessation of monsoonal rainfall were collected from different ponds and were analyzed for its chemical parameters, reported in Table 3. The parametric graphs of pondwater were plotted and are shown in Fig 7.9 (a-d). Out of the four treatments, the maximum change in pH was observed in T_3 (Fig 7.9a). This might be due to the gradual release of ions compared to T_4, which retained in the pond water after the rainfall recession. In case of EC (Fig 7.9b), more free ions were available to those ponds connected with gypsum treated plots and non-gypsum treated *slopy* plots. From Fig 7.9c it was observed that in both T1 and T2 the Na^+ ions retention was almost equal but were less than those of T_3 and T_4 ponds. This means that both T_3 and T_4 treatments were equally responsible in Na^+ ions flushing.

Further from Fig 7.9c & 7.9d it was observed that the field slop aggravated the removal of soil particles with flow of water along the slope. The gypsum addition further resulted in flow of silt along with salt, indicating the flushing of salt, especially Na^+ ions. The experiment is continued for wheat crops (photo).

Standing wheat crop in experimental field (Rabi 2024-24)

Table7.13Ranges of chemical parameters of samples (N=11) analysed in laboratory

pH	EC	pHe	EC_e	Na^+	K^+	Ca^{++}
7.78 - 10.52	0.51 - 2.01	7.67 - 9.88	1.00 - 4.83	8.44 - 65.10	0.040 -0.250	1.50-4.00
Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	OC	CEC	ESP
0.50 - 2.00	2.00 - 24.0	5.50 - 24.5	4.00 - 27.50	0.30 - 0.83	7.40 - 14.12	10.32 - 99.63

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 objective of this project was to acquire soil samples from the heavy textured high sodic areas, particularly from Hardoi, Unnao and Lucknow districts of Uttar Pradesh and to analyze the samples in laboratory for chemical properties for Vis-NIR spectroscopic analysis. Once a definite number of soil samples were obtained and their chemical properties were evaluated, then these will be put for spectral signatures in Vis-NIR spectral band for statistical analysis and model development. In view of these, soil samples from high sodic areas were collected from 29 places from Hardoi, Unnao and Lucknow districts with sampling depths of 0-15 and 15-30 cm. Total 58 dried and sieved samples of required quantity were preserved for Vis-NIR scanning. Out of total 58 samples, 11 samples were chemically analyzed in the laboratory for pH, EC, pHe, ECe, Na^+, K^+ Ca^{++} Mg^{++} CO_3^{--} HCO_3^-, Cl^-,OC CEC and ESP. The range of chemical parameters of these analyzed samples are reported in table 7.13. The wide range variability of chemical parameters looked more promising for Vis-NIR modeling of soil characteristics. The soil sampling and their chemical analysis are still underway to get desired number of samples as required in spectroscopic modeling for better accuracy.

A genetic investigation on the prospect of pearl millet as alternative *Kharif* crop for sodic soils of Uttar Pradesh (Ravikiran K.T., Sanjay Arora and A.K. Dixit)

The present research project was undertaken to test the feasibility of pearl millet as an alternative *Kharif* crop for salt affected soils (sodic) of Uttar Pradesh, considering the increased emphasis on millets during the International Year of Millets, 2023.

Experiment 1

A pot experiment was conducted during the previous *Kharif* season to evaluate the sodicity tolerance of 23 pearl millet hybrids at the vegetative stage under greenhouse conditions. Two treatments were applied: one under normal conditions (pH_2 ~7.5; E.C. ~ 0.39 dS/m; Na: 240.13±29.28 ppm; N: 161.64±19.19 mg/kg; K: 309.66±11.65 mg/kg; P: 30.67±2.23 mg/kg; Ca: 555.20±40.16 ppm; Mg: 160.19±26.44 ppm; O.C.: 0.60±0.11) and the other under sodic stress (pH_2 ~9.6; E.C. ~ 0.66 dS/m; Na: 1047.15±60.26 ppm; N: 143.22±21.94 mg/kg; K: 152.78±7.66 mg/kg; P: 63.17±6.55 mg/kg; Ca: 357.14±20.83 ppm; Mg: 139.18±13.23 ppm; O.C.: 0.25±0.08), with each genotype replicated three times in a factorial CRD design. In addition to the morphological and physiological traits reported in the previous annual report, ion concentrations, specifically shoot and root sodium (Na^+) and potassium (K^+) contents, were assessed to understand their roles in the growth reductions observed in the hybrids. The analysis of variance revealed significant effects ($p < 0.001$) of treatment, hybrid, and their interaction (treatment × hybrid) on all traits (Table 7.14). Across all conditions, Na^+ concentration was consistently higher in the roots than in the shoots, while K^+ concentration showed the opposite trend. Under sodic stress, Na^+ content increased significantly in both shoots (by an average of 544%) and roots (by an

Table 7.14 Analysis of variance for Na and K estimated in root and shoot tissues of 23 pearl millet hybrids

Source of variation	Df	Na^+ content shoot (mg g^{-1} DW)	Na^+ content root (mg g^{-1} DW)	K^+ content shoot (mg g^{-1} DW)	K^+ content root (mg g^{-1} DW)
Treatment (T)	1	2362.15^{***}	1040.79^{***}	24429.36^{***}	1126.71^{***}
Hybrid (H)	22	106.53^{***}	50.25^{***}	480.90^{***}	49.51^{***}
T×H	21	98.61^{***}	45.62^{***}	561.79^{***}	53.17^{***}
Error	93	5.59	4.76	36.72	5.18
C.V. (%)		41.75	26.93	18.87	40.43
C.D. (5%) (T)		0.79	0.74	2.05	0.77
C.D. (5%) (H)		2.71	2.50	6.95	2.61
C.D. (5%) (T×H)		3.83	3.54	9.83	3.69

Source of variation	Df	K^+/Na^+ ratio shoot	K^+/Na^+ ratio root
Treatment (T)	1	126406.00^{***}	68.16^{***}
Hybrid (H)	22	8000.30^{***}	1.47^{***}
T×H	21	6580.05^{***}	1.64^{***}
Error	93	655.05	0.28
C.V. (%)		-	-
C.D. (5%) (T)		8.65	0.18
C.D. (5%) (H)		29.35	0.60
C.D. (5%) (T×H)		41.50	0.85

Df: Degrees of freedom; C.V.: Co-efficient of variation; C.D.: Critical difference; *** - $p<0.001$

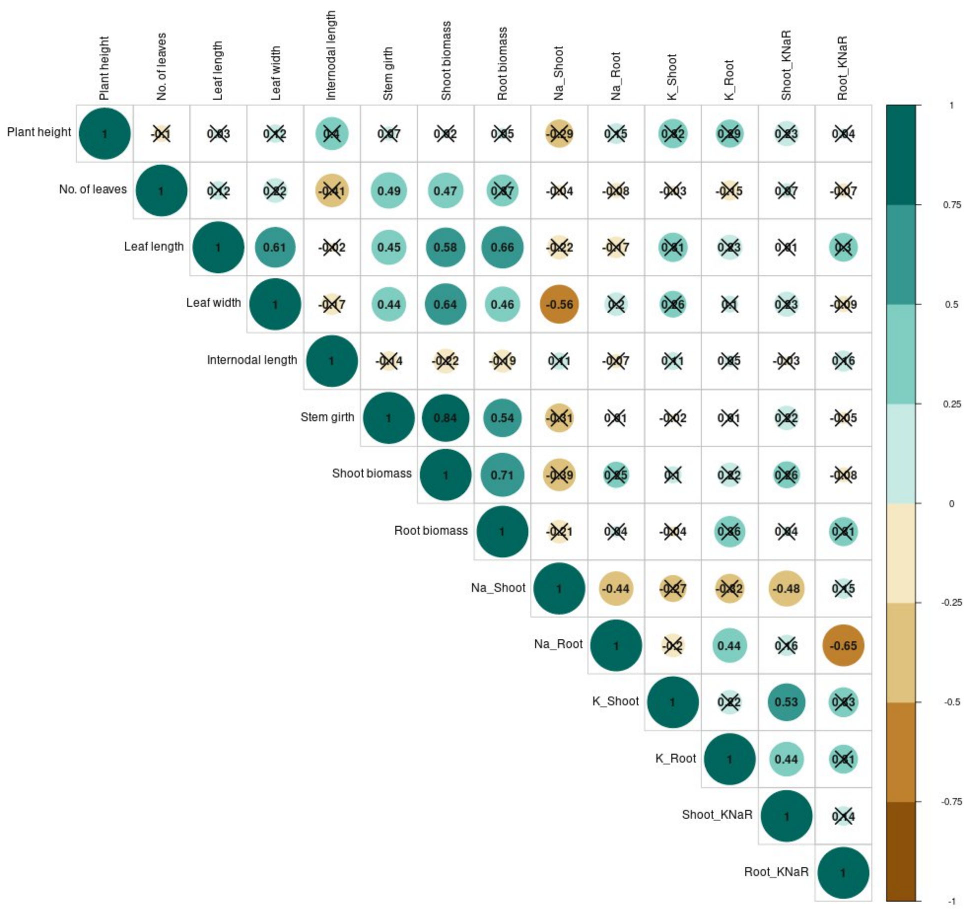


Fig 7.10 Pearson correlation coefficients among various traits estimated on 23 pearl millet hybrids tested under sodicity (pH ~ 9.6). The correlations whose p value is >0.05 are crossed out.

average of 103%) compared to normal conditions. Conversely, K^+ content decreased significantly in shoot (by an average of 59%) and roots (by an average of 67%). This marked increase in Na^+ and decrease in K^+ uptake under sodicity were strongly associated with the observed decline in the overall performance of the pearl millet genotypes. The increase in shoot Na^+ content and the concurrent reduction in K^+ highlight the partial or complete failure of the ion exclusion mechanism across all hybrids. However, hybrids such as GHB 1225, GHB 732, JKBH 1326, MPMH 21, RHB 223, RHB 234 and BHB 1202 showed relatively higher Na^+ in root compared to shoot. Two hybrids, BHB 1602 and HHB 67 IPM showed higher Na^+ accumulation in shoot, albeit, better growth under sodic stress indicating true tissue tolerance. In addition, certain other genotypes showed better selective K^+ uptake such as DHBH 1121, GHB 732, RHB 234, Pusa 1201, and JKBH 1326. Two hybrids GHB 732 and RHB 234 showed both Na^+ exclusion and selective K^+ uptake whereas hybrids JKHB 1326 and RHB 234 displayed better growth and ion hoemostasis. Correlation analyses between ion concentrations in shoots and roots and various growth parameters revealed that shoot Na^+ content was negatively correlated with all growth parameters. Among these, it exhibited a significant negative correlation with leaf width (Figure 7.10). Additionally, shoot Na^+ content was significantly negatively correlated with root Na^+ concentration. The K^+/Na ratio in both shoots and roots showed significant negative correlations with their respective Na^+ contents.

Experiment 2

In another experiment conducted during the previous *Kharif* season, 24 pearl millet hybrids were sown twice. However, due to rainfall occurring 1–2 days after sowing and the subsequent waterlogging in the sodic plots, germination failed in both instances. During *Kharif* 2024, the genotypes were sown again in the last week of May, but germination was again unsuccessful. To assess whether modifications to the sowing date and method could sustain pearl millet growth in sodic soils, two hybrid varieties, AHB 1200 and MPMH 21, were sown on five different dates at weekly intervals starting from June 20, 2024. These sowings employed two methods: farmers' practice (flat bed) and sowing on ridge (Table 7.15). The experiment was conducted under both normal (pH < 8.5) and sodic stress conditions (pH ~9.0–9.3) using a factorial randomized complete block design (RCBD) with three replications. Data were recorded on grain yield (kg ha^{-1}) and its related attributes. The analysis of variance for various traits is presented in Table 7.16. The results indicated that the main effect of stress treatment (S) was highly significant across all traits, highlighting a clear distinction between normal and sodic conditions based on pH levels. The date of sowing (D) was significant for most traits, though notably not for grain yield. Similarly, the method of sowing (M) was significant for all traits except grain yield, plant height, panicle diameter, and grain weight per panicle. Variety (V) emerged as a significant source of variation for biomass, grain yield, the number of productive tillers, plant height, stem diameter, panicle diameter, grain weight per panicle, and panicle harvest index. However, it was not a significant factor for the remaining traits.

Among the first-order interaction effects, the S × D interaction was significant for all traits except panicle harvest index (HI), indicating that pearl millet performance can be modified to some extent by adjusting the sowing dates. The S × M interaction was non-significant for four out of the ten traits evaluated, including grain yield. In contrast, the D × M interaction was significant for six traits, including grain yield. The S × V interaction was significant for only four traits, including biomass and grain yield, highlighting a clear distinction between the two varieties in terms of grain yield under normal and sodic stress conditions. The D × V and M × V interactions were non-significant for most traits,

Table 7.15 Treatment details of experiment 2 conducted for agronomic evaluation of pearl millet hybrids under normal and sodic conditions.

S.No.	Treatment	Number of levels	Details
1.	Stress	2	Normal (pH_2 ~ 7.5 – 8.0) Sodic (pH_2 ~ 9.0 – 9.4)
2.	Date of sowing	5	20-06-2024, 27-06-2024, 04-07-2024, 11-07-2024, 19-07-2024
3.	Method of sowing	2	Farmers' practice Sowing on ridge
4.	Variety	2	AHB 1200 and MPMH 21

Table 7.16a Factorial RBD analysis variance of various results for traits estimated

Source of variation	Df	Biomass (t ha^{-1})	Grain yield(kg ha^{-1})	NPT	PH (cm)	PL (cm)
Replication	2	20.71	1296865.05	31.21	767.02	76.45
Stress (S)	1	80.21***	3409624.79***	703.61***	42804.78***	84.71***
Date of sowing (D)	4	10.4***	384853.84^{ns}	54.31***	2808.44***	62.18***
Method of sowing (M)	1	9.51*	89598.41^{ns}	162.80***	619.15ns	124.07***
Variety (V)	1	20.04**	1436870.01***	194.36***	1208.70**	1.87^{ns}
S × D	4	7.47*	463344.37*	89.95***	1156.37***	48.19***
S × M	1	16.43**	9110.23^{ns}	109.61***	6087.27***	13.60^{ns}
D × M	4	16.07***	499672.69*	80.57***	468.40*	10.21^{ns}
S × V	1	23.72**	1452504.46**	86.19***	902.30*	5.32^{ns}
D × V	4	6.09*	137428.30^{ns}	20.99^{ns}	1098.45***	7.35^{ns}
M × V	1	4.21^{ns}	104299.23^{ns}	0.31ns	332.40^{ns}	0.06^{ns}
S × D × M	4	13.35***	600647.41*	84.73	902.98**	4.71^{ns}
S × D × V	4	8.07**	165797.71^{ns}	30.23*	429.17*	22.42*
S × M × V	1	2.46^{ns}	10206.86^{ns}	10.83^{ns}	21.69^{ns}	1.56ns
D × M × V	4	0.62^{ns}	75114.10^{ns}	38.68**	624.14**	10.02^{ns}
S × D × M × V	2	3.26^{ns}	88237.89^{ns}	52.99***	2645.88***	12.34^{ns}
Error	74	2.12	165497.35	8.69	159.51	6.87

Table 7.16b Factorial RBD analysis variance of various results for traits estimated

Source of variation	Df	PW (g)	SD (mm)	PD (mm)	GWPP	PHI
Replication	2	146.73	19.30	211.51	60.16	5.10
Stress (S)	1	1594.70***	54.61***	623.88***	478.71***	265.58**
Date of sowing (D)	4	158.17***	33.10***	137.16***	57.39***	90.38*
Method of sowing (M)	1	118.90*	40.19***	37.42^{ns}	7.49^{ns}	618.40***
Variety (V)	1	18.31ns	34.54**	35.09ns	10.81^{ns}	91.97^{ns}
S × D	4	167.97***	8.24*	32.77*	59.80***	71.54^{ns}
S × M	1	39.07^{ns}	42.90***	76.59*	14.63^{ns}	256.22**
D × M	4	60.26^{ns}	8.98*	22.89^{ns}	7.98^{ns}	114.92**
S × V	1	4.57^{ns}	0.53^{ns}	2.45^{ns}	4.67^{ns}	42.66^{ns}
D × V	4	33.51^{ns}	7.39^{ns}	21.76^{ns}	7.07^{ns}	74.18*
M × V	1	2.42^{ns}	3.86^{ns}	46.68*	1.43^{ns}	9.25ns
S × D × M	4	22.28^{ns}	21.91***	11.94^{ns}	22.88*	283.30***
S × D × V	4	84.95*	4.60^{ns}	38.40*	21.52*	56.45^{ns}
S × M × V	1	33.42^{ns}	0.14^{ns}	31.35^{ns}	5.32^{ns}	1.16^{ns}
D × M × V	4	44.36^{ns}	4.03^{ns}	7.25^{ns}	8.41^{ns}	116.69**
S × D × M × V	2	30.61^{ns}	6.32^{ns}	13.54^{ns}	6.81^{ns}	209.40***
Error	74	27.07	3.25	10.95	7.71	28.92

Df: Degrees of freedom; C.V.: Co-efficient of variation; C.D.: Critical difference; ***: *p*<0.001; **: p<0.01; *: p <0.05; ns – non-significant; NPT: no. of productive tillers; PH: plant height; PL: panicle length; PW: panicle weight; SD: stem diameter; PD: panicle diameter; GWPP: grain weight per panicle; PHI: panicle harvest index

Table 7.17 Mean performance (grain yield in kg ha^{-1}) of two pearl millet hybrids under different treatment combinations

Stress	Date of sowing	Method of sowing	AHB 1200	MPMH 21
Normal	20-06-2024	Farmers' practice	412.96	925.92
		Ridge and furrow	1005.56	2122.22
	27-06-2024	Farmers' practice	768.52	633.33
		Ridge and furrow	255.56	672.22
	04-07-2024	Farmers' practice	627.78	916.67
		Ridge and furrow	197.22	403.70
	11-07-2024	Farmers' practice	851.85	1533.34
		Ridge and furrow	444.44	1242.59
	19-07-2024	Farmers' practice	557.41	1016.67
		Ridge and furrow	742.59	786.11
Sodic	20-06-2024	Farmers' practice	464.98	450.17
		Ridge and furrow	368.33	400.00
	27-06-2024	Farmers' practice	637.27	637.27
		Ridge and furrow	415.02	585.56
	04-07-2024	Farmers' practice	414.63	376.30
		Ridge and furrow	403.91	422.43
	11-07-2024	Farmers' practice	653.70	600.00
		Ridge and furrow	374.28	365.02
	19-07-2024	Farmers' practice	457.41	355.72
		Ridge and furrow	503.48	488.66

affecting seven and nine traits, respectively. For second-order interaction effects, S × D × M and S × D × V were non-significant for only three traits each. However, grain yield was non-significant for S × D × V. The S × M × V interaction was non-significant for all traits, reflecting the minimal influence of sowing methods in combination with stress and variety. Similarly, D × M × V and the third-order interaction S × D × M × V were non-significant for seven out of the ten traits, including biomass and grain yield. Focusing on grain yield specifically, while D and M were non-significant as primary effects, the interactions D × M and S × D × M were significant at $p < 0.05$. A clear difference between the varieties was observed under normal conditions; however, they exhibited similar yields under sodic stress (Table 7.17). Under both normal and sodic conditions, the highest grain yield was recorded when sowing occurred on 11-07-2024, regardless of the sowing method or variety. Across all sowing dates, grain yield was comparable between the two sowing methods under normal conditions. In contrast, under sodic stress, the traditional farmer's method of sowing demonstrated a clear yield advantage over ridge sowing. Overall, variety and sowing method appear to have limited relevance for sustaining pearl millet production under sodic conditions. Adjusting the sowing date according to the onset of the monsoon can help sustain cultivation to some extent. However, this finding requires confirmation through more detailed studies. The results from both experiments suggest that the currently cultivated pearl millet hybrids have limited tolerance to sodicity. While agronomic management, such as optimizing sowing dates, can partially mitigate stress, achieving economic yields under sodicity will require the development of tolerant varieties. This underscores the need for a dedicated breeding program in the future to enhance sodicity tolerance in pearl millet hybrids.

Evaluation of multiple auger planting technique for fruit crops in partially reclaimed sodic soil. (A.K. Dubey, C.L. Verma, A.K. Singh and S.K. Jha).

In 2023, apple ber was planted using a multiple auger planting system in highly textured

Table 7.18 Performance of apple ber under sodic soil conditions planted using multi-auger with or without addition of bioformulation

Characters	Multi auger plating + Bioformulation	Multi auger plating without bioformulation	Percent change
Tree height (m)	1.97	2.00	1.52
Trunk circumference(cm)	10.99	11.46	4.28
Canopy spread (N-S) (m)	2.47	2.04	-17.41
Canopy spread (E-W) (m)	2.58	2.13	-17.44
TCSA (cm^2)	392.27	418.32	6.64
Canopy volume (m^3)	7.54	6.41	-14.99
Fruits/tree	572.67	564	-1.51
Fruit density (fruits/ m^3 cv)	57.79	67.55	16.89
Yield Efficiency (kg/m^3)	3.22	3.32	3.11
Yield (kg/tree)	28.56	27.66	-3.15
Chlorophyll 'a' (mg/g)	1.42	1.57	10.56
Chlorophyll 'b' (mg/g)	0.85	1.04	22.35
Total Chlorophyll (mg/g)	2.27	2.61	14.98
Chlorophyll 'a'/'b' ratio	1.64	1.61	-1.83
RWC (%)	67.72	67.43	0.44

sodic soils. The experiment comprised two treatments: multiple auger planting with bioformulations and without bioformulations, along with a control treatment using mono holes. Five auger holes (one central hole with a 30 cm diameter and four peripheral holes with a 10 cm diameter) were dug in six rows. After creating three holes at each location, the tractor's direction was adjusted at a right angle to dig three additional holes in two passes, superimposing the central hole. In Treatment-1, all pits were filled with a mixture of dug-out soil, sand, and FYM (1:1:1) combined with 2 kg of gypsum and microbial bioformulations. In Treatment-2, the same mixture of soil, sand, and FYM along with gypsum was used, but without bioformulations. The control consisted of six pits (40 cm x 40 cm x 40 cm) filled with FYM and soil. The results revealed that despite considerable effort, no apple trees survived under traditional mono-hole planting in highly textured sodic soils. However, a 100% survival rate was observed in both treatments using the multiple auger planting system (Table 7.18). Growth data indicated meaningful differences between the two treatments. After two years, tree height was similar in both treatments. However, trunk circumference and total cross-sectional area (TCSA) were higher in the treatment without bioformulations (11.46 cm and 418.32 cm^2, respectively) compared to the treatment with bioformulations (10.99 cm and 392.27 cm^2, respectively). This represented an increase of over 4% in trunk circumference and over 6% in TCSA in the treatment without bioformulations. Conversely, canopy diameter in both directions was greater in the treatment with bioformulations under the multiple auger planting system. Data on fruit yield indicated a higher number of fruits per tree (572.67 fruits/tree) in the treatment with bioformulations, while fruiting density was greater in the treatment without bioformulations (67.55 fruits/m^3 canopy volume). Moreover, multi hole planting without bioformulation has highest yield efficiency (3.32 kg/m^3), while yield kg/tree was recorded the highest in treatment having bioformulation.

Fruiting of apple ber planted under multi auger system under multiple auger planting system in partially reclaimed soil

Perusal of fruit quality data showed that treatment did not have significant difference for fruit weight, fruit size (length and width), However, significantly higher heavier stone was measured in treatment with bioformulation, while pulp stone ratio and TSS was found to be higher in treatment without bioformulations (Table 7.19). Furthermore, chlorophyll

Table 7.19 Fruit quality of apple ber under sodic soil conditions planted using multi-auger with or without addition of bioformulation

Characters	Multi auger plating + Bioformulation	Multi auger plating without bioformulation	Percent change
Fruit weight (g)	49.31	49.37	0.12
Fruit length (mm)	47.39	46.90	-1.03
Fruit width (mm)	44.04	43.88	-0.36
Pulp weight (g)	44.80	45.52	1.61
Stone weight (g)	3.76	3.44	-8.51
Pulp/stone ratio	11.92	13.29	11.49
TSS (^{0}B)	8.84	9.90	11.99

Table 7.20 Tissues nutrients status of apple ber under sodic soil conditions planted using multi-auger with or without addition of bioformulation

Characters	Multi auger plating + Bioformulation	Multi auger plating without bioformulation	Percent change
K (%)	0.89	0.80	-10.11
Ca(meq/L)	653.33	600.00	-8.16
P (%)	0.080	0.048	-40.00
Cl (meq/L)	21.33	27.67	29.72
Na (%)	0.044	0.039	-11.36

analysis showed higher values of chlorophyll 'a' (1.42 mg/g fwt), chlorophyll 'b' (1.04 mg/g fwt), and total chlorophyll (2.61 mg/g fwt) in the treatment without bioformulations. However, the chlorophyll 'a' to 'b' ratio was slightly higher in the treatment with bioformulations. In conclusion, the multiple auger planting system significantly improved tree survival and growth in sodic soils, with each treatment showing distinct advantages in specific growth and fruiting parameters.

The leaf tissue nutrients analysis exhibited variation between treatments (Table 7.20). A decline in K, Ca, P and Na was noted in treatment without bioformulation with varying degree. The greater reduction (40%) was noted in P followed by 11% inhibition in leaf Na, but Cl in leaf tissues of was found higher (29.72%) in treatment without bioformulations.

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

In September 2023, four date palm varieties along with one male variety were planted under two soil pH conditions: (1) pH >10 and (2) pH 9.0, at the Shivri Research Farm. Pits measuring 75 x 30 cm, spaced at a distance of 7m x 7m, were dug on raised beds and filled with a mixture of soil, sand, and FYM in a 1:1:1 ratio. The results indicated varying degrees of tree mortality in soil with pH >10. The highest mortality rate was observed in the Medjool variety (80%) after one year of growth, while Khuneji and Khadrawi varieties recorded significantly lower mortality (20%) (Table 2.21). In contrast, all varieties exhibited good survival in pH 9 soil, with Khuneji and Barhi achieving 100% survival. The remaining two varieties showed only 20% mortality under this pH condition. Growth data revealed significant differences in plant height, trunk circumference, and the number of leaves per plant after one year of growth under the two pH conditions. In soil with pH >10,

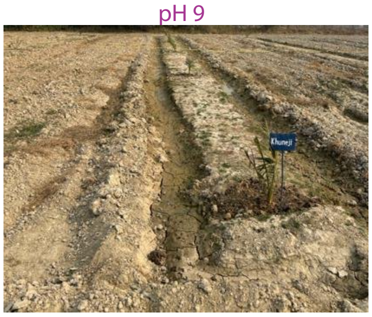
Table 2.21 Performance of date palm under varying pH of high textured sodic soils.

Characters	Plant height (m)	Plant circumference (cm)	No of leaves	Mortality (%)
pH above 10				
Khuneji	1.16	23.67	5.33	20
Medjool	0.96	18.00	5.00	80
Barhi	0.56	8.33	3.00	60
Khadrawi	0.93	15.67	4.67	20
pH 9.0				
Khuneji	1.37	38.00	4.00	0
Medjool	0.91	10.72	8.67	20
Barhi	1.08	27.53	12.33	0
Khadrawi	1.22	31.50	9.67	20


Performance of Date palm in pH 9


Performance of Date palm in pH >10


Performance of Khuneji variety in pH 9


Performance of Khuneji variety in pH >10

the highest plant height (1.16 m), trunk circumference (23.67 cm), and number of leaves per plant (5.33) were recorded in the Khuneji variety. However, all varieties performed significantly better in pH 9 soil. The highest plant height (1.37 m) and trunk circumference (38.00 cm) were also recorded in the Khuneji variety, while the highest number of leaves per plant (12.33 leaves) was observed in the Barhi variety. Based on overall performance, the Khuneji and Khadrawi varieties demonstrated better growth under both pH conditions. However, all four varieties performed notably better when planted in pH 9 soil under high-textured sodic conditions.

Evaluation of open hydroponic planting system (OHPS) 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), acid lime (var. Kagzi lime), 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 and watered immediately after planting. 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. Among the different fruit crops, pummelo, sweet orange, and acid lime exhibited better performance in terms of plant height, trunk circumference, and mortality (Table 2.22). Although survival was 100% in guava, custard apple, pummelo, and sweet orange after seven months of planting under the open hydroponic planting system (OHPS), 100% mortality was observed under the traditional planting system. Observations on chlorophyll fractions, chlorophyll 'a' to 'b' ratio, and relative water content (RWC) revealed variations among treatments. Chlorophyll 'a' (1.73 mg/g fwt) and total chlorophyll (2.85 mg/g fwt) were highest in pomegranate under OHPS, followed by custard apple. Chlorophyll 'b' was highest in custard apple (1.23 mg/g fwt). The

Table 7.22 Performance of shallow rooted fruit crops under high pH >10 planted in OHPS

Crop/variety	Plant height (m)	Trunk circumference (cm)	Mortality (%)
Pomegranate 'Bhagwa'	90.00	9.38	8.33
Pummelo 'Pusa Arun'	56.67	10.02	0.00
Sweet orange ' Pusa Round'	70.00	11.56	0.00
Acid lime 'Kagzi lime'	82.33	13.07	00.00
Custard apple	58.00	9.72	0.00
Guava 'CISH Sweta'	89.00	14.52	0.00

Evaluation of shallow rooted fruit crops in OHPS under high pH of highly textured soils

Table 7.23 Performance of shallow rooted fruit crops under high pH >10 planted in OHPS.

Crop/variety	Chlorophyll 'a' (mg/g fwt)	Chlorophyll 'b' (mg/g fwt)	Total Chlorophyll (mg/g fwt)	a/b ratio	RWC (%)
Pomegranate 'Bhagwa'	1.73	1.11	2.85	1.56	65.74
Pummelo 'Pusa Arun'	0.63	0.51	1.14	1.22	69.09
Sweet orange ' Pusa Round'	0.85	0.93	1.78	1.02	72.46
Acid lime 'Kagzi lime'	1.13	0.44	1.57	2.58	71.08
Custard apple	1.56	1.23	2.79	1.34	63.74
Guava 'CISH Sweta'	1.36	1.10	2.63	1.23	68.92

Table 7.24 Tissues nutrients status of different shallow rooted fruit crops under high pH >10 planted in OHPS

Crop/variety	Na (%)	Cl (meq/L)	K	P	Ca (meq/L)	Mg (meq/L)
Pomegranate 'Bhagwa'	0.03	34.00	0.145	0.102	1.00	5.00
Pummelo 'Pusa Arun'	0.10	17.67	0.368	0.136	17.67	2.17
Sweet orange ' Pusa Round'	0.03	20.67	0.412	0.135	16.67	4.33
Acid lime 'Kagzi lime'	0.02	27.00	0.283	0.144	4.50	3.00
Custard apple	0.02	22.33	0.098	0.158	4.00	2.50
Guava 'CISH Sweta'	0.03	27.67	0.253	0.168	4.00	2.50

Table 7.25 Chemical composition of soils of experiment of OHPS of different fruit crops

Character	Soil depth		Character	Soil depth	
	0-15	15-30 cm		0-15	15-30 cm
$EC_{1:2}$	0.77	1.01	Ca + Mg	1.50	1.50
$pH_{1:2}$	9.21	9.44	CO3 Meg	1.67	1.33
Ec_e	1.57	1.60	HCO_3 Meg	4.67	4.83
pH_e	8.69	8.71	Cl meg	3.83	3.83
Na meg	10.45	10.87	OC (%)	0.35	0.13
K meg	0.08	0.12	Available N (kg/ha)	65.71	176.59
Ca meg	1.50	1.33	Available K (kg/ha)	62.91	62.01

chlorophyll a/b ratio was recorded highest in acid lime (2.58), followed by pomegranate (1.56). Similarly, RWC varied among crops, with sweet orange and acid lime showing more than 70% RWC, while the lowest RWC was observed in pomegranate (65.74%) (Table 7.23). Data pertaining to nutrient status of leaf tissues of shallow rooted fruit crop showed variation among fruit crops (Table 7.24). The highest Na content in leaf tissues was highest in pummelo var Pusa Arun (0.10%) and lowest was recorded in custard apple, and acid lime (0.20%), however, Cl content in leaf tissues was recorded the highest in pomegranate (34.00 meq/L). Leaf K and P was measured the highest in sweet orange and guava, respectively. Citrus fruit like sweet orange and pummelo had higher content of Ca in their leaf tissues, while higher Mg content was found highest in pomegranate (5 meq/L). Initial soil pH and electrical conductivity (EC) at a depth of 0-15 cm were recorded as 9.21 and 0.77, respectively, while at a depth of 15-30 cm, the pH was 9.44 and EC was 1.01. Additional soil parameters were also measured at the time of planting (Table 7.25).

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

Two varieties of dragon fruit (red flesh and white flesh) were planted to evaluate their performance under different planting methods and media. The study compared three planting methods: (1) Single Hole Planting (T1), (2) Alternate Pit Planting (T2), and (3) Open Filed Hydroponic Planting (OFHP, T3) and three media i.e., 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 planted near cement poles. A tractor-mounted multiple auger was used to dig three

White Flesh dragon fruit under alternate Pit planting

White Flesh dragon fruit under OFHP

Red Flesh dragon fruit under alternate pit planting

Red Flesh dragon fruit under OFHP

holes for T1and T3 and five holes for T2. In T2, two simultaneous holes were dug leaving 10-15 cm distance between pits. In each treatment, the central hole was designated for fitting a cement pole to support the dragon fruit plants. The planting media, consisting of soil, sand, and farmyard manure (FYM) in a 1:1:1 ratio and Soil:cocopeat:FYM (1:1:1) were filled into designated pits. In T1, planting was done in both holes, while in T2, planting was done in alternate pitsbut, remaining one pits was also filled with same media. In OFHP, polyethylene/gunny bags (100 x 30 cm size) were filled with the same media and placed in pre-dug pits on both sides of the cement poles. Planting was conducted in September 2023. Proper drainage system was installed in all treatments. Mean effect of media showed the highest mortality rate for the white flesh variety in T2 (7.41%), while the red flesh variety exhibited the highest mortality in M2 (25%) and least was noted in M3 media (11.11%). However, regardless of media, planting system showed higher mortality (33.39%) in TP which was closely followed by APP. There was no mortality in OFHP. Interaction of all factors clearly showed impact of treatment of mortality. In both varieties, none plant died in OFHP in either media. Furthermore, highest mortality in White Flesh variety was noted in M2 media (50%), while in Red Flesh variety, higher mortality was recorded in both M1 and M2 media (Table 7.26). Data pertaining to plant height and sprout also indicated significant effect of media and planting system. Mean effect of media exhibited highest plant height in M3 media, while mean effect of planting system showed highest plant height in OFHP and lowest was there in TP. Furthermore, combined effect suggested higher plant height in both varieties while planting was done following OFHP. The number of sprouts varied across treatments. Irrespective of varieties and planting

Table 7.26 Growth and survival of dragon fruit planted in Alternate holes Planting system and OFHP compared to traditional planting system in different growing media under high textured sodic soils

Treatment	**Plant height (cm)**		
White Flesh	**M1**	**M2**	**M3**
TPS	41.67	48.00	54.00
APP	42.33	43.33	46.00
OFHP	42.67	51.67	71.33
Red Flesh			
TP	34.00	34.33	55.00
APP	55.67	69.33	70.33
OFHP	73.00	91.67	93.67
White Flesh	**Sprout (no)**		
TP	2.33	4.67	3.33
APP	2.33	3.67	4.33
OFHP	2.00	2.67	3.33
Red Flesh			
TP	1.67	2.67	2.00
MP	2.33	3.00	3.67
OFHP	2.33	3.67	4.33
White Flesh	**Mortality (%)**		
TP	33.50	50.00	16.67
MP	33.33	33.33	16.67
OFHP	0.00	0.00	0.00
Red Flesh			
TP	33.33	33.33	16.67
APP	33.33	33.33	16.67
OFHP	0.00	0.00	0.00

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

Table 7.27 Chemical composition of soils of experiment on dragon fruit under different media planted in multi holes plating system and OFHP.

Character	Soil depth		Character	Soil depth	
	0-15 cm	15-30 cm		0-15 cm	15-30 cm
$EC_{1:2}$	0.81	1.01	Ca + Mg	2.00	1.67
$pH_{1:2}$	8.71	9.46	CO3 Meg	1.00	1.33
Ec_e	1.85	1.70	HCO_3 Meg	3.83	5.67
pH_e	8.47	8.70	Cl meg	6.67	5.67
Na meg	9.33	9.96	OC (%)	0.64	0.36
K meg	0.10	0.05	Available N (kg/ha)	180.69	86.24
Ca meg	1.83	1.33	Available K (kg/ha)	82.54	67.39

system, the highest number of sprouts was recorded in M3 media, while MP produced highest number of sprouts. The combined effect of variety, media and planting system that in white flesh variety, the highest no of sprouts was counted when planning was done under MPP in M3 media, but in Red Flesh variety, OFHP planting in M3 media produced highest number of sprouts. Observations on soil analysis are presented in Table 7.27.

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)

IFS 1. Fish +date palm – vegetable based

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 for high textured sodic soils

In this system total area of 6300 sqm was utilized. Out of that a pond covering an area of 4100 sqm was dug for fish culture, 800 sqm meter was allocated for vegetable production and 1400 sqm was used for roads and paths.A total 30 trees of date palm variety Khuneji was planted on the three side of embarkment 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, ridge gourd and bottle gourd were planted. The vegetables yielded a harvest that was sold for Rs 3600/- from 200 sqm area. In the winter season, the same area will be utilized for cultivating broccoli, spinach (palak), Kale and cauliflower. The performance of winter crops such as spinach, broccoli, cauliflower and kale, as well as in rainy season crops such as bottle gourd and sponge gourd, was found to be satisfactory. Broccoli, bottle gourd, ridge gourd, palak and kale gave Rs 18800/- from an area of 200 sqm. The vegetative growth performance of the date palm variety 'Khuneji' was observed to be highly satisfactory. After one growth cycle, the average recorded measurements were as follows: height - 1.27 m, trunk circumference - 28 cm, canopy circumference - 2.63 m, and an average of 5.44 leaves per plant. Rs 5000 has been realized from sale proceeds of vegetables. Due to non-availability of water, fish and chest cultivation was not initiated.

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

A total 6200 sqm area was allocated for this model. This model is based on fish-horticulture-dairy. In this model, 3000 sqm area was allocated for fish pond, 600 sqm for guava plantation, 1500 sqm for fodder/marigold, 300 sqm was allotted to dairy unit and

IFS 2. Fish +vegetable – field crop based

remaining area of 800 sqm was allocated to paths and roads. The guava varieties BNR and CISH Sweta wasplantedat distance of 4m x 4m in the September, 2023. Fish pond was prepared and fish cultivation will be initiated from next years. A cow was also kept in this system utilizing.

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

A total 6000 sqm area was utilized in this system. A ponds of 1500 sqm was dug for fish culture and two varieties of fish was applied in the pond, 350 sqm area was allocated to the vegetable production, 650 sqm for fodder, 1700 sqm area was allotted to the field crops and remaining was used for road, dairy and paths. The embarkment 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, mustard and different vegetables were recorded. During summer monsoon season, ridge gourd and bottle gourd were planted. During winter season, lettuce, brinjal, tomato and cauliflower were planted. Vegetables were harvested and yield was recorded. This year, Rs 50000/- was earned from selling of fish plus Rs 16900- was realized from vegetables from an area of 400 sqm. 650 sqm area was used for rainy season fodder sorghum from which 20 q green fodder was harvested from which total Rs 1200/- was realized. In addition, from the field crop area (1700 sqm), a total of 4.28 q paddy and 7.08 q paddy straw was harvested which yielded Rs. 10544/-. Grass planted on the ridge of pond was used as fodder for cow.

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 11.86 q paddy grain and 16.12 q paddy straw was realized from this system. This system yielded Rs 28890/ from an area of 2300 sqm.

IFS 3. Fish +horticulture – field crop-dairy based

Table 7.28 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)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Sc1	0.48	0.44	210.6	190.5	18.13	16.55	195.7	189.1	64.56	107.36
Sc2	0.49	0.48	195.6	200.8	18	15.94	199.4	189.3	63.27	125.1
Sc3	0.50	0.43	76.83	78.04	11.67	10.15	171	164.3	83.7	89.05
Sc4	0.43	0.47	109.8	107	14.61	11.8	171.3	165.7	87.86	94.26
Sc5	0.54	0.45	118.1	109.7	14.23	14.82	171	166.2	77.67	126.6
Sc6	0.51	0.44	113.3	105.4	15.13	15.69	184.7	167	87.91	126.4

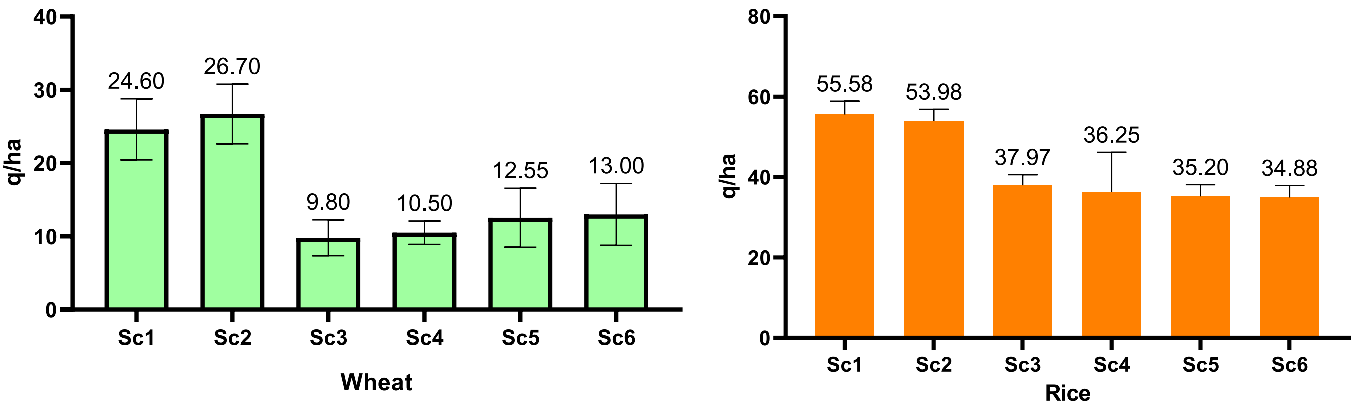


Figure 7.11 Trends of yield under LBNF (Sc3, Sc4, Sc5, Sc6) as well as fertilized treatments (Sc1, Sc2) with wheat (a - left) and rice (b - right)

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

In the fifth cropping cycle of the project, effect of the natural farming component was evaluated on growth and productivity of the rice (var. CSR 46) as well as wheat (var KRL283). Among 6 treatments, 2 treatments (viz; Sc-1 and Sc-2) were based on recommended chemical input-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. The field experiment was conducted with rice varieties CSR 46 and wheat variety KRL283. In case of wheat, 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 (Figure 7.11a). 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 from 0.5 % to 0.43 % (Table 7.28). 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 76.83 to 109.7 kg/ha whereas the treatments receiving chemical inputs has available N to the range of 190-205 kg/ha. Changes in soil microbial biomass was estimated in terms of dehydrogenase activity. It was found that dehydrogenase activity increased in all the natural farming treatments, under under wheat it increased from 64.56 to 126.22 μg/ml/hr. Although the treatments receiving natural farming components showed improvement in soil OC content and also microbial load, but the yield response of the rice were low. In case of rice the yield ranged from 34.88 to 37.97 q/ha (Figure 7.11b). The use of natural faming 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.

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

In the third season of cropping trials with salt tolerant wheat (var. KRL 283) and mustard (var. CS 60) were taken on the reclaimed plots with marine gypsum. The soil chemical parameters at the time of sowing was pH range 8.86 to 8.90, OC (%) ~ 0.24 to 0.27 and available nitrogen 56.37 to 57.2 kg/ha (Table 7.29). After the crop harvest the parameters showed increasing trends with respect to organic carbon and available nitrogen. Soil microbial activity showed decline because of low organic matter in the soil. The fish biomass gain showed improvement with the natural feeding, the income generated from the sale of fish was Rs 16,800/-, whereas the productivity of wheat obtained was 30.99 q/ha and for mustard was 1.32 q/ha.

Table 7.29 Changes in soil properties (chemical and biological) modules of Integrated farming system model

Treatments	pH_2		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	Initial	Final
Mustard Plots	8.96	8.9	0.27	0.26	56.37	58.04	11.62	11.18	218.3	185.4	81.64	72.28
Wheat Plots	8.86	9.0	0.24	0.27	57.20	105.7	10.48	9.843	204.3	191.4	79.99	71.64

During the year 2024, laminar air flow, Chisel plough and shieve shaker like infrastructure amounting Rs 1.9. 0.75 and 1.44 lakh, respectively were also procured under this project.

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)

The present project was undertaken to collect, multiply, and test traditional genotypes or landraces of various millet types for salt affected soils of Uttar Pradesh. As a part of first objective exploratory visits are currently being undertaken to collect millet races from farmers who are traditionally growing millets over years. Based on the millet production statistics available in public domain, districts were initially delineated where millet production has been documented with major focus on minor millets. Accordingly, the districts Sonbhadhra, Sitapur, Hardoi, Amethi, Etawah, Kaushambi, Lakhimpur Kheri, Kushinagar, Jalaun, Kanpur, Rampur, Mau, Jaunpur, Banda, Behraich, Barabanki, Ayodhya, Allahabad. As an attempt of ground truthing, before proceeding for exploration, the KVKs located in the respective districts were contacted to enquire whether there are any farmers who are growing millets traditionally since a long time. Through this exercise, it was observed that in districts of Kaushambi, Lakhimpur Kheri, Kushi Nagar and Banda such type of traditional millet cultivation is not followed. In addition to this, it was observed through interactions that such farmers are available in Raebareli, Gonda, Gazipur, Mirzapur, Chitrakoot and Azamgarh. In addition to these districts, major millets, i.e., sorghum and bajra are grown districts such as Auraiya, Ambedkar Nagar, Agra, Baduan, Baghpat, Ballia, Deoria, Etah, GB Nagar, Gorakhpur, Jalaun, Jhansi, Kannauj, Hatras, Mainpuri, Mathura, Meerut, Shahjahapur, and Varanasi. Thus, exploratory visits are started and locations which are nearer to Lucknow were covered so far which include



Photos of Farmers' Field Visit

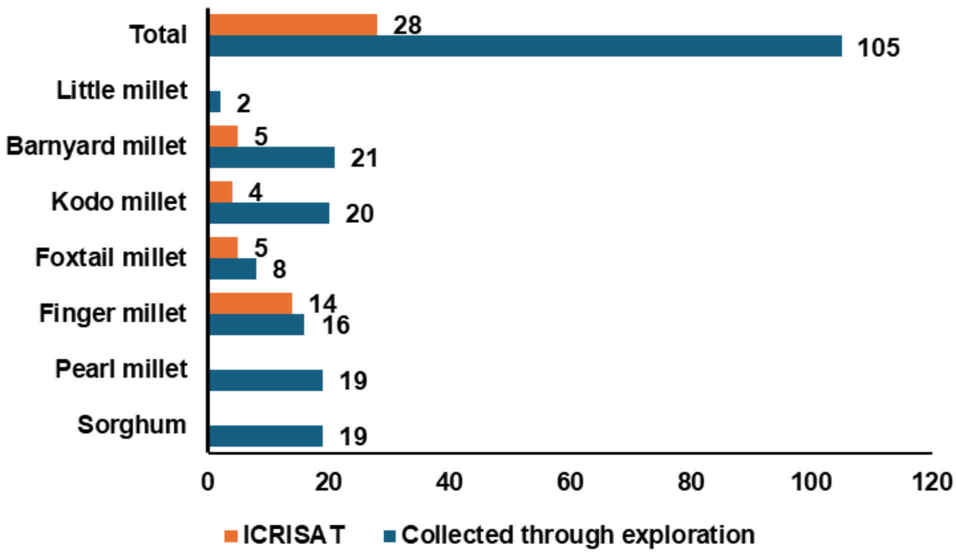


Fig 7.12 Number of various millet genotypes collected across different districts of Uttar Pradesh

Sitapur, Hardoi, Amethi, Raebareli, Behraich, Mau, Gazipur, Azhamgarh, Ayodhya, Basti, Deoria, Chitrakut, and Saravasthi. In addition, germplasm was also procured from ICRISAT, Hyderabad genebank. From the genebank portal only those genotypes were selected with GPS coordinates falling in Uttar Pradesh. The number of germplasm collected so far has been presented in figure 7.12. A total of 19 genotypes each of sorghum and pearl millet, 16 of finger millet, eight of foxtail millet, 20 genotypes of kodo millet, 21 genotypes of barnyard millet and two genotypes of little millet have been collected so far. In addition, 28 germplasm of finger millet, foxtail millet, kodo millet and barnyard millet are received from ICRISAT. Thus, a total of 133 millet germplasm is available so far. These will be multiplied during the summer season next year.

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)

During Rabi 2023-24 and Kharif 2024, demonstrations of salt tolerant varieties of wheat, mustard and paddy, reclamation and amelioration technologies at CATT, Sandila has been instituted. These demonstrations were visited by 17 batches of farmers representing 6 blocks of Hardoi district. On-farm assessment of varieties demonstrated in crop cafeteria and technological interventions including microbial bioformulations, nano formulations was done.

Soil samples of about 1680 farmers selected for demonstration of halophilic microbial bioformulation based amelioration coupled with salt tolerant varieties was done. Fourteen on-site farmers trainings were organized in 8 blocks of Hardoi district with total beneficiary of 737 farmers to boost productivity of sodic soils. Organized 2 on-campus trainings with 54 field officials for advanced technological management of sodic soils. On-farm demonstrations in wheat and mustard were conducted during rabi 2023-24 on about 1000 farmers field in 8 blocks of Hardoi district with moderate to high sodic soils. Different interventions like residue management through microbial decomposer 'Halo-CRD', salt tolerant variety and liquid microbial formulation 'Halo-Mix'.

On-farm demonstrations

Twelve varieties of paddy that includes CSR 10, CSR 13, CSR 23, CSR 27, CSR 36, CSR 43, CSR

Table 7.30 Performance of paddy varieties in crop cafeteria plots

Variety	Avg Plant Height (cm)	No. of tillers (Avg)	Avg Production of Grains (kg/m^2)
CSR-27	85.1	10.3	0.44
CSR-36	85.3	11.8	0.49
CSR-43	63.3	11.5	0.48
CSR-49	89.2	11.5	0.52
CSR-56	72.1	9.20	0.44
CSR-60	78.5	11.2	0.40
CSR-46	67.7	10.7	0.49
CSR-30	98.1	16.4	0.45
Damini	65.2	15.3	0.35
CSR-10	57.1	15.6	0.35
CSR-13	83.2	13.1	0.55
CSR-23	81.6	12.9	0.45

46, CSR 49, CSR 56 and CSR 60 were demonstrated at CATT center, Sandila, Hardoi under sodic environment as Crop Cafeteria. For comparison, a local popular check Damini was also demonstrated. The growth and yield observations for performance of varieties are presented in Table 7.30.

Technology demonstration was instituted 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, Nano Iron and Nano NMN as foliar spray compared with spray of zinc sulphate.

To demonstrate marine gypsum as an amendment for sodic soil compared with mineral gypsum, a demonstration was also conducted. The observation on performance of soil amendment showed that the soil amended with marine gypsum produced 8% higher crop yield compared with that of mineral gypsum.

Enhancing efficiency of chemical ameliorants for sodic soils

Isolated, screened and tested biochemically the sulphur oxidizing bacterial (SOB) strains for enhancing efficacy of gypsum dissolution for reclaiming sodic soils. Bio-chemical characterization of 13 effective strains of SOB and tested for their efficacy to enhance dissolution of mineral and marine gypsum for effective reclamation of sodic soils. In-vitro testing confirmed gypsum dissolution.

Reclamation and Management of Salt Affected Vertisols

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

A study on use of highly saline groundwater (7.5 to 8 dS m^{-1}) for irrigating wheat crop was carried out at the experimental farm, Samni (Bharuch) under drip, mini-sprinkler and border irrigation methods with adequate and deficit irrigation regimes. In case of adequate irrigation, full irrigation considering irrigation efficiency was applied in all three irrigation methods. For deficit irrigation, 25% less water was applied in drip and mini-sprinkler methods whereas surge irrigation was applied in border irrigation method. The results of the 2023-24 *rabi* season are discussed in this report

The performance of wheat crop in terms of yield and growth parameters was assessed and results are summarized in table 8.1. It was observed that drip irrigation was superior in terms of grain yield and test weight as compared to mini-sprinkler and border irrigation methods. As far as plant height and spikelet length is considered, there was no significant difference among the treatments.

Table 8.1 Yield and growth parameters of wheat under different treatments

Treatment	Test Weight (g)	Grain Yield (t ha^{-1})	Spikelet Length (cm)	Plant Height (cm)
SA	41.9	2.73	7.01	67.93
SD	40.7	2.53	7.20	65.73
DA	44.0	3.11	7.20	64.90
DD	43.2	2.95	7.13	64.47
BA	41.6	2.64	7.40	65.70
BD	39.2	2.55	7.33	67.93

SA: Sprinkler Adequate, SD: Sprinkler Deficit, DA: Drip Adequate, DD: Drip Deficit, BA: Border Adequate, BD: Border Deficit

The salt accumulation under different treatments was also studied and it was observed that the ECe of surface soil was higher than 5 dS m^{-1} for all the treatments whereas salt accumulation in subsurface layer was minimum in drip irrigation. Overall, performance of drip irrigation found better due to superior grain yield and quality and lesser salt accumulation in soil as compared to mini-sprinkler and border irrigation methods.

Performance of Indian mustard (*Brassica juncea*) under saline vertisols (Monika Shukla and Anil R. Chinchmalatpure)

To find out suitable fertilizer dose with application of sulphur and Zn for mustard crop for this region. Experiment was set in split plot design with three replications. Mustard variety CS 58 was taken for this experiment. In the main plot treatments different levels of recommended dose of fertilizers (N and P) *i. e.* 100, 125 and 150% was taken and in the subplots application of additional nutrients was done i.e. No Additional Nutrients, S application @ 40 kg/ha, Zn application @ 5 kg/ha, S application @ 40 kg/ha + Zn application @ 5 kg/ha and K application @ 40 kg/ha + S application @ 40 kg/ha + Zn application @ 5 kg/ha.

Different growth parameters i. e. plant height and dry weight per plant at 30 and 60 DAS was found significantly highest with application of 150% recommended dose of

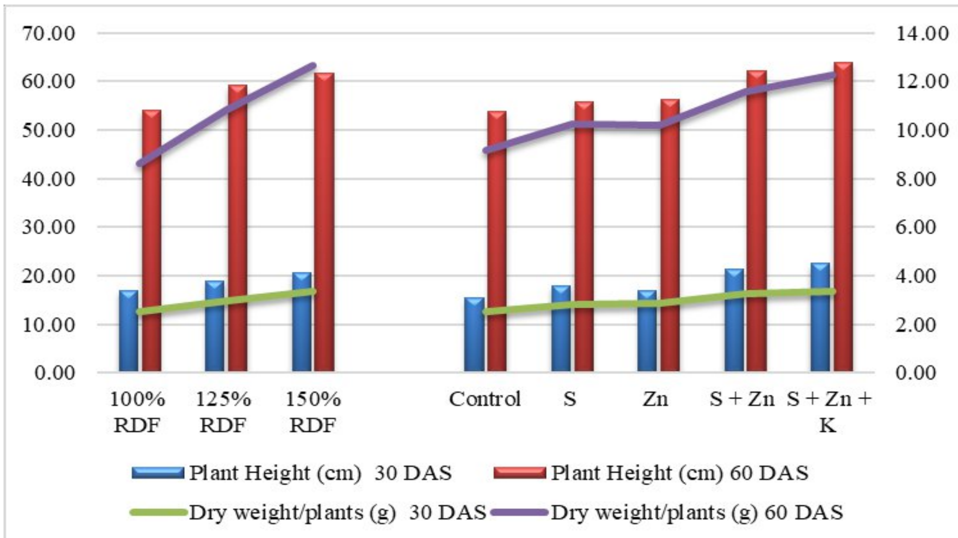


Fig 8.1 Plant height and dry weight of mustard at different interval as affected by various fertilizer treatments

nutrients (N & P) followed by application of 125% recommended dose of nutrients (N & P) (Fig 8.1). Significantly higher no. of primary and secondary branches were recorded with application of 150% recommended dose of nutrients (N & P), however, results were comparable to 125% dose for both parameters (Table 8.2).

Plant height and dry weight per plant at 30 and 60 days was significantly higher with application of K @ 40 kg/ha + S @ 40 kg/ha + Zn @ 5 kg/ha (N5), these results were found at par with application of S @ 40 kg/ha + Zn @ 5 kg/ha (N4) for all parameters (Table 8.2). Significantly highest primary and secondary branches was counted with application of K @ 40 kg/ha + S @ 40 kg/ha + Zn @ 5 kg/ha (N5), however similar results were observed with application of S @ 40 kg/ha + Zn @ 5 kg/ha (N4). Individual application of S and Zn gave comparable results for all parameters and these results were significantly higher in compare to no additional nutrient application (Table 8.2). No. of pods per plant affected significantly with different fertilizer doses and application of 150% recommended dose of nutrients (N & P) gave highest no. of pods per plant, however, it was comparable with

Table 8.2 Different growth and yield parameters of mustard as affected by various fertilizer treatment during 2023-24

	No. of Primary Branches/ Plant	No. of Secondary Branches/ Plant	No. of Pods/ Plant	No. of Seeds/ Pod	Yield (q/ha)		Total Biomass (q/ha)	Test weight (g)	Harvest Index (%)
					Seed	Stover			
Fertilizer Levels									
F1: 100% RDF	5.41	9.37	199	8.10	8.24	30.65	38.89	4.35	21.41
F2: 125% RDF	6.27	10.70	218	8.28	9.46	34.11	43.57	4.49	21.74
F3: 150% RDF	6.61	11.59	234	8.64	10.13	34.51	44.65	4.61	22.76
SeM	0.09	0.24	6	0.14	0.19	0.46	0.50	0.07	0.49
CD	0.35	0.94	22	NS	0.75	1.79	1.95	NS	NS
Additional Nutrients									
N1: No Additional Nutrients	5.41	9.44	201	7.46	8.58	31.41	39.99	4.26	21.63
N2: S @ 40 kg/ha	6.08	10.51	214	8.51	9.12	33.06	42.19	4.59	21.62
N3: Zn @ 5 kg/ha	5.98	10.31	204	7.96	8.86	32.64	41.50	4.31	21.39
N4: S @ 40 kg/ha + Zn @ 5 kg/ha	6.39	11.06	230	8.80	9.87	33.88	43.75	4.59	22.73
N5: K @ 40 kg/ha + S @ 40 kg/ha + Zn @ 5 kg/ha	6.61	11.44	235	8.96	9.96	34.45	44.41	4.67	22.48
SeM	0.10	0.24	5	0.17	0.16	0.68	0.65	0.08	0.55
CD	0.30	0.70	13	0.51	0.47	1.99	1.89	0.22	NS

125% dose. No. of seeds/pod did not affected significantly by any fertilizer dose treatment (Table 8.2).

Application of 150% recommended dose of nutrients (N & P) provided significantly highest seed yield (10.13q/ha), stover yield (34.51 q/ha) and total biomass (44.65 q/ha), however the results were comparable to 125% dose of fertilizers. Harvest index and test weight did not affected by treatments however numerically higher values were observed with 150% dose of fertilizers (Table 8.2). Significantly highest no. of pods per plant was observed with K @ 40 kg/ha + S @ 40 kg/ha + Zn @ 5 kg/ha (N5), these results were found at par with application of S @ 40 kg/ha + Zn @ 5 kg/ha (N4) followed by S @ 40 kg/ha (N2). No. of seeds/pod and test weight were found highest and comparable in N5 (K @ 40 kg/ha + S @ 40 kg/ha + Zn @ 5 kg/ha), N4 (S @ 40 kg/ha + Zn @ 5 kg/ha) and N2 (S @ 40 kg/ha). Seed yield, Stover yield and total biological yield was found significantly higher with application of N5 and N4. Application of different additional nutrients provided statistically similar harvest index with numerically higher value for N4 and N5. Total biomass was found significantly higher in N5, N4 and N2 as compare to others.

Seed Production of six mustard varieties from Breeder Seed: Seed production of six mustard salt tolerant varieties developed by CSSRI, including newly released varieties (CS-56, CS-58, CS-60, CS-61, CS-62 and CS-64) were done in small plots at ICAR-CSSRRI, RRS, Bharuch. However the sowing was done very late in mid of December, all salt tolerant varieties germinated and grown very well in Bharuch condition.

Assessment of Aniline-ETP treated effluent irrigation on growth and yield of wheat crop in black cotton soils (Anil R. Chinchmalatpure, Sagar Vibhute D, David Camus, Monika Shukla and R.K. Yadav)

A field experiment was conducted with wheat variety (KRL 210) with the application of nitrogen through urea and irrigation using treated effluent of Aniline ETP of GNFC Unit II in factorial design with three replications. The treatments comprises of (I_1) best available water (BAW) as such *i.e.* treated effluent: BAW (0:1 ratio); (I_2) treated effluent & BAW (1:1 ratio); and (I_3) treated effluent as such i.e. treated effluent: BAW (1:0 ratio) with combination of three nitrogen doses (N_1= 0 kg N ha^{-1}; N_2= 80 kg N ha^{-1}; N_3=120 kg N ha^{-1} and N4=160 kg N ha^{-1}). The plot (3.0 m x 1.5 m) was prepared for fine tilth with designed layout. The seed of wheat (variety KRL210) was sown during the month of December and applied irrigation as well as fertilizer as per the design of layout. Germination percentage was 85-90 percent in all the treatment combinations. Each plot was irrigated with water at 25 days interval. A total of four irrigations were given during the course of the experiment. Soil samples analyzed for pHs and ECe from the field at different depths (0-15, 15-30, 30-90, 90-120 cm). Soil samples were collected prior to each treatment and analyzed for salinity build up, pH and ionic compositions. The pH values were observed at neutral range. Soil pH values were ranged from 7.0-7.4, 6.9-7.4 and 6.9-7.5 for I_1, I_2 and I_3 treatments, respectively with mean values of 7.3, 7.2 and 7.2. Similarly ECe values ranged from 1.2-2.0 dS m^{-1}, 1.2 to 4.3 dS m^{-1} and 1.4 to 4.5 dS m^{-1}, respectively for I_1, I_2 and I_3 treatments with mean values of 1.7 dS m^{-1}, 2.7 dS m^{-1} and 2.8 dS m^{-1}. In I_2 and I_3 treatments, surface soil having slightly higher electrical conductivity values (> 4.0 dS m^{-1}), while I_1 having lower values at surface layer.

Soil samples analyzed for soil saturation extract composition (Table 8.3). In 0-15 cm soil layer, mean pH_2 values were 7.1, 7.3 and 7.2 for I_1, I_2 and I_3 treatments, respectively, while

Table 8.3 Soil pH, ECe and saturation extract composition from soil before experiment

Treatment	pH_2	EC_e	Cations (me/l)			Anions (me/l)					
			SAR	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3-	HCO_3^-	Cl^-	SO_4^{2-}
0-15 cm											
I1	7.1	0.69	1.75	3.18	1.69	0.008	3.95	1.89	3.88	0.038	1.07
I2	7.3	0.88	2.16	3.78	1.98	0.010	3.93	1.36	2.56	0.036	1.15
I3	7.2	1.15	1.92	3.69	2.40	0.007	4.23	1.39	4.48	0.037	1.43
15-30 cm											
I1	7.4	0.78	1.78	3.85	1.61	0.01	3.25	1.19	3.60	0.035	0.94
I2	7.5	1.89	2.66	4.54	1.76	0.01	4.91	1.65	3.90	0.029	0.89
I3	7.3	2.15	1.98	2.81	2.30	0.01	5.65	2.19	4.46	0.028	1.51

I1= 0:1 (Treated Effluent: BAW); I2= 1:1 (Treated Effluent: BAW); I3= 1:0 (Treated Effluent: BAW)

Table 8.4 Effect of treated effluents and nitrogen on yield parameters of wheat crop

Treatment	Fresh weight (g)	Dry weight (g)	Plant height (cm)	No of Spike	No of tiller	Grain Yield (q/ha)	Straw Yield (q/ha)
I1N1	21.58	9.83	31.82	5.67	7.67	29.96	50.17
I1N2	23.46	9.46	36.15	6.67	8.33	23.46	42.40
I1N3	22.67	9.42	40.82	6.67	6.33	31.20	52.50
I1N4	31.81	12.57	45.43	7.67	8.00	30.45	51.94
I2N1	23.53	9.59	36.92	6.33	8.00	28.35	50.62
I2N2	23.78	10.06	37.83	6.33	8.67	27.47	49.06
I2N3	31.64	11.47	41.70	7.00	6.67	30.60	51.06
I2N4	33.40	13.50	44.12	7.67	6.00	31.51	55.72
I3N1	24.86	5.34	28.27	6.00	5.67	27.97	49.95
I3N2	25.43	6.12	32.63	7.00	5.67	26.85	47.95
I3N3	23.38	6.49	33.87	6.67	4.67	25.66	46.84
I3N4	26.22	9.46	35.12	6.67	5.33	24.54	39.96

the concurrent values for 15-30 cm soil layer, pH_2 values were 7.4, 7.5 and 7.3, respectively, which showing overall in neutral in range. Similarly ECe values were 0.69 dS m^{-1}, 0.88 dS m^{-1} and 1.15 dS m^{-1}, respectively for I_1, I_2 and I_3 treatments, while in the lower depth it varied from 0.78 to 2.15 dS m^-1 for I_1 to I_3 treatment. Among the cations compositions, Mg^{2+} ions was predominant which was followed by Ca^{2+}, Na^+ and K^+ in I_2 and I_3 irrigated plot while among anions composition, the trend were as followed $CO_3^{2-} > Cl^- > HCO_3^- > SO_4^{2-}$ in both soil layer.

Growth and yield parameters of wheat crop

Data indicated that wheat growth parameters like fresh weight (g), dry weight (g), plant height (cm), number of spikes and number of tillers, grain yield (q/ha) and straw yield (q/ha) were found to be higher under treated effluent (I_2) treated plot which was followed by I_1 and (I_3) treated plot (Table 8.4). Treated diluted effluent application has resulted in higher yield of wheat crop as compared to BAW. Treated effluent diluted with BAW (I_2) gave the highest seed yield (3151 kg ha^{-1}) suggesting the possibility of using the effluent in slightly diluted manner for maximizing the yield. On the basis of dilution of treated effluent and optimum dose of nitrogen, effect on yield and its parameters of wheat crop would be beneficial for improving crop productivity as well as soil health, because treated effluent irrigated soils are having higher organic carbon content as compared to normal soils (without treated effluent irrigated soils) which ultimately supplying macro & micro nutrient to arable crops for achieving sustainable yield (based on the study of long term use of treated effluents as source of irrigation).

Table 8.5 Initial soil parameters of the experimental plots

Parameters	0-15 cm	15-30 cm	30-60 cm
$EC_e (dSm^{-1})$	0.47	0.46	0.42
pH_s	7.55	7.44	7.36
Na (me/l)	5.66	3.59	3.05
K (me/l)	0.14	0.22	0.09
Ca (me/l)	1.38	1.13	1.50
Mg (me/l)	2.13	1.75	1.50
Cl- (me/l)	11.25	8.75	5.00
SO_4^{2-} (me/l)	1.31	0.85	2.13
CO_3^{2-} (me/l)	5.00	5.00	3.75
HCO_3^- (me/l)	0.00	0.00	0.63
OC (%)	0.52	0.41	0.49
Av. P_2O_5 (kg/ha)	48.01	51.50	47.19
Av. K^+ (kg/ha)	650.80	591.78	531.83

Enhancing Productivity and Sustainability of Saline Vertisols through Drumstick Agroforestry (David Camus D, Monika Shukla and Anil R Chinchmalatpure)

This project aims to improve productivity and sustainability in these areas by integrating a drumstick-based agroforestry system with conservation agriculture practices. A field experiment with *Moringa oleifera* var. PKM-1 as the main component is being conducted at Samni experimental farm of ICAR-CSSRI, RRS, Bharuch. The detailed treatments are as follows:

Factor 1: Pruning Time

- Level 1: Regular pruning
- Level 2: Pruning for off-season production

Factor 2: Tillage

- Level 1: Conventional tillage
- Level 2: Zero/reduced tillage

Factor 3: Cropping Sequence

- Level 1: Wheat-Fodder crop-Arhar/cow pea
- Level 2: Wheat-Fallow-Arhar/cow pea

One-month-old, 40 cm tall *Moringa oleifera* var. PKM-1 seedlings were planted, and irrigation water with an EC of 7.34 dSm^{-1} is being used. The mortality after one month was 27 %. The initial soil parameters were collected at different depths (0-15 cm, 15-30 cm, and 30-60 cm) and are presented in the table 8.5.

To evaluate the impact of these treatments on crop productivity, soil health, and overall system sustainability, the field experiment will commence after the establishment of the *Moringa oleifera* var. PKM-1 seedlings.

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

A field experiment with three dragon fruit cultivars is being conducted at the experimental farm, Samni of ICAR-CSSRI, RRS, Bharuch. The detailed treatments are as follows:
Factor 1: Dragon fruit cultivars

- Jumbo red
- Srilankan red
- Lemon orange

Dragon fruit experimental site

Factor 2: Saline water irrigation

- 3 dS/m
- 6 dS/m
- 9 dS/m

Factor 3: Bio-stimulants

- No bio-stimulant
- Seaweed extract
- Humic acid
- Green miracle anti-transpirant bio-stimulant

Dragon fruit cultivars, namely Jumbo red, Srilankan red, and Lemon orange, were planted at a plant-to-plant spacing of 3 m and a row-to-row spacing of 4 m, as shown in photo. Bio-stimulants will be applied foliarly/basally at recommended rates. The initial soil analysis revealed the following parameters: EC_e (0.45 dS/m), pH_s (7.45), Na^+ (4.10 meq/l), K^+ (0.15 meq/l), Ca^{2+} (1.34 meq/l), Mg^{2+} (1.79 meq/l), Cl^- (8.33 meq/l), SO_4^{2-} (1.43 meq/l), CO_3^{2-} (4.58 meq/l), and HCO_3^- (0.21 meq/l).

Data will be collected on plant growth parameters, physiological parameters, fruit yield, fruit quality parameters, and soil parameters to identify the most salt-tolerant dragon fruit cultivar, determine the optimal salinity level for each cultivar, evaluate the effectiveness of different bio-stimulants in mitigating salinity stress, and develop best management practices for dragon fruit cultivation in saline environments.

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

Experiment 1: 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 (ECe 6-7 dS m^{-1}). Plant height varied from 62.22 cm (HD-2851) to 106.56 cm (Kh 65). HD-2851, HD-2009, KRL-99, KRL-2020, KRL-2311 came to 50% flowering in 41-48 days however KRL-2213, KRL-2214, KRL-2303, KRL-2304, KRL-2305, KRL-2308, KRL-2310, KRL-2114, came late in 50 % flowering in 58-70 days. Grain yield (0.9 m^2) ranged from 159 g (KRL-2213) to 396 g (KRL 2207). Biomass yield (0.9 m^2) varied from 466 g (KRL-2308) to 939 g (KRL-2302). Top five high yielding varieties were KRL 2207 (396 g), KRL 2302 (388 g), KRL-1803 (359 g), KRL-283 (352 g), KRL-210 (352 g). Moreover, test weight of the genotypes ranged from 37.47 g (KRL 2212) to 50.60 g (KRL 2207). Yield and yield attributes of top 15 genotypes performed best in terms of yield is given in table 8.6.

Table 8.6 Yield and yield attributes of fifteen best performing KRL and IIWBR wheat genotypes during the 2023-24 on saline Vertisols

Variety	Plant Height	Days to 50% Flowering	Length of Panicle (cm)	Seed Yield (g)	Biomass yield (g)	Test Weight	Days to maturity
KRL 2207	77.00	56	9.25	396	923	50.60	100
KRL 2302	91.33	56	7.95	388	939	45.43	99
KRL 1803	83.00	57	8.02	359	804	49.90	103
KRL 283	73.60	54	7.70	352	757	45.37	103
KRL 210	77.44	54	7.85	352	937	47.80	100
HD 2009	74.22	48	7.47	349	847	47.40	99
HD 3086	78.00	54	8.23	349	823	47.07	104
KRL 2305	83.44	58	8.67	342	775	47.13	106
KRL 2020	86.33	48	7.90	334	772	47.13	99
KRL 2301	84.89	56	7.40	330	873	50.20	99
KRL 2215	83.56	57	8.33	330	813	48.07	99
DBW 222	80.89	56	8.33	327	820	42.47	103
KRL 99	73.00	48	7.68	319	743	45.40	99
KRL 2307	83.00	57	8.57	314	746	47.00	104
KRL 423	78.11	57	7.73	295	690	45.97	103

Table 8.7 Yield and yield attributes of five best performing SPLASN wheat genotypes during the 2023-24 on saline Vertisols

Variety	Plant Height	Days to 50% Flowering	Days to Maturity	Grain yield (g/plot)	Test weight (g)
SPLASN 10	83.0	53	105	1089	57.3
SPLASN 16	92.3	57	113	1068	35.0
SPLASNCK 04	69.4	48	105	1060	40.2
SPLASN 15	79.7	57	106	1059	40.0
SPLASN 22	85.7	63	107	1047	40.8

Table 8.8 Yield and yield attributes of eleven best performing KRS wheat genotypes during the 2023-24 on saline Vertisols

Variety	Plant Height	Days to 50% Flowering	Days to Maturity	Length of Panicle (cm)	Grain yield g/plot)
KRS 23029	86.00	56	105	7.75	700
KRS 21053	86.33	62	112	9.05	675
KRS 21001	93.33	51	110	10.25	637
KRS 23032	85.67	55	110	9.65	620
KRS 23034	94.67	57	110	8.55	613
KRS 23035	84.00	57	110	8.20	610
KRS 21061	97.00	55	110	10.00	603
KRS 23026	83.33	55	110	8.95	595
KRS 23033	89.00	55	110	8.85	592
KRS 23057	91.00	55	105	9.45	557
KRS 23004	93.33	56	110	9.95	547

Experiment 2: Wheat SATSN trial with 24 entries with 5 checks was conducted in 2023-24. Entries were evaluated in given protocol and design on salt affected *Vertisols* (ECe 6-7 dS m^{-1}). Plant height varied from 69.4 cm (SPLASNCK 04) to 108.7 cm (SPLASNCK 01). Days to flowering ranged from 48 (SPLASNCK 04) days to 70 (SPLASN 07) days. Days to maturity ranged from 105 (SPLASNCK 02-05) -116 (SPLASN 07 & SPLASN 11) days. Top five high yielding entries were SPLASN 10 (1089 g/plot), SPLASN 16 (1068 g/plot), SPLASNCK 04 (1060 g/plot), SPLASN 15 (1059 g/plot) and SPLASN 22 (1047 g/plot) (Plot size 3 Sqm).

A glimpse of various crop improvement trials at ICAR CSSRI RRS Bharuch

Test weight ranged from 30.3 g (SPLASN 11) to 57.3 (SPLASN 10). Yield and yield attributes of top 5 entries performed best in terms of yield is given in table 8.7.

Experiment 3: 140 advanced breeding lines from ICAR-CSSRI were also evaluated on salt affected *Vertisols*, irrigated with saline water of EC_{iw} 6-7 dS/m in an augmented completely randomized block design. Among them 92 lines only harvested this year, other lines get damaged due to the animal's attack in the farm. Plant height varied from 70 cm (KRS 23068) to 98 cm (KRS 23103 & KRS 23105). Days to flowering ranged from 47 days (KRS 21009 & KRS 23097) to 68 days (KRS 23021, KRS 23054, KRS 23068, KRS 23071, KRS 23073 & KRS 23075). Length of panicle ranged from 7.25 cm (KRS 23036) to 11.4 cm (KRS 21135). Grain yield (1.5m^2 plot) ranges from 140 g (KRS 23094) to 700 g (KRS 23029). Days to maturity ranges from 105 days to 114 days. Test weight ranged from 33.99 g (KRS 23068) to 58.87 g (KRS 23091). Yield and yield attributes of top 11 lines performed best in terms of yield is given in table 8.8.

Genetic enhancement of maize (*Zea mays* L.) for the development of high yielding and climate resilient hybrids (Monika Shukla)

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

Twenty nine maize genotypes (IMR-1 to IMR-29) were evaluated under varying levels of irrigation water salinity (0, 6 and 9 dS m^{-1}) on salt affected *Vertisols* in rabi 2023-24. The objective was to identify salt tolerant lines along with key physiological traits related to salt tolerance.

Germination and plant growth affected significantly with saline water irrigation. IMR-24 did not germinate in the experiment. IMR-11 and IMR-26 germinated in no salinity, however did not grow up in 6 and 9 dS m^{-1} saline water irrigation. Germplasms from IMR-21 to IMR-29, germinated well in no salinity water and 6 dS m^{-1} saline water irrigation however, did not germinated in 9 dS m^{-1} saline water irrigation except IMR-25. Range for various growth and yield parameters under different levels of saline water irrigation is given in table 8.9. Days to flowering ranged from 80-70 days in no salinity water irrigation. Range of 80-73 days to flowering was observed with 6 dS m^{-1} and 9 dS m^{-1} saline water irrigation. No. of cobs per plant did not show much variation and 2-1 cobs per plant range was observed for no salinity water and 6 dS m^{-1} saline water irrigation, however only 1 cob per plant was observed for 9 dS m^{-1} saline water irrigation. IMR 15 performed best under all levels of saline water irrigation in terms of yield and various yield parameters.

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

Traits	Best available water		6 dS m^{-1} irrigation water		9 dS m^{-1} irrigation water	
	Max	Min	Max	Min	Max	Min
Plant height	190 (IMR-14, IMR-15)	113 (IMR-22)	176 (IMR-15)	82(IMR-27)	156 (IMR-15)	96 (IMR-8)
Cob length (cm)	18.8 (IMR-15)	9.8 (IMR-29)	17 (IMR-15)	8.3(IMR-21, IMR-22)	15.1 (IMR-15)	7.4 (IMR-19)
Cob weight (g)	211 (IMR-15)	26(IMR-29)	141(IMR-15)	17.8 (IMR-29)	78 (IMR-15)	12.8 (IMR-19)
Cob yield per plant (g)	317(IMR-15)	26(IMR-29)	170(IMR-15)	18 (IMR-29)	95(IMR-15)	13(IMR-19)
Grain yield per plant (g)	78(IMR-15)	5(IMR-29)	56(IMR-15)	4(IMR-29)	33(IMR-15)	3(IMR-19)
No. of Grains/cob	395(IMR-15)	120(IMR-11)	246(IMR-2)	55(IMR-21)	231(IMR-2)	24(IMR-25)
100 Seed weight (g)	29(IMR-15)	14(IMR-26)	24(IMR-15)	13(IMR-21)	22(IMR-15)	13(IMR-25)

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 and its associated impacts, such as rising sea levels and increased soil and water salinity, pose significant threats to food production in the coastal regions. This study aims to assess the impact of climate change and salinity on rice yields and validates the FAO AquaCrop model for predicting future yield responses. A field experiment was conducted during the dry season of 2023-24 at 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 dS m^{-1}) to calibrate the AquaCrop model. Canning 7 recorded the highest average yield (3.64 t ha^{-1}), followed by Sada Minikit (3.42 t ha^{-1}) and BPT 5027 (1.60 t ha^{-1}). While the highest grain yield (3.77 t ha^{-1}) was recorded with good quality irrigation water, the lowest (2.19 t ha^{-1}) was observed with irrigation water salinity of 6 dS m^{-1} (Table 9.1). Significant interaction effects between water 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 (5.41 t ha^{-1}), followed by Sada Minikit (moderately tolerant, 4.76 t ha^{-1}) and BPT 5027 (sensitive, 4.50 t ha^{-1}). There was a reduction in rice yield by 8.2-20.4% in Canning 7 followed by 16.6-32.9% in Sada Minikit with saline water irrigation of 4 and 6 dS m^{-1}, respectively. A severe yield reduction of 68.8 to 80.0% was recorded in the sensitive variety BPT 5027.

The AquaCrop model was also calibrated using the *rabi* 2023-24 experimental data. The model's performance was evaluated using statistical indices: RMSE for the grain yield was 0.42, NRMSE was 14.35%, and R^2 was 0.95, while for the biomass yield, RMSE was 0.50, NRMSE was 6.48%, and R^2 was 0.91. The model marginally overpredicted the grain yield, with an average deviation of 13.08%, whereas the biomass predictions were more accurate, with only a 0.83% deviation. The calibrated model will be validated in the next season and used to predict the impacts of salinity increases and climate change on rice production in the Sundarbans region.

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	3.77a	5.40a
Saline water (EC_{iw} - 4 dS m^{-1})	2.70b	4.92b
Saline water (EC_{iw} – 6 dS m^{-1})	2.19c	4.35c
$LSD_{0.05}$	0.24	0.28
Variety		
Canning 7	3.64a	5.41a
Sada Minikit	3.42b	4.76b
BPT 5024	1.60c	4.50b
$LSD_{0.05}$	0.18	0.26
Interaction		
Water quality x Variety	0.31	Ns
Variety x Water quality	0.35	Ns

Treatment means with the same letter are not significantly different; ns – non-significant

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

Paddy straw mulched potato plant under drip irrigation

The rainfall in coastal West Bengal is confined to a few months of the Monsoon. As the post-monsoon rainfall is erratic and there is fresh water scarcity for agriculture. The water scarcity is more towards summer as the surface water sources dry up. All the coastal low lands are inundated with rain water during the *kharif* season where mainly paddy is cultivated and the productivity is low. 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 the next crop in conventional *rabi* cropping. However, zero tillage potato can immediately be planted with less water by utilizing residual soil moisture available during rice harvest and incremental water saving is made by applying efficient irrigation through 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 three objectives; (i) evaluate the water savings 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 different water qualities through irrigation system and conventional method on crop productivity and (iii) to devise irrigation scheduling for better cropping. The test crop is potato (var. Kufri Pukhraj). Before experimentation, soil samples were collected from the root zone and analyzed for EC_e and pH_s. After the *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 (Photo). The drip laterals were placed over the straw layer and water of desired quality supplied from tanks by a 0.5 hp electric pump. Water salinity such as 1~2 dS m^{-1} and 5~6 dS m^{-1} were prepared and used in the experiment. Irrigation scheduling was done based on IW/CPE ratios 0.5 and 0.7. There were eight treatments for two water salinities such as T1: ECw(1~2 dS m^{-1}), IW/CPE=0.5; T2: ECw (5~6 dS m^{-1}), IW/CPE=0.5; T3: ECw (1~2 dS m^{-1}), IW/CPE=0.7; T4: ECw (5~6 dS m^{-1}), IW/CPE=0.7 irrigated with drip system and TC1: ECw (1~2 dS m^{-1}) IW/CPE=0.5; TC2: ECw (5~6 dS m^{-1}), IW/CPE=0.5; TC3: ECw (1~2 dS m^{-1}), IW/CPE=0.7; TC4: ECw (5~6 dS m^{-1}), IW/CPE=0.7 irrigated as per the farmers' practice (Control) by spraying water on the crop. Saline water irrigation was imposed after 1 month of seed sowing when the crop got established.

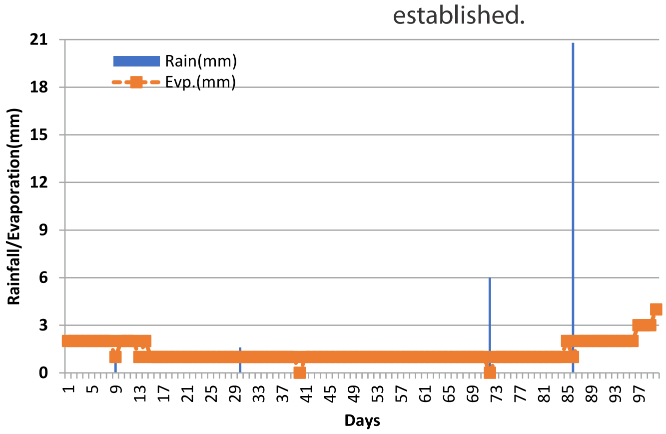


Fig 9.1 Rainfall and evaporation during the cropping period

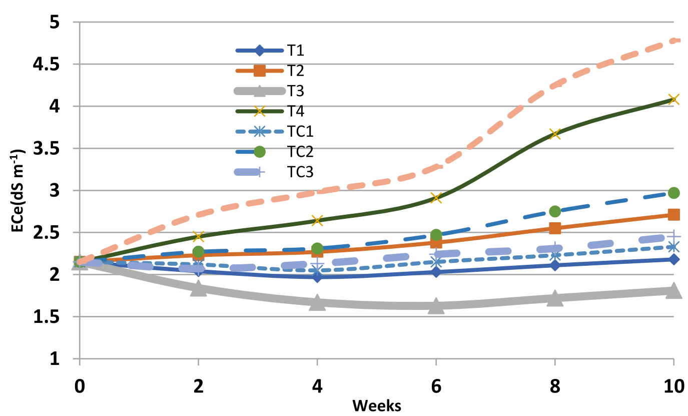


Fig 9.2. Temporal soil salinity variation during the cropping period

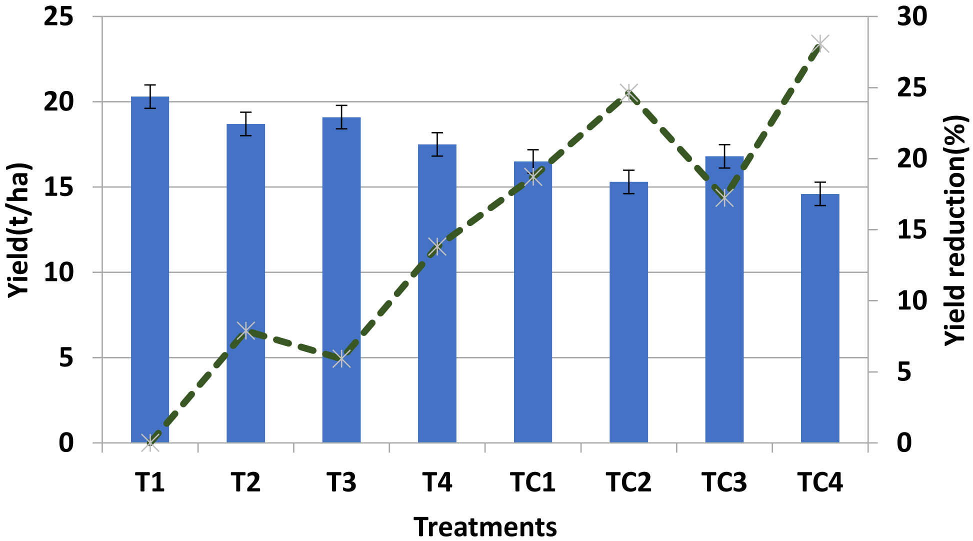


Fig 9.3 Yield of zero tillage potato with straw mulch

Sowing of the potato seed was done in 2nd week of November 2023 when the soil ECe was less than 3 dS m^{-1} and harvesting of potato was done in 3rd week of February 2024. The weather data (rainfall & evaporation) during the cropping period is shown in Fig 9.1. There was a rainy day with about 20 mm rainfall at the crop maturity stage.

Recommended doses of fertilizers applied at 30, 45 and 60 days after date of sowing. Irrigation for conventional zero tillage potato was given by spraying water on the crop. It was observed that the growth of potato plant was the best for T1. Salinity of the top soil (15 cm) was the highest (4.78 dS m^{-1}) for saline water (5~6 dS m^{-1}) with IW/CPE=0.7 in control (TC4) at the time of harvest (Fig 9.2). There was 27 % water saving for treatment with IW/CPE ratio 0.5 than IW/CPE ratio 0.7.There was 29.8 mm rainfall during the cropping period of 100 days.

The chlorophyll content of potato plants were 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 harvesting was done by removing the straw and laterals and picking up the potatoes. Potato yield was 28 % higher for T1 where irrigation was applied through drip than higher saline water irrigation applied as per farmers' practice (TC4). The highest yield of 20.3 t/ha was obtained for treatment, T1. The highest yield was 7 % lower than the previous year highest yield (Fig 9.3). This was due to infestation of the crop by late blight during the end stage.

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

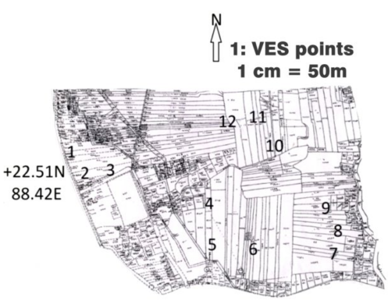


Fig 9.4 Study area (Kanthalberia village of coastal West Bengal; 1: VES Points)

The productivity of agricultural crops produce of Coastal West Bengal is low. This is mainly due to high groundwater salinity particularly during spring season. In many areas ground water may occur in perched aquifer at greater depths (>40 m and up to 300 m) which is non saline and available for cultivation of crops. Exploration of groundwater sources by geo-electrical method is one of the inexpensive and in-situ methods and has been used for long. Field investigations were carried out in the Kanthalberia village of coastal West Bengal. Twelve VES were carried out throughout the village (Fig 9.4) to determine the resistivities of different subsurface layers and correlate with the nearby borehole

Table 9.2. Resistivity data of Kathalberia village of Coastal West Bengal (2nd season)

VES No.	Layer No.					T (40 m) Ohm-m^2	S (40 m) dS
	I	II	III	IV	V		
1 h	0.4	12	41	22	?	16066.8	0.49
ρ	537	450	212	80	50		
2 h	15	30	388	54	?	29420	0.089
ρ	200	250	370	90	86		
3 h	10	15	30	10	?	26130	0.224
ρ	180	208	400	182	395		
4 h	3.0	8	10.0	42	?	16542	0.29
ρ	148	132	376	240	370		
5 h	6.7	8.7	17.5	68	?	17797	0.59
ρ	148	119	124	200	318		
6 h	4	20	27	39	?	32739	0.32
ρ	146	143	344	213	100		
7 h	3.7	4.9	10.5	25	?	11295	0.25
ρ	300	100	190	250	250		
8 h	14	25	30	45	?	25620	0.69
ρ	205	250	400	100	150		
9 h	10	5	10.6	25	?	24200	0.68
ρ	145	250	100	200	250		
10 h	5	4	10	21	?	16123	0.13
ρ	300	100	341	213	150		
11 h	2.5	5	10	25	?	6125	0.64
ρ	400	100	350	250	200		
12 h	2	10	20	10	?	13900	0.14
ρ	300	150	340	300	250		

T- Transverse unit resistance; S- Longitudinal unit conductance

lithologs to understand the overall geohydrological situations. Out of these, VES 1, 2, 3 come in the western part and VES 4,5,6,7,8,9,10,11 and 12 come in the eastern part of the study area. A road passing north-south direction divides the VES points. The field data were interpreted for true resistivity and corresponding thickness of different sub-surface horizons. To locate the potential aquifer, the Dar Zarrouk parameters were used. Ground water samples were collected from tube-wells situated near different VES locations and analyzed for EC_w, pH_w, Na, K, Ca, Mg, CO3, HCO3, Cl etc. The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate five geoelectric layers (Table 9.2). Resistivity data of VES 1 was correlated with nearby bore-hole data. Resistivity data of VES 1 was compared with the borehole lithology of adjoining tubewells. The resistivity data of VES 1 show the presence of a layer of 537 ohm-m up to 0.4 m and another layer of 450 ohm-m at 12.0 m (Fig 9.5).

The resistivity values of 145-537 ohm-m up to 0.4-15 m depth indicate presence of soil cover (clay) and mangrove roots. The 450 ohm-m resistivity up to 12.0 m depth represents soil cover and sand. The 3rd layer with a resistivity of 212 ohm-m corresponds to fine sand and clay. In the interpreted data, the interface between 3rd and 4th layers is at 41.0 m below ground level (bgl) which agrees well with the borehole data. The resistivities of 3rd and 4th layer indicate water bearing zones. The resistivity of 80 and 50 ohm-m in the4th and 5th layer indicates presence of clay, salinity and small amount of kankar.

The first layer is upper ploughed layer and unsaturated soil. Predominantly clayey, high resistivity of 537 ohm-m at VES1 is due to the presence of hard plant root. Existence of a

Fig 9.5 Correlation of nearby borehole lithologs with resistivity data

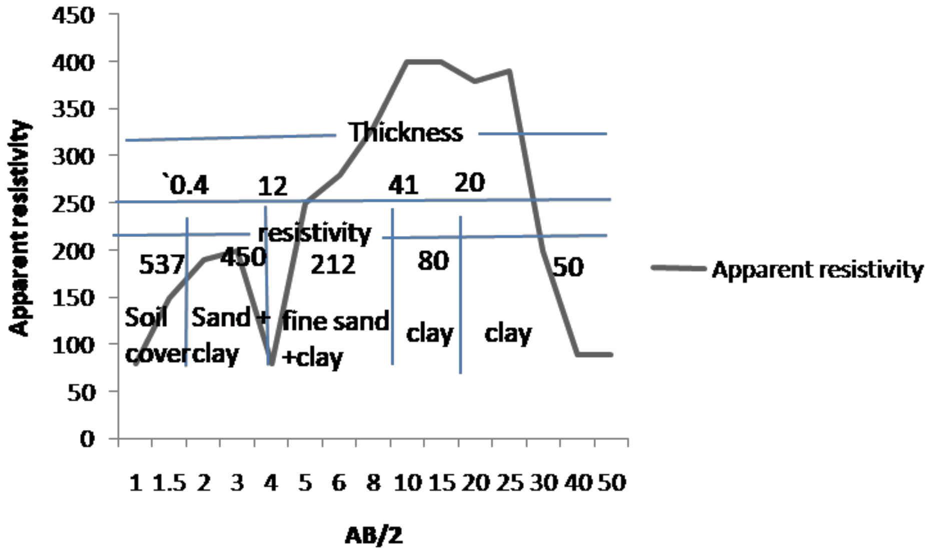


Table 9.3 Chemical characteristics of groundwater samples of Kanthalberia village

Tube well location	EC (dS/m)	pH	RSC (me/l)	SAR	Cations and anions (me/l)						
					Na^+	K^+	Ca^{+2}	Mg^{+2}	CO_3^{-2}	HCO_3^{-1}	Cl^{-1}
1	1.4	5.4	2	0.77	1.9	0.24	8	4	2	12	13.5
2	1.67	5.6	1	0.79	0.5	0.16	10	7	3	15	9
3	1.06	5.7	2	0.94	2.3	0.51	5	7	4	10	27
4	1.06	5.4	2	0.43	0.9	0.15	5	5	2	10	4.5
5	0.93	5.0	3	0.51	1.1	0.18	5	4	2	10	4.5
6	0.76	5.3	1	0.45	0.9	0.15	5	4	3	7	5
7	0.55	5.0	1	1.90	4.2	0.38	6	4	4	7	27
8	1.68	4.1	1	1.02	2.5	0.21	6	6	5	8	18

Tube-wells 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 9, 8. Near VES 10

hard layer below the puddled rice soil, contains sand and clay with relatively higher resistivity values. This layer extends 0.4 to 15 m below ground level (bgl) (Table 9.3). The 2nd layer is a ploughed layer and saturated soil. This layer extends from 4 m to 30 m bgl. Third layer is semi weathered zone of gneisses, contains clay and fine sand at deeper depth up to 21-39 m and clay and hard sand (kankar) with relatively high resistivity (=300 ohm-m) at higher depth of 21-68 m. Occurrence of good quality of groundwater is found throughout. Fourth layer extends from 10-68 m with a resistivity of 80 to 300 ohm- m indicating good quality groundwater, low resistivity layer is also the aquifer with high amount of clay. The fifth layer is having a resistivity of 50-395 indicates the presence of clay and small amount of kankar. High resistivity at VES 3 & 4 indicates presence of kankar. Low resistivity of other VES points are due to presence of clay.

The electrical conductivity (EC) of groundwater ranged from 0.55 to 1.68 dS m^{-1}, representing medium ($C_2/_3$) salinity group of USDA classification of irrigation water. The relatively high salinity (C_3) of irrigation water near some of the VES points was possibly due the presence of saline aquifer zone. The pH of the water samples varies from 4.1-5.7 with majority of the samples having pH>5.0, which indicates that the ground water was acidic. Carbonates in the groundwater samples were in trace amount in most of the tube wells (2-5 me l^{-1}). Bi-carbonate ion ranged from 7.0-15.0 me l^{-1}. The bi-carbonate content of the tube well water 6 and 7 were less than the other tube-wells. High bicarbonate caused slight alkalinity in the groundwater. 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 2,6,7, 8 could be safe, although RSC of other samples were slightly higher (samples 1, 3, 4 and 5), the harmful effects were not prominent because of low carbonate content. In clay loam to loam soil under Indian conditions, the samples 5 are also considered to be safe, although these are not suitable for use as per USDA classification. The sodium absorption ratio (SAR) of groundwater samples varied from 0.51 to1.9 me l^{-1}. On the basis of USDA classification, the samples may be classified under S_1 (low alkali hazards). The high chloride and sodium ion concentration in sample 1, 3, 7 & 8 (> 5 me l^{-1}) in the groundwater samples were responsible for relatively high SAR values. On the whole, the groundwater of the study area could be grouped under $C_2/_3S_1$.

Assessment of ichthyofaunal diversity, biology and population dynamics of selected species along the estuary of Sundarbans (R.N. Bhutia and U.K. Mandal)

The study on hydro-biological parameters, including water quality, plankton dynamics, and their relationship with fish abundance in the estuary offers a comprehensive understanding of the hydrobiological dynamics, providing essential information for the conservation and management of this vital ecosystem.

During 2024, seasonal variations in physico-chemical properties and fish abundance were studied and the data was subjected to General Additive Model (GAM) to assess the influence of key water quality variables on fish abundance, highlighting the prominent role physio-chemical parameters on fish abundance. Additionally, Pearson's correlation and BIO-ENV analysis were used to examine the relationships between phytoplankton abundance and water quality parameters, providing valuable insights into the primary producers' role in the estuarine ecosystem. Ecopath with Ecosim (EwE) software was used to construct a mass-balance trophic model, describing the food web and trophic structure of the estuary.

The water quality parameters did not reveal spatial variation with statistically significant differences, however, one-way ANOVA (post hoc Tukey test) of seasonal variation in water quality parameters showed statistically significant differences ($p < 0.05$) for the parameters such as water temperature, air temperature, alkalinity, dissolved oxygen, free carbon dioxide, salinity, transparency, silicate, nitrate, nitrite, ammoniacal nitrogen and chlorophyll-a except for pH and orthophosphate. During the post-monsoon season, air temperature (23.75 ± 3.39°C) and water temperature (22.58 ± 3.48°C) were significantly lower ($p < 0.05$) compared to the pre-monsoon season, which recorded the highest temperatures (air: 30.29 ± 1.44°C; water: 28.38 ± 1.21°C). Dissolved oxygen peaked in the monsoon (5.5 ± 0.90 mg l^{-1}) and was the lowest in pre-monsoon (2.33 ± 1.67 mg l^{-1}), while salinity showed significant variation, ranging from 10.92 ± 3.99 psu (monsoon) to 22.08 ± 3.55 psu (pre-monsoon). Free CO_2, silicate, and chlorophyll-a levels were significantly higher in the monsoon, with chlorophyll-a lowest post-monsoon. Nitrate was substantially higher in monsoon (17.88 ± 2.44 µg l^{-1}), while nitrite levels were significantly lower pre-monsoon (4.27 ± 1.32 µg l^{-1}). Ammoniacal nitrogen was highest post-monsoon (1.71 ± 0.49 µg l^{-1}) and lowest during the monsoon (1.02 ± 0.12 µg l^{-1}). In contrast, pH and orthophosphate showed no significant seasonal variation. The spatio-temporal variations of physico-chemical parameters are depicted in Fig 9.6.

The application of General additive model (GAM) best predictive model for fish abundance (Mod6) explained 97% variations with the lowest AIC (Akaike Information Criterion) value of 362.85 which includes all five predictor variables (total alkalinity +

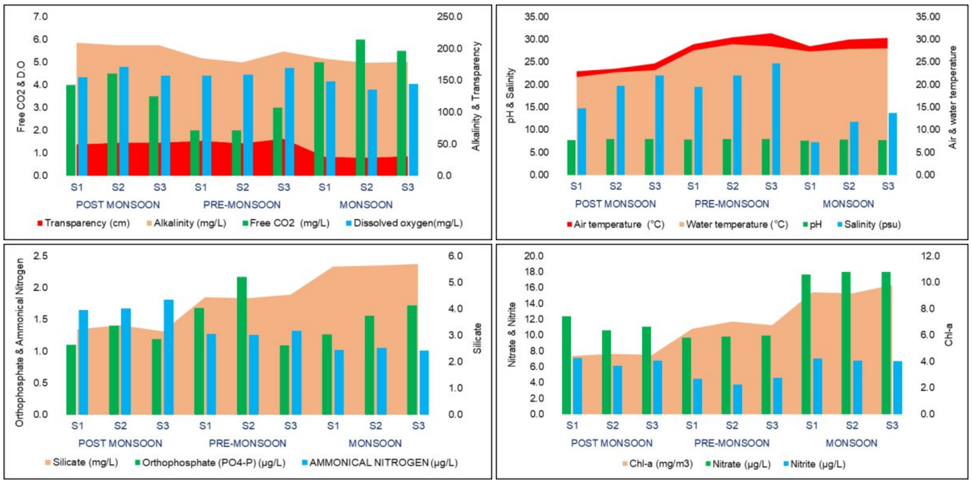


Fig 9.6 Spatio-temporal variation in the physico-chemical parameters of Matla Estury

Table 9.4 Stepwise GAM analysis with deviance explained and AIC value

Parameters	Deviance explained (%)	AIC
TA	28.7	435.87
TA + SiO4_Si	53.7	427.84
TA + SiO4_Si + NO2_N	73.3	415.60
TA + SiO4_Si + NO2_N + TP	91	394.51
TA + SiO4_Si + NO2_N + TP + WT	97	362.85

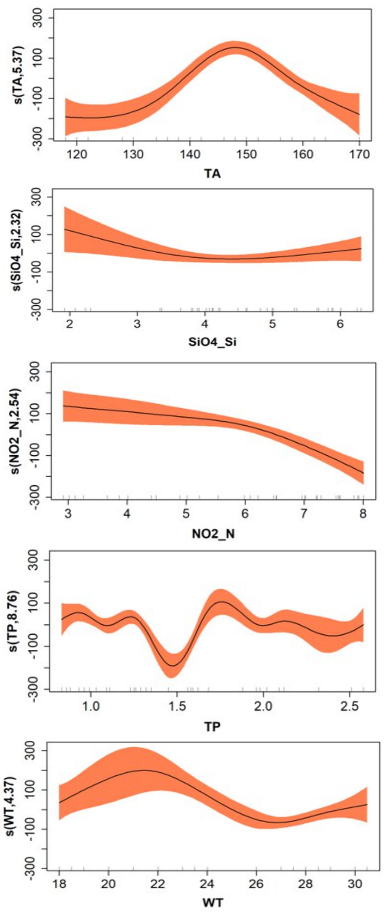


Fig 9.7 Model (GAM)-based response curve of each predictor variable on fish abundance (Shaded lines indicate 95% confidence intervals. The relative density of data points is shown by the rug plot on the x-axis)

silicate + nitrate + total phosphate + water temperature) (Table 9.4). The model explained the influences of water quality variables on fish abundance in the study area. However, individual predictor analysis shows that total alkalinity was the most influencing variable (28.7% deviance explained) for fish abundance variations followed by silicate, nitrate, total phosphate and water temperature. The GAM-derived response curve of the best predictive model is shown in Fig 9.7. All the parameters had a non-linear effect in the response curve. The total alkalinity level near 150 ppm has positive effects on fish abundance indicating higher fish abundance at these levels of alkalinity. A non-linear relationship between silicate concentrations (SiO_4_Si) and fish abundance, was observed with a slight negative effect at lower SiO_4_Si levels transitioning to a positive effect at higher concentrations. NO_2_N indicated a negative effect on fish abundance at higher nitrite concentrations.

The Pearson's correlation analysis revealed the significant relationships between phytoplankton classes and water quality parameters. Cyanophyceae showed strong positive correlations with free CO_2, NO_3, alkalinity, and NO_2 ($p<0.001$), and negative correlations with pH, salinity, transparency, and D.O ($p<0.001$). Bacillariophyceae was positively correlated with NO_3 and chlorophyll-a ($p< 0.001$), while negatively correlated with salinity, transparency, and D.O ($p<0.001$). Xanthophyceae exhibited positive correlations with chlorophyll-a, silicate, and temperatures ($p<0.01$), but negative correlations with salinity, pH, transparency, D.O, and ammoniacal nitrogen ($p<0.01$). Chlorophyceae correlated positively with chlorophyll-a, silicate, and temperatures ($p<0.001$), and negatively with ammoniacal nitrogen ($p<0.001$). Dinophyceae showed a positive correlation with ammoniacal nitrogen ($p<0.001$) and negative correlations with chlorophyll-a, silicate, and temperature ($p<0.001$). Zygnematophyceae correlated positively with alkalinity and ammoniacal nitrogen, but negatively with several variables including temperature and orthophosphate.

BIO–ENV method (using Spearman rank correlation) depicted that the physio-chemical

Table 9.5 BIO-ENV analysis correlating between phytoplankton abundance and environmental variables

No. of variables	Environmental variables	Spearman Correlation
1	FCO_2	0.3900
2	AT, FCO_2	0.4929
3	ALK, FCO_2Chla	0.4291
4	AT, FCO_2, NO_2, Chla	0.4239
5	AT, ALK, FCO_2, NO_3, Chla	0.4221
6	WT, FCO_2, TRN, NO_3, NO_2, Chla	0.3730
7	AT, ALK, FCO_2, SIL NO_3, NO_2,Chla	0.3686
8	AT, ALK, FCO_2, TRN, SIL, NO_3, NO_2, Chla	0.3645
9	WT, AT, ALK, FCO_2, TRN, OP, NO3, NO_2, Chla	0.3174
10	WT, AT, DO, ALK, FCO_2, TRN, SIL, NO_3, NO_2, Chla	0.3104

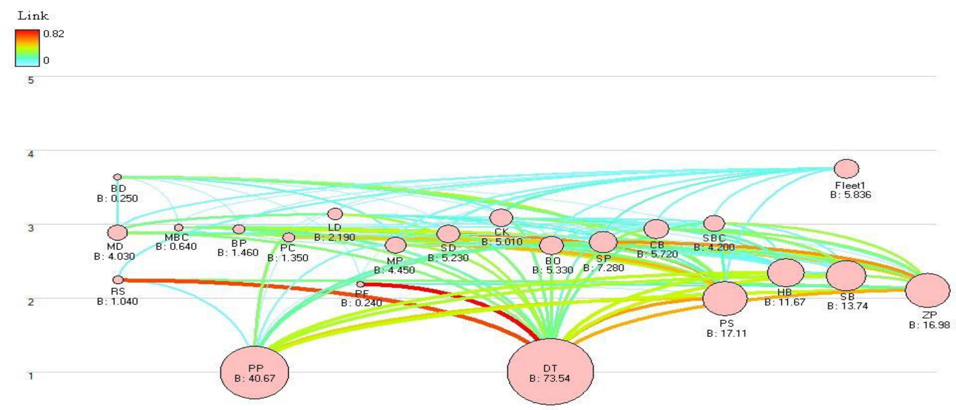


Fig 9.8 Food web structure of Matla Estuary (ME) describing the trophic structure of the system. (Size of the nodes, and the thickness of the arches are proportional to their biomass and quantity of material flow respectively. Trophic levels are denoted on the left side.)

parameters such as air and water temperatures, free CO_2, nitrate, nitrite, silicate, alkalinity, transparency, orthophosphate, dissolved oxygen and chlorophyll-a were correlating to phytoplankton population (Table 9.5). The highest correlation was observed between phytoplankton and parameters, air temperature and free CO_2 (ρ= 0.4929). In contrary, the minimum correlation of ρ= 0.3104) was observed in the set of air and water temperature, free CO_2, nitrate, nitrite, silicate, alkalinity, transparency, dissolved oxygen and chlorophyll-a.

A mass-balanced trophic model for the Matla estuary (ME) was constructed using the Ecopath with Ecosim (EwE) software. The mass balancing of the trophic model for the ME was performed using input data gathered from experimental fishing, field surveys and secondary literatures. In the ME, trophic levels (TLs) varied from 1, which includes groups like detritus (DT), and phytoplankton (PP), up to 3.6 for Birds (BD). Most functional groups, such as RS, MP, MBC, BP, PC, PF, MP, SD, BO, SP, CB, PS, HB, SB, and ZP, were classified within TL 2. Trophic level 3 encompassed four groups: BD, LD, SBC and CK. The average trophic level of the fish in Matla estuary was 2.75. The trophic interactions among 21 ecological groups within the Matla estuarine food web were illustrated using an Ecopath flow diagram, as depicted in the Fig 9.8.

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)

Aquaculture plays a key role in food security and economic growth, with *Heteropneustes fossilis* (stinging catfish) being highly valued in South and Southeast Asia for its market demand, nutrition, and adaptability. Optimal stocking density is crucial for maximizing

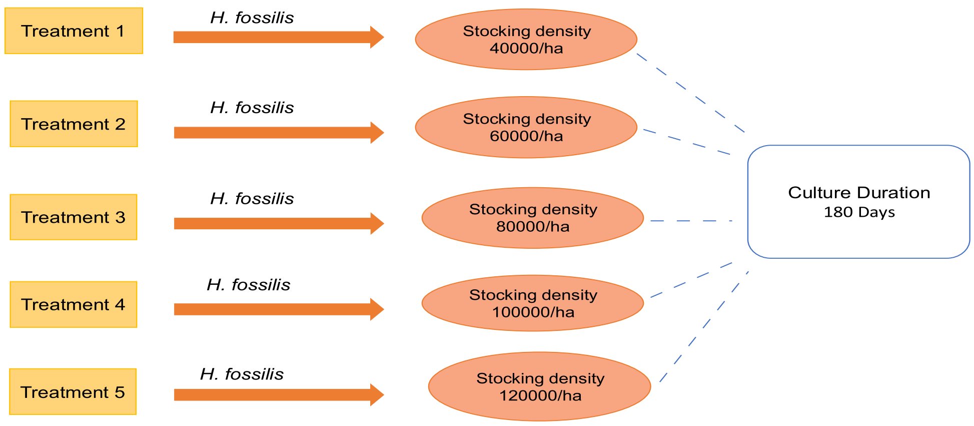


Fig 9.9 Layout of the experiment on stocking density

Table 9.6 Growth parameters and production performance of Heteropneustes fossilis under different stocking densities

Growth parameters	Treatments				
	T-1	T-2	T-3	T-4	T-5
Initial weight (g)	2.50	2.50	2.50	2.50	2.50
Final weight (g)	42.53 ±4.29	42.13±3.26	37.86±2.90	31.63±3.57	26.2±1.53
Absolute weight (g)	40.03	39.63	35.37	29.13	29.53
SGR	1.57	1.57	1.51	1.41	1.31
PI	17.79	17.61	15.72	12.95	11.64
Fish yield (kg/ha/six months)	1361.06 ±137.17	2022.4 ±156.48	2423.46 ±185.66	2530.66 ±286.24	2515.2 ±148.93

***PI, Performance index; SGR, specific growth rate%. ***Sample size (n)= 10

yield while minimizing stress and environmental impacts. High densities can reduce growth, while low densities waste resources. *H. fossilis* also integrates well with Indian major carps in ponds, making it a promising species for sustainable aquaculture and species diversification.

During 2024-25, a study was conducted to evaluate the effects of different stocking densities on the growth and production performance of *H. fossilis*. Five different stocking densities of *H. fossilis* (40000, 60000, 80000, 100000 and 120000/ha) were tested in farmer's field (Fig 9.9). Parameters such as specific growth rate (SGR), performance index (PI) and water quality indicators were monitored to assess the impact of varying densities.

The growth parameters of *H. fossilis* under five stocking density treatments (T-1 to T-5) are given in Table 9.6. The growth parameters such as absolute weight gain, specific growth rate and performance index in T1, T2, and T3 were not significantly different ($p > 0.05$) to each other, while T4 and T5 are significantly different from T1, T2, and T3, but not from each other. Final weight gain ranged from 42.53 ± 4.29 g in T-1 to 26.2 ± 1.53 g in T-5, indicating that higher stocking densities led to reduced growth performance. Absolute weight gain followed a similar trend, decreasing from 40.03 g in T-1 to 29.53 g in T-5. The specific growth rate (SGR) was highest (1.57%) in T-1 and T-2 and progressively declined to 1.31% in T-5, reflecting reduced growth efficiency with increased density. Performance index (PI) showed a similar decline, from 17.79 in T-1 to 11.64 in T-5. However, fish yield per hectare over six months was the lowest in T-1 (1361.06 ± 137.17 kg) and highest in T-4 (2530.66 ± 286.24 kg), indicating that intermediate densities optimized yield despite reduced individual growth.

The economic analysis is given in table 9.7 and it revealed a progressive increase in total input costs (₹ ha^{-1} $crop^{-1}$) from ₹333,000 in T-1 to ₹768,000 in T-5. Total production also shows an initial increase, peaking at 2,530.667 kg ha^{-1} $crop^{-1}$ in T-4, before slightly declining

Table 9.7 Economic analysis of *Heteropneustes fossilis* culture under different stocking densities

Economic analysis	T-1	T-2	T-3	T-4	T-5
Total input costs (Rs ha-1 crop-1)	333000	443000	553000	658000	768000
Total production (Kg ha-1 crop-1)	1361.067	2022.4	2423.467	2530.667	2515.2
Net return (Rs. ha-1 crop-1)	347533.3	568200	658733.3	607333.3	489600
BC ratio	2.04	2.28	2.19	1.92	1.63

Table 9.8 Monthly, mean values and ranges of water quality variables during the study period

Water quality parameters	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Min	Max
EC (dS m^{-1})	0.76	0.92	0.63	0.33	0.64	0.71	0.67	0.33	0.92
pH	7.7	7.8	8.19	8.35	7.6	7.5	7.86	7.5	8.3
DO (ppm)	3.9	4.42	5.98	3.7	4.5	5.34	4.64	3.7	5.98
TDS (ppm)	919	1121	711	660	822	957	865	660	1121
Salinity (psu)	0.36	0.47	0.32	0.15	0.34	0.35	0.33	0.15	0.47
Temperature (°C)	29.6	28.3	32.4	24.5	21.9	22.4	26.52	21.9	32.4

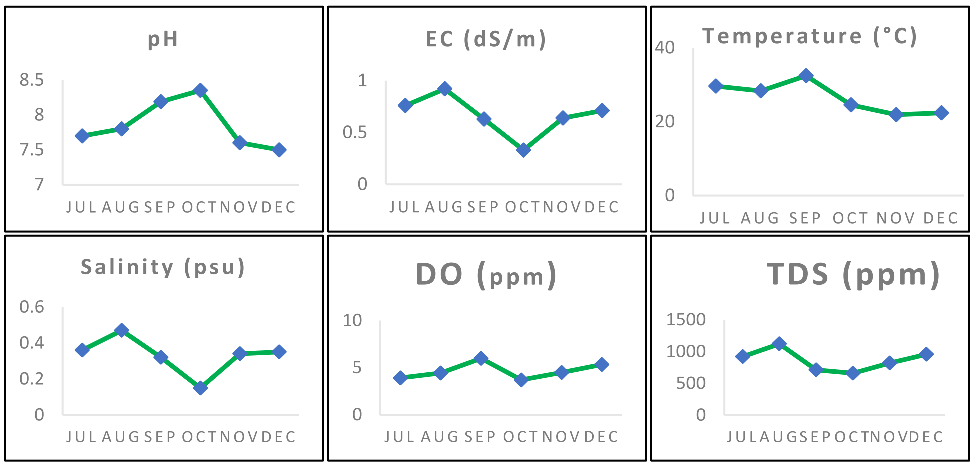


Fig 9.10 Monthly variations of water quality parameters

to 2,515.2 kg ha^{-1} $crop^{-1}$ in T-5. Correspondingly, the net return (₹ ha^{-1} $crop^{-1}$) increases from ₹347,533.3 in T-1 to a maximum of ₹658,733.3 in T-3, followed by a decline in T-4 and T-5. This trend highlights that while increasing input costs and production initially drive higher net returns, diminishing returns set in after T-3, likely due to reduced efficiency or other constraints. The benefit-cost (B-C) ratio reflects this dynamic, starting at 2.04 in T-1, rising to a peak of 2.28 in T-2, and then gradually declining to 1.63 in T-5. This indicates that the economic viability decreases with higher input costs and production levels beyond a certain point. Therefore, while moderate investment levels (T-2 and T-3) yield the best economic outputs, excessive input costs (T-4 and T-5) may not justify the returns, emphasizing the importance of optimizing input use for sustainable profitability.

The key water quality parameters were also monitored during the experimental period from July to December 2024 and are given in Table 9.8 along with their mean, minimum, and maximum values. The monthly variations of water quality parameters are illustrated in Fig 9.10. Electrical conductivity (EC) ranged from 0.33 to 0.92 dS m^{-1}, with a mean of 0.67 dS m^{-1}, indicating moderate ion concentration variations, the highest in August and the lowest in October. pH values remained slightly alkaline, varying from 7.5 to 8.35, with an average of 7.86, peaking in October. Dissolved oxygen (DO) levels fluctuated between 3.7 ppm in October and 5.98 ppm in September, averaging 4.64 ppm, reflecting seasonal oxygen availability influenced by temperature and biological activity. Total dissolved solids (TDS) showed a similar trend, ranging from 660 ppm in October to 1121 ppm in August, with a mean of 865 ppm, correlating with EC values. Salinity varied modestly between 0.15 and 0.47 psu, with a mean of 0.33 psu, indicating a optimal condition for freshwater species, the lowest in October and the highest in August. Temperature displayed significant seasonal changes, peaking at 32.4°C in September and dropping to 21.9°C in November, with a mean of 26.5°C. These variations highlight the dynamic interactions between environmental factors and water quality across seasons in the study area.

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)

This study provides a comprehensive review of the literature on livelihood resilience in agricultural communities, taking into account various factors such as environmental, economic, institutional, political, and social influences. A citation analysis was conducted using the bibliometrix package in R Studio, with a dataset of 1,738 articles retrieved from the Scopus database as shown in Fig 9.11. The analysis identified key journals and highlighted trending articles in the field of livelihood resilience research. By combining citation analysis with a detailed content review of the 22 most-cited publications, five primary research themes were recognized: (1) the effects of climate change and environmental stressors, (2) the role of adaptation and coping strategies in enhancing livelihood resilience, (3) socio-ecological systems and their connections to resilience, (4) frameworks used for evaluating livelihood resilience, and (5) policy and institutional responses. This process led to the development of a comprehensive framework that categorizes resilience factors and suggests three critical dimensions for assessing

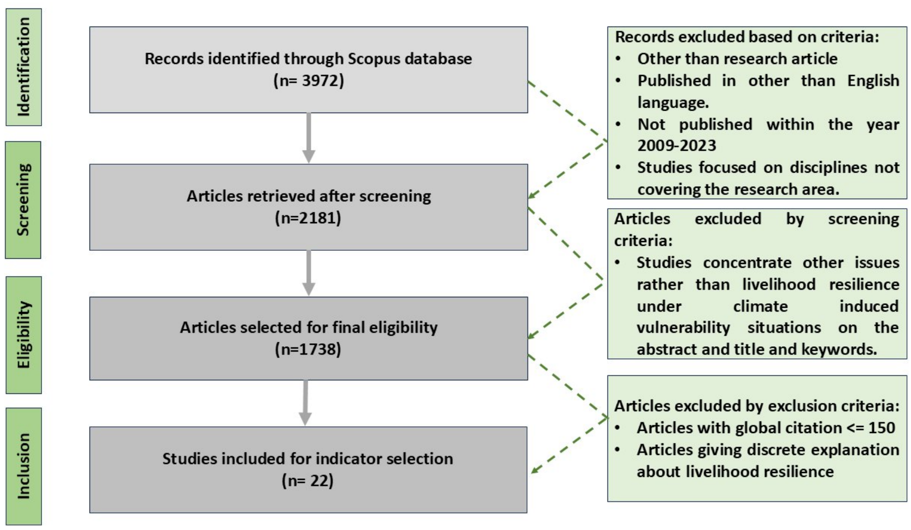


Fig 9.11 Flow chart of selection of articles for the study

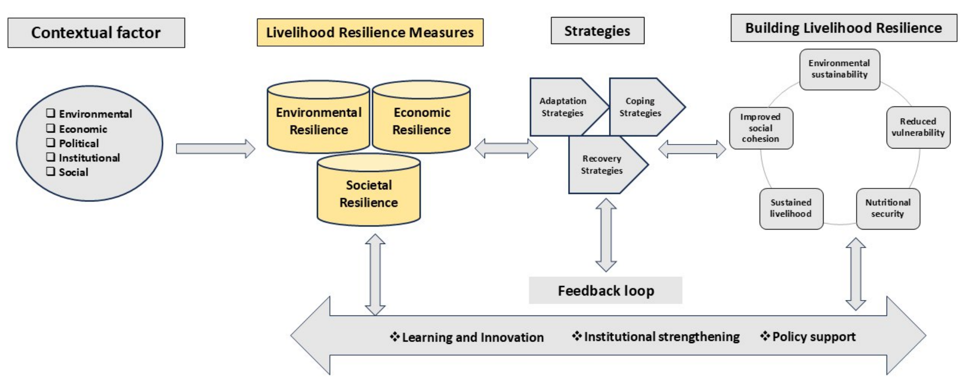


Fig 9.12 Conceptual framework of livelihood resilience

livelihood resilience: (a) environmental resilience, (b) economic resilience, and (c) social resilience as shown in Fig 9.12. Additionally, the framework incorporates a feedback loop and proposes future research areas based on key insights from the most influential studies. These include examining the impact of regional strategies on resilience, establishing standardized dimensions for different contexts, integrating climate data into resilience assessments, investigating gender and social dynamics in resilience, evaluating institutional frameworks and governance structures, exploring migration and its effects on agricultural livelihoods, conducting longitudinal studies, and incorporating indigenous knowledge into resilience strategies.

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 water treatments

An experiment was conducted at ICAR-Central Soil Salinity Research Institute (CSSRI), RRS, Canning Town during the *kharif* season of 2024 to evaluate the effect of salinity on morphological traits and yield of rice genotypes. The study followed a Factorial Completely Randomized Design (FCRD) with three replications. Twelve rice genotypes, namely CSR 10, CSR 36, CSR 30, Nona Bokara, Canning 7, Amalmana, CSR 60, CSR 43, CSR 46, Swarna, MTU1010, and IR 29, were subjected to four salinity treatments with different electrical conductivity (EC) levels: 0 dS m^{-1} (control), 4 dS m^{-1} (Treatment 1), 6 dS m^{-1} (Treatment 2), and 8 dS m^{-1} (Treatment 3) (Photo). The treatments were applied at the panicle initiation stage. The measurements of various morphological parameters and yield were recorded, i.e., plant height, root length, days to flowering, relative water content (RWC) and grain yield per plant. The experiment showed significant variations in plant height, root length, relative water content (RWC), and yield loss among the rice genotypes with the different salinity water treatments. The genotypes were grouped as tolerant and sensitive groups based on their response to salinity stress. Among the tolerant genotypes CSR 30, CSR 36, CSR 10, Nona Bokara, Canning 7, Amalmana, CSR60, CSR 43 and CSR 46, the plant height declined only moderately even with the higher salinity levels. Among the tolerant genotypes CSR 30, CSR 36, CSR 10, Nona Bokara, Canning 7 and Amalmana indicated their tolerance at 6 dS m^{-1} and 8 dS m^{-1}. These genotypes maintained significantly higher plant height in all the treatments than the control. However, the sensitive genotypes IR 29, Swarna and MTU1010 exhibited significant in plant height with increased salinity, particularly at 6 and 8 dS m^{-1} indicating their sensitivity to salinity stress. Similarly, root length also exhibited the same trend. The tolerant genotypes exhibited only moderate loss in root length with increased salinity, maintaining relatively longer roots, indicating their better adaptability. However, the sensitive genotypes exhibited significant loss in root length, with the highest declines at 6 and 8 dS m^{-1}, indicating their poor tolerance to saline conditions. The RWC values also indicated the better performance of tolerant genotypes, which maintained relatively stable RWC values even with higher salinity levels, indicating better water retention capacity. On the other hand, the sensitive genotypes exhibited a considerable decline in RWC with increasing salinity, particularly at 6 and 8 dS m^{-1}, indicating their greater sensitivity to salt stress.

Reduction in yield also indicated the difference between the two groups. The tolerant genotypes, particularly Nona Bokara, Canning 7, and Amalmana, incurred only marginal losses in yield (2-12%) under all the salinity treatments, indicating their tolerance (Fig 9.13). In contrast, the sensitive genotypes IR 29, Swarna, and MTU 1010, incurred heavy

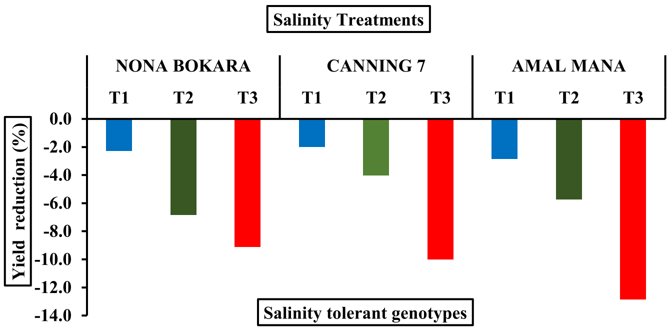


Fig 9.13 Yield reduction in salinity-tolerant rice genotypes

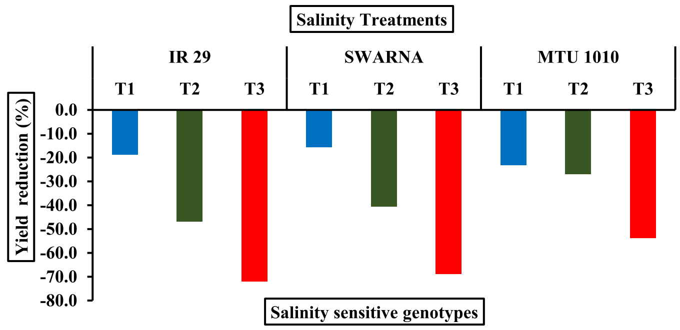


Fig 9.14 Yield reduction in salinity-sensitive rice genotypes

losses in yield (20-70%) particularly at 6 (30-50%) and 8 dS m^{-1} (60-70%), indicating their sensitivity under salinity stress (Fig 9.14). Overall, the tolerant genotypes were more versatile, with superior growth, water retention, and yield stability under the saline conditions whereas the sensitive genotypes were drastically affected by salinity stress.

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 the project this research station has undertaken various research activities under WP1 (Adapting Deltaic Production Systems) in the Ganges Delta region of India with a objective to develop improved agronomy packages for diversified delta production systems, tailored to local contexts for increased climate resilience. The key strategies undertaken for enhancing agricultural productivity and livelihood security in the Ganges delta are enhancing land and water productivity through management of critical soil and water resources, careful planning of crop calendar, and efficient agronomic practices; improved farm productivity and livelihood security of farmers through implementation of land shaping techniques, improving the existing homestead production system (HPS) to enhance nutritional security and income of small holding farmers; and capacity development of small and marginal farmers.

Improved varieties of rice (Pratikshya, CR-1017, Banga Bandhu, Jai Shri Ram, Santoshi), jute (JROG 1, CO 58, JRO 204 and S 19) and mustard (CS 60, CS 58) crops along with improved agronomic practices were demonstrated in the farmers' fields at different locations in the salt affected South and North 24 Parganas districts. Higher yield of the *kharif* rice was obtained with improved varieties (4.70 t ha^{-1}) as compared to farmer's varieties (4.02 t ha^{-1}). The improved varieties of mustard were introduced in the area and higher yield was obtained with improved varieties (1.95 t ha^{-1}) as compared to varieties commonly grown by the farmers (1.51 t ha^{-1}). Improved cultivars of jute produced higher yield (3.56 t ha^{-1}) as against 2.89 t ha^{-1} in case of farmers' variety. In rice-mustard-jute cropping system 30.8% higher REY was obtained due to introduction of improved varieties of rice, mustard and jute crops in the salt-affected coastal region in the Ganges Delta (Fig 9.15). Potato seeds of 25 tonnes distributed among 450 farmers in collaboration with CIP & IRRI for large scale demonstration and refinement of zero tillage potato with straw mulching technology in the salt-affected Ganges delta (Photo). Yields of potato from both the conventional tillage (CT) and zero tillage (ZT) with rice straw mulch methods were compared among the same group of farmers, showing a difference of 0.85 t ha^{-1} with ZT with a higher yield of 29.98 t ha^{-1} compared to 29.13 t ha^{-1} from CT. Further

Zero tillage potato cultivation with paddy straw mulching

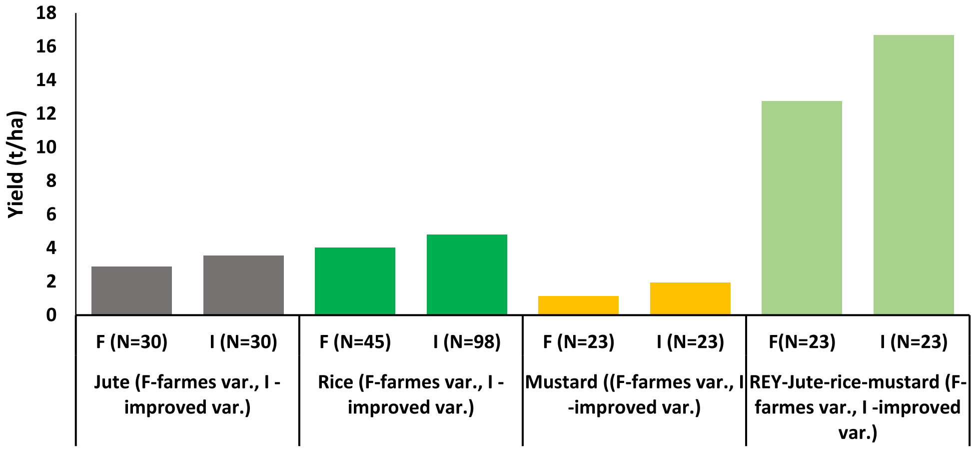


Fig 9.15 Yield of jute, rice, mustard crops and cropping system with improved vs. farmer's varieties

analysis involved different groups based on gender and tillage methods, comprising female farmers practising zero tillage and conventional tillage potato as well as male farmers in both practices. The average yield for female farmers practising zero tillage (ZT) was 29.94 t ha^{-1} whereas for conventional tillage (CT), it was 29.56 t ha^{-1}, resulting in a mean difference of 0.38 t ha^{-1} favouring ZT. The average potato yield among male farmers practising zero tillage was 30.48 t ha^{-1}, while those using conventional tillage reported 29.36 t ha^{-1}, indicating a significant mean difference of 1.12 t ha^{-1}. Follow-up survey of zero tillage potato cultivation technology was conducted on the farmers who participated in zero tillage potato cultivation first time in 2023-24 cropping season to understanding farmers' willingness to implement zero tillage and the reason for not doing zero tillage. A total of 200 households form two villages viz. Ramgopalpur and Chatrakhali (100 respondents in each village with 28% women) participated in the survey. According to the survey in Chatrakhali, 80% of respondents are willing to grow potato with zero tillage, while 20% of respondents said they won't grow potato with zero tillage or not decided yet. The rate of willingness is lower than that of Ramgopalpur where 97% of respondents are willing to adopt zero tillage. The result also shows that women are more active in Ramgopalpur in potato production compared to Chatrakhali. More than 90% of women in Ramgopalpur participated in major activities in potato production such as planting, rice straw mulching, harvesting and irrigation. Therefore, it is expected that zero tillage practice significantly reduce women's labour as well as men's.

Vegetable production in the raised land and aquaculture in pond are the two major components of homestead production system (HPS) in the Ganges Delta region in West Bengal. However, the productivity of vegetables/fish is very low as the farmers practice traditional methods of cultivation of vegetable and fish. There is scope to enhance the production capacity of HPS through introduction of improved management practices. The intensification of HPS was done through introduction of improved vegetable crops and scientific aquaculture practices in two villages in the Ganges Delta. The income, Simpson Crop Diversification Index and extent of sale were calculated for each household. Intensification resulted in increase of gross farm income which varied from Rs.10,592 to Rs. 35,900 with an average income of Rs.21,018 per house hold. The farmers got Rs. 4710 to Rs. 24,180 per household with average of Rs. 11904 from marketable surplus from their homestead production system. Homestead farm diversity index varied from 0.32 to 0.99 with an average value of 0.56. The farm commercialization diversity index varied from 0.03 to 0.85 with avarege value of 0.59.

Table 9.9 Fish growth parameters recorded in three different treatments

	Treatments (Species stocked)	Initial MBW (g)	Final MBW (g)	Absolute growth (g)	SGR (%/Day)	Performance index (PI)
T-1	Gibelion catla	11.76	134.24	122.48	1.62	65.32
	Labeo rohita	10.98	119.03	108.04	1.59	57.62
	Cirrhinus mrigala	8.85	87.41	78.56	1.53	41.90
T-2	Gibelion catla	11.76	143.53	131.78	1.67	70.28
	Labeo rohita	10.98	122.40	111.42	1.61	59.42
	Cirrhinus mrigala	8.85	104.40	95.55	1.65	50.96
	Oreochromis niloticus (Monosex)	1.80	37.49	35.69	2.02	19.03
T-3	Oreochromis niloticus (Monosex)	1.80	45.00	43.20	2.15	23.04

***MBW,mean body weight; SGR, specific growth rate %. ***Sample size (n)=10,for each species.

During 2024, a study was conducted in Ramgopalpur village, West Bengal, to assess the growth, production, and profitability of aquaculture in nine ponds (~0.75 bigha each) over 150 days using three setups: 100% IMC (T-1), 50% IMC and 50% monosex tilapia (T-2), and 100% monosex tilapia (T-3), with stocking densities of 10,000 IMC ha^{-1} and 20,000 monosex tilapia/ha. The results indicated that IMC exhibited higher absolute growth, specific growth rate, and performance index when co-cultured with monosex tilapia, whereas monosex tilapia performed the best when cultured alone (Table 9.9). The highest gross production was observed in T1 (925.02 kg ha^{-1}), followed by T2 (801.76 kg ha^{-1}) and T3 (720.05 kg ha^{-1}). In T1, *Gibelion catla* contributed the most (46.44%) to total production, while *Cirrhinus mrigala* had the lowest share (22.68%). In T2, *Oreochromis niloticus* accounted for the highest share (37.41%), with *Cirrhinus mrigala* contributing the least (15.63%). The highest net return (Rs. 64,000) and benefit-cost ratio (3.24) were recorded in polyculture of IMC, outperforming its partial or complete replacement with monosex tilapia. Water quality parameters, including temperature, dissolved oxygen (D.O), pH, electrical conductivity (EC), salinity, and total dissolved solids (TDS), did not show significant differences ($p>0.05$) among treatments, with temperature (24–32°C), D.O (5–8 ppm), and pH (6–9) remaining within the optimal range. EC and salinity levels were low across all the treatments, supporting freshwater species.

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)

An ACAIR funded project is implemented in the farmers' fields of the Gosaba, Chandipur and Bali islands in the salt affected Sundarbans region of Ganges Delta in West Bengal. The project activities were carried out with direct involvement of 1438 farmers (871 male and 567 female) for dissemination of cropping system intensification technlogoies and implementation of field experiments, demonstrations and upscaling activities.

Water samples from surface and groundwater sources were collected periodically from the project sites for determining the quality parameters. The water samples were collected from piezometers installed (depth 20 ft.) near the field experimental sites. Surface water samples from rivers, canals/ nayanjuli, drainage channels and ponds were also collected for analysing the quality parameters. The depth of water and salinity of water in piezometers increases from monsoon to dry season. The highest depth of water in piezometers at Sonagaon, Gosaba was 1.90 m bgl and water salinity varied from 0.43 to 17.6 dS m^{-1} with mean value of 6.9 dS m^{-1}. At Bali Island, water salinity in piezometers varied between 0.44 and 6.78 dS m^{-1} with mean ground water salinity of 2.79 dS m^{-1} during the study period and the groundwater reaches to a depth of 3.92 m. The water salinity in piezometers at Chandipur was 0.13 – 5.92 dS $m^{-1}$with mean value of 1.67 dS m^{-1}. The highest water depth at Chandipur was 2.96 m bgl. Surface water and groundwater from tube-well (depth around 1400-1700 ft.) samples were collected from 12 sources at Bali Island, 11 sources at Chandipur island and 10 sources at Sonagaon, Gosaba islands. The surface water salinity was higher in the rivers surrounding the islands, however there was seasonal variation of salinity even in the rivers with comparative lower salinity during the monsoon period. Rain water harvesting in ponds provides fresh water resources for agriculture in these islands, with water salinity < 1 dSm^{-1}, however, in some of the ponds the water salinity increased during the dry period (at Bali Island, the salinity increased to >0.89 dSm^{-1}, at Chandipur the pond water salinity increased to >1.3 dSm^{-1}, and at Gosaba in some ponds water salinity increased to >2.6 dSm^{-1}). Salinity of tube-well water is comparatively higher than pond water and it varies from 1.54 to 3.23 dSm^{-1}. Magnesium adsorption ratio (MAR) of most of the water samples were >50 during April to June.

The climate change risk in agricultural sector of the Ganges Delta region (Fig 9.16) was assessed. As per IPCC fifth assessment report risk results from the interaction of vulnerability, exposure and hazard. Very high risk to climate change in agriculture was recorded in 7 upazila of Bangladesh namely Khulna Sadar, Paikgachha, Dacope, Koyra, Kala Para, Galachipa and Manpura which cover an area of 5376 sq km and a population of 20.21 lakh whereas high risk area was noted in 18 Administrative units (AU), covering an area of 7174 sq km with a population of 37.09 lakh. Similarly Medium, low, and very low risk area was found in 19, 34 and 11 AU. All 11 Upazila located towards landward side of northern part of the study region are under very low risk category. Out of 19 blocks of West Bengal, Minakhan from North 24 Parganas is under high-risk category whereas remaining 5 and 13 blocks are under moderate and low risk category. A decision matrix has been prepared based on severity of vulnerability and risk for prioritization of intervention plan. Immediate attention needs to be paid in Paikgachha of coastal Bangladesh and Minakhan of North 24 Parganas district of West Bengal for risk mitigation where both vulnerability and risk are very high. Next immediate attention is required in

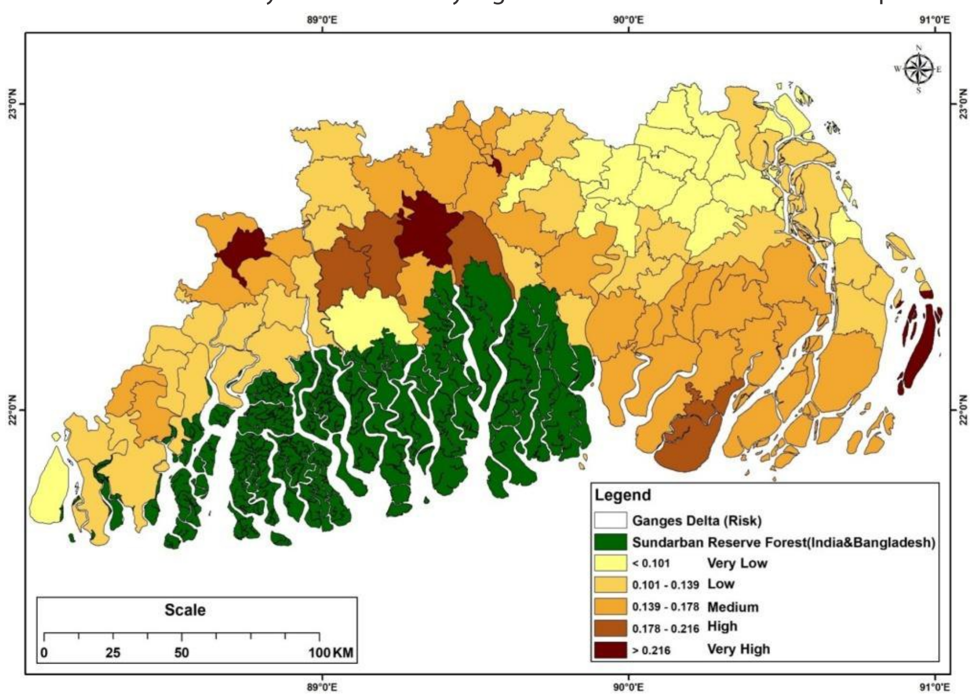


Fig 9.16 Risk map of the Ganges Delta (Upazila level in Bangladesh and Block level in West Bengal, India)

Assasuni and Dacope, situated beside Paikgachha and Manpura situated extreme West coast of Bangladesh. Risk mitigation attention is also needed for Khulna Sadar, Kaliganj, Kala Para, Dumuria, Batiaghata, Koyra, Rampal, Morrelganj, Patharghata, Amtali, Galachipa, Dashmina and Char Fasson of Bangladesh and Sandeshkhali-I of West Bengalwhere risk and vulnerability are varied from moderate to very high category.

During the *Kharif* season, ten fodder crops viz. para grass, humidicola grass, guinea grass, nandi grass and HNB Co-3, HNB Co-4 HNB Co-5, super napier, red napier and smart napier were evaluated in farmers' field for three dates of planting (D1: first week of July, D2: first week of August and D3: first week of September). Date of planting had a significant impact on fodder yield during the *Kharif* season. The average green fodder yield was 50.31, 45.39 and 42.38 t ha^{-1} for July, August and September planting, respectively. However, among the fodder crops, the highest mean fodder yield was recorded for super napier (63.21 t ha^{-1}) followed by nandi grass (60.66 t ha^{-1}), smart napier (47.11 t ha^{-1}), HNB Co-4 (45.99 t ha^{-1}), HNB Co-3 (44.26 t ha^{-1}), HNB Co-5 (43.81 t ha^{-1}), para grass (41.15 t ha^{-1}), red napier (40.32 t ha^{-1}), humidicola grass (39.51 t ha^{-1}), and gunea grass (34.25 t ha^{-1}).

Shade tolerant crops under homestead production system were evaluated by involving 414 farmers of different islands during the *kharif* season to identify promising shade tolerant crops for the homestead gardens. The planting materials for these crops were supplied to the collaborating farmers and crops were grown in the homestead area. Elephant foot yam and turmeric crops were grown in the land adjacent to dwelling house whereas ginger was planted in the soil and manure filled bags. At Gosaba, elephant foot yam yield varied from 17.0 to 22.6 t ha^{-1} (average 19.8 t ha^{-1}), turmeric yield was 18.2 – 22.8 t ha^{-1} (average 20.5 t ha^{-1}) and ginger yield was 13.2-18.3 t ha^{-1} (average 15.8 t ha^{-1}). At Chandipur, the elephant foot yam yield varied from 12.5 to 22.5 t ha^{-1} (average 17.5 t ha^{-1}), turmeric yield was 16.1 – 23.2 t ha^{-1} (average 19.7 t ha^{-1}) and ginger yield was 15.4-19.7 t ha^{-1} (average 17.6 t ha^{-1}). At Bali Island, the elephant foot yam yield ranged from 16.0 to 23.8 t ha^{-1} (average 19.9 t ha^{-1}) whereas turmeric yield was 14.8 – 20.5 t ha^{-1} (average 17.7 t ha^{-1}) and ginger yield was 17.7-21.1 t ha^{-1} (average 19.4 t ha^{-1}).

The study analyzed crop diversification and the extent of sale among 163 households across three clusters: Sonagaon, Chandipur, and Bali. Households were categorized based on landholding size into four groups: <0.268 ha, 0.269-0.536 ha, 0.537-0.804 ha, and 0.805-2.412 ha. Simpson Crop Diversification Index (SI) and extent of sale were calculated for each household. The results showed that smaller landholdings (<0.268 Ha) had higher crop diversification scores (0.43) compared to larger landholdings. However, the extent of sale increased with landholding size, reaching 80.5% for households with 0.805-2.412 ha. On average, 60.86% of produce was sold across all households. Further, local polynomial regression analysis indicated that crop diversification decreased with landholding sizes (up to 1.5 ha) while the extent of sale increased with landholding sizes. This suggests that smallholders tend to diversify their crops to meet household consumption needs, which may limit their marketed surplus. Beyond 1.5 ha, diversification levels plateaued, and the extent of sale remained high. This pattern reflects a shift from subsistence agriculture in small landholdings to market-oriented production as landholding size increases. The best cropping system intensification technologies developed in the Phase I of the project such as paddy + vegetable cultivation during *Kharif* season was out scaled in four clusters in Sundarbans (Gosaba, Bali, Chandiput and Canning). To facilitate faster adoption and disseminations, along with the technological back up, inputs such as good quality planting materials and soil amendments were provided to the farmers. Paddy + vegetable cultivation technology was demonstrated in

Demonstration of paddy + vegetable cultivation during the *kharif* season

73 farmers' fields (32 at Sonagaon, 25 at Bijoynagar and 16 at Chandipur) (Photo). This technolgy has been found highly profitable for the coastal rainfed lowland situation. The cost of cultivation of sole paddy varied from ₹51750 to 59175 ha^{-1}, net return varied from ₹43200 - 74325 ha^{-1} and BCR was 1.8 – 2.4. In case of paddy + vegetable cultivation, the cost of cultivation was ₹42300 to 56479 ha^{-1}, net return varied from ₹60698 to 219996 ha^{-1} and BCR was 2.3 – 6.0.

Several meetings, trainings and field visits were conducted during the reported period to the project sites for dissemination of cropping system intensification technlogoies and implementation of field experimetns, demonstrations and upscaling activities.

NICRA Project: Climate change mitigation and adaptation strategies for salt-affected soils (U.K. Mandal, K.K. Mahanta, S. Raut, R.N. Bhutia and A.K. Bhardwaj)

Historical and future of climate data for average of yearly maximum value of daily maximum temperature (Tmax_mean), Average of yearly minimum value of daily minimum temperature (Tmin_mean), and mean annual rainfall were analysed for Indian Sundarbans. Satellite-based gridded historical climate data for 1985-2020 was downloaded from the ECMWF (European Centre for Medium Range Weather Forecasts) website (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5). We used future climate data for the period 2041-2060 based on IPCC sixth assessment report for scenario SSP585 (Shared Socio-Economic Pathways) and the data was downloaded from https://esgf.nci.org.au/projects/esgf-nci/. The bias corrected dataset was developed using multi-criteria decision analysis algorithm for the historic and projected climate. Historical minimum and maximum temperature and rainfall varied from 8.66 to 8.73°C, 41.49 to 41.66°C and 1569 to 1574 mm, respectively (Fig 9.17) whereas the projected values as per the SSP585 during 2041-2060 were 10.04-10.55°C, 42.91-43.80°C and 1786-1860 mm, respectively (Fig 9.18). The projected minimum and maximum temperature will increase between 1.31-1.88°C and 1.42-2.14°C, respectively and the mean annual rainfall may increase to 212-292 mm in the region.

The land surface temperature (LST) distribution over the region was estimated by applying Plank's law using Landsat thermal bands the sixth band of Landsat's 5 TM, and 10 and 11 bands of Landsat's 8 and 9 OLI sensor. The LST for the years 1989, 2002, and 2019 ranged from 16.56 to 26.67°C, 19.28 to 31.24°C, and 17.22 to 26.86°C, respectively (Fig 9.19). The maximum and minimum LST values increased from 1989 to 2002 but decreased again during 2019. The mean LST distribution across various LULC classes for the years 1989, 2002, and 2019 was estimated using the zonal statistics in ArcGIS (Fig 9.20). The lowest LST was consistently observed in aquaculture areas, while the highest

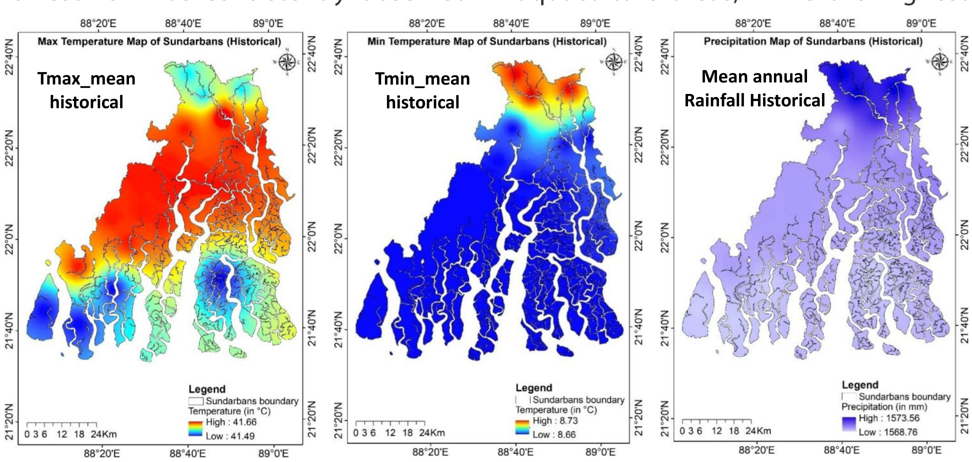


Fig 9.17 Historical climate data during 1985-2020, Tmax_mean (Average of yearly maximum value of daily maximum temperature), Tmin_mean (Average of yearly minimum value of daily minimum temperature), and mean annual rainfall for Indian Sundarbans region

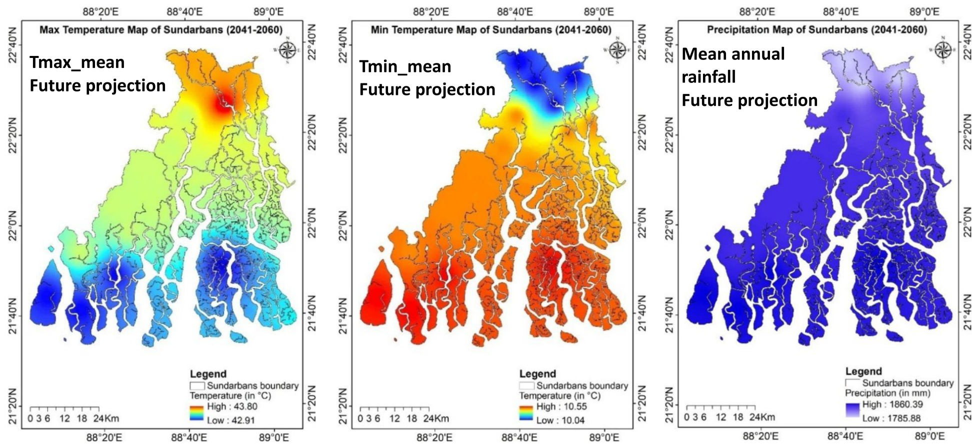


Fig 9.18 Projected future climate data during 2041-2060 based on SSP585 (Shared Socio-Economic Pathways) Tmax_mean, Tmin_mean, and mean annual rainfall for Indian Sundarbans region

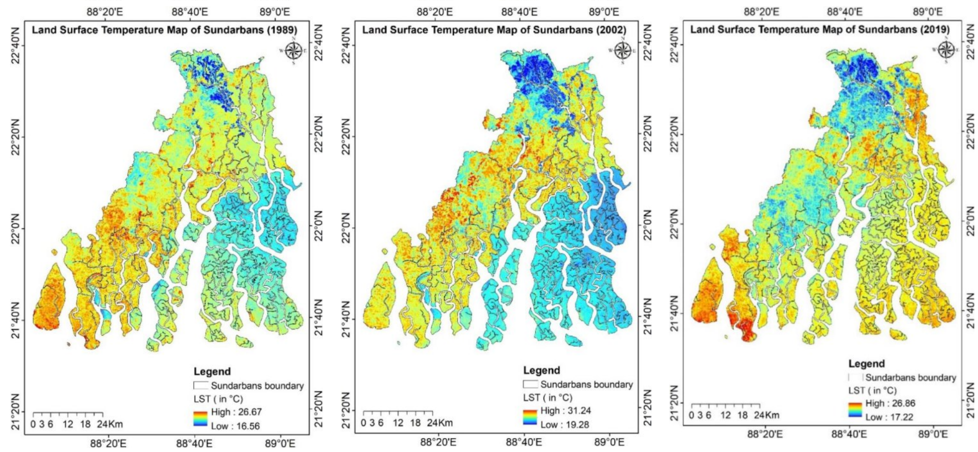


Fig 9.19 Land surface temperature (LST) of Indian Sundarbans during 1989, 2002 and 2019

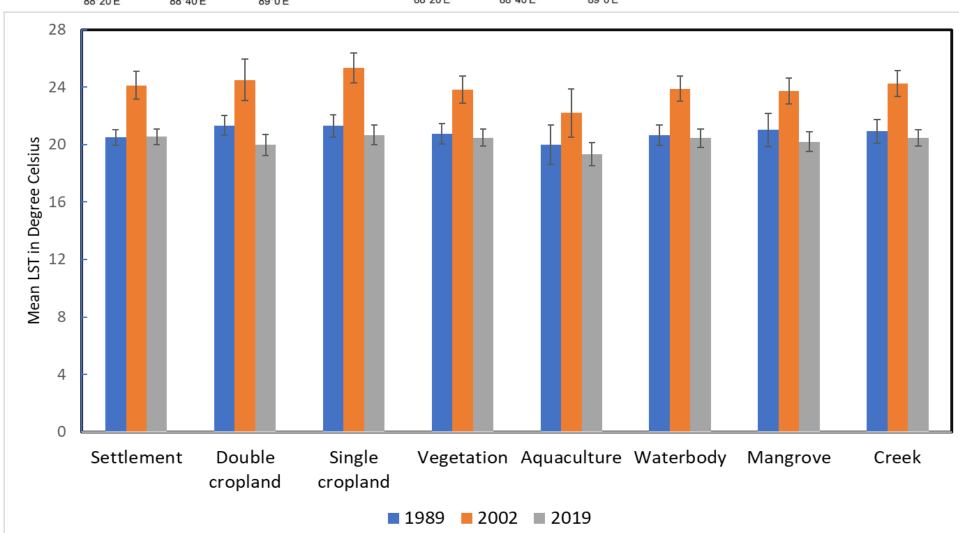


Fig 9.20 Land surface temperature over different LULC classes in 1989, 2002 and 2019

temperatures were recorded in single-cropped areas for the year 2002 and 2019, which were fallow during the acquisition of imagery, and in double-cropped areas for the year 1989. The LST was considered as one of explanatory variable for estimating soil salinity as it influenced soil drying, leading to increased capillary rise of shallow saline groundwater and higher salt accumulation on the soil surface. The acquisition period of imagery plays a role in the variation of LST in different years of the study. Different surface LCLUs in the region exhibit varying emissivity. The LST may be attributed to factors such as unplanned urbanization, impact of climate change, and reductions in vegetation and surface waterbodies within the study area.

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)

Water footprints (WF) for each land shaping systems and rice-fallow and rice-rice systems were calculated on yearly basis by dividing the total volume of blue, green and gray water used ($m^3 ha^{-1}$) by yield of the crop ($t ha^{-1}$) and fish reared converted to rice equivalent yield. The total as well as the components of WF i.e., blue, green and gray was higher in rice-fallow and rice-rice systems than any of the land shaping systems (Table 9.10). The Year 2024 recorded total rainfall of 2096.6 mm within a span of 96 rainy days.

A field experiment was conducted on bhendi (*Abelmoschus esculentus*) and sunflower with different quality of irrigation water under rice straw mulch or no mulch condition during the *rabi* season. Sunflower variety LSFH171 and bhendi F1-Hybrid Anuradha were sown during the last week of December (27.12.23). Four type of saline irrigation water was tested in this experiment. T1 (fresh water (EC < 1dS/m), T2 (saline water, EC 4dS/m), T3 (saline water, EC 8 dS/m) and T4 (saline water, EC 12dS/m). Treatment of irrigation water was imposed after one month of sowing of crops. The irrigation water was applied through drip irrigation system. The sunflower crop was harvested on 4.4.24 whereas bhendi was harvested till 17.5.24. Total rainfall received by sunflower and bhendi was 41.2 mm and 152.4 mm respectively. The amount of irrigation applied for sunflower was 81 mm and 117 mm in no mulch and mulch plots whereas for bhendi irrigation applied was 113 mm and 149 mm in no mulch and mulch plots. The results of yield data showed that sunflower crop can be grown without any yield reduction up to 8dS/m saline water under no mulching and up to 12dS/m with rice straw mulching condition whereas bhendi crop showed yield reduction under saline water condition both mulching and no mulching

Table 9.10 Water footprint and water productivity under different land shaping systems 2024

Land use system	Rice equivalent yield(kg ha^{-1})	Blue water footprint ($m^3 t^{-1}$)	Gray water footprint ($m^3 t^{-1}$)	Green water footprint ($m^3 t^{-1}$)	Total water footprint ($m^3 t^{-1}$)	Water productivity (kg m^{-3})
Rice-mono	4070	0.0	774.0	1396.6	2170.5	0.46
Rice-rice	8510	616.9	370.2	709.3	1696.4	0.59
Farm pond	17550	88.3	143.6	524.0	755.9	1.50
Ridge furrow	19295	81.0	122.4	485.7	689.1	1.64

Table 9.11 Applied saline water (mm/m^3) through drip for sunflower and Bhendi cultivation

2024	Sunflower no mulch	Sunflower mulch	Bhendi no mulch	Bhendi mulch
T1 (Fresh water (EC < 1.0 dS/m))	2306	2456	4016	4423
T2 (Saline water EC 4 dS/m)	2298	2361	2592	2960
T3 (Saline water EC 8 dS/m)	2152	2345	1244	1724
T4 (Saline water EC 12 dS/m)	1581	2260	896	1084
LSD (p = 0.05) Water quality (WQ)	162	NS	270	298
LSD (p = 0.05) mulch (M)	198			310
WQ x M	218			348
2023	**Sunflower no mulch**	**Sunflower mulch**	**Bhendi no mulch**	**Bhendi mulch**
T1 (Fresh water (EC < 1.0 dS/m))	2412	2510	4488	4734
T2 (Saline water EC 4 dS/m)	2373	2354	3243	3544
T3 (Saline water EC 8 dS/m)	2134	2426	1865	2171
T4 (Saline water EC 12 dS/m)	1597	2301	1066	1624
LSD (p = 0.05) Water quality (WQ)	280	NS	360	382
LSD (p = 0.05) mulch (M)	288			334
WQ x M	321			360

Table 9.12 Soil salinity after harvest of crop irrigated with saline water

Soil Salinity (ECe)	Sunflower no mulch		Sunflower mulch		Bhendi no mulch		Bhendi mulch	
	0-20cm	20-40cm	0-20	20-40	0-20	20-40	0-20	20-40
T1 fresh	5.26	4.87	5.08	5.16	5.43	3.45	5.30	5.13
T2 (EC 4dS/m)	6.88	6.39	7.62	6.18	7.63	5.60	5.90	5.40
T3(EC 8dS/m)	8.55	6.43	8.33	7.01	11.87	5.78	7.14	5.78
T4(EC 12dS/m)	10.43	7.40	10.52	7.33	11.16	6.18	7.17	6.42

condition (Table 9.11). The soil samples collected immediately after the harvest of the crop showed salinity build up where saline water was applied (Table 9.12).

We estimated block wise food requirement, water demand and surface and groundwater available and water gap in Indian Sundarbans region. Food requirement for year 2011 and 2031 was calculated based on normal food requirement of cereal, vegetables, fruits, egg, milk, chicken and meat per person per day considering the local food habit. Block wise population for the year 2031 was estimated based on trend of population growth in each block since 1971.

The water demand to meet the food demand was estimated based on water footprint of each food items (Table 9.13). Total water demand was estimated based on domestic water demand, livestock water demand, industrial water demand and crop water demand. Crop water demand was estimated based on block wise net crop area, gross crop area and rice and non-rice crop area in each block. The surface and groundwater available were added to meet the available water within a block (Table 9.14). In order to have an idea of the dynamic groundwater potential within a block, an attempt has been made to estimate the total quantity of groundwater flow by applying Darcy's Law equation of flow of fluids through porous media, which is $Q = TIL$; where Q is the Quantity of water flowing through a section of aquifer, T is the Transmissivity of aquifer, I is the hydraulic gradient of the piezometric surface and L is the length of groundwater flow-path in the section of the

Table 9.13 Present and future food and water requirement for Indian Sundarbans

Blocks	2011 Population	2031 estimated Population	2011 food requirement (MT)	2031 food requirement (MT)	2011 water requirement (MCM)	2031 water requirement (MCM)	% Increase
Haroa	214401	280333	60.2	78.7	91.0	119.0	30.8
Minakhan	199084	284000	55.9	79.7	84.5	120.6	42.7
Sandeshkhali-I	164465	189200	46.1	53.1	69.8	80.3	15.0
Sandeshkhali-II	160976	201000	45.2	56.4	68.4	85.3	24.9
Hasnabad	203262	236500	57.0	66.4	86.3	100.4	16.4
Hingalganj	174545	202333	49.0	56.8	74.1	85.9	15.9
Canning-I	304724	403500	85.5	113.2	129.4	171.3	32.4
Canning-II	252523	380500	70.9	106.8	107.2	161.6	50.7
Mathurapur-I	195104	238000	54.7	66.8	82.8	101.1	22.0
Jaynagar-I	263151	299667	73.8	84.1	111.7	127.2	13.9
Jaynagar-II	252164	291333	70.8	81.7	107.1	123.7	15.5
Kultali	229053	284000	64.3	79.7	97.3	120.6	24.0
Basanti	336717	426000	94.5	119.5	143.0	180.9	26.5
Gosaba	246598	283750	69.2	79.6	104.7	120.5	15.1
Mathurapur-II	220839	248250	62.0	69.7	93.8	105.4	12.4
Kakdwip	281963	413000	79.1	115.9	119.7	175.4	46.5
Sagar	212037	294667	59.5	82.7	90.0	125.1	39.0
Namkhana	182830	220250	51.3	61.8	77.6	93.5	20.5
Patharpratima	331823	482500	93.1	135.4	140.9	204.9	45.4
Total	**4426259**	**5658783**	**1241.9**	**1587.7**	**1879.5**	**2402.9**	**26.8**

Table 9.14 Water demand and water availability for Indian Sundarbans

Blocks	Domestic water demand MCM 2011	Livestock water demand MCM	Crop irrigation Water demand MCM	Industrial Water Demand	Power Generation MCM	Total water Demand MCM	Surface water availability MCM	Ground water availability MCM	Total water availability MCM	Water Gap MCM
Haroa	10.56	0.45	56.73	0.07	0.00	67.81	37.62	60.14	97.77	29.96
Minakhan	9.81	0.46	24.16	0.01	0.00	34.44	13.52	61.33	74.85	40.42
Sandeshkhali-I	8.10	0.44	28.46	0.01	0.00	37.01	12.17	65.71	77.88	40.87
Sandeshkhali-II	7.93	0.62	8.09	0.01	0.00	16.65	15.71	68.34	84.05	67.40
Hasnabad	10.02	0.59	51.96	0.00	0.00	62.56	34.17	60.21	94.39	31.82
Hingalganj	8.60	0.71	20.33	0.00	0.00	29.63	25.19	75.21	100.39	70.76
Canning-I	15.02	0.55	74.38	0.00	0.00	89.95	164.03	66.71	230.73	140.8
Canning-II	12.44	0.70	118.45	0.00	0.00	131.6	134.43	71.35	205.78	74.19
Mathurapur-I	9.61	0.26	64.27	0.00	0.00	74.14	35.19	59.07	94.26	20.12
Jaynagar-I	12.97	0.37	46.45	0.00	0.00	59.79	111.59	55.70	167.29	107.5
Jaynagar-II	12.43	0.61	79.06	0.00	0.00	92.09	107.58	66.42	174.00	81.90
Kultali	11.29	0.98	75.82	0.00	0.00	88.08	70.80	85.16	155.96	67.88
Basanti	16.59	1.24	156.33	0.00	0.00	174.2	143.76	97.84	241.60	67.45
Gosaba	12.15	1.22	130.87	0.00	0.00	144.2	62.15	83.83	145.98	1.74
Mathurapur-II	10.88	0.26	118.20	0.00	0.00	129.3	43.76	73.40	117.15	-12.19
Kakdwip	13.89	0.87	131.25	0.00	0.00	146.0	52.17	77.37	129.54	-16.48
Sagar	10.45	1.29	69.37	0.00	0.00	81.12	72.23	81.74	153.97	72.85
Namkhana	9.01	0.67	72.82	0.00	0.00	82.50	30.33	93.69	124.02	41.52
Patharpratima	16.35	1.74	151.65	0.00	0.00	169.7	163.62	107.12	270.74	101.0
Total	218.10	14.02	1478.63	0.09	0.00	1711	1329.99	1410.33	2740.33	1029

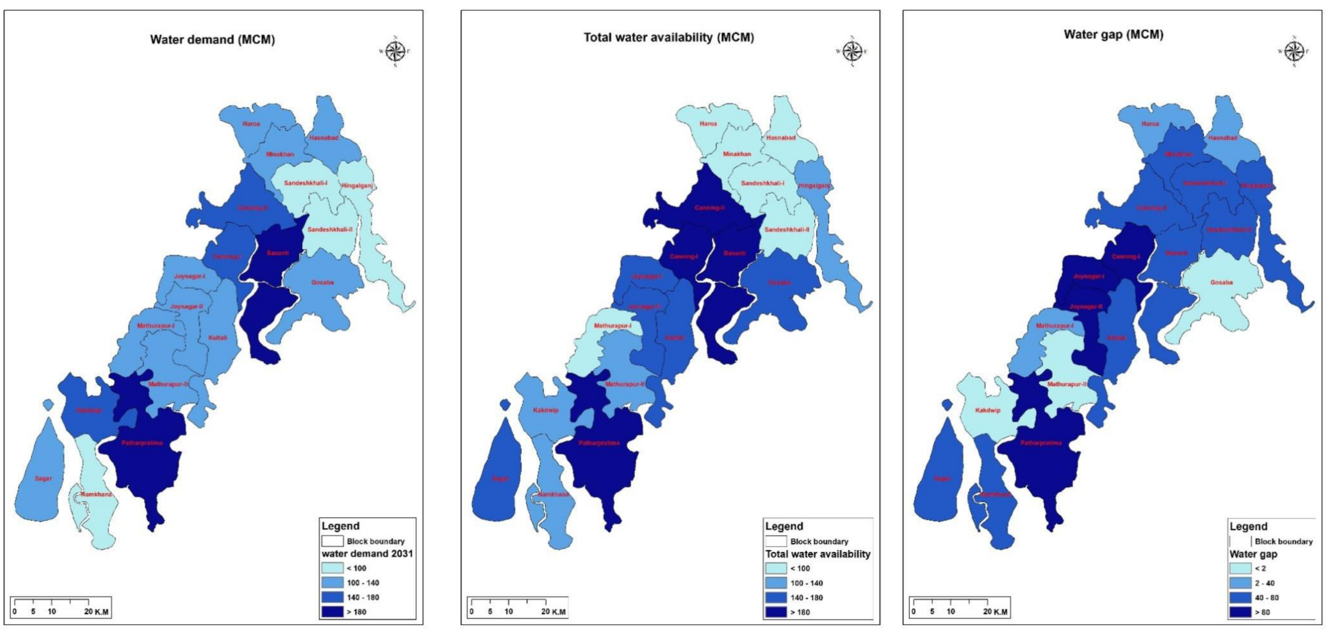


Fig 9.21 Block-wise water demand and water availability was estimate based on domestic, livestock, crop and industrial water demand, and surface and groundwater availability.

aquifer under consideration, perpendicular to the flow direction. For the area under consideration, we took average values of T=2000 m^2/day, I = 1:1500. Our estimation shows that the block Kakdwip, Mathurapur-II and Gosaba may face water scarcity in near future (Fig 9.21).

AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture

Groundwater Survey, Characterization and Mapping of Quality for Irrigation Purpose

Survey and mapping of groundwater in Srikakulam district (Revisiting sites) Bapatla

A total of 883 ground water samples were collected from available water resources in erstwhile Srikakulam district and were analysed for various quality parameters like pH, EC, soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (CO_3^{2-}, HCO_3^{-} and Cl^{-}). Values of electrical conductivity ranged from non-saline (0.15 dS m^{-1}) to highly saline (7.3 dS m^{-1}). The chloride content varied from safe to injurious to several plants. The number of samples under various classes were in the order of good water (79 %) > marginally saline (11.8 %) > marginally alkali > alkali > high SAR alkali > high SAR saline = saline water (0.23 %). Generated spatial groundwater quality variation map of the district (Fig10.1).

Survey and mapping of groundwater in Vizianagaram district (Bapatla)

A total of 736 ground water samples covering all the 34 mandals of erstwhile district were collected from the available water resources. Grouping of water samples based on various parameters indicated that 90.35 per cent of samples were good for irrigation based on electrical conductivity without growth limitation. While 73.78 per cent samples were excellent for irrigation based on chloride content. Overall around 98 per cent of samples have pH >7.0 with 42.66 per cent of samples in alkaline range (pH >8.0). Regarding SAR, 97.42 per cent samples are safe for irrigation. Considering the residual sodium carbonate, 3.94 and 6.52 per cent of samples were marginally alkaline and alkaline, respectively.

The overall quality of groundwater was grouped into seven classes considering the EC, SAR and RSC using the water classification standards of CSSRI, Karnal. The number of samples under different classes was recorded as good water (85%) >slightly saline (7.5%)

Water quality map of erstwhile Srikakulam district, A.P.

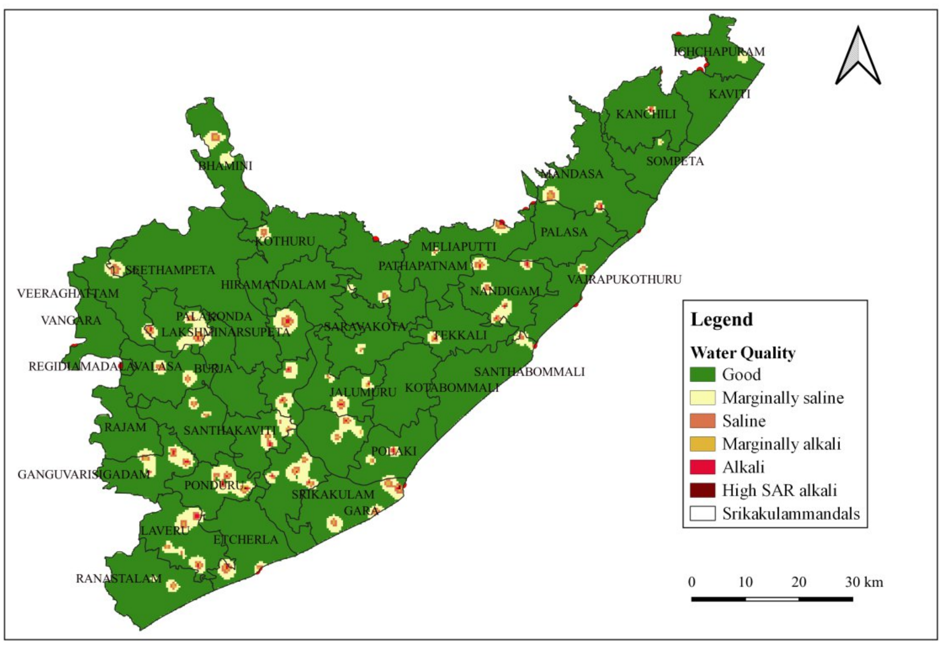


Fig 10.1 Groundwater quality map of erstwhile Srikakulam district

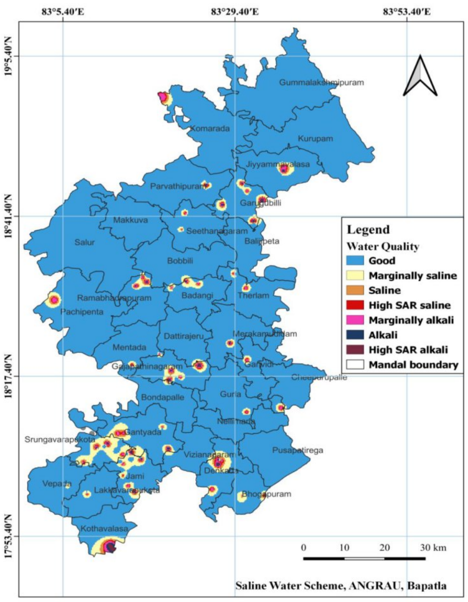


Fig 10.2 Groundwater quality map of erstwhile Vizianagaram district

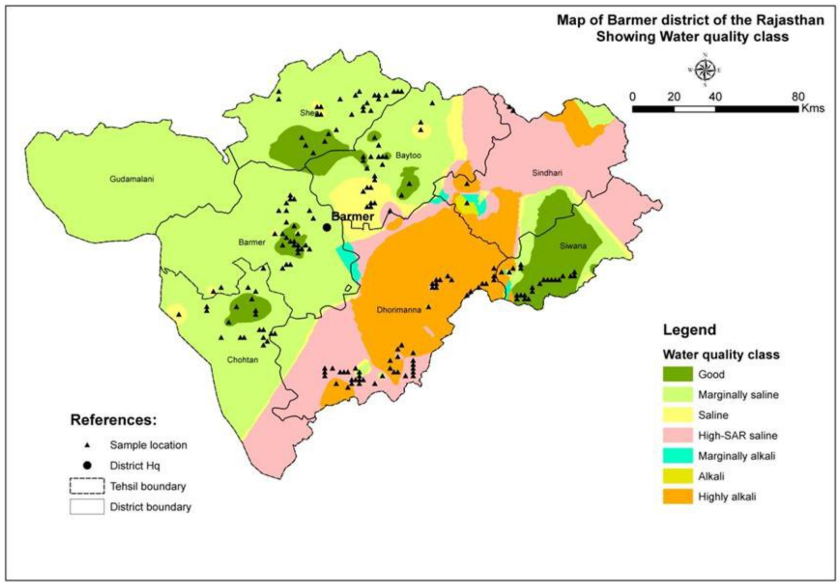


Fig 10.3 Map of Barmer district of the Rajasthan

>Marginally alkaline (3.8%) >high SAR alkali (2.3%) >alkali (0.95%) >high SAR saline (0.27%) >saline water (0.14%). Majority of the samples collected from different mandals were good in quality except 2 or 3 samples. Generated spatial groundwater quality variation map of the district (Fig 10.2).

Survey and mapping of groundwater in Barmer district (Bikaner)

The survey and characterization of underground water and soils for agricultural purpose of Dhorimana, Gudamalani, Sindhari, Siwana, Baytu Sheo, Barmer shahar and Chohtan tehsils of Barmer district were carried out. Water samples from 247 tube wells distributed in 141 villages (15 Dhorimana, 15 Gudamalani, 12 Sindhari, 15 Siwana, 21 Baytu, 21Sheo, 20 Barmer shahar and 21 Chohtan) from eight tehsils of Barmer district were collected and analyzed for various chemical characteristics. As per the results of analysis, 3.33, Nil, Nil, 73.53,37.50,24.24,48.39 and 14.81 per cent water samples in Dhorimana, Gudamalani, Sindhari, Siwana, Baytu Sheo, Barmer shahar and Chohtan tehsil were under good, respectively. While, 16.67, 3.33, Nil, 14.71, 40.62, 57.58, 38.71 and 74.08 per cent water samples in Dhorimana, Gudamalani, Sindhari, Siwana, Baytu Sheo, Barmer shahar and Chohtan tehsil was marginally saline, respectively, about 6.67, 3.33, Nil, Nil, 6.25, 18.18, 12.90 and 11.11 per cent water samples in Dhorimana, Gudamalani, Sindhari, Siwana, Baytu Sheo, Barmer shahar and Chohtan tehsil saline, About 56.67, 80.01, 56.67, 2.94, 15.63, Nil, Nil and Nil per cent water samples in Dhorimana, Gudamalani, Sindhari, Siwana, Baytu Sheo, Barmer shahar and Chohtan tehsi high SAR saline, respectively, About 3.33,3.33 Nil, Nil, Nil, Nil, Nil and Nil per cent water samples in Dhorimana, Gudamalani, Sindhari, Siwana, Baytu Sheo, Barmer shahar and Chohtan tehsi marginally alkali, respectively, about 13.33, 10.00, 43.33, 8.82,Nil, Nil, Nil and Nil per cent water samples in Dhorimana, Gudamalani, Sindhari, Siwana, Baytu Sheo, Barmer shahar and Chohtan tehsil highly alkali, respectively as shown in figure 10.3.

The groundwater of Barmer district, 26.32, 30.36, 7.29, 25.51, 0.81, 0.00, 9.72 per cent samples were recorded under good, marginally saline, high SAR saline, marginally alkali, highly alkali, respectively (Table 10.1).

Table 10.1 Per cent water samples under different category of water quality in Barmer and Jalore district

Water quality classes	Barmer district	Jalore district
Good (EC < 2 dS/m, SAR<10 & RSC < 2.5 meq/L)	26.32	48.55
Marginally saline (EC 2- 4 dS/m, SAR<10 & RSC < 2.5meq/L)	30.36	19.65
Saline (EC >4 dS/m, SAR<10 & RSC < 2.5meq/ L)	7.29	0.58
High SAR saline (EC > 4 dS/m, SAR>10 & RSC < 2.5 meq/L)	25.51	21.39
Marginally alkali (EC< 4 dS/m, SAR<10 & RSC 2.0-4.0 meq/L)	0.81	0.58
Alkali (EC< 4 dS/m, SAR<10 & RSC >4.0 meq/L)	0.00	0.00
Highly alkali (EC <4> dS/m, SAR>10 & RSC> 4.0 meq/L)	9.72	9.25

Survey and mapping of groundwater in Jalore district (Bikaner)

Total 173 samples of underground irrigation water collected from total 109 villages of different tehsils i.e. Ahore, Bhadrajun, Bhinmal, Jalore, Jaswantpura and Sayla tehsils of Jalore district of Rajasthan. About 66.67, 72.41, 27.78, 57.84, 54.29 and 6.67 per cent water samples in Ahore, Bhadrajun, Bhinmal, Jalore, Jaswantpura and Sayla tehsils were under good quality. While, 6.67, 13.79, 44.44, 9.68, 5.71and 50.00 per cent water samples in Ahore, Bhadrajun, Bhinmal, Jalore, Jaswantpura and Sayla tehsils were under marginally saline, respectively. Only 3.23 percent water samples in Jalore tehsils was under saline.

About 23.33,10.36, 27.76, 19.35, 11.43 and 40.00 per cent per cent water samples in Ahore, Bhadrajun, Bhinmal, Jalore, Jaswantpura and Sayla tehsils were under High SAR Saline, respectively. Only 3.23 percent water samples in Jalore tehsils was under marginally alikali. 3.33, 3.45, 0.00, 9.68, 28.57 and 3.33 67 per cent water samples in Ahore, Bhadrajun, Bhinmal, Jalore, Jaswantpura and Sayla tehsils were under highly alkali, respectively. In the district as a whole, 48.55, 19.65, 0.58, 21.39, 0.58 and 9.25 per cent water samples were under good, marginally saline, saline, High SAR Saline, Marginally Alkali and Highly alkali, category, respectively (Table 10.1).

Survey and mapping of groundwater in Salem district of Tamil Nadu (Trichy)

A study was conducted to evaluate and map groundwater quality across different blocks in Salem district viz., Salem, Gangavalli, Thalaivasal, Attur, Pethanaickenpalayam, Valappady, Ayothiyapattinam, Yercaud, Panamarathupatty, Veerapandi, Edappadi, Sankari, Kadayampatti, Kolathur, Konganapuram, Magudanchavadi, Mecheri, Nangavalli, Omalur, and Tharamangalam. Survey was conducted during 2024 and a total of 200 samples were collected. The samples were examined for pH, electrical conductivity, cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, anions like CO_3^{2-}, HCO_3^{-}, SO_4^{2-}, and Cl^{-}. Based on the ionic concentration, the water quality parameters are derived such as Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC). The pH and EC values were in the range of 7.08- 8.58 and 0.74 - 2.75 dS/m, respectively. The residual sodium carbonate (RSC) concentration ranged from 0 to 10.1 meq/L, while the sodium adsorption ratio (SAR) ranged from 0.7 to 9.7 $mmol^{1/2} L^{-1/2}$.

According to the CSSRI, Karnal Water Quality Classification, approximately 66.5 % of the

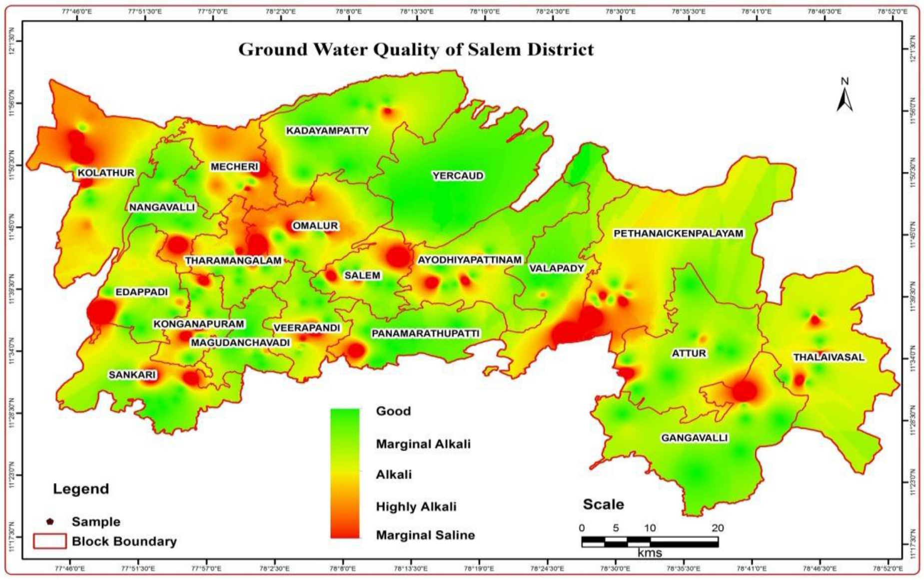


Fig 10.4 Spatial distribution of different water quality parameters in Salem district

samples fit into the good quality category, approximately 13% of the samples fit into the alkaline water category, and 20% of the samples fit into the saline water category in the Salem district. Using this classification, thematic maps depicting groundwater quality in the Salem district were generated with ArcGIS software (Fig 10.4). The study concludes that the majority of the samples are classified as good-quality water, while saline and alkali water emerge as the next major concern.

Conjunctive use of alkali and canal water for Til (Sesame) and Lentil cropping sequence (Agra)

Response of sesame and lentil crop to the conjunctive alkali water irrigation were evaluated. Increase in the ratio of alkali water irrigation caused decline in the sesame and lentil yield compared to the canal water irrigation. The higher grain and stover yield were recorded in all canal irrigated treatment 5.6 q/ha and 28.0 q/ha and minimum in all alkali water irrigated treatment 3.9 q/ha and 19.8 q/ha respectively. The 1C:1A and 1A:1C irrigation modes were at par with 4.5 q/ha and 4.2 q/ha grain yield, respectively. The net profit was also recorded Rs 53,200 maximum in all canal treatment with 3.14 B:C ratio and Rs. 29,400 minimum in all alkali water with 2.18 B:C ratio. Simlialry, maximum grain yield of lentil was recorded in all canal irrigation mode (12.73 q/ha). Yield was minimum (9.21 q/ha) in all alkali mode, here is the interesting point that the mixing 1C:1A mode gave the grain yield 12.25 q/ha which has the proximity with all canal mode. In 1C:1A and 1A:1C modes, one thing is attracting that in cycling irrigation, if we gave canal water first then it gave more yield than other(i.e. 11.67 q/ha in 1C:1A and 10.75 q/ha in 1A;1C). The net profit was maximum with all canal Rs 67,136.50 followed by mixing mode Rs 63,512.50, however it was Rs 40,560.50 in all alkali mode with B:C ratio 2.82, 2.50 and 1.58 respectively.

A case study on the functioning of *doruvu* technology in farmers' fields in coastal area (Bapatla)

The water quality in *doruvu* wells and bore wells was regularly monitored every month. It was observed that good quality water was available throughout the year in improved *doruvu* wells but in bore wells salinity was high in summer months and availability of water was also low in bore wells. Cropping intensity was more under improved *doruvu* wells compared to bore wells. But one lacuna was there *i.e* installation cost was more in case of improved *doruvu* well when compared to bore well. Improved *doruvu* well installation cost was nearly Rs.1,00,000 but bore well installation cost was Rs. 2,000-3,000.

Effect of saline irrigation water on growth, yield attributes and yields of different varieties of fennel through drip (Bikaner)

An experiment was conducted during Rabi 2021-22 to 2023-24 to study the effect of saline irrigation water on growth, yield attributes and yields of different varieties of fennel through drip. The experiment consisted of 4 level of Saline water (BAW, EC_{iw} 4, 6, 8 dS/m) and 4 varieties of fennel (AF1, RF-157, RF281, RF290) were evaluated under spilt plot design with five replications. It was inferred that saline water up to EC_{iw} 4 dS m^{-1} can safely be used through drip irrigation in case of fennel crop on sandy soil in arid region of Rajasthan without any significant reduction in yield and yield attributes.

Performance of mycorrhizal (*Glomus mosseae*) inoculation in cotton-wheat under saline water irrigation (Hisar)

A pot experiment was conducted on Performance of mycorrhizal (*Glomus mosseae*) inoculation in cotton-wheat cropping system under saline water irrigation. The mean seed cotton yield decreased by 21.25% in saline water irrigation of EC 8 dS/m as compared to canal irrigation. Minimum mean seed cotton yield (30.59 g/pot) was recorded in control and maximum seed cotton yield (65.20 g/pot) was recorded in RDF+FYM+ Mycorrhiza treatment which is at par with RDF+ Mycorrhiza (63.35 g/pot) and RDF (62.71 g/pot).

Performance of brinjal cultivars under different irrigation water quality (Bathinda)

An experiment was conducted to study the effects of fluoride in irrigation water on yield and quality of brinjal in poly house with irrigation water containing varying amount (0.12, 2, 4, 6, 8 and 10 mg/L) of fluoride. The brinjal yield was not affected significantly due to fluoride content in irrigation water. However, fluoride accumulation in soil was significantly higher after crop harvest (6.0 mg/L) as compared to control. However, fluoride content in fresh brinjal fruits and leaves were under safe limit (<1.5 mg/kg).

Effect of treated sewage water (SW) as a source of irrigation and nutrients supply for Marigold-Chrysanthemum rotation (Agra)

Marigold: The flower yield of marigold was 36.8% higher in SW+RDF over TW (tube well)+75% RDF, however 12.6 % higher over SW+75% RDF and the maximum yield 89.3 q/ha was recorded with SW+RDF. In respect of the yield of marigold, the TW+125% RDF, SW+50% RDF and 1SW:1TW+RDF modes were statistically at par. The maximum net profit Rs 1,17,330 was found in SW+ RDF and the minimum Rs 68,290 in TW+75%RDF, however the B:C ratio of marigold crop found maximum in SW+RDF (2.92) and the minimum in TW+75% RDF (2.10). Whereas the survivability of the seedlings were 72.8 to 79.2% in sewage and tube well irrigated plots, respectively.

Chrysanthemum: The survivability was recorded 100% in all the treatments. The primary branches, secondary branches, no. of flower/plant and flower weight/plant were maximum 140.6 cm, 57, 197.3, 202.3 and 729.0 gm in SW+RDF treatment, respectively. The flower yield of chrysanthemum was maximum 238.7 q/ha SW+RDF. The TW + 125%

RDF were at par statistically with SW+50% RDF and 1SW:1TW+RDF. The net profit was found maximum in SW+RDF treatment Rs 2,22,170 and the minimum in TW+75% RDF Rs. 1,55,690. The B:C ratio of chrysanthemum crop was found maximum in SW+RDF (4.45) and the minimum in SW+75% RDF (3.26).

Effect of method of planting in the establishment of rice seedling in high salinity (Vyttila)

The objectives of the experiment were to compare different methods of planting in seedling establishment in saline soils and to find out the best method of planting for the seedling establishment with minimum land preparation and to reduce the mortality of seedlings caused by non-insect pests. The experiment was laid out during June 2024 with different methods of land preparation (mound, ridges, raking with tiller) and planting (sowing/transplanting on mounds/ridges and with transplanter) with the Pokkali rice variety Vyttila 10 (KAU Lavanya) grown organically with zero inputs. The transplanting on ridges recorded a significantly higher yield (3488.43 kg ha^{-1}). This was on par with raking with garden tiller and transplanting manually, raking with garden tiller and transplanting with transplanter, transplanting on mounds, raking with garden tiller and sowing. The lowest yield was recorded in direct sowing without land preparation (116.09 kg ha^{-1}) due to poor germination percentage (10%) of seeds.

Management of Saline Acidic Soils

Management of salinity and acidity of Pokkali soils using suitable amendments (Vyttila)

The objectives of the study was to find out the effect of Ca salts and silica on managing soil acidity and salinity and to find a suitable ameliorant for economic yield in IFS in the Pokkali ecosystem. The experiment was conducted in June 2024 in RBD with 8 treatments and 3 replications with the Pokkali rice variety Vyttila 11 (KAU Jyotsna) grown organically without fertilizers and pesticides, except for the treatments. The treatments were the application of calcium nitrate, calcium chloride, gypsum, rock phosphate dolomite, lime and rice husk ash @1000kg/ha respectively. The results showed that rice husk ash recorded a significantly higher yield (2749.36 kg ha^{-1}). This was on par with dolomite, absolute control, rock phosphate, and calcium chloride. The lowest yield was recorded in the calcium nitrate (1923.5 kg ha^{-1}) treated soils. The treatment effects were not marked, as a result of neutral pH, and the EC below 4 dS m^{-1} throughout the cropping season.

Technology Assessed and Transferred

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)} NRMACSSRICOL202102101042.

Wheat Varietal trial: A field experiment was conducted to assess the yield potential of twelve different varieties (DBW 187, DBW 222, DBW 303, DBW 332, DBW 370, DBW 371, DBW 372, HD 3086, HD 3226, KRL 210, KRL 283 and WH 1270) of wheat to identify the most suitable varieties for the famers during 2023-24 under the Farmer FIRST project in Kathura village. Results of experiment showed that use of quality seeds of above-mentioned improved varieties led to higher yield in comparison to conventional varieties. It was observed that average yield of local was 51.00 q/ha while yield of demo varieties was ranging from 53.00 to 63.70 q/ha. Highest percent increase in yield over local variety was 25.74 % for DBW 371 followed by DBW 303 (24.90 %) and DBW 187 (24.12 %). Range of net return of varieties was from Rs. 101157 to Rs. 130854 , while it was Rs. 95589 for local. BC ratio for local variety was 2.06, However, it ranged from 2.18 to 2.82 for improved varieties. Maximum BC ratio was observed for DBW 303 followed by DBW 371 & DBW 187 (Table 11.1).

Rice Varietal performance under waterlogged saline soils: The present study was conducted to determine the yield potential, net return and BC ratio of different rice varieties, *viz.*, PB 1121, PB 1509, PB 1692 and PB 1718, in comparison to local variety, which was used as control during 2024-25 under the Farmer FIRST project. Results of the experiment revealed that yield of local variety was 42.32 q/ha. However, among the demo varieties, the highest yield was observed in PB 1509 (57.23 q/ha) which was at par with PB 1692 (57.12 q/ha); while minimum yield (46.56 q/ha) was observed in PB 1121. Range of

Table 11.1 Yield, Net return and BC ratio of demo and local wheat varieties

Variety	Yield (q/ha)			Net return			BC Ratio	
	Demo	Check	% Δ	Demo	Check	% Δ	Demo	Check
DBW 187	63.30	51.00	24.12	129926	95589	35.92	2.80	2.06
DBW 222	56.30	51.00	10.39	110437	95589	15.53	2.38	2.06
DBW 303	63.70	51.00	24.90	130854	95589	36.89	2.82	2.06
DBW 332	54.00	51.00	5.88	103941	95589	8.74	2.24	2.06
DBW 370	59.00	51.00	15.69	117861	95589	23.30	2.54	2.06
DBW 371	63.50	51.00	24.50	130390	95589	36.40	2.81	2.06
DBW 372	55.50	51.00	8.82	108117	95589	13.11	2.33	2.06
HD 3086	57.30	51.00	12.35	113221	95589	18.45	2.44	2.06
HD 3226	54.50	51.00	6.86	105333	95589	10.19	2.27	2.06
KRL 210	55.00	51.00	7.84	106725	95589	11.65	2.30	2.06
KRL 283	53.00	51.00	3.92	101157	95589	5.83	2.18	2.06
WH1270	54.33	51.00	6.53	104869	95589	9.71	2.26	2.06

Table 11.2 Yield, Net return and BC ratio of demo and local paddy varieties

Variety	Yield (q/ha)			Net return			BC Ratio	
	Demo	Check	% Δ	Demo	Check	% Δ	Demo	Check
PB 1121	46.56	42.32	9.95	144511	110032	31.33	2.96	2.25
PB 1509	57.23	42.32	35.23	131595	110032	19.60	2.70	2.25
PB 1692	57.12	42.32	34.97	148271	110032	34.75	3.04	2.25
PB 1718	52.55	42.32	24.17	153512	110032	39.51	3.15	2.25

Table 11.3 Effect of supplements (Mineral mixture, Anionic mixture and BergaFat) on Milk production (litre/animal/day), Net return (Rs. /litre) and BC Ratio

Supplementation	Demo (No.)	Milk production (litre/animal/day)			Net return (Rs. /litre) (Demo)	BC ratio (Demo)
		Demo	Control	% Δ		
Summer season						
Mineral Mixture	25	9.41	8.97	4.91	1848	3.08
Anionic mixture	13	9.94	9.24	7.58	2940	3.92
BergaFat	25	10.12	9.07	11.57	4410	6.12
Winter season						
Mineral Mixture	20	10.37	9.86	5.17	1539	2.57
Anionic mixture	20	10.57	9.58	10.33	3424	4.57
BergaFat	20	10.82	9.66	12.01	4140	5.75

percent increase in yield over the local variety was from 9.95 % (PB 1121) to 35.23 % (PB 1509). Net return of demo varieties *viz*., PB 1121, PB 1509, PB 1692 and PB 1718 was Rs 144511, 131595, 148271 and 153512 per ha, respectively. Result of experiment also revealed that BC cost ratio of demo varities *viz*., PB 1121, PB 1509, PB 1692, and PB 1718 was 2.96, 2.70, 3.04, and 3.15, respectively; that was higher than BC ratio of local variety i.e. 2.25 (Table 11.2).

Performance of demonstrations on mineral mixture, anionic mixture and BergaFat on milk production of animals: An experiment was conducted to examine effect of animal nutrition supplements like mineral mixture, anionic mixture and BergaFat on milk production of animlas during winter and summer season in Kathura village of Sonipat district. Results revealed that provided supplements had a positive effect on milk production. Maximum percent increase in milk production was observed due to BergaFat followed by anionic mixture and mineral mixture. Benefit cost ratio was maximum for BergaFat supplementation followed by anionic mixture and mineral mixture during both season (Table 11.3).

Farmer participatory integrated farming system model for improving livelihood security under reclaimed sodic land (IFS) (Rajkumar (Hort.), Suresh Kumar, Awtar Singh, R. K. Fagodiya and R. N. Bhutia)

The objectives of the projects are: to enhance the profitability and sustainability of diversified agricultural enterprises; to quantify the GHG emissions and assess the GWP of diversified land use systems; and to analyse risks and optimize resources. The IFS model has three key components: grains; horticultural crops, and subsidiary enterprises, with allocated areas of 1.0, 0.80, and 0.20 ha, respectively. The grain component represents three different crop sequences: (a) rice-wheat; (b) rice-wheat-moong and (c) maize-wheat-moong cropping systems. The horticultural crop-based component includes orchard (guava), seasonal vegetables, and fodder crops. The subsidiary enterprises are dairy, fishery, poultry, and fruits on dykes. With the increasing adverse effects of the conventional system (CS), which is dominated by the incessant mono-cropping of rice-wheat system area, it was expected that IFS will help in enhancing the profitability and resource-use efficiency without harming the soil health with minimal dependence on the use of external inputs. Based on the prevailing prices (year 2023-24) of the inputs and outputs, the estimated value of the gross returns from the IFS model (2.0 ha) and conventional system (2.0 ha, Rice-wheat system) were Rs 10,16,350 and Rs 6,26,400, respectively. Furthermore, at the disaggregate level, the gross returns were Rs 2,59,940, Rs 81,350 and Rs 6,75,060 from the grains, horticultural crops, and subsidiary component of

Table 11.4 Performance of the integrated farming system during 2023-24

Component loss	System	Area (ha)	Gross Returns (Rs)	Expenditure (Rs)	Profit/Loss
Grain Component	Rice-Wheat	0.40	125280	41086	84194
	Rice-Wheat-Moong	0.20	64380	22543	41837
	Maize-Wheat-Moong	0.40	70280	33848	36432
	Sub-total	**1.00**	**259940**	**97477**	**162463**
Horticultural including fodder	Horticulture	0.20	18500	0	18500
	Vegetables	0.20	32850	5340	27510
	Fodder	0.40	30000	8583	21417
	Sub-total	**0.80**	**81350**	**13923**	**67427**
Subsidiary	Dairy		553270	294252	259018
	Fishery	0.20	85830	24960	60870
	Poultry		19960	9475	10485
	Fruits/Vegs on dykes		16000	0	16000
	Sub-total	**0.20**	**675060**	**328687**	**346373**
Overall	Conventional RWS	2.00	626400	205430	420970
	Diversified Agriculture	2.00	1016350	440087	576263
	Net Gain (Incremental)	**2.00**			**155293**

the IFS model, with respective shares of 25.58 %, 8.00 %, and 66.42 %. Similarly, the expenditure incurred (cost of inputs including the imputed family labour) was Rs 97,477, Rs 13,923 and Rs 3,28,687, respectively in these components. In the case of the IFS model, the estimate shows that because of multiple components, the expenditure was 2.14 times, however, the gross returns were also 1.62 times that of the CS. As a result, the profit of the IFS model (Rs 5,76,263) over the CS (Rs 4,20,970) was higher to the tune of Rs 1,55,293, which was 1.36 times higher than the CS. Among the different enterprises, based on the profitability index (ratio of profit over expenditure per ha), the horticultural component (4.84 with profit of Rs 84,283 per ha) is more remunerative, followed by grains component (1.66 with profit of Rs 1,62,463 per ha) and subsidiary enterprises (1.05 with profit of Rs 17,31,865 per ha). In conformity with previous reports, it can be stated that IFS is more profitable than CS. However, discussions with the farmers indicate that poor access to the market (for small and multiple produces) and IFS being more efforts and knowledge intensive along with growing labour shortage were identified as major issues hindering its farm-level adoption.

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)

A new research project aims to address the identification of date palm varieties suitable for Haryana and to understand the physiological bases of salt tolerance in date palm. This

Dohki, Bhiwani

Barwas, Bhiwani

Kathura, Sonipat



IIWBR Farm, Hisar Sajuma, Kaithal CSSRI, Karnal

project also aims to promote sustainable production strategies of date palm cultivation through capacity building and exposure visit programmes. As per the technical programme, date palm orchards were established at six locations (one acre at each site) in different parts of Haryana: reclaimed sodic soils of CSSRI Experimental Farm, Karnal; under saline soils at ICAR- IIWBR Farm (Hisar); under subsurface sodicity at Sajuma (Kaithal), under waterlogged saline soils of Kathura (Sonipat), normal soil and saline water irrigation of Dohki & Barwas (Bhiwani) and dry land salinity in sand dunes of Madhogarh (Mahendergarh); respectively.

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

Crop production in dry land saline areas confined with saline underground water has become a challenging to sustain the productivity due to continuous rise in salinity. The most of the common field crops being grown in such areas has limited threshold salinity levels. When salinity rises beyond threshold level prescribed, the production become uneconomical due very less crop yields. The alternate strategy such as introduction of high salinity tolerant halophytic crop species of good economic value can be adopted for continuing production for high saline agro-ecosystems. Quinoa (*Chenopodium quinoa*) is one of the natural salt tolerant semi-halophytic crops, recently has gained attention worldwide due to its natural salinity tolerant ability and higher nutritional values.

Based on the comments of IRC 2022, to explore the possibilities of quinoa sowing in early October, a field experiment was carried out to evaluate the performance of quinoa crop under varied sowing dates starting from October 1st. Ten number of sowing dates as 1st October, 5th October, 10th October, 15th October, 20th October, 25th October, 30th October, 10th November, 20th November and 30th November were evaluated in randomized block design with three replications at the research farm of ICAR-CSSRI, Karnal main farm during winter season of 2023-24. The crop was sown in well prepared field with staggered pre-sowing irrigation based on dates of sowing. Periodical observations on growth, physiological indices, yield parameters and yield were recorded.

Results showed that plant height of quinoa at 30 and 60 DAS was measured significantly the highest in 1st October and 5th October sown crop, respectively over rest of the sowing dates. The early emergence and faster growth due to higher temperature attributed for higher plant height under these sowing dates. However, the plant height at 90 DAS was higher and at par under 1st October to 25th October sown crop which was significantly higher over rest of the sowing dates. The dry matter accumulation per plant at 30 DAS was significantly highest in the 5th October sown crop followed by 1st, 10th and 15th October

Table 11.5 Effect of sowing dated on SPAD and NDVI of quinoa

Date of sowing	SPAD			NDVI		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
01 October	45.2[a]	48.9[abc]	48.9[abc]	0.64[a]	0.69[a]	0.43[e]
05 October	45.3[a]	47.8[abc]	47.8[abc]	0.59[a]	0.58[cd]	0.45[de]
10 October	43.1[ab]	48.0[abc]	48.0[abc]	0.48[a]	0.61[bc]	0.50[cd]
15 October	43.0[ab]	48.2[abc]	48.2[abc]	0.60[a]	0.66[ab]	0.53[c]
20 October	40.5[bc]	52.3[a]	52.3[a]	0.53[a]	0.59[cd]	0.62[b]
25 October	41.0[bc]	49.5[ab]	49.5[ab]	0.54[a]	0.62[bc]	0.63[b]
30 October	41.6[abc]	46.7[abcd]	46.7[abcd]	0.51[a]	0.62[bc]	0.66[ab]
10 November	41.8[abc]	42.6[bcd]	42.6[bcd]	0.31[b]	0.54[d]	0.70[a]
20 November	38.4[c]	39.2[d]	39.2[d]	0.32[b]	0.40[e]	0.69[a]
30 November	43.6[a]	40.9[cd]	40.9[cd]	0.19[c]	0.37[e]	0.46[de]

sowing dates, while at 60 DAS, the dry matter accumulation was statically similar between 1st to 25th October sowing dates which were significantly higher over other dates. At 90 DAS, the dry matter accumulation in all the date of sowings in the October was varied non-significantly but significantly higher over November sown crops. The better weather conditions for growth under October sown crop showed higher dry matter accumulation while the low temperatures during November-January months sluggish the growth of quinoa in November sown crop.

The physiological parameters, the relative chlorophyll content in terms of SPAD meter readings and Normalized Difference Vegetation Index (NDVI measured with green seeker hand held crop sensor) under various dates of sowing are presented in Table 11.5. At 30, 60 and 90 DAS, the SPAD values of quinoa were significantly higher under October sown crop in most of the cases with non-significant variations among all the October sowings and also with 30th November sowing at 30 DAS. The NDVI values recorded art 30 DAS were significantly higher under crop sown during 1st to 30th October over 10, 20 and 30th November sown crop. At 60 DAS, the crop sown on 1st and 15th October recorded significantly higher NDVI values followed by 10th, 25th and 30th October sowing dates. Conversely at 90 DAS, the crop sown on 30th October and 10th and 20th November showed significantly higher NDVI values than remaining October sowing dates. The congenial weather conditions for growth of quinoa up-to November month favored better ground coverage and photosynthetic activity resulted in higher SPAD and NDVI in October sown crop during first 60 days of growth.

The no. of branches/plant of quinoa significantly highest under 01 and 5th October sowing at 30 and 60 DAS (Table 11.6). The number of branches in 10th October to 25th October decreased non-significantly, but further delay in sowing to November month drastically reduced the no. of branches/plant. At 90 DAS, the no. of branches/plant were counted significantly maximum in 10th October sowing being at par with sowing dates up to 30th October. The length of main panicle of quinoa was significantly highest in crop sown on 1st October which was statistically similar in all the sowing dates of October month. The October sown crop at all the sowing dates showed significantly superior panicle length over 10-30th November sown crop. The test weight (1000-grain weight) of quinoa was measured significantly highest under 15th October sown crop closely followed by 10th October and 20th October sown crop over rest of the sowing dates. The lowest test weight was recorded under the 20th and 30th November sown crop. The harvest index of quinoa crop found maximum from the 05th and 30th October sown crop.

Table 11.6 Effect of sowing dated on yield parameters and yield of quinoa

Date of sowing	No. of branches/plant			Length of main panicle (cm)	Test weight (g)	Harvest index
	30 DAS	60 DAS	90 DAS			
01 October	12.2^{ab}	22.7^{a}	22.7^{bc}	16.1^{a}	3.37^{cd}	60.0^{b}
05 October	13.3^{a}	22.1^{ab}	22.8^{bc}	15.9^{a}	3.51^{b}	65.5^{ab}
10 October	11.8^{bc}	20.8^{bc}	23.8^{a}	16.1^{a}	3.55^{ab}	62.8^{b}
15 October	11.8^{bc}	21.7^{b}	22.8^{ab}	15.1^{ab}	3.62^{a}	61.4^{b}
20 October	10.8^{bc}	19.9^{cd}	23.1^{ab}	15.0^{ab}	3.58^{ab}	61.4^{b}
25 October	10.0^{bc}	18.8^{d}	23.0^{ab}	14.3^{ab}	3.41^{c}	27.7^{d}
30 October	8.6^{c}	19.9^{cd}	23.3^{ab}	14.9^{ab}	3.31^{d}	72.9^{a}
10 November	5.4^{d}	13.4^{e}	21.7^{de}	13.8^{b}	3.11^{e}	43.2^{c}
20 November	9.7^{c}	13.1^{e}	18.7^{f}	13.6^{b}	2.62^{f}	46.9^{c}
30 November	9.3^{c}	13.2^{e}	21.2^{e}	13.5^{b}	2.36^{g}	30.5^{d}

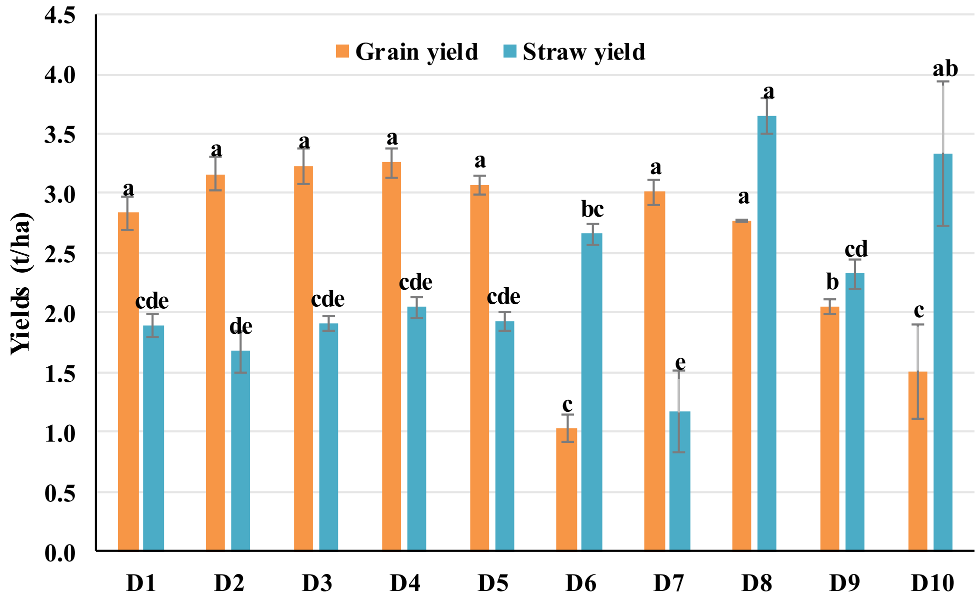


Fig 11.1 Spatial distribution of different water quality parameters in Salem district

The grain yield of quinoa crop varies significantly under various sowing dates (Fig 11.6). The grain yield showed numerical increase when sowing dates advanced from 1st October up-to 15th October then non-significant decline was seen on further advancing to 20th October, 30th October and 10th November. This showed that quinoa can be grown from 1st October to 10th November without significant variation in grain yield. The crop sown on 25th October suffered due to untimely rain and hail at maturity stage, resulted in lower yield. The grain yield was almost similar (3.23-3.26 t/ha) and highest under 15th and 20th October sown crop compared to other sowing dates. There was substantial decline in crop yields under 20th and 30th November sown crop showing 37-54% decline, respectively. Furthermore, the quinoa sown on 1st, 5th , 20th and 30th October and 7th November showed -13, -3, -6, -8 and -15 per cent yield compared to 15th October sown crop. The straw yields of quinoa also showed different trend against the grain yield. The crop shown on 10 and 30th November recorded higher straw yield compared to the rest of the dates of sowing (Fig 11.6).

Agripreneurship for Sustainable Agricultural Development-Technological and Institutional Innovations and Strategies, NASF funded (Suresh Kumar, Rajkumar and SK Sanwal)

The major focus of the project is to understand site-specific issues hindering the taking-

Table 11.7 Economic, technical and climatis stress faced by farmers in taking-up horticultural crops as enterprise

Constraints	GR Score	Rank
Economic		
High volatility/fluctuation in prices	77.15	1
High charges on availing private storage facilities	71.79	2
Poor access to market facilities and charges and high dependence on middle-men	68.46	3
Lack of storage and processing facilities	65.13	4
Increasing cost for inputs (transportation, labor, planting material, fertilizers etc.)	60.80	5
No government support economic losses/insurance	58.47	6
Labour shortages and high wages	56.14	7
Inadequate credit and Subsidy facilities for the purchase of inputs	51.81	8
High initial investment	49.48	9
Costly grading and packaging and post-harvest management machines	45.15	10
Technical		
Non-availability of quality planting material	76.60	1
Lack of knowledge about proper package of practices (Nutrient; irrigation; pest and diseases management etc.)	72.05	2
High incidence of disease and pests	69.50	3
Non-availability weather advisories	60.95	4
Wild and stray animals menace	58.40	5
Difficult to diversify being smallholders	55.85	6
Longer period for attaining economic harvesting stage	49.30	7
Lack of need-based training and know-how programme	48.75	8
Non-availability of good quality of irrigation water	40.20	9
High mortality of plants during initial years	35.65	10
Climatic		
Degradation of land and increasing area under water-logging	77.48	1
Increasing frequency and degree of climatic stresses (e.g., unseasonal rainfall and high temperature during May-June; frost and heat waves)	74.00	2

up of agripreneurship, with specific objectives: (a) map the nature of constraints in agriculture and assess the extent of risks in entrepreneurship development; (b) identify technological and institutional innovation in the study area to overcome the risks in entrepreneurial development; (c) explore institutional innovations for community mobilization and collective action; and (d) identify the attributes for success of agripreneurship and design strategies for sustainable agriculture through agripreneurship. As part of constaints analysis, issues faced by the enterprenuers in taking-up the horticultural crops were analized based on the primary survey of 70 farmers. Amongst the key economic constraints, the high volatility in prices followed by high charges for storage facilities were ranked first and second, respectively. Similarly, the non-availability of quality planting material (Ranked first) followed by lack of knowledge about proper package of practices were the key technical constaints faced by the farmers. The major climatic constraint faced by the farmers was degradation of land and increasing area under water-logging.

Using the Kruskal-Wallis chi-squared, the mean scores climatic stresses across the different farm categories (marginal, small, medium, semi-medium and large) were compared, the result shows that statistically there was no significant difference in the mean scores of climatic stresses percived by the different categories of the farmers (*Kruskal-Wallis chi-squared = 7.31, df = 4, p-value = 0.1202, figure 11.2*). However, in case of the technical (*Kruskal-Wallis chi-squared = 268.17, df = 4, p-value < 0.0001*) and economc

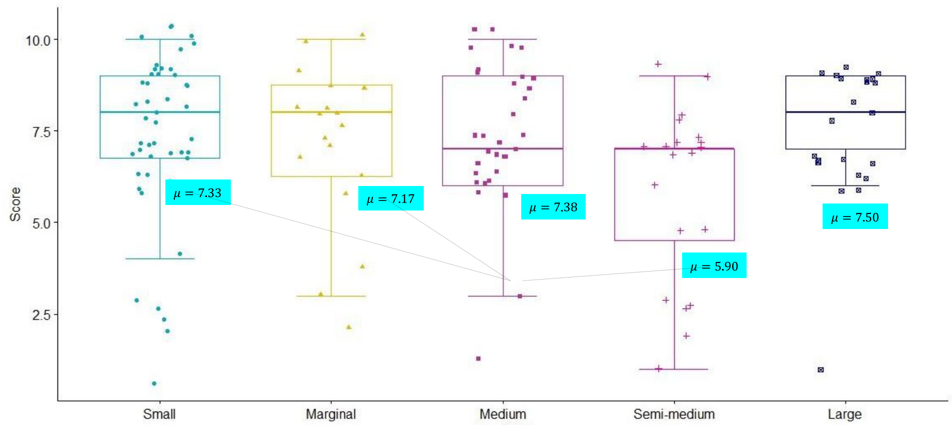


Fig 11.2 Comparison of climatic stresses across farm-categories

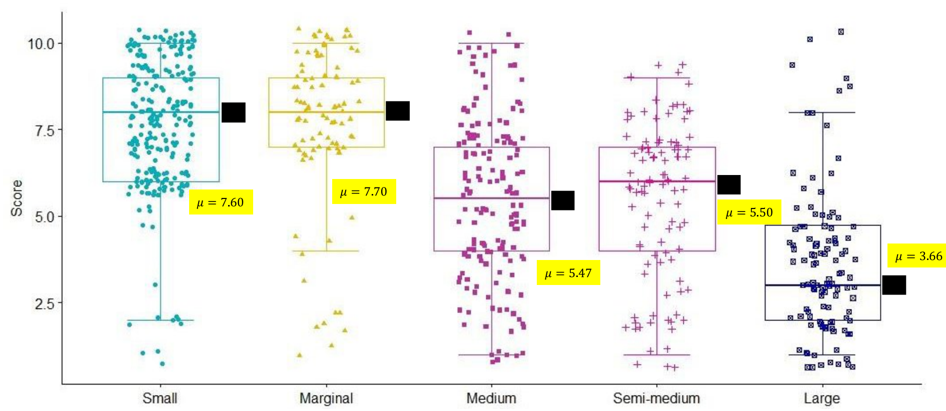


Fig 11.2 Comparison of economic stresses across farm-categories

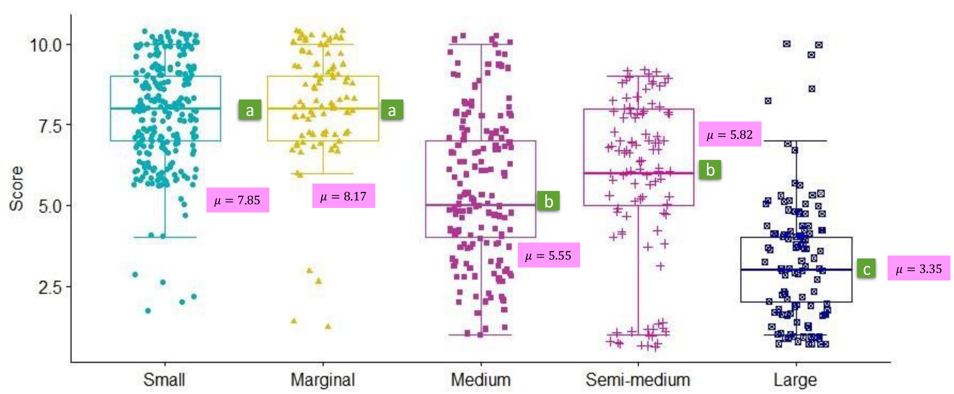


Fig 11.3 Comparison of technical stresses across farm-categories

stresses (*Kruskal-Wallis chi-squared = 224.3, df = 4, p-value < 0.0002*), results show that there was signicant differece among the different farm categories. To examine the how exactly the percived stresses differ across the farm categories, a pairwise comparisons was carried out using Wilcoxon rank sum test. In case of the economic stresses, the higher level of the stress was percieved by smallhoders (mean score was 7.70 and 7.60 for marginal and small farmers, respectively) followed by semi-medim and medium category of farmers with mean score level ~5.5, and the least level of economic stress was percived by the large category of farmers with mean score of 3.66 (Figure 11.3). Statistically, small and marginal farmers were at par. Further, semi-medium and medium category of farmers were at par but their score was significantly higher than the large farmers. Like the economic stresses, the similar pattern was observed in case of techncial stresses percived by the farmers in opting horticultural crops as enterprise (Figure 11.4).

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)

Under this project, the impact of subsurfcae drainge (SSD) was assessed using the economic surplus model (ESM). Amongst different input parameters required to exceute the ESM, the results relating to exogenous growth rate and factor affecting the SSD are presented. In the waterlogged-saline affected districts of Haryana, the peformce of the rice and wheat was examined. The results indicated that in Haryana state, the production of rice increased from 856 thousand tons in 1997-98 to 2117 thousand tons by 2019-20, increased at CAGR (Compound Annual Growth Rate) of 4.48 ($P < 0.001$). Similarly, the production of wheat has increased at CAGR of 2.11% ($P < 0.001$), from 3339 to 5751 thousand tons in 1997-98 and 2019-20, respectively. In Maharashtra state, sugarcane production was 31061 thousand tons in 1998-99, and surged to the tune of 46841 thousand tons by 2019-20, increased CAGR of 2.11% during this period (Figure 11.4).

The determinants affecting the adoption of SSD were analyzed utilizing the logit model. In Maharashtra, it was observed that farmers experiencing moderate to high levels of salinity on their farms were found to be more likely to adopt SSD, with adoption probabilities estimated at approximately 35.2% and 59.8% higher compared to those with low/no salinity plots (Table 11.8). Additionally, farmers who had witnessed the benefits of SSD in real-field situations demonstrated a significantly positive association with its adoption (1.568; $p < 0.001$). Membership in sugar mill cooperatives was also linked to increased SSD adoption, with a probability of adoption 37.4% greater than that of non-members. Furthermore, farmers engaged in sugarcane cultivation exhibited a 43.5% higher likelihood of adopting SSD. Farmers whose plots were affected by flooding showed a greater predisposition towards adopting SSD compared to those whose fields

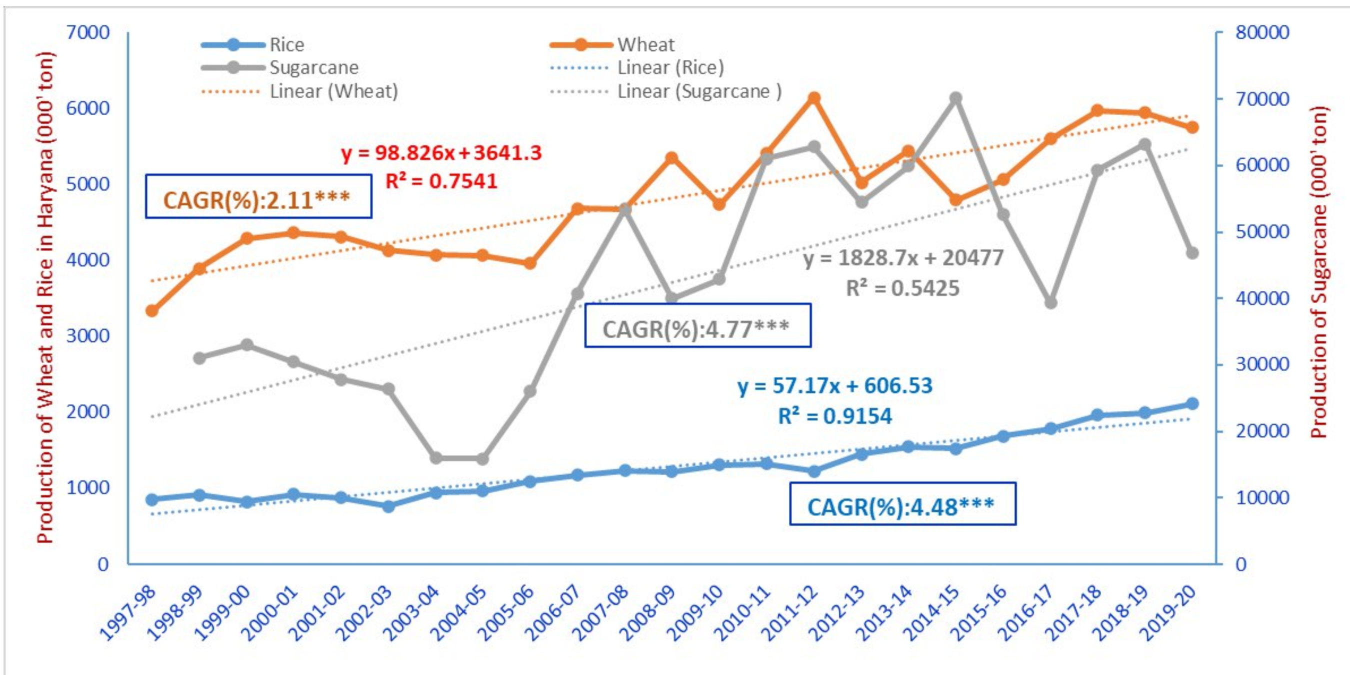


Fig 11.4 Crop production performance in water-logged saline area

Table 11.8 Factors affecting the adoption of SSD (estimates of the logit model)

		Maharashtra				Haryana			
		Estimate	SE	ME	SE	Estimate	SE	ME	SE
Constant		-5.103	4.030			-4.043**	1.494		
Age	Number of years	0.039	0.048	0.010	0.007	0.009*	0.019	0.002	0.005
Education	Number of schooling years	0.055	0.117	0.014	0.018	0.087	0.044	0.022**	0.010
Landholding	Size of land holding (ha)	-0.615	0.466	-0.154	0.102	0.265	0.288	0.066	0.071
Family size	Number of family members	-0.228	0.190	-0.057**	0.029	0.079	0.121	0.020	0.029
Off farm income	Takes one if farmer has any source of off-farm income; otherwise, zero	0.800	0.711	0.197	0.129	0.580	0.417	0.144	0.102
High salinity	Takes one if farmer perceive level of salinity high at his farm; otherwise, zero	1.480*	0.854	0.352***	0.133	1.468**	0.588	0.351***	0.119
Medium salinity	Takes one if farmer perceive level of salinity medium at his farm; otherwise, zero	3.053***	1.101	0.598***	0.081	1.526**	0.613	0.361***	0.118
Perceived benefits of SSD	Takes one if farmer perceive high level of benefits from SSD; otherwise, zero	1.568**	0.768	0.373***	0.121	0.989*	0.425	0.242**	0.100
Member to cooperative	Takes one if farmer is member of cooperative society; otherwise, zero	1.573*	0.823	0.374***	0.133	-	-	-	-
Area under sugarcane crop	Area under sugarcane crop (hectare)	0.905**	0.435	0.226***	0.081	-	-	-	-
High prone to flood	Takes one if farmer state that his/her farm is high prone to floo ding; otherwise, zero	1.533*	0.921	0.365***	0.105	-	-	-	-
Medium prone to flood	Takes one if farmer state that his/her farm is medium prone to flooding; otherwise, zero	0.791	0.897	0.195	0.122	-	-	-	-
Number of observations			80				120		

were not flood-prone. In Haryana, farmers having waterlogged-saline soils (at high to medium levels) and those who had a positive perception about the benefits of SSD were found to be more motivated to adopt SSD.

MISCELLANEOUS

Training and Capacity Building

Name and	Subject/Training Program	Place/Organizer	Duration/Period
Sonali Mallick	Professional Attachment Training as part of FOCARS training	IFPRI, New Delhi	1 Feb - 30 Apr, 2024
Ravikiran K T	Training on 'Genome utilization and editing of plant for useful traits'	ICAR-NIPB, New Delhi	07 Feb - 27 Feb, 2024
Jitendra Kumar Devika S.	Training on Reclamation and Management of Salt Affected Soil	ICAR-CSSRI, Karnal	26 Mar - 28 Mar, 2024
Rakesh Banyal	Pedagogy development program (NAAS) – Enhancing Pedagogical Competencies	NASC Complex, New Delhi	29 Apr - 3 May, 2024
Amresh Choudhary	Training on RS & GIS Technology and Applications	IIRS, Dehradun	13 May - 5 Jul, 2024
Ravikiran K T	Training on "Bioinformatics Advances in Genomics Data Analysis"	ICAR-IASRI, New Delhi	24 Jun - 28 Jun, 2024
Devika S.	Institutional Orientation Training (NAARM)	ICAR-CSSRI, RRS, Canning Town	29 Jul - 28 Aug, 2024
Jitendra Kumar	Training Programme on Solar Pump Irrigation System	BISA Research Station, Ludhiana	29 Aug - 31 Aug, 2024
Devika S.	Professional Attachment Training (NAARM)	ICAR-IARI, New Delhi	14 Oct 2024 - 16 Jan, 2025
Sagar Vibhute	Training Programme on ArcGIS Pro Foundation (online)	ESRI India	11 Nov - 15 Nov, 2024
Aslam L. Pathan	Training on Advances in Simulation Modelling & Climate Change Research	IARI, New Delhi	19 Nov - 9 Dec, 2024
Bhaskar Narjary	Training on Remote Sensing & GIS Applications on Digital Soil Mapping	IIRS, Dehradun	2 Dec - 13 Dec, 2024
Arjun Singh Manish Kumar	Advanced International Course on "Conservation and Regenerative Agriculture"	CIMMYT-BISA and CSSRI, Karnal	3 Dec - 23 Dec, 2024

Deputation of Scientists Abroad

Name and	Subject/Training Program	Place/Organizer	Duration/Period
A.K. Bhardwaj	Training on BNI-enabled wheat	JIRCAS, Tsukuba, Japan	17 Feb - 25 Feb, 2024
T.D. Lama	Workshop of the CGIAR Initiative on Asian Mega-Deltas project	Dhaka & Khulna, Bangladesh	27 Feb - 01 Mar, 2024
D. Burman K.K. Mahanta	International ACIAR Salinity Futures Symposium	Can Tho, Vietnam	3 Mar - 6 Mar, 2024
Nirmalendu Basak	ISTRO Conference	Virginia, USA	22 Sep - 27 Sep, 2024
A.K. Bhardwaj	5th International BNI Consortium Meeting	JIRCAS, Tsukuba, Japan	3 Dec - 6 Dec, 2024
D.S. Bundela Awtar Singh	International HIROS Learning and Knowledge Sharing Workshop (NWO-DST Consortia project)	WUR, TU-Delft and Irriwatch, Netherlands	9 Dec - 14 Dec, 2024

Awards and Recognitions

- Dr. A.K. Bhardwaj received NAAS fellowship, the Dr. J.S.P. Yadav Memorial Award (2024), the Dr. S. Nagarajan Memorial Award (2024), and the Recognition Award (2022–23) the Society for Conservation of Nature (SCON) and Sustainable India Trust (SIT).
- Dr. Suresh Kumar, received NAAS Associateship (2024) from the National Academy of Agricultural Sciences, New Delhi, and the Uma Lele Mentor Fellowship (2024) from the AAEA Trust.
- Dr. A.K. Dubey was awarded the Girdhari Lal Chadha Award in Fruit Science by the Indian Academy of Horticultural Sciences, New Delhi.
- Dr. Sanjay Arora was awarded the "Agriculture Scientist Award 2024" by ICFA at the 1st Uttar Pradesh Agriculture Conclave 2024.
- Dr. R. K. Fagodiya received the Young Scientist Award (2023) from the Society for Science of Climate Change and Sustainable Environment (SSCE).
- Dr. N. Basak received the Young Scientist Award (2021–22) from the Indian Society of Soil Salinity and Water Quality. He also received the ISTRO Fellowship to attend the ISTRO-2024 Conference, Virginia, USA.
- Dr. Raj Mukhopadhyay received membership of the Indian National Young Academy of Science (2025) in the field of clay mineralogy and soil science.
- Dr. Arjun Singh was the recipient of the Young Scientist Award at the 1st International Conference on "Innovations to Achieve Climate Resilient Smart Agriculture for Ensuring Global Food and Nutritional Security."
- Dr. Jitendra Kumar received the Best Centre Award (2023) under AICRP of the PEASEM Project.
- M.J. Kaledhonkar and R.L. Meena received the Best Poster Presentation Award by at the International Salinity Conference on "Rejuvenating Salt Affected Ecologies for Land Degradation Neutrality under Changing Climate".
- Dr. P. Chandra received the Best Oral Presentation Awards (two) at the 5th International Group Meeting on "Climate-Proofing Cereal Agriculture: Strategies for Resilience and Sustainability and at the "Rejuvenating Salt Affected Ecologies for Land Degradation Neutrality under Changing Climate".
- Dr. A.K. Bhardwaj received Best Poster Awards (two) at the International Salinity Conference on "Rejuvenating Salt Affected Ecologies for Land Degradation Neutrality under Changing Climate," 14–16 February 2024, ICAR-CSSRI, Karnal.
- Dr. Rajkumar was awarded Fellow of the Society for Horticultural Research and Development (SHRD-2023). He also received the Best Poster Presentation Award at the International Salinity Conference.
- Dr. Kailash Prajapat received the Best Oral Presentation Award at the 4th International Web Conference on "Natural Resource Management for Global Food Security and Environmental Stewardship".
- Dr. U.K. Mandal received the Best Poster Presentation Award at the International Salinity Conference on "Rejuvenating Salt Affected Ecologies for Land Degradation Neutrality under Changing Climate".
- Dr. S. Mallick received the Outstanding Research Scholar Award for Ph.D. (2024) at the 11th National Seminar on "Transformative Agriculture and Sustainable Development: Rethinking Agriculture for a Changing World".

- Dr. R.H. Rizvi was conferred the Best Research Paper Award at the National Conference on "Soil, Water, and Energy Management for Sustainable Agriculture and Livelihood Security.
- Dr. Ravikiran K.T. was awarded Best Poster at the First International Conference on "Innovations to Achieve Climate Resilient Smart Agriculture for Ensuring Global Food and Nutritional Security".
- Dr. N. Basak served as Editor of the *Journal of the Indian Society of Soil Science* (2024–25) and as Associate Editor of the *Indian Society of Soil Salinity and Water Quality*.
- Dr. A.K. Bhardwaj served as Chief Editor of *the Journal of Natural Resources Conservation and Management*, Associate Editor of *Scientific Reports* and *Ecological Processes*, and as Editorial Board Member of the journals *Frontiers in Plant Science*, *Frontiers in Soil Science*, and *Frontiers in Environmental Science*

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 collborate 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), Fodazione 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.

Instituttes'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.

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प्रियंका चंद्रा, पारुल सुन्धा, निर्मलेंदु बसक, अरविन्द कुमार राय 2024 एकीकृत पोषक तत्व प्रबंधन में जीवाणु खाद की भूमिका 6 संख्या 1 जनवरी–जून, कृषि जीवन ।

अवतार सिंह, कीर्ति यादव, प्रियंका चंद्रा, राम किशोर फगोडिया एवं राजेन्द्र कुमार यादव 2024 क्षारीय मृदाओं में कार्बनिक पदार्थ का महत्व एवं इसे बढ़ाने वाली उन्नत प्रणालिया, मृदा स्वास्थ्य आलोक,भाकृ अनुप–भारतीय मृदा विज्ञान संस्थान, भोपाल

शिवानी खोखर, कैलाश प्रजापत, मधु चौधरी, तनुजा पूनिया, और एच एस जाट 2024। संरक्षण कृषि के तहत खरपतवार प्रबंधन। खेती सितम्बर पृष्ठसंख्या 26–28

तनुजा पूनिया, मनीष ककरालिया, चारुल चौधरी एवं मधु चौधरी, संरक्षण कृषि आधारित प्रबंधन प्रथाओ का मिट्टी की गुणवत्ता पर प्रभाव 2024 मृदा स्वास्थय आलोक, आईसी एआर केन्द्रीय मृदा विज्ञान संस्थान, भोपाल पृष्ठसंख्या 26 –30

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रामेश्वर लाल मीणा एवं कैलाश प्रजापत (संपादक) कृषि किरण वार्षिकांक 15 वर्ष 2022–23. पृष्ठ 126

Participation in Conference/Seminar/Symposia/Workshop

Name and	Subject/Training Program	Place/Organizer	Duration/Period
Raj Kumar	3rd Indian Horticulture Summit-cum-International Conference-2024	RARI, Jaipur	01 Feb - 03 Feb, 2024
D Burman Suresh Kumar	XXVIII Biennial Workshop 2021–2022 of AICRP on SAS&USW	ICAR-CSSRI, Karnal	12 Feb – 13 Feb, 2024
ICAR-CSSRI (60 scientists)	International Salinity Conference on "Rejuvenating Salt Affected Ecologies for Land Degradation Neutrality under Changing Climate"	ISSWQ, Karnal	14 Feb – 16 Feb, 2024
U.K. Mandal	Delivered a lecture in 11th Annual Convention and National Webinar	Society for Fertilizer and	23 Feb – 24 Feb, 2024
T.D. Lama	Asian Mega-Deltas Project Workshop: 'Securing the Asian Mega-Deltas from sea-level rise, flooding, salinization and water insecurity'	Dhaka, Bangladesh	27 Feb – 01Mar, 2024
D. Burman K.K. Mahanta	International ACIAR Salinity Futures Symposium	Can Tho, Vietnam	03 Mar – 06 Mar, 2024
S. Mallick	11th National Seminar on 'Transformative Agriculture and Sustainable Development: Rethinking Agriculture for a Changing World'	Society for Community Mobilization for Sustainable Development, New Delhi	05 Mar – 07 Mar, 2024
T.D. Lama	Awareness Programme on Quality Assurance of Soil Testing Labs under Soil Health Card Scheme	Sasya Shyamala KVK, RKMVERI, Kolkata	15 Apr, 2024
D. Burman T.D. Lama	1st Quarterly Dialogue (FY-2024-25) on Coastal Area Management	CWC, Salt Lake, Kolkata	9 May, 2024
Arjun Singh	National Conference: "Expanding the Horizons of Microbial Research in Agriculture"	ICAR-NBIAM, Mau	10 Jun - 11 Jun, 2024
Suresh Kumar	National Conference on Living with Nature: Soil, Water and Society in Ecosystem Conservation (LNSWSEC-2024)	Himalayan Cultural Center, Dehradun	20 Jun - 22 Jun, 2024
R.K. Fagodiya	National Conference on SHASHWAT SRISHTI SANRAKSHAN	ICAR-CARI, Jhansi	23 Aug – 24 Aug, 2024
S. Mallick	Workshop of RUPANTAR Project on 'Agrarian Transformation in Eastern Gangetic Plains of South Asia'	Cooch Behar, West Bengal	11 Sep - 13 Sep, 2024
D. Burman U.K. Mandal T.D. Lama K.K. Mahanta S. Raut R.N. Bhutia Dr. Devika S.	Workshop: Securing Climatic Resilient Agricultural Production Systems in Ganges Delta and Brainstorming Session for Innovative Production	ICAR-CSSRI, RRS, Canning Town, West Bengal	13 Sep, 2024
Rakesh Banyal	Webinar on Carbon Credits in Agriculture: Unraveling the Enigma	CoE-WRM, University of Agricultural Sciences, Bengaluru	19 Sep, 2024
Priyanka Chandra	Eighth Group Monitoring Workshop	IIT, Madras	19 Sep - 21 Sep, 2024
Bhaskar Narjary	Global Symposium on Soil Information and Data (Online presentation)	FAO, Institute of Soil Science, Chinese Academy of Sciences, Nanjing	25 Sep - 28 Sep, 2024
Monika Shukla	Online National Hindi Scientific Seminar (Hindi Fortnight Celebration)	ICAR-NINFET, Kolkata	26 Sep, 2024
Kailash Prajapat Raj Kumar	4th International Conference on "Natural Resource Management for Global Food Security and Environmental Stewardship"	University of Agricultural Sciences, Bengaluru	15 Oct - 16 Oct, 2024
SK Jha Sanjay Arora	32nd National Conference of SCSI on "Soil, Water and Energy Management for Sustainable Agriculture and Livelihood Security"	SCSI at CSAUAT, Kanpur	18 Oct - 20 Oct, 2024
D Burman UK Mandal TD Lama KK Mahanta S Raut RN Bhutia S Mallick	Annual Review and Planning Workshop of ACIAR funded project	ICAR-CSSRI, RRS, Canning Town, West Bengal	5 Nov, 2024
Sanjay Arora	Workshop: "Innovative Solutions for Strengthening the Rural Ecosystem: Empowering Agriculture through Startups"	GIZ India at Fairfield, Lucknow	5 Nov, 2024

Name and	Subject/Training Program	Place/Organizer	Duration/Period
Arjun Singh	1st International Conference on Innovation to Achieve Climate Resilient Smart Agriculture for Ensuring Global Food & Nutritional Security	ICAR-IISR, Lucknow	18 Nov - 19 Nov, 2024
Satyendra Kumar Bhaskar Narjary Jitendra Kumar AK Rai Priyanka Chandra UK Mandal	Global Soils Conference 2024: Caring Soils Beyond Food Security	Indian Society of Soil Science, New Delhi	19 Nov - 22 Nov, 2024
Sagar Vibhute	Overview of Drainage Design & Implementation in the US Midwest for Drainage Pipe Manufacturers, Dealers, SSD Consultants and Farmers	Ohio State University and ARS Kasbe Digraj, Sangli	23 Nov, 2024
Sanjay Arora	Online - International Soil and Water Forum 2024 - Managing Water Scarcity & Reversing Soil Degradation for Sustainable and Resilient Agrifoods Systems	FAO	9 Dec, 2024
Sanjay Arora	National Symposium and Annual Convention on "Remote Sensing for Sustainable Future: A Roadmap towards Viksit Bharat"	ISRS-ISG & RSAC UP at Dr. APJAK TU, Lucknow	11 Dec - 13 Dec, 2024
Suresh Kumar	32nd Annual Conference of Agricultural Economics Research Association(India) on "Digitalization of Agriculture for Higher, Sustainable, and Inclusive Growth"	Indira Gandhi Krishi Vishwavidyalaya	11 Dec - 13 Dec, 2024

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 ventillated 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 Kulshershtha, 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 Kulshershtha) 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 Arbusular Fungi (AMF) based plant biostimulant to enhance productivity of salt affected soils. (Priyanka Chandra, Arvind Kumar Rai, Nirmalendu Basak, Parul Sundha, Kailash Prajapat and R.K Yadav) DST-SERB funded.

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

Dr. NK Tyagi, Chief Guest, delivering the foundation day lecture

56th Foundation Day of the Institute

ICAR-Central Soil Salinity Research Institute celebrated its 56th Foundation Day on 1st March 2024. Chief Guest, Dr. Narender Kumar Tyagi, Ex-Member, ASRB, inaugurated the function with lightning the lamp. Dr. Raj Kumar shared a brief presentation about the present postion of research and technologies of the Institute. Dr. Rajender Kumar Yadav, Director briefed about the various technologies developed by the institute and also about the achievements of the institute. The chief guest congratulated the Director and staff of ICAR-CSSRI for their work in development of various reclamation technologies, new varieties for different climatic eco-regions and other initiatives towards the progress in recent soil map. He also mentioned about how closely he is able to monitor the work of CSSRI and how it pleases him to see the Institute performing so good in so many areas. Chief guest also distributed the Annual Awards for the year 2021. Sh. Dilbagh Singh and Sh. Kartar Singh were awarded with best employee award in technical category for the year 2023. Sh. Gurcharan Singh was awarded with best employee award in administrative staff category for the year 2023. Sh. Abhishek Rana, Chief Administrative Officer of the Institute, addressed the audience with vote of thanks. On this occasion: Dr. Gurbachan Singh, Ex-Chairman, ASRB and Dr. PC Sharma, Ex-Director of CSSRI were also present. Dr. Gyanender Singh, Director, ICAR-IIWBR also graced the function with his presence.

Activities under Scheduled Caste Sub Plan (SCSP)

Theoretical Orientation of Farmwomen

Three capacity building programmes for landless schedule caste farmwomen of villages Budhanpur, Pundrak and Uncha Samana of Karnal district were organized under SCSP during 2024 as an initiative to promote agri-entrepreneurship in order to increase their income and improve their livelihood security. For this purpose, three theme-based SHGs (Self Help Groups) of farmwomen were formed based on their interest, viz., vermicomposting, Bread making and Masala making. There were 50 members in vermicomposting group, and 25 each in Bread making and Masala making groups. These

Capacity building on Vermi-Composting

Capacity building on Bread Making

groups were imparted 3-days first-hand training in the respective enterprise with the help of subject matter specialists from ICAR-CSSRI, ICAR-CIPHET and Sikari Farm, Kurukshetra. The farmwomen were taken to visit the Sikari farm and the workshop of ICAR-CIPHET Ludhiana for hands-on practical training in the respective field. After the training, the adopted farmwomen were provided critical inputs from SCSP to start the enterprise and were given constant guidance and support for running the enterprises. Besides, five Awareness Camps were organized in the scheduled castes dominated villages of Budhanpur, Pundrak, Uncha Samana, Ramba and Norta in Karnal district. These camps were focused on improving the crop productivity through the use of bio-fertilisers, micro-nutrients and plant growth promoters, and also on improving the productivity of milch animals through the use of mineral mixture and bypass fat. The adopted farmers and farmwomen were provided critical inputs from SCSP to support their endeavour to improve crop and dairy production, thereby improving their income and livelihood security.

Five-day training to SC Farmers

ICAR-Central Soil Salinity Research Institute, Regional Research Station, Bharuch organized Five-day training on "Entrepreneurship development among resource-poor farmers of saline lands through diversified agriculture" from 22 to 26 April 2024 at Village-Ankhi; Taluka-Jambusar; Dist.- Bharuch under SC Subplan Scheme of central government. 50 SC farmers participated from 14 villages (Ankhi, Umra, Magnad, Jhamdi, Kavli, Vavli, Jambusar, Samoj, Kalak, Karmad, Uchhad, Chhidra, Runad and Achhod) of Jambusar and Amod Taluka of Bharuch district. Among 50 participant eight participants were women farmers. Station Head Dr. Anil Chinchmalatpure, all scientific staff, Dr. Monika Shukla, Dr. Sagar Vibhute and Dr. David Camus and Farm Manager Sh. Champak Taviyad attended and managed the training programme for five days.

Some photos from the training programme

Introduction of Mineral Mixture Making Machine and Supplements Distribution Programme for Livestock's under FFP

The ICAR-Central Soil Salinity Research Institute (CSSRI) organized a Mineral Mixture, anionic mixture and BergaFat Distribution Programme under the Farmer FIRST Project on

Scenes from FFP Activities

May 16, 2024, in Kathura village of Sonipat district of Haryana. The initiative involved distributing supplements to enhance livestock health and productivity, addressing the nutritional deficiencies in animals. The program witnessed the participation of around 35 dairy farmers from Kathura Village, who enthusiastically participated and took advantage of the opportunity to improve the health and well-being of their livestock. Farmer FIRST project provides a mineral mixture machine to use at village level to improve the socio-economic conditions of the farming community in Kathura Village. Dr. Sohanvir Singh (Co-PI, Farmer FIRST Project), Principal Scientist, ICAR-NDRI, told farmers about method to prepare mineral mixture by machine and addressed farmers about working of mineral mixture machine. Mineral mixture in the diet helps strengthen the immune system of dairy animals, making them more resistant to diseases and infections. Bergafat is a bypass fat that does not affect feed intake, and is broken down in the intestine by lipase enzyme and enhances milk production performance in cows and buffaloes. Dr. Sohanvir Singh demonstrated a method by using microscope for heat detection of livestock by using saliva of animal and a microscope is also given at village level. Further, he also discussed that addition of 4 % urea to animal fodder increase availability of nutrients to livestock and helps in minimization of nutrient deficiency in animals. Dr. Suresh Kumar (Co-PI, Farmer FIRST Project) discussed results of wheat research trail with farmers and took their feedback. It was concluded that distribution of quality seeds of wheat under Farmer FIRST project among farmers in last season increased productivity and benefitted farmers economically; and farmers were keen to use quality seeds for future. The Kisan Goshthi served as a platform for farmers to share experiences, discuss best practices, and gain insights into modern farming techniques. In this Kisan Goshthi programme, quality rice seeds (PB 1718, PB 1121, PB 1509 and PB 1692) were distributed among farmers. Dr. Rajkumar, PI, FFP addressed farmers about information on proper cultivation techniques, water management, and pest control and Nirmal Singh (SRF) told farmers about nursery preparation of rice. The distribution of high-quality paddy seeds expected to improve crop yields, enhance resilience to pests and diseases, and ultimately increase farmers' income. Farmer FIRST project team also visited SSD installed sites of adopted village.

Farmers-scientist interface meeting-cum-rice seed distribution programme

Glimpse of programme

On 22nd May 2024, a farmers-scientist interface meeting-cum-Kisan Goshthi was organised under CSSRI led Farmer FIRST Project to distribute seeds of various high yielding varieties (PB 1718, PB 1692, PB 1121 & PB 1509), promoting sustainable agricultural practices, and enhancing crop productivity of rice among 60 farmers of Village Kathura, Dhanana, Chhiri, Banwasa and Khalpa. This initiative aims to empower local farmers by providing them with high-quality rice seeds. The distribution of seeds was accompanied by educational sessions on soil health management, irrigation practices, and pest control, equipping farmers with comprehensive knowledge to improve their farming practices. Fields belonging to three progressive farmers—Ajmer Ji s/o Govardhan Ji, Krishan Pandit Ji s/o Birkha Ram Ji, and Satish Ji s/o Hariram Ji—have been chosen for the purpose of conducting research trials. Dr. Rajkumar, PI (FFP), shared knowledge on modern cultivation techniques and the importance of adopting improved seed varieties to combat challenges such as soil salinity and changing climate conditions. He emphasised the significance of utilising seeds of excellent quality in order to cultivate healthy and disease-free seedlings, which would result in improved crop establishment and increased yield. Further, he mentioned that farmers should use balanced fertilisers that include micronutrients based on the Soil Health Card in order to reduce the amount of money wasted on applying only NPK fertilisers. The participation of local farmers was commendable, indicating a strong community interest in adopting innovative agricultural practices.

Monitoring Visit & Review of Farmer FIRST Project at ICAR-CSSRI, Karnal

On 27-28th August, 2024 Dr. Ram Chand, Former ADG (AE), ICAR & Expert Member PMC, ICAR along with FFP team of ICAR-CSSRI visited beneficiary farmer who are involved in livestock rearing with the help of know-how and inputs extended by the project team. He had personal discussion with these farmers covering various aspects of the interventions such as effect of nutrition supplements (e.g., anionic mixture, mineral mixture and BergaFat etc.) on the growth, productivity, and overall health of the livestock.

Glimpse of visit of beneficiaries at Kathura

Team members during visit

Around 529 ha area in Kathura village was severely affected by waterlogged-saline soils, and practically lands were barren, having adverse bearing on the livelihood security of resource-poor farmers of the areas. As a part of the NRM-based module implemented in the Farmer FIRST project led by the ICAR-CSSRI, Karnal, in collaboration with the HOPP scheme of Haryana State, around 289 ha, covering 7 blocks was reclaimed by installing subsurface drainage technology. The effectiveness and efficiency of the SSD enhanced by introducing an innovative "Trolley-Mounted sliding type solar pumping-sets".

All the team members visited Guava cv. Hisar Safeda orchard established under FFP. This orchard is under fruiting since last year and the farmer was benefitted with approximately Rs. 30000/- by selling the guava fruits in the local market. By seeing the demand of Hisar Safeda in market the farmer showed interest in increasing the area under guava plantation. The farmer is not using any kind of insecticides and pesticides in his farm. Therefore, the fruits from his orchard are fetching more prices in the market as compared to the other growers.

World Environment Day at CSSRI: A call to action for a sustainable future

Institute celebrated World Environment Day-2024 during 26 May to 5 June 2024, with a series of planned activities to promote the objectives of Mission LiFE-Lifestyle for Environment. The theme of this year's programme was "Land Restoration, Desertification, and Drought Resilience". On this occasion, Dr R. K. Yadav, Director ICAR-CSSRI, Karnal emphasized the need to use renewable energy sources, conservation of natural resources, and reduce the consumption of electricity. He also encouraged the use of ecofriendly bags instead of plastic bags to prevent the pollution and associated

Dr. RK Yadav promoting *LiFE* for environment

Dr. RK Yadav during plantation event

environmental implications. The celebrations began with the LiFE pledge for promoting the sustainable production and consumption for better environmental outcomes. During this period, institute organized various activities including a tree plantation drive, a bi-cycle and walk rally. Additionally, a drawing competition for children was organized, and winner were given prizes.

Kisan Diwas celebrations in FFP village Kathura on 23rd December, 2024

The team comprising of Dr. Rajkumar (PI, Farmer FIRST Project), Dr. Suresh, and Dr. Ashwani Kumar successfully organized Kisan Diwas cum Swachhta Awareness Programme on 23rd December, 2024 in Kathura village under the Swachhata Pakhwada drive from 16-31 Dec, 2024. The event witnessed active participation of 35 farmers from village, aiming to enhance agricultural productivity and sustainability. As part of the programme, the team distributed essential agricultural inputs, including spray pump machines, nano-urea, and zinc supplements. These items were provided to promote efficient resource utilization and address nutrient deficiencies in crops. The Kisan Goshthi, an interactive session, allowed farmers to voice their challenges and learn about innovative farming techniques, soil health management, and the advantages of using nano-urea and zinc in crop production. The distribution initiative drew an enthusiastic response from the farmers of Kathura, reflecting their eagerness to adopt advanced agricultural practices. Dr. Rajkumar highlighted the advantages of using spray pump machines, emphasizing their role in ensuring uniform application of pesticides and fertilizers, thereby reducing waste and costs. Dr. Suresh and Dr. Ashwani elaborated on the benefits of nano-urea and zinc, stressing their effectiveness in improving soil health and plant growth. The event was further enriched by the celebration of Swachhata Pakhwada, 2024, emphasizing cleanliness and sustainable farming practices. Farmers take pledge that they will remain committed towards cleanliness. Farmers were educated on waste management, the importance of maintaining hygienic surroundings, and the integration of organic practices to reduce chemical dependency. The programme received an overwhelming response, with farmers expressing gratitude for the support and guidance offered by the Farmer FIRST team. The initiative not only empowered the farming community with modern agricultural tools but also reinforced the commitment to sustainable and eco-friendly farming.

Glimpse of visit of beneficiaries at Kathura

Swachhta Pakhwada 2024 celebration

As per guidelines received from council, in the ICAR-Central Soil Salinity Research

Employees gathered for Swachhta Plegde

Institute, Karnal the 'Swachhta pakhwada' is to be organized during l6-31 December, 2024 including 'Kisan Diwas' on 23rd December, 2024. In this context, 'Swachhta Pledge' Day was organized in the institute in which Director (A), ICAR- CSSRI, Karnal Dr. S. K. Sanwal led the programme with all the staff members. During the 'Swachhta Plegde' taking programme all the scientific/technical/administrative/ supporting staff and RA/SRF/Students were present on 16th December, 2024. Dr. Rajkumar, Nodal Officer 'Swachhta Pakhwada' briefed about the awareness campaign on cleanliness by undertaking a fortnightly awareness drive by various teams from l6-31 December, 2024.

Farmer participation in workshop entitled 'Innovative Approaches to Crop Residue Management'

Farmers actively participating in workshop

On November 29, 2024, the ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, organized a workshop titled "Innovative Approaches to Crop Residue Management". Sixteen farmers from Kathura village actively participated in the workshop, which focused on sustainable agricultural practices to manage crop residue effectively. The workshop began with an introduction to the pressing issues surrounding crop residue burning, including its detrimental impact on soil health and air quality. Participants were introduced to several practical and cost-effective residue management technologies, including the use of happy seeders, rotavators, and microbial decomposers. These tools could be employed to integrate crop residues back into the soil, enhancing soil fertility and reducing the reliance on chemical fertilizers. Farmers shared their experiences and challenges regarding residue management. They expressed concerns about the labor and costs associated with traditional practices. The interactive session provided them with clarity on government subsidies and support schemes available for purchasing advanced equipment. Farmers appreciated the hands-on approach and expressed their willingness to adopt these practices in their own fields. This initiative not only addressed environmental concerns but also equipped farmers with sustainable solutions to improve productivity and profitability. The workshop was a significant step toward promoting eco-friendly agricultural practices in Kathura village.

Members of QRT, IMC and CSSRI Staff

List of Scientific, Technical and Administrative Personnel

Rajender Kumar Yadav, Ph.D., Director

Division of Soil and Crop Management

A.K. Rai, Ph.D., Head

A.K. Bhardwaj, Ph.D.

Rakesh Banyal, Ph.D.

Gajender Yadav, Ph.D.

Raj Kumar, (Agroforestry) Ph.D.

Madhu Choudhary, Ph. D.

Nirmalendu Basak, Ph.D.

Ashim Dutta, Ph.D.

Manish Kumar, Ph.D.

Parul Sundha, Ph.D.

R.K. Fagodiya, Ph.D.

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Joginder Singh, Ph.D.

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Meena Luthra, M. Lib.

Estate Section

Kulbir Singh, Diploma

Akshay Kumar

* 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 01.07.2025.

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	03	60	63	04	6.35	4	6.35
Lowest rung of Class-1	-	5	5	1	20.00	0	0
Class-II	-	36	36	02	5.55	02	5.55
Class-III	-	73	73	03	4.11	05	6.85
Class-IV (excluding sweepers)	-	-	-	-	-	-	-
Class-IV (only sweepers)	-	-	-	-	-	-	-
Total	03	174	177	10	5.65	11	6.21

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 01.07.2025.

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 2024

Main Institute, Karnal

During the year 2024, a total rainfall of 612.0 mm was recorded at CSSRI Agro-met Observatory, Karnal as compared to the mean annual rainfall of 746.8 mm (for the last 50 years). The year was a almost deficient rainfall year (82% of the long-term mean annual rainfall) whereas the year 2023 was an excess rainfall year (131%). The maximum monthly rainfall of 180.8 mm was recorded during August month. During the monsoon season, the highest rainstorm of 55.4 mm was recorded on 4th September and the second highest of 43.4 mm on 3rd March. During January and February, there was a low amount of rainfall of 25.8 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 moderate amount of winter rainfall, 43.4 mm (March) as compared to winter rainfall last year (96.2). Low rainfall resulted in moderate irrigation demands for different *Rabi* crops during March leading to bumper *Rabi* crop production. There were 59 rainy days same as during the last year.

The minimum and maximum air temperatures, 2.8 and 44.7 °C were recorded on 23th January and 1st June, respectively. The air relative humidity was the lowest (13%) on 8th April while the highest (100%) was recorded on several occasions during the year. The highest soil temperatures at 5, 10 and 20 cm depths were 58.0, 50.5 and 42.0 °C on 16th June. The lowest values at same depths were recorded as 5.0, 5.5, and 10.0 °C on 7th Feb (5, 10 and 20 cm depth). The total open pan evaporation during the year was 1538.2 mm, which was almost 151% higher than the current annual rainfall. The lowest evaporation of 0.1 mm was recorded on various days of January and the highest of 17.0 mm was on 20 June. The average sunshine hours per day were 9.8. The highest and lowest vapour pressure values were 30.2 and 6 mm on 31st July and 15th January, respectively. The highest average wind speed was 5.6 km per hour. The monthly weather parameters recorded at Agro-meteorological Observatory, ICAR-CSSRI, Karnal (Haryana) for the year 2024 are presented in Table W1.

Weather Report 2024 Bharuch

Agro-meteorological observations (Table W2) recorded at Regional Cotton Research Station, NAU, Bharuch during the year 2024 revealed that this region received normal rainfall of 1496.5 mm spread over 51 days. Season's highest rainfall 509.6 mm was received during July followed by 435.1 mm, 411.5 mm and 86.4 mm in the month of August, September and October 2024, respectively. Maximum air temperature ranged from 29.3°C (January) to 41.7 °C (May) and minimum air temperature varied from 14.9 °C (January) to 28.8 °C (June). Pan evaporation varied from 2.6 mm day^{-1} to 11.6 mm day^{-1} during the year. The average bright sunshine hours varied from 0.2 to 9.9 hr/day. Mean relative humidity ranged from 31 to 78 per cent the year. The average wind speed varied from 0.4 kmph to 9.8 kmph during the year.

Weather Report 2024 Canning Town

The southwest monsoon onset in this region was recorded on June 27, 2024. The total annual rainfall measured by the meteorological unit at this Centre was 2,096.6 mm. The highest monthly rainfall of 602.0 mm occurred in August, with 20 rainy days. However, the maximum number of rainy days (22) was observed in July. The highest single-day rainfall of 138.0 mm was recorded on August 2, 2024. Rainfall in August was significantly above normal, leading to flooding in coastal rice fields of West Bengal, which adversely affected the initial growth of transplanted rice during the kharif season. Additionally, erratic rainfall after the monsoon period necessitated supplemental irrigation for rabi crop cultivation. In 2024, a total of 87 rainy days were recorded. Sunshine hours remained moderate throughout the year. The maximum temperature of 43.6°C was recorded on April 30. Temperatures ranged between 40.0°C and 42.0°C for 15 days in April, indicating extreme heat conditions. The average mean monthly temperature increased from 18.2°C

Table W1. Mean monthly weather parameters for the year 2024 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.	13.4	6.1	-	7.3	12.6	7.2	10.9	7.6	8.9	99	82	21.4/28	9.0/24	9.0/30	2.8/23
Feb.	21.7	7.9	-	9.9	21.3	9.3	15.7	8.6	10.1	91	54	26.0/19	15.6/01	14.2/19	4.2/06
Mar.	27.5	12.1	-	15.0	27.0	13.6	19.0	11.1	11.8	85	44	36.0/30	20.2/06	19.6/28	5.0/06
Apr.	35.8	17.8	-	23.7	34.9	18.1	20.4	12.3	9.3	56	23	40.8/27	31.2/02	22.8/27	11.6/02
May	39.8	24.2	-	28.4	39.4	22.2	25.0	16.6	15.2	56	29	44.6/29	32.0/02	30.0/30	15.8/02
Jun.	40.1	27.0	-	30.5	38.7	25.5	28.0	22.4	23.3	65	45	44.7/01	33.5/27	31.2/19	22.0/20
Jul.	34.6	27.5	-	28.9	33.5	27.3	28.8	26.2	26.7	88	69	37.8/15	31.0/04	29.2/21	24.6/15
Aug.	33.0	26.2	-	28.0	31.9	26.9	27.9	25.9	25.9	91	72	36.4/01	29.0/30	27.8/19	23.2/29
Sept.	32.3	24.1	-	26.3	31.3	25.4	27.3	23.9	24.8	93	73	35.8/24	25.8/14	26.2/25	22.0/14
Oct.	33.4	19.9	-	21.6	32.8	20.6	24.2	17.7	17.5	91	47	35.8/05	31.8/28	35.6/05	16.0/26
Nov.	27.6	13.6	-	15.2	27.1	14.7	19.9	12.6	13.2	94	49	32.8/01	22.0/14	18.4/12	8.6/29
Dec.	21.0	7.4	-	9.0	20.4	8.0	14.4	7.6	8.6	85	52	27.0/03	13.2/31	12.0/28	3.6/16
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	**30.0**	**17.8**	-	**20.3**	**29.2**	**18.2**	**21.8**	**16.0**	**16.3**	**82.8**	**53.2**	-	-	-	-

Month	Soil Temperature, °C (Depth-wise)						Rainfall*			Evaporation		Sunshine (hr/day)	Wind Speed (km/hr)
	5 cm		10 cm		20 cm		Monthly (mm)	No of rainy days	Heavy/ date	mm/ day	mm/ month		
	I	II	I	II	I	II							
Jan.	9.4	18.1	9.6	15.8	12.2	14.1	0.0	0	0.0/*	0.5	16.2	2.9	1.0
Feb.	9.8	28.4	9.8	23.4	13.2	18.1	25.8	3	12.0/01	2.0	57.0	7.9	6.0
Mar.	15.4	37.2	15.6	31.0	19.0	24.3	43.4	1	43.4/03	3.6	106.8	6.9	7.1
Apr.	23.6	47.8	23.6	40.5	27.0	33.4	8.4	2	5.6/24	7.0	209.7	8.3	8.2
May	29.4	51.9	29.1	45.2	32.4	37.8	10.4	2	9.4/13	8.9	276.5	8.5	9.8
Jun.	31.7	50.4	31.7	45.2	34.8	39.7	43.0	6	22.4/20	10.0	300.7	7.3	8.4
Jul.	30.3	42.5	30.6	38.8	33.3	36.1	58.9	9	16.0/31	5.0	154.5	4.8	4.2
Aug.	28.1	35.0	28.2	34.0	29.7	31.9	180.8	18	41.6/12	3.4	105.0	6.7	5.7
Sept.	26.6	32.7	26.8	32.2	28.3	30.8	177.5	13	55.4/04	3.1	91.9	7.3	4.7
Oct.	23.1	31.7	23.7	30.9	26.4	29.1	17.8	1	17.8/06	3.1	96.4	7.8	7.0
Nov.	16.6	25.7	17.6	24.1	20.4	23.0	0.0	0	0.0/*	2.1	64.1	5.2	3.1
Dec.	9.6	21.5	10.9	17.6	14.2	16.5	46.0	4	27.2/28	1.9	59.4	5.2	1.6
Total	-	-	-	-	-	-	**612.0**	**59**	-	-	**1538.2**	-	-
Average	**21.1**	**35.2**	**21.4**	**31.6**	**24.2**	**27.9**	**51.0**	**4.91**	-	**4.2**	**111.0**	**7.0**	**5.6**

Table W2. Monthly average agro-meteorological parameters at Bharuch during 2024

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	29.3	14.9	0.0	0.0	39	9.2	7.8	4.1	7.8	6.9
February	33.1	18.4	0.0	0.0	41	11.7	9.5	4.1	8.9	6.2
March	36.0	21.7	0.0	0.0	31	9.4	8.6	4.0	8.9	7.0
April	39.6	24.4	0.5	0.0	35	12.3	11.5	5.7	9.8	9.2
May	41.7	27.4	3.0	1.0	47	21.1	16.4	7.7	9.9	11.6
June	38.2	28.8	50.4	4.0	58	22.1	21.5	9.8	7.1	9.7
July	30.6	24.7	509.6	18.0	75	23.2	22.4	0.4	0.6	2.6
August	31.0	25.4	435.1	13.0	78	23.7	23.5	6.1	0.2	3.6
September	31.7	25.6	411.5	11.0	73	23.9	22.3	3.9	4.6	4.3
October	34.3	24.7	86.4	4.0	61	20.1	19.9	3.3	7.0	5.6
November	33.0	21.5	0.0	0.0	60	17.6	15.8	2.9	6.8	6.1
December	30.0	17.1	0.0	0.0	55	11.3	13.5	4.2	7.8	4.6
Total			**1496.5**	**51.0**						
Average	**34.0**	**22.9**		**51.0**	**54**	**17.1**	**16.1**	**4.7**	**6.6**	**6.5**

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-2024

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							
Jan	23.9	12.6	18.2	82.6	58.2	6.0	1.0	4.7	2.8	01
Feb	27.9	16.6	22.3	84.5	55.4	20.8	3.0	5.6	3.7	01
Mar	32.3	21.6	27.0	79.1	58.4	14.4	4.0	5.6	4.6	03
Apr	38.4	25.7	32.1	76.7	51.5	0.0	6.7	8.0	6.2	0
May	35.5	26.1	30.8	79.7	71.0	360.0	4.1	6.2	8.8	11
Jun	35.1	27.4	31.3	84.2	74.4	156.4	3.5	5.1	9.2	07
Jul	33.1	26.6	29.9	93.3	84.5	357.3	2.0	3.7	7.2	22
Aug	31.7	26.0	28.9	94.4	90.1	602.0	1.3	2.2	5.6	20
Sep	32.5	26.2	29.3	92.3	82.5	319.9	1.9	4.9	6.3	13
Oct	32.5	25.1	28.8	88.6	76.2	255.0	1.5	5.2	3.4	08
Nov	29.5	20.6	25.1	87.1	62.3	0.0	1.0	6.6	1.5	0
Dec	26.3	16.1	21.2	85.6	54.4	4.8	1.0	6.0	2.3	01
TOTAL	**378.7**	**270.7**	**324.7**	**1028**	**819**	**2096.6**	**30.8**	**63.8**	**61.6**	**87**
MEAN	**31.6**	**22.6**	**27.1**	**86**	**68**	**-**	**2.6**	**5.3**	**5.1**	-

Max. temperature: 43.6°C on 30.04.24;
Minimum temperature: 10.0°C on 23.01.24;
Maximum average wind speed: 26.0 Km/h on 27.05.24;
Heavy rainfall: 138.0 mm on 02.08.24

in January to 32.1°C in April, marking a rapid temperature rise. Relative humidity remained high throughout the year, contributing to weed infestation, pest outbreaks, and disease occurrences. A high average wind speed of 26.0 km/h was recorded during Cyclone *Remal*, which occurred from May 26 to May 27, 2024. Cyclone *Dana* also impacted the region on October 25, 2024, bringing 80.2 mm of rainfall. The monthly weather parameters recorded at RRS, Canning, are presented in Table W3.

संस्थान कार्यकलापों में राजभाषा हिन्दी

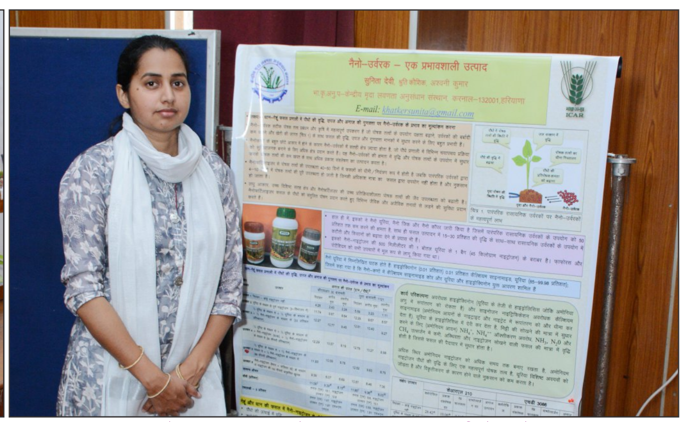
हिंदी के महत्व को बढ़ाने के लिए संस्थान में प्रति वर्ष अनेक गतिविधियाँ आयोजित की जाती हैं और प्रत्येक प्रतिभागी को पुरस्कार और प्रमाण पत्र प्रदान करके सम्मानित किया जाता है। संस्थान में प्रत्येक वर्ष चार तिमाही बैठकें और हिंदी कार्यशाला आयोजित की जाती हैं हिन्दी कार्यशाला का विषय वैज्ञानिकों द्वारा उपलब्ध 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 ह। वर्ष 2024 के दौरान हिंदी पखवाड़ा 17 से 30 सितम्बर 2024 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 17 से 30 सितम्बर 2024 के मध्य हिन्दी पखवाडे का आयोजन किया गया। हिन्दी पखवाडे का आयोजन डा. अश्वनी कुमार (वरिष्ठ वैज्ञानिक), डा. राज कुमार (वरिष्ठ वैज्ञानिक), डा. अवनी दहिया (वैज्ञानिक), श्री ब्रह्म प्रकाश (प्रशासनिक अधिकारी) एवं श्री विनोद कुमार (सहायक) की समिति द्वारा किया गया। दिनांक 17 सितम्बर 2024 को हिन्दी पखवाडे का शुभारम्भ मुख्य अतिथि श्री नीरज, आयुक्त नगर निगम, करनाल ने दीप प्रज्जवलित करके किया। हिन्दी पखवाड़ा समिति के अध्यक्ष डा. डा. अश्वनी कुमार 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 डा. राजेन्द्र कुमार यादव ने मुख्य अतिथि का पुष्पगुच्छ देकर स्वागत किया और 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। भारतीय नेता विदेशों में जाकर विश्व मंच पर हिन्दी में भाषण देते हैं। हमें अपने दैनिक कार्य हिंदी में अधिक से अधिक करने चाहिए। हिन्दी पखवाड़ा उद्घाटन समारोह के मुख्य अतिथि श्री नीरज, आयुक्त नगर निगम, करनाल ने कहा कि आजादी के बाद से अब तक सिनेमा, प्रिंट मीडिया, सोशल मीडिया में हिन्दी का प्रभाव बढ़ा है। हमें अपनी भावनाएं हिन्दी को माध्यम बनाकर व्यक्त करनी चाहिए। इस संस्थान में हिन्दी में काफी कार्य हो रहा है। उन्होने कहा की हमें अपने दैनिक

कविता पाठ प्रतियोगिता का दृश्य



हिन्दी पोस्टर प्रतियोगिता (विद्यार्थियों के लिए)

कार्यचर्या में हिन्दी को महत्व देना चाहिए और सहज और सरल हिन्दी भाषा में संवाद करना चाहिए।

हिन्दी पखवाड़े के अंतर्गत 12 प्रतियोगिताएंः 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 (विद्यार्थीओ 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 पखवाडे का का समापन समारोह दिनांक 30 सितम्बर 2024 को आयोजित किया गया जिसके मुख्य अतिथि श्रीमति मानसी, प्रधानाचार्य बिनस्टाँक जूनियर विद्यालय, करनाल थी। 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 सर्वोत्तम माध्यम है। इस अवसर पर एक तत्काल भाषण प्रतियोगिता का भी आयोजन किया गया जिसमें विभिन्न प्रतिभागियों ने 'एक राष्ट्र एक चुनाव' विषय पर प्रस्तुतियाँ दी। समापन समारोह के दौरान विभिन्न प्रतियोगिताओं के विजेताओं को प्रमाण–पत्र देकर सम्मानित किया गया। संस्थान के कार्यकारी निदेशक डा. सतीश कुमार सनवाल 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 2023–24' एवं 'वार्षिक प्रतिवेदन 2023' 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।

नगर स्तरीय टिप्पणी एवं मसौदा लेखन प्रतियोगिता में प्रतिभागी भाग लेते हुए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