वार्षिक प्रतिवेदन
ANNUAL REPORT
2019

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

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

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Mandate

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

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

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

4. Centre for training in salinity researches in the country

Preface

Relentless salinization continues to cause huge economic and environmental losses across the globe. Being a signatory to different global initiatives for halting land degradation, India remains committed to achieving Land Degradation Neutrality, and has recently increased its target of restoring degraded lands: from 21.0 to 26.0 Million hectares by 2030 in tune with Sustainable Development Goals. Recently concluded Conference of the Parties to the UN Convention to Combat Desertification (COP14) adopted the 'Delhi Declaration' that, among other things, renews global commitment to tackling the pressing issues of land degradation, climate change and biodiversity loss that world faces today. It acknowledges that land restoration practices remain vital to human well-being: an area that reflects our unending commitment to the society. We, at ICAR-CSSRI, have left no stone unturned to bring cheers on farmers' faces in several environmentally harsh salt-affected areas, and remain focused- often swimming against the tide- to ensure that farmers tilling degraded salty soils and using poor quality waters do not remain lame-duck landowners.

The Annual Report for the period 2019 brings out the major achievements in the areas of technology development and dissemination to the farmers' fields. Some major research breakthroughs during the period under report were: novel alternative amendments for improving sodic soils; Feasibility of subsurface drip technology in cereal based systems of IGP; cropping systems intensification in coastal salt-affected soils; soil bacterial community composition under reclaimed sodic soils; impact of land modification models in waterlogged sodic areas; technical guidance, monitoring and evaluation of SSD projects; conjunctive irrigation for improving water productivity in saline Vertisols; climate smart agriculture practices to improve systems' adaptability and bio-formulation for successful management of banana fusarium wilt disease.

A pre-Kharif kisan mela was organized on 16th March, 2019 at Village Habri, District Kaithal. About 1000 farmers, school students and extension workers attended the Mela. A pre-Rabi Kisan Mela organized on 13th October, 2019 at District Palwal witnessed the presence over 2500 farmers and extension workers. A total of 5 pre-Rabi and 5 pre-Kharif Kisan Gosthis were organized under 'Mera Gaon Mera Gaurav' programme in salinity affected parts of Haryana, Uttar Pradesh, West Bengal and Gujarat states involving over 2000 farmers. Similarly, 25 front line demonstrations on salt tolerant crop varieties were also conducted during this period. During 2019, a total of 7 exhibitions were also organized at different research institutions and developmental agencies. Institute produced 11.66 tonnes of breeder seeds of rice, wheat and mustard for distribution among various agencies.

Different capacity development programmes were organized to enhance the knowledge and skills of the farmers and farm women.

'Swachh Bharat Abhiyan' was organized periodically in the Main Campus, at Regional Research Stations and in some of the adopted villages to spread the message that keeping homes and surroundings clean is critical to human well being. National Productivity week was celebrated during 12-18 February, 2019 with the aim to enhance agricultural productivity by facilitating adoption of appropriate technologies developed by the Institute. Institute celebrated its 51st Foundation Day on 19th March 2019. Chief Guest Dr. Ashok Dalwai, CEO, National Rainfed Area Authority, Govt of India, in his foundation day lecture, exhorted the need for integrated policy and planning to be executed in collaborative manner with all the stakeholders for productive management of salt-affected lands.

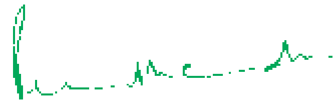
Biennial Workshop of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture was organized during 5-6 February 2019. Golden Jubilee International Salinity Conference (GJISC- 2019) was organized from 7-9 February, 2019 in collaboration of Indian Society of Soil Salinity and Water Quality, Karnal. In his valedictory address, the Chief Guest, Prof. Ramesh Chand, Member, NITI Aayog applauded the ICAR-CSSRI's illustrious journey of five decades that has led to the productive use of about 2.14 Million ha salt affected area in environmentally harsh conditions.

'Hindi Pakhwara' was organized at ICAR-CSSRI Karnal during 14-28 September, 2019. 'Van Mahotsav', celebrated on 8th August, 2019 in collaboration of Haryana State Forest Department, witnessed planting of over 300 saplings. Training programs for scientists/technical personnel conduced during 2019-20 included MANAGE sponsored program on 'Technologies for Doubling Farmers Income in Salt Affected Soils' (19-23 August), 'Functional Characterization of Differential Gene Expression' (11-13 September), 'Advancements in Soil, Water and Plant Analysis Techniques' (16-21 September), CCSNIAM sponsored program on 'Innovative Marketing Practices for Enhancing Farmers Income in Salt Affected Regions' (18-20 September), and AARDO and Ministry of Rural Development sponsored 'International Capacity Building Programme on Use of Poor Quality Water in Agriculture' during 23 October-05 November. Institute Research Committee (IRC) meeting was held from 25-29 March & 2-3 April, 2019 under the Chairmanship of Dr. P.C. Sharma, Director, ICAR-CSSRI, to review the progress of the ongoing research projects and to take up new research project proposals at the main institute, and its three regional research stations at Bharuch (Gujarat), Canning Town (West Bengal) and Lucknow (U.P.). Total 98 projects reviewed, 57 institute funded and 41 external funded projects reviewed during this IRC Meetings. All Heads of Divisions/Stations and Scientists of the Institute participated in this Meeting. Research Advisory Committee was held during 5-6 August, 2019 under the chairmanship of Dr. A.K. Sikka, Former DDG, NRM, ICAR, New Delhi

Some major farmer capacity development programs conducted during 2019 included five one-day training programs on 'Management of Alkali Soils and Water' in collaboration of HLRDC; and 'Farmers Day' for celebrating the birth anniversary of Late Prime Minister Chaudhary Charan Singh on 23rd December. Hon'able Union Minister of State for Agriculture and Farmers Welfare Sh. Kailash Chaudhary graced Farmers Day as Chief Guest and addressed the scientists, farmers and other staff.

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

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



(Parbodh Chander Sharma)

Director

सारांश

वर्ष 1969 में करनाल (हरियाणा) में स्थापित भा.कृ.अनु.प.–केन्द्रीय मृदा लवणता अनुसंधान संस्थान एक प्रमुख अनुसंधान संगठन है। यह देश के विभिन्न कृषि पारिस्थितिकी क्षेत्रों में लवणता प्रबंधन एवं कृषि में निम्न गुणवत्ता वाले जल के प्रयोग पर बहुविषयक अनुसंधान कार्यों के लिए समर्पित है। मुख्यालय में बहुविषयक अनुसंधान कार्यक्रम चार विभागों–मृदा एवं फसल प्रबंध, सिंचाई एवं जलनिकास अभियांत्रिकी, फसल सुधार और सामाजिक विज्ञान अनुसंधान द्वारा संचालित किये जाते हैं। विभिन्न कृषि जलवायु क्षेत्रों की विनिर्दिष्ट अनुसंधान आवश्यकताओं को पूरा करने के लिए संस्थान के तीन क्षेत्रीय अनुसंधान केन्द्र–केनिंग टाउन (प.बंगाल), भरूच (गुजरात) और लखनऊ) (उत्तर प्रदेश) क्रमशः समुद्र तटीय लवणता, लवणग्रस्त वर्टीसोल और सतही जल स्तर वाली मध्य एवं पूर्वी सिंधु–गंगा के मैदानों की क्षारीय मृदा संबंधी समस्याओं के निदान हेतु कार्यरत हैं। संस्थान में एक अखिल भारतीय समन्वित परियोजना लवणग्रस्त भूमियों के प्रबंधन और खारे पानी के कृषि में प्रयोग हेतु विभिन्न पारिस्थितिकी क्षेत्रों–आगरा, कानपुर, हिसार, इंदौर, बीकानेर, बापटला, गंगावटी और त्रिचुरापल्ली बठींडा (पंजाब), पैनवलै (महाराष्ट्र),पोर्टब्लेयर (अण्डेमान एवं निकोबार द्वीपसमूह), एवं वाईटिल्ला (केरल) में कार्यरत हैं। संदर्भित अवधि के लिए विभिन्न महत्वपूर्ण क्षेत्रों में संस्थान की कुछ प्रमुख अनुसंधान उपलब्धियाँ निम्नलिखित हैं।

क्षारीय मृदा सुधार के लिए नवीनतम वैकल्पिक सुधार

कृषि श्रेणी जिप्सम की घटती उपलब्धता एंव गुणवता के दृष्टिगत क्षरीय मृदा सुधार की गति को बनाए रखने के लिए वैकल्पिक मृदा सुधारों का विकास आवश्यक हैं। दो ऐसे वैकल्पिक सुधार–रिलांयस निर्मित सल्फर (RFS) एंव नगरीय ठोस प्रदार्थ कम्पोस्ट (MSWC) ने इस सदंर्भ में आशजनक परिणाम दिए है। RFS एक तात्विक सल्फर आधारित सुधारक हैं जिसे धान के रोपण से 21 दिन पेहले प्रयोग करने पर मृदा पी. एच. में प्रभावि गिरावट दर्ज कि जाती है नियत्रित प्रक्षेत्र प्रयोगों एंव किसान सहभागी प्रयोगों कैथल (हरियाणा) पटियाला, (पंजाब) एंव एटा, (उत्तर प्रदेश) के परिणामो ने दर्शाया है कि RFS कि सुधार क्षमता एंव फसल प्रदर्शन समतुल्य जिप्सम (GR_{50}) उपचारित भूखडों सें अधिक या साख्यिंकी दृष्टि से बराबर थी। किसान प्रक्षेत्रों पर धान, गेंहू, कपास एंव गन्ना में RFS के प्रयोग से फसल उपज में प्रभावी वृद्धि हुई है। इसी प्रकार MSWC जिप्सम एंव सीवेज–सलज के विभिन्न संयोजनों का परिक्षण नियर्त्रित लाईसीमीटर एंव अत्यधिक क्षारिय किसान प्रक्षेत्रों पर किया गया। हरियाणा के कैथल जिले में किसान प्रक्षेत्र पर (पीएच$_2$ 9.37 इसी$_2$ 0.92 डेसीसीमन/मी.) में इन समायोजनों के प्रयोग नियत्रिंत उपचार कि तुलना में धान की दाना उपज में सार्थक वृद्धि हुई है। लवण सहिष्णु धान प्रजाति सी. एस. आर 30 कि दोनो उपज (2.52 टन/है) MSWC एंव जीभार 50 उपचारों में समतुल्य थी।

तटीय लवणीय मृदाओं में फसल प्रणाली सघनीकरण

पशिचम बगांल के दक्षिण 24 परगना जिले के गोसाबाा द्वीप के लवणीय क्षेत्रों में उन्नत फसल प्रबधंन, नई फसले व प्रजातियों जैसे तकनीकी हस्तक्षेप ससांधन हीन किसान परिवारों कि आय एंव पोषण सुरक्षा बढाने में कारगर सिद्ध हुए हैं। चुंकि गोसावा द्वीप के पास बहने वाला पानी अति लवणीय (16.8–47.7 डेसीसीमन/मी.) और सिचांई हेतु अनुपयुक्त है अतः ऐसी कृषि जलाक्रांत तकनीकियों का महत्व और भी बढ जाता है। बारह किसान प्रक्षेत्रों पर, जिनमें पहले धान कि खेती की जाती थी का सघनीकरण सब्जियों कि खेती द्वारा किया गया जिसका लाभ–लागत अनुपात 1.63 सं 4.46 था। शुन्य जुताई और धान की पुआल से आच्धादन कर कि जाने वाली आलु कि खेती भी अध्ययन क्षेत्र में फसल सघनीकरण के लिए एक उपयोगी विकल्प सिद्ध हुई। इस पद्धति में तीन वर्षों के बाद जैविक कार्बन, उपलब्ध नत्रजन और फास्फोरस में वृद्धि दर्ज की

गई। परम्परागत बाद सिंचाई की तुलना में टपकादार सिंचाई और मल्चिंग से श्रमिक और धान के प्रआल की मल्चिंग से खडी फसलों में खरपतवार की समस्या भी काफी घट गई। पश्चिम बगांल के अन्य तटीय लवणीय क्षेत्रों में तकनीकियों के प्रसार के आवश्यक प्रयास किए जा रहे हैं।

जलग्रस्त क्षारिय क्षेत्रों में भू–आकार परिवर्तन प्रारूपों का प्रभाव

मध्य सिंधु–गंगा मैदानी क्षेत्रौं में जलग्रस्त क्षारिय भुमियों की उत्पादकता बढाने हेतु किसान सहभागी रीति में नहरी रिसाव के प्रबंधन पर पर आधारित विभिन्न भू–आकार परिवर्तन प्रारूपों का विकास किया गया। प्रक्षेत्र आप में काफी वृद्धि कें अतिरिक्त ये माडल भुमि और जल उत्पादकता बढाते है और द्वितीयक क्षारियता को रोकते है। प्रक्षेत्रों स्तर पर इन माडलों के प्रभाव विश्लेषण अध्ययन ने इंगित किया कि इन माडलों को अपनाकर किसान वर्ष भर खेती करते है। जिससे फसल सघनता में 125–300% तक व फसल विविधकरण में 0.24–0.86% तक वृद्धि हुई तथा किसान परिवारों को वर्ष भर रोजगार के अवसर मिलें। इन लाभो के बावजूद इस तकनीक के प्रसार में कुछ भुमि बाधको को दुर करने कि आवश्यकता है। उपयुक्त भुमि प्लाट आकार कि उपल्बधता (फसल मछली प्रणाली हेतु है व फसल मछली प्रणाली 0.5 है) एक मुख्य बाधा है। इसी प्रकार कुछ किसान इन माडलों के अंगीकरण हेतु इच्छुक हैं परन्तु उन्हे परिवर्तित किए जाने वाले भु–क्षेत्र के बारे में सटीक जानकारी नही है। इसी प्रकार कुछ बडे किसान मत्स्य पालन अपनाने हेतु अनिच्छुक पाए गए। चुंकि जल ग्रस्त क्षारिय भुमियों अवकमित है अतः कुछ किसानों ने उन्हे निवेशको को पटटे पर देने की इच्छा प्रकट कि जो दर्शाता है कि सरकारी, सरकारी–निजी या निजी निवेश द्वारा इन माडलों को और प्रसार किया जा सकता है।

उपसतही जलनिकास परियोजनाओं का तकनीकी मार्गदर्शन अनुसरण एंव मूल्यांकन

उपसतही जल निकासी व्यवहार्यता के आधार पर हरियाणा प्रदेश में वर्ष 2019–20 में 6 नए स्थलों का चयन किया गया जिनका कुल जलग्रस्त लवणीय क्षेत्र 3800 है। इन स्थलों पर उथले जलस्तर (< 1.5 मी.) मध्यम से अधिक मृदा लवणता (इसी $_{1w}$ > 8.0 डेसीसीमन/मी.) व भुजल लवणता (इसी $_{1w}$ > 2.0 डेसीसीमन/मी.) की समस्या थी सभी स्थलों पर लवणीय जल के निकाा हेतू सतही नालियां उपलब्ध थी। उप सतही जलनिकास प्रणाली की डजाईन व उनके राष्ट्रीय कृषि विकास योजना के अतंर्गत वितपोषण हेतू इन स्थलों का स्थलाकृतिक सर्वेक्षण किया जाना है जींद व सोनीपत –III परियोजनाओं के अतंर्गत आने वाले गगांना (110) व कथुरा (90 है) स्थलों पर वर्ष 2019–20 में उपसतही जल निकासी प्रणाली विकसित कि गई। जून,2019 तक हरियाणा में कुल 11,044 है। जलग्रस्त लवणीय क्षेत्र का 18 उपसतही जलनिकास की गति धीमी है जिसे हरियाणा अपरेशनल पायलट परियोजनस के ससाधनों के प्रयोग या जल निकासी उद्योग/ठेकेदारों द्वारा आउटर्सोसिंग कर गति प्रदान करने की आवश्यकता है जिससे वर्श 2030 भुमि अवक्रमण उदासीनता के लक्ष्य को प्राप्त किया जा सकें।

लवणीय वर्टीसोल की जल उत्पादकता बढाने हेतू संयोजित सिंचाई

समनी प्रायोगिक प्रक्षेत्र भरूच पर एक टपकादार सिंचाई प्रयोग के परिणामों ने दर्शाया कि सतही स्वच्छ जल व लवणीय भुजल(1.1) के चक्रीय प्रयोग द्वारा गेहूं की दाना उपज में बिना प्रभावी गिरावट कें परम्परागत सीमा सिंचाई (स्वच्छ जल द्वारा) की तुलना में 50% स्वच्छ जल की बचत की जा सकती है। मृदा परिक्षण परिणामों में दर्शाया की लवणीय भूजल (इसी $_{1w}$ 7.2–8.1 डेसीसीमन/मी.) द्वारा सभी सिंचाईया करने पर मृदा लवणता में काफी वृद्धि हुई है इसके विपरित, स्वच्छ जल से नियमित सिंचाई करने पर लवणता में न्युन्तम वृद्धि (इसी$_{1w}$ 1.1 डेसीसीमन/मी.) पराम्परागत सीमा सिचाई में सर्वाधिक गेंहू दाना उपज के बावजुद साख्यिकीय दृष्टि से समतुल्य दाना उपज, लवणता में समान वृद्धि और स्वच्छ जल में 50% कि बचत ने स्वच्छ सतही और लवणीय भुजल (1.1) द्वारा चक्रीय सिंचाई की उपयोगिता प्रदर्शित की। अतः यह स्पष्ट है कि टपकादार सिंचाई द्वारा अधिक जल उत्पादकता, स्वच्छ जल में बचत एंव मृदा लवणता में न्युनतम बढोतरी सम्भव है।

सिंधु गंगा के मैदानी इलाकों में अनाज आधारित प्रणालियों में उप–सतही ड्रिप सिंचाई प्रौद्योगिकी की व्यवहार्यता

सघन अनाज आधारित धान–गेहूं प्रणालियों में, सटीक पानी और पोषक तत्व प्रबंधन को उप–सतही ड्रिप सिंचाई (एसडीआई) के साथ जोड़कर सटीक शस्य–प्रबंधन के साथ मिलकर भोजन, पोषण, पानी, ऊर्जा, मिट्टी के स्वास्थ्य की कई चुनौतियों को देश के ग्रीन कॉरिडोर में जलवायु परिवर्तन को ध्यान में रखते हुये इसके समाधान हेतु विज्ञान समर्थित प्रमाण इक्कठा किये गये। सामान्य मिट्टी में क्रमशः 67.5 व 20 सेमी और लवण प्रभावित मिट्टी में 45 व 15 सेमी पर पंक्ति से पंक्ति की दूरी और गहराई को मानकीकृत किया गया। उप–सतही ड्रिप सिंचाई में बाढ़ (फलड) सिंचाई प्रणाली की तुलना में क्रमशः चावल–गेहूं और मक्का–गेहूं प्रणाली के तहत 47 (93.6 सेमी प्रति हेक्टर) और 45 प्रतिशत (29 सेमी प्रति हेक्टर) सिंचाई पानी की समान प्रबंधन स्तर पर बचत हुयी। मक्का–गेंहूँ प्रणाली में उच्चतम (4.46 प्रति हेक्टर सेंटिमीटर, 669 प्रतिशत) सिंचाई जल उपयोग दक्षता और सबसे कम (0.58 प्रति हेक्टर सेंटिमीटर) चावल–गेंहूँ में किसानों की पद्धति के साथ दर्ज की गई। उप–सतही ड्रिप सिंचाई प्रणाली में धान, गेहूं और मक्का फसलों की प्रत्येक फसल के तहत और फसल प्रणाली के आधार पर उर्वरक नत्रजन की आवश्यकता को 20 प्रतिशत (30 किलोग्राम नत्रजन प्रति हेक्टर) तक कम कर दिया। फसल प्रणाली के आधार पर, धान–गेंहूँ, मक्का–गेंहूँ सिस्टम ने बाढ़ विधि की तुलना में एसडीआई के साथ 45 और 50 प्रतिशत अधिक नत्रजन आंशिक कारक उत्पादकता (पीएफपी–एन) दर्ज किया। धान–गेंहूँ–मुंगबीन प्रणाली की फसल उत्पादकता और खेत की लाभप्रदता बाढ़ सिंचाई प्रणाली वाले किसानों की पद्धति की तुलना में एसडीआई प्रणाली के तहत लगभग 11 और 29 प्रतिशत बढ़ी हुयी पायी गयी। हालांकि, मक्का–गेंहूँ प्रणाली में, बाढ़ धान–गेंहूँ प्रणाली की तुलना में एसडीआई प्रणाली के तहत् लगभग 20 प्रतिशत उच्च उत्पादकता एवं 49 प्रतिशत उच्च लाभप्रदता दर्ज की गई। एसडीआई ने अनाज आधारित प्रणालियों में मुंगबीन के एकीकरण को सक्षम किया, जिससे फसल प्रणाली उत्पादकता और लाभप्रदता में लगभग 10 और 25 प्रतिशत वृद्धि का योगदान हुआ।

सुधरी हुयी क्षारीय मुदाओं में मृदा जीवाणु संगठन

मृदा जीवाणु समुदाय संगठन को समझने के लिए छह प्रबंधन परिदृष्यों को शामिल किया गया था जो इस प्रकार हैः–पारंपरिक जुताई आधारित धान–गेंहू (परिदृष्य–1; किसान की पद्धति), बाढ़ (फलड) सिंचाई के साथ पारम्परिक धान–जीरो टिलेज गेहूं–मूंगबीन (परिदृष्य–2; आंशिक संरक्षण कृषि), जीरो टिलेज आधारित बाढ़ सिंचाई के साथ धान–गेहूं–मुंगबीन (परिदृष्य–3; सम्पुर्ण संरक्षण कृषि/आंशिक जलवायु स्मार्ट कृषि), बाढ़ सिंचाई के साथ जीरो टिलेज मक्का–गेहूं–मूंगबीन (परिदृष्य–4; सम्पुर्ण संरक्षण कृषि/ आंशिक जलवायु स्मार्ट कृषि), उप–सतही ड्रिप सिंचाई (सब–सरफेस ड्रिप/सडीआई) के साथ परिदृश्य–3 (परिदृष्य–5; सम्पुर्ण जलवायु स्मार्ट कृषि) एवं सब–सरफेस ड्रिप के साथ परिदृष्य–4 (परिदृष्य–6; सम्पूर्ण जलवायु स्मार्ट कृषि) का मूल्यांकन किया गया। परिणामों से यह पता चला कि फसल प्रबंधन प्रथाएं जीवाणु समुदाय के संगठन को प्रभावित करती है क्योंकि कोपियोट्रॉफ (प्रोटियोबैक्टीरिया) संरक्षण कृषि (सीए) आधारित परिदृष्यों में प्रमुख रूप से पाये गये जबकि ओलिगोट्रोफ्स (एसिडोबैक्टीरिया और एक्टिनोबैक्टीरिया) पारंपरिक जुताई (सीटी) आधारित परिदृष्यों में प्रमुख रूप से पाये गये। कुल 40 फाइला छह परिदृष्यों में देखे गऐ, और परिणामों से पता चला कि शस्य प्रबंधन प्रथाओं ने जीवाणु समूहों के सापेक्ष बहुतायत को प्रभावित किया है। एसिडोबैक्टीरिया और एक्टिनोबैक्टीरिया सभी परिदृष्यों में प्रोटियोबैक्टीरिया से कम पाये गये। धान आधारित संरक्षण कृषि परिदृष्यों (परिदृष्य 3 एवं 4) में प्रोटियोबैक्टीरिया की सापेक्ष प्रचुरता 29 प्रतिशत अधिक थी और किसान की पद्धति के मुकाबले मक्का आधारित परिदृष्यों (परिदृष्य 4 एवं 6) में 16 प्रतिशत अधिक थी। एसिडोबैक्टीरिया और एक्टिनोबैक्टीरिया के संयुक्त सापेक्ष बहुतायत क्रमशः धान आधारित सीए परिदृष्य, मक्का आधारित परिदृष्य और आंशिक सीए धान आधारित परिदृष्य की तुलना में किसानों की पद्धति में 67, 52 और 24 प्रतिशत अधिक पाये गये।

संरक्षण कृषि आधारित परिदृष्यों की तुलना में उच्च (11 प्रतिशत) शैनन विविधता सूचकांक पारंपरिक जुताई आधारित परिदृष्यों (परिदृष्य–1 एवं 2) में दर्ज किया गया। धान आधारित सीए परिदृष्यों (परिदृष्य 3 एवं 5) की तुलना में सभी विविधता सूचकांकों (शैनन, सिम्पसन, चाओ 1 और आउट) को मक्का आधारित परिदृष्यों (परिदृष्य 4 एवं 6) में अधिक दर्ज किया गया।

फसल प्रणाली की अनुकूलता में सुधार के लिए जलवायु स्मार्ट कृषि पद्धतियां

जलवायु–स्मार्ट कृषि (सीएसए) को आंशिक रूप से सुधरी हुयी क्षारीय मिट्टी में बदलती जलवायु में खाद्य सुरक्षा सुनिश्चित करने के लिए एक व्यावहारिक दृष्टिकोण माना जाता है। जलवायु–स्मार्ट कृषि के सिद्धांतों पर आधारित अनुकूलन रणनीति जलवायु परिवर्तन के प्रभावों का मुकाबला करने में सक्षम है, जैसे कि संरक्षण कृषि का प्रसार, प्राकृतिक संसाधनों का स्थायी प्रबंधन और जलवायु–स्मार्ट फसलों का प्रसार। जलवायु–स्मार्ट कृषि विकल्पों में पानी, ऊर्जा, पोषक तत्व, कार्बन, मौसम और ज्ञान–मार्ट प्रौद्योगिकियां, क्षेत्र में विभिन्न फसलों और फसल प्रणालियों के लिए उपयुक्त अभ्यास और सेवाएं शामिल होती हैं। जलवायु स्मार्ट कृषि प्रथाओं (सीएसएपी) जैसे लेजर लैंड लेवलिंग, डायरेक्ट सीडेड राइस, जीरो–टिलेज, फसल अवशेश प्रबंधन, ग्रीनसीकर और न्यूट्रिएंट एक्सपर्ट के माध्यम से पोषक तत्व प्रबंधन और धान एवं गेहूं की उन्नत किस्मों का उपयोग इत्यादि का परीक्षण करनाल के 25 गांवों में किया गया। जलवायु स्र्माट कृषि से उत्पादकता में लगातार वृद्धि, लचीलापन/अनुकूलन बढ़ाने, ग्रीनहाउस गैसों (जीएचजी) के उत्सर्जन को कम करने एवं राष्ट्रीय खाद्य सुरक्षा और विकास लक्ष्यों को प्राप्त करने में मदद करता है तथा बढ़े हुए कार्बन स्टॉक के संदर्भ में सह–लाभ भी देते हैं। जलवायु स्र्माट कृषि अपनाने से धान–गेहूं फसल प्रणाली की उत्पादकता में 5–10 प्रतिशत की वृद्धि, आय में 15–20 प्रतिशत की वृद्धि को प्राप्त करते हुये लगभग 15–20 प्रतिशत पानी की बचत की जा सकती है। लगातार 3 साल जलवायु–स्मार्ट कृषि करने के बाद खेत में जैविक कार्बन की मात्रा में 25–30 प्रतिशत की वृद्धि मापी गयी। साथ ही साथ जलवायु–स्मार्ट कृषि करने से गेहूं की फसल में टर्मिनल गर्मी के प्रभाव को कम करने में मदद मिलती है।

पुरस्कार एवं मान्यताएं

- डॉ. एच.एस. जाट ने सर्वश्रेष्ठ उर्वरक उपयोग अनुसंधान के लिए फर्टिलाइजर एसोसिएशन ऑफ इंडिया द्वारा उत्कृष्टता के लिए गोल्डन जुबली अवार्ड 2 दिसंबर 2019 को प्राप्त किया
- डॉ. राज मुखोपाध्याय को ग्रेट ब्रिटेन और आयरलैंड के मिनरलॉजिकल सोसाइटी के खनिज समूहों से क्ले मिनरल बर्सरी पुरस्कार मिला
- डॉ. एस मंडल ने डार्विन,ऑस्ट्रेलिया में अंतर्राष्ट्रीय सम्मेलन के दौरान शोध पत्र प्रस्तुत करने के लिए प्रारंभिक कैरियर पुरस्कार प्राप्त किया।
- डॉ आशिम दत्ता को विज्ञान और इंजीनियरिंग अनुसंधान बोर्ड, भारत सरकार, नई दिल्ली द्वारा हिल्टन एडिलेड, ऑस्ट्रेलिया में आयोजित मृदा कार्बनिक पदार्थ पर 7 वें अंतर्राष्ट्रीय संगोष्ठी में अंतर्राष्ट्रीय यात्रा फैलोशिप से सम्मानित किया गया।
- डॉ. रंजय कुमार सिंह को 23 अप्रैल, 2019 के दौरान यूनिवर्सिटी ऑफ ऑक्सफोर्ड, यू के में आयोजित पोस्टडॉक्टरल के लिए कॉमनवेल्थ–चेवेनिंग फैलोशिप से सम्मानित किया
- डा. रंजय कुमार सिंह को राष्ट्रीय कृषि विज्ञान अकादमी, नई दिल्ली का फेलो (सामाजिक विज्ञान : कृषि प्रसार) चयनित किया गया।
- डॉ. सत्येंद्र कुमार को इंडियन सोसाइटी ऑफ एग्रीकल्चर इंजीनियरिंग द्वारा बेस्ट पेपर अवार्ड मिला
- डॉ. ए.के. भारद्वाज को संयुक्त अंतर्राष्ट्रीय सम्मेलन एस. सी. एस. आई. एवं आई. एस. सी.

ओ. और डब्लू. ए. एस. डब्लू. ए. सी. 5–9 नवंबर, 2019, को नई दिल्ली, द्वारा बेस्ट पेपर अवार्ड मिला

- डॉ. परवेंदर श्योरान को फेलो इंडियन सोसाइटी ऑफ तिलहन रिसर्च हैदराबाद से सम्मानित किया
- डॉ. परवेंदर श्योरान को फेलो इंडियन सोसाइटी ऑफ वीड विज्ञान जबलपूर चुना गया

कार्यशाला

- लवणग्रस्त मृदाओं का प्रबंन्ध एवं खारे जल का कृषि में उपयोग विषय पर अखिल भारतीय समन्वित अनुसंधान परियोजना की द्विवार्षिक कार्यशाला 5–6 फरवरी 2019 को आयोजित की गई।
- स्वर्ण जयंती अंतर्राष्ट्रीय लवणता सम्मेलन का आयोजन 7–9 फरवरी, 2019 के मध्य किया गया।
- महाराष्ट्र प्रदेश के अहमदनगर जिले के किसानों हेतु 'लवण प्रभवित मृदाओं एवं निम्न गुणवत्ता सिंचाई जल का प्रबंधन' विषय पर एक चार दिवसीय प्रशिक्षण कार्यक्रम 26–29 सितंबर, 2019 के मध्य आयोजित किया गया।
- राष्ट्रीय उत्पादकता सप्ताह 12–18, फरवरी, 2019 के मध्य आयोजित किया गया।
- खरीफ किसान मेले का आयोजन 16 मार्च, 2019 को कैथल जिले के हाबड़ी गाँव में किया गया।
- 08 अगस्त, 2019 को संस्थान में वन महोत्सव का आयोजन किया गया।
- "लवण प्रभावित क्षेत्रों में किसानों की आय दोगुनी करने हेतु तकनीक" विषय पर 19 अगस्त से 23 अगस्त तक 5 दिवसीय प्रशिक्षण कार्यक्रम हुआ।
- संस्थान में लवण तनाव के अंतर्गत गुणसूत्र अभिव्यक्ति के कार्यात्मक लक्षण वर्णन विषय पर तीन दिवसीय प्रशिक्षण कार्यक्रम 11–13 सितम्बर 2019 के बीच सम्पन्न हुआ
- संस्थान द्वारा 13 सितम्बर 2019 को पलवल जिले के नेताजी सुभाष चन्द्र स्टेडियम में रबी किसान मेला आयोजित किया गया
- संस्थान में 14-29 सितम्बर 2019 के बीच हिन्दी पखवाड़ा आयोजित किया गया
- संस्थान में "लवणता एवं क्षारीय प्रबंधन हेतु उन्नत उपकरणों द्वारा मृदा, जल एवं पादप विश्लेशण तकनीकियों में प्रगति संबंधी जानकारी विशय पर 16-21 सितम्बर को प्रशिक्षण पाठ्यक्रम कार्यक्रम हुआ।
- लवणग्रस्त क्षेत्रों में किसानों की आय बढ़ाने हेतु नवीन विपणन विधियों पर तीन दिवसीय प्रशिक्षण पाठ्यक्रम 18 से 20 सितम्बर 2019 के बीच तक आयोजित किया गया।
- निम्न गुणवत्ता वाले जल का कृशि में उपयोग विशय पर अंतर्राष्ट्रीय प्रशिक्षण कार्यक्रम 23 अक्तूबर से 5 नवम्बर, 2019 के बीच तक आयोजित किया गया।
- भारत सरकार के **'स्वच्छ भारत मिशन'** कार्यक्रम के अन्तर्गत दिनांक 16–31 दिसम्बर, 2019 के दौरान स्वच्छता पखवाड़ा का आयोजन किया गया
- 23 दिसम्बर 2019 को भाकृअनुप–केमृलअनुसं, करनाल में **'क्षेत्रीय किसान दिवस'** का आयोजन किया गया

क्षेत्र प्रदर्शनी व भ्रमण

वर्ष 2019 के दौरान कृषि में लवणग्रस्त मृदा के सुधार और प्रबंधन व निम्न कोटि जल के उपयोग पर विभिन्न अनुसंधान संस्थानों और विकास अभिकरणों में 7 प्रदर्शनियां लगाई गई। 1473 हितधारकों ने संस्थान के सूचना प्रौद्योगिकी केन्द्र व प्रायोगिक फार्म का दौरा किया। 488 किसान 851 विद्यार्थी 112 प्रसारकर्मी और वस्तु विषय विशेषज्ञ, 22 भारतीय व विदेशी वैज्ञानिक आए थे।

किसान सलाहकार सेवा

किसानों की मृदा लवणता, क्षारीयता व जल गुणवत्ता संबंधित समस्याओं के त्वरित और समुचित समाधान हेतु संस्थान 18001801014 नम्बर पर निःशुल्क फोन सेवा शुरू की है। वर्ष 2018–19 के दौरान देश के विभिन्न क्षेत्रों से कृषि संबंधित समस्याओं संबंधित 172 कॉल प्राप्त हुई और संस्थान के वैज्ञानिकों द्वारा इन समस्याओं के निदान हेतु वैज्ञानिक उपाय सुझाए गए।

अंतर्राष्ट्रीय सहयोग

- अफ्रीका और दक्षिण एशिया के गरीब किसानों के लिए तनाव सहिष्णु चावल (आईआरआरआई व वीएमजीएफ द्वारा प्रायोजित)
- सूखा, जलमग्नता और लवण सहिष्णुता के लिए मार्कर की सहायता प्रमुख क्यूटीएल के साथ अजैविक तनाव सहिष्णु चावल किस्मों का प्रजनन (डी बी टी, आई आर आर आई, वित्त पोषित)
- धान की अधिक जस्तायूक्त किस्मों का विकास (आई आर आर आई, वित्त पोषित)
- दक्षिण एशिया में शहरी बाड़ को कम करने तथा ग्रामीण क्षेत्रों में पानी की सुरक्षा में सुधार के लिये भूगत नवप्रवर्तनकारी परीक्षणात्मक को बढ़ावा देना (आई डब्ल्यू एम आई)
- भारत के जल संवेदनशील क्षेत्रों में सतत संसाधन प्रबंधन प्रणालियों का विकास (जिरकास, जापान)
- प्रतिकूल दशाओं हेतु जलवायु दक्ष प्रजातियों के विकास के लिये गुणों, जीन एवं कार्यिकी लक्षणों का चिन्हीकरण
- जलवायु परिवर्तन, कृषि एवं खाद्य सुरक्षा (सीसीएएफएस) (सीआईएमवाईटी, मैक्सिको)
- बांग्लादेश एवं पश्चिम बंगाल, भारत के लवण प्रभावित तटीय क्षेत्रों में फसल प्रणाली सघनीकरण (सीएसआईआरओ एवं मुडोर्क विश्वविद्यालय, आस्ट्रेलिया द्वारा वित्त पोषित)

प्रकाशन

- संस्थान द्वारा प्रमुख जरनलों में 93 अनुसंधान आलेख, 23 पुस्तक अध्याय, 21 पुस्तक/मैनुअल, 16 बुलेटिन,फोल्डर, प्रचलित आलेख, तकनीकी प्रतिवेदन छपवाये गये और 109 आलेख सेमीनार/ सिमपोसिया और कानफ्रेन्सों में प्रस्तुत किये गये।

वैज्ञानिकों का विदेश भ्रमण कार्यग्रहण व सेवानिवृत्ति

ज्ञान व कुशलता को बढ़ाने हेतु संस्थान के 13 वैज्ञानिकों ने विभिन्न देशों जैसे मैक्सिको, मोरक्को फिलीपीन्स, ईजराईल सिगांपुर चीन अमेरिका और बांग्ला देश, का दौरा किया। इस अवधि में 2 वैज्ञानिकों ने कार्यभार संभाला।

Executive Summary

ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana is an internationally recognized premier research organization dedicated to multi-disciplinary research on salinity management and use of poor quality irrigation water in different agro-ecological regions of the country. Multi-disciplinary research programmes at the main institute are conducted through four divisions: Soil and Crop Management, Irrigation and Drainage Engineering, Crop Improvement, and Social Science Research. To pursue specific research needs of different agro-climatic regions, the institute has also established three Regional Research Stations at Canning Town (West Bengal), Bharuch (Gujarat) and Lucknow (Uttar Pradesh) to deal with the problems of coastal salinity, salt-affected vertisols and alkali soils of the central and eastern Indo-Gangetic plains, respectively. The Coordinating Unit of All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture is also located at the main institute and is functioning through 8 regular research centres at Agra (Uttar Pradesh), Baptala (Andhra Pradesh), Bikaner (Rajasthan), Gangawati (Karnataka), Hisar (Haryana), Indore (Madhya Pradesh), Kanpur (Uttar Pradesh), Tiruchirapalli (Tamil Nadu) along with 4 voluntary centres at Bathinda (Punjab), Panvel (Maharashtra), Port Blair (A&N islands) and Vyttila (Kerala) representing different agro-ecological regions of the country. For the period under report, some of the major research achievements of the institute in different thrust areas are as under:

Novel Alternative Amendments for Improving Sodic Soils

Declining availability and quality of agricultural-grade gypsum has given impetus to developing novel alternative amendments for sustaining the pace of alkali soil reclamation in country. Two such amendments *viz*., 'Reliance Formulated Sulphur' (RFS) and 'Municipal Solid Waste Compost' (MSWC) have given promising results. RFS, an elemental sulphur-based formulation, applied 21 days prior to rice transplanting led to significant decline in soil pH. Efficiency of reclamation and crop performance in controlled field experiments as well as farmers' participatory evaluation [Kaithal

(Haryana), Patiala (Punjab) and Etah (UP)] were superior or at par with gypsum applied on equivalent basis (GR 50). Yield advantage with RFS application at farmers' fields was highly significant in rice wheat, cotton and sugarcane crops. Different combinations of MSWC, gypsum and sewage sludge were also tested in lysimeters using highly sodic soils, and at farmers' field. At farmers' field (pH_2 9.37, EC_2 0.92 dS m^{-1}) in Kaithal district of Haryana, there was significant increase in rice grain yield over contol. Yield of salt-tolerant rice variety CSR-30 (2.52 t ha^{-1}) was at par with 50 GR.

Feasibility of subsurface drip technology in cereal based systems of IGP

In intensive cereal based rice-wheat systems, bundling precise water and nutrient (N) management using subsurface drip irrigation (SDI) coupled with precision agronomic management provides science backed evidence to address multiple challenges of food, nutrition, water, energy, soil health & climate change in the 'Green Corridors' of the county. We have standardized the laterals spacing and depth at 67.5 x 20 cm in normal soil and a 45 x 15 cm in salt affected soils, respectively. On system mean basis, SDI saved 47 (93.6 cm yr^{-1}) and 45% (29 cm yr^{-1}) irrigation water under rice-wheat (RW) and maize-wheat (MW) system, respectively compared to flood irrigation system under same management level. The highest (4.46 q ha-cm^{-1}; 669%) irrigation water use efficiency was recorded with MW system and lowest (0.58 q ha-cm^{-1}) with farmers' practice. The SDI system reduced the fertilizer N requirement by 20% (30 kg N ha^{-1}) under each crop of rice, wheat and maize crops and on system basis. On system basis, RW and MW systems recorded 45 and 50% higher PFP_N with SDI compared to CT flood. The crop productivity and farm profitability of RW-mungbean system increased by ~11 and 29%, respectively under SDI system compared to farmers' practice (FP) of flood irrigation system. However, in MW system, ~20% higher productivity, 49% higher profitability was recorded under SDI system compared to flood RW system. The SDI enabled the integration of mungbean in cereal (RW/MW) systems, which contributed to ~10 and 25% increase in productivity and profitability, respectively irrespective of cropping systems.

Cropping systems intensification in coastal salt-affected soils

Technological interventions viz., improved management practices, new crops and varieties are giving encouraging results for improving income and nutritional security of resource poor farm families in fragile salt-affected areas of Gosaba island of South 24 Parganas district, West Bengal. These interventions assume paramount significance as locally available river water (surrounding the Gosaba island) is highly saline (16.8-47.7 dS m^{-1}) and unfit for irrigation. Intensification of waterlogged paddy fields was achieved through cultivation of vegetables in bags filled with soil and farm yard manure at 12 farmers' fields, with B: C ratio of 1.63-4.46. Zero tilled paddy straw mulched potato cultivation technology was also found to be a sustainable practice for the cropping system intensification in the study area. After three years, there was increase in organic carbon, available N and P due to this practice. Drip irrigation with different mulching materials also resulted in considerable saving of labour and fresh irrigation water compared to the conventional flood irrigation. Paddy straw mulching also significantly reduced weed infestation in the standing crops. All possible efforts are underway to disseminate these doable technologies to other salinity-affected coastal areas of West Bengal.

Soil bacterial community composition under reclaimed sodic soils

To understand the soil microbial community composition six management scenarios consisting- conventional-till (CT) rice-CT wheat (ScI; farmers' practice; FP); CT rice-Zero tillage (ZT) wheat-ZT mungbean with flood irrigation (ScII; partial CSA); ZT rice-wheat-mungbean with flood irrigation (ScIII) ZT maize-wheat- mungbean with flood irrigation (ScIV); Sc3 with subsurface drip irrigation (SDI) (ScV); Sc4 with SDI (ScVI) were evaluated.

Results showed that crop management practices influences bacterial community composition as copiotroph (*Proteobacteria*) were favored by conservation agriculture (CA) based scenarios while oligotrophs (*Acidobacteria* and *Actinobacteria*)were by conventional tillage (CT) based scenarios. Total 40 phyla were observed in six scenarios, and the results showed that management practices significantly affected the relative abundances of bacterial groups. *Proteobacteria* was dominant in all scenarios followed by *Acidobacteria* and *Actinobacteria*. Relative abundance of *Proteobacteria* was 29% higher in rice based CA scenarios (ScIII and ScV) and 16% higher in maize based CA scenarios (ScIV and ScVI) over farmer's practice (ScI). Combined relative abundance of *Acidobacteria* and *Actinobacteria* was 67%, 52% and 24% higher in farmers practice than rice based CA scenarios, maize based scenarios and partial CA rice based scenario, respectively. Higher (11%) Shannon diversity index was recorded in conventional tillage based scenarios (ScI and ScII) as compared to CA based scenarios. All diversity indices (Shannon, Simpson, Chao1 and out) were recorded higher in maize based scenarios (Sc IV and ScVI) as compared to rice based CA scenarios (ScIII and ScV).

Impact of land modification models in waterlogged sodic areas

Different land modification modules based on harvesting and management of canal seepage water were developed under farmers' participatory mode for reviving the waterlogged sodic lands in central Indo-Gangetic Plains. Besides considerably improving farm incomes, such models also boost land and water productivity and help check secondary sodication. Farm-level impact analysis of such models revealed that these models were being utilized to grow crops throughout the year, hence increasing the cropping intensity from 125% to over 250-300%, crop diversification from 0.24 to 0.86 and providing employment to the whole family throughout the year. There are, however, some obstacles that need to be overcome to upscale this technology. Availably of land in suitable plot sizes (1.0 ha for crop-fish based interventions and 0.50 ha for fish-crop based interventions) remains an important bottleneck. Besides, farmers willing but remaining unaware about the exact land area to be converted and large farmers remaining reluctant to convert the land for fish rearing (a social taboo) are major barriers to the spread of this technology. As waterlogged sodic lands are highly degraded, several farmers showed willingness to lease-out their land to the investors, suggesting that such models can be promoted through public, public-private or private investments.

Technical guidance, monitoring and evaluation of SSD projects

Based on the feasibility for sub-surface drainage (SSD), 6 new sites (total waterlogged saline area of 3,800 ha) were identified in Haryana state during 2019-20. These new sites had shallow watertable (≤ 1.5 m), moderate to high soil salinity (EC_e > 8 dS m^{-1}) and groundwater salinity (EC_{gw} > 2 dS m^{-1}) with availability of adjoining surface drain for discharge of drainage saline water. Pre-drainage investigations and topographic surveys at these sites are to be conducted for designing of SSD systems and funding under RKVY scheme. SSD systems in 200 ha were also installed at Gangana (110 ha) and Kathura (90 ha) under Jind and Sonipat-III SSD projects during 2019-20. Up to June 2019, total of 11,044 ha waterlogged saline area in Haryana has been reclaimed under 18 SSD projects benefitting 7,948 farmers. However, annual installation rate is quite low which needs to be accelerated to meet farmers expectation through modernizing HOPP infrastructure and manpower or through project outsourcing to drainage industries/contractors to achieving land degradation neutrality by 2030.

Conjunctive irrigation for improving water productivity in saline vertisols

Results of a drip irrigation experiment conducted at Samni Experimental Farm, Bharuch revealed that 50% fresh surface water could be saved without any significant reduction in wheat grain yield when surface and saline groundwaters (1: 1) were applied in cyclic mode compared with the conventional border irrigation using fresh water. Soil sample analysis showed considerable increase in salinity when all irrigations were done using saline groundwater (EC_{iw} 7.2-8.1 dS m^{-1}). In contrast, the lowest increase in soil salinity (1.1 dS m^{-1}) was noted with the regular use of fresh surface water. Despite highest wheat grain yield in conventional border irrigation using fresh water, overall better performance of cyclic irrigation [surface and saline groundwaters (1:1)] was evidenced by statistically at par grain yields, same degree of salinity increase and 50% saving of fresh water compared with the conventional method. Evidently, increased water productivity, saving of fresh water and lesser salinity build up can be achieved by conjunctive water use through drip irrigation.

Climate smart agriculture practices to improve systems' adaptability

Climate-smart agriculture (CSA) is considered a pragmatic approach to ensuring food security in a changing climate in partially reclaimed sodic soils. Adaptation strategies based on the principles of CSA can counter the impacts of climate change, such as the promotion of conservation agriculture, the sustainable management of natural resources and the promotion of climate-smart crops. CSA options include *water, energy, nutrient, carbon, weather and knowledge-mart* technologies, practices and services suitable for various crops and cropping systems in the region. The climate smart agriculture practices (CSAPs) like laser land levelling, direct seeded rice, zero-tillage, residue retention, nutrient management through GreenSeeker and Nutrient Expert and use of improved varieties of rice and wheat were tested in ~25 villages of Karnal both in isolation and in combination. The term CSAP encompasses farming practices that sustainably increase productivity, enhance resilience/adaptation, reduce greenhouse gasses (GHG) and help achieve national food security and development goals. These CSAPs can also deliver co-benefits in terms of reduced GHG emissions and enhanced carbon stock in soils. CSAPs increased 5-10% in rice-wheat system productivity, 15-20% in profitability, and 4-45% in energy productivity with 15-20% less water. The organic carbon content was increased by 25-30% after 3 years of continuous cultivation. It also reduces the terminal heat effects in wheat crop and able to cope up the losses by 50% compared to conventional wheat production practices.

ICAR-FUSICONT – bio-formulation for successful management of banana fusarium wilt disease

The epidemic outbreak of banana fusarium wilt disease in the commercial banana cultivation covering 7 districts in Uttar Pradesh and 5 districts of Bihar threatened the cultivation of G-9 banana in the country. ICAR-Central Soil Salinity Research Institute (CSSRI), RRS, Lucknow and ICAR-Central Institute of Sub-tropical Horticulture (CISH) characterized the hot spots of the disease through mapping and identified the antagonistic fungi *Trichoderma reesei* from banana rhizoshpere of sodic soils that contained the development of the disease pathogen *Fusarium oxyspourum* f.sp.*cubense* Tropical race 4 (Foc TR-4). A bio-formulation ICAR-FUSICONT was developed using the antagonist on an IPR protected media and substrate. The bio-formulation was validated under *in-vitro* and *in-vivo* conditions including the field trials at hot spot regions. The disease incidence was reduced to 10.58% in the FUSICONT applied fields as against 46.50% in the untreated fields. The collaborative research enabled the introduction and validation of the community empowered disease management in about 273 acres of the hotspot region and also restricted the proliferation of the disease to other districts of the country. The technology restored the livelihood to the farmers and revived the income of banana growers in the hotspot region to about 16.38 crores.

Awards and Recognitions

- Dr. H.S. Jat received National Award: Golden Jubilee Award for Excellence- 2019 by the Fertilizer Association of India (FAI), New Delhi for best Fertilizer Use Research in the Country during 2nd December 2019.

- Dr. Raj Mukhopadhyay received Clay Mineral Bursary award from Mineralogical Groups of Mineralogical Society of Great Britain & Ireland
- Dr. S. Mandal received Early Career Sponsorship from ACIAR for attending and presenting research paper during International Conference on 'Extension's Role in Climate, Rural Industry and Community Challenges', 11-13 September 2019, Darwin, Australia
- Dr Ashim Dutta received International Travel Fellowship from Science and Engineering Research Board (SERB)-DST, Govt. of India, New Delhi for participating in the 7th International Symposium on Soil Organic Matter, held in Hilton Adelaide, Adelaide, Australia during 6-11th October, 2019
- Dr. Ranjay Kumar Singh conferred Commonwealth-Chevening Fellowship for postdoctoral held in University of Oxford, UK, during 23rd April, 2019.
- Dr. R.K. Singh, conferred NAAS Felloship (Agril. Extension) on 1st January 2019
- Dr. Satyendra Kumar received Indian Society of Agricultural Engineering (ISAE) JAE Best Paper Award
- Dr. A.K. Bhardwaj got Best Paper Award in Joint International Conference by SCSI-ISCO-WASWAC, 5-9 November, 2019, New Delhi, India.
- Dr. Parvender Sheoran conferred Fellow of the Indian Society of Oilseeds Research, Hyderabad
- Dr. Parvender Sheoran conferred Fellow of the Indian Society of Weed Science, Jabalpur

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

- Biennial Workshop of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture was organized at ICAR-CSSRI, Karnal during 5-6 Feb. 2019.
- Golden Jubilee International Salinity Conference was held at ICAR-Central Soil Salinity Research Institute, Karnal during 7-9 Feb. 2019.
- ICAR-CSSRI, Karnal celebrated the 'National Productivity Week' during 12-18 February, 2019
- Kharif Kisan Mela on 16th March 2019 at Habri village in Kaithal District of Haryana
- ICAR-CSSRI, Karnal celebrated its 51st Foundation Day on 19th March 2019
- Van Mahotsav were celebrated on 8th August, 2019
- MANAGE sponsored training programme on "Technologies for Doubling Farmer's Income on Salt Affected Soils" during August 19-23, 2019
- Three days short training on *"Functional Characterization of Differential Gene Expression under Salt Stress"* at ICAR-CSSRI, Karnal from 11-13 September, 2019
- Rabi Kisan Mela was organized by the institute in collaboration with Department of Agriculture and Farmers' Welfare, Govt. of Haryana at Netaji Subhash Chandra Stadium, Palwal on 13th September, 2019.
- Hindi Pakhwara was organized during 14-28th September, 2019
- A Model Training Course entitled "Advancements in Soil, Water and Plant Analysis Techniques using Sophisticated Equipment with respect to Salinity and Sodicity Management" was held during 16-21st September, 2019
- 3 days training programme sponsored by CCS National Institute of Agricultural Marketing, Jaipur on "Innovative Marketing Practices for Enhancing Farmers Income in Salt Affected Regions" during 18-20th September, 2019

- International Capacity Building Programme on "Use of Poor Quality Water in Agriculture" was organized at ICAR-CSSRI, Karnal, during 23rd October to 05th November 2019.
- 5 days Farmers' Training Programme organized during November to December, 2019
- Institute celebrated Swachhata Pakhwara during 16-31st December, 2019
- Institute organized farmers' day on 23rd December, 2019 on the eve of birth anniversary of Late Prime Minister Chaudhary Charan Singh.

Field Exhibition and Visit

During 2019 a total of 7 exhibitions were organized at different research institutions and developmental agencies to portray the improved technologies for the reclamation and management of salt-affected soils and poor quality waters. Out of 1473 stakeholders, 488 farmers, 851 students, 112 extension workers and 22 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 2019 a total of 332 advisories on soil testing, salinity and alkalinity management, salt tolerant crop varieties, crop management practices, animal husbandry, horticultural crops, and nutrient management were provided to the farmers through TOLL Free Number 1800 180 1014. Besides, fortnightly advisories on crop and soil management for salt affected areas were given to 172 farmers associated through WhatsApp groups with the institute International Collaboration

International Collaboration

- Stress Tolerant Rice for Poor Farmers of Africa and South Asia (funding IRRI-BMGF)
- Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTL for Drought, Submergence and Salt Tolerance (funding DBT,IRRI)
- Development of high zinc rice varieties (IRRI Funded)
- Piloting and up-scaling an innovative underground approach for mitigating urban floods and improving rural water security in South Asia (IWMI)
- Developing of Sustainable Resource Management System in the Water-Vulnerable Area in India (Funding JIRCAS)
- Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment. (ICAR-IRRI)
- Strategic Research Platform on Climate Smart Agriculture "Developing and defining climate smart agricultural practices portfolios in South Asia". (ICAR-CCAFS)
- CSIRO, Murdoch University, Australia–Project on cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India

Publications

The Institute published 93 research papers in peer reviewed journals, 23 Book/Manual/ Chapter, 21 Technical Bulletins/Folder/popular articles. Besides, 16 papers were presented in different National and International Seminar/Symposia and Conferences.

Scientists' visit abroad and new scientists joined

To upgrade their knowledge and skills, 13 scientists of the institute visited different countries *viz.* United Kingdom, Hong Kong, Canada, Japan, Australia, Philipines, Turkey, Dubai and Bangladesh. Two scientists joined the Institute during period under report.

Introduction

Historical Perspective

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

Over the years, Institute has grown into an internationally recognized esteemed centre of excellence in salinity research. Multidisciplinary research activities at the main institute are being strengthened through four research divisions. The major research activities in the Division of Soil and Crop Management include preparation and digitization of database on salt affected soils besides periodic assessment of state of soil resources, developing alternate amendments for the reclamation of alkali soils besides developing technologies for the optimal management of gypsum amended alkali soils and the use of high RSC and saline waters for crop production. In the post reclamation phase, focus is on developing resource conservation technologies and development of farming system models for resource poor farmers. Agro-forestry and horticulture on salt affected soils is another area of focus that includes multipurpose tree species, fruit plants, vegetables and seed spices. Development and propagation of individual farmer based groundwater recharge technologies, subsurface drainage for amelioration of waterlogged saline soils and decision support systems for ground water contaminations with fluoride and climate change are some of the major issues being addressed by the Division of Irrigation and Drainage Engineering. Development of high yielding genotypes tolerant to salinity, alkalinity and water logging stresses in rice, wheat, mustard and chickpea through conventional breeding and modern molecular and physiological approaches are the major concerns of the Division of Crop Improvement. The Division of 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, mustard and chickpea and the biological reclamation of salt affected soils through salt tolerant multipurpose trees. A microbial consortia CSR BIO as a plant growth enhancer has been developed and commercialized. Land shaping technologies for the productive utilization of waterlogged sodic soils and coastal saline soils have also been developed. Nearly 2.0 million ha salt affected lands have been reclaimed using these technologies and put to productive use. It has been estimated that reclaimed area is contributing about 17 million tonnes food grains to the national pool. For waterlogged saline soils, subsurface drainage technology developed by the Institute initially for Haryana has been widely adopted and replicated in Rajasthan, Gujarat, Andhra Pradesh, Maharashtra and Karnataka. So far, about 70,000 ha waterlogged saline areas have been reclaimed, through institutional and private modes. Artificial groundwater recharge is another area of interest for the region with depleting water table. Besides, the technologies are also being developed for the salt affected areas of Vertisols and coastal regions of the country.

An International Training Centre to impart training at national and international level was established during 2001 under Indo-Dutch collaborative research programme. The Institute faculty also serve as guest teachers and advisors for the Post Graduate education and research programmes of State Agricultural Universities (SAUs), other Universities and Institutes. The Institute has several national and international projects to fund its research and development activities. The notable amongst them are: IRRI sponsored rice improvement programme, ACIAR sponsored programme for coastal saline soils, CIMMYT sponsored programme on the improvement of cereal based systems and IWMI sponsored programme on taming underground flood water systems.

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

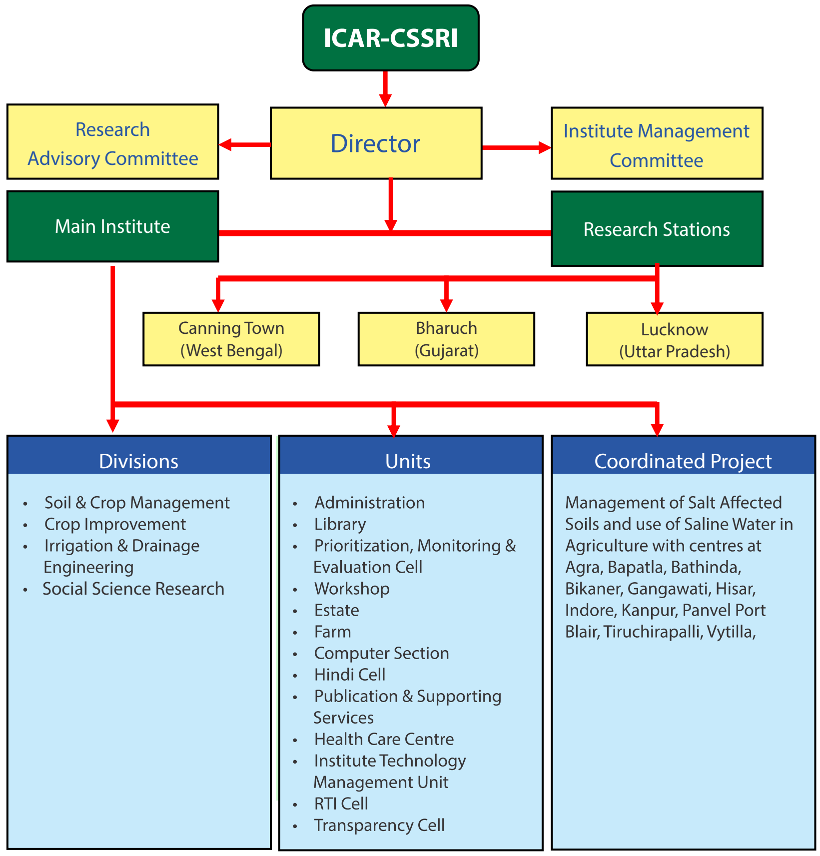
Mandate

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

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

Organogram

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



Research Farm, Karnal

Agricultural farm at CSSRI, Karnal has total area of 82 ha. A motorable road has been laid all along the boundary of this farm, for regular monitoring, upkeep and proper watch and ward. Whole of the farm area under cultivation has been divided and laid out in standard plot size of 1.0 ha size and each plot is connected with road for easy accessibility, underground water conveyance and lined channels for irrigation. Eight tube wells are installed in the farm to meet irrigation requirement of general agriculture, research experiments and water supply in the campus and laboratories. All essential farm machinery and implements *viz.,* laser leveler, multi-crop thresher, turbo seeder, zero till machines, laser leveler, tractors, hydraulic trolley, cleaner, shrub master, maize thresher, Straw bailer, Riper binder, Jet sprayer, Rotavator, bund maker and ride on lawn mower etc. are available; most of farm operations are mechanized. To achieve the optimization of water and other inputs, all the plots are precisely leveled with laser leveler at regular intervals. Combination of different cropping system is being practiced to optimize the land use in the farm. Experimental crops are grown on 21.60 ha area, while general crops are grown in 16.6 ha, which also includes the 10 ha area under seed production mainly of

Productivity of crops at CSSRI farm

Crop	Variety	Average yield (t ha^{-1})
	Rabi 2018 - 19	
Wheat	KRL 210	5.10
	KRL 213	4.15
Mustard	CS54	2.45
	CS56	2.65
	CS 58	2.84
	CS 60	2.90
Chickpea	Karnal chana 1	2.25
	Kharif 2018	
Paddy	CSR 30	3.40
	CSR 56	6.50
	CSR 60	6.80
	Pusa 44	5.80
	PB 1718	4.60

salt tolerant varieties of rice and wheat. This year seed processing plant is also installed to provide quality of seed of salt tolerant varieties to the farmers. During the period under report, the farm unit generated revenue of Rs. 95 lakh. To reduce the emission of green house gases, most of area has been put under minimum tillage and residue burning is not practiced in the farm. Agro-forestry system is practiced on 6.2 ha area of the farm, where multipurpose tree species have been planted in combination with arable crops of the region. The area under fruit crops such as ber (*Ziziphus mauritiana* Lam.), aonla (*Emblica officinalis* L.), jamun (*Syzygium cumini* L.), guava (*Psidium guajava* L.), litchi (*Litchi chinensis* Sonn.) and mango (*Mangifera indica*) is 7.4 ha. An herbal garden consisting of 104 species of medicinal/ aromatic herbs, shrubs and trees has also been established and maintained in an area of 1.20 ha, besides fish are reared in ponds covering about 2.5 ha area. The 27.3 ha area of the farm is permanently covered under glass house, net houses, micro-plots, laboratories, offices, residences, oxidation pond, roads and landscape.

Nain Experimental Farm, Panipat

The Nain experimental farm is located at Nain village, west of Panipat-Gohana road, 25 km from Panipat town (District Panipat) and is about 65 km from Karnal. This farm covers an area of 10.8 ha. Initially, the site had *Prosopis juliflora* and other salt tolerant grasses and herbs as *Sporobolus marginatus*, *Saccharum spontanium* (Kans), *Cynodon dactylon* (Dub grass), *Suaeda fruticosa* (Noon khari), *Kochia indica* (Bui) and *Calotropis procera* (Aak) etc. A wide range of soil salinity (<4 to >30 dS m^{-1}) existed at surface and sub-surface. The soil reaction showed sodic nature ranging from <8.2 to 8.9. The area has watertable at a depth of about 15 metres. The ground water showed neutral pH (7.7) and higher EC (13 dS m^{-1}) indicating high salinity with dominance of Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and HCO_3^-. Higher SAR (19.3 $mmol^{1/2}L^{-1/2}$) showed limitations for use during seed germination. Such water may be used in cyclic mode with good quality water preferably for salt tolerant crops and forestry/fruit plantations. Institute has initiated many experiments on forestry, horticulture, agro-forestry and sustainable management of such salt affected resources. Since no fresh water supply source is available on the farm, two ponds have been dug to harvest and store rain water and two tubwells have also been installed for supply of different quality water for experiments. Institute screens its mustard, wheat and rice germplasm and agroforestry/fruit crops for salinity tolerance. In addition, institutes like Regional Research Stations of IARI and SBI, Karnal also use this facility for screening of the germplasm.

Finances

Summary of allocation and expenditure during the year 2019-20 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)	81.33	-	-	81.33
Establishment Expenses (grant in aid-salaries)	2503.59	-	-	2503.59
Grant in aid general	1253.50	-	-	1253.50
Grand Total	3838.42	-	-	3838.42
Loan and advance	-	-	-	-

Staff

The total staff strength of the institute is 297. The category wise details are:

Category of post	Sanctioned	In position	Vacant	% Vacant
Scientific	81	70	11	14.00
Technical	112	83	29	26.00
Administrative	56	36	20	35.71
Skilled Supporting Staff	48	42	6	16.00
Total	297	236	66	22.22

Library

Library plays a crucial role in supporting the research and academic programmes of the Institute. It identifies, evaluates, procures, processes and then makes these learning resources available to the faculty and students to meet their teaching and research needs. Library has always been striving hard to meet the expectations of its users. ICAR-CSSRI library is well furnished, fully air-conditioned and equipped with four computers, one server and two UPS. The Institute library has rare and large collection of Technical, Scientific books, Journals, Reports and other publications. Library possesses Indian and Foreign publications related to the fields of Water Management, Soil Salinity, Drainage, Alkalinity, Water Resources, etc. to achieve the mandate of the institute. Presently, the library has total collection of 15736 books including Hindi books. A separate section is maintained for Hindi books. There are 8451 bound volumes of the Journals. It has a rich collection of special publications of FAO, IRRI, UNESCO, ILRI, ICID, IFPRI, ASA, ASAE which fulfill the needs of scientists, researchers, teachers and students.

About 162 theses on subjects relating to Soil Science, Agric. Engg., Water Management, etc. are available in the library. Annual Reports from the different Institutes, Agricultural Universities are being received from time to time.

e-Services

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

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

Online Public Access Catalogue (OPAC): Library book catalogue is available in online form which is a systematic record of the holding of a collection to find the physical location of information for easier to search using LIBSYS software version 6.0. Now "KOHA" software has also been implemented and all the data of Books, Journals, Theses, etc. has been migrated to "KOHA" to strengthen the digital resources of all Libraries under NARS (e-Granth). The Web OPAC of Library in "KOHA" may be accessed through http//egranth.ac.in

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

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

Documentation and other Services

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

The library also works as a repository center where Institute's Publications such as Salinity News, Technical Bulletins, Annual Reports, Brochures, etc. are stocked and sent to Research Institutes, Agricultural Universities, NAAS members, QRT members, RAC members etc. and also distributed amongst the distinguished visitors, farmers, etc. We have 03 priced publications also which are supplied on cash payment or D.D.in advance.

Laboratories

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

Allied Facilities

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

RESEARCH ACHIEVEMENTS

Database on Salt Affected Soils

Mapping and characterization of salt affected soils in 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 continuation of the previous report on the mapping and characterization of salt affected soils in Uttar Pradesh, visual image analysis was carried out to locate the salinity affected areas and assess current status of salt affected soils using IRS LISS III Resource SAT data for 2015-16. To prepare the base map of the UP state, a total of 303 topo-maps on 1:50, 000 scale were digitized and were used for image interpretation. Based on image analysis, geo-referenced soil sampling sites (1688 Nos.) were identified that covered salt affected areas in 40 districts of UP state (Fig. 1).The image interpretation revealed spatial distribution of salt affected soils along the Ganga, Yamuna and its tributaries. Critical areas of soil salinization, surface and sub-surface (high water table depth) waterlogging were also seen along the Sarda, Upper and Lower Ganga canal areas of the upper-, middle- and lower Gangetic plains. Based on the high reflectance on the imagery, severe and moderately salt affected soils were easily identified while the associations of salt and vegetation made delineation of slightly salinized areas a little cumbersome which was done on the strength of ground truth data. The close association of soil salinity and waterlogging in canal command areas also caused difficulty in delineating salt affected soils due to higher moisture contents at surface and sub-surface depths. These were authenticated using ground truth data. Soil salinity was also identified in large areas of wastelands distributed along the Gangetic plains where water availability, infrastructure, canal irrigation and low soil quality in terms of soil fertility, water, aeration and restricted internal drainage were reported. The difficulty of mapping such areas interspersed with dry land areas calls for consultation of the wastelands database of NRSC (2005). These were also delineated using the ground truth data only.

Ground truth studies were conducted during March 2019 to assess soil salinity at surface (0-15 cm) and sub-surface (15-30 cm) depths. It included current land use, soil salinity features on surface and sub-surface depths; the impact of soil salinity on crops or vegetation, salinity development in canal and tube well irrigated areas, and soil and water management for salinity control at farmer's field. Geo-referenced soil samples were collected from Agra, Mainpuri, Etah, Hathras and Kanpur Nagar districts and were analyzed for the determination of soil reaction (pH_s), electrical conductivity (EC_e); cations and inion (Na^+, K^+, Ca^+, Mg^+, Cl^- and SO^-_4), CEC, ESP and $CaCO^-_3$. Severely sodic soils were distributed as barren soils while moderate and slightly sodic soils were used for wheat and mustard, horticultural crops and for raising grasslands, scrub and pastures. Soil sodicity is higher at the surface depths and the highly sodic properties were found at surface and sub-surface depths, respectively. The range of EC_e values showed higher salinity at surface and was related to the higher Na^+, Ca + Mg and CO^-_3 + HCO^-_3 contents at surface depth. Contrarily Cl^- and SO^-_4 values were higher at sub-surface depths.Organic carbon content were higher at surface soils and $CaCO^-_3$ content much higher at subsurface than surface soils. Overall, soil salinity distribution indicated occurrence of large scale patchy along the Gangetic plains showing abundance of salt in poorly drained soil profiles of Uttar Pradesh state.

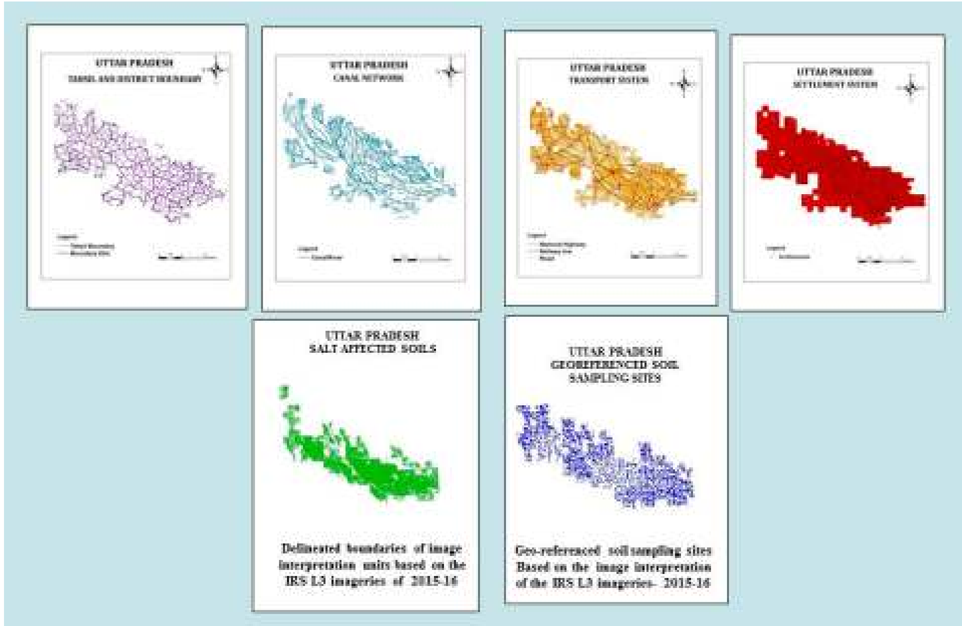


Fig.1. Soil salinity mapping in Uttar Pradesh

Methodology for real-time assessment of salt affected soils Ghaghar Plain of Haryana using hyperspectral remote sensing (Arijit Barman, A.K. Mandal, B. Narjary and P. Sheoran)

The salt affected soils Haryana covered 0.31 M ha, of which saline and sodic soils covered 0.14 and 0.17 M ha, indicating increased extent of soil salinity in the irrigated areas. The increment of area exaggerated by the application of poor quality irrigation water. More than 80% of the groundwater is of poor quality (RSC:3 – 6 meq l^{-1}) in central Haryana and specifically high in kaithal district of Ghaghar alluvial Plain (CSSRI, 2014). This salt affected soils (SAS) can be reclaimed and managed by periodic assessment and monitoring which is prerequisite.The hyperspectral remote sensing data (in the region of 350 to 2500 nm) provides real time assessment of soil salinity in time and cost effective way, but there is need for standardise the methodology for real-time assessment of SAS. We have collected Landsat 8 imagery, DEM SRTM 30 m imagery, SOI toposheet for the preparation of base map and different thematic map. The important base and thematic maps are presented in Fig. 2.

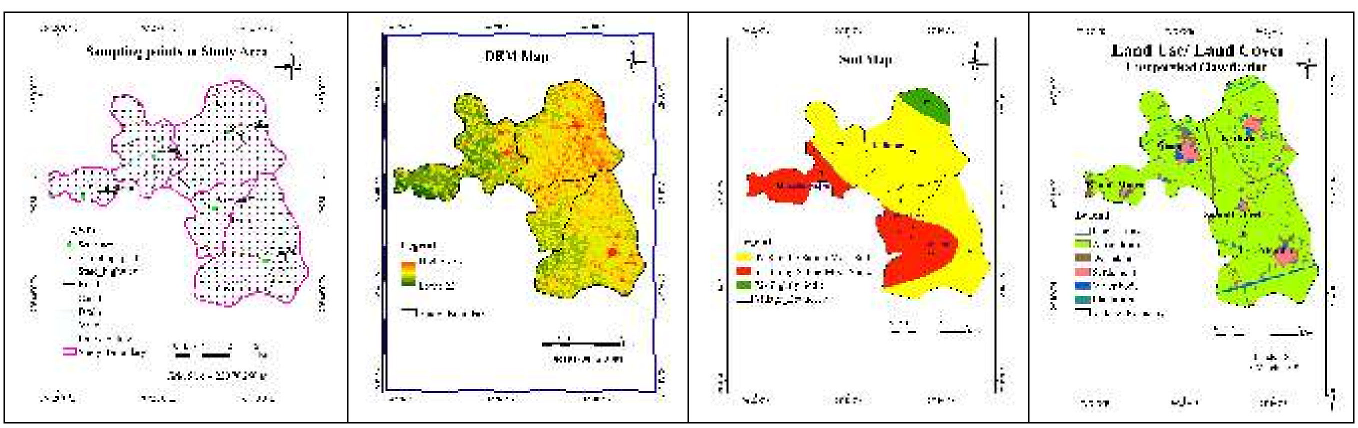


Fig. 2: Base map, DEM map, Soil series map, LULC (Unsupervised classification) map

The study area (3237 ha) cover five villages namely Mundri (1083 ha), Geong (551 ha), Kathwar (1032 ha), Sampli Kheri (337 ha) and Bhaini Majra (234 ha). We have imposed 250 ×250 m grid (Fig. 2) for regular soil sampling. In this way total 445 soil samples collected after kharif season of 2019 and analysis being done. The slope map, LULC map (kappa statistic – 0.719) and soil series maps are used as input with base map for the preparation of soil physiographic unit (Fig. 3). The one unit represent the homogeneous soil but there are heterogeneous soil within the physiographic unit. This map helps to generate the land capability classification map for agriculture field which suggest in the preparation of crop suitable map, suggest proper crop management techniques to overcome the limitations. Different spectral index like normalised difference vegetation index, salinity index, salinity ratio index, normalised difference salinity index map of March (crop coverage) and May (soil exposed/less crop coverage) imagery were developed to identified the SAS zone. The minimum, maximum and mean value of important spectral indexes were tabulated to compare the change of index over two different time (Table 1) Stressed vegetation index (NDVI, EVI) could be an indirect sign for the presence of salt in the soils. Salt affected soils are indirectly characterized by poorly vegetated are

Table 1: Temporal variability of different salinity index

Spectral Index	March (L8-18-03-2019)			May (L8-21-05-2019)		
	Min	Max	Mean	Min	Max	Mean
S1	0.026	0.259	0.05	0.053	0.276	0.15
S2	0.069	0.542	0.34	0.106	0.548	0.33
S3	0.039	0.37	0.08	0.076	0.395	0.21
S4	0.023	0.194	0.04	0.042	0.210	0.12
NDSI	-0.896	0.196	-0.75	-0.772	0.267	-0.20
EVI	-0.071	0.845	0.52	-0.132	0.649	0.14
SR	-0.857	0.167	-0.72	-0.743	0.267	-0.21

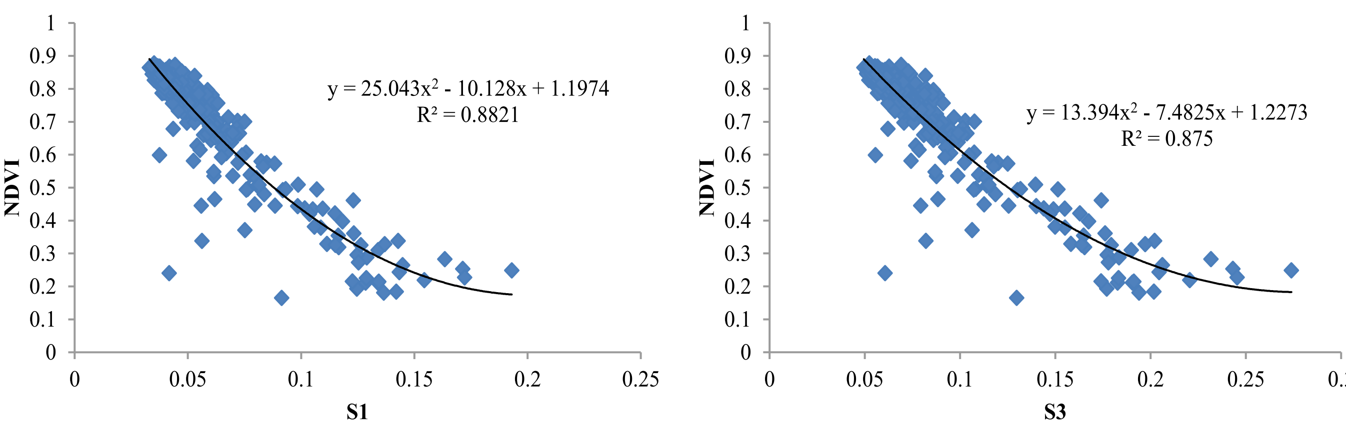


Fig.3. Regression relationship among vegetation and salinity index

More than 85% variability can be explained by the regression relation among vegetation (NDVI) and salinity indexes (S1=$\sqrt{Green \times Red}$; S3=$\sqrt{Green^2 + Red^2}$. The best fitted curves are presented in Fig. 3. These indexes generated from satellite images will be correlated with ground based hyperspectral data recorded by spectroradiometer.

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

Timely identification and monitoring of soil salinity and sodicity by the traditional techniques are time-consuming, expensive and required rigorous sampling to illustrate spatial variability, but hyperspectral spectroradiometer predict the SAS properties without laboratory analysis based on spectral library. There is a need to standardize the relation of different SAS properties among disturbed and undisturbed soil samples. In our study we observed that there is strong correlation among SAS parameters with 1st derivative spectra at the visible region in case of undisturbed soil over disturbed soil samples (Fig. 4). In case of undisturbed soil the high correlation spectral zone are 1400 to 1600 nm and 1900 to 2200 nm, whereas, for disturbed soil this zones are synchronized *i.e.* 1400 to 1550 nm and 1900 to 2100 nm.

The whole spectral region was used for the development of PLSR model with SAS parameters. The model accuracy in terms of coefficient of determination was best in case of disturbed soil over undisturbed soil. But the PLSR model was more stable between calibration and validation data sets in case of undisturbed soil than disturbed soil (Table 2).

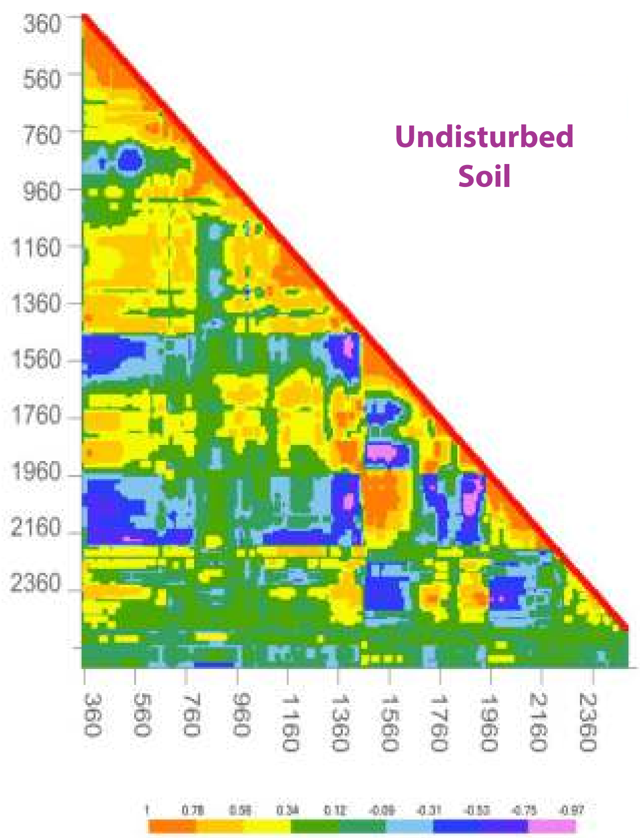


Fig.4.Contour Map of SAS parameters with 1st derivative spectra

Table 2 : Summary statistics for the spectral models (PLSR)

Soil parameters Undisturbed Soil	No. of Factors	Calibration set			Validation set				
		N	R^2	RMSE	N	SD	R^2	RMSEP	RPD
EC_e (dS m^{-1})	4	74	0.49	1.34	38	1.87	0.30	1.56	1.20
pH_s	5	72	0.69	0.26	37	0.48	0.33	0.44	1.09
SOC(%)	2	74	0.18	0.11	38	0.12	0.11	0.13	0.92
SE Cl^- (meq L^{-1})	9	74	0.70	2.78	31	5.14	0.26	3.34	1.54
SE Na^+ (meq L^{-1})	6	74	0.54	4.58	33	6.75	0.49	3.11	2.17
SE SAR ([meq $L^{-1}]^{0.5}$)	4	74	0.49	1.61	33	2.26	0.55	1.82	1.24

Soil parameters Disturbed Soil	No. of Factors	Calibration set			Validation set				
		N	R^2	RMSE	N	SD	R^2	RMSEP	RPD
EC_e (dS m^{-1})	3	149	0.54	1.14	75	0.97	0.52	1.16	0.97
pHs	5	149	0.81	0.22	75	1.48	0.64	0.29	1.48
SOC(%)	9	149	0.78	0.06	75	1.10	0.50	0.10	1.10
SE Cl- (meq L^{-1})	6	149	0.77	2.20	75	1.42	0.65	2.47	1.42
SE Na+ (meq L^{-1})	3	149	0.65	3.70	75	0.90	0.47	3.86	0.90
SE SAR ([meq $L^{-1}]^{0.5}$)	7	149	0.71	1.46	75	1.22	0.67	1.63	1.22

Table 3: Significant spectral bands of respected soil properties

Soil Properties (Undisturbed Soil)	**Waveband (µm)**
EC_e (dS m^{-1})	0.54, 1.89, 1.95, 2.21
pH_s	0.56, 1.88, 1.91, 2.22
SOC(%)	0.53, 0.87, 2.37, 2.39
SE SAR ([meq $L^{-1}]^{0.5}$)	1.83, 1.89, 1.95, 2.21, 2.39
SE Na^+ (meq L^{-1})	1.9, 1.95, 2.03
SE Cl^- (meq L^{-1})	0.68, 1.90, 1.98, 2.21
Soil Properties(disturbed Soil)	Waveband (µm)
EC_e (dS m^{-1})	1.42, 1.91, 1.98
pH_s	0.45, 1.37, 1.97, 2.21, 2.26, 2.37, 2.42
SOC(%)	0.69, 1.36, 1.85, 2.14, 2.21, 2.23, 2.36, 2.40
SE SAR ([meq $L^{-1}]^{0.5}$)	1.37, 1.94, 1.97, 2.10, 2.29, 2.36, 2.42
SE Na^+ (meq L^{-1})	1.42, 1.91, 1.98, 2.18
SE Cl^- (meq L^{-1})	1.86, 1.90, 1.94, 2.39

Excellent prediction accuracy of PLSR was recorded for Na variable in undisturbed soil, whereas, the acceptable prediction accuracy was found for Cl in both disturbed and undisturbed soil. Approx. 60% variability of SAR explained by PLSR model in both disturbed and undisturbed soil (Table 2). Significant spectral bands were identified of important SAS parameters from the highest and lowest regression coefficient values of PLSR model in both disturbed and undisturbed soil (Table 2).

Similar spectral bands or band range (varied within 100 nm) of soil EC_e, pH_s, SOC, Cl, Na and SAR parameters (bold values of Table 3) were identified from PLSR model in both disturbed and undisturbed soil samples. Bands range of 530 – 680 nm, 1900 – 2000 nm and 2200 – 2250 nm are identified from PLSR model as more important region for SAS parameters monitoring,characterization and quantification purpose.

Reclamation and Management of Alkali Soils

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

Keeping in mind the urgent need for improving water, nutrient and energy use efficiency through better management of land and water resources to sustain agriculture in semi-reclamed sodic areas, a field experiment has been continuing from 2006 with revised treatments from 2011 to evaluate the effect of different resource conservation strategies viz., tillage, residue and irrigation methods for enhancing crop productivity and sustaining soil health in semi-reclaimed sodic soils. Conventional practice (CV) *vis-à-vis* nine adopted resource conservation techniques were imposed. High yielding varieties of rice (Arize 6129) and wheat (HD 2967) were taken as test crops. The results of wheat (2018-19) and rice 2019 are presented.

Highest grain yield of rice (6.84 t ha^{-1}) was recorded in transplanted rice with wheat residue incorporation (TPR+WRI) followed by conventional transplanting (6.53 t ha^{-1}). Crop residue incorporation in transplanted rice (TPR+WRI) gave 4.74% additional grain yield compared to conventional transplanting without residue incorporation (TPR). DSR with residue incorporation produced 10.5% lower grain yield (5.84 t ha^{-1}) while saved 31.3% irrigation water compared to conventional puddled transplanted rice. Grain yield under DSR+R was 4.08 % higher than DSR without residue (Fig. 5).

In wheat, the highest grain yield was recorded under reduced tillage with rice residue incorporation (6.64 t ha^{-1} in RTW+RRI); 20.23% higher than conventional practice (5.52 t ha^{1}). Incorporation of residue under conventional tillage gave additional 9.24% grain yield than without residue. Likewise, wheat under zero tillage with anchored rice residue (RTW+RRI) and under zero tillage without rice residue produced grain yield 6.08 and 6.18 t ha^{-1}, 10.14 and 11.96% higher than conventional practice (5.56 t ha^{-1}). No significant difference in grain yield of wheat was found under zero tillage with anchored rice residue (ZTW+RR) and without residue (ZTW). Sprinkler irrigation system in wheat under zero tillage with 100% rice residue produced grain yield of 6.50 t ha^{-1}, highest nitrogen use efficiency (NUE) of 76.45 kg grain kg^{-1}N along with saving of 38% irrigation water and 43.33% nitrogen (140.1 kg urea ha^{-1}) compared to conventional practice.

Mini-sprinkler irrigation system in DSR under reduced tillage with wheat residue incorporation produced grain yield of 5.71 t ha^{-1} along with saving of 55.43% of irrigation water than conventional transplanted rice. Saving of 26.7% N (compared to recommended dose of 150 kg ha^{-1}) along with the highest NUE (51.9 kg grain kg^{-1} N) was also corded in this treatment. Drip irrigation in zero tilled wheat with 100% rice residue mulched produced grain yield of 6.08 t ha^{-1}, the highest NUE (52.23 kg grain kg^{-1} N) along with saving of 50.40% irrigation water and 17.3% nitrogen (~37.3 kg urea ha^{-1}) compared to the conventional practice. Drip irrigation system in DSR under reduced tillage produced grain yield 5.54 t ha^{-1} with NUE of 50.36 kg grain kg^{-1} N and irrigation water productivity of 1.78 kg grain m^{-3} along with saving of 60.36% irrigation water compared to conventional puddle transplanted rice.

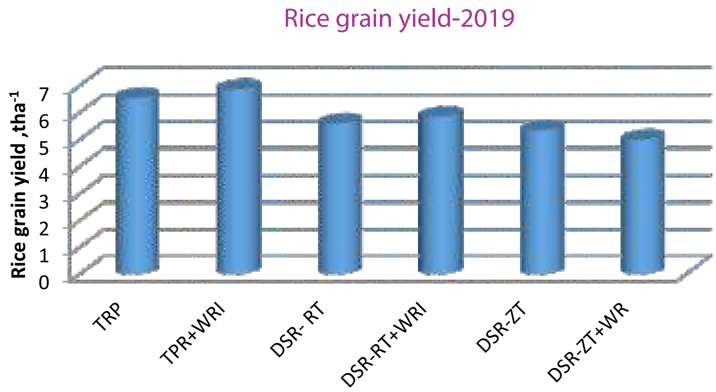


Fig. 5. Effects of tillage and residue management on grain yield (t ha^{-1}) of rice during 2019

Note: TPR= Transplanted rice; WRI= wheat residue incorporation; DSR= direct seeded rice; RT= reduced tillage; ZT= zero tillage; WR= Wheat residue retained/anchored

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

Integrated nutrient management experiments are being carried out with ten treatments replicated four times in randomized block design. The treatments are- T_1=Control (without organic and inorganic fertilizer, O), T_2= $N_{180}P_{22}K_0Zn_5$ (Farmer's practice; FP), T_3= $N_{180}P_{39}K_{63}Zn_7$ (F), T_4= $N_{100}P_{16}K_{26}$+Moong (LE), T_5= $N_{100}P_{16}K_{26}$+ green manuring with *Sesbania aculeata* before rice transplanting (GM), T_6= $N_{100}P_{16}K_{26}$+FYM @10 t ha^{-1} before rice transplanting (FYM), T_7=$N_{100}P_{16}K_{26}$+wheat straw (standing stubble incorporated before rice transplanting, WS), T_8= $N_{100}P_{16}K_{26}$+Rice straw (standing stubble incorporated before wheat sowing (RS), T_9= $N_{150}P_{26}K_{42}S_{30}Zn_7Mn_7$ (SMN) and T_{10}= $N_{150}P_{26}K_{42}S_{30}Zn_7Mn_0$(S). At the time of harvesting, 33% of the total rice stalk length was kept untouched and incorporated into the soil by power tiller before wheat sowing in T_8 treatment. Before rice transplanting, green gram seeds were sown in first fortnight of May 2019 in the specified plots and incorporated *in situ* after two pickings of pods. Similarly, dhaincha (*Sesbania aculeata*) as green manure crop was sown in May in the plots of T_5 treatment. At the age of 40-45 days, it was harvested, weighed and incorporated *in situ* in the specified plots before rice transplanting. Farm yard manure (FYM) and wheat straw (WS) were added in soil 15 and 30 days before rice transplanting, respectively. Rice (cv. Pusa-44) seedlings (30 days old) were transplanted in first week of July2019 at 20 cm × 15 cm spacing. One third of N and full doses of other macro and micro nutrients were applied at the time of sowing (in wheat) / transplanting (in rice) according to the treatment specifications. Remaining N was applied in two equal splits after 3 and 6 weeks of sowing (in wheat) / transplanting (in rice). Soil samples were taken at the time of harvesting of both rice and wheat crops. Ion exchange resin (IER) membranes (cation, anion) were used as plant root simulators. The membranes are implanted in soil for 10-15 days intervals, throughout the season, to determine daily nutrient availability in soil solution. The membranes were regularly installed-removed, and nutrients were extracted with 2M KCL over the full growing season.

Nitrogen use efficiency: The fertilizer-N use efficiency for both rice and wheat crops, over a 14 year aggregated period, was at par for 100% inorganic fertilizer and integrated management treatments (Fig. 6). The total applied-N use efficiency in rice crop was

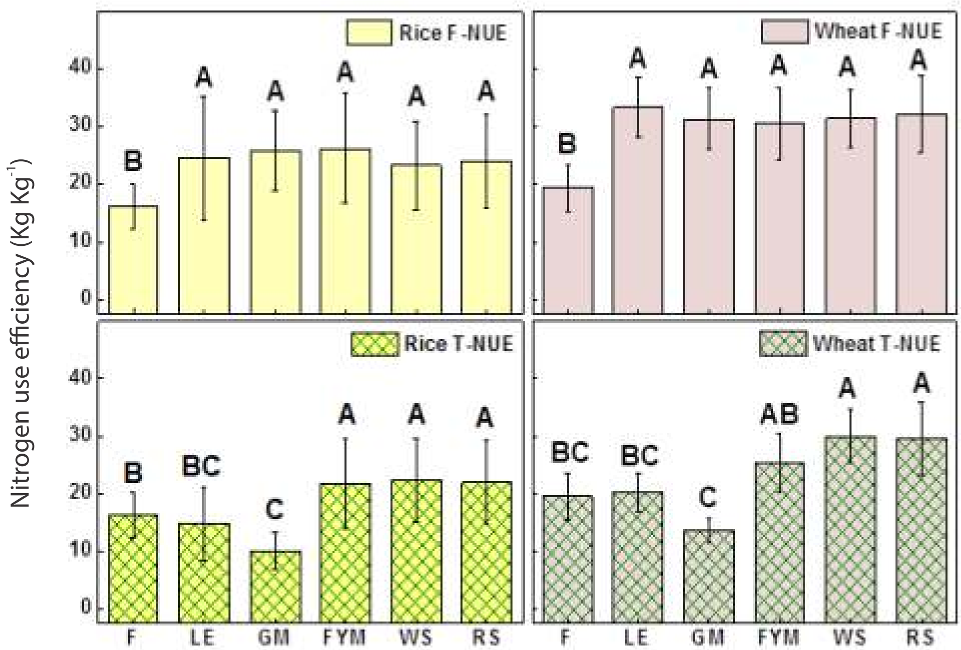


Fig.6. Fertilizer-N use efficiency and total applied-N use efficiency in rice and wheat crop over 14 years period. Management: F= 100% inorganic fertilizer, LE= Legume (Vigna radiata) in rotation and its biomass incorporation + 55% inorganic fertilizers, GM= Green manuring with Sesbania aculeata+ 55% inorganic fertilizers, FYM= farmyard manure incorporation + 55% inorganic fertilizers, WS= 1/3 wheat stubble retention + 55% inorganic fertilizers, RS= 1/3 rice stubble retention + 55% inorganic fertilizers. Error bars denote ± 1SD.Treatments with same letters are not different significantly at P≤0.05

highest in case of crop residue based management (WS, RS) and FYM, followed by F, LE and least in GM. The total applied-N use efficiency in wheat crop was highest in case of crop residue based management (WS, RS) followed by FYM, F,LE and least in GM.

Microbial diversity and dominance: The diversity, as indicated by soil culturable microbial diversity index, was maximum in no inputs treatments followed by crop residues (WS, RS), F and LE, GM, and FYM, in the decreasing order.

Screening of potato genotypes for higher tuber yield under salinity stress

(Parveen Kumar and V.K. Gupta)

Fifty six potato varieties were evaluated at two levels of irrigation water salinity [BAW (EC_{iw}: 0.8 dS m^{-1}) and saline water (EC_{iw}: 10.0 dS m^{-1})] under field conditions to investigate the effect of irrigation water salinity on growth, development, graded tuber number and yield. Well sprouted potato tubers of different varieties were planted on 25 October 2019 with 60 × 30 cm crop geometry and recommended dose of fertilizers. First irrigation was given on 29th October, 2019 with best available water (BAW) to facilitate proper emergence followed by two irrigations up to 30 days with saline water. Initial observations indicated that across potato varieties, growth traits (plant height and stem no. plant^{-1}) and all gas exchange characteristics decreased in response to saline irrigation water (Table 1). Potato varieties differed significantly for all growth and physiological traits and interaction between irrigation water salinity × potato genotypes were also significant for all physiological traits reported in Table 4.

Table 4. Effect of irrigation water salinity on growth and physiological traits of potato varieties

Irrigation water salinity	PH (cm) 45 d	SP plant^{-1} 45 d	Gas exchange traits (75 d)				
			Pn (µmol CO^2 $m^{-2}sec^{-1}$)	gS (µmol CO^2 $m^{-2}sec^{-1}$)	Ci	E (µmol H_2O $m^{-2}sec^{-1}$)	Ci/Ca ratio
BAW (0.8 dS m^{-1})	52.80	4.98	16.90	0.51	302.08	2.64	0.80
SW (10 dS m^{-1})	48.10	4.69	14.10	0.38	284.59	2.24	0.75
CD (P=0.05)	1.35	NS	0.50	0.04	5.34	0.11	0.01
Potato varieties (based upon last year yield plant^{-1})							
K. Arun	58.70	4.66	17.60	0.35	259.20	2.14	0.69
K. Khyati	59.10	4.33	12.70	0.27	265.34	1.76	0.70
K. Mohan	48.90	4.00	17.50	0.34	256.50	2.12	0.68
K. Sindhuri	51.50	4.83	15.00	0.32	269.70	2.10	0.71
K. Neelkanth	48.20	6.25	19.50	0.51	298.30	2.94	0.80
Range	22.8-71.2	3.25-8.66	9.5-19.5	0.20-0.10	247.6-328.7	1.49-3.61	0.65-0.87

BAW: best available water; SW: saline water; PH: Plant height(cm), SP: Stemps/plant, Pn: photosynthetic rate, gs: stomatal conductance, Ci: intercellular CO_2, (ppm) E: transpiration rate

Elemental S based formulations - An alternate to gypsum in reclamation of sodic soil (Arvind Kumar Rai, Nirmalendu Basak, R.L. Meena, R. K. Yadav, P.C. Sharma, Parul Sundha, S.K. Jha, U.R. Khandkar, R.V. Jasra, Chintansinh Chudasama, Prakash Kumar, Kalpesh Sidhpuria, Sachin Rawalekar, Yamini Shah, Chandrakanth Gadipelly, Sunil Soni, Niranjan Kumar, Jyothirmayi Kumpatla and Hemant Katti)

Elemental Sulphur-based formulation was developed in collaboration with Reliance Industries Ltd., Mumbai, as an alternative technology for reclamation of sodic soils. Formulation applied 21 days prior to rice transplanting led to significant decline in $pH_{1:2}$. Efficiency of reclamation and crop performance in controlled field experiment at Karnal, Lucknow and Indore as well as farmers' participatory evaluation in Kaithal (Haryana), Patiala (Punjab), and Etah (UP) were superior or at par with gypsum applied on equivalent basis (GR 50). Yield advantage of S based formulation (RFS) application in pre-kharif season before sowing the crop at different farmers field in Haryana, Punjab, Uttar Pradesh, and Madhy Pradesh compared to control were highly significant (rice wheat, cotton and sugarcane). This response varies with the severity of sodicity, crop and variety grown.


Rice and wheat crop in sodic soils reclaimed with RFS application Jaunpur (UP) and Patiala (Punjab)

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

Urban wastes such as sewage sludge and municipal solid waste compost in conjunction with gypsum have potential to reduce the soil sodicity. Additionally, these organic amendments provide essential nutrients (N, P, K and others secondary and micronutrients); improve soil physical and chemical properties and enhance microbial populations and activities. Different combinations of MSWC, gypsum and sewage sludge were tested in lysimeter conditions with sodic soils collected from Haibatpur, Karnal and Saraswati range. The selected treatment combinations were further evaluated at farmers' field. Treatments of the experiment carried out at farmer's field were: control, 50GR, 25GR+Compost 10 t ha^{-1} and Wet Mixing (25GR + C10WM), 25GR+Compost 10 t ha^{-1} Dry Mixing (25GR + C10DM). Salt tolerant rice variety (CSR-30) was transplanted in the field and changes in soil properties and yield increase were observed.

The experiment of sodic soil reclamation through the applicaton of municipal solid waste compost in conjuction with gypsum was carried out at farmers filed in Kaithal district of Haryana.The initial soil pH_2 was 9.37, EC_2 0.92 dS m^{-1} and gypsum requirement of 13.0 t ha^{-1}. There was significant increase of rice grain yield over contol. The yield of salt-tolerent rice variety CSR-30 (2.52 t ha^{-1}) was at par to 50 GR. Plant height, panicle length and productive tillers were also significantly higher in amended plots (Fig.7).

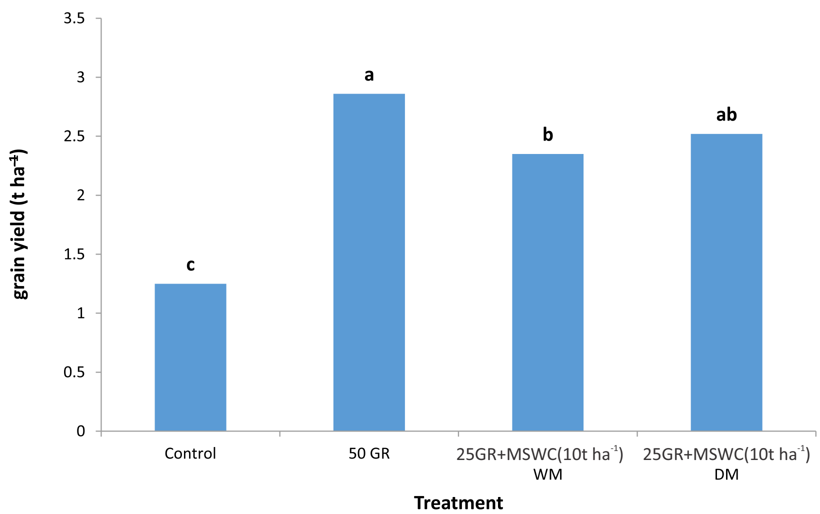


Fig. 7. Effect of treatments on total grain yield (t ha^{-1}) of rice crop (CSR-30) at farmer's field in Kaithal

Control

50 GR

25GR+MSWC (10t ha^{-1})

Performance of salt tolerent rice variety (CSR-30) in compost amended sodic soil at farmer's field

Dynamics of nitrogen and organic matter fractions in soils under long-term conservation agriculture in reclaimed sodic soil (Ashim Datta, Madhu Choudhary and P.C. Sharma)

Desorption study was conducted to determine the stability. Humus complex was extracted from four crop management scenarios namely conventional rice-wheat system (TPR-CTW) (Sc1), partial CA based rice-wheat-mungbean system (TPR-ZTW-ZTMb) (Sc2), full CA-based rice-wheat-mungbean system (ZTDSR-ZTW-ZTMb) (Sc3) and maize-wheat-mungbean system (ZTM-ZTW-ZTMb) (Sc4) by shaking soil sample (5 g) with 100 ml of 0.1 M sodium hydroxide + 0.1 M sodium pyrophosphate for 2 h and centrifuged for 13 min @ 10,000 rpm. Thus, in every 2 h the reacting solutions were replaced with fresh solution and repeated for 3 times (i.e. up to the 6 h). In this batch technique, the desorbed humus was removed every 2 h to avoid backward reaction, if any, so that the rate of release remained unaffected wherein re-adsorption of humus was avoided. The total organic carbon (TOC) of the soil before and after the process and the C in the supernatant humus extracts for each time were measured.

Soils under CA based system contained more labile C at both the soil depths. Significant variation in desorption of C was observed under different CA based practices. Desorption rate constant varied from 0.11 to 0.15 day^{-1} at surface soil and 0.03 to 0.15 day^{-1} at 15-30 cm soil depth different CA based practices. At surface and subsurface soil under farmers practice, desorption rate constant was 0.10 and 0.08 day^{-1}, respectively. Significant positive relationship was observed between absorbance and TOC concentrations (Fig.8). This relationship can be used to calculate the TOC concentration from absorbance.

Fourier transform infrared spectroscopy (FTIR) of the humic acid samples revealed that higher number of functional groups was observed in CA based systems (Sc2) (Fig. 9) over conventional rice-wheat system.

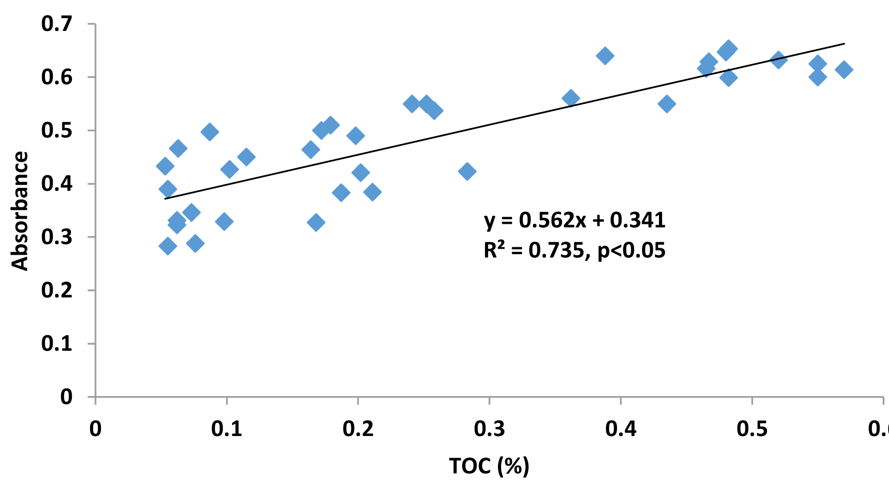


Fig. 8. Relationship between absorbance and TOC concentration irrespective of scenarios

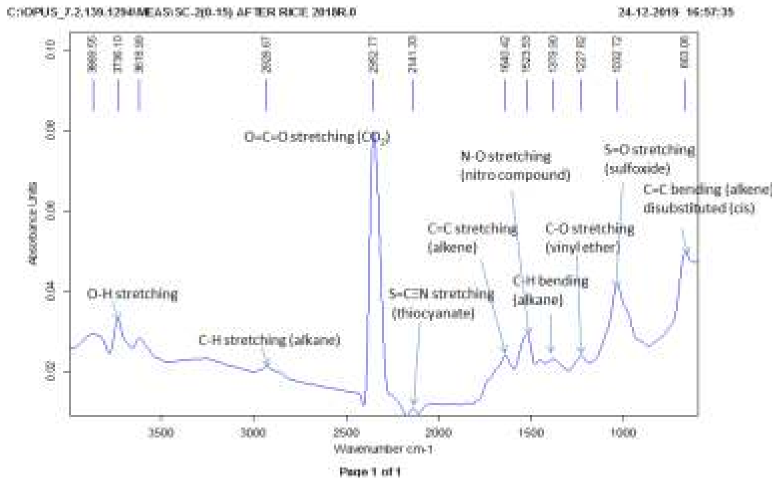


Fig. 9. FTIR spectra of humic acid extracted from soil (0-15 cm) under rice-wheat-mungbean system (Sc2)

Farmer participatory enterprise-mix diversification on reclaimed sodic land (Gajender, Raju, R., A.K. Rai, R.K. Yadav, Madhu Choudhary, Raj Kumar, Anil Kumar, Dar Jaffer Yusuf and K.S. Kadian)

Enterprise mix diversification is widely regarded as an effective strategy for mitigating multiple sources of short term economic risk to agricultural enterprises. Diversified agricultural systems also support the natural environment and contribute to capital formation, thus leading to higher overall growth in the agricultural economy. The cost and return structure of 2 ha enterprise mix diversification model recorded the gross income of Rs. 1508845 with a total cost of Rs. 1018525 including Rs.246101 for rental value of land and electricity charges. The net income generated from the model is Rs.490320 with B:C ratio of 1.48. In grain production system, the net income from rice-wheat-moong and maize-wheat-moong was Rs 78907 and 97586 with B:C ratios of 3.54 and 4.2, respectively. Among the subsidiary components, dairy enterprise provided net income of Rs. 436891 with a B:C ratio of 1.78.

Soil fertility in different components

In general the salinity was relatively higher in lower layers and pond dykes had higher salinity than other components. Soil pH of different components is provided in Fig.10. The soil pH below 90 cm depth varied from 8.0 to 9.5. The pH of pond dikes was 7.5 to 8.5 up to 60 cm depth and up to 10.0 in lower depths.

Soil organic carbon (OC %) in upper soil layers (0-15 cm) in Rice-Wheat-Moong, Fodder, vegetables and Horticulture were 0.35%, 0.56%, 0.23% and 0.73% respectively. The higher OC% in these systems may be due to higher biomass of these crops that was added to soil. The available nitrogen in various components in upper soil layer (0-15 cm) varies from 85.2 Kg ha^{-1} to 1.27 t ha^{-1} and available phosphorus ranged from 1.72 to 2.81 t ha^{-1}. The lower N in the pond area may be due to lesser application of chemical fertilizers in these components. The available K range was 1.36 to 3.13 t ha^{-1} in various components.

Thus, to understand impacts of enterprise based mixed farming across space and through time, and the farm-level trade-offs that may result, crop and livestock activities cannot be looked at in isolation. This pilot study gives an account of the dimensions in which integration and synergies can take place in mixed farms and evaluated the role of these systems to enhance the availability of and access to food and increase household

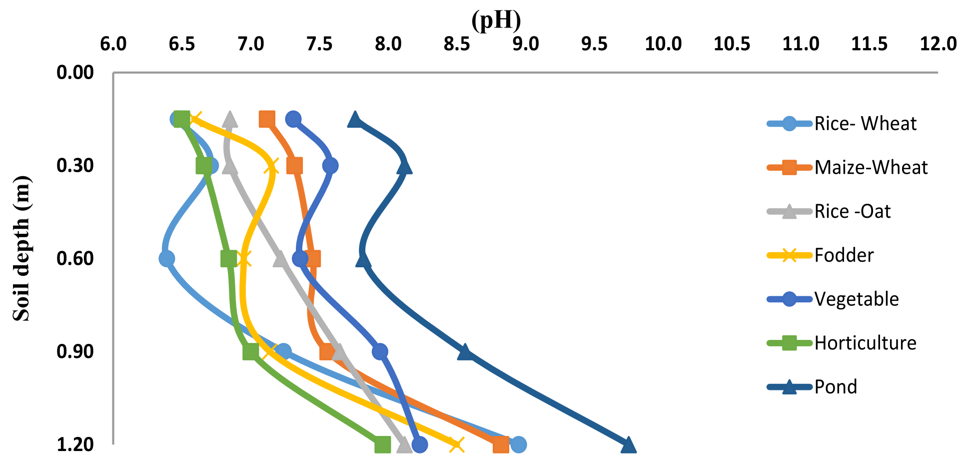


Fig. 10.Soil pH in different components of multi-enterprise model during 2019

General view of some components of Multi-enterprise Agriculture System

incomes and employment of small holders. At the same time study also evaluated the resource use efficiency and beneficial effect of enterprise mix diversification on soil health and environmental sustainability.

Rice-wheat system performances and dynamics of salt and water under contrasting tillage, residue and irrigation management practices (H.S. Jat, Ashim Datta, Madhu Choudhary, Satyendra Kumar and P.C. Sharma)

The intensive cultivation based rice-wheat system consumes large amount (~200 cm) of irrigation water, and is energy and labor intensive, and deteriorates soil health in North-West Indo-Gangetic plains of India. The sub-surface drip irrigation (SDI) is considered economically viable option for field row crops, such as maize, rice and wheat under normal soil conditions. Conservation agriculture (CA) based rice-wheat rotations allows crop residues recycling (which are otherwise burnt), saves irrigation water, lowers energy use and increases farmers' profit and appreciable amount of water saving through SDI. In salt affected soils where Na- carbonates and bi-carbonate dominate, effects of CA with SDI are unknown with respect to soil moisture influenced salt dynamics. We hypothesized that SDI technology will reduce the salt load in root zone and its consequences on crop growth and development and improve input use efficiency in CA based RW system.

During first season, soil moisture distribution pattern with SDI under different CA-based management systems was worked out. Also irrigation water saving, productivity and profitability of different scenarios were monitored. To study the wetting front in salt affected soils (pH: 8.3 at 0-15 cm and 9.2 at 15-30 cm soil depth), SDI laterals were operated for the duration of 1, 2, 3 and 4hrs, respectively and soil moisture content across the lateral was determined after 24 hrs after the system operation. In SDI, drip line was placed at the depth of 15 cm. In 1 hr irrigated plot, the lateral movement of moisture content (~ 20%) was recorded up to 10 cm, one side of the emitter placed at 15 cm soil depth while vertically movement was beyond 20 cm from the emitters. In upward direction, soil moisture content of ~ 20% was found only 5 cm below the soil surface towards emitter. However, in 2 hr irrigated plot, the lateral spreading of moisture content (~ 22%) was found up to 20 cm, while downward movement was beyond 20 cm from the emitters, and at the soil surface, the wetted zone was about5 cm laterally emitters. Under the system operation of 3 hrs, the higher soil moisture (~24%) was recorded more towards the downward side rather than the upward direction from the emitter. At soil surface also, moisture spread was > 10cm from the vertical line joining emitter. The 4 hrs operation of SDI leads to higher moisture (~32%) in surface soil. It indicates that excess water application in SDI system where wetting of surface particularly in sodic soil is not desirable for optimum plant growth. (Fig.11).

The grain yield of rice ranged from 5.01 to 5.89 Mg ha^{-1} under different scenarios. The higher grain yield of rice was recorded with ScII and ScIII where it was grown under ZT condition with and without residue and it was at par with full CA based systems {ScVI: Rice-wheat, ZT+R+SDI}.

The transplanted rice consumed highest (~1155 mm) amount of irrigation water with flood irrigation, whereas ZT with flood and ZT with SDI consumed ~770 and 390 mm or irrigation water, respectively. ZT rice with flood irrigation saved 34% of irrigation water, however with SDI it saved 66% or irrigation water, irrespective of different management scenarios in rice crop. With SDI system, INR 65971 ha^{-1} was recorded and it was ~21% higher over the farmers' practice (54414 ha^{-1}).

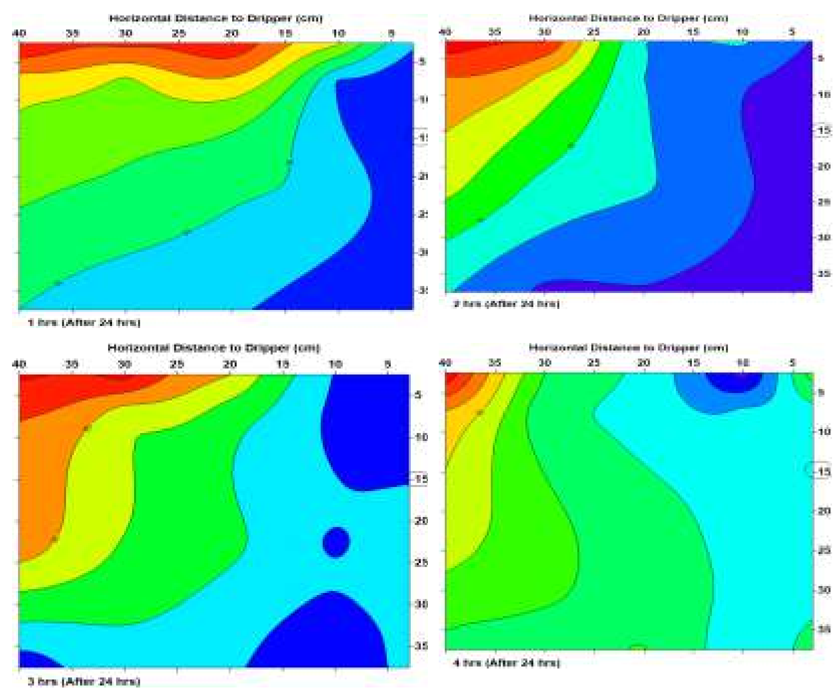


Fig. 11. Soil moisture distribution pattern under sodic soils

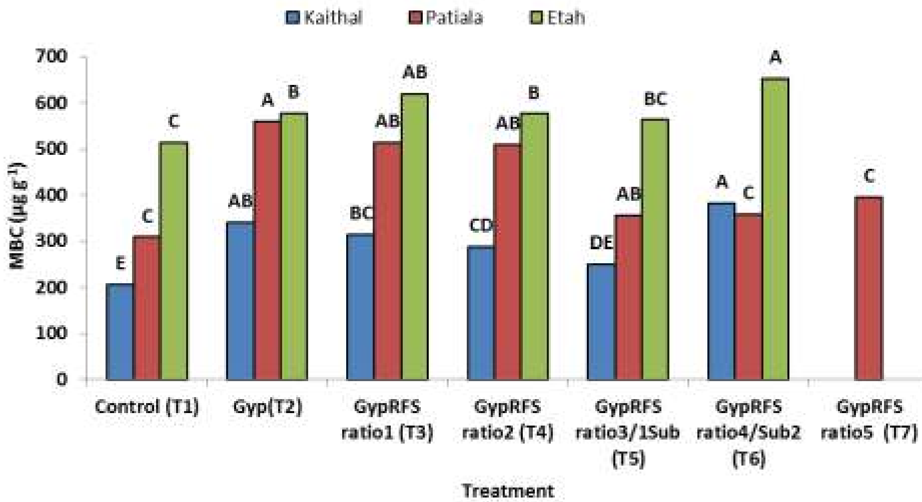


Fig. 12.Effect of amendments on microbial biomass C (MBC) after wheat 2019 in 0-15 cm soil depth. *(Numbers followed by different uppercase letters significantly different at P ≤ 0.05 by DMRT for separation of mean)*

Performance of wheat under different amendments in Moiudinpur, Etah, Uttar Pradesh

Developing soil quality indices for sodic soil under different reclamation strategies

(Nirmalendu Basak, Arvind Kumar Rai, Parul Sundha, R.L. Meena, R.K. Yadav and P.C. Sharma)

Gypsum, pyrites, aluminum chloride, inorganic sulphur, press mud, acids, acid-formers, phosphogypsum, fly ash, and bio-augmented material with gypsum are the amending material to reclaim soil sodicity. An attempt has been made to identify key soil quality indicators in progress of soil reclamation under different management strategies and developing the soil quality index. Results of the multi-location field trials (Mundri, Kaithal, Haryana; Budhmore, Patiala, Punjab and Moiudinpur, Etah, Uttar Pradesh) showed that the sole application of RSF/or its conjunctive application with gypsum declined soil pH_s of surface 0-15 cm soil layer. However, the decrement varied with soil types, inherent sodicity (ESP/pH) and use of water for irrigation. The decrement of soil pH_s was greater in Moiudinpur, Etah (from 8.92 to 7.77 by applying RFS+Substrate1, T_5) followed by Budhmore, Patiala (8.1 to 7.75 by applying GypRFS ratio2, T_4) and Mundri, Kaithal (7.89 to 7.55 by applying GypRFS ratio2, T_6). Reclamation with RFS+Substrate1 in Maidinpur, Etah increased Walklay and Black organic C (WBOC 2.88 g kg^{-1}) than control (1.60 g kg^{-1}); and treatment GypRFS ratio4, T_6 in Mundri, Kaithal increased WBOC 7.32 g kg^{-1} from control 5.58 g kg^{-1}. Further, GypRFS ratio4, T_6 improved microbial biomass C (MBC) in Mundri, Kaithal with 381.8 µg g^{-1} compared to control 206.5 µg g^{-1}; GypRFS ratio1, T_3 maintained MBC 514.6 µg g^{-1} than control 308.5 µg g^{-1} in Budhmore, Patiala; whereas, RFS+Substrate2 in Maidinpur, Etah showed highest values of MBC 652.5 µg g^{-1} than control 514.2 µg g^{-1}(Fig.12).

Developing low cost amendments for reclamation of sodic soil by using municipal solid waste

(Gajender, R.K. Yadav , Madhu Choudhary, Bhaskar Narjary, Ashim Datta and Parul Sundha)

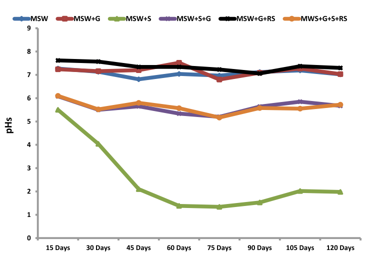


Fig. 13. Changes in pH of composting material with time

Soil degradation is a major impediment to sustainable crop production in arid and semi-arid regions of the world. Additionally, the increase in the generation of MSW, thereis a need to make available more areas for the disposal of wastes in landfill. Therefore, other alternatives of wastes disposal should bestudied and evaluated. This study has been

undertaken to investigate the effects of MSW compost as an ameliorant and soil conditioner to alleviate the negative effect of salt-affected soils. For development of low cost ameliorating amendments using municipal solid waste (MSW) to reclaim the sodic soils, MSW was collected for second composting cycle from Karnal and Panipat Municipal Corporations, Haryana. Raw MSW from both sites was segregated into degradable and non-degradable waste materials and analyzed for chemical and nutrient properties. It was observed that in MSWcollected from Karnal site, 35 % material was degradable comprising of organic matter, leaf, paper etc. and remaining 65% was non-degradable materials consisting of metals, stone, plastic and glasses. The MSW collected from Panipat site consist of 41% degradable compostable material and remaining 59% consist ofrages, clothes, pebbles, plastic and low amount of glass, metals and woods..

The Biodegradable solid waste material in combination with other soil amendments as per treatments (MSW, MSW+Gypsum, MSW+ Elemental Sulphur, MSW+Gypsum+Elemental Sulphur, MSW+ Gypsum+Rice straw and MSW+ Gypsum+ElementalSulphur+Rice straw) were filled in a 1x1x1.2 m^3 compost pit inoculated with Pusa compost inoculantand compost was prepared in 125 days. Mixing, sampling and temperature recording of compost was done at 15 days interval. Changes in chemical compositions of composting material were analyzed at 15 days interval and observed that the trend was similar for MSW collected from Karnal and Panipat sites. All treatments having elemental sulphurviz; MSW+S, MSW+S+G and MSW+G+S+RS effectively reduced the pH of composting material but most significant reduction in pH was recorded in MSW+ElementalSulphur treatment. The ECe of the composting material was reduced over time in all treatments except MSW+ElementalSulphur treatment which had highest ECe initially and the salinity was increased upto 90 days of composting and then reduced drastically at 105 and 120 days of composting.

Developing and defining climate smart agriculture practices portfolios in South Asia (P.C. Sharma, Ashim Datta and Madhu Chaudhary)

During *kharif* 2019, rice equivalent yield was significantly higher in scenario 6 (8.71 t ha^{-1}) followed by scenario 4 (8.37 t ha^{-1}) and lowest in scenario 1 (6.78 t ha^{-1}) (Table 5). The yield of rice was higher by 7% in scenario 2 over scenario 1, while in scenario 5 (6.48 t ha^{-1}), it was similar with scenario 3 (6.35 t ha^{-1}). In maize based systems about 23-28% higher productivity was observed over farmers practice. In rice, irrigation water application was highest in scenario 1 (1736 mm/ha) and lowest in scenario 6 (94 mm/ha). However, irrigation water application varied significantly amongst scenarios (Table 5). In scenario 5, about 40% less irrigation was applied over farmers practice. Similarly, sub-surface drip irrigation saved about 39% water in scenario 5 over scenario 3.

Highest SOC was observed in Sc3 (1.16%) at 0-15 cm soil depth whereas Sc2 showed highest SOC (0.57%) at 15-30 cm soil depth (Table 6). Lowest SOC was observed in farmers practice (0.64%). Highest and lowest available K was observed in Sc3 (286 kg ha^{-1}) and Sc1 (209 kg ha^{-1}) at 0-15 cm soil depth, respectively (Table 6).

In another experiment highest maize grain yield was recorded in Maize-Mustard-Mb in permanent bed treatment (10.4 t ha^{-1}) followed by Maize-Wheat-Mb (9.55 t ha^{-1}). Soybean yield was 3.03 t ha^{-1} in soybean-wheat-Mb on permanent bed treatment. Highest irrigation water was applied in PTR-CTW (2782 mm ha^{-1}) followed by ZTDSR-ZTW (2736 mm/ha) and CTDSR-ZTW treatments (2709 mm ha^{-1}) (Table 7). Significant improvement in soil quality (physical, chemical and biological) was observed in CA based practices.

Table 5: Yield and water use under different scenarios during rice/maize, 2019

Scenario	Systems	Residue management	Productivity (REY t ha^{-1})	Irrigation water (mm ha^{-1})
I-farmers practice	Rice-wheat (CT/TPR)	No residue	6.78^{c}	1736^{a}
II- partial CA based	Rice-wheat-mungbean (TPR-ZT-ZT)	Full (100%) rice & mungbean and anchored wheat	7.28 (7)^{b}	1723 (-0.7)^{a}
III-full CA based	Rice-wheat-mungbean (ZT-ZT-ZT)	Full (100%) rice and mungbean; anchored wheat	6.35 (-6)^{c}	1694 (-2.4)^{a}
IV-full CA based	Maize-wheat-mungbean (ZT-ZT-ZT)	Maize (65%) and full mungbean and anchored wheat	8.37 (23)^{a}	152 (-91)^{c}
V-full CA+ based with SSD	Rice-wheat-mungbean (ZT-ZT-ZT)	Full (100%) rice and mungbean; anchored wheat	6.48(-4)^{c}	1041 (-40)^{b}
VI-full CA+ based with SSD	Maize-wheat-mungbean (ZT-ZT-ZT)	Maize (65%) and full mungbean and anchored wheat	8.71 (28)^{a}	94 (-94.6)^{d}

Similar lower case superscript letters are not statistically different as per DMRT tests of separation of mean.
Values in parenthesis= % change from scenario 1

Table 6: Effect of CA based practices on soil organic carbon and available soil potassium after Rice/maize, 2019

Treatments/Soil depth (cm)	SOC (%)		Available K (kg ha^{-1})	
	0-15	15-30	0-15	15-30
Sc1	0.64d	0.36b	209c	169c
Sc2	0.91b	0.57a	267b	195a
Sc3	1.16a	0.44b	286a	179b
Sc4	0.74c	0.41b	270b	156d
Sc5	0.96b	0.39b	283a	189ab
Sc6	0.80c	0.39b	267b	182b

Similar lower case superscript letters are not statistically different as per DMRT tests of separation of mean. Values in parenthesis= % change from scenario 1

In CSVs, there were 850, 100 and 50 trials on Happy seeder, Green seeker and Nutrient expert on wheat grown on farmers field.

Table 7: Yield and water use of rice, maize, soyabean and pigeon pea under different scenarios during kharif season 2019

Treatments	Productivity (Mg ha^{-1})	Irrigation water (cm ha^{-1})
TPR-CTW	5.95	2782
CTDSR-ZTW	5.77 (-3)	2709 (-2.6)
ZTDSR –ZTW-ZTMb	5.42 (-8.9)	2736 (-1.6)
Maize-Mustard-Mb on PB	10.40 (74.8)	273 (-90.2)
Maize-Wheat-Mb on PB	9.55 (60.5)	282 (-89.9)
Soybean-wheat-Mb on PB	3.03	200 (-92.8)
Pigeonpea-wheat-Mb on PB	0.75	100 (-96.4)

Table 8. List of climate smart villages in Karnal district

Block	CSVs
Nilokheri	Nadana, Taraori
Indri	Chandsamand, Chorpura
Ghauranda	Bastada
Nissing	Sambhli

Management of Waterlogged/Saline Soils

Technical guidance & monitoring and evaluation of large scale SSD projects in Haryana (D.S. Bundela, Satyendra Kumar, R.L. Meena, Bhaskar Narjary, R. Raju, R.K. Fagodiya, Jaffer Y Dar, Raj Mukhopadhyay, Arijit Barman, Kailash Prajapat, and P.C. Sharma)

Identification of new sites

Six new sites at Rithal, Madina Gindhran and Samar Gopalpur (Rohtak district), Mandkola (Palwal), Hussainpur (Mewat) and Nathusary Chopta (Sirsa) with a total waterlogged saline area of 3,800 ha were jointly identified during 2019-20 based on the feasibility for SSD system. These new sites were characterized by shallow water (water table depth ≤ 1.5 m), moderate to high soil salinity ($EC_e > 8$ dS m^{-1}) and groundwater salinity ($EC_{gw} > 2$ dS m^{-1}) with availability of adjoining surface drain for discharge of drainage saline water. Pre-drainage investigations and topographic surveys at these sites are recommended to be conducted for designing of SSD systems to be submitted to CSSRI by HOPP for evaluation and approval and further funding under RKVY scheme.

Evaluation of design and layout of SSD systems

SSD systems in 200 ha were installed at Gangana (110 ha) and Kathura (90 ha) under Jind and Sonipat-III SSD projects during 2019-20. Up to June 2019, total of 11,044 ha waterlogged saline area in Haryana has been reclaimed under 18 SSD projects benefitting 7,948 beneficiaries. However, annual installation rate is quite low which needs to be accelerated to meet farmers expectation through modernizing HOPP infra structure and manpower or through project outsourcing to drainage industries/contractors to achieving land degradation neutral status by 2030 by the country.

Monitoring and evaluation of five SSD projects

Monitoring and evaluation (M&E) study of five SSD projects with 67 drainage blocks covering reclaimed area of 2,443 ha and 1,863 beneficiary farmers located at Gharwal, Katwara, Siwana Mal, Mokhra Kheri and Kharkhara under Sonipat-II & III, Jind, and Rohtak-I and II projects, respectively, were conducted during 2019-20 for improvement in soil salinity and crop yield. The average yields of paddy, cotton and wheat crops increased by 42-97, 65-200% and 32-125 and 15-35, 20-55 and 35-95%, respectively, for adequate and

New Waterlogged saline sites in Samar Gopalpur (Rohtak district), Hussainpur (Mewat) and farmers' interaction at Mandkola (Palwal)

Table 9: Different levels of pumping operation on crop yields of three major crops

S No	Level of pumping operation	Paddy	Cotton	Wheat
1.	Pumping hours for full reclamative leaching (200-400 hours)	42-97%	65-200%	32-125%
2.	Pumping hours for partial reclamative l eaching (100-200 hours)	15-38%	35-100%	20-65%

partial pumping operations done by farmers for achieving full or partial reclamative salt leaching in almost drainage blocks (Table 9). Out of 67 drainage blocks, adequate pumping was achieved in 24 blocks (36%). This technology has transformed barren waterlogged saline lands into good croplands in 2-3 year period and reduced the soil salinity (EC_e) from 15-38 to 2-8 dS m^{-1}. It can be conclusively stated that SSD projects in the past years significantly enhanced crop yields and doubling farmers' income provided adequate pumping for full reclamative salt leaching was achieved with farmers' support.

Pilot study on vertical drainage at Sikrona site (Faridabad)

About 120 ha of waterlogged saline land located near Sikrona village on Qabulpur Bangar-Sikrona Road in Ballabhgarh block of Faridabad district was selected by HOPP as the study site under the pilot study. Lithology study of six soil profile pits was conducted and revealed that a hard calcareous/kankar layer of about 4-45 cm thick was present at 90-120 cm depth may hinder proper installation of SSD pipes by trencher machines and further restricts the effective salt leaching. Therefore, a network of 12 drainage tubewells at 120-134 m spacing along Sikrona drain was planned for controlling water table and soil salinity under Gurgaon canal command. Twelve drainage tubewells with 30.5 cm bore size were drilled at 120-134 m spacing up to 22 m (72 feet) deep based on the bore lithology of the study site. Three 200 mm diameter PVC perforated casing pipes of 6 m long each and a 4.27 m blind pipe (including 0.61m above the ground) were lowered into the tubewell and then medium grade round gravel pack material was filled in between inter-spacing. These tubewells were made operational with 5 HP Kirloskar solar submersible pump sets to pump out saline drainage water into Sikrona drain through six underground pipe lines to control the water table and soil salinity for slow reclamation of waterlogged saline area with hard and thick calcareous /kankar layer at shallow depth. Three pump houses were constructed and solar panels with 15 plates and solar controller were installed and saline effluent water from the tubewells is disposed into Sikrona drain through 6 HDPE UGPL lines of 120 mm dia. Pumping operation of all the tubewells was made from Oct 2019 to assess the effect of pumping on water table and salt leaching. Change in soil, groundwater and drain water salinity was monitored.

Soil salinity of Sikrona site changed from 39.6 to 8.58 dS m^{-1} (0-15 cm layer) and from 40.2 to 10.67 dS m^{-1} (15-30 cm depth layer) by pumping operation and salt leaching by monsoon rainfall. Salinity of canal water was changed slightly from 1.24 to 1.20 dS m^{-1} and similarly, salinity of groundwater changed slightly from 11.05 to 11.00 d S/m (Table 6). The pumped tubewell water disposing into Sikrona drain from six UGPL outlets were collected and analyzed. It revealed that salinity of pumped tubewell water from six UGPL outlets ranged from 13.83-0, 33.78 to 11.03-31.25 dS m^{-1} (Table 10). This disposal has resulted in increase of salinity of Sikrona drain water from 1.72 to 3.71 dS/m during the Kharif season and may cause drainage water pollution and soil salinization in downstream fields, if the drain water is lifted for irrigation purpose.

Table 10: Change in salinity of canal, ground, pumped and drain waters at Sikrona site

S No	Source of water samples	Salinity of water samples, dS m^{-1}		
		Pre-project	During project (13 Nov 2019)	During Project (4 Feb 2020)
1.	Canal water	1.24	1.20	1.21
2.	Adjoining tubewell water (Groundwater)	11.05	11.00	11.00
3.	Water of soil profile pit dug (Accumulated)	30.6	--	--
4.	Drainage water of Tubewell no. 11 & 12 (UGPL Line 6)	--	24.00	20.10
5.	Saline pump water of Tubewell 1 & 10 (Line 5)	--	30.12	26.41
6.	Saline pump water of Tubewell 2 & 9 (Line 4)	--	33.79	31.25
7.	Saline pump water of Tubewell 3 & 8 (Line 3)	--	28.53	26.68
8.	Saline pump water of Tubewell 4 & 7 (Line 2)	--	13.83	11.03
9.	Saline pump water of Tubewell 5 & 6 (Line 1)	--	24.57	21.00
10.	Sikrona drain water (upstream of the project site)	1.70	2.19	2.62
11.	Sikrona drain water (D/s of the project site)	1.72	4.13	7.12

Water table in the project area was improved from 0.60 to 0.92-1.18 m below the ground level. The yield of paddy crop in the first year is increased to 3.1 t ha^{-1} (by 20-25%) due to lowering of water table and partial salt leaching from the soil profile. The vertical drainage is beneficial to farmers in the project area who are satisfied with project performance. However, there is drain pollution problem for downstream farmers. Two farmers have reported the problem of increased drain water salinity and yield loss of paddy crop, due to irrigation applied with drain water. The salinity of irrigation water used from Sikrona drain changed from 2.92 to 7.32 dS m^{-1} up to the mid Rabi season when two drainage tubewells were running only (Fig. 14). Good wheat crop is standing in the project area. Salinity of irrigation water used from Sikrona drain may further deteriorate up to 12.50 dS/m during Rabi season with one-fourth drain flow when all twelve tubewells are running. It is a serious issue for downstream farmers, if water is drawn from the drain for irrigation purpose. Water salinity of Sikrona drain has changed from 1.47 to 7.12 and then to 1.85 dS m^{-1} from drain start point to Kabulpur culvert during early February 2020 when two tubewells were only functional. Therefore, vertical drainage may not good option with groundwater salinity exceeding 6 dS m^{-1}. Further vertical drainage may be feasible with large disposal point such branch/sub-branch canals where full supply flow is more than 500 cusecs.

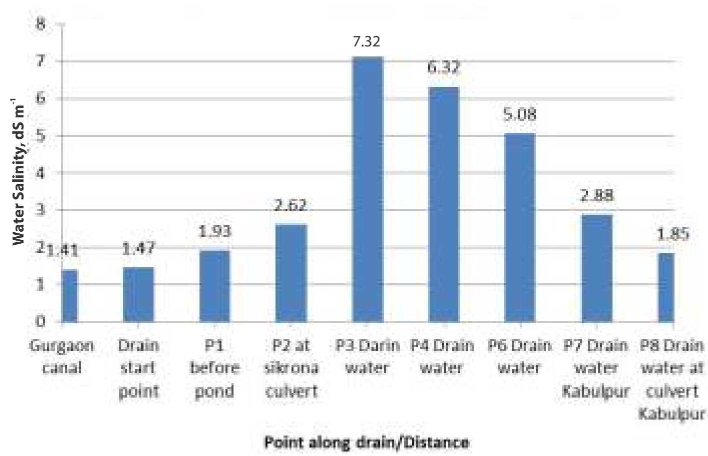


Fig 14. Change of water salinity of Sikrona drain over 3 km stretch

Astral-Rex consultancy on sub surface drainage in heavy soils of Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Telangana (D.S. Bundela, Anil Cinchmalatpure, Sagar Vibhute, Raju R. and P.C. Sharma)

Consultancy services on pre-drainage investigations and surveys, design and layout approval of new projects, drainage material testing, stakeholders' training, and evaluation of large-scale SSD projects were provided to M/s Astral Poly Technik Ltd (Astral Pipes), Rex Infra Division, Sangli (Maharashtra) during 2019-20. Open drain was not constructed to dispose saline water from the affected areas to the stream/river in the cooperative lift minor irrigation schemes along the River Krishna and its tributaries in Maharashtra and Karnataka. Therefore, pipe main drain is adopted as an integral part of SSD projects. Four drawings and designs of 3 farmers society funded SSD projects with 20 m drain spacing and total area of 590.2 ha at Terwad Zone-I & II, Majrewadi, and Shirati in Shirol Taluka of Kolhapur district were technically evaluated with respect to maximum permissible length of laterals and collectors, size and length of DWC pipe main drains, etc and approved for the implementation). Lateral spacing of 20 m is also recommended in the National Drainage Guidelines under a condition when additional cost over 30 m spacing is recovered from additional crop yields in the first 3 years. This condition is fully met with sugarcane in Maharashtra and Karnataka.

Waterlogged saline black soils in Shirol (Kolhapur district) for reclamation through SSD technology package

In order to address the excessive drainage from SSD system and slow reclamation process, controlled drainage approach was adopted and nine farmers' society funded controlled SSD projects with 20 m spacing along with pipe main drain in total area of 2,404 ha with 3,745 beneficiary farmers (Project cost- Rs. 5,467 lakhs) were being implemented semi-mechanically in Kolhapur district during 2018-19 and 2019-20 by farmers' land reclamation cooperative societies through CSSRI trained drainage contractors under supervision of three sugar factories and Astral Poly Technik Ltd with technical approval from ICAR-CSSRI (Table 11). The loan amount was released to nine farmers' cooperative societies for SSD projects by three cooperative banks. In the controlled drainage system, 80 mm diameter PVC Single Wall Corrugated (SWC) perforated pipes wrapped with suitable synthetic filter, and 90 and 100 mm diameter non-perforated PVC SWC (IS 9271:2004 & 2010) were used for lateral drains and collector drain, respectively. The lateral spacing of 15 or 20 m was chosen based on the severity of saline-sodic soils. The drainage water from the project area is discharged through the gravity outlet to a large open drain/stream. The controlled drainage was applied by installing a collector pipe for every 2.50-4.00 ha area (for 4-6 farmers) with ball based control valve at the collector pipe end inside the manhole (900 mm dia RCC pipe) for regulating drainage discharge from each collector by turning valve a quarter by the farmers as needed to address the environmental pollution by excessive drainage in long-term. Pipe main drain (in absence of open drain) was laid using HDPE Double Wall Corrugated (DWC) pipes (IS 16098 Part 2: 2013) with diameter varying from 135 to 500 mm towards the outlet.

The SSD work has been completed in about 675 ha up to June 2019 out of 2,404 ha project area and the lateral laying work is in progress whereas the pipe main drains in 7 projects have been completed except Majrewadi and Terwad-I & II. From the analysis of monthly drainage water samples from Shedshal and Bubnal sites with 20 m spacing, it was observed that the EC and SAR of drainage water decreased from 28.1 to 4.8 dS m^{-1} and 56.6 to 9.5, respectively, from April to Nov 2018 which reflects the significant removal of soluble salts by leaching. Similarly, the Soil EC2.5 at 8 locations along the collector decreased from 9.9-24.0 to 5.4-16.8 dS m^{-1} (by 58% average) and the $pH_{2.5}$ was increased

Table 11: Detailed information of 9 controlled SSD projects in Kolhapur district of Maharashtra

S No	Name of SSD project	Area (ha)	No of Beneficiaries	Pipe main drain (km)	No of Manholes	Project cost (Lakhs)	Name of farmer coop. society
Jaysingpur Udgaon Sahakari Bank funded (Supported by Shree Datta Sugars)							
1.	Shedshal, Zone-I, II & III	484.0	900	26.23	194	1261.50	Annadata BKJSCS
2.	Ganeshwadi, Zone-I & II	267.0	335	17.66	107	643.69	Krishi Sanjivani
3.	Arjunwad	452.0	768	16.89	181	898.15	Arjuneshwar
4.	Ghalwad	240.0	550	13.69	96	567.18	Shri Gholeshwar
5.	Kavathesar	167.0	299	10.44	67	356.45	Kavathesar,
6.	Bubnal, Zone-I & II	200.0	255	11.12	80	417.75	Krishnamai,
Sanmati Cooperative Bank funded (Supported by Sharad Sugars)							
7.	Shirati	225.0	232	24.900	56	500.63	Shri Bhaireshwar
C) Kolhapur District Central Cooperative Bank funded (Supported by Shri Gurudutt Sugars)							
8.	Majrewadi	244.0	287	23.986	61	542.90	Shri Gurudatt
9.	Terwad, Zone-I & II	125.2	119	10.921	32	278.57	Shri Gurudatt
	Total	2,404.2	3,745	155.843	874	5,466.82	

(Note: BKJSCS stands for Bahuudeshiy Ksharpad Jamin Sudharna Cooperative Society)



Semi-mechnical installation of SSD work with Hydraulic excavator in Arjunwad (Kolhapur) and manhole installed in the field

by 0.90 due to salt leaching during the first year. The cane yield increased from 33.7-51.4 t ha^{-1} (Pre-project) to 78.5-97.0 tonnes per ha during the first year of controlled SSD implementation and the highest yield would be achieved in next 2-3 years.

The SSD technology package has also been implemented successfully through PPP (Public-private partnership) mode or project outsourcing in two states of the country (Maharashtra, and Karnataka) realizing its significant benefits and impact on soil salinity, crop yield and farmers' income. The cost of installing SSD system for waterlogged saline heavy soils including Vertisols is Rs. 109,500/- ha^{-1} (with 30 m drain spacing) and Rs. 148,500/- ha^{-1} for 20 m spacing. Additional cost of HDPE pipe main drain is 45,000-62,500/- ha^{-1} in absence of open drain.The institute is providing backstopping and consultancy support on SSD technology package to different states for further refinement and dissemination for location specific needs.

Developing guidelines for suitability of synthetic filter materials for SSD systems in different agro-climatic regions (D.S. Bundela, R.K. Fagodiya and Raj Mukhopadhyay)

Under the project, BIS/ISO standards based methodologies for testing the suitability of non-woven and woven synthetic filters have been developed to ensure the optimal quality of drainage filter fabrics for different agro-climatic regions of the country in order to prevent clogging of drain pipes of SSD systems. During the year, two non-woven polypropylene filter samples were collected and tested for thickness, mass per unit area and characteristic opening size (O_{90}) for 80 mm lateral pipe of SSD system. The non-woven polypropylene filter samples (NWCA-1 & 2) from *M/s CA Polytech Pvt Ltd*, Gaziabad have met all three criteria and are recommended for use in SSD projects in Haryana. Further, two woven nylon sock filter samples (WCA-1 & 2) collected from the same manufacturer were tested for their suitability for collector pipes in terms of thickness, mass per unit area

Table 12: Test results of woven nylon sock filters

S. No.	Test Parameter Filter Sample ID	Reference Value/ Guideline ---	Test Results WCA-1	 WCA-2
1.	Material	Nylon	Nylon	
2.	Category	Woven	Woven	
3.	Appearance	Regular	Regular	
4.	Thickness	1 mm	0.32	0.31
5.	Pore size (mesh)	60 mesh	53	52
Recommendation: The samples met the above three criteria and hence suitable to use on collector pipes of SSD system				

and pore size (mesh< 60) and met all three criteria and are recommended for use in SSD projects in Haryana (Table 12). These methodologies have worked well for waterlogged saline alluvial soils in North-west India, but need to be refined for waterlogged saline black soils in western and southern India.

Studies on salt load of drainage water and improvement in soil salinity in sub-surface drainage sites in Haryana (Satyendra Kumar, Bhaskar Narjary, Kailash Prajapat and D.S. Bundela)

Subsurface drainage (SSD) system helps in controlling waterlogging and salinity problems and facilitates sustainable crop production. However, improper design and management may lead to accelerated losses of field water, nitrogen and other nutrients and water quality issues at downstream areas. Hence, performance evaluation of SSD systems is essential to assess success or failure of the project. In order to evaluate the performance of installed SSD system, soil and water quality was monitored on spatio-temporal scale at Kahni project site situated in Rohtak district of Haryana. For this purpose, SSD block 2 which was operational by farmers own effort. The performance indicators were compared with SSD block-1 where pumping was not started yet.

The determined soil profile salinity in functional SSD block-2 is presented in Fig. 15. It is clear that salinity in soil profile was less on January 2020 in comparison of a December 2018. The salinity at each depth was recorded to be less in November 2019 also as compared to December 2018, but higher than the January 2020. This shows that salt concentration in soil profile of functional SSD block decreased with the passing days. The change in soil salinity with time was attributed to salt leaching from soil profile with rain and good quality irrigation water. Interestingly, this area was waterlogged and operation of SSD ensured salt leaching out of crop root zone by controlling groundwater level and facilitating for leaching process. The impact of SSD on controlling groundwater table and reducing soil salinity ultimately results into good crop performance. A critical view on salinity curves presented in Fig. 14 show that the major changes in salinity was in upper 0-75 cm layer and beyond that (75-135 cm soil profile) changes was not visible. It was probably due to the fact that during rainy season, ground water level comes up and remained there which did not allowed salt leaching from these soil layers .

The ground water table fluctuation and changes in salt concentration in water with the time in SSD block-2 are presented in Fig. 16. The groundwater level was recorded to be 80 cm below ground level (bgl) in the month February 2019, which went down to 130 cm bgl in the month of May 2019. It started coming up during the rainy season of 2019. In post monsoon period, groundwater level started declining again. Despite of continuous pumping operation of SSD, water table fluctuation varied with the season. The upward movement of groundwater level during rainy season clearly indicates that the amount of water pumped out from the SSD block was not matched with the amount of rain and irrigation water received. Further, pumping of groundwater in adjoining SSD blocks was not done and groundwater level rose with the irrigation and rain water received. This may also contribute in upward flux in SSD block-2 despite of continuous pumping. This could be another reason of rise in groundwater table in SSD block-2 despite of continuous pumping during rainy season. It was also seen that groundwater salinity changed with time and the highest was recorded in summer season, while the lowest water salinity values were in rainy season probably due to the dilution effect with rain water. The overall

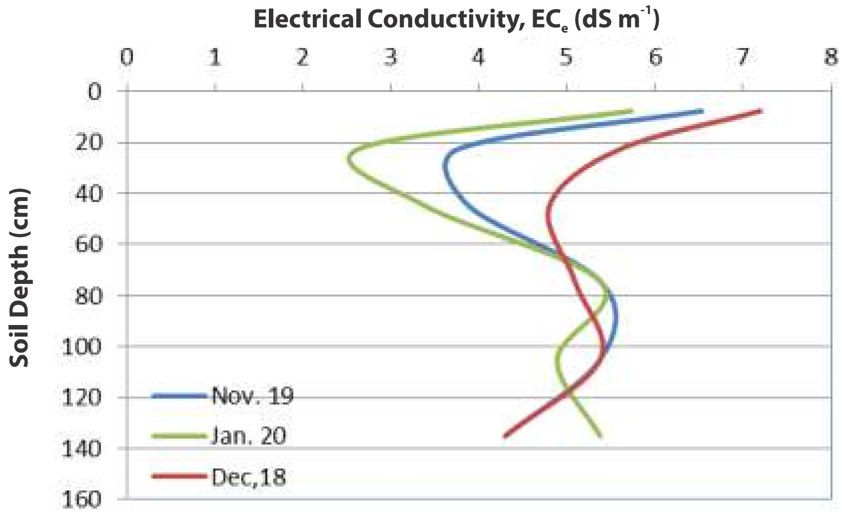


Fig. 15. Temporal changes in soil profile salinity in operational SSD block-2

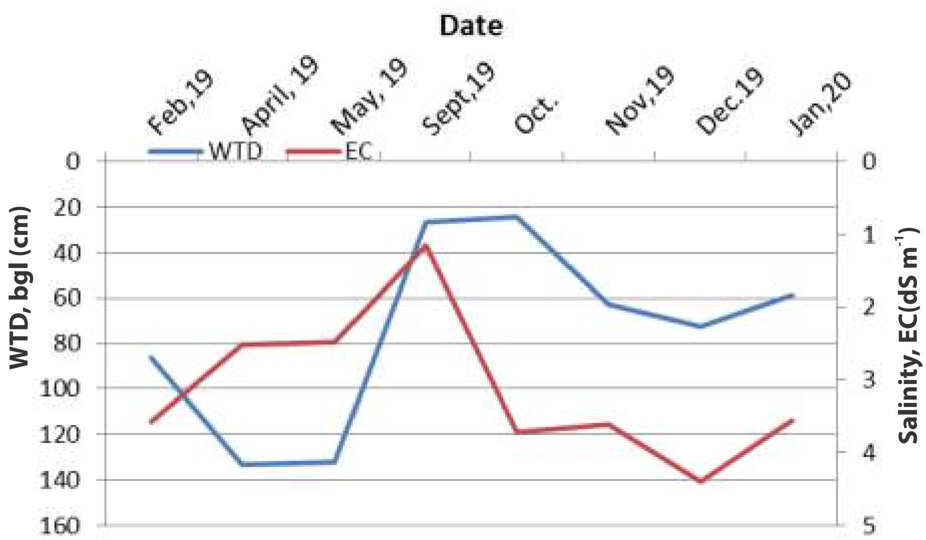


Fig. 16: Temporal changes in water table depth and salinity in SSD block-2

results of the study revealed that fully functional SSD can improve the soil condition and reduce soil salinity for sustainable crop production in waterlogged saline soil.

Salinity management through drip Irrigation, raised bed and mulch condition for crop production (Bhaskar Narjary, Satyendra Kumar, Ram Kishor Fagodiya and Raj Mukhopadhyay)

There is a pressing need to shift from conventional to resource efficient technologies for the effective utilization of saline water resources in India. This project has been initiated with drip irrigation in raised bed mulched system in salt-affected soil. An experiment was laid out in *kharif*-2019 at Nain experimental farm with two treatment in main plot i.e drip irrigated flat bed and raised bed system and 4 saline irrigation water treatments comprising of EC of 6,9,12, dS m^{-1} and best available water in the farm (~ 4dS m^{-1}) combination in subplots. Experimental site was surveyed and soil samples were collected in July, 2019 before sowing the *kharif* crop (pearl millet). In most of the experimental plots soil salinity was inverted i.e. higher salinity in the surface and decreasing depth wise. EC_e

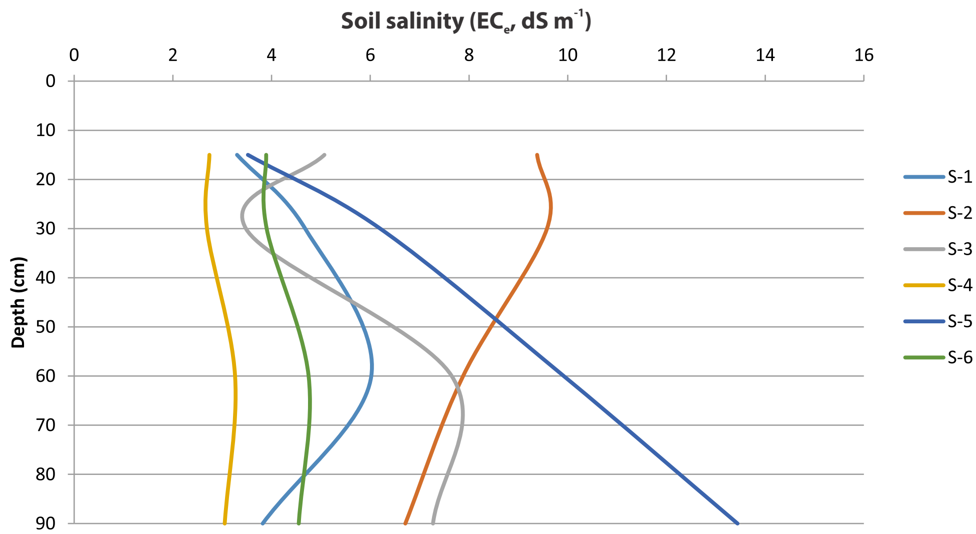


Fig. 17: Initial soil salinity distribution in different plots of the experiment

of the 0-90 cm profile soil of the experimental site varies in the range of 3-14 dS m^{-1} and surface soil salinity ranges between 3-10 dS m^{-1} (Fig. 17). There was no significant difference in the biomass and yield of pearl millet was observed in main as well as sub plots. Large variability was observed in biomass and yield mainly due to variation in soil salinity in different plots. In between the main plots, highest biomass and grain yield was recorded in raised bed plots (7.67 and 1.79 Mg ha^{-1}) compared to flat bed plots (6.79 and 1.74 Mg ha^{-1}). In saline irrigation treatments, highest grain and biomass (1.93 and 8.13 Mg ha^{-1}) was observed in plots irrigated with low saline water (BAW~4 dS m^{-1}), followed by 6 dS m^{-1} saline water (1.78 and 7.48 Mg ha^{-1}), followed by 9 dS m^{-1} saline water (1.73 and 7.39 Mg ha^{-1}) and least in 12 dS m^{-1} (1.63 and 5.98 Mg ha^{-1}).

Development of salinity-yield relations for different crops under micro-irrigation for updating water quality guidelines (R.K. Fagodiya, B.L. Meena, R.L. Meena, M.J. Kaledhonkar, D.S. Bundela and P.C. Sharma)

The field experimental data from four AICRP on SAS&USW Centres (Agra, Bapatla, Bikaner, Hisar) working on use of saline groundwater for irrigation were collected. These experiments were grouped into sensitive, semi tolerate and tolerate categories on basis of sensitivity of crops to saline water. Further, these experiments were grouped on basis of levels of irrigation water salinities used for crop production into two categories a) four or more, and b) three or less. The threshold salinity curves were developed for the experiments having four or more level of irrigation water salinity and relative yield were worked out. The threshold salinity of wheat at Bikaner, Rajasthan under drip irrigation method is 7.3 dS m^{-1} and the salinity level at which yield is reduced by 50% is 14.5 dS m^{-1} (Fig. 18). This threshold salinity and salinity at 50% relative yield under drip irrigation was higher than the surface irrigation. The comparative study of wheat under surface and drip irrigation methods showed that wheat tolerated higher level of irrigation water salinity under drip irrigation. The results showed that the crops responded differentially to varying levels of irrigation water salinity under different irrigation methods. Likewise, the salinity for 90, 75 and 50% relative yield for rest of the experiments were also worked out. These results are helpful in deciding the different water salinity for optimizing crop production using micro-irrigation methods. It can be further used for the development of guidelines for use of poor quality groundwater for irrigation using micro

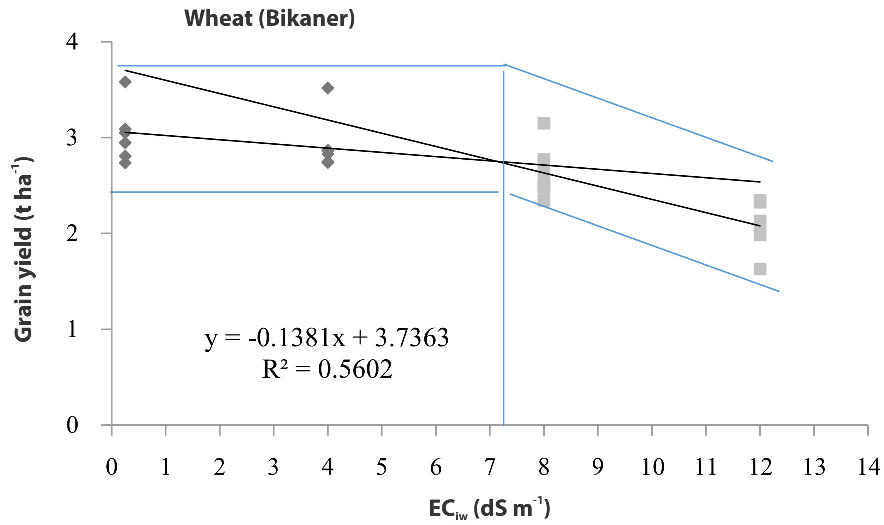


Fig. 18: The relative yield of wheat.

irrigation methods. These guidelines will be crop specific and can be used in specific climatic region.

Performance assessment of subsurface drainage technology in saline vertisols of Maharashtra (Raju, R., Sagar D. Vibhute, D.S. Bundela and Anil Kumar)

In Maharashtra, about 1.84 lakh ha cultivable land is degraded by soil salinity, affecting the food and income security of farmers. Sub-surface drainage (SSD) maintains the productive capacity of soil by removing the excess water and salts from soil, improving the air circulation and bringing salt content within permissible limit. The first large scale implementation of SSD system was initiated in the state in 2003-04 and reclaimed about 2,165 ha area in Dudhgaon and Kasabe Digraj villages of Sangli district under Reclaim-I and II Projects, which were funded by Department of Land Resources, Ministry of Rural Development, Govt. of India. Keeping in view the expanse of waterlogging and soil salinity and more demand from the affected farmers, it was decided by the Govt. of Maharashtra to take up SSD project (Reclaim-III) under Rashtriya Krishi VikasYojana (RKVY) to reclaim about 900 ha in four villages (Borgaon, UrunIslampur, Kasegaon and Sakharale) in Sangli District 2010-11 onwards. As a result of encouraging performance of SSD systems in reclaiming waterlogged saline soils in the region, individual farmers initiated installing the technology by making their own investment. As per CSSRI recommendation, lateral spacing of SSD in waterlogged and saline vertisols is of 30 m, whereas majority of the farmers in the region were installing the technology at 20m and currently at 15m lateral spacing. Drain spacing is mainly affected by soil texture; heavy textured soils (vertisols) requires less spacing and light textured soils requires larger spacing. The spacing has inverse relationship with the cost of SSD installation. Drain spacing of 20 m in heavy textured soils is also suggested as feasible under a condition when additional cost over 30 m drain spacing is recovered from additional crop yields in the first three years (CSSRI). Keeping this in view, the current study has been undertaken to compare the performance of SSD systems installed in different spacings in

Table 13: Soil properties of different SSD villages of Maharashtra (as on June 2019)

Villages	Year of SSD installation	SSD Spacing	EC_e ($dS\ m^{-1}$)	pH_s
Shedshal	2017-18	15 m	17.88	7.6
Shirati	2018-19	15 m	22.99	7.3
Kagwad	2019-20	15 m	73.00	7.6
Bubnal	2005-06	30 m	4.25	7.5

waterlogged and saline vertisols of Maharashtra.

In recent years, sugar factories are playing a major role in reclamation of waterlogged saline vertisols by funding and installation of SSD in Maharashtra. Three sugar factories have undertaken SSD installation in about 15 villages covering an area of 1148 ha.

Status of soil and water in SSD villages

Soil sample analysis of SSD villages revealed that very high EC in majority villages where land was barren for many years and SSD was installed recently. The EC of village Bubnal was very less as due to the improvement of soil quality where SSD is working since more than a decade which led to land improvement (Table 13). Water sample analysis revealed that higher EC in main outlet of village Shirati as compared to the samples collected from chambers located in farmers field in village Shedshalwhich revealed lower EC.

Features of SSD Projects in Maharashtra

The first large scale implementation of SSD system in Maharashtra was initiated with 30 m lateral spacingsduring 2003-04 and reclaimed about 2,165 ha area in Dudhgaon and Kasabe Digraj villages of Sangli district under Reclaim-I and II Projects funded by the Govt. of India. Similarly, Reclaim-III project under Rashtriya Krishi Vikas Yojana (RKVY) was also implemented with 30 m lateral spacings and reclaimed about 900 ha in four villages (Borgaon, Urun Islampur, Kasegaon and Sakharale) in Sangli District of Maharashtra in 2010-11 onwards. Whereas, SSD installed under farmers own investment involves higher cost mainly due to the installation of main drain to the longer distance to carryout the drain water from the individual farmers field to the open main drains. Though the costs were not comparable across the later spacings as SSD were installed in different years, but the costs are higher as compared to SSD installed under Govt. schemes. The average cost of SSD with 15 m lateral spacings were Rs. 2.43 lakh per hectare. The higher cost of SSD is mainly attributed to lesser spacing of laterals (15 m), open chambers with a provision of control valves for every farmers field (each chamber covers 1-2 ha area) and closed main drains.

Economics of SSD across different spacings in Maharashtra

The study revealed that higher sugarcane yield with lesser lateral spacings of SSD pipes (Table 14). Economic estimation also indicated the higher net returns in 15 m spacings and net returns decreases with increasing lateral spacing. Input-output ratio was also showed similar trend. Increasing yield in 15 m spacings of lateral SSD pipes leads to the reduction in cost of production of sugarcane crop by Rs. 304 and Rs. 346 as compared to 20 m and 30 m spacings, respectively in the study region. Overall the study indicated the lesser spacing of laterals has economic advantage as compared to the laterals with higher spacings.

Table 14: Economics of sugarcane cultivation across the lateral spacing in SSD project area

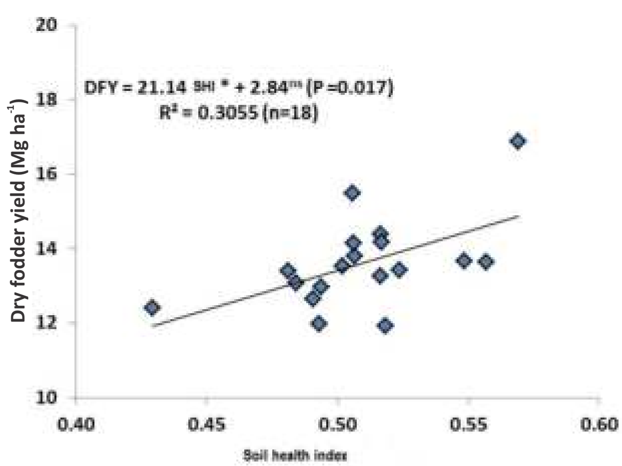
Particulars	Spacing of SSD lateral pipes			Additional Advantage of 15 m SSD spacing over	
	15 m (n=21)	20 m (n=3)	30 m (n=1)	20 m	30 m
Yield (t ha^{-1})	127.50	108.33	102.50	19.17	25.00
Gross Returns (Rs. ha^{-1})	384253	333141	305076	51112	79177
Cost of cultivation (Rs.ha^{-1})	285365	275420	264829	9946	20536
Net Returns (Rs. ha^{-1})	98888	57722	40246	41166	58642
Cost of production (Rs t^{-1})	2238	2542	2584	-304	-346
Input-Output Ratio	1.35	1.21	1.15	0.14	0.19
Employment generated (Man days/ha $annum^{-1}$)	212	207	203	5.64	9.76
Wage earnings from farm employment (Rs./ha $annum^{-1}$)	53074	51664	50635	1410	2439

A total of 3065 ha salinity affected area has been reclaimed with SSD *(30 m spacing) in* Sangli district under Reclaim-I, II & III Projects, which were funded by GOI. Majority farmers in the study area belongs to small and marginal category with land holding size of 1 to 2 ha and about 60-80% are depends on agriculture for their livelihood. Sugar factories in Kolhapur district playing a pivotal role in funding and implementation of SSD in the study area. About 1148 ha area has been undertaken for SSD implementation through private funding by farmers. *All new SSD projects in Maharashtra are planned with 15 m lateral spacing,closed main drain and control valve in each farmers field.*

Management of Marginal Quality Water

Conjunctive water use strategies with conservation tillage and mulching for improving productivity of saline soils under high SAR saline water irrigation (Arvind Kumar Rai, Nirmalendu Basak, Satyendra Kumar, Bhaskar Narjary and Gajender Yadav)

Soil and irrigation water salinity deleteriously affect crop performance and degrade soil health (SH) in semi-arid ecosystems. A field experiment was conducted in highly salt affected soils of ICAR-CSSRI research farm located at Nain village (Panipat), India to evaluate the impact of tillage, deficit saline irrigation and rice straw mulch application on soil chemical and biological properties and its interrelation with sorghum and wheat productivity. Zero -reduced tillage (ZT-RT), conventional -conventional tillage (CT-CT) and zero-zero tillage (ZT-ZT) were taken as main plots and saline irrigation (EC_{iw} 8 dS m^{-1}) with 100, 80 and 60 per cent of water requirement (WR) and rice straw mulch (0 and 5 t ha^{-1}) as subplots. Results revealed that surface soil salinity (EC_e) was more after wheat (8.87 and 6.41 dS m^{-1}) compared to sorghum (5.48 and 3.59 dS m^{-1}) in both consecutive years. Soil microbial biomass C, N (MBC, N), activities of dehydrogenase (DHA), urease (URE), and alkaline phosphatase (AlP) decreased with increment of EC_e. Irrigation with 60 per cent WR maintained higher values of MBC and MBN compared to 100WR. High MBN activity was recorded in zero tillage than conventional tillage. Soil health index (SHI) was developed using key soil properties. Soil enzyme *α*-glu, MBC, EC_e, available N, MBC, MBC:MBN were identified as significant contributor towards SHI after sorghum harvest. Whereas, SHI developed with MBC: MBN, EC_e, MBC, URE, and available N was ineffective in addressing variability in wheat grain yield because of the better adaptation of salt-tolerant wheat cultivars (KRL-210) in salt-affected soils (Fig.19). Saline irrigation at 60 per cent WR showed higher values of SHI than 100 per cent WR. Largely, cultural practices improved the SH and zero tillage maintained SHI more than the conventional tillage.



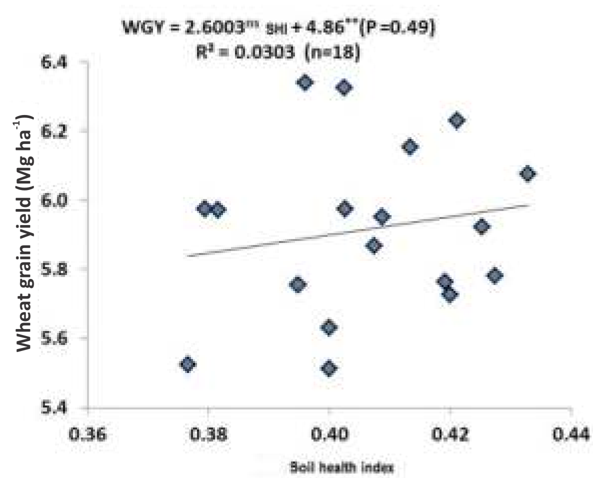


Fig. 19. Relationship between SHI and sorghum dry fodder yield and wheat grain yield.

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

Plant-microbe interactions play a major role in the existence and survival of both under stressed conditions. Presence of high concentration of salts in soil leads to the inhibition of many metabolic processes, enzymatic activities and photosynthesis which results in the reduction of crop growth and yield. Some bacteria have ability to promote growth of plants by direct and/or indirect mechanisms. These were isolated from saline soils and screened for plant growth promoting activities.After two pot experiments on wheat and okra, four types of consortia were used to see their effect on tomato plant growth. Freshly grown isolates were mixed as per different combinations and root of tomato plants were dipped in the microbial consortia for ten minutes. Pusa Early Dwarf (PED) variety of tomato was used in the pot experiment. Treated plants were sown in pots having different levels of soil salinity (EC_e: 2, 4, 6, and 8 dS m^{-1}). One doses of inoculated formulation were also applied in the each pot. Plant growth was observed after every one month. It was observed that the plants treated with only nutrient broth died at all salinity levels probably due to attack of other native soil microbes. Different plant parameters like plant height, yield $plant^{-1}$, and number of fruit $plant^{-1}$ were observed.

In comparison to control, higher first yield was observed in treated plants. Effect of microbial treatment was also observed for fruit number per plant (Table 15). In normal soils, it was 14.27 fruit $plant^{-1}$ and in treated plants it was 18.20, 18.27 and 18.13, respectively at EC_e 4,6 and 8 dS m^{-1}.

Treatment effect was also observed in mean values of fruit number is higher with microbial treatments. After harvesting, soil was analysed for chemical and biological properties. Significant differences were observed only for biological properties among different treatments. Higher bacterial count was observed in treated soil at all salinity levels. Dehydrogenase activity was also observed to be high in treated soils.

Effect of microbial treatments on growth of tomato plant under different levels of salinity EC_e 8 dS m^{-1}

Table 15: Effect of microbial consortia on fruit number/plant

Treatment/ EC level	C1	T1	T2	T3	T4	Mean
EC_e2	12.00Aab	13.33Aa	17.67Aa	12.67Aa	15.67Aa	14.27b
EC_e4	12.00Aab	18.33Aa	18.00Aa	20.00Aa	22.67Aa	18.20 a
EC_e6	15.33Aab	20.67Aa	16.00Aa	21.33Aa	18.00Aa	18.27 a
EC_e8	17.00Aa	18.67Aa	18.00Aa	17.33Aa	19.67Ab	18.13 a
Mean	**14.08B**	**17.75AB**	**17.42AB**	**17.83A**	**19.00A**	

Same upper (treatment wise)/lower case (salinity levels) letters are not significantly different at $P < 0.05$ according to LSD test for separation of mean

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

Zinc deficiency in soils has been identified as an important factor, responsible for reduction in yield and nutritional quality of crops. Worldwide occurrence of zinc deficiency in crops is due to the low solubility of zinc, rather than zinc content in the soil. In this context, the use of zinc solubilizing rhizospheric microorganism is an economical option to increase the availability of native zinc to crops. Therefore, the present study was initiated in 2017 for enhancing zinc solubility in soils utilizing zinc solubilising bacterial isolates. Total 20 isolates were selected on the basis of their morphological identification and zinc solubilization potential in broth. The screened isolates were further evaluated with high (DTPA extractable zinc 5.68 ppm) and low (DTPA extractable zinc 1.12 ppm) zinc soils for testing their zinc solubilization potential. A zinc sensitive rice cultivar (cv. Sita) was used as test crop. Seeds were treated with bacterial culture before sowing. In high DTPA-Zn soils, none of the bacterial isolates significantly affected zinc uptake and dry weight (Fig. 20) of rice. However, in low DTPA-Zn soils, one bacterial isolates (SCM-3) significantly enhanced zinc uptake compared with control and two bacterial isolates (SCM-9 & SCM-30) significantly enhanced dry weight (Fig. 21) of rice compared with control.

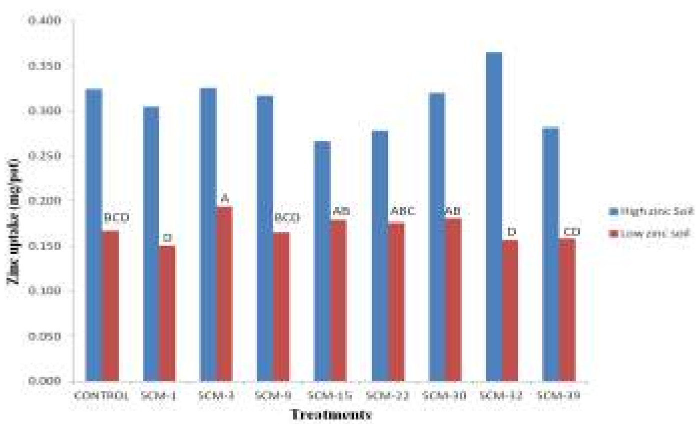


Fig. 20. Effect of different bacterial isolates on zinc uptake of rice

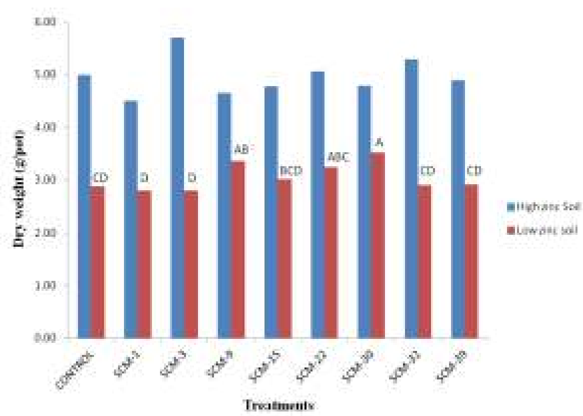
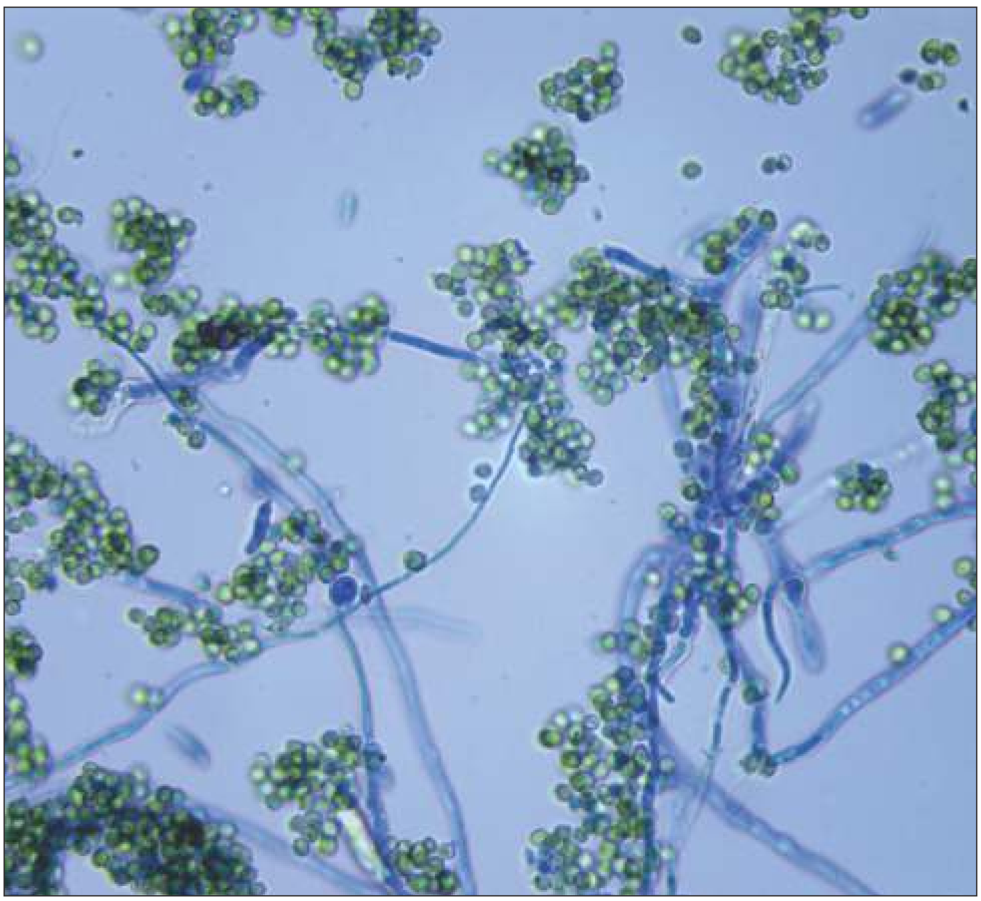


Fig. 21. Effect of different bacterial isolates on dry weight of rice

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

Plant growth-promoting microorganisms are symbiotically associated and reported increased salt tolerance in crops through mechanisms such as production of IAA, ACC deaminase, exo-polysaccaride, siderophore, phosphate solubilization, and nitrogen fixation. Several salt tolerant fungi were isolated and screened for P solubilization activity. Along with them, some salt tolerant *Trichoderma* spp. were also isolated on selective *Trichoderma* agar. A total number of 6 cultures (Tc1-Tc6) were obtained from selective *Trichoderma* agar which was further confirmed by spore arrangement under microscope. The *Trichoderma* cultures were grown on medium supplemented with different concentrations of NaCl (2-10%) to check their salt tolerance. Trichodema showed variation in the salt tolerance. The Tc3 culture showed tolerance upto 6% of NaCl. The culture will be used further for the development of the consortium with mycorrhiza and will be tested further for its efficacy under salt stress conditions.

An experiment was carried out in normal, saline (EC_e~8 ds m^{-1}) and sodic soil (pH_2~ 9.0) with treatments (T1: Control; T2: Normal soil +Mycorrhiza; T3: Saline soil (EC_e ~ 8 dS m^{-1}); T4: Saline soil + Mycorrhiza; T5: Sodic soil (pH_2~ 9.0) ; T6: Sodic soil + mycorrhiza) on sorghum crops. Improved plant growth was observed in Mycorrhiza inoculated plants. The results also demonstrated improved P-uptake in Mycorrhiza inoculated plants as compared to the non-inoculated ones. The effect was highest in normal soil followed by sodic and least in saline soil (Table 16).



Microscopic view of *Trichoderma* culture

Table 16. Effect of vesicular-arbuscular mycorrhizal (vam) fungi on sorghum crop

Treatment	Plant height (cm)	Fresh weight (g)	Dry weight (g)	P-conc.(%)	P-uptake(mg pot^{-1})
T1	113.00^{C}	14.90^{D}	3.27^{BC}	0.07^{D}	2.36^{B}
T2	138.67^{A}	32.20^{A}	4.70^{A}	0.09^{CD}	4.28^{B}
T3	75.33^{D}	10.53^{D}	2.53^{C}	0.13^{B}	3.42^{B}
T4	125.10^{B}	30.00^{AB}	3.96^{AB}	0.18^{A}	7.33^{A}
T5	79.67^{D}	20.27^{C}	2.62^{C}	0.11^{BC}	2.90^{B}
T6	131.33^{AB}	26.67^{B}	4.37^{A}	0.19^{A}	8.39^{A}
Significance	**	**	**	**	**

** - Significant at 1%; * - Significant at 5%; NS - Non Significant

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

Combinations of hydrological cycles, groundwater processes and irrigation practices induce soil salinization. The progress of sub-surface drainage technology, recommended for controlling salinization, is constrained by requirement of heavy machinery involving high cost and community approach. Cut-soiler is a machine that cuts and opens V-shape furrow and fills it back with scattered straw and residue lying on soil surface at bottom and soil. Cut-Soiler technology has been found effective in the management of waterlogged saline rice fields of Japan and also tested in other parts of world. In this back ground, JIRCAS-CSSRI collaborative research project is being undertaken with focus on effectiveness of such low cost sub-surface drainage in conjunction with efficient irrigation management in saline conditions. The study is continued at three locations, simultaneously. The effect of cut-soiler operation on salt and water dynamics under shallow saline fluctuating water table along with an irrigation experiment are carried outin controlled condition lysimeters at ICAR- CSSRI, Karnal. The field experiment on optimum spacing of cut-soilerconstruction line by a material-filled subsurface drain machine (cut-soiler) in salinized fields of semi-arid conditions is in progress at Nain Experimental Farm of ICAR-CSSRI at Panipat, Haryana. The feasibility trial on effectiveness of cut-soiler for sub-surface soil sodicity management was initiated at village Budhmor (Patiala) Punjab.

Optimum spacing of construction line by a material-filled subsurface drain machine (Cut-soiler) in salinized fields of semi-arid zone:Nain Farm Experiment

Effect of cut-soiler construction line spacing and irrigation methods, i.e. every furrow irrigation (EFI), skip furrow irrigation (SFI) and border irrigation, are evaluated on soil salinity and moisture. To achieve objective, "development of low-cost subsurface drainage and irrigation technology in salt-affected fields for sustainable agricultural production", soil water and salinity is regularly monitored using GS3 sensors. The sensors, installed at six depths and lateral regular intervals of 1/8, 1/4 and ½ distance between cut-soiler construction lines, record horizontal and vertical water and salt movement after rainfall and irrigation in field conditions.

The weather conditions, recorded with HOBO weather stationinstalled at Nain farm, showed relatively lesser precipitation from October to December in 2019 compared to last year. Groundwater table (monitored by HOBO water level logger) remained deeper from October to May, 2019 and then moved upward from August onwards- 3.0 m. 5.

Horizontal and vertical GS3 soil water and salinity sensors at Nain Farm, Panipat

Observation of soil water and EC around cut-soiler was recorded by GS3 soil moisture and salinity sensors in each plot. Groundwater EC went down after about fluctuations during the rainy season. Samples were collected and analyzed for EC, pH, soil moisture, Carbonates and bicarbonates. The EC ranged 3.04 to 12.28 dS m^{-1} and pH varies from 7.58 to 8.34. Pearl- millet crop response to various treatments was determined.

Effect of cut-soiler on salt and water dynamics under fluctuating water table: CSSRI lysimeter

Regular recording of volumetric water content VWCs, EC and temperature was done by 5TE (VWC, EC, temperature) sensors installed at 10, 50 and 80 cm depths in and outside the cut-soiler lines and analyzed. The values of surface VWCs increased after irrigation and rainfall event, then gradually decreased. The peak values of surface soil EC were compared after irrigations (Fig. 22). There are big differences between by with cut-soiler (in-12 cm) and by without cut-soiler (out-12 cm). Soil samples were collected and analyzed for soil moisture, EC, pH. The soil EC_2 and pH ranged from 0.28 to 2.64 dSm^{-1} and 7.29 to 8.37, respectively and soil moisture varied from 10.8 to 17.3%. Pearl millet crop response to various treatments was also determined.

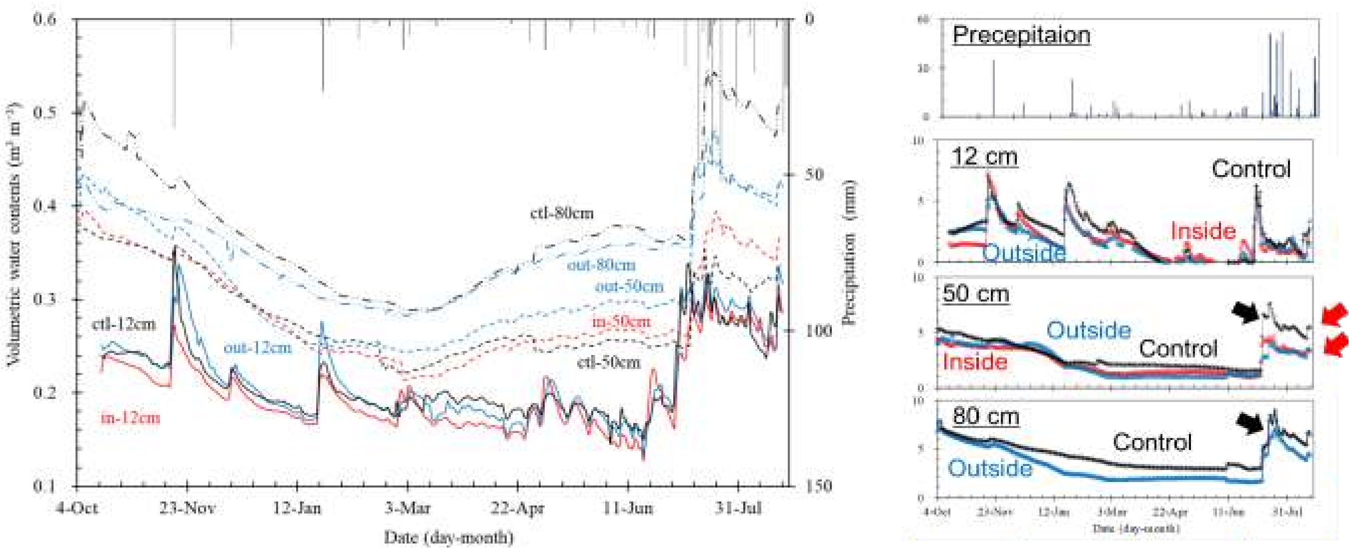


Fig. 22: Changes in soil moisture (VWCs) in cut soiler and without cut soilerlysimeters monitored by 5TE sensors.

Irrigation experiment lysimeter: CSSRI, Karnal

Salt and water dynamics of four irrigation methods i.e. border irrigation (conventional), EFI, FSFI and FSFI+ dehydration (black and white) was monitored by 5TE sensors installed at 15, 25, 35, 50, 70 cm depths from the center of ridge and/or 25, 35 cm depths under furrow. In border irrigation, the VWC of 5 cm was increased in response to rainfall and irrigation. VWC of 35 to 70 cm settled down at around 20%. Soil moisture is mainly consumed in soil layers up to 15 cm depth. ECa of 5 cm increased in response to irrigation. ECa of 5 cm was lower than other depths. 3. InEFI, the VWC of 5 cm was increased in response to rainfall and irrigation. VWC of 50 to 70 cm settled down at around 30%. Soil moisture is mainly consumed in soil layers up to 15 cm depth. ECa of 5 cm was increased in response to irrigation. ECa of 70 cm was high compared to other depths. ECa of 5 to 50 cm was under 1.0 dS m^{-1}. In FSFI, the VWC of 5 cm increased in response to rainfall and irrigation. VWC of 25 to 70 cm settled down at around 30%. Soil moisture is mainly consumed in soil layers up to 15 cm depth. Between Border, EFI and FSFI, there were no large differences. ECa of 5 cm was increased in response to irrigation. First, ECa of 25 and 35 cm is high, but decreased up to around 1.0 dS m^{-1} and remained almost stable.

Feasibly trial of cut-soiler in managing sub-surface sodicity at Budhmor, Patiala, (Punjab)

A representative heavy soil site was selected for feasibility study with a drainage channel sideby (Fig. 23). The cut soiler was run at 2.5, 5.0 and 10.0 m spacing with straw as surface residue, gypsum and straw+ gypsum and being monitored for spatio-temporal changes in soil ESP, BD, hydraulic conductivity and rice-wheat yield.

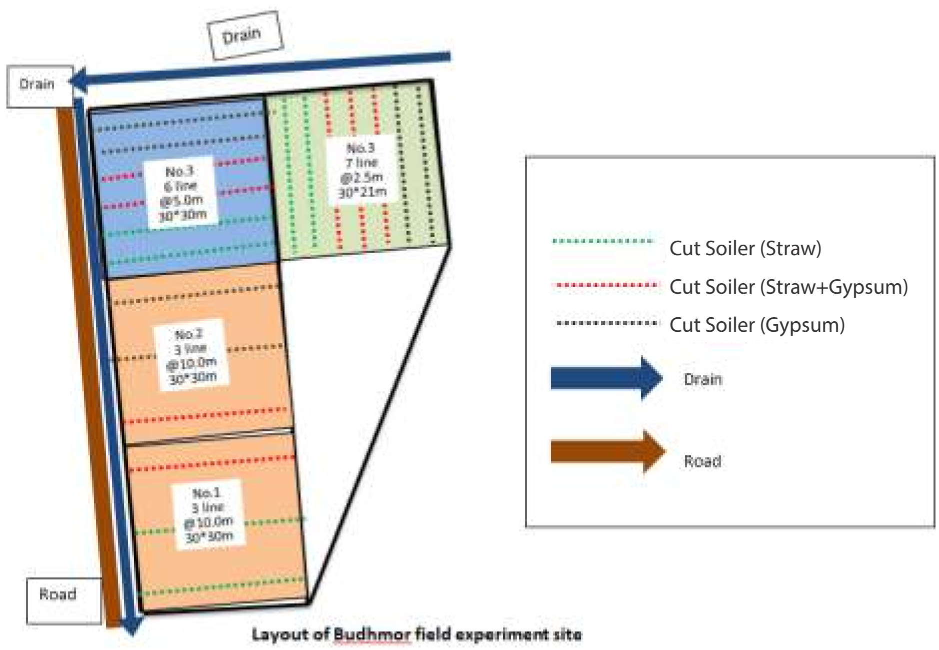


Fig. 23. Layout of feasibility trail at village Budhmor, Patiala, Punjab under ICAR-JIRCAS project.

Crop Improvement for Salinity, Alkalinity and Waterlogged Stresses

Development of salt tolerant genotypes in rice – conventional and molecular breeding approaches (S. L. Krishnamurthy, P.C. Sharma, Y.P. Singh, S.K. Sarangi, and B.M. Lokeshkumar)

This project aims at the development, evaluation and dissemination of improved salt tolerant rice genotypes. To achieve the objectives, following trials were conducted and the breeding material was advanced during *Kharif* 2019.

A. National trail

a) IVT-Alkaline and Inland Saline Tolerant Variety Trial-2019

The IVT-Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL&ISTVT) comprised of 24 entries including five check varieties (CSR 36, CSR 23, CSR 10, Pusa 44 and FL-478) which were evaluated across four salt stress locations in Random Block Design with three replications. The GGE analysis was carried out using 24 IVT rice genotypes for yield across four salt stress locations. Five entries namely 3501, 3509, 3513, 3520 and 3523 performed very well both under saline and sodic conditions over saline check CSR 27 and sodic check CSR 36. The entry 3523 performed better under saline microplot with an yield of 3.93 t ha^{-1}, whereas entry 3520 performed very well under saline field condition, sodic field and microplot condition with an yield of 4 t ha^{-1}, 3.60 t ha^{-1} and 3.82 t ha^{-1} respectively.

b) AVT-Alkaline and Inland Saline Tolerant Variety Trial-2019

The AVT-Alkaline and Inland Saline Tolerant Variety Trial (AVT-AL&ISTVT) comprising of 11 entries including check variety (CSR 36, CSR 23, CSR 10, Pusa 44 and FL-478) were tested across four salt stress locations in Random Block Design with three replications. The two entries namely 3402 and 3405 were performed very well under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36. The entry 3402 performing better under saline microplot with an yield of 4.3 t ha^{-1}, whereas entry 3405 perform very well under saline field condition, sodic field and microplot condition with an yield of 3.7 t ha^{-1}, 3.6 t ha^{-1} and 3.7 t ha^{-1} respectively.

b) IVT and AVT Basmati Varietal Trial-2019

The IVT-BT trail comprising of 24 entries including check variety (Pusa basmati 1, Taroari Basmati, Pusa Basmati 1121 and Local check) were tested in Random Block Design with three replications in CSSRI Karnal. All the entries performed well over the check CSR 30 except 1914, 1917, 1921 and 1922. The three entries namely 1901, 1908 and 1912 were top performing entries with an yield of 6.1 t ha^{-1}, 6.0 t ha^{-1} and 6.0 t ha^{-1} respectively. Similarly The AVT-BT trail comprising of 28 entries including check variety (Pusa basmati 1, Taroari Basmati, Pusa Basmati 1121 and Local check) were tested in Random Block Design with three replications in CSSRI Karnal. All the entries performed well over the check CSR 30 except 1805, 1814 and 1826. The three entries namely 1802, 1807 and 1806 were top performing entries with an yield of 6.0 t ha^{-1}, 5.9 t ha^{-1} and 5.9 t ha^{-1} respectively.

B. Station Trials

Monitoring, maintenance and development of breeding materials

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

Evaluation of basmati rice genotypes

The main aim was to develop or improve the Basmati CSR 30. Hence, we developed the BC_1F_6 lines by crossing the Basmati CSR30 and FL 478. We have identified 198 lines with basmati back ground and salt tolerance on the basis of plant duration, plant height and grain yield

A total of 200 genotypes including 198 selected BILs along and parents were phenotyped in augmented block design with parents under 2 environments {normal (field) and moderate salinity (EC_{iw} ~ 8.0 dS m^{-1}) micro plots} during *Kharif* 2019.

The grain yield range 111 kg ha^{-1} (CSR30/FL478-198-S12) to 5.800 t ha^{-1} (CSR30/FL478-198-S1) with mean 1.96 t ha^{-1} under normal, whereas, the range was 1053 (CSR30/FL478-198-S1) to 2440 (CSR30/FL478-198-S112) with mean 1.39 t ha^{-1} under saline stress condition. The highest grain yield was 5.80 t ha^{-1} and 2.44 t ha^{-1} under normal and saline stress respectively. CSR30/FL478-198-S112 genotypes performed better over CSR 30 with plant height 114cm, plant duration 142 days and grain yield 5.52 t ha^{-1} followed by CSR30/FL478-198-S193 (5.38 t ha^{-1}), CSR30/FL478-198-S172 (5.1.67 t ha^{-1}), CSR30 /FL478-198-S159 (5.12 t ha^{-1}) and CSR30/FL478-198-S62 (4.09 t ha^{-1}) under normal stress and saline as well .

Evaluation of basmati lines from different background

A total of 208 genotypes of different basmati background were evaluated in normal fields at CSSRI Karnal. Genotypes CSR YET-75 shows highest grain yield 7.09 (t ha^{-1}) with plant height 126.5 and plant duration 118 days over the other genotypes. The grain yield ranged from 782 (PS3/CSR30-94) to 7090 (YET-75) with mean 4384. The top five high grain yield performing genotypes are YET-75 (7.09 t ha^{-1}), PET-6 (7.05 t ha^{-1}), CSR89IR15/PB1-55 (7.00 t ha^{-1}), PET -7 (7.00 t ha^{-1}) and TRICHY/PB1-102 (6.85 t ha^{-1}).

Evaluation of rice genotypes under DSR

A total of 82 rice genotypes were evaluated in RCBD experimental design with 4 replications. These genotypes mainly evaluated for direct seeded rice, these genotypes were mechanically sown using Happy-Seeder with row spacing of 22.5 of nine rows. Each variety consists of 7.875 m^2 plot area. The average yield range observed was 883 to 5.72 t ha^{-1} . The genotypes CSR YET 7, CSR PET 6 and CSR PET 26 were top performing genotypes with a yield of 5.72 t ha^{-1}, 5.32 t ha^{-1} and 5.16 t ha^{-1} respectively.

Breeder seed production

Breeder seed of the salt tolerant rice varieties i.e., CSR 10 (1.0 Q), CSR 13 (1.0 Q), CSR 23 (1.0 Q), CSR 27 (1.0 Q), CSR 30 (15.0 Q) CSR36 (10.0 Q), CSR 43 (20.0 Q), CSR 46 (5.0 Q), CSR49 (5.0Q), CSR52 (5.0Q), CSR56 (5.0Q), CSR60(5.0Q), was produced to meet the demand of seed producing agencies as per DAC (Department of Agriculture and Cooperation) during 2019.

Rice entries nominated to AICRP 2019

1. **NILs trail** :- CSR187-11-241 (PUSA44+*saltol*), CSR187-11-229 (PUSA44+*saltol*), CSR187-11-252 (PUSA44+*saltol*), CSR189-11-123 (Sarjoo52+*saltol*)
2. **CSTVT**:- CSR 2013-IR 42-22, CSR62, CSR63 and CSRM1-27
3. **Medium slender Trail:** - CSR27SM66, CSR27SM160, CSR27SM59, CSR27SM117, CSR27SM132 and CSR27SM161
4. **AL&ISTVT trail :-** CSR449S-13,CSRM1-7, CSR-RIL-06-178, CSRM1-45 and CSR89-IR 15
5. **Bio fortification trail :-** CSR HZR 17-1, CSR HZR 17-4, CSR HZR 17-8 and CSR HZR 17-41
6. **Basmati trail :- CSR 179-11-23S, CSR 179-11-66S, CSR 162-11-917, CPB-100-50 and TBP-100- 82**

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

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

Genotyping of BILs using 50K SNP chip

A total of 50051 SNP markers are used to genotype the parents and backcross population. 9119 polymorphic markers were identified between the parents. Further processing of these polymorphic markers for removal of duplicate markers gave 4034 SNPs. Segregation distortion or $\chi 2$ filtrations lead to further reduction in the number from 4034 to the 2703 markers. Markers not genotyped in more than ten individuals removed and ultimately the genotypic data came down to 1136 markers. Finally 1136 SNP polymorphic data was used for further construction of linkage map

QTL for salinity tolerance at reproductive stage were calculated in terms of plant growth and yield related trait. Yield related traits were; days to 50% flowering, plant height, panicle length, total productive tiller number per plant and yield per plant were recorded under salinity stress and QTL for these traits were mapped. In total 6 QTL were mapped for yield related traits under salinity, out of which two QTLs were for days to 50% flowering and mapped on chromosome 2 & 4 named as qDF2.1 & qDF4.1 with positions 181.51 & 55.58CM. A single QTL was mapped for plant height and named as *qPH8.1* on the chromosome 8 with position 102.86CM. A QTL for panicle length was mapped as *qPL11.1* on chromosome 11 with position 44.61CM. Similarly, total productive tiller number per plant were mapped as QTL name ***qTN2.1*** on chromosome 2 with position 33.71 and QTL for yield per plant were mapped to chromosome number 11 with position 44.61CM and named as *qYP11.1*. The phenotypic variance for all these QTL was shown by R^2 value that was found highly significant.

Phenotyping of fine mapping population (CSR 89IR15/PB1)

A total of 196 genotypes including RILs along with two parents(CSR89 IR15/PB1) were evaluated in replicated Simple Lattice Design in 3 environments {normal, moderate sodic (pH_2 ~ 9.5) and high sodic (pH_2 ~ 9.9) soil conditions} during *Kharif* 2019.

The range, mean and percent reduction of different traits for RIL population were recorded during 2018. High mean grain yield and other related traits performance was noticed under normal soil as compared to moderate sodic and high sodic stresses. The grain yield was the most sensitive traits and reduced by 42.83% followed by plant height, productive tiller per plant, panicle length and total tillers per plant under moderate sodicity stress. The grain yield was reduced by 59.36% under high sodicity stress followed by productive tiller per plant, plant height, total tillers per plant, and panicle length. The grain yield was ranged from 2 (RIL 32) to 30 (RIL148), 0.20 (RIL 183) to 26(RIL 126) and 0.1(RIL 116) to 8 (RIL 121) under normal modarate sodic (pH_2 ~ 9.5) and high sodic (pH_2 ~ 9.9), respectively.

CRP on agrobiodiversity - evaluation of rice germplasm for salinity/sodicity – ICAR funded (S.L. Krishnamurthy and P.C. Sharma)

The present experiment was carried out with a total 924 genotypes including two checks (IR 29- sensitive check and FL478- tolerant check) were phenotyped for seedling stage salinity tolerance in 2019. Out of these 924, five hundred twenty seven genotypes did not germinate. Screening for salt tolerance at seedling stage was performed in hydroponics using Yoshida culture solution, under controlled conditions in the CSSRI glasshouse. The nutrient solution was salinized (EC ~ 10 dS m^{-1}) on 14^{th} day after sowing by adding NaCl salt. Standard Evaluation Score (SES), root and shoot lengths root were measured on 28^{th}day after sowing.The mean, maximum and minimum values of the recorded traits during 2019 are presented in Table 17.

Shoot length and root length were reduced in salinized condition. Vigour score (SES) ranged from 3 to 9 under saline conditions. Nearly 10 genotypes were found tolerant (score-3), 16 genotypes were moderately tolerant (score-5), 56 were moderately sensitive (score-7) and 315 genotypes were highly sensitive (score-9). Root length ranged from 1 cm to 14.33 cm with a mean of 4.25 cm. The range of shot length is from 5 cm to 34.33 cm with a mean of 19.10.

Table 17: Summary statistics for root length and shoot length recorded on 924 rice genotypes

Parameter	Vigour score	Root length	Shoot length
Mean	7.0	4.25	19.10
Maximum	9.0	14.33	34.33
Minimum	3.0	1	5

From QTL to variety: Marker assisted breeding of abiotic stress tolerant rice varieties with major qtls for drought, submergence and salt tolerance (DBT Funded) (S.L. Krishnamurthy and P.C. Sharma)

The project is aimed to transfer of major quantitative trait loci (QTL) for salinity tolerance into high yielding varieties of rice by using molecular marker-assisted backcross breeding. The donor parent (CSR27) crossed with the recipient parents (Sarjoo 52, PR 114, PUSA 44) to transfer the salinity tolerance QTL for reproductive stage.

Introgression of the SSISFHS 8.1 QTL for salt-tolerance into popular Indian varieties

Recurrent parents (Pusa44, PR114 and Sarjoo52) were identified based on the higher yield and popularity in the specific region of the country and donor parent (CSR27) was selected to transfer the *SSISFHS*8.1 QTLs.

Development of BC_1F_1 progenies

The true F1 were selected and used for développement of BC_1F_1 in all three cross combinations namely, Pusa44 / CSR27, PR114 / CSR27and Sarjoo 52 / CSR27. Selected the BC_1F_1 seeds were harvested and stored at refrigerated condition.

Development of BC_2F_1 progenies

We used the foreground markers namley, RM3395 and HvSSR 8-25 for selection in of BC_1F_1 progenies and produced of BC_2F_1 progenies. The experiment was conducted in fields at CSSRI Karnal to produce BC_2F_1 population. BC_1F_1s will be used as male parent and recipient parent used as female in cross. Recipient parents (Pusa44, PR114 and Sarjoo 52) were sown and transplanted in five staggered dates to synchronize the flowering with the BC_1F_1 population. Thirty days old seedlings of parents were transplanted with 20 x 15 cm spacing in 8m row in field. Two rows of each parent were transplanted and practiced the recommended package for the healthy crop in the crossing block. A total of 423,371 and 277 seeds were obtained from Pusa44 X CSR27, PR114 X CSR27and Sarjoo 52 X CSR27, respectively.

Identification of traits, genes, physiological mechanisms to development of climate smart varieties for unfavourable environment (IRRI funded) (S.L. Krishnamurthy and P.C. Sharma)

Under unfavourable environments, frequent occurrence of drought, salinity, flood causes high yield losses. Low fertilizer use by resource poor farmers is another cause for lower yield. In recent years, labor and water shortages have emerged as new concerns for sustainable rice production. Rice typically exhibits high yield loss through incomplete grain filling under drought. Salt tolerance of rice should be an essential trait in coastal and inland crop production areas marred with high salt concentration in the soil and water. Improved resource efficient rice varieties by the resource poor farmers in the rainfed lowlands who cannot afford relatively higher doses of fertilizers for the present day modern varieties to provide required grain yields could increase productivity of rainfed system. New traits, pre-breeding lines and varieties are needed for mechanized dry direct seeded rice (DSR) for water-labor short regions of India as well as better rice varieties combining traits required for boro season rice- tolerance to low temperature at seedling stage and high temperature at reproductive stage are in demand. The project shall undertake joint studies between CSSRI India and IRRI, Philippines to identify QTLs/genes for resource remobilization under tolerance to reproductive stagesalinity. Understand the physiological mechanisms associated with different identified genes and develop rice varieties for tolerance to reproductive stage salinity following marker assisted breeding of traits /QTLs/genes identified and Capacity building of breeders.

Seed multiplication of mapping population

We imported the two BC_1F_1 mapping population namely IRRI154/Cheriviruppu and IRRI154/Pokkali during 2018 and advanced to BC_1F_2 the generation in 2019.

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

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

Phenotyping of mapping population (CSR 20/VSR 156) for salinity tolerance

The salient findings of the systematic phenotyping of 176 recombinant inbred lines (RILs) derived from CSR 20 x VSR 156 cross are presented, 178 genotypes including 176 RILs along with two parents were evaluated in RCBD in 2 environments {normal and moderate saline (EC~ 6) during *Kharif* 2019.

The range, mean and percent reduction of different traits for RIL population were recorded during 2019. High mean grain yield and other related traits performance was noticed under normal soil as compared to moderate salinity stresses. The grain yield ranged from 10.40 (RIL 90) to 24.7 (RIL 131) and 10.2 (RIL 176) to 16.6 (RIL117) under normal and moderate salinity, respectively. The plant height ranged from 69 (RIL23) to 124 (RIL 1) and 106 (RIL 151) to 147 (RIL82) under normal and moderate saline respectively.

Development of high zinc rice varieties (S.L. Krishnamurthy and P.C. Sharma)

The experimental material comprised of 50 rice genotypes. The genotypes were evaluated in randomized block design with two replications under one environments *viz.*, {normal (pH ~ 7.5) in field at Central Soil Salinity Research Institute, Karnal, Haryana, India during *Kharif* 2019. The data was recorded for yield and its contributing traits.

The range and mean of different traits for rice genotypes were recorded during 2019 (Table 18). Under normal condition, days to 50% flowering varied from 89 (IR 95044:8-B-5-22-19-GBS)-137 (DRRDhan-45), plant height (cm) varied from 85 (IR15M1328) to 135 (IR15M1054) with a mean of 107.30, panicle length (cm) ranged from 20 (DRRDhan-45) to 32 (IR15M1322) with a mean of 26.31 , total tillers varied from 10.5 (IR14M124) to 44 (IR15M1337) with a mean of 16.97, productive tillers ranged 8 (IR14M124) to 40 (IR15M1337) between with a mean of 14.22, and the grain yield varied between 362 kg ha^{-1} (DRRDhan-45) to 6.96 t ha^{-1} (IR15M1293) with a mean of 5.05 t ha^{-1}. Three genotypes did not reach flowering stage and grain yield was not obtained.

Table 18: Mean and range for different traits of rice genotypes under normal.

Traits	Mean	Range
Days to 50% flowering	99.11	89(IR 95044:8-B-5-22-19-GBS)-137 (DRRDhan-45)
Plant Height (cm)	107.30	85(IR15M1328)-135(IR15M1054)
Panicle length (cm)	26.31	20 (DRRDhan-45)-32(IR15M1322)
Total tillers plant^{-1}	16.97	10.5(IR14M124)-44(IR15M1337)
Productive tillers Plant^{-1}	14.22	8(IR14M124)-40(IR15M1337)
Grain yield per plant (t ha^{-1})	5.05	362(DRRDhan-45)-6963(IR15M1293)

Wheat improvement for salt and waterlogging tolerance through conventional and molecular approaches (Arvind Kumar, Ashwani Kumar, Y.P. Singh, and P.C. Sharma)

The project was taken up with the goal of Improvement/development of disease resistant high yielding salt and waterlogging tolerant lines. To achieve to goal following activities was done during 2018-2019 under the project.

During the year 2018-19 thirty promising wheat entries were sent for evaluation against rust diseases in Initial Plant Pathological Screening Nursery.Out of 30 entries only 6 entries were found resistant to all the three rust pathotypes. Because ACI score of all the six entries were less than acceptable standard (20.0). Out of six entries two entries already were present in salinity/alkalinity tolerance screening nursery (2018-19) but could not qualify for special trial-2019-20. However KRL 1803, KRL 1808and KRL 1810 were found superior from the best ruling check (HD 3086) in station trial, conducted under normal fertile soil and these entries has been promoted to National Initial Varietal Trial. KRL 1803 and KRL 1808 were promoted in NIVT-1B-IR-TS-TAS, 2019-20 however KRL 1810were promoted in NIVT-1A-IR-TS-TAS, 2019-20.

Contribution to Coordinated Trial (NIVT) and nursery (SATSN)

Two genotypes namely KRL 423 and KRL 429 were evaluatedunder NIVT 1B 2018-19 (Timely sown irrigated high fertility condition of NWPZ and NEPZ zones). NIVT 1B was conducted at 17 locations (Delhi, Ludhiana,Gurdaspur, Hisar, IIWBR-Karnal, Pantnagar, Durgapura, Kanpur, Faizabad, Varanasi, IARI-Pusa, Sabour, RPCAU-Pusa, Ranchi, Kalyani,Burdwan and Coochbehar) of NWPZ and NEPZ zones. Unfortunately out of 32 genotypes, no one genotype was promoted in AVT as they could not performed better than best check (HD 3086). Performance of KRL 423 and KRL 429 is given below (Table 19).

Table19: Performance of KRL 423 and KRL 429 in NIVT 1B

Yield in t ha^{-1} and rank			
Centre	KRL 423	KRL 429	Best Check
NWPZ	6.62 (7)	6.25 (19)	HD 3086: 70.9 (1)
NEPZ	4.77 (16)	4.87 (24)	HD 3086: 51.3 (5)
Gurdaspur	7.32 (3)	5.13 (27)	HD 3086: 81.8 (1)
IARI-Pusa	4.68 (24)	5.43 (2)	HD 2967; 53.3 (4)
RPCAU-Pusa	6.41 (3)	5.94 (16)	HD 2967; 66.3 (1)

Ten genotypes namely KRL1705, KRL1714, KRL1724, KRL1731, KRL1733, KRL 1740, KRL 1741, KRL 1742, KRL 1743 and KRL 1744 were contributed to the salinity/alkalinity tolerance screening nursery 2018-19.Out of 26 test entries of SATSN, 5 entries were found to be promising on the basis of mean yield alongwith resistance to all the three rusts (stem leaf and yellow rust) as evident from IPPSN 2018-19. However, most of the entries were found to be susceptible to rusts in IPPSN. Unfortunately these entries could not perform better than best check (KRL 210). During Rabi 2018-2019, AICRP special trial on salinity/alkalinity comprising seven entries (AST-101, AST-102, AST-103, AST-104, AST-105, AST-106 and AST-107) was conducted under sodic condition at CSSRI farm, Karnal and under saline condition at Nain Farm Paipat. None of the new entry was statistically at par with check variety KRL 210.

Seed multiplication and breeder seed production

During the crop season, 30 entries of IPPSN and SATSN, two entries of NIVT (KRL 423 and KRL 429) were multiplied. In addition, the seed of released varieties, Kharchia 65, KRL 99, KRL 3-4 and Kharchia local was also multiplied to meet out the demand as checks. Breeder seed of CSSRI varieties KRL 210 (4.0 t) and KRL 213 (5.15 t) was produced at CSSRI Karnal farm for distribution to various public and private seed producing agencies. Nucleus seed of five released varieties KRL 1-4, KRL19, KRL 210, KRL 213 and KRL 283 was produced at CSSRI experimental farm for use in the next season.

Hybridization and generation advancement

During the year 2018-19, a total of 418 new cross combination involving different targeted donors were attempted to diversify base, improving tolerance against disease resistance, waterlogging tolerance and salt tolerance. Under segregation generation F_2 (85 Crosses), F_3 (96 Crosses), F_4(165 Crosses) and F_5 (195 Crosses) were advanced under intensive selections pressure. Selections were made on the basis on disease resistance and agro-morphological traits. Apart from this, F_6 bulks (8 Crosses), F_7 bulks (18 Crosses) and F_8bulks (25 Crosses) were advanced during the rabi season 2018-19.

New source of multiple disease resistance (KRL 370)

Elite Entry KRL 370 screened out as a new source of multiple disease resistant (leaf rust, strip rust, Flagsmut and Karnal bunt)in Multiple Disease Screening Nursery, 2018-19.In MDSN thirty eight resistant sources identified in EPPSN (Elite Plant Pathological Screening Nursery 2017-18) against rusts are cross checked for resistance toother diseases at hot spot multi-locations under artificially created conditions to reconfirm their resistance. Based on the ACI up to 10.0, Karnal bunt up to 5.0%, Flagsmut up to 5%, powdery mildew up to 3, head scab upto 2, and leaf blight up to Avg. score upto 35and highest score upto 57 entries were categorized resistant.

New Sources of Salt Tolerance

A total of 288 promising advanced lines were screened under controlled sodic environment (PH_2>9.5). Out of 288 lines, five highest sodicity tolerant advanced generation (KRL 330/NW 1014, KRL 283/PBW 593, HS 245/KRL 99, KRL 99/Lr28 and KRL 346/KRL 250) were screen out for future breeding program. These selected advanced breeding lines will be screen for disease resistance and desirable agro-morphological traits.

Higher tolerance of promising bread wheat genotypes

Haryana state varietal trial 2018-19: In Haryana many district such as Panipat, Sonepat, Kaithal Rohtak, Jhajjar, Bhiwani, Jind and Sirsa are affected by salinity. For enhancing the wheat productivity in salt affected area of Haryana, an evaluation trial of wheat was conducted in five selected district for promotion and evaluation of salt tolerant wheat entries in farmer participatory approaches. Entries were evaluated in large plot trials (LPT) experimental design under farmer participatory mode with the plot size of 1000 m^2. The entry KRL 386 was top ranker which attain the highest yield i.e. 4.42 t ha^{-1} followed by KRL 210 (4.30 t ha^{-1}) and KRL 283 (4.17 t ha^{-1}) in salt affected ecosystems of Haryana.

Evaluation of wheat varieties for salt stress in Microplots

Twenty three wheat varieties were evaluated for their performances under sodic condition (pH_2: 9.5±0.10) in microplots. Genotypes were evaluated in RBD with six replications. In sodic environment genotypes KRL 3-4 attained the highest yield followed by KRL 99, KH.LOCAL and NW 5054, however least grain yield attained by the genotype PDW 291 followed by PBW 550, DUCULA 4 and RAJ 4120.

Consortium research platform on agro biodiversity (crp-ab) "sub-project 1. characterization, multiplication and evaluation for important biotic and abiotic traits of plant genetic resources of selected crops (NBPGR)" component II (Biotic and abiotic evaluation) under sub-project 1 (Arvind Kumar and P.C. Sharma)

A sets of 224 accessions of bread wheat was evaluated in Augmented Randomized Block Design with 8 blocks under sodic soils (pH_2 9.3±0.3). A total of four checks were used namely Kharchia 65, KRL 19, KRL210 and HD 2824 were randomized within 28 accessions in each blocks. In the experiment quantitative data on days to 50 % flowering, days to maturity, number of effective tillers, plant height (cm), spike length, spikelets per spike, grain yield (gram per meter row length)and above ground biomass (gram per meter row length) were recorded. The analysis of variance depicted significant differences among genotypes for days to heading, days to maturity spike length and grain yield. Variance (mean sum of squares) was observed highest for biological yield followed by grain yield although variance for biological yield and effective tillers per meter row length was non-significant. Low amount but significant variance was showed by days to heading, days to maturity and spike length content. Based on the mean performance over the blocks, KRL 210 was the top performing check followed by Kharchia 65 and KRL 19 respectively in alkaline environment. Based on the critical differences only two accessions i.e IC 35163 and IC 535330 significantly superior from KRL 210, while ever grain yield of 14 germplasm namely IC 35163, IC 535330, IC 443633, IC 252771, IC 402041, IC 75221, EC 11071, EC 313719, EC 578134, IC 535330, IC 128280, IC 527448, IC 290161, EC 313710, IC 122726, EC 549435 were numerically higher than the best salt tolerant check (KRL 210).

NICRA Project: Focused collection of climate-smart germplasm of rice and wheat, their valuation and genetic enhancement through pre-breeding for abiotic stress tolerance" (Arvind Kumar)

A minicore set of 169 accessions (including checks) of bread wheat was evaluated in 13x 13 duplex lattice experimental design with the plot size of 1 row 2 meter, under sodic (pH_2: 9.2±0.16) and normal condition. A total of four checks namely KH.65, KRL 19, HD 2851 and HD 2985 were randomized within 165 accessions in each replication. Significant differences were observed among treatments for all characters studied except effective tillers per meter row length. Salt tolerance index (STI) was used to characterize the accessions for sodicity tolerance. Salt tolerance index of 10 genotypes (IC 59610, IC 534306, IC 246681, IC 104542, IC 532897, IC 290066, IC 252813, IC 252816, IC 252799, IC 290323) was greater 1.0, indicating the these accessions attained the higher grain yield in sodic condition than the normal condition. The reason observed for attaining the less grain yield in normal condition was lodging due to tall nature (>130 cm height) of the genotypes. Salt tolerance index of 14 genotype (IC 252727, IC 529374, IC 252389, IC 335669, IC 290155, IC 335712, IC 547662, IC 445498, IC 533742, IC 395686, IC 79058, IC 290196, IC 531833 and IC 532897) was between 0.88 to 0.96, higher than the salt tolerant check KRL 19 (STI: 0.87). These genotypes may be considered as sodicity tolerant genotypes.

Development of salt tolerant and high yielding Indian mustard (*Brassica juncea* L. Czern & Coss) genotypes using classical and modern breeding approaches (Jogendra Singh, P.C. Sharma and Vijayata Singh)

Development and Evaluation of advanced breeding lines (PY and YET) in saline and alkali soils

Thirty two breeding lines including five checks (Kranti, CS 58, Giriraj, CS 56 and RH 749) were evaluated in PYT for seed yield in screening trial in saline soils (EC_e 11-16 dS m^{-1}) at Nain Farm (Distt. Panipat) and in reclaimed alkali soils (pH 8.5 to 9.3) at Karnal. Seed yield ranged from 1.02 to 2.28 t ha^{-1} (Mean 1.43 t ha^{-1}, CD $_{(0.05\%)}$ 0.31 t) in saline conditions while it ranged from 1.48 to 2.72 t ha^{-1} (Mean 2.19 t ha^{-1}, CD $_{(0.05\%)}$ 0.43 t) in alkali condition. One line gave significantly higher yield over the best check CS 58 (2.01 t ha^{-1}) with CS 2009-313 (2.28 t ha^{-1}) recording maximum seed yield under salinity. However,14 lines gave significantly higher yield over the best check CS 58 (2.26 t ha^{-1}) with CS 2004-112 (2.72 t ha^{-1}) followed by CS 2009-135 (2.70 t ha^{-1}) recording maximum seed yield under alkali condition.

Further, 74 breeding lines including five checks (Kranti, CS 58, Giriraj, CS 56 and RH 749) were evaluated in YET for seed yield in screening trial in saline soils (EC_e 11-16 dS m^{-1}) at Nain Farm (Distt. Panipat) and in reclaimed alkali soils (*p*H 8.5 to 9.3) at Karnal. Seed yield ranged from 0.97 to 2.90 t ha^{-1} (Mean 1.57 t ha^{-1}, CD $_{(0.05\%)}$ 0.68 t) in salinity while it ranged from 1.35 to 2.39 t ha^{-1} (Mean 1.97 t ha^{-1}, CD $_{(0.05\%)}$ 0.25 t) in alkali condition. Six line found superior over best check CS 58 (2.01 t ha^{-1}) with RIL-35 (2.90 t ha^{-1}) followed by RIL-3 (2.78 t ha^{-1}) under salinity while 13 lines gave significantly higher yield over the best check CS 58 (2.26 t ha^{-1}) with CS 2009-119 (2.39 t ha^{-1}) followed by RIL-20 (2.38 t ha^{-1}) recording maximum seed yield under alkali condition.

Development and Evaluation of advance breeding lines (F_{11} and F_{12}) of Mustard in saline and semi– reclaimed alkali soils

Forty seven breeding lines including five checks (Kranti, CS 58, Giriraj, CS 56 and RH 749) were evaluated in F_{11} generation for seed yield in saline soils (EC_e 11-16 dS m^{-1}) at Nain Farm (Distt. Panipat) and in reclaimed alkali soils (pH 8.5 to 9.3) at Karnal. Seed yield ranged from 0.65 to 2.02 t ha^{-1} (Mean 1.22 t ha^{-1}, CD $_{(0.05\%)}$ 0.53 t) under saline conditions wherever, it ranged from 1.17 to 2.35 t ha^{-1} (Mean 1.67 t ha^{-1}, CD $_{(0.05\%)}$ 0.20 t) under alkali conditions. One line gave significantly higher seed yield over the best check CS 58 (2.01 t ha^{-1}) with CS 2013-10 (2.02 t ha^{-1}) under salinity while two lines gave significantly higher seed yield over the best check CS 58 (2.26 t ha^{-1}) with CS 2013-66 (2.35 t ha^{-1}) followed by CS 2013-1 (2.29 t ha^{-1}) under alkali conditions..

Further, Sixty six breeding lines including five checks (Kranti, CS 58, Giriraj, CS 56 and RH 749) were evaluated in F_{12}generation for seed yield in saline soils (ECe 11-16 dS m^{-1}) at Nain Farm (Distt. Panipat) and in reclaimed alkali soils (*p*H 8.5 to 9.3) at Karnal. Seed yield ranged from 0.47 to 2.20 t ha^{-1} (Mean 1.04 t ha^{-1}, CD $_{(0.05\%)}$ 0.44 t) under salinity while it ranged from 1.25 to 2.27 t ha^{-1}(Mean 1.57 t ha^{-1}, CD $_{(0.05\%)}$ 0.23 t) under alkali conditions. Two lines gave significantly higher seed yield over the best check CS 58 (2.01 t ha^{-1}) with CS 2002-99 (2.20 t ha^{-1}) followed by CS 2002-65 (2.12 t ha^{-1}) in saline conditions whereas one line gave higher seed yield over the best check CS 58 (2.26 t ha^{-1}) with CS 2002-99 (2.27 t ha^{-1}) in alkali conditions.

Development and Evaluation of segregating material (BC_6) of Mustard in semi–reclaimed sodic soils

The objective behind these crosses was to develop multistress (Salinity, Heat, Drought and Frost) tolerant mustard genotypes with higher yield. Thirty seven breeding lines including five checks (Kranti, CS 58, Giriraj, CS 56 and RH 749) were evaluated in BC_6F_3 generation for seed yield in sodic soils (*p*H 9.3) at Karnal. Seed yield ranged from 1.44 to 2.47 t ha^{-1} (Mean 1.88 t ha^{-1}, CD $_{(0.05\%)}$ 0.20 t). Three lines gave significantly higher seed yield over the best check CS 58 (2.26 t ha^{-1}) with CS 330-1 x Q 2061-41 (2.47 t ha^{-1}) followed by CS 54 x ROHINI and RH 781 x CS 54 (2.40 t ha^{-1}).

Monitoring and Evaluation of promising salt tolerant strains of Indian Mustard (Brassica juncea) in AICRP on Rapeseed Mustard Salinity/Alkalinity Trial -2018-19

Twelve genotypes were evaluated in AVT-I+II under saline condition (EC_e 11.0 dS m^{-1}) at experimental farm Nain (Distt. Panipat) and alkali condition (pH 9.3) at Karnal. Significant differences were observed in seed yield amongst the genotypes evaluated, both under salinity and alkalinity stresses. Under salinity stress, seed yield ranged from 1.48 to 2.50 t ha^{-1} (Mean 2.11 t ha^{-1}, CD $_{(0.05\%)}$ 0.31 t) at Nain, while 1.41 to 2.50 t ha^{-1} (Mean 2.10 t ha^{-1}, CD $_{(0.05\%)}$ 0.31 t) under high alkaline conditions (*p*H 9.3) at Karnal. Genotypes CSCN-18-11 (2.50 t ha^{-1}) followed by CSCN-18-7 (2.47 t ha^{-1}) showed highest seed yield over the saline/ alkali conditions.

Monitoring and Evaluation of Salinity/alkalinity entries of Indian mustard as influenced by different fertility levels in All India Coordinated Research Project on Rapeseed Mustard Trial-2018-19

Seven genotypes were evaluated in Agronomy trial alkaline conditions (pH 9.3) at Karnal with three nitrogen levels; 100%, 125% and 150% of recommended dose. Significant differences were observed in seed yield amongst the genotypes evaluated. Ag 1, Ag 4 and Ag 7 responded favourably to the additional doses of fertilizer (NPK). Further, 100% RDF was found economically suitable for these genotypes

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

During the year 2018-19, breeder seed (graded) of Indian mustard varieties; CS 52 (0.050 t), CS 54 (0.30 t), CS 56 (0.80 t), CS 58 (2.2 t) and CS 60 (1.50 t) was produced for distribution to central and state govt. agencies.

Output During Period Under Report

- Developed and submitted four genotypes (CS 2007-165, CS 2009-313, CS 2002-99 and CS 2005-143) to AICRP on Rapeseed & mustard for IVT Salinity/Alkalinity trial-2019-20.
- Developed 4 Recombinant Inbred Lines (RILs) population CS 614-1-1-100-13 x CS 56; CS 245-2-80-7 x CS 56; CS 614-1-1-100-13 x Varuna and CS 245-2-80-7 x Varuna (250 lines of each) in F_8 generation according to objectives of project.

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, P.C. Sharma and Vijayata Singh)

Development of genetic and genomic resources for facilitating research on salt tolerance in Indian mustard: *Advancement, Phenotyping and genotyping of RILs mapping populations*

Two hundred fifty two Recombinant Inbred Lines (RILs) including their parents (CS 56 and CS 614-1-1-100-13) were sown in October 2018 and advanced F_7 generation in to F_8 using single siliqua decent method. Phenotyping of RILs including their parents were done under normal and salinity (EC_{iw} 12 dS m^{-1}) conditions for yield and contributing traits. The plant height of the parental lines CS 614-1-1-100-13 and CS 56 was 202.5 and 196.5 cm respectively under normal and 148.5 and 120.0 cm saline (EC_{iw} 12 dS m^{-1}) conditions. The height of RILs ranged from 153- 251 cm under normal and 102.5-175.0 cm under saline soils respectively. The number of primary branches of RILs ranged from 3.5 to 8 and 3 to 8.5 under normal and saline soils, respectively. There was no significant difference in the mean number of primary branches of parents and RILs under normal and saline soils. The number of secondary branches of RILs ranged from 5.5 to 18.5 and 2 to 15 under normal and saline conditions, respectively. The number of secondary branches of the parental lines CS 56 and CS 614-1-1-100-13 was 10.5 and 7.5 under normal and 11 and 5.5 in saline conditions. The main shoot length of RILs ranged from 61.5-105.5 cm under normal and 34- 71.5 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 77.0 under normal and 56.0 and 54.0 in saline conditions. The number of siliqua on main shoot of RILs ranged from 41- 76 cm under normal and 20- 52 cm under saline conditions, respectively. The number of siliqua on main shoot of the parental lines CS 56 and CS 614-1-1-100-13 was 48.0 and 44.0 under normal and 57.0 and 41.5 in saline conditions. The test weight of RILs range varies from 3.55- 7.21g and 3.84-6.6 g under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed test weight of 5.3 and 5.2g under normal and 4.2 and 4.3g in saline conditions. The yield/plant of RIL ranged from 21.7 to 58.8g and 6.83 to 14.01g under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed yield of 38.2 and 30.8g under normal and 11.3 and 8.9g in saline conditions.

Further, RILs and their parents (CS 56 and CS 614-1-1-100-13) were also subjected to morphological screening in terms of root and shoot fresh weight and dry weight and Na and K content at seedling stage in normal and saline (EC_{iw} 12 dS m^{-1}) conditions at Karnal. Root fresh weight of the RILs ranged from 0.25 to 0.99g and 0.07 to 1.78g under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed root fresh weight of 4.3 and 2.5g under normal and 1.3 and 0.3g in saline conditions. Root dry weight of the RILs ranged from 0.05 to 0.59g and 0.02 to 1.0g under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed root dry weight of 0.5 and 0.3g under normal and 0.2 and 0.1g in saline conditions. Shoot fresh weight of the RILs ranged from 4.5 to 9.5g and 2.55 to 47.5g under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed shoot fresh weight of 67.5 and 44.5g under normal and 13.9 and 7.0g in saline conditions. Shoot dry weight of the RILs ranged from 0.42 to 4.02g and 0.2 to 2.04g under normal and saline conditions, respectively. CS 56 and CS 614-1-1-100-13 displayed shoot dry weight of 3.3 and 2.0g under normal and 1.6 and 0.7g in saline conditions. Root Na content of the RILs ranged from 6.82 to 40.79 mg kg^{-1} dry wt. and 7.30 to 43.15 mg kg^{-1} 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^{-1} dry wt. under normal and 9.4 and 10.6 mg kg^{-1} dry wt. in saline conditions. Root K content of the RILs ranged from 18.6 to 73.51 mg kg^{-1} dry wt. and 10.9 to 78.35 mg kg^{-1} 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^{-1} dry wt. under normal and 32.8 and 22.0 mg kg^{-1} dry wt. in saline conditions.

Identification of QTLs/genes for tolerance to salinity stress: *Genotyping of RILs generated for mapping QTLs governing salinity tolerance*

A total of 1144 SSR markers were surveyed on parents CS 56 and CS 614-1-1-100-13 to identify polymorphic markers. Out of them 44 markers showed polymorphism, which will be further used for genotyping of RILs and tagging QTLs for salt tolerance in Indian Mustard.

Understanding physiological and biochemical bases of salinity tolerance: *Identification physiological and biochemical parameters involved in salt tolerance*

The net photosynthesis, stomatal conductance, water use efficiency and transpiration rate decreased substantially in the all genotypes evaluated at higher salinity (EC_{iw} 15 dS m^{-1}) as compared to control. The highest reduction in photosynthesis rate at 15 dS m^{-1} was recorded in CS 614-4-1-4-100-13 (95.76%), while the lowest was recorded in CS 52-SPS-1-2012 (55.85%) followed by CS 54 (59.07%) compared to control. Similarly, highest reduction in stomatal conductance was noted in CS 614-4-1-4-100-13 (86.46%) while CS 52-SPS-1-2012 (33.33%) displayed lowest reduction at EC_{iw} 15 dS m^{-1} compared to control. Salt stress significantly reduced transpiration rate in all the genotypes and the rate of reduction increased with increasing salinity stress. At EC_{iw} 15 dS m^{-1}, the highest reduction in transpiration rate was recorded in CS 614-4-1-4-100-13 (67.82%), while CS 52-SPS-1-2012 displayed the lowest reduction (48.19%), compared to control. Further, the increasing salinity, also significantly (< 0.05) affected the instantaneous water use efficiency in all the genotypes evaluated. The highest reduction in $_{i}$WUE was noted in CS 614-4-1-4-100-13 (86.88%) while CS 52-SPS-1-2012 (14.80%) displayed the lowest at EC_{iw} 15 dS m^{-1} compared to control. Salt stress significantly reduced CO_2 assimilation rate in all the genotypes and the rate of reduction increased with increasing salinity stress. The highest reduction in CO_2 assimilation rate at higher salinity was recorded in CS 614-4-1-4-100-13 (41.98%), while CS 52-SPS-1-2012 (26.74%) displayed the lowest, compared to control.

Further, Na^+/K^+ ratio of the shoot and root was significantly lowest in the salt tolerant mutant CS 52-SPS-1-2012 (1.64 and 2.33, respectively), whereas, the ratio was highest in the salt susceptible mutant CS 614-4-1-4-100-13 (2.58 and 6.87) followed by Pusa bold (2.37 and 6.04) for shoot and root, respectively, across the salinity levels. The significant differences in ion accumulation (both Na^+ and K^+) in shoot and roots under different salinity treatments were recorded in all the genotypes. Increasing levels of salinity lead to elevated concentration of Na^+ in shoot of salt sensitive genotypes CS 614-4-1-4-100-13 and Pusa bold than the salt tolerant genotypes CS 52-SPS-1-2012 and CS 54 compared to control. Higher salinity also lead to drastic reduction in the concentration of K^+ in both shoot and root tissues of salt sensitive genotype CS 614-4-1-4-100-13 than the salt tolerant genotype CS 52-SPS-1-2012 compared to control treatment.

Further, genotypes were analysed for Na^+/K^+ ratio in leaves (basal, middle and top), branches and shoot (middle and top) to study the partitioning behaviour of Na^+ and K^+ in different plant parts. The Na^+/K^+ ratio increase in all the genotypes with respect to salinity levels and leaf positions from top to basal. As compared to control conditions, CS 614-4-1-4-100-13 showed about 52 times higher Na^+/K^+ ratio in basal leaves, whereas CS 52-SPS-1-2012 showed on twice under increased salinity levels as compared to control. The trends of Na^+ concentrations and Na^+/K^+ ratio in middle and top leaves are similar to basal leaves with a lower extent. The Na^+/K^+ ratio increased under various imposed salinity levels in branches of all the genotypes. However, the sensitive genotype, CS 614-4-1-4-100-13 and Pusa bold displayed 42 and 51 times, respectively, higher Na^+/K^+ ratio as compared to control, at the highest salinity level. Whereas, CS 52-SPS-1-2012 was able to maintain a comparatively lower Na^+/K^+ to only 12 times higher as compared with the control conditions. The Na^+/K^+ ratio was extremely low in the top shoot as compared to the middle one in all the genotypes. The Na^+/K^+ ratio increased in mid shoot of CS 614-4-1-4-100-13 under salinity was to the tune of 16 times higher compared with the control.

Development of salt tolerant rice (*Oryza sativa* L.) genotypes for coastal salinity (Jogendra Singh, SL Krishnamurthy and S.K. Sarangi)

Evaluation of rice genotypes under salt stress conditions during kharif 2018

Forty diverse genotypes of rice were evaluated under salinity (ECiw 7 dS m^{-1}) for germination at ICAR-CSSRI RRS, Canning Town (W. Bengal). Germination ranged from 74 to 100% (Mean 96%, $LSD_{(P=0.01)}$ 0.03%). 10 line namely IR52280-117-1-1-3, CANNING-7, CSR-4, CSRC(S)32-B-B-B-3-B, CSRC(S)36-B-B-2-B, CSRC(S) 49-B-5-2-B-1, CSRC(S) 53-1-B-1-B, IR 77664 -B-25-1-2-1-3-12-5, AJOY, IR 75395-2B-B-19-2-1-B and CSR 36 germinated 100% under salinity. Further, these genotypes also characterised coastal salinity (EC_{iw} 8.07 dS m^{-1}) for yield and associated traits. Grain yield range from 2.36 to 6.40 t ha^{-1} (Mean 4.67 t ha^{-1}, $LSD_{(P=0.01)}$ 0.28 t). 24 lines gave higher grain yield than mean value. The highest yielding genotype was Canning-7 (6.40 t ha^{-1}) followed by CSR-4 (6.23 t ha^{-1}).

Similarly, 142 advanced breeding lines were also evaluated under coastal salinity (EC_{iw} 8.07 dS m^{-1}) for yield and associated traits during *kharif* 2018 at ICAR-CSSRI RRS, Canning Town. Grain yield range from 0.01 to 4.58 t ha^{-1} (Mean 2.03 t ha^{-1}, $LSD_{(P=0.01)}$ 0.10 t). 67 lines gave higher grain yield than mean value. The highest yielding line was ABL 114 (4.58 t^{-1}ha) followed by ABL 84 (3.93 t ha^{-1}).

Evaluation of rice genotypes under salt stress conditions during rabi 2018

The 40 diverse genotypes of rice characterised under coastal salinity (EC_{iw} 10.50 dS m^{-1}) for yield and associated traits during *rabi* 2018 at ICAR-CSSRI RRS, Canning Town. Grain yield range from 1.22 to 5.72 t ha^{-1} (Mean 3.58 t ha^{-1}, $LSD_{(P=0.01)}$ 1.24 t). 23 lines gave higher grain yield than mean value. The highest yielding genotype was IR52280-117-1-1-3 (5.72 t ha^{-1}) followed by BOBY (5.46 t ha^{-1}).

Further, 140 advanced breeding lines were also evaluated under coastal salinity (EC_{iw} 10.50 dS m^{-1}) for yield and associated traits during *rabi* 2018 at ICAR-CSSRI RRS, Canning Town. Grain yield range from 0.22 to 4.37 t ha^{-1} (Mean 1.78 t ha^{-1}, $LSD_{(P=0.01)}$ 0.38 t). 56 lines gave higher grain yield than mean value. The highest yielding line was ABL 20 (4.37 t ha^{-1}) followed by ABL 47 (4.15 t ha^{-1}).

Survived chickpea lines under alkaline condition

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

Phenotyping of mapping population under saline and sodic conditions

A total of 150 RILs along with parents (HC-5 x Karnal Chana-1) were evaluated under normal, sodic (pH 9.5±0.2) and saline environments (EC_{iw} 6 dS m^{-1}) during rabi season of 2018-19. All the lines were germinated under alkalinity but 32 lines didn't survive after germination. The range, mean and per cent reduction of different traits for RIL population were recorded (Table 20). High mean seed yield and other related traits performance was noticed under normal soil as compared to alkaline and saline stresses. The flowering and maturity was early under stress condition. The mean plant height was 68.54, 63.26 & 64.24 cm under control, alkalinity & salinity and there was a 7.70 % & 6.27 % reduction under alkaline and saline condition respectively. The seed yield/plant was the most sensitive trait and reduced by 44.94 % and 50.08 % under alkaline and saline environment. The seed yield (g) ranged from 8.9(RIL62) to 51.45(RIL104), 1.26(RIL34) to 28.25(RIL11) and RIL61 (1.08) to RIL35(24.5) under normal, alkaline and saline condition, respectively. On

Table 20: Mean performance of the 150 RILs and parents under normal, alkaline and saline condition for different traits.

S. No	Characters	Mean			Range			% reduction	
		Control	pH 9.5±0.2	EC_{iw} 6 dS m^{-1}	Control	pH 9.5±0.2	ECiw 6 dS m^{-1}	pH 9.5±0.2	EC_{iw} 6 dS m^{-1}
1	Days to 50% flowering	106.30	99.67	98.72	77-127	73-116	75-114	6.23	7.13
2	Days to 50% maturity	149.52	142.84	143.20	134-162	126-155	124-156	4.47	4.23
3	Plant height (cm)	68.54	63.26	64.24	48.2-82.45	42.8-79.15	41.25-77.44	7.70	6.27
4	Yield plant-1 (g)	31.75	17.48	15.85	8.9-51.45	1.26-28.25	1.08-24.30	44.94	50.08
5	100 seed wt. (g)	15.40	13.55	13.40	8.85-19.45	6.35-17.44	6.45-16.36	12.01	12.99
6	Root Na+ (%)	1.46	2.48	2.61	0.81-2.16	1.69-3.92	1.56-3.86	-41.13	-44.06
7	Root K+ (%)	1.88	1.43	1.32	1.33-2.98	1.17-2.48	1.33-2.62	23.94	29.79
8	Shoot Na+ (%)	0.46	0.73	0.86	0.24-0.61	0.43-1.09	0.56-1.27	-36.99	-46.51
9	Shoot K+ (%)	2.38	1.55	1.48	1.74-4.17	0.66-2.23	0.58-2.30	34.87	37.82

the basis of higher yield 10 best lines from each treatment were selected. 100 seed wt. was also affected by salt stress and it was about 12.01 and 12.99 % less under alkalinity and salinity respectively. Na^{+} content under alkalinity in both root and shoot ranged from 1.69-3.92 and 0.43-1.09 % and it was 41.13 & 36.99 % higher than control while under salinity it was 44.06 & 46.51 % higher.

Evaluation of advanced breeding materials (F_5 generation) under saline soils

Four breeding lines and one check (KC-1) were evaluated in F_5 generation for seed yield under saline environment (ECiw 6 dS m^{-1}).Seed yield ranged from 19.73 to 25.77 g $plant^{-1}$. Three lines gave significantly higher seed yield than check (22.8 g $plant^{-1}$).

Advancement of mapping population

A total of 713 lines of three mapping population (BG1103 × Karnal Chana-1, 330 lines, HC 5 × Karnal Chana-1, 150 lines and DCP92-3 × ICCV-10, 233 lines) were sown in single line for advance to next generation. From each row single plant was harvested and seeds were kept.

Crossing of salt tolerant lines with prominent varieties.

High yielding salt sensitive varieties were selected for crossing with salt tolerant genotypes. A total of 62 pods of 6 cross combinations were harvested and will be evaluated in next year.

Maintenance of germplasm and parental lines

A total of 267 germplasm lines and 13 parental lines were maintained for their use in future breeding programme.

Breeder seed production

During 2019, 28 q breeder seed of the salt tolerant variety Karnal Chana-1 was produced to meet the demand of different stakeholders.

Molecular approaches for mapping of novel gene(s)/ QTL(s) for resistance/ tolerance to different stresses in rice, wheat, chickpea and Indian mustard including sheath blight complex genomics and resistance mechanisms. Sub project 3: chickpea (S.K. Sanwal and P.C. Sharma)

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

Phenotyping of recombinant inbred lines: Yield and contributing traits

A total of 163 recombinant inbred lines (RILs) received from IARI, New Delhi were sown on 06.11.2018 in microplots for evaluation in control and saline (EC_{iw} 6 dS m^{-1}) conditions for seed yield and other yield contributing traits at CSSRI, Karnal. The saline irrigation of EC_{iw} 6 dS m^{-1} was given at 30, 60 and 90 days after sowing. The data was recorded on days to 50% flowering, days to maturity, plant height (cm), seed yield plant^{-1}, 100 seed weight and ionic analysis

Days to 50% flowering ranged from 73 to 134 and 63-131 respectively under control and saline condition. Under stress condition, flowering was early and it was 8.62 %. Days to 50% maturity was ranged from 139-168 to 133-166 days respectively under control and saline environments. The plant height of 163 RILs ranged from 44.00 to 97.5, 35.0 to 104.5 cm, respectively under control and saline. There was 0.65% reduction in plant height under stress compared to control condition (Table 21). The mean yield plant^{-1} was 30.10 g in control while it was 8.20 g in stress. It ranged from 4.4 to 74.98 and 0.47 to 21.47 g, respectively under control and saline condition. There was reduction in yield plant^{-1} under salinity and it was 72.76 % less than control (Table 21). The 100 seed weight of these RILs ranged from 9.60 to 25.08 g, and 7.10 to 20.00 g, respectively under control and saline condition. There was major reduction in 100 seed weight in salinity condition compared to control condition. Top 20 lines from each treatment were selected on the basis of yield (Table 2). Out of 163 RILs the RILs 27 recorded highest yield followed by RIL20, RIL44, RIL16, RIL52 and RIL14 under control condition. These lines produced >60 g plant^{-1} yield. Under saline environment, the RIL4 recorded highest yield followed by RIL69, RIL115, RIL83, RIL29, RIL26, RIL62, RIL78 and RIL108. All these lines had >15g yield/plant.

Total chlorophyll was measured from the top third leaf using 80 % Acetone method. Under saline stress, total chlorophyll content decreased. The lines RIL31, RIL126, RIL60, RIL65, RIL116, RIL63, RIL88, RIL97 and RIL88 had maximum chlorophyll content under saline condition. At flowering stage, the Na and K content of root and shoot was analyzed. The mean value for root Na content in 163 RILs was 1.61 and 2.94% in control and saline environment. In Shoot, mean value for Na content was 0.39 and 0.65 % in control and saline environment respectively. The higher content of Na in root may be due to the fact that roots restrict the entry of Na into shoot and thus upward flow of toxic Na ions. The

Table 21: Mean, range and percent reduction of different characters of 163 recombinant inbred lines evaluated at salinity EC_{iw} 6 dS m^{-1}.

S. No.	Characters	Mean		Range		% reduction over control
		Control	EC_{iw} 6 dS m^{-1}	Control	EC_{iw} 6 dS m^{-1}	
1	Days to 50% Flowering	110.53	101.01	73-134	63-131	8.62
2	Days to 50% maturity	157.23	153.17	139-168	133-166	2.59
3	Plant height (cm)	77.70	77.20	44-97.5	35-104.5	0.65
4	Yield Plant^{-1} (g)	30.10	8.20	4.4-74.98	0.47-21.47	72.76
5	100 Seed weight (g)	16.25	12.85	9.60-25.08	7.10-20.00	20.93
6	Root Na+ (%)	1.61	2.94	0.73-2.85	1.86-4.76	-154.73
7	Root K+ (%)	2.62	1.75	2.13-3.93	1.25-3.37	41.31
8	Shoot Na+ (%)	0.39	0.65	0.27-0.43	0.75-1.47	-59.26
9	Shoot K+ (%)	3.57	1.47	2.02-4.96	0.80-2.68	60.39

mean value of root K^+ content was 2.62 and 1.75 % in control and saline environment while it was 3.57 and 1.47 % in shoot. The genotypes RIL111, RIL118, RIL131, RIL82 and RIL58 had maximum Na content in roots in saline condition and behaves as sodium excluder.

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

The main aim of this project is to categorize of soybean germplasm for salt tolerance and identification of donors for salt tolerance and its introgression in to high yielding varieties. A panel of 291 soybean genotypes (germplasm, released varieties, wild accession and breeding lines) was evaluated under the field sodicity conditions (Control and pH 9.3) and irrigation saline water (EC_{iw} 5.0 and 8.0 dSm^{-1}) during wet season of *Kharif* 2019.

Screening of soybean germplasm under sodicity

All the 291 accessions including checks (PS 1347, SL 958, JS 20-34 and JS 20-29) were also evaluated under the field sodicity conditions (Control and pH 9.3) during wet season of *Kharif* 2019. Impact of sodicity was more pronounced on pods/plant and seed yield/plant which significantly reduced these traits 74% pods $plant^{-1}$, 79% seed yield $plant^{-1}$ and 57% 100- Seed weight.

The higher salinity significantly reduced seed yield/plant and 100-Seed weight. Whereas, Na/K ratio in root and shoot was significantly increased with increasing sodicity levels as compared to control. Best performing genotype under sodicity for yield per plant are SL 958 (122.85 g $plant^{-1}$), E- 94 (117.80 g $plant^{-1}$), DS 228 (109.24 g $plant^{-1}$), SL 113 (105.50 g $plant^{-1}$) and AGS -751-6 (103.20 g $plant^{-1}$). We are being used best performing genotype as a donor for crossing.

Screening of soybean germplasm under saline irrigation

Initially, five seeds of each of accessions were sown at depth of 1 cm in 20 kg capacity ceramic pots filled with sand inside the net house facility. The bottom of each pot was delved for drainage of extra water. The pots were irrigated by normal tap water (Control), saline water (EC_{iw} 5.0 and 8.0 dS m^{-1})and maintained at full strength field capacity. Here, we selected above salinity levels because EC_{iw} 5 dS m^{-1} is the threshold limit for soybean crop. The saline water for irrigation was prepared in Hoagland nutrient solution by adding NaCl, Na_2SO_4 and $CaCl_2$, keeping Na:Ca and $Cl:SO_4$ ratios of 4:1 which reflect the major ion compositions of naturally occurring saline waters/soils. The pots were arranged in a factorial experiment based on completely randomized block design (CRBD) with 2 replications. The pots were irrigated daily so as to maintain the respective salinity level in the root zone throughout the life cycle of the crop. Saline irrigation was continued until the harvest of the crop for recording yield. Plant sampling for ionic study was done at the harvesting stage. At maturity, three plants per pot were harvested and air dried prior to recording their grain yield. Seed yield of all the genotypes under different salinity regimes was also recorded.

Out of 291 accessions including checks (PS 1347, SL 958, JS 20-34 and JS 20-29) only 121 survived till maturity under saline condition. The higher salinity significantly reduced 65% pods $plant^{-1}$, 69% seed yield/plant and 58% 100- Seed Weight.

The higher salinity significantly reduced Seed yield/plant and 100-Seed weight. Whereas, Na/K ratio in root and shoot was significantly increased with increasing salinity levels as compared to control. Top five best performing soybean germplasm are AGS 75-13 (20.03 g plant^{-1}), IC 195 (18.5 g plant^{-1}), AGS 75-14 (16.32 g plant^{-1}), SL-1254 (14.23 g plant^{-1}) and IC 391326(13.51 g plant^{-1}) under salinity. We are being used best performing genotype as a donor for crossing.

Enhancement of genetic potential of moongbean and lentil in multi season- and different cropping system adaptation (Vijayata Singh and S.K. Sanwal, Collaborative project ICAR-CSSRI with ICAR-IARI)

Maintenance, evaluation and screening of 99 lentil germplasm, 40 genotypes under station trial and field demonstrations of PDL-1 and PSL-9 under were screened for yield under EC_e 7 dS m^{-1}salinity during *rabi* 2018-2019 at Nain Experimental Farm, Panipat. The highest yield was recorded for PDL-1 (1.43 t ha^{-1}) followed by LSL-16-3 (1.27 t ha^{-1}), PSL-9 (1.70 t ha^{-1}) and LSL-16-13 (1.70 t ha^{-1}) as compared to checks DPL-62 (0.62 t ha^{-1}) and IPL-406 (0.16 t ha^{-1}) under salinity upto 7 dS m^{-1}.

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

Salt-specific transcriptome libraries of *Urochondra setulosa* and *Dichanthium annulatum* at EC 30, 40 and 50 dS m^{-1}were analyzed for differential expression. An average of 64.47% of transcripts in *Dichanthium* and 65.52% in *Urochondra* were functionally annotated. The Venn diagram (Fig. 24) showed that 1065 transcripts (2.8%) were commonly up regulated at EC 30 and 40 dS m^{-1}, 11209 (29.2%) transcripts between EC 40 and 50 dS m^{-1}and even 1627 transcripts (4.2%) were common at EC 30 and 50 dS m^{-1} in *Urochondra*. Similarly, 1234 transcripts (2.4%) were down regulated at both saline levels of EC 30 and 40 dS m^{-1}, 18151 transcripts (35.7%) at EC 40 and 50 dS m^{-1}and only 842 transcripts (1.7%) were commonly down regulated at EC 30 and 50 dS m^{-1}. In *Dichanthium,* out of total 147851 transcripts, 29482 DEGs were up regulated while 42425 DEGs were down regulated.

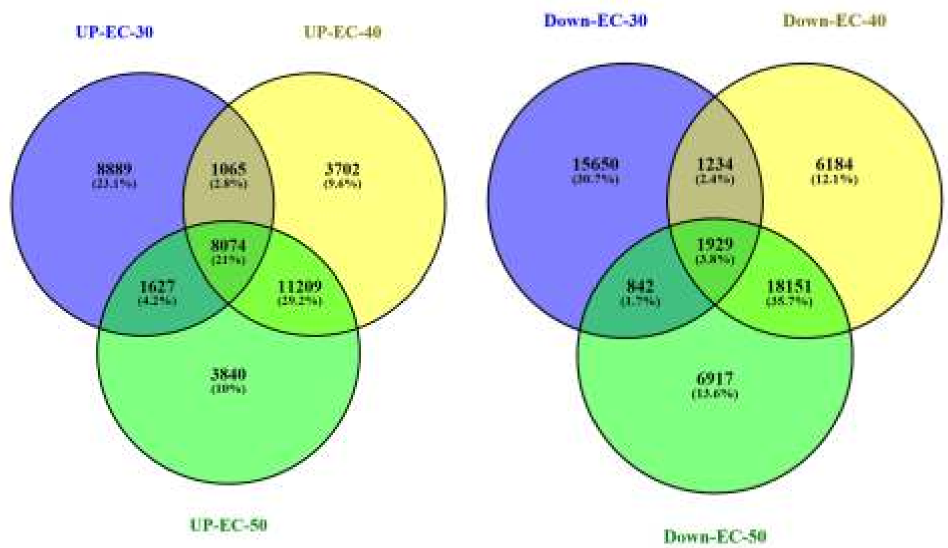


Fig. 24. Venn diagram of DEGs at different saline levels in *Urochondra setulosa*

Gene Ontology (GO) analysis revealed biological process (BP) was most abundant in terms of different categories followed by molecular function and cellular component. In biological processes category of *Urochondra*, about 143 transcripts were found to be related to salt responsive stress with 19 transcripts related to positive regulation of salt stress, 340 transcripts were related to response to oxidative stresses and 47 transcripts were related to cellular response to oxidative stresses. From KEGG comparative analysis, total of 18,953 and 27,431 unique transcripts were annotated in *Urochondra* and *Dichanthium* against KAAS server. From unique pathways identified, Ribosome (981 sequences) was the most abundant pathway and anthocyanin biosynthesis (1 transcript) was the least in *Urochondra* in terms of the number of homologous transcripts. Similarly, Protein processing in endoplasmic reticulum (1274 sequences) was the most abundant pathway and anthocyanin biosynthesis (1 transcript) was the least in *Dichanthium*.The top 10 unique pathways identified for all transcripts are presented in Fig. 25. To confirm the reliability of RNA-Seq in identification of differentially expressed genes under salt stress, qPCR analysis of 10 randomly selected unigenes at salinity levels of EC_e ~ 30 dS m^{-1}, EC_e ~ 40 dS m^{-1} and EC_e ~ 50 dS m^{-1} was done. DEGs involved in salt tolerance pathways namely, dehydrin/LEA group 2-like protein, potassium transporter, catalase, peroxidase, transcription factor DREB, sodium/hydrogen exchanger, trehalose-6-phosphate synthase etc from grass halophytes were randomly selected for validation.A similar expression level was observed between qPCR results and RNA-Seq data but with some variations, few DEGs have been depicted in table 22. The results obtained have confirmed the reliability of our de novo assembly.

The relative expression of unigenes such as NHX, dehydrin, DREB and helicase increased with increase in the salt stress. The relative expression of NHX gene increased significantly from 0.05 at 30 dS $m^{-1}$to 0.76 at 50 dS m^{-1}. It increased about 107% at 40 dS $m^{-1}$and about 1435% at 50 dS m^{-1}as compared to 30 dS m^{-1}. Dehyrdin increased approx. 56% at 40 dS $m^{-1}$and about 992% at 50 dS m^{-1}as compared to 30 dS m^{-1}. Dehydrin protein is major protein expressed in response to drought and salt stress. The higher expression of NHX and dehydrin along with the increase in the salinity level suggested the tolerance ability of the *Urochondra* to salt stress.

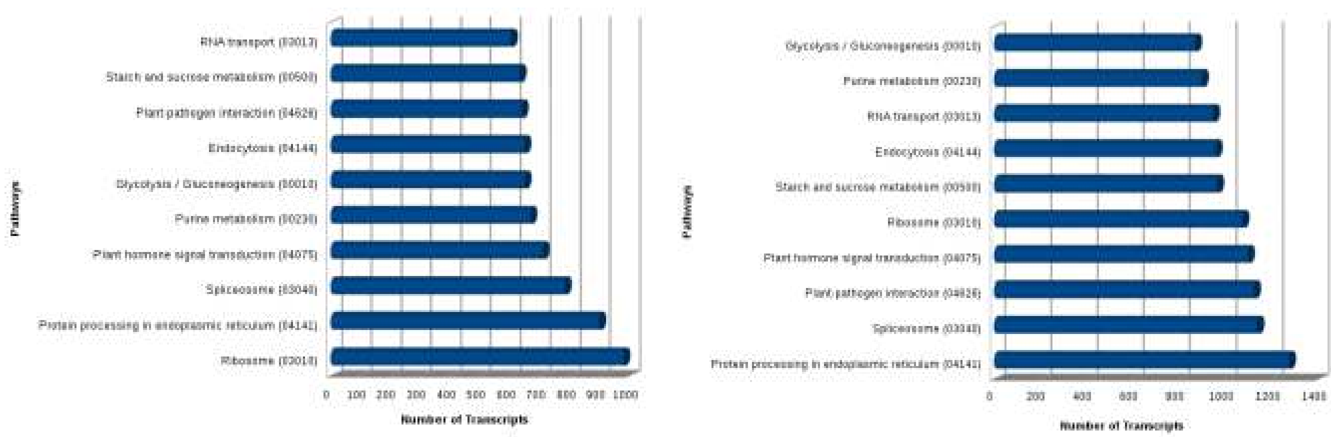


Fig. 25. Top ten pathways expressed in *D. annulatum* (A) and *U. setulosa* (B)

Table 22: Quantitative expression of DEGs in *U. setulosa* and *D. annulatum*

Sr. No.	Transcript ID	Protein Name	Fold Change				Regulation
				EC_e 30 dS m^{-1}	EC_e 40 dS m^{-1}	EC_e 50 dS m^{-1}	
1.	Urochondra_DN22778_c0_g1_i2	Unknown	NGS qPCR	5.93 1.01	9.88 1.33	10.82 10.88	Up-regulation
2.	Urochondra_DN33781_c0_g1_i1	NHX	NGS qPCR	1.44 0.05	3.29 0.10	3.50 0.76	Up-regulation
3.	Urochondra_DN32950_c0_g1	ATP -dependent DNA helicase	NGS qPCR	7.62 0.80	8.75 1.61	9.14 1.92	Up-regulation
4.	Urochondra_DN38352_c1_g1_i4	Flavin-containing monooxygenase	NGS qPCR	4.65 0.68	5.68 1.15	6.72 1.81	Up-regulation
5.	Urochondra_DN29996_c0_g1_i1	Dehydrin/LEA group 2-like protein	NGS qPCR	6.31 2.63	8.98 4.25	9.27 11.39	Up-regulation
6.	Urochondra_DN40311_c0_g1_i1	Plasma membrane ATPase	NGS qPCR	1.20 7.64	6.56 8.24	6.79 16.00	Up-regulation
7.	Urochondra_DN40034_c6_g2_i3	Potassium transporter	NGS qPCR	5.68 0.98	6.66 1.54	7.66 1.88	Up-regulation
8.	Urochondra_DN38901_c2_g3_i3	Late embryogenesis abundant protein, putative / LEA protein, putative	NGS qPCR	0.60 3.09	-0.75 3.04	-1.42 1.28	Down-regulation
9.	Dicanthium_DN72170_c4_g1_i2	Sodium/hydrogen exchanger	NGS	1.62	-	-	Up-regulation
10.	Dicanthium_DN62473_c2_g2_i3	ABA responsive element binding factor 1	NGS qPCR	1.65 1.44	- -	- -	Up-regulation

Phytoremediation potential of selected halophytes for salt affected lands of Haryana (Ashwani Kumar, Arvind Kumar, B.L. Meena and Anita Mann)

The halophytic species collected from various salt affected sites of Haryana were evaluated for their physiological and biochemical traits responsible for their tolerance. Na^+, K^+ and Cl^- partitioning in leaves, stem and roots revealed that higher content were accumulated in leaves than stem and roots. Maximum accumulation of Na^+ in leaves was recorded in *Sueada nudiflora* (5.01 %) followed by *Urochondra setulosa* (4.99 %) and *Atriplex nummularia* (4.93 %) whereas *Heliotropium ramosimum* and *Withania somnifera* showed lowest accumulation. While in stem, *Urochondra* (1.29 %) had maximum accumulation and in roots, *Atriplex nummularia* had the highest accumulation (1.73 %) in comparison to other halophytic species (Fig. 26).

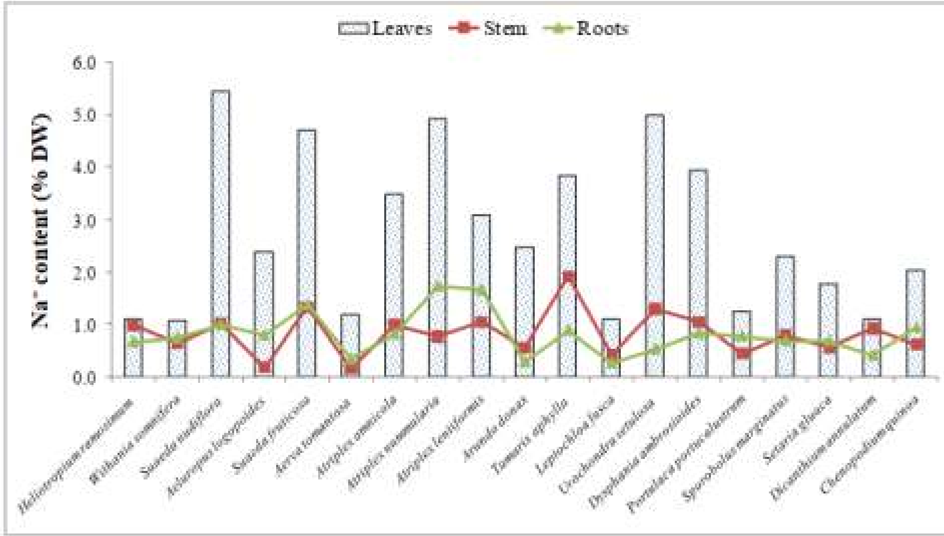


Fig.26. Na$^+$ partitioning in leaves, stem and roots of the halophytic plants

K$^+$ and Cl$^-$ accumulation was also higher in *Sueada nudiflora* followed by *Urochondra setulosa* and *Atriplex nummularia* while *Portulaca portucalustrum* and *Desmostachya bippinnata* had the lower accumulation. Among osmolytes, higher accumulation of proline, total soluble sugars and total soluble proteins were noted in both leaves and stem. Maximum proline accumulation in leaves was recorded in *Chenopodium quinoa* (5.67 mg g^{-1}) followed by *Aerva tomatosa* (5.51 mg g^{-1}) whereas in roots higher amount in *Aerva tomatosa* (2.32 mg g^{-1}) followed by *Aeluropus lagopoides* (2.32 mg g^{-1}). *Sueada nudiflora* recorded highest accumulation of total soluble sugars (7.07 mg g^{-1}) which was closely followed by *Dysphania ambrosioides* (7.07 mg g^{-1}) in leaves and *Aeluropus* accumulated highest TSS in stem (5.12 mg g^{-1}). On mean basis, leaves had accumulated 6.52 mg g^{-1} of total soluble proteins while roots had 2.81 mg g^{-1}, maximum amount was recorded in leaves of *Heliotropium ramosimum* (8.53 mg g^{-1}) and in roots of *Atriplex amnicola* (5.55 mg g^{-1}).

Table 23: Effect of salinity on the antioxidative defense system in halophytic plants

Halophytes	Ascorbate peroxidase activity (Unit g^{-1} FW)	Superoxide dismutase activity (Unit g^{-1} FW)	Catalase activity (Unit g-1 FW)	Peroxidase activity (Unit g^{-1} FW)	MDA content (nmol g^{-1} FW)	H_2O_2 content (nmol g^{-1} FW)
Urochondra setulosa	24.35±1.61	87.58±1.75	3.71±0.08	285.0±22.53	4.91±0.06	44.69±2.53
Sporobolus marginatus	8.13±0.53	34.31±1.78	2.71±0.02	117.29±8.79	3.56±0.07	71.25±2.78
Leptochloa fusca	16.62±0.82	46.86±0.76	2.91±0.05	216.43±5.3	3.85±0.05	65.16±3.61
Atriplex numuleria	20.84±0.35	63.87±0.86	3.79±0.04	519.36±3.1	4.44±0.07	68.9±3.98
Atriplex lentiformis	21.64±1.44	72.74±1.29	3.0±0.009	508.08±9.3	3.32±0.05	42.98±2.23
Sueada nudiflora	18.59±0.39	55.13±0.43	4.05±0.10	125.75±6.34	2.15±0.03	49.36±2.63
Tamarix aphylla	11.79±0.23	40.69±0.97	2.18±0.14	161.28±6.17	1.47±0.02	29.04±2.33
Arundo donax	15.7±0.113	39.41±0.86	2.56±0.14	141.54±9.77	2.51±0.02	53.91±1.79
Aeluropus lagopoides	17.73±0.33	55.45±0.79	2.91±0.11	133.76±10.85	3.42±0.06	36.52±3.21
Heliotropium ramosimum	10.52±0.27	33.51±1.29	2.24±0.06	109.4±6.37	3.92±0.03	42.26±1.42
CD@5%	2.46±0.82	3.36±1.123	0.219±0.07	30.64±10.24	0.156±0.05	7.04±2.35
CV 8.564	3.679	4.222	7.648	2.687	8.077	

Based on these characters, 10 halophytic species were selected and analyzed for their antioxidative defense mechanism. Significant variability was noted among the halophytes and observed that *Urochondra setulosa* showed higher APX (24.35 Units g^{-1} FW) and SOD (87.58 Units g^{-1} FW) activity, *Sueada nudiflora* showed higher CAT activity (4.05 Units g^{-1} FW) and *Atriplex nummularia* showed higher peroxidase activity (519.36 Units g^{-1} FW), respectively in comparison to other species. This showed that the enhanced activity of antioxidative enzymes protect these plants from the damage caused by salt induced oxidative stress as well as these species have some potential to mitigate the negative effects of reactive oxygen species (ROS). *Urochondra setulosa* had higher lipid peroxidation (MDA content) closely followed by *Atriplex nummularia*. Maximum values of H_2O_2 content was recorded in *Sporobolus marginatus* (71.25 nmol g^{-1} FW) followed by *Atriplex nummularia* (68.9 nmol g^{-1} FW) and *Leptochloa fusca* (65.16 nmol g^{-1} FW).

Morpho-physiological characterization and standardization of agronomic practices of quinoa (*Chenopodium quinoa*) for salt affected agro-ecosystems

(Kailash Prajapat, S.K. Sanwal and P.C. Sharma)

Quinoa (*Chenopodium quinoa*) could be a potential economic crop in saline areas of India. Looking into its prospective as salt tolerance economic crop, a pot experiment is being carried out to evaluate the available germplasm lines under varying levels of irrigation water salinity. During *rabi* season (November–April) of 2018-19, 19 germplasm lines have been evaluated under four levels of irrigation water salinity (Best available water (BAW), 8.0, 16.0 and 24.0 dS m^{-1}) to evaluate the response of quinoa to saline water in Indian conditions. Among the various germplasm lines, EC 507740 recorded significantly maximum mean grain yield of 11.08 g $plant^{-1}$ being on par with local accession 1 (L1), local accession 2 (L2), EC507746 and EC507748 . The

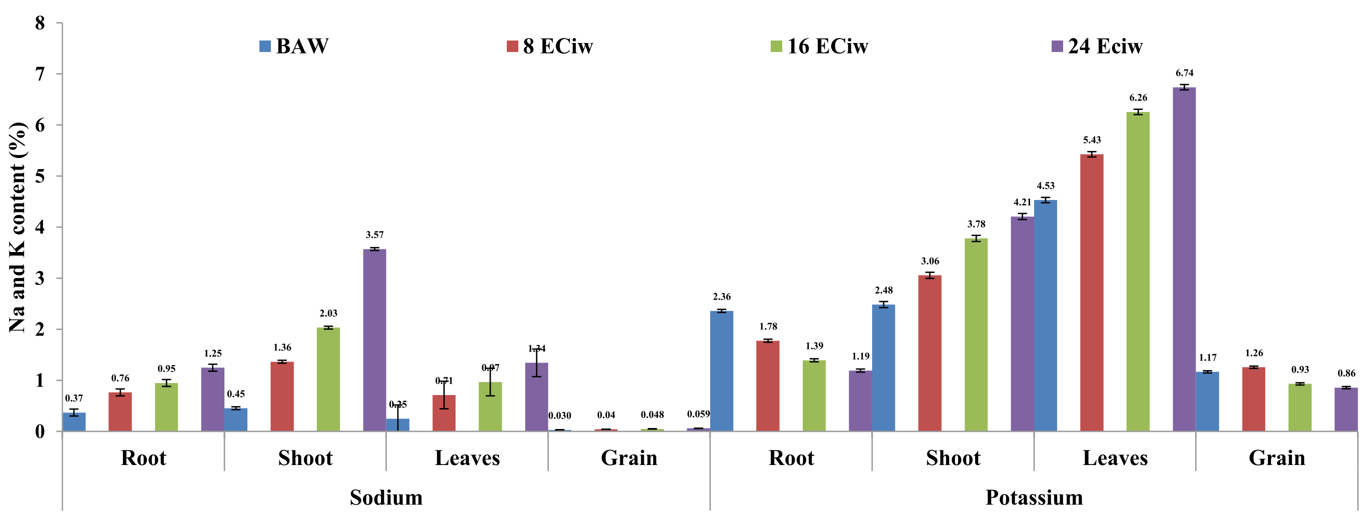


Fig. 27.Effect of irrigation water salinity on Na and K concentration in root, shoot, leaves and grains of quinoa

germplasm EC 507740 also gave maximum grain yield of 9.20 g $plant^{-1}$ at highest levels of salinity (24 dS m^{-1}). The increase in irrigation water salinity significantly reduced the grain yield of quinoa lines and across the germplasm, the magnitude of reduction was19.5, 34.9 and 50.2 per cent under 8.0, 16 and 24 dS m^{-1} EC_{iw} over BAW irrigation.

The ionic partitioning of Na and K also studied in plant root, shoot and leaves of quinoa lines at flowering stage and in grains after harvesting. The Na concentration in all the plant part increased significantly with the increasing irrigation water salinity (Fig. 27). The maximum accumulation of sodium under saline water irrigation was found in shoot of the plants followed by leaves and root, and very less quantity of sodium trans-located to the seeds. The accumulation of sodium in shoot was much higher (1.35, 2.03 and 3.57 per cent content) as compared to other plant parts, which shows adaptive advantage to leaves by controlling Na transport from shoot to leaves. The K content in root and grains of quinoa germplasm was decreased significantly with the increase in salinity of irrigation water from 8-24 dS m^{-1} EC_{iw}. Contrary to this, the K content in shoot and leaves increased significantly with consistent increase in ECiw from 8 to 24 dS m^{-1}. This indicated the capability of quinoa to maintain high K concentration in leaves to mitigate the adverse effect of Na by maintaining favourable K/Na ratio.

Alternate Land Use

Identification of salt tolerant genotypes in jamun (*Syzygium cumini* L. Skeels)

(Anshuman Singh and Ashwani Kumar)

Jamun (*Syzygium cumini* L. Skeels), a medicinally important underutilized fruit of Indian origin, is widely grown in salt-affected arid and semi-arid areas. In this study, 48 jamun accessions (20 monoembryonic and 24 polyembryonic types) collected from different agro-ecological regions of India were assessed for salt tolerance. Plants were grown in earthen pots containing normal soil and irrigated with control and saline waters. Salinity of irrigation water (EC_{iw}) was increased gradually to 12.0 dS m^{-1}. Salt stress suppressed plant growth as evidenced by significant reductions in plant height, stem diameter, number of leaves, leaf area and plant dry mass. Although salt-induced reductions in plant height, stem diameter and number of leaves as compared to control (i.e., ~22.0, 8.0 and 10.0%, respectively) were almost similar in monoembryonic and polyembryonic seedlings, decreases in leaf area (individual leaves) and plant dry mass were relatively more in monoembryonic (~13.6 and 26.6%, respectively) than in polyembryonic types (~11.4 and 22.5%, respectively). Regardless of seedling type (*i.e.*, mono- or poly-embryonic), leaf, stem and root Na^+ and Cl^- contents were significantly higher in salt stressed than in fresh water treated plants. However, individual genotypes differed with each other in leaf Na^+ and Cl^- accumulation. Relative increase in leaf Na^+ than control revealed strong Na^+ exclusion efficiency in genotypes 'HR-9' (Sonipat), 'GJ-2' (Bharuch), 'MH-1' (Nandurbar), 'RJ-2' (Ajmer), 'RJ-6' (Rajsamand) and 'RJ-7' (Sirohi). Similarly, genotypes 'MH-1' (Nandurbar), 'MH-3' (Amravati), 'TS-1' (Hyderabad), 'UP-5' (Mirzapur) and 'UP-8' (Jaunpur) were found to be efficient Cl^- excluders. Interestingly, leaf and root K^+ contents did not differ significantly between control and salt treatments (Table 24). Based on relative reduction in plant dry mass in saline than in control treatment, genotypes were grouped into highly salt tolerant (3), tolerant (5), moderately tolerant (33), sensitive (5) and highly salt sensitive (2) categories. Genotypes 'RJ-6' (Rajsamand) and 'UP-6' (Varanasi) were found to be the highly salt tolerant and sensitive, respectively. Selected genotypes, with contrasting salt tolerance are being assessed for elucidating different physio-biochemical traits underpinning salt tolerance.

Table 24: Effect of salinity on leaf, stem and root Na^+, K^+ and Cl^- (mg g^{-1} DW) in monoembryonic and polyembryonic jamun genotypes.

Variable	Monoembryonic			Polyembryonic		
	Control	Salinity	Sig.	Control	Salinity	Sig.
Leaf Na+	1.24±0.09	2.28±0.17	***	1.19±0.04	2.13±0.13	***
Stem Na+	1.69±0.04	2.66±0.11	***	1.83±0.04	2.76±0.09	***
Root Na+	1.63±0.03	2.26±0.05	***	1.66±0.04	2.50±0.06	***
Leaf K+	4.97±0.17	5.37±0.26	NS	4.89±0.16	4.69±0.18	NS
Stem K+	8.96±0.33	6.50±0.16	***	8.79±0.21	7.08±0.13	***
Root K+	3.62±0.06	3.58±0.07	NS	3.70±0.06	3.59±0.06	NS
Leaf Cl-	0.75±0.03	1.32±0.06	***	0.97±0.06	1.64±0.12	***
Stem Cl-	0.49±0.03	0.73±0.05	*	0.50±0.02	0.77±0.04	**
Root Cl-	0.51±0.02	0.72±0.03	**	0.53±0.02	0.68±0.02	**

Note: Each value represents mean ±SE. * ** and *** denote significant differences at 5, 1 and 0.1%, respectively. NS- non-significant.

Identification of high yielding and salt tolerant genotypes of pomegranate

(Anshuman Singh and Anita Mann)

Pomegranate (*Punica granatum* L., family: Lytheraceae) is a major fruit crop in many regions of the world where soil salinity and fresh water scarcity are principal constraints to crop production. Although adverse effects of salinity on pomegranate growth are well understood, little is known about how pomegranate plants respond to salinity and associated problems like waterlogging under field conditions. This experiment was conducted at ICAR-CSSRI Outreach Experimental Farm, Nain (Panipat, India) to study the effects of salinity on vegetative growth, leaf physiological parameters and fruit quality traits in 15 genotypes of pomegranate. The maximum (216.80 cm) and the minimum (174.77 cm) plant heights were recorded in genotypes 'Jaipur-1' and 'Bhagwa', respectively. Similarly, the highest (3.75 m^3) and the lowest (1.66 m^3) canopy volumes were noted in 'Rajsamand-2' and 'Jodhpur-1'. Trunk cross sectional area was the maximum (48.20 cm^2) in 'Ajmer-1' and the minimum (28.58 cm^2) in 'Bhagwa'. Pomegranate genotypes exhibited significant differences for the leaf physiological traits. Total leaf chlorophyll (mg g^{-1} FW) ranged between 0.61 ('Jaipur-1') and 1.36 ('Jaipur-3'), water potential (Mpa) between -2.24 ('Rajsamand-3') and -3.26 ('Ganesh'), osmolarity of leaf sap (mmol kg^{-1}) between 167.0 ('Jaipur-1') and 266.3 ('Pali-1'), H_2O_2 (nmol g^{-1} FW) between 129.78 ('Rajsamand-3') and 209.43 ('Jaipur-1'), malondialdehyde (nmol g^{-1} FW) between 1.93 ('Rajsamand-1') and 4.09 ('Rajsamand-2'), and leaf proline (mg g^{-1} FW) between 1.77 (Jodhpur-1) and 2.74 ('Rajsamand-1'). Pomegranate genotypes differed considerably from each other in leaf Na^+ and K^+ accumulation. Based on leaf Na^+ content, genotypes were grouped into three different categories: low accumulators (*i.e.*, leaf $Na^+ <$ 2.0 mg g^{-1} DW: 'Ajmer-1', 'Udaipur-1', 'Udaipur-2', 'Jodhpur-1', 'Ganesh' and 'Bhagwa'), medium accumulators (leaf Na^+ 2.0-3.0 mg g^{-1} DW: 'Jaipur-1', 'Jaipur-2', 'Ajmer-2', 'Rajsamand-2', 'Rajsamand-3', 'Pali-1' and 'Nagaur') and high accumulators (leaf $Na^+ >$ 3.0

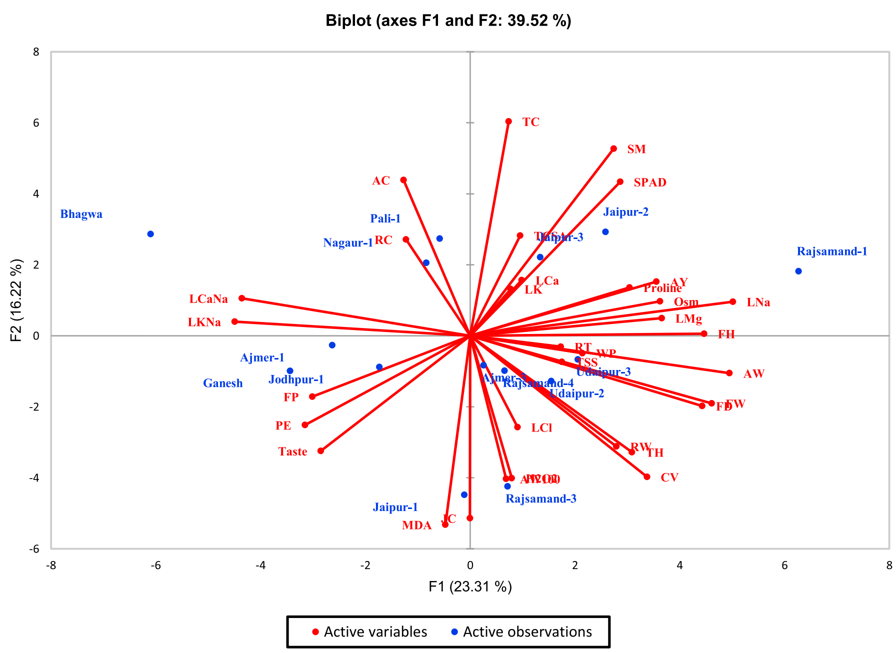


Fig. 28: Scatter plot based on PC1 and PC2

mg g^{-1} DW: 'Jaipur-3' and 'Rajsamand-1'). Leaf K^+ was the maximum (13.59 mg g^{-1} DW) in 'Ajmer-2' and the minimum (6.70 mg g^{-1} DW) in 'Jaipur-1'. Considerable genotypic variation was also seen for fruit quality traits like fruit length (6.64-8.20 cm), fruit diameter (6.58-7.68 cm), fruit weight (129.62-241.57 g), aril weight (77.0-156.7 g), juice content (36.02-55.57%) and fruit total soluble solids (12.88-15.41 °Brix). Principal component analysis (PCA) based on plant growth, physiological traits and fruit quality attributes revealed that first six principal components explained about 80.0% of the variability in data. First two components explaining about 40.0% of the cumulative variation (PC1: 23.31%; PC2: 16.22%) were retained for further analysis (Fig. 28). Fruit length, fruit diameter, fruit weight and aril weight were some of the highly loaded variables in PC1; while leaf chlorophyll, H_2O_2 and malondialdehyde contents in PC2. PCA results confirmed that genotype 'Bhagwa' was distinct from others with regard to the traits studied, which was also confirmed by the grouping of genotypes according to agglomerative hierarchical clustering.

Identification of salt tolerant scion and rootstocks in mango and low chill temperate fruits (Anshuman Singh, Ashwani Kumar, R. K. Yadav and P. C. Sharma)

In this project, selected scion and rootstock cultivars in mango and low chill temperate fruits (peach and pear) are being evaluated for salt tolerance.

Mango: In mango, 23 genotypes consisting of 2 wild species (*Mangifera zeylanica* and *M. odorata*), monoembryonic (e.g., 'Angoordana', 'Baramasi' and 'Ceylon') and polyembryonic (e.g., 'Bappakai' 'Kurukkan' and 'Moovandan') types collected from different sources were characterized using different growth and physiological parameters. Considerable inter-genotypic variability was observed for 24 different traits like plant height, number of leaves, leaf area, net photosynthesis and plant dry mass. Results of principal component analysis (PCA) confirmed that first six principal components explained about 82.0% of the cumulative variability in data. First two principal components explained 40.05 and 15.59% of the variability (*i.e.*, 59.64% of cumulative variation). Further analysis indicated that plant height, leaf area, leaf dry mass and stem dry mass were some of the highly represented variables in PC1; while leaf length: width ration, leaf chlorophyll and gas exchange traits in PC2. Genotypes 'Indonesia' and 'Baramasi' (Vengurla) were found to be distinct from others with respect to the traits studied. These genotypes are being assessed for salinity tolerance.

Low chill temperate fruits: In this study, pear cultivars 'Punjab Beauty' and 'Patharnakh' grafted on 'Kainth' (*Pyrus pashia*) and peach cultivars 'Partap' and 'Shan-e-Punjab' grafted on 'Sharbati' rootstock were planted in a partially reclaimed alkali soil for evaluation. There was considerable variation in soil pH_s at lower depths (30-60 and 60-100 cm) with some patches having very high pH_s (~9.0) than the rest (~8.4). High sub-soil pH_s suppressed plant growth to varying extents. For example, tree height decreased by about 16.0% and 29.0% in pear cultivars 'Punjab Beauty' and 'Patharnakh', respectively, when root zone soil pH_s was around 9.0. Corresponding reductions in canopy volume and trunk cross sectional area for these cultivars were 44.5% and 69.3%; and 16.5% and 41.9%, respectively. In case of peach, plant growth was more adversely affected in 'Partap' than in 'Shan-e-Punjab'. Decrease in total leaf chlorophyll, increased accumulation of malondialdehyde, hydrogen peroxide and proline was observed with increase in soil pH_s in all the cultivars (Table 25).

Table 25: Effects of high soil pH on physiological parameters in leaves.

Cultivar	Treatment	Total Chl. (mg g^{-1})	MDA (nmol g^{-1})	H_2O_2 (nmol g^{-1})	Proline (mg g^{-1})
	Pear				
Punjab Beauty	T1	1.41	8.95	130.41	3.78
	T2	1.03	9.81	146.27	5.06
Patharnakh	T1	1.12	7.43	105.74	3.92
	T2	0.88	8.91	118.55	4.71
Source of variation					
T	*	*	*	NS	
C	*	**	**	NS	
T x C	NS	*	NS	NS	
	Peach				
Partap	T1	1.56	7.74	138.12	4.06
	T2	1.08	10.58	175.57	5.31
Shan-e-Punjab	T1	1.05	7.04	153.89	4.16
	T2	0.86	10.0	187.33	5.39
Source of variation					
T	*	**	*	*	
C	**	NS	*	NS	
T x C	NS	NS	NS	NS	

Note: T1 and T2 refer to low and high sub-soil pHs, respectively. T: treatment, C: cultivar. ** - Significant at 1%, * - Significant at 5%, NS - Non Significant.

High soil pH_s altered leaf Na^+ and K^+ composition in all the cultivars studied. In comparison to low soil pH_s, leaf Na^+ increased while K^+ decreased in plants facing high soil pH_s. Pear cultivars 'Punjab Beauty' and 'Patharnakh' had 43.9% and 74.6% more leaf Na^+ at high soil pH_s than control (low soil pH_s) trees. As expected, leaf K^+ declined by about 18.0% and 29.0% in high soil pH_s treatment. Peach cultivars 'Partap' and 'Shan-e-Punjab' facing high soil pH_s had about 72.0% and 58.0% more leaf Na^+, respectively, than control trees. These observations suggested better adaptability of pear cultivar 'Punjab Beaty' and peach cultivar 'Shan-e-Punjab' in partially reclaimed alkali soils with high sub-soil pH_s.

Enhancing productivity potential of saline soil through agroforestry interventions

(Rakesh Banyal, Ajay K. Bhardwaj, Parveen Kumar and Raj Kumar)

An experiment was initiated to develop agroforestry systems and understanding of behaviour of agroforestry trees in terms of biometric gains under the influence of saline irrigation in saline soils. *Eucalyptus* and *Melia* based agroforestry systems with mustard and pearlmillet is developed through conjunctive saline irrigation (ECiw:<1, 4, 8 and to 12 dS m^{-1}). Five agroforestry tree species (*Eucalyptus tereticornis*, *Melia composita*, *Azadirachta indica*, *Dalbergia sissoo* and *Terminalia arjuna*) were planted in saline soils to develop relationship of biometric gains corresponding to age of the trees with predictive allometric models for biomass and carbon sequestration assessment.

Survival ranged from 94.4 to 100 % under varying salinity regimes giving overall to 96.7 per cent irrespective of induced irrigation and landuse treatments in *Eucalyptus*. In *Melia,* average survival was 77.2 % (varied from 66.7 to 83.3 %) along the irrigation regimes. Plant height, DBH and crown spread gave consistent decline with increase in salinity level but the lowest values were reported under rainfed conditions in both the species. There was 25.3 % reduction in plant height at ECiw 12dS m^{-1} (higher salinity) and 28.3 per cent under rainfed conditions compared to BAW in *Eucalyptus*. Similar trend was observed for other growth attributes in *Eucalyptus* and *Melia*.Mustard yield was 1.28 t ha^{-1} in open landuse, 0.53 t ha^{-1} in *Eucalyptus* and 1.14 t ha^{-1} in *Melia* based landuses. Open landuse gave higher yield than the tree based landuses. Higher saline irrigation (12 dS m^{-1}) gave lowest mustard yield compared to moderate and low salinity regimes. Mustard yield was less by 53.5 % in open plots, 44.4 % with *Eucalyptus* and 18.71 % with *Melia* based landuses under higher saline irrigation than the BAW irrigation regimes (Fig. 29). Similar observations were also reported with Pearlmillet yield trends (Fig. 30). The Peralmillet yield was 1.21 t ha^{-1} in open landuse and 0.53 and 0.82 t ha^{-1} under *Eucalyptus* and *Melia* based landuses. There was 47.4, 44.4 and 21.5 % yield was compromised with higher (12 dS m^{-1}) salinity irrigation regime compared to BAW in open (sole crop), *Eucalyptu*+crop and *Melia*+crop based landuses. The yield trends showed sharp decline after 8 dS m^{-1} irrigation water in all three landuses and in both *Rabi* and *Kharif* seasons. *Melia* trees showed cohesive effect on the companion crops because of less yield decline while compared with other two landuses. Soil EC_e observation showed that the plots irrigated with high salinity water accumulated more salts in both the seasons. Sub-surface profile showed high accumulation of salts than surface layers.

The highest increase in plant height of *Eucalyptus* was recorded from 8.21 to 13.42 m with BAW and minimum from 6.74 to 9.78 m under rainfed conditions in span of three years from 2017 to 2019. *Melia* trees also gave similar trends of increment in growth attributes. However, the plant height was less and DBH was higher in *Melia* than *Eucalyptus*. Intercrops gave decreasing trend from 2017 to 2019 under the plantations. However, the yield of both the crops almost remained same in open landuse system in all the three years.

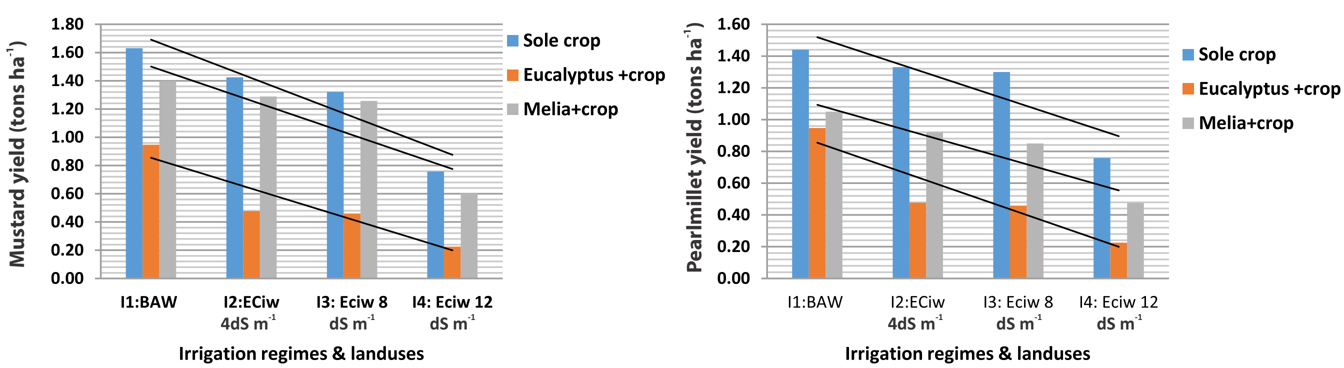


Fig. 29. Trends of Mustard and Pearlmillet yield with varying saline irrigation and land uses

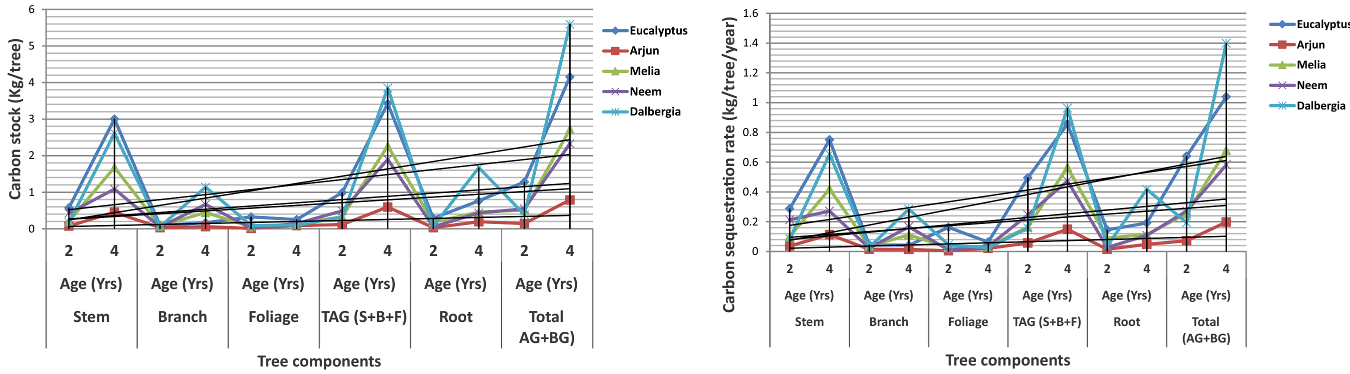


Fig. 30. Carbon stock and sequestration rate of agroforestry trees in shallow saline conditions

Soils were found to reclaim as it showed the lower values of EC_e and pH and higher values of organic carbon, nitrogen, phosphorus, potassium compared to the initial status with the plantations. *Melia*+crop land use gave higher rate of soil reclamation compared to sole crop and *Eucalyptus*+crop land use. Irrigation with low saline water i.e. BAW (best available water) showed better potential of soil reclamation than moderate and high saline irrigation with *Eucalyptus* and *Melia* based agroforestry systems. *Eucalyptus* and *Melia* plantations showed direct effect on the level of ground water table. It was at deeper level under *Eucalyptus* than the *Melia* plantations. Both the systems developed for saline soils are proven to be equally good in terms of biomass accumulation, yield of intercrops and soil reclamation. But, the *Melia* based system gave better results than the *Eucalyptus* based systems.

Eucalyptus gave highest survival of 84.78 per cent among five agroforestry trees with lowest (67.0%) in *Melia*after 4 year of plantation. The order of growth performance was *Eucalyptus* > Neem > *Dalbergia* > *Melia* > Arjun in saline soils. *Eucalyptus* also gave the higher biomass accumulation compared to other four species. *Eucalyptus* emerged as number one plant species in biomass production at 2 and 4 years of age followed by *Dalbergia*, *Melia*, Neem and Arjun. Biomass partionning showed that above ground covers 78.3 and 77.2 per cent of total biomass in all the tested trees at 2 and 4 years age. In above ground biomass, major chunk allocated to the stem and minimum to foliage component. Similar trend was observed in carbon stock, carbon dioxide equivalent (CO_2e), carbon sequestration rate and average CO_2e mitigation rate. *Eucalyptus* gave

Mustard under *Eucalyptus*

Melia trees with clear

highest CO_2e mitigation rate followed by *Dalbergia*, *Melia*, Neem and Arjun. Biomass allocation coefficients and growth efficiency attributes advocate the best performance of *Eucalyptus* in saline soils. The results showed that the *Eucalyptus tereticornis* emerged as most potential tree species for afforesting saline soils. However, *Dalbergia sissoo, Melia composita* and *Azadirachta indica* also performed equally good to each other and comparable to *Eucalyptus*.

Impact of *eucalyptus* plantations on waterlogged saline ecologies in indo-gangetic plains (Rakesh Banyal, Ajay K. Bhardwaj, R.K. Singh, Manish Kumar, Gajender, Aslam L. Pathan, Jagdish Chander and Vinod Bhatia)

Thirteen sites with seventeen data points were selected across Haryana state for assessing the impact of *Eucalyptus* plantations done by Haryana State Forest department, Govt. of Haryana. Plantations were done in two types of planting geometry i.e. block and boundary. In blocks, the spacing was 1.5 x 3.0 m, 1.5 x 4.0 m and 1.5 x 6.0 m and 1.5 x 1.5 m and 1.5x2.0 m in parallel and staggered row strip in boundary, commonly known by farmers as kila line.The overall impact of the plantation was realized through growth evaluation of *Eucalyptus*, dynamics of physical and chemical attributes of soils, exploration of potential *Eucalyptus* based agroforestry systems and above all social acceptance with impediments of *Eucalyptus* as biodrainge species in the state.

Annual percent increment of 3.85 to 22.85 in height, 16.7 to 25.11 in DBH in boundary and 8.6 to 60 in height and 8.19 to 81.5 in DBH in blocks was observed. The average plant height varied from 6.5 to 15.27 m in blocks with highest (15.27 m) at Muradpur Tekna, Rohtak in two year plantations and lowest (6.5 m) at Khabra Kalan, Fatehabad in one year plantations. DBH was maximum (14.81 cm) at Muradpur Tekna, Rohtak and lowest (7.08 cm) at Bhatol Jatan. The percent increment in growth parameters did not show any definite trend but found to vary from 3.5 to 85 percent in both the plant height and DBH attributes. Significant ground water table draw down was observed compared with the age of plantations in second, third, fourth and fifth year. Farmers were happy that the excess water is drained by the *Eucalyptus* which made their fields suitable for agriculture crops. The higher drawdown was observed in blocks than boundary plantations. The water table at Kiloi drawdown from 4.2 feet in 2018 to 2.33 feet in 2019 in block of 1400 *Eucalyptus* trees. Ground water was RSC in nature at Lahli and Ghar Tekna sites. All the selected sites showed the problem of salinity from low to moderate and high category. Bhatol Jatan in Hisarand Balana in Ambala gave highest and lowest EC_e, respectively. The soil EC_e was less in b/w plant point compared to b/w row and OFA (open fellow adjoining area) indicated the role of *Eucalyptus* in soil reclamation. Nitrogen was highest under plantation than (adjoining agriculture field) and OFA. As such, no specific well defind *Eucalyptus* based agroforestry model was seen in blocks. But, sporadically farmers of Ghar Tekna & Kiloi in Rohtak and Balana in Ambala were cultivating wheat and rice crops under *Eucalyptus* in block plantations. In boundary plantations, the farmers were growing wheat and rice with ease. However, absentee farmers rated block better than boundary plantations. As such, no vegetable and medicinal & aromatic plants (M&AP) models have been reported. The farmers were not well aware about the salt tolerant varieties of wheat, rice, mustard and gram developed by ICAR-CSSRI, Karnal. The observations were made during the field visits that the farmers are forced to give-up the farming and migrated to cities for livelihood in severely affected waterlogged saline areas.

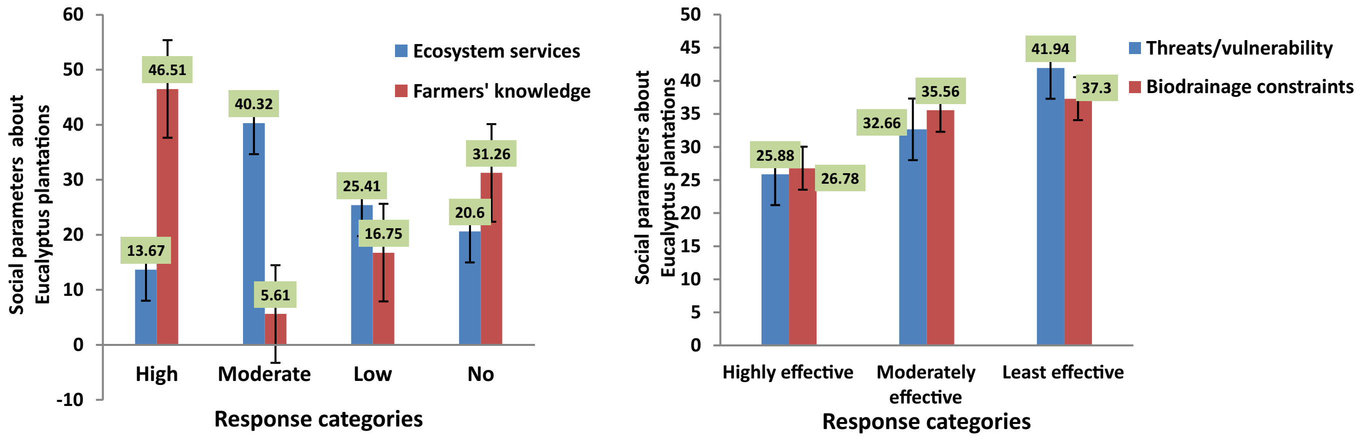


Fig. 31.Framers' response towards ecosystem services, threats/vulnerability and constraints

The farmers were interviewed through pre-tested questionnaire primarily for testing their knowledge about the role of *Eucalyptus* in providing ecosystem services, planting knowledge, preferred trees, economics and ecological effects, threats and vulnerability and constraints in biodrainge implementation. The knowledge about ecosystem services was under moderate (40.32 %) category followed by low (25.41 %), no (20.60 %) and high (13.67 %). The farmers were well versed with plantation techniques. The responses under threats/vulnerability compounding for adaptation of *Eucalyptus* plantations were under least (51.94 %) category followed by moderately (32.66 %) and highly (25.88 %) effective (Fig. 31). The responses inquired from the farmers regarding complexity of the biodrainage technology were in the order of least> moderately> highly. Biodrainage technology is socially accepted across the Haryana. Study suggests that *Eucalyptus* plantation need to be promoted for eco-friendly remediation of waterlogged saline habitats besides improving the livelihood of the distressed farming communities inhabited waterlogged saline areas of Haryana state.

Development of *prosopis* germplasm bank (Rakesh Banyal)

Ten survived *Prosopis* genotypes out of twelve gave significant accumulation in terms of growth attributes in two year old planted germplasm bank. Survival percentage was

Prosopis cineraria

Prosopis alba

highest (100 %) in PG_1 (*Prosopis cineraria*), PG_4 (*Prosopis juliflora*), PG_5 (*Prosopis juliflora)* and PG_9 (*Prosopis levingata*) and lowest (16.7%) in *Prosopisp allida* (PG_7) (Fig. 8). PG_7 outscored in plant height and crown spread among all the planted genotypes. Stem diameter was lowest in PG_5 compared to all other genotypes. The efforts will continue to add more potential genotypes of *Prosopis* to the germplasm bank in future.

Evaluation of potential olive germplasm for salt affected soils (Manish Kumar, Rakesh Banyal, Ashwani Kumar and Arijit Barman)

Olive (*Olea europea* L.) can be potential Tree Borne Oil seed (TBOs) crop for greening marginal lands, especially salt affected one due to its wider adaptability and moderately salt tolerant nature. Popularly, it is cultivated for its valuable oil in it's natural habitat in Mediterranean basin, Asia and Africa. The desired pace for bringing larger areas in India under Olive cultivation was not attained, inspite of concerted efforts for its introduction at various levels. The main knowledge gap for the existing lacuna was non-availability of suitable Olive cultivars for salt affected lands in Indian situations. Therefore, a systematic study has been initiated to screen the potential olive germplasm adapted to saline and sodic environment.

Eight cultivars procured from department of Horticulture, Jammu & Kashmir and Rajasthan Olive Cultivation Ltd. (ROCL), Jaipur, Rajasthan for testing their adaptability and understanding of its adaptive mechanism under varying salinity (control (normal) ECiw <1.0, ~5.0, ~7.5 and ~10 dS m^{-1}) and sodicity (<8.2, 8.6, 9.0 and 9.4) regimes. Eighteen months aged saplings, uniform in height were subjected to saline irrigation and sodic environment. The recorded response variables from the saplings under applied treatments were categorized in biometric, physiological and biochemical heads.

The average survival was 86, 68, 61 and 56 per cent against the four induced salinity regimes including normal (control), irrespective of cultivars. However, the highest (97%) survival was observed in Arbequina and lowest (39.5%) in Picholine cultivar, giving the highest survival rate in control and decreased with the increase in salinity level from 5 to 10 dS/m in all the cultivars.

Arbequina registered lowest 23 and 19 per cent reduction in plant height and collar diameter while compared with normal (EC_{iw} <1 dS m^{-1}) to higher saline irrigation (EC_{iw} 10 dS m^{-1}) than the rest of the tested cultivars. Proline accumulation was higher in Arbequina to the tune of 40-45 per cent compared to Leccino and Picholine cultivars, accumulated minimum proline content. Five times higher proline accumulation was observed at ECiw 10 dS m^{-1} level compared to control in Arbequina. Leaves exhibited higher Na^+ and Na^+/K^+ ratio at ECiw 10 dS m^{-1}, irrespective of cultivars. Chlorophyll content showed decreasing trend from normal to higher saline irrigation regimes and 61 per cent less chlorophyll content was observed at EC_{iw} 10 dS m^{-1} in Arbequina compared to normal. Relative water content (RWC) also decreased with the increase in salinity levels in irrigation water, causing osmotic stress in plants. Relative Stress Injuries (RSI) increased with the increase in salinity levels in all the Olive cultivars. Principal, component analysis of all the response variables reveals that 55.98 and 13.67 per cent contributed by component-1 and component-2, respectively in reference to salinity tolerance (Fig. 32). Tolerance index of survival, plant height and relative growth rate (%) in all the cultivars across the salinity regimes was worked out and found that Arbequina showed the highest average (7742) tolerance index among the tested cultivars. Picholine cultivar registered minimum (2518) tolerance index. The performance of cultivars in salinity regimes was in order of Arbequina> Koroneiki> Barnea> Picual> Coratina> Frantoio> picholine> Leccino based on the survival, biometric and physiological attributes.

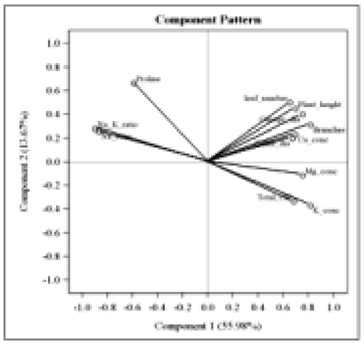


Fig. 32. PCA analysis of different traits influencing salt tolerance

Arbequina showed the better growth in sodic conditions compared to other cultivars. The ionic analysis of Na, Ca and Mg content in leaf showed increasing trend with increase in sodicity. Two times higher Na^+ concentration was recorded in high pH soil (9.4) compared to normal soil (<8.2). K^+ content showed low concentration at high pH soil. Inverse relationship was observed between leaf chlorophyll content and sodicity level. Relative stress injury (RSI) was higher at high sodicity (pH 9.4) because of reduction in water uptake by the Olive plant. The order of cultivar performance in sodic environment was Arbequina> Koroneiki> Leccino> Barnea> Frantoio> Picual> Coratina> picholine.

Overall, three cultivars (Arbequina, Koroneiki and Barnea) showed the better tolerance and adapting mechanism in reference to biometric, physiological and biochemical attributes under saline and sodic environments.

All the cultivars were planted in partially reclaimed sodic soils for evaluating their field performance. Initial trends showed that the Barnea, Picholine and Arbequina performed better compared to rest of the cultivars. The study recommends that Arbequina, Koroneiki and Barnea cultivars showed the potential for saline and sodic environments in semi-arid regions to enhance the production function of such landscapes.

Improvement of *Melia dubia* for salt tolerance through selection approach (Raj Kumar, Rakesh Banyal and Awtar Singh)

This project was initiated during March, 2018 with the aim to identify and develop quality planting material of *Meliadubia* for the salt affected soils. Twenty five germplasm of *M. dubia* were collected from different parts of the country to assess their alkalinity tolerance potential at pH 7.7, 8.5, 9.0, 9.5 and 10.0 under pot house conditions. Experimental results observed higher growth index (relative Ht. + relative Dia.) in MDFRI22 at pH 7.7 and 8.5, and in MDSS06 germplasm at pH 9.0, 9.5 and 10.0. Likewise, minimum growth index was observed in MDSS06 at these pH levels. Seedlings growth rate was satisfactory upto pH 9.0 and declined afterwards till 9.5,while, extremely less growth was observed at pH 10. Under same pH conditions, number of branches (per plant) and number of leaves (per branch)during October month was ranged maximum between 14 to 10 and 42 to 15 in MDSS06 and minimum between 6.67 to 3.33 and 24 to 5in MDSS07germplasm, respectively. Physiological parameters such as photosynthetic rate, transpiration rate, stomatal conductance and internal CO_2 concentration was observed maximum in MDSS17 and minimum in MDSS05germplasmat pH 7.7, 8.5, 9.0, 9.5 and 10.0, respectively.

In leaf tissues, accumulation of Na^+ ions was observed maximum in MDSS08 and minimum in MDSS09 germplasm. Likewise, K^+ ions at these pH levels were recorded maximum in MDFRI21 and minimum in MDFRI24 germplasm. Early seedling vigor is the key indicator of fast growth and tolerance to abiotic stresses in field conditions. Moreover, further screening and evaluation of different *M.dubia* germplasm under varying alkalinity regimes is in progress under field conditions. Overall, growth, morphological, physiological and biochemical parameters of *M. dubia* germplasm were significantly affected under increasing alkalinity levels.

Reclamation and Management of Alkali Soils of Central Eastern Gangetic Plains

Managing soil sodicity and water logging problems in permanent land modification modules under sarda sahayak canal command area (V. K. Mishra , C. L. Verma, Y. P. Singh, S. K. Jha, T. Damodaran, M.J. Kaledhonkar and P. C. Sharma)

Waterlogging and salt build up in the crop root zone are the major associated problems in canal command. Sharda Sahayak Canal is one of the major canal, which provides irrigation to 17.80 lakh ha in 16 districts of Uttar Pradesh. About 0.12 to 0.18 million ha sodic land suffer from shallow water table conditions in Sharda Sahayak Canal Command. Water and land productivity of these area are very poor. Waterlogged sodic soil can not be reclaimed sustainably through gypsum based technology. To address these problems, different land modification modules based on harvesting and management of canal seepage water for multipurpose use have been developed under farmers participatory mode on 0.6 ha land in village of Patawakhera, Lucknow.

Effect of land modification on soil properties

Soil samples were collected from different location of seepage interception zone of land modification model during the month of December 2019. The soil properties are presented in table 26. The significant reduction in surface and sub surface soil pH was recorded under land shaping model over the control. Before the interception of seepage water, the pH was higher over the after inter caption zone (AIZ) The soil EC was found to be in order of IZ< AIZ<BIZ <FIZ. The IZ significantly increased the soil organic carbon content with its maximum value of 0.325 %.

Pond water quality

The pH of the pond water was almost same during the period of 2015-19. The EC of the water was less than <1 dS m^{-1} during five years. The CO_3 and HCO_3 which is major sources of alkalinity varied from 0 to 2.07 me l^{-1} and 4.06 to 8.12 , respectively. The Ca content in water slightly increased from 1.50 me l^{-1} in 2014 to 2.12 me l^{-1} in 2018. The Cl content was decreased over the time and minimum value 1.0 me l^{-1} was recorded in 2019. The Na ions is dominant while the K is apparently low.

Impact of land modification on farmers income

The monthly and total income earned by the farmers is presented in Fig. 33. From 0 .60 ha

Table 26: Soil Properties under different intercept zone (Patwakhra)

Soil Parameter	Depth Cm	BIZ	IZ	AIZ	FIZ	LSD=0.05
pH_2	0-15	9.47	8.21	9.18	9.63	0.23
	15-30	9.63	8.60	9.49	9.70	0.24
EC_2 (dS m^{-1})	0-15	0.67	0.33	0.646	1.01	0.10
	15-30	0.58	0.28	0.621	0.92	0.22
Organic Carbon %	0-15	0.16	0.33	0.184	0.13	0.03
	15-30	0.12	0.28	0.150	0.12	0.02

BIZ= before interception zone (Between canal and land modification model), IZ=interception zone(land modification model),AIZ= after interception zone (area after model on seepage interception line)FIZ=free interception zone (Control)

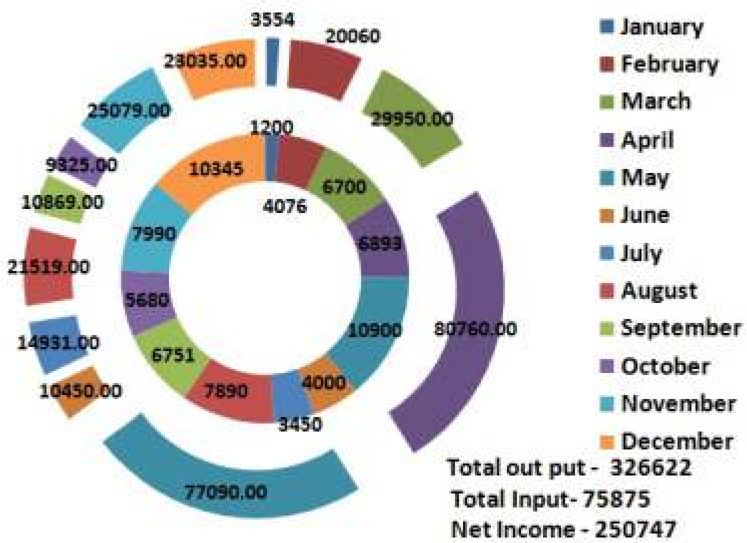


Fig. 33. Farmers monthly income from the 0.6 ha land under waterlogged sodic soil by land modification model

land, the beneficiaries received net income of Rs 250747 in 2019. The maximum income was received during the month of April. The model has also boosted the land and water productivity remarkably and has helped in checking further secondary salinization of the area. The system may bring back more than lakh ha of barren unproductive land under cultivation in canal command area of Uttar Pradesh. The migration of the farmers from rural to urban may also be halted besides providing employment opportunity at village level for school drop outs.

On farm demonstration of salt tolerant rice cultivars (V. K. Mishra)

A field demonstrations of salt tolerant rice cultivars were conducted in Barraiya and Barahi village, Sandila, Hardoi Uttar Pradesh under normal and sodic environment. The initial soil pH of normal soil varied from 7.25 to 7.95 where as sodic soil pH was in the range of 9.22-9.34. Two salt tolerant cultivars CSR 43 , CSR 56 and one rice hybrid cultivars Golden 6444 were used for comparison. Rice was transplanted on 18 July 2019. The recommended dose of fertilizers was used for normal soil whereas 1.25 times higher dose of NPK was applied in sodic soil. Zinc sulphate was applied @ 25 kg ha^{-1} in each plot. Seed was treated with CSR Bio. In sodic soil, the performance of both the salt tolerant cultivars was superior over the hybrid rice. However, under normal soil highest yield was produced

Table 27: On farm demonstration of salt tolerant rice cultivars at village Birahana, Sandila, Hardoi

Soil pH	CSR 43	CSR 56	Golden 6444 (Hybrid)	Per cent Increase/ decrease of salt tolerant cultivar yield
	Rice Grain Yield (t ha^{-1})			
7.91	4.21	-	6.42	-52.49
9.34	3.56	-	2.97	16.57
7.25	-	4.56	5.97	-30.92
9.22	-	3.74	2.84	24.06

Note: Each value represents mean ±SE. * ** and *** denote significant differences at 5, 1 and 0.1%, respectively. NS- non-significant.

by hybrid rice. Between two salt tolerant cultivars, the performance of CSR 56 was better than CSR 43 (Table 27).

Evaluation of irrigation system and improvement strategies for higher water productivity in canal command (Chhedi Lal Verma, Y.P. Singh, A.K.Singh, T. Damodaran, Sanjay Arora, S.K. Jha and V.K. Mishra)

Sharda sahayak canal command

Sharda Sahayak Canal System was constructed about 60 years ago to supply irrigation water to Ganga-Ghaghra doab area. Problems of waterlogging and sodicity in the canal command started precipitating within five years after the commissioning of the canal. A study was initiated in Sharda Sahayak Canal System with the following objectives.

1. To work out major production constraints in selected minor of Sharda Sahayak Canal Command.
2. Evaluation of pond based IFS Model in waterlogged sodic conditions

Land modification based integrated farming system (LMBIFS) model

The pond based integrated farming system model was constructed over Mr. Karuna Shankar's field located in village Mahraura, Raebareli (U.P.). The area suffers with severe waterlogging and sodicity. The area under the pond was 2330 m^2 and under elevated field bed was 2730 m^2 making system area of 5060 m^2.

Land and water productivity of different crops grown over old pond based integrated farming system models were calculated for different crops and presented in Table 28. It may be seen from that Ghasita Ram from Patwakheda obtained yield potential of wheat, onion, grass and fish as 6.11, 1.15, 1.51 and 3.31 t ha^{-1} for which water use efficiency

Crop performance at IFS Models.

Table 28: Water and land productivity for different IFS Models.

Crop Name	Area m2	Yield t ha^{-1}	Water use efficiency kg/ha-cm Rs/m^3	Water Productivity	Land Productivity kg/m^2
	Farmer: Ghasita Ram Village: Patwakheda				
Wheat (2018-19)	700	6.11	382.14	66.30	0.61
Onion (2018-19)	250	11.52	384.00	57.60	1.52
Grass (2018-19)	200	15.10	1006.67	50.30	1.51
Fish (2018-19)	1300	3.31	33.07	39.69	0.33
	Farmer: Dinesh, Village: Patwakheda				
Rice 2019	375	4.96	248.00	46.25	0.50
Sponge Gourd (2019)	375	43.39	1314.75	236.65	4.34
Cow pea (2019)	250	17.76	444.00	146.52	1.78
Brinjal (2019)	375	62.53	1202.53	240.51	6.25
Tomato (2019)	300	113.27	1936.18	425.96	11.33
Fish (2019)	1300	3.66	33.29	43.27	0.37
	Farmer: Jitendra Singh, Village: Lalaikheda				
Tomato (2018)	560	116.07	1842.40	368.48	11.60
Watermelon (2019)	560	23.21	1289.68	290.17	2.32
	Farmer: Sher Bahadur, Salempur Achaka				
Mentha (2019)	1100	182 liter	3.030	45.45	0.02
Fodder (2019)	1100	45.46	2272.72	113.63	4.54
Fish	1225	8.53	77.92	77.92	0.86

were 3.82, 3.84, 1.00 and 3.3 t ha^{-1} cm; water productivity 66.30, 57.60, 50.30 and, 39.69 Rs/m^3 and land productivity were 0.61, 1.52, 1.51 and 0.33 kg/m^2, respectively. Dinesh from Patwakheda obtained yield potential of rice, sponge gourd, cow pea, brinjal, tomato and fish as 4.96, 43.39, 17.76, 62.53, 113.28 and 3.66 t ha^{-1} with corresponding water use efficiency of 248.00, 1314.75, 444.00, 1202.53, 1936.18 and 33.29 kg/ha-cm, water productivity of 46.25, 236.65, 146.52, 240.51, 425.96 and 43.27 Rs/m^3 and land productivity of 0.50, 4.34, 1.78, 6.25, 11.33 and 0.37 kg/m^2, respectively. Jitendra from Lalaikheda village reported yield potential of Tomato and water melon as 116.07 and 23.21 t ha^{-1} which resulted in water use efficiency of 1842.40 and 1289.68 kg/ha-cm, water productivity of 368.48 and 290.17 Rs/m^3 and land productivity of 11.60 and 2.32 kg/m^2, respectively. Sher Bahadur of Salempur Achaka village with normal soil obtained yield potential of mentha, fodder and fish as 182 liter, 45.45 t ha^{-1} and 8.53 t ha^{-1} with corresponding water use efficiency of 3.030, 2272.72 and 77.92 kg/ha-cm, water productivity of 45.45, 113.63 and 77.92 Rs/m^3 and land productivity as 0.02, 4.54 and 0.86 kg/m^2, respectively.

Salt accumulation model

Salt accumulation in the root zone is a common problem in waterlogged soil. The salt accumulation rate is directly related to the evaporation rate from the soil surface. A water evaporation model was developed in response to the water table depth below ground surface for estimating salt accumulation in soil with time. Four hypotheses were tested with lysimetric and climatic data of the region. The hypothesis which was found the best is stated below.

Hypothesis: The rate of change of incremental evaporation loss with respect to the incremental water table depth below ground surface (dy) over a specified time span is inversely proportional to appropriated water table depth below ground surface (y^a). Mathematically it can be expressed as below.

$$\frac{dE}{dy} \propto \frac{k}{y^a} \qquad (28)$$

which was translated to a governing equation as below.

$$\frac{dE}{dy} = \frac{k}{y^a} \qquad (29)$$

A generalized solution of the governing equation (20) was obtained as below.

$$E_y = \frac{1}{\left(\frac{1}{E_p}\right) + a\, y^b} \qquad (39)$$

Lysimetric data and climatic data used for estimation of model constants are given in Fig. 34. The model fitted best with the experimental data with high correlation of r=0.98399711 and S=3.03717202 (Fig. 35). The model is named as Inverse Appropriated Water Table Depth Model. Continuous water table was monitored at Kashrawan village for studying the effect of biodrainage belt for year 2003 was used for the calculation of salt accumulation using the present model. The range of salt accumulation was 0.1110 to 0.6015 mg kg^{-1} with average of 0.3178 mg kg^{-1}. Model seems to be performing well under field conditions.

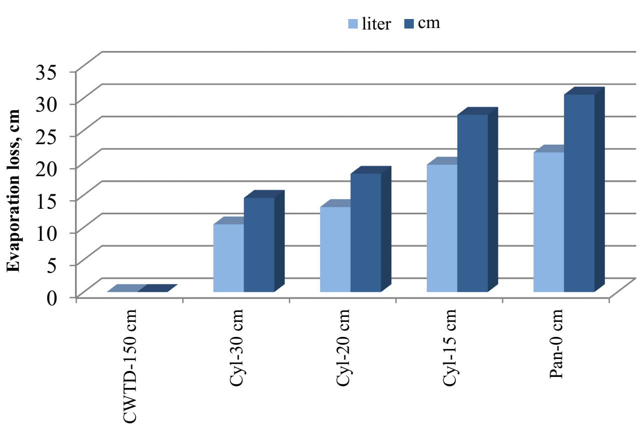


Fig. 34. Variation of evaporation loss with water table depth in lysimeters.

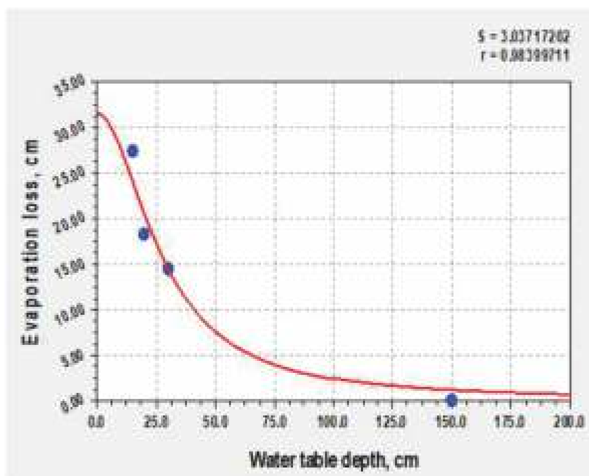


Fig.35. The Model explaining the evaporation loss against water table depths.

Rain Water harvesting, storage, use and recharge in fluoride affected area of U.P. (Chhedi Lal Verma, S.K. Jha and A. K. Singh)

Safe limit of fluoride concentration in drinking water is given as 1.0 ppm which was reset by the BIS: 105001991 as 1.5 mg l^{-1} keeping the climate of Indian sub-continent in view. Rural people in different parts of the country are forced to consume fluoride laden water up to 24 mg l^{-1}. Children up to an age group of 12 years has great risk to fluorosis due to formative/growth stage of their body tissues. Ground water is the source of fluoride in rural areas as it is being used directly for human consumption without any prior test and treatments. In the area receiving plenty of rainfall, storage and dilution of fluoride in drinking water seems an easiest solution of the problem. Roof top harvesting, storage and its use for dilution of fluoride concentration and total dissolved solid can be considered as a solution. Storage and recharge through open well could be looked as a solution for the community. The present study was taken up for remediation of fluoride contaminated water in Unnao district of U.P. in high risk zone.

Variations of fluoride

Fluoride variations in hand pumps and open wells of the Maheshkheda village of Unnao district were measured. The fluoride concentrations of the village ground water (hand pump) ranged between 0.83 to 10.20 mg l^{-1} with an average value of 4.42 and total dissolved solid (TDS) ranged 460.00 to 2889.00 mg l^{-1} with average value of 1237.8 mg l^{-1}. Fluoride variations in open wells ranged from 5.17 to 9.96 with average value of 7.65 and TDS ranged from 313.0 to 4054.0 with average of 2169.97 mg L^{-1}. Fluoride and TDS levels were high in open wells.

Construction of rain water storage structure

A rain water storage structure of dimension 2.0 m x1.5 m x 1.5 m was constructed at the campus of CSSRI RRS, Lucknow for detailed study Rain water harvested through roof top was diverted through 100 mm PVC pipe to the storage tank (Fig. 36). Average EC of rain water was measured as 0.26 dS m^{-1} and average pH 6.15. EC of rain water stored in plastic drum ranged 0.12 to 0.26 dS m^{-1} and pH 7.35 to 7.55 and that stored in brick cement structure ranged 0.23 to 0.36 dS m^{-1} and pH 7.80 to 7.85 during five month storage period. Expenditure the major share (49.22%) of the construction cost goes to brick procurement followed by cement (16.61%). The share of the labour was to the tune of 20.76%. Total cost of the construction of one rain water stroage structure was Rs. 13000.00.

Evaporation loss

Initial evaporation loss during the month of September 2019 was the highest and reduced to the minimum during December 2019. Evaporation losses during the month of September, October, November and December were recorded as 334.95, 235.5, 150.3 and 74.0 mm with open top and 143.75, 89.25, 43.4 and 20.2 mm with covered top, respectively.

Cleaning of open well

A well was selected for recharge using roof top harvested rain water and storing it in ground water was cleaned by employing a pumping set in the mid of rain season.

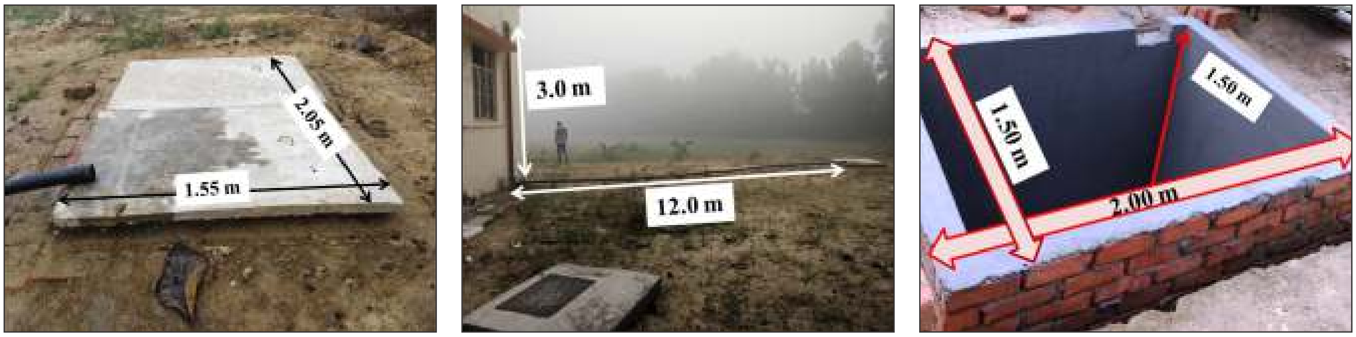


Fig. 36. A system of roof top harvesting and rainwater storage structure

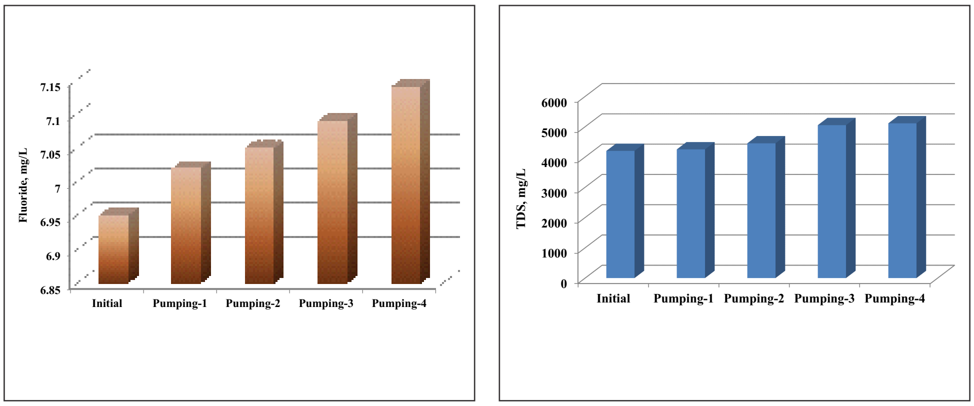


Fig. 37. Water quality during pumping spells.

Four spells of the pumping was done at an interval of 30 minute in order to avoid excessive drawdown within the well. About 1.42 m drawdown was created in first and second pumping spells and 1.18 m in third and fourth pumping spells resulting to cumulative volume of water pumped as 1.42, 2.84, 4.02 and 5.2 m^3. The variations of fluoride and TDS during pumping spells are shown in Fig. 37. It can be seen from figure that fluoride as well as TDS levels increased with each pumping spells. It is quite obvious as with depleting water level the TDS and fluoride concentration increased. Fluoride concentration increased from 6.95 to 7.14 mg l^{-1} and TDS in the water crossed the level of 5000 mg l^{-1}.

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

A field experiment continued from kharif season of 2017 which was carried out on sodic soil of Shivri farm, Lucknow with 6 treatments and three replications in the plots of 40 m^2 using a randomized block design with the hypothesis that marine gypsum (MG) could be used as an alternative to mineral gypsum (GYP) in the reclamation of sodic soils. The amendments (GYP and MG) were added based on gypsum requirement (GR) determined in the laboratory. The treatments were: T_1 – Control; T_2 – 50 GR GYP; T_3 – 50 GR MG; T_4 – 25 GR GYP; T_5 - 25 GR MG; T_6 – 25 GR

GYP+25 GR MG. In rabi 2019, the wheat was harvested and the yield was found to be numerically higher (3.15 t ha^{-1}) in 50 GR GYP but statistically on par with 50 GR MG (3.07 t ha^{-1}) and 25 GR GYP+25 GR MG (2.84 t ha^{-1}) (Fig. 37). The soil samples were collected after wheat

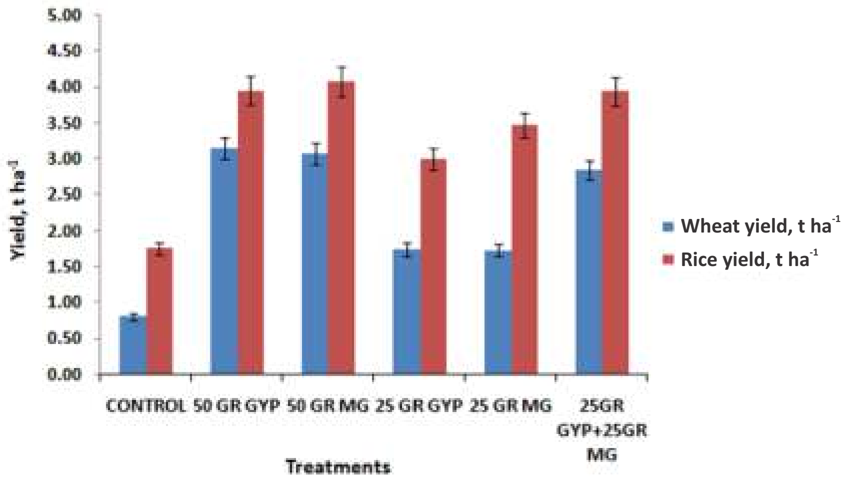


Fig. 38. Effect of marine gypsum on wheat and rice yield

harvest was subjected to physico-chemical analysis. Maximum reduction in pH_2 of 0-15 cm depth was recorded in 50 GR MG with a pH value of 8.77 which was statistically on par with 50 GR GYP and 25GR GYP+25GR MG with respect to control. No significant difference in electrical conductivity (EC_2) was noticed among the treatments. In 15-30 cm soil depth, the pH_2 values were statistically at par in 50 GR GYP, 50 GR MG and 25 GR GYP+25 GR MG.

The rice yield in kharif 2019, yielded numerically higher (4.08 t ha^{-1}) in 50 GR MG but statistically on par with 50 GR GYP and 25GR GYP+25GR MG. In 25 GR MG, the rice yield was found to be statistically higher (3.47 t ha^{-1}) compared to 25 GR GYP.

As the marine gypsum contained some impurities such as NaCl, KCl, $MgCl_2$ and $MgSO_4$ (Table 29), its solubility might be different than the gypsum. In order to evaluate the presence of impurities (foreign ions) on solubility of gypsum, analytical grade gypsum was shaken in presence of 0.1M, 0.2 M, 0.4M, 0.6 M, 0.8M and 1.0 M Na Cl, Mg Cl_2, and KCl. It was found that maximum solubility of gypsum existed in presence of Mg Cl_2 solution followed by KCl and Na Cl (Fig. 39).

The Mg^{2+} ions inhibit the nucleation and growth stage of precipitation of $CaSO_4.2H_2O$ and thus assisted in increasing solubility of the gypsum. The above results confirmed that the presence of the impurities in the marine gypsum is the causative factor for the increased solubility

The solubility of different size fractions of marine gypsum in terms of Ca^{2+} ion released was also evalauated and found that Ca^{2+} ion released was maximum in the lowest sized

Table 29. Composition of marine gypsum

	Literature value	Determined value
$CaSO_4.2H_2O$	89.72-92.62%	92.40%
NaCl	0 .48 to 2.08%	0.054% Na
KCl	Not Found	0.0236% K
$MgCl_2$ +$MgSO_4$	3.99%	2.88%

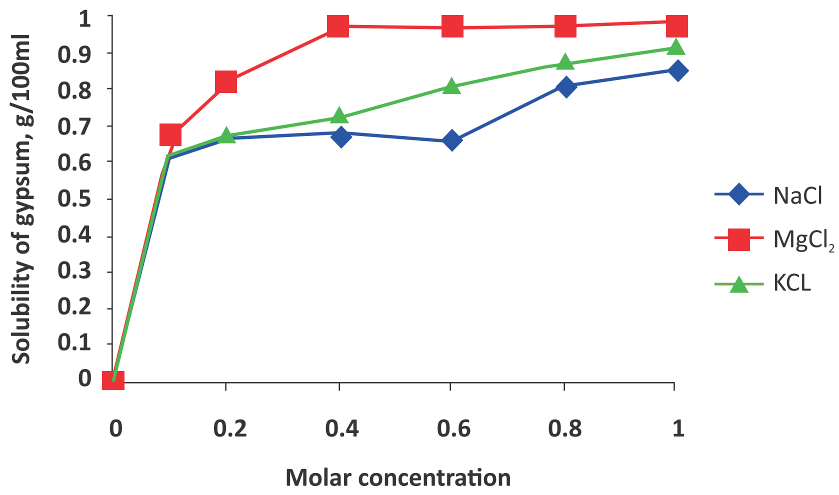


Fig. 39. Effect of impurities on the solubility of gypsum

fraction (0.2 mm size) of marine gysum, when shaken with distilled water upto 180 minutes.

Assessing potential of microbial enriched municipal solid waste compost for improving soil health and sustaining productivity of sodic soils (Y.P.Singh, Sanjay Arora, V.K. Mishra and A.K. Singh)

Salt induced soil degradation is a major concern throughout the world because it often results in the dramatic decline of agricultural production and also affects the soil physico-chemical and biological properties. Municipal Solid Waste (MSW) compost represents a source of nutrients that can improve soil fertility and, thereby contribute to restoring the productivity of salt affected soils. In addition enrichment of MSW compost with halophilic plant growth promoting microbes can be beneficial for ameliorating salt stress vis-à-vis enhance crop productivity. Keeping this in view, the work on 1) Isolation of strains of bacteria and fungi from native salt affected soil and other organic decomposing material like cow dung and municipal solid waste using specific media and 2) Enrichment of municipal solid waste compost through identified efficient microbes during composting and monitoring its performance in different sodicity levels on performance of rice and wheat crops.

Composition of Enriched MSW compost

The MSW compost collected from municipal solid waste treatment plant, Shivri, Lucknow was enriched with microbial formulations like Halo Azo + Halo PSB + Halo Zinc and analyzed for bio-chemical and microbial properties. From the analysis, it was observed that after enrichment, the quality of MSW compost improved in terms of C:N ratio and total N , P and K contents.

To monitor the efficacy of enriched municipal solid waste, three times replicated pot experiment with four treatments like T_1- 100% RDF (150;60:40 NPK + zinc sulphate 25kg ha^{-1}), T_2- Un-enriched MSW compost @10 t ha^{-1}, T_3- Enriched MSW compost @10 t ha^{-1}, T_4- Gypsum @50%GR + 100% RDF, T_5- Gypsum @25%GR + Enriched MSW compost @10 t ha^{-1} +100% RDF was conducted in a highly sodic soil (pH$_2$ 9.7, EC$_2$ 1.17,

Table 30. Plant growth and yield of rice under different treatment

Treatments	Mortality (%)	Plant height (cm)	Tillers/hill	Dry biomass (g pot^{-1})	Grain yield (g pot^{-1})
T_1	40	46	2.0	8.98	23.0
T_2	21	63	3.0	17.85	34.0
T_3	14	73	4.3	23.24	43.0
T_4	0	85	5.0	39.97	56.0
T_5	0	88	5.0	41.73	62.0
CD (p=0.05)		8.42	0.43	4.62	7.36

OC.0.05%). A uniform quantity of soil (8.0kg) was filled in each pot. The quantity of chemical amendment (gypsum) calculated on the basis of soil volume filled in the pot was mixed in the soil surface and ponded with water for 10 days to leach down the salts. As per treatment, enriched and un-enriched MSW compost was added in the pots and mixed in surface layer. Five plants of 30 days old seedlings of salt tolerant variety of rice 'CSR 36' were planted in each pot on 30.07.2018. All the relevant observations were recorded. Highest mortality (40%) was recorded in treatment T_1 followed by T_2 (21%) and T_3 (14%) and there was no mortality in treatment T_4 and T_5. Maximum plant growth in terms of plant height , tillers/hill and dry biomass were recorded in treatment T5 (application of gypsum @25%GR + enriched MSW compost @10 t ha^{-1} +100% RDF followed by T4 was applied but the difference height was recorded with treatment T5 followed by T4 (application of gypsum @50%GR + 100% RDF) but the difference between them was not significant. Grain yield increased significantly with application of enriched MSW compost over recommended dose of fertilizer and un-enriched MSW compost. Highest grain yield (62.0g pot^{-1}) was recorded with treatment T_5 which was significantly higher over T_1, T_2, T_3 but at par with T_4 (Table 30). Based on the study it was conclude that the grain yield of rice can be increased with the application of reduced dose of gypsum and enriched MSW compost @ 10 t ha^{-1}.

Stress tolerant rice for poor farmers in Asia and South Africa (STRASA) (Y.P. Singh and V.K. Mishra)

1. Sustainable farming systems and farm diversifications (ICAR-W3)

Effect of integrated nutrient management on productivity potential of Rice-wheat cropping system under different sodicity levels

To monitor yield optimizing level of salt tolerant variety of wheat (KRL 283) at different sodicity levels with integrated nutrient management a field experiment with four sodicity levels viz. S_1 –8.8, S_2 –9.0, S_3 –9.2 and S_4 – 9.4 and four integrated nutrient management (INM) treatments viz. T_1 – 100% of recommended dose of fertilizers (RDF) (150:60:40 (N:P:K), T_2 – 75% of RDF + microbial inoculants (Halo AZO + Halo PSB), T_3 - 75% of RDF + microbial inoculants (Halo AZO + Halo PSB + Halo zinc) and T_4 - 75% of RDF + growth enhancer (CSR Bio)+ zinc sulphate @ 25kg ha^{-1}. The experiment was conducted in split plot design with a plot size of 25m^2 at CSSRI, Research Farm Shivri with the objectives 1) To monitor the yield optimizing level of salt tolerant variety of rice and wheat 2) Optimizing nutrient requirement of salt tolerant varieties of rice and wheat through integration of microbial inoculants. Half dose of N, full dose of P and K was applied as basal and the remaining N was applied in two equal splits after 25 and 50 days of sowing. As per treatment wheat seed was treated with different microbial inoculants two hours before sowing and dried in shed and sown in the field.

From the data, it is evident that the plant growth and yield reduced significantly as the sodicity level increased. Maximum plant growth in terms of height, productive tillers, and dry matter were recorded with S_1 sodicity levels. As the level of sodicity increased from S_1 to S_2, S_3 and S_4, plant growth, yield contributing characters and yield reduced significantly (Table 31). Integrated nutrient management (INM) using microbial inoculants and growth enhancers played significant role in plant growth and yields. Highest grain yield was recorded with treatment T_3 (75% RDF+ Halo Azo+ Halo PSB + Halo Zinc) which was significantly higher over T_1 (100% RDF) and T_2 (75% RDF+ Halo Azo+ Halo PSB) but at par with T_4 (75% RDF+CSR-Bio+ Zinc sulphate @25kg ha^{-1}). Significant interaction between sodicity levels and INM was observed in 1000 grain weight and grain yield. (Table 31).

After harvesting of wheat salt tolerant variety of rice CSR 46 was transplanted on 10.07.2019 with the same treatments. Observations related to plant growth and yield were recorded at maturity. Maximum plant growth and yield was obtained with S_1 sodicity level and it reduced significantly with increasing sodicity levels (Table 32). Integrated nutrient management (INM) also played significant role in plant growth and yields. Highest grain yield was recorded with S_1 sodicity level at all the nutrient management treatments which was significantly higher over treatment T_2 and T_4 but at par with treatment T_3 N_1. However, in case of sodicity level S2, S3 and S4 grain yield with RDF (T_1) was significantly higher over rest of the treatments.

Cost economics of the treatments based on total variable cost, gross return, gross margin, and benefit/cost ratio (BCR) was done after rice-wheat cropping system. The economic analyses was done using prevailing market prices of inputs, labor and minimum support price of wheat and rice during 2019-20. Highest gross return was calculated from

Table 31. Crop growth and yield of salt tolerant variety of wheat (KRL 283) under different sodicity levels and integrated nutrient management practices

Treatments	Plant height (cm)	Productive tillers $plant^{-1}$	Dry matter (g $plant^{-1}$)	Spike length (cm)	Grains $spike^{-1}$	1000grain weight (g)	Grain yield (t ha^{-1})
		Sodicity levels (pH)					
S1	95.9	6.0	19.3	16.8	43.1	32.2	3.71
S2	88.7	5.2	14.3	15.3	35.5	30.1	3.35
S3	86.9	5.0	12.8	14.6	32.6	30.7	3.19
S4	80.9	4.4	10.7	14.0	31.2	30.8	2.91
CD (P=0.05)	1.27	0.29	0.98	0.65	1.17	0.54	0.11
		Integrated nutrient management					
T1	84.4	4.7	12.9	15.8	34.2	28.2	2.96
T2	86.8	5.3	15.4	16.2	36.5	32.0	3.27
T3	90.4	5.6	14.7	13.7	38.7	32.2	3.53
T4	90.9	5.1	14.1	15.1	33.3	31.34	3.41
CD(P=0.05)	1.34	0.32	1.02	1.31	2.35	0.54	0.13

Performance of KRL 283 wheat under different sodicity levels and integerated nutrient management

Table 32: Grain yield of CSR 46 under different sodicity levels and integrated nutrient management practices

Sodicity levels	Nutrient management treatments				Mean
	T1	T2	T3	T4	
S1	6.78	6.27	6.72	6.41	6.54
S2	6.65	6.19	6.41	5.81	6.26
S3	6.03	5.57	5.72	5.46	5.69
S4	5.90	5.22	5.53	5.33	5.49
Mean	6.34	5.81	6.10	5.75	
CD(p=0.05)	0.16				

treatment S_1T_3 whereas; minimum with S_4T_2. It is because of highest grain and straw yield with treatment T_3 (75% of RDF + microbial inoculants (Hallo AZO + Hallo PSB + Hallo zinc). The highest net return and B:C ratio was computed from treatment S_1T_3 where, 25% N was replaced with treating the rice seedlings and wheat seed with microbial inoculants (Halo AZO + Halo PSB + Halo zinc) followed by S_1T_4. Similar trend was recorded at all sodicity levels (Fig. 40).

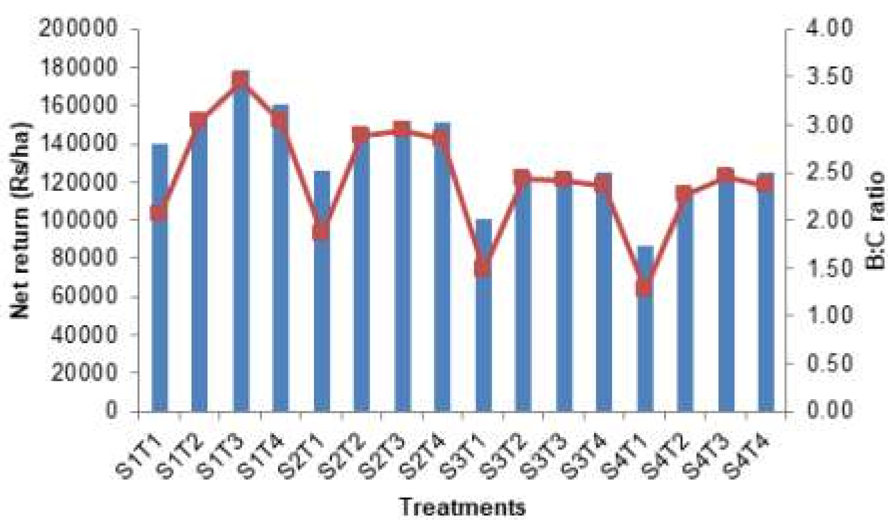


Fig. 40. Net returns and B:C ratio of Rice-wheat cropping system under different integerated nutrient management treatments

Developing climate smart management practices for salt tolerant variety under rainfed conditions in sodic soils (Y.P.Singh and V.K. Mishra)

Agricultural production continues to be constrained by a number of biotic and abiotic factors that can reduce crop yield and quality. Out of all the mineral nutrients, potassium is one of the important macronutrients that plays a key role in the survival of plants under abiotic stress conditions, as stress negatively affects the physiological processes of plants. Under sodic soil conditions, plants suffer a deficiency of potassium mainly because of the excess of Na^+ in the rooting medium, which acts as an antagonist and decreases the availability of potassium. Foliar application of K fertilizer could be effective in correcting salinity-induced K-deficiency, decreasing salinity-induced damage to membranes and increasing biomass production in plants. In view of the above, a field experiment consisting of four transplanting windows viz. W1-05.07.2019, 15.07.2019, 25.07.2019 and 05.08.2019 as main plot treatment and four levels and methods of potassium application viz. T_1- 40kg K /ha as basal,T_2-40kg K /ha in three splits- 50% as basal, 25% as foliar at 30DAT and 25% foliar at panicle initiation stage,T_3-60kg K in 3 splits- 50% as basal, 25% topdressing at 30DAT and remaining 25% top dressing at panicle initiation stage, and T_4-60kg K in 3 splits- 50% basal, 25% foliar spray at 30DAT and 25% foliar at panicle initiation stage having three replications was conducted in split plot design at ICAR-CSSRI, RRS, Lucknow during Kharif 2019-20 to mitigate the effect of climate change under rainfed conditions in partially reclaimed sodic soils. Highest grain yield was obtained from treatment W_2T_3 where rice was transplanted on 15th July and 60kg K was applied in 3 splits (50% as basal, 25% top dressing at 30days after transplanting and remaining 25% as top dressing at panicle initiation stage. However, there was no significant difference in W_2 and W_3 (Table 33).

Head to head trial

Head to head trial to monitor the comparative performance of 7 high yielding latest salt tolerant rice varieties released from CSSRI viz. CSR 36, CSR 43, CSR 46, CSR 49, CSR 52, CSR 56 and CSR 60 was conducted at ICAR-CSSRI, Research farm, Shivri. The pH of the experimental field was 9.1 and EC 0.57dSm^{-1}. The recommended dose of fertilizer (150:60:40kg NPK and zinc sulphate @ 25 kg ha^{-1} was applied uniformly to all the

Table 33: Effect of transplanting windows and mode of K application on grain yield of rice (t ha^{-1}) under rainfed condition in partially reclaimed sodic soils

Transplanting windows	Treatments				
	T1	T2	T3	T4	Mean
W_1	4.95	4.39	5.22	4.00	4.64
W_2	5.58	5.52	6.10	5.87	5.77
W_3	5.12	5.66	6.04	5.78	5.65
W_4	4.02	3.67	4.25	4.76	4.17
Mean	4.92	4.81	5.40	5.16	
CD (p=0.05) for windows			0.92		
CD (p=0.05) for treatments			0.40		
CD(P=0.05) for W x T			ns		

genotypes. Among the varieties, highest grain yield (5.67 t ha^{-1}) was obtained from CSR 46 followed by CSR 36 (5.46 t ha^{-1}) and CSR 43(5.18 t ha^{-1}).

Screening and Evaluation of wheat, mustard, rice and lentil genotypes for sodicity tolerance (Y.P. Singh and V.K. Mishra)

This trial on wheat consisted of 30 entries including 2 checks was conducted at CSSRI, Research Farm Shivri, Lucknow in an augmented design with 2 replications. The pH_2 of the experimental field at the time of sowing was 9.3 and EC_2 0.92dS m^{-1}. The trial was sown on 20.11.2018 and harvested on 20.04.2019. Recommended dose of fertilizer (120:60:40 N: P: K) was applied. Among the genotypes evaluated genotype KRL1724, LBP2018-25, KRL1740 and KRL1741 found promising in terms of grain yield and produced 3.48, 3.13, 3.12, and 2.81 t ha^{-1} respectively.

All India coordinated wheat improvement (SPL-Alkalinity/Salinity) Trial

The trial consisted of 7 entries viz. SPL-AST-101, SPL-AST-102, SPL-AST-103, SPL-AST-104, SPL-AST-105, SPL-AST-106, and SPL-AST-107. The initial soil pH of the experimental field was 9.3. The experiment was laid in Randomized Block design with 4 replications having row spacing 20 cm and 4m row length with a net plot size of 8.4m^2. Wheat crop was sown on 20.11.2018 and harvested on 20.04.2019. Among the genotypes/varieties screened, genotype SPL-AST-105 produced maximum grain yield (2.9 t ha^{-1}) followed by genotypes SPL-AST-101 (2.6t ha^{-1}) and minimum (1.5 t ha^{-1}) in SPL-AST-102.

Mustard

All India coordinated trial on rapeseed mustard

An AV-1+II mustard saline/alkaline trial consisted of 12 lines was conducted under alkaline condition (pH_2 9.1 and EC_2 0.57 dS m^{-1}). These lines were sown on 16.10.2018 and harvested on 02.03.2019. Four times replicated field experiment with two rows of each entry at a spacing of 45 x 15cm was conducted in Randomized Block design. Significant differences were observed in seed yield amongst the genotypes evaluated. Seed yield ranged from 1.41 to 1.86 t ha^{-1}. Highest grain yield was recorded in entry CSCN 18-11 (1.86 t ha^{-1}) followed by CSCN18-10(1.82 t ha^{-1}) and CSCN18-7 (1.80 t ha^{-1}) (Fig. 41).

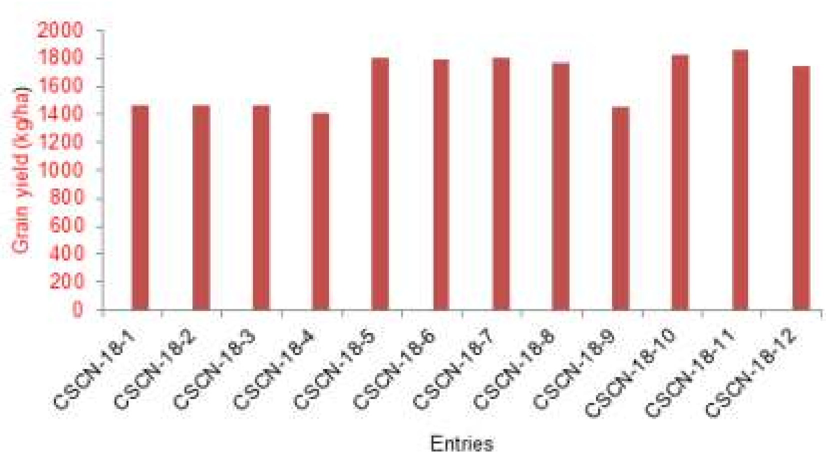


Fig. 41. Grain yield of musterd strains in alkaline conditions

Table 34: Seed yield (t ha^{-1}) of promising mustard (*Brassica juncea*) entries under different fertility levels in alkalinity conditions

Entries	Fertility levels			Mean seed Yield (t ha^{-1})
	100%RDF	125% RDF	150%RDF	
Ag-1	1677.33	1690.93	1922.23	1.76
Ag-2	1548.73	1740.83	1977.77	1.76
Ag-3	1614.97	1851.23	2015.67	1.83
Ag-4	1736.30	1885.93	2091.60	1.90
Ag-5	1352.83	1476.83	1620.17	1.48
Ag-6	1702.97	1907.07	2041.73	1.88
Ag-7	1386.17	1584.13	1844.43	1.60
Mean	1574.19	1733.85	1930.51	1.75
CD (P=0.05)	Entries (E) = 132.90	Fertility (F) = 81.15	Interaction (E x F) = NS and (F x E) = NS	

All India Coordinated Agronomy trial of AVT-2 entries under alkalinity conditions was conducted at CSSRI, Research farm Shivri, Lucknow to evaluate the performance of 7 promising rapeseed-mustard entries (Ag-1 to Ag-7) under three fertilizer levels viz. 100% of RDF, 125% of RDF and 150% of RDF. Three times replicated field experiment was conducted in split plot design at pH 9.1 and EC 0.57 dS m^{-1}. These entries were sown on 16.10.2018 having 2 rows of each and 7m length covering 7.35 m^{2} areas. Among the entries, AG-4 produced significantly higher grain yield with all the fertility levels (Table 34).

Lentil

All India Co-ordinated research project on improvement of Lentil

Consisting of 8 lentil genotypes (code 18-1 to 18-8) and three times replicated field experiment with 6 rows of 4m each was sown on 12.10.2018 in Randomized Block design and harvested on 26.04.2019. The initial soil pH and EC of the experimental field was 8.4

Performance of lentil genotypes at pH 8.4

and 0.35 dS m^{-1} respectively. The recommended dose of fertilizer (80:40:40kg ha^{-1} N:P:K) was applied uniformly in all the genotypes. Significant genotypic variation for alkalinity stress was observed among the genotypes evaluated. Among the genotypes evaluated , highest grain yield (2.12 t ha^{-1}) was obtained from genotype 18- 3 followed 18-7 92.03 t ha^{-1}) and the lowest (1.51 t ha^{-1}) in genotype 18-2.

Rice

Advance varietal trial- 1-alkaline and inland saline tolerant variety trial (AVT-1 AL& ISTVT

Advance variety trial consisting of 11 rice entries (entry no.3401 to 3411) including one local check (CSR 36) was conducted during Kharif 2019. The initial pH and EC of the experimental field was 9.5 and 1.1dS m^{-1} respectively. Thirty days old seedlings was planted on 09.08.2019. The recommended dose of fertilizer (150:60:40 N:P:K) and 0.025 t ha^{-1} zinc sulphate was applied uniformly in all the entries. Among the entries evaluated, entry number 3405, 3410 and 3402 yielded 0.022, 0.021 and 0.021 t ha^{-1}, respectively and ranked 1st , 2nd, and 3rd in terms of grain yield (Fig 42).

All India Coordinated Agronomy Trial

Nitrogen response trials on selected AVT-2 rice cultures under high and low input management environments was conducted with the objectives to study the grain yield potential, nutrient response and nutrient use efficiency and to identify promising and stable genotypes. Treatments consisted of two nitrogen levels (N_1-100% of recommended dose, N_2-150% of recommended dose in main plot and six rice cultures/varieties viz. CSR 10, CSR 23, CSR 36, IET 27077, Jaya and Moti in sub plots. The initial soil pH and EC of the experimental field was 9.0 and 0.37dS m^{-1}. Grain yield of all the entries increased with increasing levels of N. Maximum grain yield at both low and high N doses was recorded with IET 27077 which was at par with CSR 36 (Fig. 43)

F3 rice segregating lines

To evaluate the comparative performance of F3 segregating lines for alkalinity tolerance, a field experiment consisting of 44 entries was conducted. The pH of experimental field at 0- 15cm soil depth was 9.8 and EC 1.4 dSm^{-1}. The crop was transplanted on 18.07.2019 with

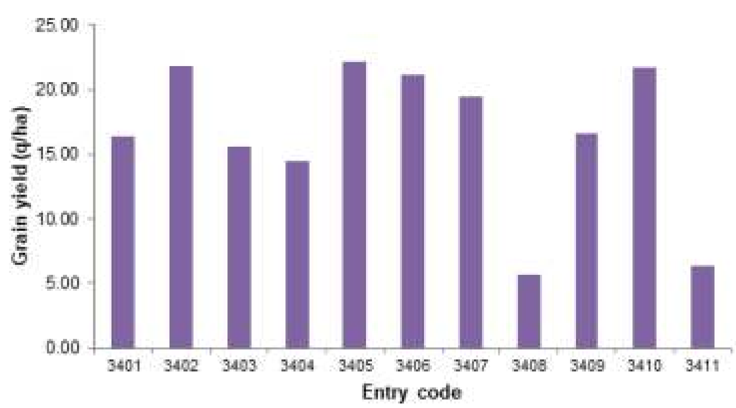


Fig. 42. Grain yield of advance alkaline and inland saline tolerant variety Trial (AVT-1 AL& ISTVT)

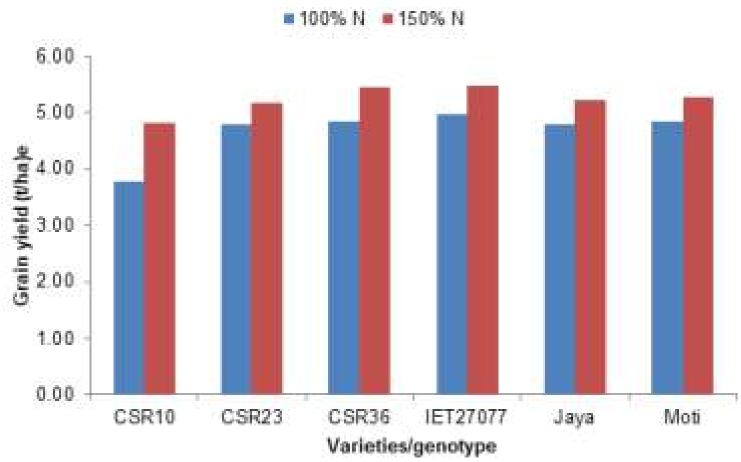


Fig.43. Grain yield of varieties/ genotypes under high and low N levels

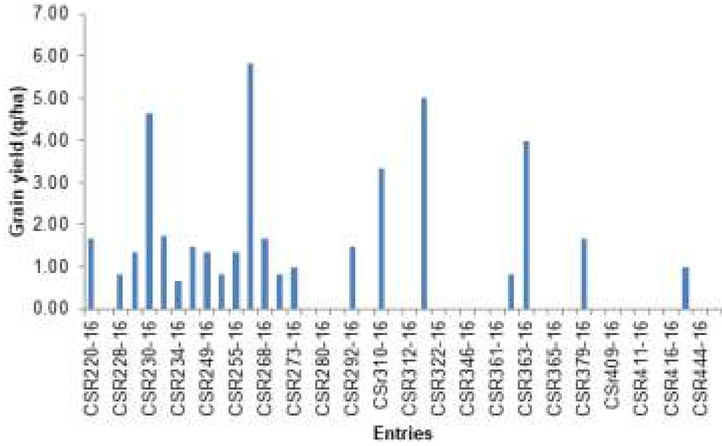


Fig.44. grain yield of F3 rice segregating lines

3 rows of 5m length having plot size of 3.0 m^2. Among the lines evaluated, 18 entries died before panicle initiation stage, 26 entries reached to the panicle initiation stage. Out of 26 entries having panicles 5 entries did not produce any grain, 16 entries produced <2.0q ha^{-1} and only 5 entries CSR257-16, CSR320-16, CSR230-16, CSR363-16 and CSr310-16 produced >3.0q ha^{-1} grain yield (Fig.44)

Performance of F_3 segregating rice lines

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

Soil moisture sensors may provide instantaneous information of soil moisture status within the root zone and accordingly help in timely application of water in desired amount. A prototype sensor based on resistive method was developed which comprises of two probes that measure the conductivity in the soil. The two probes send an electrical current into the ground, and the level of moisture is established by examining the resistance encountered by the current. When there is high moisture, the soil is more conductive and less resistant and vice versa.

Summary

A circuit based on the resistive method with constant current source was developed for preliminary testing. Probes of copper and aluminium material were selected in form of plates available in the market. The copper probes of 1.9 and 0.9 cm width having 0.3 cm thickness and aluminium probes of 2.4 and 1.1 cm width having thickness of 0.5 cm were fabricated by varying the spacing between the probes (i.e. at 1, 2, 3 and 4 cm). The length of all the probes were equal and can be inserted at varying depth of 5, 7.5, 10 and 12.5 cm in soil. The investigation resflects that with increase in probe spacing voltage drop increases due to higher resistance whereas with increase in the depth of the probes the voltage drop decreases.

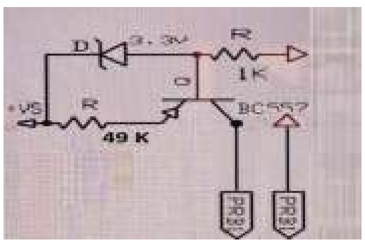


Fig. 45. Electronic circuit based on constant current source

Fig.45 shows the developed circuit, designed to supply constant current when probes will be inserted in the soil and based on change in soil resistance the voltage drops can be read. The soil resistance will vary with change in soil moisture status. Employing ohms law (V = IR, V - Voltage, I – Current and R – Resistance) at higher soil moisture content the soil will provide less resistance to conduct electric and vice versa.

The probes fabricated from aluminium and copper plates were attached with the circuit and was tested for its performance it is observed that voltage drop incase of aluminium material is higher in comparison to copper probes.

Economics of land modification models under waterlogged sodic soils of Uttar Pradesh (Subhasis Mandal, V. K. Mishra and C. L. Verma)

Land modifications models have been evolved and demonstrated by ICAR-CSSRI, RRS Lucknow in farmers field under waterlogged & saline conditions near *Sharda Shahyak* canal irrigation command areas in Uttar Pradesh to address the challenge of growing crops. The information was collected from the collaborative (8 farmers) and other farmers (55 farmers) through primary survey and focussed group discussion (FGD) during 2019-20.

Farm-level impact of land modification models (LMM)

Farm-level impact of land modification models has been analysed through identifying and estimating different indicators, cropping pattern, cropping intensity, level of crop diversification, employment opportunities, income, crop productivity, production risk, asset creation by farmers and externalities. The models were utilised to grow crops throughout the year, hence increasing the cropping intensity (from 125% to over 250-300%), crop diversification (from 0.24 to 0.86 of Simpson crop diversification index) and providing employment to the whole family throughout the year (Table 35).

Farm characteristics and socio-economic suitability of adoption of land modification models

Average farm size of the farmers in the study area was 1.03 ha and out of which 39% of their land was highly degraded (*usher*), highly sodic and also waterlogged. The land modification models are suggested for the degraded land. Based on the economics and financial feasibility of the land modification models, it was estimated that a plot size of around 1.0 ha of land will be suitable for the land modification models when farmers aspire for both crops (63% area) and fish (47% area) cultivation. On the other hand, a plot size of 0.55 ha with 64% pond area will be suitable for farmers who aspire for intensive fish cultivation along with crops (33% area).

Challenges and way forward for implementation of land modification models

Availably of land in suitable plot sizes (1.0 ha for crop-fish based interventions and 0.50 ha for fish-crop based interventions) were important challenge. Besides, willingness of farmers those having land but not sure how much land to be converted, land owners having larger plots but reluctant to convert land for fisheries as rearing fish is a social taboo, farmers were willing but land was not in their name or it was shared with multiple

Table35: Farm-level impact of land modification models at demonstration field

Indicators	With Land Modification Model	Without Land Modification Model	Remarks
Cropping pattern (choice)	Rice, wheat, vegetables, fruits, spices, mentha, fodder, potato	Rice, wheat, mentha	Any crops can be taken in LMM
Cropping intensity (%)	250 to above 300	125	Increased more than double
Crop diversification (Simpson Index)	Very high (0.86)	Low (0.24)	Multiple crops choice
Employment (man-days)	Year round	55 -70 days	Gainful engagement
Income (Rs/year)	1.45 to 3.5 lakh	negative to meager	Increased many folds and continuing benefits
Crop productivity (t ha^{-1} system yield)	3.08 to 7.78	1.5 to 2.0	Increased and benefits continuing
Risk (% yield losses)	Low	Very high (45-62)	Often returns are negative, high instability
Asset creation	35000 to 55000	meager	Buying livestock, bike, pucca house etc
Externalities	Positive	Neutral to negative	LMM improved quality of other land too

ownership, were some of the key determinants for large scale implementation of such models in the study area. This challenge can be addressed through aggregation of land by attracting private investment. As the land are highly degraded farmers were willing to leased-out their land to the investors and therefore such models can be promoted through public, public-private or private investment.

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

In-situ crop residue degradation versus residue management

Amongst the three efficient strains of cellulose and lignin degrading microbes, application of CDM3 + whey on in-situ paddy residue resulted in highest wheat yield. Similarly, maximum paddy yield with consortia of CDM and whey application was observed compared to control. In both wheat and paddy residue, the consortia of microbes degrade the crop residues to the desirable extent in 30-35 days after harvest and addition of whey had an additional advantage. Soil organic C stock in surface layer was maximum in CDM consortia application in which change in stock was 3.381 t ha^{-1} followed by 2.415 t ha^{-1} while urea 4% resulted in change in SOC stock in surface soil layer to the tune of 1.449 t ha^{-1}.

The consortia of two efficient and compatible halophilic bacterial lingo-cellulolytic strains having plant growth promotion traits was developed as liquid bio-formulation 'Halo-CRD'- a crop residue decomposer. The bioformulation was used for in-situ residue degradation in comparison to burning residues and use of urea for degrading stubbles and leftover straw in the field. Application of liquid bio-formulation Halo-CRD followed by residue incorporation resulted in maximum grain and straw yield of 23.2 and 43.7 q ha^{-1} compared to 22.7 and 41.6 q ha^{-1} with urea 4% spray (Table 36). Similarly, after harvest of wheat, the succeeding paddy yield was about 3% higher with the application of bio-formulation Halo-CRD with residue incorporation compared to urea application (Table 37).

It was observed that after treatments on the wheat residues, soil pH decreased from 8.82 as initial value to 8.25 and 8.35 with incorporation of residue with Halo-CRD and urea spray, respectively. The soil organic C content was 0.41% in residue incorporation with Halo-CRD spray compared to 0.36% in residue burning. Similarly, available N, P and K content in soil increased from initial values with CRD spray and residue incorporation. Soil bio-chemical properties also improved with application of Halo-CRD and residue

Table 36: Effect of paddy residue management on succeeding wheat (Rabi 2018-2019)

Treatment	Plant height (cm)	Grain yield (t ha^{-1})	Straw yield (q ha^{-1})
Residue burnt	84.3	1.83	3.34
Residue retained	86.5	1.89	3.65
Residue incorporated	91.7	2.02	4.04
Urea 4%+residue incorporated	97.3	2.27	4.16
CRD+ residue retained	103.4	2.19	3.98
CRD+ residue incorporated	108.2	2.32	4.37
CD (5%)	4.3	0.14	0.22

Use of Halo-CRD for in-situ crop residue degradation

Table 37: Effect of wheat residue management on succeeding paddy (*Kharif* 2019)

Treatment	Plant height (cm)	Grain yield (t ha^{-1})	Straw yield (q ha^{-1})
Residue burnt	93.2	3.68	3.84
Residue retained	95.5	3.87	3.53
Residue incorporated	96.7	4.16	4.13
Urea 4%+residue incorporated	101.6	4.61	4.27
CRD+ residue retained	105.3	4.22	4.07
CRD+ residue incorporated	107.8	4.75	4.49
CD (5%)	3.5	0.21	0.28

incorporation. Build up of DTPA-Zn and Mn content with incorporation of residues inoculated with spray of Halo-CRD.

The soil C stock in the surface soil layer was minimum of 7.392 t ha^{-1} in plots where residue was burnt while maximum of 9.471 in Halo-CRD spray with residue incorporation followed by 9.240 t ha^{-1} in residue incorporation. Soil C stock in urea sprayed with residue incorporation was only 8.316 t ha^{-1} which was 11.6% inferior to Halo-CRD spray. Soil C sequestration was negative during 2 years of imposed treatments under rice-wheat system while there was build up of 0.554 Mg/ha/yr of soil C sequestration in Halo-CRD spray with residue incorporation followed by 0.462 Mg/ha/yr in residue incorporation and 0.277 Mg/ha/yr in Halo-CRD spray with residue retained (Fig 46).

As an indicator of soil quality, soil C stratification is related to the rate and amount of soil C sequestration. Stratification ratio of soil organic C was 2.13 in residue retained plots compared to 1.75 in residue retained plots. Similarly, stratification ratio for total soil C content was 1.25 in plots where halo-CRD was sprayed with residue incorporation while 1.33 where urea was applied with residue incorporation and 1.72 where residue were burnt.

Energy transformation

Net energy transformation due to management of crop residues through efficient degrading microbes was estimated. Net energy in terms of NPK increased by 78.3% with residue incorporation after spray with Halo-CRD over the residue burning. However, urea application @4% on incorporated residue resulted in 53.4% increase in net energy. Net energy in terms of only nitrogen showed increase of 66.4% over residue burning and 17.4% over urea spray.

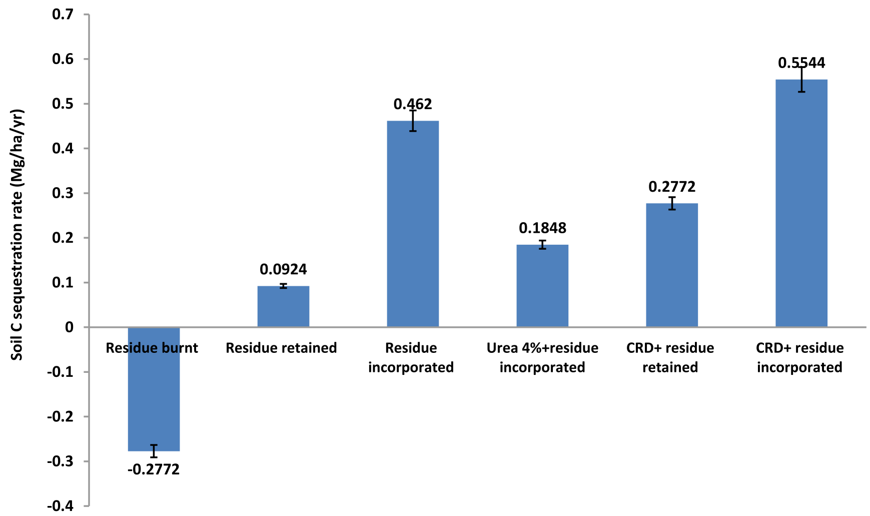


Fig 46. Soil C sequestration rate (Mg/ha/yr) 2017-19

Decomposition rates of crop residues

The decomposition rates of rice, wheat and sugarcane residue increased gradually over time, and the rice and wheat residue decomposition rate was obviously higher than that of the sugarcane leaf trash. The release rate tended to exhibit a rapid-slow-rapid-slow trend. With the application of microbial formulation Halo-CRD, the decomposition rates after 35 days of decomposition of the rice, wheat and sugarcane trash straw were 71.2, 62.7 and 52.3% over the 35 days decomposition period. This indicates that with microbial interventions, the decomposition of the rice and wheat residue was faster and more complete than that of the sugarcane leaf trash. Comparison of spray of urea and Halo-CRD on crop residues decomposition with respect of time showed that initially upto 3 weeks, the decomposition rate was faster where the crop residues were treated with urea compared to Halo-CRD. However, there after when the degrading microbial population stabilized to optimum, the degradation of residues paced up.

Farmers perception on residue management

In a survey conducted in 8 districts, showed that the major constraint for proper management of crop residues is due to collection of residues as tedious work for utilizing it for composting etc. Out of the 89 farmers, 94% farmers of the view that lack of awareness is also a limiting factor in adoption of improved residue management options. Keeping this in view a mobile application is being developed to make farmers aware for eco-friendly management of the left over stubbles and residues after harvest of rice and wheat crops to avoid burning.

Halo-CRD use at multilocational farmer's field

The multilocational demonstrations and trials at farmers field with the liquid bioformulation Halo-CRD were continued for validating the effect of its use for in-situ degradation of crop residues to avoid residue burning. The demonstrative trials at Sitapur, Unnao, Hadoi, Lucknow, Barabanki and Kanpur were conducted on sodic and non-sodic lands. It was observed that with incorporation of paddy residue along with inoculation of Halo-CRD, the subsequent wheat was 7.4 to 11.6% higher while wheat residue inoculated with Halo-CRD and incorporated resulted in 8.4% to 14.3% higher paddy yield at nine location trials.

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

Lately banana production in the sub-tropics of the Northern plains has surpassed many of the traditional banana growing regions of the country due to the dominance in the growth of the Grand Naine cultivar and sustainable economic returns. The banana cultivation in the region came under threat with the outbreak of the Fusarium wilt Tropical race 4 has resulted in the 30-40% loss in major banana growing regions of Bihar and Uttar Pradesh.

Comparative assessment of the efficacy of *Trichoderma reseei* (CSR-T-1) and *Trichoderma harzianum* (CSR-T-1) for the control of FOC Race 4

The virulent strain of the *Fusarium oxysporum* f. sp. *cubense* Tropical race 4 was tested for disease suppression with three *Trichoderma* isolates were used in this study: *Trichoderma reesei* (CSR-T-3) MH997668 isolated from the rhizosphere soil of G-9 banana cultivar grown in salt affected soil, *Trichoderma asparellum* (CSR-T-4) MN227242 and *Trichoderma koningiopsis* (CSR-T-2) KJ812401. The inhibition efficacy of *Trichoderma* isolates on mycelia growth of Foc TR-4, the radius of Foc colony in each plate was measured and inhibition effect of CSR-T-3 found maximum.

Effects of *Trichoderma reesei* (CSR-T-3) on disease control and growth of banana plants in pot culture

Three treatment groups were established (TC – Non-inoculated *F. oxysporum* f. sp. *cubense* Race 4 and application of sterile water; TF – Treatment inoculated with *F. oxysporum* f. sp. *cubense* Race 4 ; TFTR– Treatment inoculated with *F. oxysporum* f. sp. *cubense* Race 4 and CSR-T-3 isolate of *Trichoderma reesei*. The disease severity indices (DSI) was very high in Foc TR-4 alone treated plants under treatment TF (3.75), while the prevention and control effect was better in CSR-T-3 applied plants with a significantly decreased mean disease severity index (DSI) (Table 38). At 60 days after planting, the mean DSI of the TFTR treatment was 0.75 much lower than the Foc TR-4 alone treated plants and similar to the plants of control that were not inoculated with the pathogen.

Experimental results showed that after 18 months of storage at two locations with different climatic conditions (sub-tropical and tropical) there was no significant change

Table 38: Effect of *Trichoderma reesi* (CSR-T-3) on *Fusarium* wilt incidence and growth of banana plantlets under green house pot experiment

Treatment	Plant height			Plant girth			No. of leaves	Disease severity index
	Initial	Final	Increment	Initial	Final	Increment		
TF	17.15b (± 1.63)	26.5a (± 4.40)	33.83a (±13.17)	3.35a(± 0.17)	3.62a (± 0.17)	7.51a(± 4.51)	1.75a(± 1.25)	3.75b (± 1.50)
TFTR	14.9b(±2.01)	33.75b(± 1.49)	55.79b(±6.29)	3.50a(± 0.40)	5.47b(± 0.55)	35.82b(± 7.44)	4.50b(± 0.57)	0.75a(±0.50)
TC	13.12a(± 1.51)	35.47b(±1.94)	62.89b(±5.14)	3.80a(± 0.35)	5.55b(± 0.17)	31.63b(± 4.35)	5.00b(± 0.00)	0.00a(± 0.00)

TF- Treatment *Fusarium*; TFTR – Treatment *Fusarium* and *Trichoderma*; TC- Treatment Control, Values are the means of three replicates with the sample size n=5. Means in the columns followed by the same letter are not significantly different according to Duncan's multiple range test at P=0.05. Values in the parentheses indicate the standard deviation of the mean

Inhibition of radial growth of Foc TR-4 by the fungal isolates of *Trichoderma spp.*

in the population density of *Trichoderma reesei* (CSR-T-3). The mean population in the formulation was 7.48×10^7 CFU/g at the start of the study (0^{th} month) and 8.27×10^6 CFU/g at the end of the experimental period (18 months).The decline in the CFU count was within the prescribed limits and also level of microbial population, moisture content, pH and bacterial contaminants were not influenced by the storage period under both the locations of study.

Table 39: Post commercialization impact of CSR-BIO

Firms producing	Quantity produced (2015-19)	Area benefitted (ha)	% yield increase	Crops	Disease controlled
CSSRI, RRS, ICAR Lucknow	2 tonnes (solid) 300 L (liquid)	120	14-16	Paddy, wheat, potato, banana, tomato,capsicum, okra, gladiolus, mango and guava (both salt affected and normal soils)	Wilt of tomato, banana, Fe+ availability, Blight of potato and Paddy smut
M/S Krishicare Bioinputs, Tamil Nadu	47.5 tonnes (solid) 4650 L (liquid)	2622 ha	18-24	Paddy, Vegetables, Mango, Guava, Chillies, Onion,Banana, Ixora, Jasmine, Beetle wine, Ixora	Wilt of Ixora, Fe+ availability and Blight of potato
M/S Alwin Industries, Madhya Pradesh	2 tonnes (solid) 550 L (liquid)	160 ha	18-22	Chilies and garlic etc.,	Wilt and blight
M/s Khandelwal Biofertilizers, Karnataka	9500 L (liquid) 122 tonnes (solid)	5600 ha	16-20	Chick pea, Pigion pea, cumin and pomegranate, orange, grapes, turmeric, sugarcane, apple, banana	Blgiht and wilt control
ICAR -CISH, Lucknow	2 tonnes	32 ha	NA	Mango, guava, banana	Guava and mango wilt

Demonstration of the FUSICONT formulation in the North Eastern tribal region under TSP Program

The ICAR-FUSICONT formulation was demonstrated for the growth promotion and disease control properties in collaboration with Central Institute of Horticulture, Nagaland and Assam Agricultural University, Jorhat. A total of 45 beneficiaries were covered under the program where demonstration using 450 kg was made in banana at Jorhat. The successful wilt control was found at Dimapur in Nagaland in the strawberry, tomato and gerbera.

Impact of CSR-BIO

The CSR BIO was commercialized in the year 2014 and the data given in table 39 states that since 2015 the product has reached of 8534 ha in the country contributing for an average increase in the production of agri-horticultural crops to the level of 17%.

Reclamation and Management of Salt Affected Vertisols

Assessment and mapping of salt affected soils of Gujarat using remote sensing and GIS (Anil R. Chinchmalatpure, Shrvan Kumar, Bisweswar Gorain, A.K. Mandal, M. J. Kaledhonkar and Arijit Barman)

Soil salinisation is a serious problem especially in arid and semi-arid regions, areas near coastal vicinity and irrigation command areas. Therefore, the present study has been undertaken to characterize, assess and map salt affected soils of Gujarat state using remote sensing and GIS. Survey of India toposheets, satellite imageries (Resource sat-2 LISS-III data) have been procured to be used in mapping of salt affected soils of Gujarat.

Soil sampling for ground truth collection has been initiated and completed for thirteen districts namely Bharuch, Surat, Anand, Navsari, Vadodara, Tapi, Narmada, Ahmedabad, Kheda, Bhavnagar, Surendranagar, Mehsana, and Patan in Gujarat. The grid size of soil sampling has been adopted is 8 km x 10 km, which is approximately 8 to 10 samples per toposheets (1: 50000). The soil sampling from each grid point has been done up to a soil depth of 120 cm with depth intervals like 0-15 cm, 15-30 cm, 30-60 cm, 60-90cm and 90-120 cm. Till date, soil samples were collected from 427 point locations (geo-referenced points) with total cumulative samples accounting to 2135. Soil samples collected are being processed in the laboratory for its detailed analysis. Data on soil EC, pH and cation and anion composition of analyzed samples are presented in tables 40 to 42.

Table 40: Number of analyzed soil samples in different soil salinity category

Depth (cm)	No. of samples			
	< 4dS m^{-1}	4-8 dS m^{-1}	>8 dS m^{-1}	Total samples analyzed
0-15	22	4	5	31
15-30	19	2	10	31
30-60	16	2	12	30
60-90	11	1	11	23
90-120	10	3	10	23

Table 41: Number of analyzed soil samples in different pH category

Depth (cm)	No. of samples			
	pH < 7.0	pH 7.0-8.0	pH 8.0-9.0	pH >9.0
0-15	2	10	19	0
15-30	2	11	18	0
30-60	1	12	14	2
60-90	0	8	14	1
90-120	0	10	11	2

Table 42: Physico-chemical properties of analyzed soil samples from different geo-referenced points

Depth 0-15 cm	EC_2 (dS m^{-1})	pH_2	EC_e (dS m^{-1})	pH_s	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
						(mel)						
Min	0.07	5.54	0.34	5.89	0.50	1.00	0.24	0.00	1.00	0.50	2.50	0.00
Max	63.00	9.26	120.0	8.87	36.0	312.0	1827.8	12.3	18.00	5.00	982.5	43.70
Mean	5.24	8.02	12.49	8.00	6.13	18.15	128.31	1.18	5.03	1.53	82.98	5.89
SD	12.18	0.64	27.63	0.61	9.94	56.91	369.69	2.69	3.73	1.14	201.8	9.54
Depth 15-30 cm	EC_2 (dS m^{-1})	pH_2	EC_e (dS m^{-1})	pH_s	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
						(me l^{-1})						
Min	0.05	5.82	0.24	5.85	1.00	0.50	0.41	0.03	1.00	0.50	2.50	0.05
Max	35.0	9.19	83.0	8.90	32.0	133.0	1736.0	6.61	20.00	4.00	937.5	29.58
Mean	3.91	8.26	14.6	8.00	6.02	16.65	149.58	1.07	6.10	1.84	99.68	6.43
SD	8.15	0.59	24.6	0.67	8.23	31.70	352.23	1.95	4.08	1.03	206.2	7.82
Depth 30-60 cm	EC_2 (dS m^{-1})	pH_2	EC_e (dS m^{-1})	pH_s	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
								(me l^{-1})				
Min.	0.07	6.57	0.27	6.78	0.50	0.50	0.33	0.03	1.00	1.00	2.50	0.08
Max.	42.00	9.45	86.00	9.06	34.00	146.0	1443.5	7.00	24.00	5.00	682.5	36.72
Mean	3.88	8.42	16.34	8.12	5.36	14.50	164.91	1.06	7.41	1.42	92.50	5.42
S.D.	8.22	0.52	25.31	0.53	8.01	31.00	348.81	1.75	5.84	1.25	161.9	7.53
Depth 60-90 cm	EC_2 (dS m^{-1})	pH_2	EC_e (dS m^{-1})	pH_s	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
							(me l^{-1})					
Min	0.13	7.45	0.44	7.15	0.5	1.0	2.01	0.04	2.0	0.5	2.5	0.05
Max	44.0	9.48	86.0	9.18	20.5	82.0	757.8	5.81	18.0	5.5	795.0	26.53
Mean	5.73	8.44	20.99	8.21	5.28	12.63	173.9	1.34	7.26	2.0	122.5	7.05
SD	9.68	0.43	28.01	0.51	5.69	21.46	262.9	1.96	4.39	1.4	215.3	7.48
Depth 90-120 cm	EC_2 (dS m^{-1})	pH_2	EC_e (dS m^{-1})	pH_s	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
							(me l^{-1})					
Min	0.14	7.61	0.29	7.52	0.5	0.5	2.14	0.04	2.0	0.0	2.5	0.39
Max	45.0	9.66	88.0	9.17	41.0	118.5	1556.5	9.32	21.0	4.5	790.0	21.88
Mean	6.36	8.46	22.2	8.22	7.22	16.59	235.7	1.50	7.74	2.14	126.8	6.25
SD	10.5	0.44	30.2	0.48	9.99	31.22	429.4	2.29	4.54	1.31	208.8	6.66

Maximization of yield and factor productivity through integrated nutrient management in desi cotton based cropping systems in saline *vertisols* (Shrvan Kumar, Bisweswar Gorain and Anil R. Chinchmalatpure)

Application of Municipal Solid Waste Compost (MSWC) in agricultural land has several beneficial effects similar to other organic manures. By combining specific approaches of integrated nutrient management (INM) and application of micronutrients, yield of field crops can be enhanced and sustainability of the system can be secured. The idea of inclusion of some other crops in the cotton monocrop system along with INM plan can be used for maximization of crop yield. Keeping this in view, experiment was planned with split plot design with three cropping systems of cotton in two year crop rotation; C1-Cotton monocropped, C2-Cotton-Sorghum-Wheat and C3-Cotton-Pigeonpea-Wheat in main plot and five treatments of Integrated nutrient management in sub plot N1-100% RDF; N2- 75% RDF + 25% through MSWC; N3-50% RDF + 50% through MSWC; N4-50% RDF + 50% through MSWC + *Azotobacter/Rhizobium;* N5-50% RDF+ 50% through MSWC + *Azotobacter/Rhizobium* + Soil application of Zn in three replications.

Among INM treatments, maximum yield and yield parameters of cotton (C1: continuous cotton system, C2: cotton-sorghum-wheat cropping system and C3: cotton-pigeon pea-wheat cropping system) were recorded under 50% RDF + 50% through MSWC + *Azotobacter* + soil application of Zn (N5) (Table 43).

After harvest of cotton crop under C1, C2 and C3 systems, soil pH_2 ranged from 7.80 to 7.92, 7.87 to 8.21 and 7.94 to 8.16 at 0-15 soil layer, respectively (Table 43). Similarly EC_2 ranged from 0.32 to 0.46 dS m^{-1}, 0.35 to 0.42 dS m^{-1}, and 0.29 to 0.41 dS m^{-1}, respectively for C1, C2 and C3 systems at 0-15 cm depth. Among the cropping systems, cotton-pigeon pea-wheat (C3) cropping system displayed higher average soil organic carbon (0.62%) and available N (319.3 kg ha^{-1}) as compared to C1 and C2 systems.

Trial on integrated nutrient management in the 4th year under C1: Cotton mono-cropping; C2: Cotton-sorghum-wheat and C3: Cotton-pigeon pea-wheat systems were undertaken, during *kharif* season using cotton (G Cot 23), sorghum (GNJ-1) and pigeon pea (ICPL-84031) varieties in a furrow-raised bed planting system at experiment farm, Samni.

Table 43: Yield and yield parameters of cotton (C1, C2 and C3 system) affected by various INM treatments

Treatments	Plant height (cm)	No. of Bolls plant^{-1}	Cotton yield plant^{-1}	Stover yield plant^{-1}	Cotton yield plot^{-1}	Stover yield plot^{-1}	Cotton yield	Stover yield
			--------- (g) -------		--------- (kg) -------		----(q ha^{-1}) ----	
N1	141.0	40.5	81.8	175.2	2.71	6.59	12.55	30.52
N2	144.2	42.2	88.0	188.3	2.82	6.82	13.03	31.55
N3	136.2	35.7	71.4	155.1	2.39	6.14	11.08	28.42
N4	139.9	40.6	81.1	171.3	2.67	6.56	12.36	30.36
N5	145.3	43.9	90.1	190.8	2.86	6.88	13.24	31.86
LSD (0.05)	5.2	4.4	6.2	21.2	0.17	0.26	0.78	1.21

N1: 100% RDF; N2: 75% RDF+25% through MSWC; N3: 50% RDF+50% through MSWC; N4: 50% RDF+50% through MSWC + Azotobacter; N5: 50% RDF+50% through MSWC + *Azotobacter* + Soil application of Zn; MSWC-Municipal solid waste compost

Cotton crop under cotton mono-cropping system (C1)

Plant height, total (root and shoot) fresh and dry biomass of cotton was recorded at 30, 60, 90 and 120 days after sowing (DAS). Results were significant at 60, 90 and 120 DAS and at 30 DAS it was non-significant. Maximum plant height was observed under the treatment N5 *i.e.* 50% RDF + 50% through MSWC + *Azotobacter* + soil application of Zn (66.4 cm, 99.7 cm and 142.3 cm) followed by N2 treatment *i.e.* 75% RDF + 25% through MSWC (65.1 cm, 95.3 cm and 140.3 cm).

Morphological analysis of sorghum and pigeon pea components under C2 cropping system

Plant height, total (root and shoot) fresh and dry weight biomass of sorghum were recorded at 30, 60, 90 and 120 days after sowing (DAS).

Plant height, total (root and shoot) fresh and dry weight biomass of pigeon pea were recorded at 30, 60, 90 and 120 days after sowing (DAS). Results were significant at 60, 90 and 120 DAS and at 30 DAS it was non-significant. Maximum plant height (Fig. 5) was observed under the treatment N5 *i.e.* 50% RDF + 50% through MSWC + *Rhizobium* + Soil application of Zn (86.1 cm, 123.2 cm and 139.3 cm) followed by N2 treatment *i.e.* 75% RDF + 25% through MSWC (85.2 cm, 112.2 cm and 127.2 cm). Maximum fresh weight (4.76 g, 63.0 g and 134.7 g) and dry weight (1.63 g, 26.6 g and 45.83 g at 60, 90 and 120 DAS, respectively) biomass at 60, 90 and 120 DAS was observed under the N5 treatment followed by N2 & N1 treatment. Minimum plant height, total fresh and dry weight biomass at 60, 90 and 120 DAS was observed in N3 treatment i.e. 50% RDF + 50% MSWC.

- Among INM treatments under cotton crop (C1: continuous cotton system, C2: cotton-sorghum-wheat cropping system and C3: cotton-pigeon pea-wheat cropping system) third year results revealed that 50% RDF + 50% through MSWC + *Azotobacter* + soil application of Zn (N_5) recorded significantly higher cotton yield parameters like no. of bolls/ plant (43.9); cotton yield/plant (90.1 g), stover yield/plant (190.8 g), cotton yield/plot (2.86 kg), stover yield /plot (6.88 g), cotton yield (1.32 t ha^{-1}) and stover yield (3.1 t ha^{-1}) than other treatments which was statistically at par with N_2 treatment *i.e.* 75% RDF + 25% through MSWC and N_1 treatment *i.e.* 100% RDF.
- Among different INM treatments under cotton crop, results revealed that N_5 treatment *i.e.* 50% RDF+50% through MSWC+ *Azotobacter* + soil application of Zn was better in terms of cotton yield (1.3 t ha^{-1}) and stover yield (3.1 t ha^{-1}) as it saved 25% inorganic fertilizers.
- Among the cropping systems, cotton-pigeon pea-wheat (C3) cropping system displayed higher average soil organic carbon (0.62%) and available N (319.3 kg ha^{-1}) status as compared to C1 and C2 systems. Among the various INM treatments, N5 (50% RDF+50% through MSWC+ *Azotobactor* + Zn @ 25 kg ha^{-1}) treatment recoreded higher available nitrogen as compared to N1 and N3 treatments.
- During rainy season, it was found that sorghum and pigeon pea crop performance was good under water logged condition on furrow raised bed planting system.

Pulpwood-based silvipastoral systems for saline vertisols (David Camus D, Shrvan Kumar and Indivar Prasad)

Tolerance of forest trees to saline water irrigation differs from species to species at different stages of growth and therefore it is necessary to screen tree species which are tolerant to salinity for these agroforestry systems to be successful in salt affected soils. The experiment was carried out in six tree species such as *Eucalyptus, Leucaena leucocephala, Acacia auriculiformis, Casuarin aequisetifolia, Meliadubia* and *Dalbergia sissoo*. 90 day old seedlings were subjected to four levels of saline water irrigation treatments viz. <2, 4, 8 and 12 dS m^{-1}, respectively for 270 days. The response of these species to saline water stress was recorded in the form of changes in biomass and relative growth after imposition of salt treatments.

At saline water irrigation of 4 dS m^{-1}, tree species like *Leucaenaleucoce phala* and, to a lesser extent, *Eucalyptus*, *Acacia auriculiformis, Meliadubia* and *Casuarina equisetifolia*, have relatively high salinity tolerance and a good ability to maintain high growth rates under saline water stress when compared to control plants (Table 44). *Leucaena leucocephala* and *Eucalyptus* and *showed* 34 and 40 % reduction in growth rate, respectively compared to controls when grown with saline water irrigation of 4 dS m^{-1}. *Dalbergia sissoo* was the most sensitive to saline water irrigation of 4 dS m^{-1} with 66 % reduction in growth. *Leucaena leucocephala* and *Acacia auriculiformis* also showed good capacity to tolerate saline water irrigation of 8 dS m^{-1}. The ability of *Eucalyptus*, *Casuarina equisetifolia, Melia dubia* and *Dalbergia sissoo* to withstand saline water irrigation reduced drastically at 8 and 12 dS m^{-1}.

Under saline water irrigation stress, all tree species showed reduction in growth after 270 days of salt application. This reduction in plant growth rate may be due to increased uptake of sodium ions as in the case of *Casuarina equisetifolia* resulting in decreased growth with increasing salinity. Species like *Leucaena leucocephala* and *Eucalyptus* were able to exclude sodium ions. Even though *Acacia auriculiformis* accumulated more sodium ions it was able to with stand salt stress. Another reason for reduction in plant growth rate can be attributed to osmotic stress and is independent of the accumulation of sodium ions in the shoot tissues. Only *Acacia auriculiformis* showed maximum tolerance to osmotic stress at saline water irrigation of 8 dS m^{-1}. Other species except *Dalbergia sissoo* which had minimum tolerance, showed moderate tolerance. At 12 dS m^{-1} of irrigation water the growth rate, all specie showed a reduction of 21 to 39 percent. The reduction of mean relative growth rates of all species at different levels of saline water irrigation is shown in Fig. 47.

Table 44: Total plant salinity tolerance

Species	**Shoot fresh weight (gm) at different saline water irrigation levels**				**Salinity tolerance at different saline water irrigation levels**		
	<2 dS m^{-1}	**4 dS m^{-1}**	**8 dS m^{-1}**	**12 dS m^{-1}**	**4 dS m^{-1}**	**8 dSm^{-1}**	**12 dS m^{-1}**
Eucalyptus spp.	546.7	327.5	238.2	176.7	0.60	0.44	0.32
Leucaena leucocephala	2001.2	1320.9	1171.6	933.9	0.66	0.59	0.47
Acacia auriculiformis	198.9	117.8	112.6	86.9	0.59	0.57	0.44
Casuarina equisetifolia	653.9	368.6	296.7	224.3	0.56	0.45	0.34
Melia dubia	948.7	511.3	372.4	209.4	0.54	0.39	0.22
Dalbergia sissoo	113.7	27.1	13.3	-	0.24	0.12	-
CD0.05(I)	134.5						
CD0.05(S)	71.7						

Plant salinity tolerance calculated using the ratio of shoot fresh weight (gm) of 360 day old species grown for 270 days in saline irrigation water of 4, 8 and 12 ds/m, respectively to irrigation water of < 2 ds/m grown species.

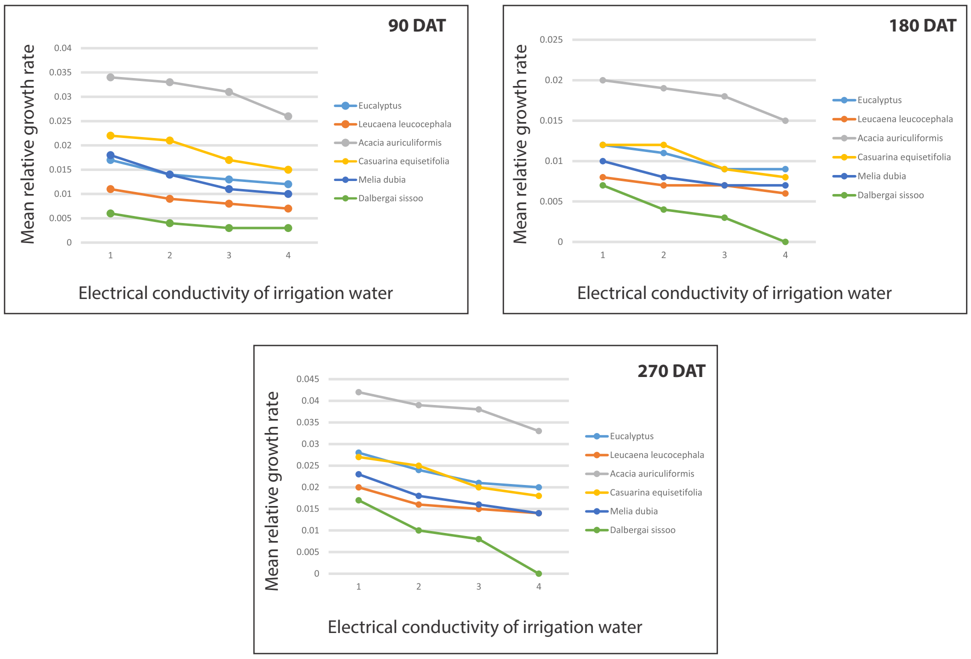


Fig. 47. Mean relative growth rate at different levels of saline water irrigation

Measurements of relative plant growth rate calculated from shoot fresh weight (gm) from 0 to 270 days after the first application of saline irrigation water of 4, 8 and 12 dS m^{-1}, respectively were used to determine osmotic tolerance.

It is clear that after 270 days of saline water irrigation at different levels, *Leucaenaleucoce phala* which uses both sodium exclusion and osmotic tolerance was the best tolerator to saline water stress followed by *Acacia auriculiformis* and *Eucalyptus*. The mode of tolerance in *Acacia auriculiformis* at 4 and 8 dS m^{-1} and *Casuarina equisetifolia* at 4 dS m^{-1} was more of osmotic in nature.

Cost effective drainage in waterlogged saline vertisols for improving crop productivity in Gujarat (Sagar D. Vibhute, Anil R. Chinchmalatpure, David Camus D. and M. J. Kaledhonkar)

Mole drainage in vertisols of Gujarat

Mole drainage is a pipe-less drainage technology and tractor-drawn mole plough is used to make an unlined circular conduit in subsoil. This technology is adopted in heavy soils because formation of conduit is possible due to its high clay (> 40%) content. In present study mole drainage installation work was undertaken for studying its adaptability and sustainability in Vertisols of Gujarat. Mole drainage installation work was carried out during the last week of November 2019 in an area of 1.0 ha at Experimental farm, Samni of ICAR-CSSRI, RRS, Bharuch. The initial soil characteristics were studied prior to the installation of mole drains. The rainfall received in the rainy season prior to the mole drain installation was recorded.

The 7 day, 15 day and 30 day antecedent rainfall from the date of installation of mole plough was estimated from the collected rainfall and it is given in table 45. This rainfall was responsible for creating favorable soil moisture conditions for mole drainage installation.

Table 45: Antecedent Rainfall received

Duration	Amount of rainfall received (mm)
7 days Antecedent Rainfall	0
15 days Antecedent Rainfall	4.32
30 Days Antecedent Rainfall	43.7

Four treatments of mole drainage comprising of 2 depths (40 and 60 cm) and 2 spacing (2 m and 4 m) and one controlled treatment where no mole drain installed were undertaken. Each treatment was replicated two times and assigned a plot size of 12 m width and 70 m length. The treatments were separated by 3 m wide buffer strips.

Performance of subsurface drainage at Adadara SSD site

Salinity of drainage effluent and crop growth was monitored at Adadara SSD site. It was found that the water drained into the sump was periodically pumped out by the farmer during summer months, which resulted in removal of salts from the field. The EC of effluent water increased from 4.9 to 7.3 dS m^{-1} during summer months whereas EC_e of soil in upper 60 cm layer reduced from 8.1 - 9.85 dS m^{-1} to 3.35 - 5.57 dS m^{-1} during this period. This indicated that effective salt removal by the SSD system. As far as crop growth is considered, sugarcane crop was not grown at Adadara SSD site before installation of SSD, however, farmer started cultivating sugarcane after 1 year of SSD installation and healthy sugarcane crop stand was observed. The average yield of the entire field was 75 t ha^{-1}.

Circular conduit formed by mole drain

Conjunctive use of saline groundwater and surface water in vertisols for improving water productivity under drip irrigated wheat (Sagar D. Vibhute, Anil R. Chinchmalatpure, Shrvan Kumar and Bisweswar Gorain)

A study on conjunctive use of saline ground water and canal water was undertaken under drip irrigated wheat at Experimental Farm, Samni of ICAR-CSSRI, Regional Research Station, Bharuch. Cyclic mode of conjunctive irrigation was adopted in the study with five drip irrigation treatments I_1 (1:1 :: Surface Water : Groundwater irrigation), I_2 (1:2 :: Surface Water : Groundwater irrigation), I_3 (2:1 :: Surface Water : Groundwater irrigation), I_4 (all Surface Water irrigation), I_5 (all Groundwater irrigation) whereas one treatment of traditional border irrigation method (I_6) was kept. The grain yield and water productivity data of these different treatments are given in table 46. It was observed that the treatment I_1 recorded comparable grain yield to treatment I_6 besides 50% saving in the quantity of freshwater.

Table 46: Grain yield and water productivity under different treatments

Treatment	Grain Yield, t ha^{-1}	Water Productivity, kg m^{-3}
I1	3.29	1.29
I2	2.74	1.08
I3	3.09	1.21
I4	3.59	1.41
I5	2.39	0.94
I6	3.83	1.20

Salinity build-up under drip irrigated wheat

Soil samples were collected before sowing and after harvesting wheat to study soil salinity build up during entire season. Soil samples were collecteed from 0-30, 30-60, 60-90 and 90-120 cm soil depths under different treatments. It was observed that soil EC_e in upper 30 cm soil layer increased significantly by 5.8 dS m^{-1} for the treatment I_5 (all irrigations with groundwater having EC ranging from 7.2 to 8.1 dS m^{-1}) while lowest rise of 1.1 dS m^{-1} was observed in treatment I_4 (all irrigations with surface water having EC 0.3 dS m^{-1}). Although highest grain yield was obtained in I_6 treatment, soil EC_e in upper 30 cm soil layer increased by 2.7 dS m^{-1} in which 4 irrigations were given.

Overall performance of treatment I_1 was found to be good as its yield was statistically at par with treatment I_6 with same degree of salinity development and 50% saving of fresh water. It also has second highest water productivity (1.29 kg m^{-3}) after treatment I_4 (drip irrigated wheat with all surface water irrigation) which has 1.41 kg m^{-3} water productivity. This shows that increase in crop water productivity, saving of fresh water and lesser salinity build up can be achieved by conjunctive use through drip irrigation method.

Salt concentration under different treatments

Cations and anions concentration under different conjunctive use treatments was measured to know the nature of salt which is responsible for salinity build up. The cations and anions concentration under different treatments is given in table 47. It was observed that chloride was the dominant anion in all the treatments and its concentration varied from 10 to 42.5 meq l^{-1}. In case of cations sodium was dominant followed by calcium and magnesium.

Table 47: Cations and anion concentration under different treatments

Treatment	Soil depth (cm)	Soluble cations (me l^{-1})				Soluble anions (me l^{-1})			
		Ca_2^+	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl-	SO_4^{2-}
I1	0-30	5.0	7.0	24.5	0.4	2.0	0.0	17.5	1.2
	30-60	14.0	3.5	15.6	0.2	2.0	0.0	15.0	1.0
	60-90	7.5	10.0	10.3	0.2	1.0	0.0	17.5	1.0
	90-120	8.5	6.0	9.8	0.2	0.0	2.5	15.0	1.1
I2	0-30	10.3	11.3	14.4	0.2	1.3	1.8	21.7	0.9
	30-60	10.5	9.5	9.0	0.2	2.3	0.2	20.0	1.0
	60-90	8.5	8.5	6.3	0.2	3.7	0.0	15.0	1.4
	90-120	6.3	10.3	6.9	0.2	3.0	0.0	15.0	0.8
I3	0-30	8.5	7.7	9.8	0.2	3.3	0.0	14.2	1.8
	30-60	6.2	8.2	6.8	0.1	3.3	0.3	15.0	0.8
	60-90	8.2	7.3	6.3	0.2	2.0	1.7	15.0	1.1
	90-120	9.0	8.5	6.8	0.2	2.7	0.0	14.2	0.7
I4	0-30	3.7	5.2	10.2	0.1	3.3	0.0	11.7	0.7
	30-60	4.5	5.3	6.0	0.1	3.3	0.7	10.0	0.8
	60-90	4.3	6.8	7.0	0.1	2.7	0.2	12.5	0.8
	90-120	6.0	7.3	5.9	0.1	2.3	0.0	13.3	0.9
I5	0-30	21.5	11.8	21.8	0.2	3.3	0.2	42.5	1.5
	30-60	14.3	10.0	13.3	0.2	3.7	0.5	33.3	1.2
	60-90	10.3	8.5	8.1	0.2	1.7	1.3	20.8	0.7
	90-120	7.7	7.8	8.6	0.2	3.0	0.5	21.7	0.7
I6	0-30	11.5	7.5	7.5	0.2	2.0	2.0	17.5	1.0
	30-60	8.5	6.5	6.1	0.1	3.0	0.5	10.0	0.5
	60-90	7.0	9.0	4.5	0.1	2.0	0.5	12.5	0.3
	90-120	7.0	10.5	3.3	0.0	2.0	0.0	15.0	0.2

Development of desi cotton genotypes (*G. herbaceum* and *G. arboreum*) for salt affected Vertisols (Lokeshkumar, B. M, Shrvan Kumar, Anil R. Chinchmalatpure and P.C. Sharma)

Salt tolerant varieties offer a low cost, scalable and easy to adopt solution to overcome salinity problem. Major portion of Gujarat soil is the Vertisol and highly suitable for the cotton crop but sizable area under Vertisols in Gujarat is affected by salinity. Therefore it is very important need, to develop salt tolerant cotton varieties suitable for salt affected areas.This project is undertaken with the objectives to screen, evaluate and develop salt tolerant *desi* cotton genotypes. About 98 stabilized (F6) *G. arboreum*and 60stabilized (F7) *G. herbaceum*lines were screened under salt affected field condition (ECe of 6.6-7.8 dS m^{-1}) at experimental farm, Samni (Bharuch) and 31 stabilized (F7) *G. herbaceum* lines were screened under micro plot (EC : 8 dS m^{-1}) at Bharuch. Among 98*G. arboreum*lines nine lines performing better than local check G.Cot 19 and four lines performing better than zonal check AKA 7. The two lines CSB-D-1-4-1-2 (2.46 t ha^{-1}) and CSB-A-1-2-1-1(2.2 t ha^{-1}) were giving 35.48% and 21.22% more yield advantage over the zonal check respectively (Table 48). Similarly in*G. herbaceum* lines eight lines performed better than the zonal and local check G. Cot 23, out of eight three genotypes CSB-3-1-4-1-1-1 (1.34 t ha^{-1}), CSB-1-1-1-2-1-

Table 48: Best performing *G. arboreum* lines under saline field condition at Experimental farm, Samni (Bharuch)

Lines	SCY (t ha^{-1})	Yield advantage Over LC	Yield advantage Over ZC
CSB-D-1-4-1-2	2.47	59.90	35.48
CSB-A-1-2-1-1	2.20	43.07	21.22
CSB-D-1-4-1-1	1.98	28.51	8.88
CSB-D-1-5-1-1	1.90	23.25	4.42
CSB-D-2-4-1-1	1.73	12.49	-4.68
CSB-C-3-5-1-1	1.68	8.69	-7.90
CSB-A-1-2-1-2	1.68	8.69	-7.90
CSB-D-1-2-1-1	1.67	8.09	-8.41
CSB-D-1-1-1-1	1.62	5.29	-10.79
LC (G.Cot 19)	1.54	0.00	-15.27
ZC (AKA 7)	1.82	18.02	0.00

Table 49: Best performing *G.herbaceum* lines under saline field condition at Experimental farm, Samni (Bharuch)

Lines	SCY (t ha^{-1})	Yield advantage Over Check
CSB-3-1-4-1-1-1	1.34	35.08
CSB-1-1-1-2-1-3	1.19	20.59
CSB-7-1-5-1-1-3	1.18	18.76
CSB-1-1-1-2-1-1	1.13	14.04
CSB-5-1-3-1-1-2	1.05	5.96
CSB-7-1-5-1-1-1	1.05	5.60
CSB-2-1-1-1-1-1	1.00	1.21
CSB-2-1-1-1-1-2	1.00	1.00
LC & ZC G.Cot 23	0.99	0

3 (1.19 t ha^{-1}) and CSB-7-1-5-1-1-3 (1.18 t ha^{-1})were giving 35.08% and 20.59% and 18.76% more yield advantage over the local and zonal check respectively (Table 49). The results of screening of *G. herbaceum*genotypesunder microplot condition (EC : 8 dSm^{-1}) indicated the genotypes CSB-5-1-3-2-1-1 (0.77 t ha^{-1}), CSB-8-1-3-4-1-1(0.72 t ha^{-1}) and CSB-7-1-4-4-2-1(0.62 t ha^{-1}) were the top performing lines among the 31 screened genotypes. The distribution of number of bolls $plant^{-1}$ and seed cotton yield (Kg ha^{-1}) for stabilized (F6) *G. arboreum*, stabilized (F7) *G. herbaceum* lines screened under field condition and stabilized (F7) *G. herbaceum*lines screened under microplot.

Groundwater contamination due to geogenic factors and industrial effluents and its impact on food chain (Agri-CRP on Water) (Anil R. Chinchmalatpure, David Camus and Shrvan Kumar**)**

The present project was taken up to evaluate the impact of industrial effluent in Ankleshwar industrial estate (AIE) of Bharuch district of Gujarat, one of the heavily industrialized regions of Gujarat in terms of ground water quality.A pot experiment was conducted to study the effect of different amendments for remediation of heavy metals from the contaminated soils. The soil used in this pot experiment was collected from the contaminated sites in the vicinity of Ankleshwar and Panoli GIDC.

Cadmium concentration was maximum (0.71 mg kg^{-1}) in control pot (T1) and minimum (0.24 mg kg^{-1}) was observed in shoot of spinach crop planted in pot amended with tourmaline 1% + vermicompost (VC) 2% treatment (T8) . The sequence of minimum accumulation of Cd was observed 0.25 mg kg^{-1} in pot amended with tourmaline 1% (T6) followed by 0.28 mg kg^{-1} in tourmaline 2% (T7), 0.32 mg kg^{-1} in tourmaline 2%+ VC 3% (T13), 0.36 mg kg^{-1} in tourmaline 2%+single RD of *rhizobacteria* (T14), 0.35 mg kg^{-1} in tourmaline 1%+ single recommended dose of *rhizobacteria* (T10), 0.36 mg kg^{-1} in tourmaline 1%+VC 3% (T9), 0.35 mg kg^{-1} in tourmaline 2%+ double recommended dose of *rhizobacteria* (T15) which were statistically at par with T8. It was observed that in case of Co, application of tourmaline 1%+VC 3% (T9) was the most effective treatment which resulted in minimum accumulation of cobalt chromium and copper, iron in shoots of spinach crop and application of tourmaline1%+VC 2% (T8) resulted in minimum accumulation of cadmium in shoots of spinach crop. Application of single RD of *rhizobacteria* (T4) was the most effective treatment for minimum accumulation of zn in shoots of spinach crop. Manganese

concentration was maximum (441.75 mg kg^{-1}) in tourmaline 1% pot (T6) and minimum (182.03 mg kg^{-1}) was observed in (T14). Nickel concentration was maximum (64.98 mg kg^{-1}) in control pot (T1) and minimum (11.29 mg kg^{-1}) was observed (T11).

Lead (Pb) concentration was maximum (13.32 mg kg^{-1}) in control pot (T1) and minimum (0.492 mg kg^{-1}) was observed in Table 50.

Translocation Factor: Translocation factor (TF) for all metals was calculated as ratio of metal concentration in shoot to metal concentration in roots (Table 51).

Table 50: Remediation factor (%) for metals studied with different treatments in spinach crop

Treatments	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
	--- (%) ---								
T1	0.12	44.00	106.91	4.41	65.93	4.89	0.72	1.96	11.36
T2	0.11	30.70	73.21	4.22	68.36	4.04	3.13	0.61	20.38
T3	0.14	30.21	79.86	4.21	53.55	3.23	1.81	0.45	5.19
T4	0.10	24.52	46.02	4.19	52.00	3.57	1.61	0.49	6.43
T5	0.12	19.73	36.68	3.90	50.42	3.74	15.60	0.56	8.83
T6	0.07	19.65	36.35	4.26	89.22	5.16	5.89	1.46	37.65
T7	0.07	15.78	42.03	3.74	112.68	4.02	10.56	0.64	13.11
T8	0.07	14.71	37.45	3.67	38.99	2.65	11.32	0.36	13.21
T9	0.10	16.20	143.99	3.61	21.19	2.86	11.83	0.48	7.23
T10	0.06	24.86	108.98	6.91	47.24	5.71	11.47	0.58	14.73
T11	0.10	25.64	72.49	7.12	59.90	5.03	121.15	1.00	14.84
T12	0.09	28.72	204.26	4.98	126.52	3.20	16.33	0.40	24.56
T13	0.09	36.37	93.25	18.17	89.78	3.97	46.53	1.20	15.19
T14	0.08	41.25	105.17	18.53	75.07	3.17	19.56	1.19	16.30
T15	0.08	22.23	224.15	18.34	153.57	3.90	15.48	0.44	24.48
Average	0.09	26.3	94.05	7.35	73.63	3.94	19.53	0.79	15.37

Table 51: Translocation factor for metals studied with different treatments in spinach crop

Treatments	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
T1	0.80	6.43	3.85	2.46	1.46	1.61	6.75	3.68	1.55
T2	1.12	4.30	2.67	2.29	1.36	1.39	1.95	0.86	1.75
T3	0.52	4.38	3.14	2.10	1.00	1.76	0.97	0.80	1.48
T4	0.50	4.19	2.73	2.50	1.16	1.10	0.81	0.79	1.22
T5	0.44	3.93	2.41	1.67	1.03	1.44	1.44	0.94	1.32
T6	0.33	2.78	2.22	1.97	0.88	1.80	0.83	1.78	1.51
T7	0.34	3.37	1.92	2.16	3.38	1.64	0.87	1.09	1.74
T8	0.19	2.45	0.94	1.56	0.41	1.00	0.68	0.61	1.49
T9	0.32	2.50	0.80	1.70	0.80	1.35	0.71	1.06	1.62
T10	0.34	3.30	1.02	1.93	1.18	1.74	0.80	0.87	2.02
T11	0.53	3.79	0.73	1.94	1.42	1.56	1.02	1.39	1.65
T12	0.40	3.41	3.21	2.23	0.98	1.16	0.87	0.13	1.07
T13	0.34	3.15	2.01	1.93	0.62	1.03	0.97	0.24	1.49
T14	0.36	2.92	1.98	2.25	0.61	0.89	0.78	0.34	1.67
T15	0.42	2.64	3.89	2.31	2.53	1.52	0.82	0.26	1.54
Average	0.463	3.57	2.234	2.06	1.255	1.4	1.352	0.99	1.54

Revival of village pond through scientific interventions in saline Vertisol area of Gujarat and management of harvested rainwater for enhancing water productivity

(Anil R. Chinchmalatpure, Shrvan Kumar and Sagar Vibhute)

Harvesting of rain water and revival of village ponds for increasing water productivity is the impending need of the hour. Two village ponds Samni and Sudi in Bharuch district (4.73 and 7.19) taking up for the study. It is observed that siltation is the major problem leading to dysfunction of the pond. Silt from both the ponds were found rich in nutrient content and may be used as manure for soil conditioning. Soils from the catchment area of the both ponds were analyzed. Data analysis revealed that soil pH ranged from 8.1 to 9.0, ECe ranged from 0.29 to 2.70 dS m^{-1} and SAR ranged from 0.4 to 3.2 in case of Samni pond soil and in case of Sudi pond soil pH ranged from 8.0 to 9.0, ECe from 0.29 to 5.80 dS m^{-1} and SAR from 0.5 to 13.8 .

Due to the growth of wild vegetation the storage capacity of the ponds was reduced and also its improper shape. The dykes of ponds of both villages were planted with about 264 and 670 tree species including fruit treewere planted, respectively at Samni and Sudi pond dykes.

Rainfall distribution and runoff from catchment areas of village ponds

The amount of rainfall received was collected from meteorological observatory of Research Station of Navsari Agricultural University, Tancha Village the total amount of rainfall received during June 2018 to April 2019 was 698.5 mm. The amount of runoff generated was calculated using USDA-NRCS curve number method and it was observed to be 327.2 mm. The monthly rainfall and runoff data is presented in Fig. 48.

It is a common practice in the villages of Gujarat to have village ponds and almost each village is having at least one pond dug for its different uses. The study conducted had positive impact on various parameters related to village pond like level of

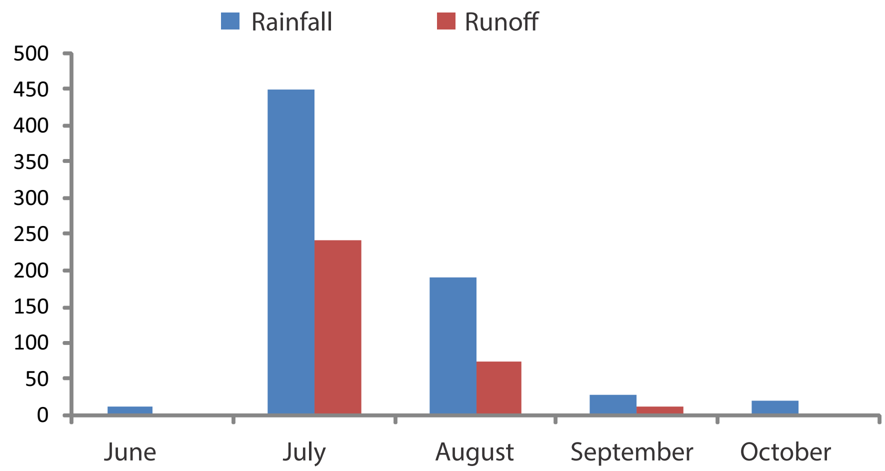


Fig.48. Rainfall and runoff distribution in catchments areas of village ponds

pollution/contamination, water harvesting and water conservation, quality of water, different uses of water and water productivity, ecological and environmental benefits. Scientific interventions adopted in the present study showed its impact on pond revival like increase in water storage capacity and farmers awareness. The water quality in pond as well as in the surrounding tubewells/borewells/handpumps was found to be improved as evidenced through water quality analysis.

Reclamation and Management of Coastal Saline Soils

Role of soil salinity and land uses on status and characteristics of organic matter under different landforms in coastal ecosystem (Shishir Raut and T.D. Lama)

Humus is the major soil organic matter component making up 75-80% of the total. The humic acid and fulvic acid fractions of organic matter were separated from the soil samples collected from three different villages of Gosaba Block (Lat. 22° 09'-22°10' N; Long. 88°47'-88°48' E) of South 24 Parganas district of West Bengal (India) coming under three different landforms namely, non-cultivated deltaic (NCD), mudflat (MUD) and depressed lowland (DL) from three different locations (three replications) under each landforms. Relationships between sorptivity and different fractions of organic matter were also studied

Humic acid and fulvic acid fraction of organic matter

The humic acid (H.A.) and fulvic acid (F.A.) fractions of organic matter for different depths of soil in the present study are given in Table 52. Fractionation of organic matter showed that the fraction of H.A. was the highest (0.31%) in DL soil and the fraction of F.A. was the lowest (0.10%) in the surface layer of the same soil. On the other hand, the F.A. fraction was the highest in NCD soil (0.12%). Decline in water repellency in NCD soil is due to the presence of water soluble fulvic acid. Or, in other words, presence of high amount of fulvic acid in NCD soil might have resulted that these soils were more capable of infiltration. DL soil with greater fraction of insoluble humic acid exhibited less cumulative infiltration (Fig. 52). The steady state cumulative infiltration of NCD soil was 5.2 cm, where as for DL soil it was around 2.0 cm. MUD soil showed intermediate steady state infiltration (3.2 cm) and F.A. content (0.11%). In the lower soil layers also H.A. % was higher in the DL soils (0.27 to 0.29 %). The H.A. / F.A. ratio decreased with depth (0.7 to 0.5 for NCD and 3.1 to 3.0 for DL land soils). Presence of humic acid in DL soils slightly decreased the volumetric water content of these soils (0.63).

Table 52. Humic acid, fulvic acid content of organic matter and their ratio

Name of soil	Total organic matter (%)	H.A(%)	F.A.(%)	H.A/F.A. ratio
0-20 cm				
NCD	2.10	0.08	0.12	0.7
MUD	1.80	0.18	0.11	1.7
DL	1.10	0.31	0.10	3.1
20-40cm				
CD	1.90	0.08	0.13	0.6
MUD	1.10	0.16	0.10	1.6
DL	0.93	0.29	0.09	3.0
40-60cm				
CD	0.88	0.07	0.11	0.5
MUD	1.10	0.14	0.09	1.5
DL	0.87	0.27	0.09	3.0

NCD: non-cultivated deltaic, MUD: mudflat/mangrove, DL: depressed low land

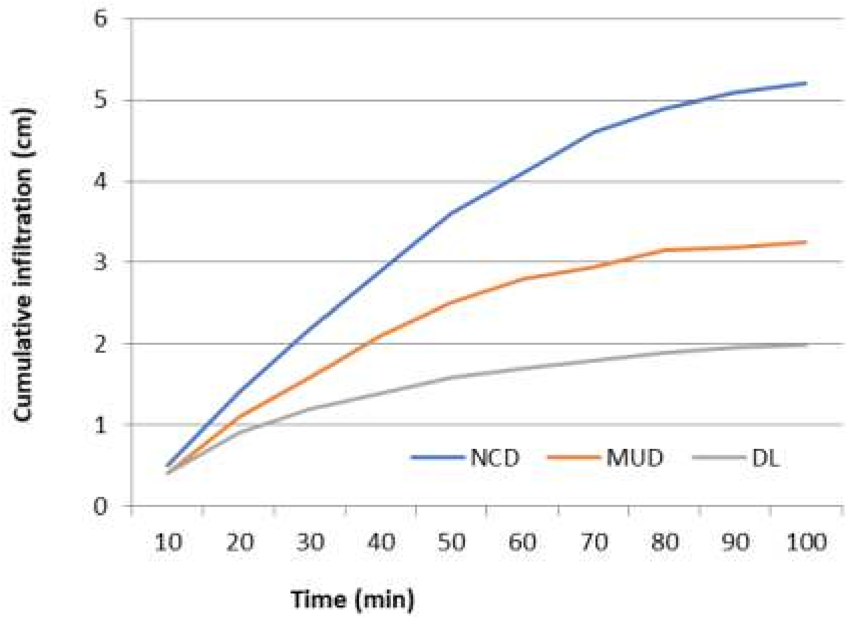


Fig. 49a. Cumulative infiltration vs time curve for different soils

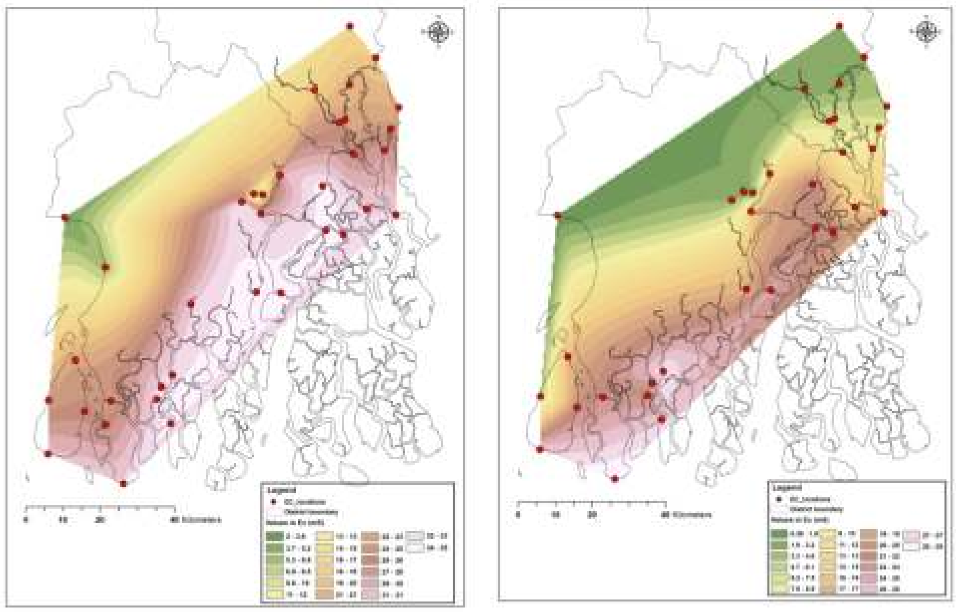
Assessment of spatio-temporal variation of surface water quality in coastal area

(D. Burman, T. D. Lama, U.K. Mandal, K.K. Mahanta and S. Mandal)

The Ganges delta is one of the largest deltas in the world. The landforms of the Bengal lowland, including the Ganges or Bengal delta and its surrounding region, consist of Pleistocene uplands and alluvial lowlands. Sundarbans located in the Ganges delta is intersected by a complex network of estuaries, tidal inlets, tidal creeks and a large number of islands. In Sundarbans, many drainage channels are excavated to drain out excess water to the estuarine rivers through sluice gates placed at different locations in the channel and to harvest rain water during rainy season for cultivation of *rabi* crops. This freshwater resource frequently becomes saline due to intrusion of saline water from the rivers. As a consequence the farmers face difficulties for using such water for irrigation purpose. Hence, the monitoring of spatial and temporal variation of water quality of these rivers and its drainage channels and its utilization patterns at different locations of Sundarbans is essential for proper assessment for its use for agricultural crop production and fisheries. This research project has been initiated with the objective to assess spatio-temporal variation of surface water quality of major river systems and drainage channels in salt affected Ganges Delta of coastal West Bengal for agricultural uses. Water samples from the rivers, Bay of Bengal and drainage channels at different locations of Sundarbans regions were collected during pre-monsoon (March-June) and monsoon (July-October) seasons. Different water quality parameters like EC_{w}, pH, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-} and SO_4^{-} were analyzed. The higher values of water quality parameters were recorded during pre-monsoon season compared to monsoon season (Table 53**).** The water quality of Hooghly river and drainage channel was found suitable for irrigation during both the seasons. The surface salinity maps for pre-mon and monsoon seasons were prepared using natural neighbor interpolation method. The salinity of water was higher in the South-Eastern part of Sundarbans and it was reduced during monsoon compared to pre-monsoon season (Fig. 47). The spatio-temporal variation of other water quality parameters also followed the similar trend.

Table 53: Seasonal variation in surface water quality in Sundarbans

Parameters	Pre-monsoon	Monsoon
EC_w (dSm^{-1})	1.41-34.56	0.34-30.60
pH	7.18-8.56	6.75-7.45
Na^+ (meq l^{-1})	22.73-522.91	2.06-253.28
K^+ (meq l^{-1})	0.15-103.50	0.12-5.68
Ca^{2+} (meq l-1)	2.64-16.28	0.44-12.32
Mg^{2+} (meq l^{-1})	2.53-96.14	3.85-82.17
Cl^- (meq l^{-1})	35.20-409.20	4.40-279.40
SO_4^{2-} (meq l^{-1})	9.37-95.88	0.66-79.38



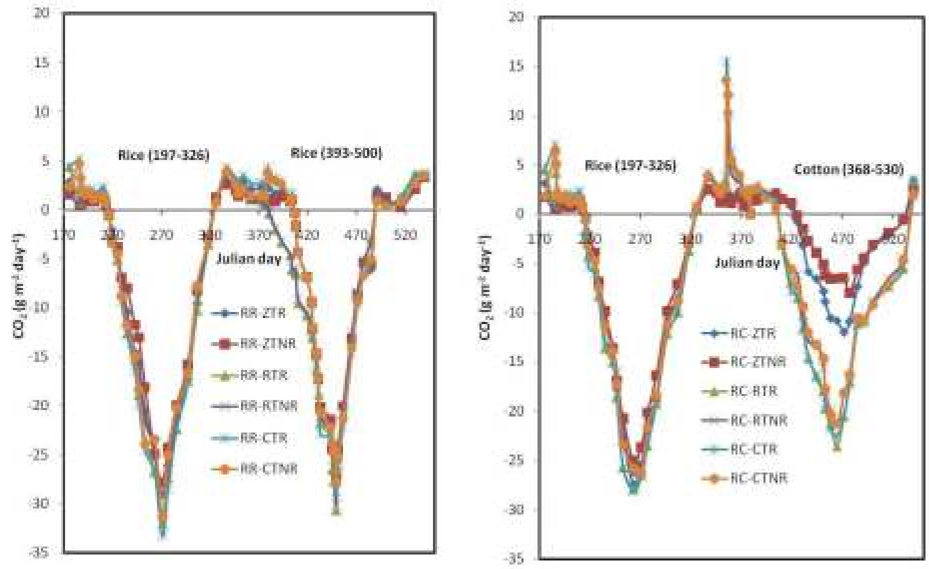
Pre-monsoon season   Monsoon season

Fig.49b. Surface water sanity map of Sundarbans

Assessing carbon sequestration potential of conservation tillage practices under rice based cropping system in coastal saline soils (U.K. Mandal, D. Burman, S.K. Sarangi and T. D. Lama)

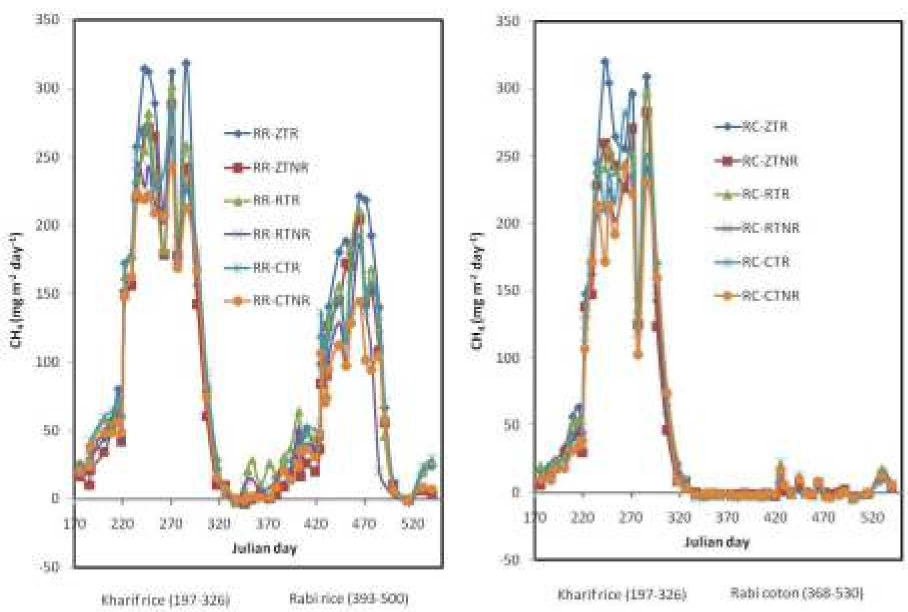
Inappropriate farm practices can increase green house gases (GHGs) emissions and reduce soil organic carbon sequestration, thereby increasing carbon footprints (CFs), jeopardizing ecosystem services and affecting climate change. In this study, a systematic assessment of net ecosystem exchange of CO_2, CH_4 and N_2O fluxes were continuously monitored under rice-cotton cropping system using static gas chambers in coastal region of West Bengal. The design of experiment was split-split plot with cropping system (rice-rice (RR) and rice-cotton (RC)) (*kharif-rabi*) as main plot treatments and tillage type such as zero tillage (ZT), reduced tillage (RT), and conventional tillage (CT) as sub plot treatments and residue (R) and no residue (NR) under sub-sub plot treatments. Energy input of different tillage and residue treatments in rice-rice and rice-cotton systems were estimated by using both direct (amount of fossil fuel used in tillage, sowing, harvesting, human labour, and electricity or diesel for irrigation) and indirect (energy used in production like mineral fertilizers, pesticides and seeds) energy inputs and converted to

Fig. 50. CO_2 emission rates measured by GC under rice-rice (RR) and rice-cotton (RC) systems



C/ha/yr. The static gas chamber consisted of a permanent round base (43 cm diameter), made of galvanized steel, inserted 8–10 cm below the soil surface, and a portable transparent chamber top cylindrical type were used for collecting GHGs flux from fields and was analysed using gas chromatography. Initially GHG emission was monitored throughout the day and night to know how photosysthesis under sunlight influence the net CO_2 flux. The results showed that CO_2 flux was negative during daytime where as it was reverse during night time, but for CH_4 and N_2O flux there was no variation in diurnal cycle . The GHG flux was monitored at 10-12 AM during day time along with the observation at 7-8PM during night time to monitor the ecosystem respiration. The net ecosystem production was calculated considering day time and night time CO_2 flux. The net CO_2 flux increased as the plant growth progress (Fig. 50). CH_4 flux was more in rice-rice system

Fig. 51. CH_4 emission rates measured by GC under Rice-Rice (RR) and rice-cotton (RC) systems



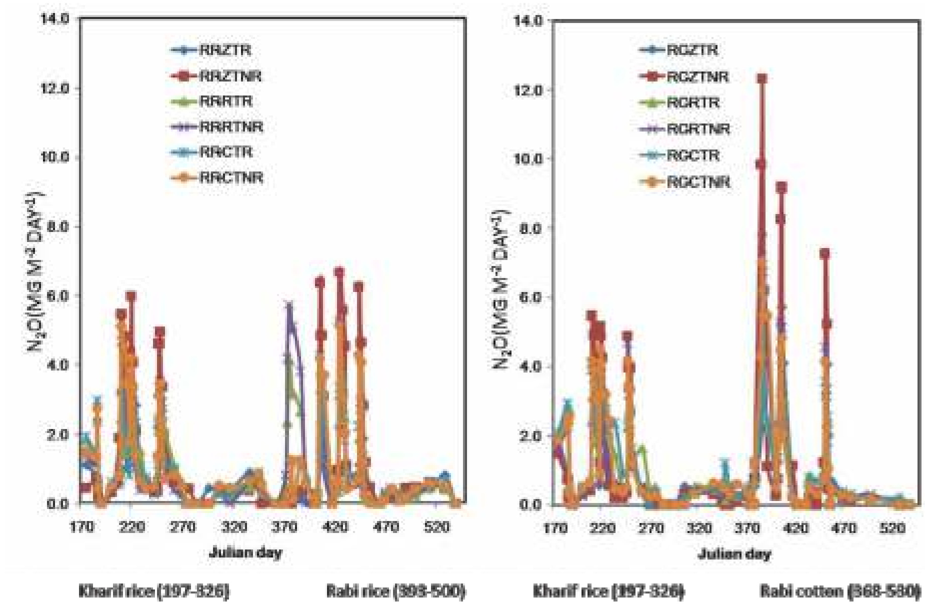


Fig. 52. N_2O emission rates measured by GC under Rice-Rice (RR) and rice-cotton (RC) systems

than rice-cotton system and it was maximum in ZT with residue in rice-rice system (Fig. 51). N_2O flux shoots up as and when N fertilizer was applied and it was maximum under ZT with no residue in rice-cotton system (Fig. 52).

Conservation agriculture for rice-maize cropping system in coastal saline region

(Sukanta K. Sarangi, U. K. Mandal, K. K. Mahanta and T. D. Lama)

Significant effect of *kharif* rice establishment and residue management practices was observed on the yield attributes and yield of *rabi* maize. Kernels per cob in *rabi* maize was significantly influenced by *kharif* establishment methods and conservation tillage practices, with highest 359 kernels per cob was observed in DSR+R, whereas significantly lowest number of cobs per plant (286) was observed in PT-R treatment (Table 54). Kernels

Table 54: Effect of *kharif* tillage, residue management and rabi nitrogen on yield attributes and yield of maize grown during 2018-19 at Canning Town, West Bengal.

Treatments	Cobs plant^{-1}	Kernels cob^{-1}	1000 Kernel wt (g)	Kernel yield (t ha^{-1})	Stover yield (t ha^{-1})
Main-plot: Tillage-cum-crop residue management (TR)					
DSR-R	1.2	336.4	234.6	4.48	7.95
DSR+R	1.4	358.7	239.5	5.07	8.95
PTR-R	1.2	285.8	227.4	3.59	6.85
PTR+R	1.3	346.7	238.7	4.36	7.88
LSD (p=0.05)	0.08	47.36	ns	0.49	1.32
Sub-plot: Nitrogen doses of maize (N)					
N0	1.1	194.8	218.2	2.53	5.61
N1	1.2	342.9	231.6	4.15	7.80
N2	1.4	388.5	248.7	5.17	9.01
N3	1.4	401.3	241.7	5.66	9.21
LSD (p=0.05)	0.07	24.59	10.23	0.53	0.50
TR×N	sig.	sig.	ns	sig.	sig.

DSR, Direct seeded rice; -R, without residue; +R, with residue; PTR, Puddled transplanted rice; N0, 0 kg N ha-1; N1, 80 kg ha-1; N2, 120 kg ha-1; N3: 160 kg ha-1; ns, non-significant; sig., significant.

Table 55: Interaction effect of tillage-cum-crop residue management (TR) with nitrogen doses (N) on kernel yield (t ha^{-1}) of maize during *rabi* 2018-19 at Canning Town, West Bengal.

Treatments	Kernel yield (2018-19)						
	N0	N1	N2	N3	Mean	Comparison	LSD (p=0.05)
DSR-R	3.06	4.58	4.79	5.50	4.48	TR means	0.49
DSR+R	3.28	5.22	5.81	5.97	5.07	N means	0.53
PTR-R	1.69	3.53	3.76	5.39	3.59	(TR×N)*	1.06
PTR+R	2.08	3.26	6.33	5.77	4.36	(TR×N)**	0.87
Mean	2.53	4.15	5.17	5.66			

per cob was also significantly influenced by the doses of N application to maize, with highest 401 kernels/cob observed with highest dose of N application (160 kg N ha^{-1}), however, it was at par (389 kernels cob^{-1}) with 120 kg N ha^{-1}. The kernel weight of maize increased with N doses from 218.2 g under control (0 kg N ha^{-1}) to highest 248.7 g with 120 kg N ha^{-1}. The performance of *rabi* maize during the third year of study in terms of kernel and stover yield was influenced due to *kharif* rice conservation tillage practices as well as *rabi* season N application. Highest mean kernel yield was observed under DSR+R (5.07 t ha^{-1}) and lowest under PT-R (3.59 t ha^{-1}). The response was up to 120 kg N ha^{-1} with kernel yield of 5.17 t ha^{-1} which was at par with 160 kg N ha^{-1} (5.66 t ha^{-1}). Similar trend was observed for stover yield (Table 55).

There was significant effect of main plot treatments (*kharif* rice tillage and residue management) and sub-plot treatment (N doses) on the yield attributes and yield of maize in the third year of study (Table 55).

There was significant interaction effect of tillage and crop residue management practices on the kernels cob^{-1}, 1000 kernel weight, kernel and stover yield of maize in the third year of study. It was observed that when no residue was retained i.e. all the crop residues are removed from the system, the maize crop responded upto 160 kg N ha^{-1}, whereas in case of retention of crop residues, the kernel yield was at par for 120 and 160 kg N ha^{-1}.

(TR×N)*: Comparison of two sub-plot means at the same main-plot treatments; (TR×N)**: Comparison of two main-plot means at the same or different sub-plot treatment; DSR, Direct seeded rice; -R, without residue; +R, with residue; PTR, Puddled transplanted rice; N0, 0 kg N ha^{-1}; N1, 80 kg ha^{-1}; N2, 120 kg ha^{-1}; N3: 160 kg ha^{-1}.

It was observed that when crop residues are retained in the system, nitrogen dose of 120 kg ha^{-1} is optimum for hybrid maize crop in coastal saline region. However, when all the crop residues are removed from the system, higher N dose (160 kg ha^{-1}) is needed to maximize the crop yield.

Coastal Saline Tolerant Variety Trial (CSTVT) (S. K. Sarangi)

During the *kharif* season of 2019 under CSTVT three trials were conducted viz. (1) IVT –CSTVT, (2) AVT 1-CSTVT and (3) AVT-1-NIL (CS). The details of the trials conducted are furnished in the Table 56.

The mean soil salinity of these trials were 5.43, 6.87 and 5.66 for IVT –CSTVT, AVT 1-CSTVT

Coastal Saline Tolerant Variety Trial (CSTVT) under All India Co-ordinated Rice Improvement Project (AICRIP) at Canning Town during *kharif* 2019

Table 56: Details of Coastal Saline Tolerant Variety Trial – CSTVT at Canning Town during kharif 2019

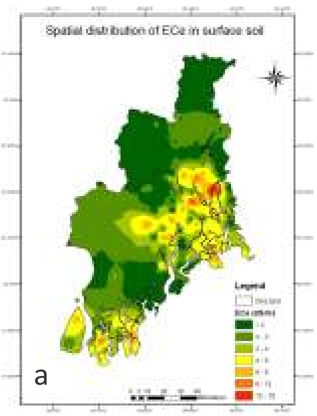
Particulars	IVT-CSTVT	AVT 1-CSTVT	AVT-1-NIL (CS)
No. of entries	27 (IET 3701 - 3727)	16 (IET 3601 - 3616)	18 (IET4501 – 4518)
Rep	4	4	4
Spacing			
Local Checks	Sumati	UtpalaS	warna – Sub 1
DOS	01.08.2019	02.08.2019	08.08.2019
DOT	28.08.2019	30.08.2019	04.09.2019
Plot size	3.24 m^2	3.24 m^2	4.32 m^2

and AVT-1-NIL (CS) respectively. Under IVT-CSTVT, out of 27 entries, highest grain yields were obtained from entry no. 3708 (4.2 t ha^{-1}) followed by entry no. 3717 (3.9 t ha^{-1}), the local check variety Sumati (3727) produced grain yield of 2.6 t ha^{-1}. Under AVT 1-CSTVT, out of 16 entries, grain yields >3.5 t ha^{-1} obtained from entry no. 3604 (3.54 t ha^{-1}) and entry no. 3613 (3.60 t ha^{-1}), the local check variety Utpala produced grain yield of 3.7 t ha^{-1}. Under AVT-1-NIL(CS), out of 18 entries, highest grain yields (3.06 t ha^{-1}) obtained from entry no. 4510 followed by entry no. 4512 (2.95 t ha^{-1}).

Seed production, maintenance and evaluation of rice germplasm (S. K. Sarangi)

Seed production of released varieties of CSSRI under taken in *kharif* 2019. TL seeds produced for Bhutnath, Sumati, Utpala, SR 26B, Sabita, Canning 7 and CST 7-1. Conservation of salt tolerant germplasms for semi-deep, low, medium, upland situations and *rabi* season was done. Rice germplasm including released varieties and lines from ICAR-CSSRI, IRRI, local landraces were maintained and evaluated under different land situations and seasons during 2019. Twenty nine ICAR-CSSRI varieties (CSR 1, CSR 2, CSR 4, CSR 8, CSR 10, CSR 12, CSR 13, CSR 14, CSR 16, CSR 20, CSR 21, CSR 22, CSR 23, CSR 25, CSR 26, CSR 27, CSR 28, CSR 29, CSR 31, CSR 32, CSR 33, CSR 34, CSR 35, CSR 36, CSR 37, CSR 38, CSR 39, CSR 40 and CSR 41) were evaluated during *kharif* 2019. Under semi-deep water situation with stagnant flooding 25 entries (Gitanjali, Swarna-Sub 1, SR 26 - B, Sabita, Patnai - 23, Dinesh, Purnendu, Ambica, Nalini, Manas swarabar, Tilak kanchari, Najani, Sada Mota, CSRC(D)5-2-2-2, CSRC(D)7-0-4, CSRC(D)7-12-1, CSRC(D)13-16-19, CSRC(D)12-8-12, CSRC(D)7-5-4, CSRC(D)2-0-8, CSRC(D) 2-17-5, C 300 BD-50-11, Asfal, NC 678 and Gavir saru) were evaluated. Twenty two entries were evaluated under low land situation (Amal-Mana, Utpala, Sumati, SR 26B, Dadsal, CST 7-1, Bhutnath, Namita-Dipti, Chamar Mani, Dudheswar, Buck Tulsi, CSR 1, CSR 2, CSR 6, Talmugur, Nona Bokra, Pankaj, Pokali, CN 1233-33-9, CN 1231-11-7, CN 1039-9 and Swarna-Sub 1). During *rabi* season forty entries are under evaluation.

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



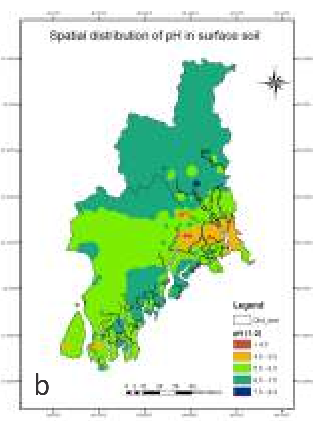


Fig. 53. Map showing the spatial distribution of (a) soil salinity and (b) soil reaction in surface soil (0-15 cm) of North and South 24 Parganas districts, West Bengal

Soil salinity is thus one of the major land degradation problems threatening agricultural production in the fragile coastal ecosystem. It is therefore vital to assess and monitor the extent of salt affected soils and the severity of soil salinity on a spatial scale to delineate areas affected by soil salinity. The present study was initiated to map and develop an updated database of the extent and nature of salt affected soils in coastal West Bengal.

Georeferenced soil samples from 0-15 and 15-30 cm depths were collected from the salt affected blocks in the districts of North and South 24 Parganas in coastal West Bengal. Samples were also collected from the adjoining non saline blocks. The samples were collected during the dry season of 2019, when soil salinity is more pronounced due to deposition of salts on the surface upon evaporation of the water carrying dissolved salts that has moved up from the saline ground water below due to capillary action. 122 geo-referenced soil samples collected from the two districts were analyzed for determination of EC and pH. Soil EC_e in surface soil (0-15 cm) ranged from 0.3 - 17.8 dS m^{-1}. Out of the total, 32% of the surface samples were found to be saline (EC_e > 4 dS m^{-1}) and rest 68 % were non saline. In the sub-surface soil samples (15-30 cm), salinity level in 76% of the samples was below 4 dS m^{-1}, while 24% of the samples were saline having EC_e values above 4 dS m^{-1}. The pH_2 in the surface soil varied from 3.61 to 8.16 and in the sub-surface soil it varied from 4.06 to 8.23. The percentage of surface soil samples having pH in the range of <4.5, 4.5-5.5, 5.5-6.5, 6.5-7.5 and 7.5-8.5 was 3, 13, 35, 46 and 3%, respectively. In the sub-surface soil, pH was <4.5, 4.5-5.5, 5.5-6.5, 6.5-7.5 and 7.5-8.23 in 3, 7, 23, 55 and 12% samples, respectively. pH < 4.5 indicated the presence of acid sulphate soils in the region. Some of the soils were also found to be highly acidic as well as saline. The spatial database generated was used to prepare soil salinity and pH maps using Inverse Distance Weighting interpolation technique in GIS environment (Fig 53 a & b).

Impact of deficit irrigation on salt dynamics and crop productivity in coastal saline soil (T. D. Lama, D. Burman, B. Maji, S. K. Sarangi and K.K. Mahanta)

Field experiment was conducted in the research farm of RRS, Canning Town, during *rabi* season of 2018-19 to study the salt dynamics and crop productivity under deficit irrigation in a heavy textured coastal saline soil. The treatments were laid in a split-plot design with water quality (GW - good quality water, SW_1 - saline water with EC_{iw} 4.0 dS m^{-1} and SW_2 - saline water with EC_{iw} 8.0 dS m^{-1}) as main plot treatments and irrigation levels [I_1 - 125%, I_2 -100%, I_3 -75% and I_4 -50% of cumulative pan evaporation (CPE)] as sub-plot treatments. The electrical conductivity (EC) of good quality water was 1.25 dS m^{-1} having 7.51, 0.24, 2.20, 4.40, 8.80 and 0.13 meq l^{-1} of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-}, respectively. In

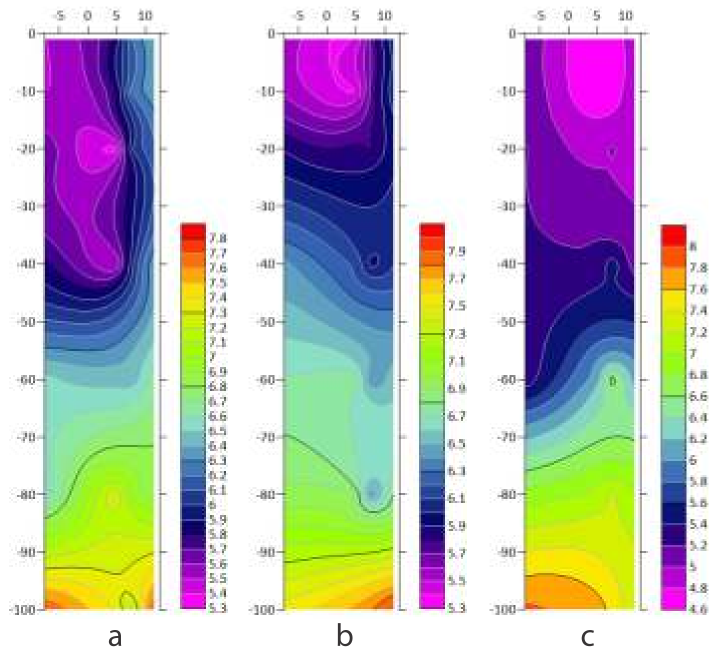


Fig. 54. Spatial variation of soil salinity in the profile under different irrigation levels in maize crop (a) Good Water (b) EC_{iw} - 4 dSm^{-1} and (c) EC_{iw} - 8 $dS m^{-1}$.

saline irrigation water having EC 4.0, their contents were 41.46, 1.26, 5.28, 13.42, 26.40 and 11.33, respectively, while it was 70.11, 2.16, 7.26, 15.29, 77.00 and 14.45 meq l^{-1} in irrigation water having 8.0 dS m^{-1} salinity.

Soil EC_e as well as moisture content was monitored at regular intervals in samples drawn from 0-10, 10-20, 20-40 and 40-60 cm depths were sampled at regular intervals. The soil EC_e increased with the application of saline water irrigation and at the end of maize crop growth period highest mean EC_e of 5.8 dS m^{-1} was recorded in the surface soil layer with the application of irrigation water having salinity level 8.0 dSm^{-1}. The corresponding soil EC_e at was 4.59 with good quality water and 5.38 with irrigation water having EC_e of 4.0 dSm^{-1}. In brinjal crop, with the application of good quality irrigation water and irrigation water with salinity levels of 6.0 and 8.0 dS m^{-1}, the soil EC_e values were 4.73, 5.72 and 6.24, respectively. The spatial distribution of soil salinity under different salinity levels of

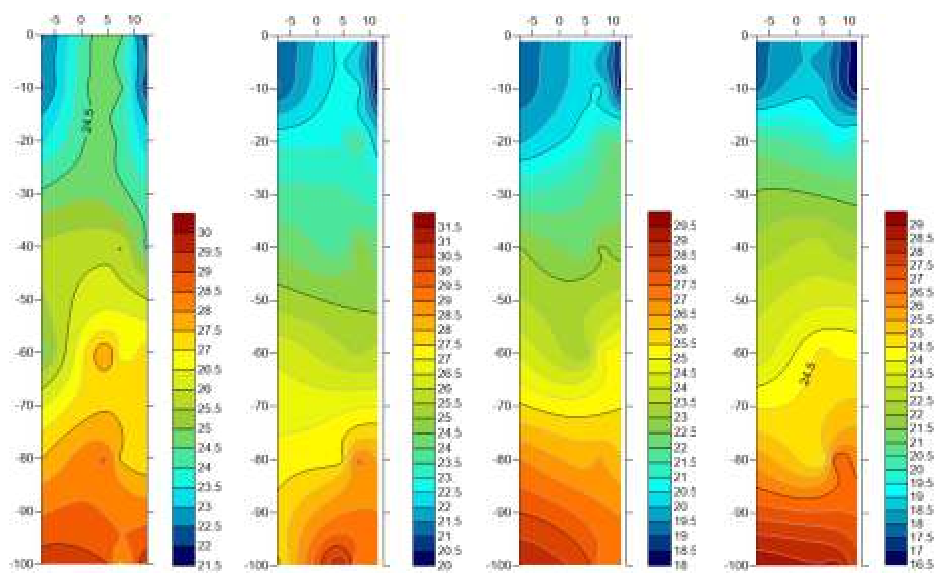


Fig. 55. Spatial variation of soil moisture in the profile under different irrigation levels (a) 125% CPE (b) 100% CPE (c) 75% CPE and (d) 50% CPE.

irrigation water is shown in Fig. 52. However, there was not much difference in soil salinity at the deeper layer below 60-70 cm across the treatments.

The distribution of soil moisture at different irrigation levels is shown in Fig. 53. With increasing distance from the dripper, the moisture content decreased in all the irrigation levels. The moisture content was highest in the zone below the dripper in the treatment where irrigation was scheduled at 125% CPE and it decreased with the decrease in amount of water applied. The zone with high moisture was smaller in the treatments receiving less amount of the water and moved upwards towards the surface

The data on growth and yield as influenced by irrigation and salinity treatments. The highest kernel yield (4.37 t ha^{-1}) of maize was obtained at irrigation level of 125% CPE which was significantly superior over the other treatments. However, the yield obtained in the rest of the treatments was at par. Among the salinity treatments, highest kernel yield (4.25 t ha^{-1}) was obtained with good quality water which was statistically at par with that obtained with application of irrigation water having 4.0 dS m^{-1} salinity, while the lowest yield was obtained in the treatment with application of irrigation water having salinity of 8.0 dSm^{-1}. In brinjal, the highest fruit yield was obtained with good quality water (14.46 t ha^{-1}), which was significantly higher than that obtained with irrigation water having 4.0 and 8.0 dS m^{-1} salinity levels. The yield among the two saline water treatments did not vary significantly. It was observed that deficit irrigation did not have significant effect on the yield of brinjal. Similarly, the irrigation levels did not influence the stover yield and aboveground vegetative biomass, in both maize and brinjal, respectively. This could be attributed to the good amount of rainfall received during the crop growth period. Overall, deficit drip irrigation at 75% and 50% CPE reduced kernel yield of maize by 5.5 and 8.9% respectively, over irrigation at 100% CPE, whereas, fruit yield of brinjal was reduced by 1.7 and 6.6 %. On the other hand, irrigation with 8.0 dSm^{-1} saline water reduced maize and brinjal yields by 21.7 and 12.5 % respectively with 4.0 dSm^{-1} saline water the reductions in maize and brinjal yields were by 10.8 and 6.5%, respectively, over that obtained with good quality water.

In maize, the highest irrigation water productivity (IWP) of 1.91 kg m^{-3} was recorded with good quality water followed by 1.70 and 1.50 kg m^{-3} with 4.0 and 8.0 dSm^{-1} irrigation water salinity. In brinjal the corresponding IWP values were 3.64, 3.43 and 3.21 kg m^{-3}. Among the irrigation treatments, due to less amount of irrigation water applied, the IWP was highest (2.26 kg m^{-3} in maize and 4.86 kg m^{-3} in brinjal) with deficit irrigation at 50% CPE as compared to 125% CPE (1.38 kg m^{-3} in maize and 2.43 kg m^{-3} in brinjal) in both the crops.

Studies on bio-optical response of rice genotypes under varying levels of soil salinity - *Collaborative research project with Regional Remote Sensing Center (RRSC) – East, Indian Space Research Organization, New Town, Kolkata* (K. Chandrasekhar, T. D. Lama, S. K. Sarangi, Prabir Kumar Das and Tanumi Kumar)

Pot experiment was carried out during the *rabi* season of 2018-19 at CSSRI, RRS, Canning in collaboration with Regional Remote Sensing Center (RRSC) - East, Kolkata to study the salinity induced effect on growth, yield, bio-chemical and chlorophyll fluorescence parameters and spectral response of rice. Three salinity regimes (Soil EC <4, 6 to 8 and 10 to 12 dSm^{-1}) were imposed using irrigation water on four rice varieties (Lalat – salt sensitive; Annada – moderately tolerant; Canning 7 – highly tolerant and IR 29 – a sensitive check).

With the increase in salinity levels there was significant reduction in the LAI and the mean peak LAI of 2.83, 2.24 and 1.46 was observed at the three salinity levels of S1 (EC < 4 dS m^{-1}), S2 (EC 6-8 dS m^{-1}) and S3 (EC 10-12 dS m^{-1}) respectively. Among the varieties, the mean peak LAI was highest in Annada, followed by Canning-7, Lalat and IR-29. The lowest peak LAI was recorded in the susceptible check genotype IR-29 (1.33) and susceptible genotype Lalat (1.81) at the highest salinity level, S3. However, it was observed that Annada had higher LAI as compared to the tolerant genotype Canning-7 at all the salinity levels which may be due to the differences in the growth habits.

The above ground plant biomass at harvest was lowest (25.40 g $hill^{-1}$) at the highest salinity level, S1, followed by S2 (26.99 g $hill^{-1}$), while it was highest (40.64 g $hill^{-1}$) under non-saline condition (EC < 4 dS m^{-1}). At harvest there was a significant reduction in biomass by 33.58 % and 37.50% in the salinity levels of 6-8 and 10-12 dS m^{-1}, respectively, as compared to non-saline condition. Among the genotypes the biomass accumulation at harvest was higher in Canning-7, followed by Lalat, Annada and IR-29 . The biomass accumulation in IR-29 (sensitive check) was lowest among all the genotypes at both the higher salinity levels (S2 and S3) while it was highest in the tolerant genotype, Canning -7.

The plant height varied with the salinity levels as well as within the varieties. of 65.07 cm was recorded under non-saline condition (EC < 4 dS m^{-1}), while it was 55.50 and 49.13 cm, respectively, at the salinity levels of 6-8 and 10-12 dS m^{-1} highest plant height of 68.68 cm was recorded in Lalat followed by Canning 7 (62.15 cm), Annada (52.93 cm) and IR-29 (42.52 cm). Among the treatment combinations, highest plant height was recorded in Lalat (67.70 cm) at EC < 4 dS m^{-1} and lowest in IR-29 (30.75 cm) at highest salinity level of 10-12 dS m^{-1}.

Both salinity and genotype had a significant effect on the Na^+/K^+ ratio in shoot, it was significantly highest in IR-29 (6.46) a sensitive check genotype and lowest in the tolerant genotype Canning 7 (2.95). The Ca^{2+}/Mg^{2+} ratio was more in Canning 7 (0.17) (tolerant genotype) and lowest values was recorded in the sensitive genotypes IR-29 (0.1) and Lalat

Table 57: Effect of salinity on yield and yield attributes of rice

Treatments	Yield(g $hill^{-1}$)	Total no. of tillers per hill	Straw wt. (g $hill^{-1}$)	Panicle wt. (g $hill^{-1}$)	Panicle sterility %	1000 grain wt. (g)
V1	7.62	13.33	16.23	9.20	42.15	14.97
V2	8.46	13.94	13.91	10.09	38.60	17.01
V3	8.96	13.50	15.99	10.61	34.38	17.31
V4	5.59	17.03	13.77	7.06	49.42	11.33
CD0.05	1.71	1.39	NS	1.80	NS	NS
S1	18.14	14.25	17.53	21.51	17.23	21.48
S2	4.29	14.65	15.67	6.46	32.79	16.24
S3	0.54	14.46	11.73	1.92	65.12	11.57
CD0.05	1.97	NS	2.46	2.08	13.06	3.99

V1 - Lalat, V2 - Annada, V3 - Canning-7, V4 - IR-29; S1 - Salinity levels; S1 - EC < 4 dS m^{-1}, S2 - EC 6-8 dS m^{-1} & S3 - EC 10-12 dS m^{-1}

(0.13). The highest yield was obtained in rice genotype Annada (20.50 g $hill^{-1}$) followed by Canning-7 (19.49 g $hill^{-1}$), Lalat (17.97 g $hill^{-1}$) and IR-29 (14.60 g $hill^{-1}$) at the lowest salinity level (< 4.0 dS m^{-1}). However, at the highest salinity level, Canning 7 recorded highest yield followed by Annada, Lalat and IR-29 (Table 57). No significant interaction was observed between the genotypes and salinity levels. Across the salinity levels, genotype Canning 7 recorded higher yield (8.96 g $hill^{-1}$) which was at par with Annada (8.46 g $hill^{-1}$) and Lalat (7.62 g $hill^{-1}$). The genotype IR-29 gave significantly the lowest yield of 5.59 g $hill^{-1}$.

The reflectance for different varieties was found to be increased during panicle initiation stage in comparison to early and late tillering stages. In most of the cases, the higher reflectance was observed in case of lower salinity level, denoting lesser impact on crop bio-physical properties. The overall reflectance was minimum in case of IR-29, showing its sensitivity to soil salinity. In case of Annada and Canning-7, the magnitude of reflectance in infrared region followed the sequences of soil salinity levels. The impacts of soil salinity across the rice genotypes were captured very efficiently. The comparison among different genotypes revealed that the IR-29 was most susceptible to soil salinity, as the reflectance was lowest among all the treatments.

Technology for management of salt-affected soils in India – implications on farm income and food security (Subhasis Mandal)

ICAR-CSSRI, Karnal has evolved many agro-technologies suitable managing salt-affected soils in India. The project has been undertaken to analyse cumulative assessment of extent, magnitude and impact of such technology adoption in salt-affected soils in India and to understand the policy needs to out-scale the benefits to larger group of farmers. District level information (224 districts spread over 13 states) on agriculturally important parameters for salt-affected soils in India has been analysed. The data from different government published sources were compiled for analysing the performance covered district wise % salt-affected areas across, district wise % poor (rural), district wise income from agriculture, district wise gross cropped area, net cropped area, cropping intensities, district wise gross irrigated area, net irrigated area, irrigation intensities, district wise yield of key food crops (rice and wheat) and district wise per capita food production (Rice and wheat). The value of each parameter has been scaled (normalised) by using formula, normalized value = (max.X_{ij} – X_{ij}) / (max. Xij – min. Xij), where X_{ij} is value of a parameter present in a district. Thus, the normalised value for each parameter was in the range of 0 to 1. Further, by using these parameters, a composite index (assuming all parameters have equal weightage) was prepared to assess the overall performance of the salt affected districts in India. Index values were in the range of 0 to 5, higher the index values indicted more attention deserves in a particular district.

Over 144 districts having the % salt-affected areas in the range of 5-10%, followed by 39 districts with 10-15%, 21 districts with 15-20% and rest beyond 20% of net sown area within the respective districts. Based on the district level information, it was analysed, how far the salt affected areas were affecting the key agriculturally important indicators at macro level. How far the change was occurring as compared to previous decade, was also analysed (Table 58). The salt-affected soils are known to be affecting the crop losses significantly at micro level (farm-level), however often magnitude of such losses are not realised at macro level. Changing positive (2007-08) to negative sign of co-efficient (2016-17) indicated, such land might be serious threat to district level food security in future, if remain unattended.

Table 58: Salt-affected areas and likely impact on key agriculturally important parameters

Questions	Functions	Co-efficient (2007 -08)	Co -efficient (2016 -17)	Remarks
Does it affect food crops yield (Y) (rice+wheat) ?	Y = f(%SAS)	-0.0112 (NS)	-0.0104 (NS)	Loss of production in SAS area might be compensated by other good land in districts
Does it affect cropping intensity (CI) ?	CI = f(%SAS)	-0.0328 (NS)	-0.5171***	Affecting cropping intensity significantly
Does it affect irrigation intensity (II)?	II = f (%SAS)	NA	-0.6848***	Affecting irrigation intensity significantly
Does it affect net sown area (NSA)	NSA = f (%SAS)	2.3667 (NS)	1.2969 (NS)	Not affecting significantly, good land co-exist within districts
Does it affect per capita food (rice+wheat) production (PCF)?	PCF = f (%SAS)	1.6385 (NS)	-1.6092 (NS)	Not affecting but might be serious threat for future if unattended

Note: NS indicates not significant, SAS indicates salt-affected soil, *** significant at 1% level. % salt-affected areas were assumed to be similar during 2007-08 and 2016-17.

Externally funded projects

NICRA: Climate change mitigation and adaptation strategies for salt affected soils with the objective of Management of sea water intrusion due to climate variability in coastal regions (U.K. Mandal, K.K. Mahanta S. Raut and A.K. Bhardwaj)

The Basanti block (Island) was identified for studying the detailed coastal salinity dynamics.

Total 15 piezometers were installed from east to west of the island up to 30 ft depth to understand the near surface water depth and salinity and monitored the water depth and quality. In most of the cases piezometric water depth was within 1.5 m below ground level indicated limited scope of recharging groundwater. Local factors influenced the salinity and water depth in Piezometer. Piezometer located nearer to tidal river recorded higher EC than the one away from river bed (Fig. 56). Even in rainy season many pizometer recorded EC < 10 dS m^{-1}. As dry season progress there was increase in water salinity of piezometer. In most of the cases there were very high concentration of Mg^{+2}, Cl^{-} and SO_4^{-2}, and Mg^{+2} level were more than Ca^{+2} in all cases indicated influence of sea water in near surface piezometric water quality. We also collected groundwater samples from 57 tube wells in Bananti block. There was slight increase in salinity during summer than winter particularly in shallow wells (Table 59). In all cases Mg^{+2} were more than Ca^{+2}. Sunbarbans

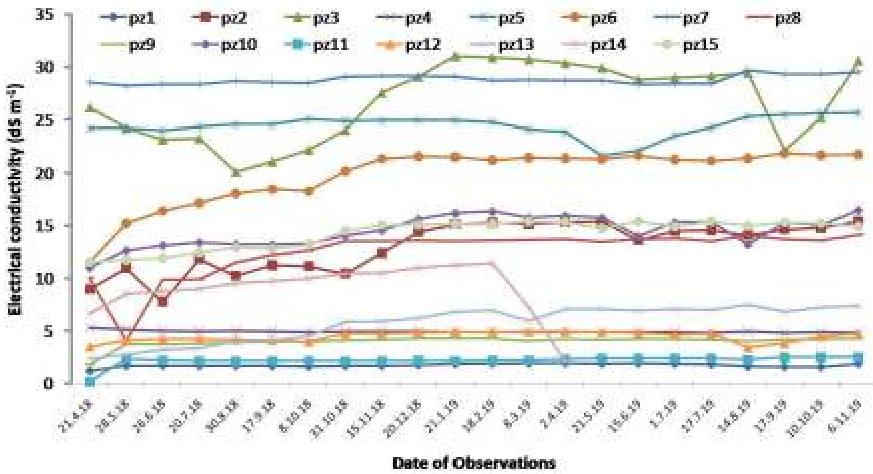


Fig. 56. EC in piezometric water

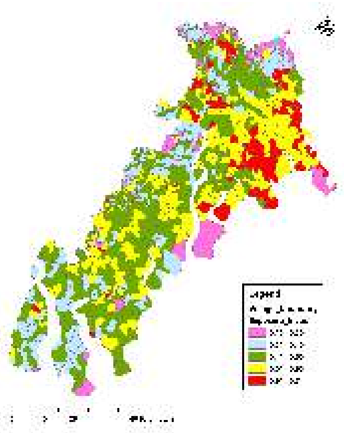


Fig. 57. Village level risk to agriculture due to climate change in Indian Sundarban

land modification systems for rainwater harvesting is most climate resilient technology in terms of lower GHG emissions than rice based systems in Sundarbans region.

In present study the climate change risk in agricultural sector of Indian Sundarbans region was assessed. As per IPCC fifth assessment report (AR5) risk results from the interaction of vulnerability, exposure and hazard. The approach used for assessing vulnerability and risk was based on indicators. The assessment is particularly useful to identify regions with different levels of vulnerability so that investments and interventions can be prioritized and targeted. Indicators were chosen that reflect the three dimensions of risk, i.e., hazard, exposure and vulnerability by considering the definition and meanings (Table 60). The future climate hazard was captured in terms of agriculturally relevant indicators derived from the climate projections from a subset of global climate models. There are 1074 villages in the islands ecosystem which are distributed among 191 gram panchayats. For the present analysis we extracted spatially interpolated long period (1970-2000) climate data from 'WorldClim' database (http://www.worldclim.org). The data was prepared for global climate surfaces on monthly precipitation, minimum, mean and maximum temperature finally from the multiplication functions of exposure, vulnerability and hazard the risk to agriculture (Fig. 57) due to climate change was generated. Out of 1074 No. villages in Sundarbans 174 villages covering an area of 858.62 sq.Km with a population of 7.724 lakhs are under highly risk to agriculture under climate change scenario.

Table 59: Tube well water analysis in Summer & Winter

Sr.	Tube well depth (ft)	pH	EC (dS m^{-1})	Ca (me l^{-1})	Mg (me l^{-1})	Na (mg l^{-1})	K (mg l^{-1})	Cl (meq l^{-1})	SAR
	During winter								
1	<100	7.1±0.1	3.1±1.4	3.6±3.9	11.1±7.0	325.1±140.9	55.1±34.36	10.1±8.99	5±1.98
2	100-500	6.7±0.0	2.6±1.0	3±1.0	5.7±2.1	238.4±72.7	3.6±2.69	25.3±9.38	3.6±0.9
3	>500	7.1±0.4	1.3±0.4	2.0±0.8	3.0±4.37	170.2±46.62	3.2±1.33	8.8±5.32	5.1±1.30
	During summer								
1	<100	8.1±0.15	3.9±1.36	5.5±2.07	13.5±3.83	609.9±306.48	61.5±13.24	18.6±6.88	8.4±3.45
2	100-500	7.4±0.17	3.2±0.51	4.5±3.42	10.1±1.26	386.4±58.55	4.9±1.48	30.7±19.49	5.9±1.08
3	>500	7.7±0.28	1.1±0.40	2.0±0.73	3.3±1.37	253.9±77.95	3.7±0.59	10.6±8.48	6.8±0.94

Table 60: Indicators selected for various scale of risk to agriculture due to climate change impact

Vulnerability	Exposure	Hazard -Historical	Hazard -Future
Normal rainfall (mm) Human Development index % irrigated area, Literacy rate, poverty rate, Livestock density	Net sown area (% of Total Geographical Area)	Annual maximum, minimum and mean temperature (oC), 1970-2000	Projected maximum, minimum and mean temperature (oC) (HadGEM2-AO)Represented concentration pathways 8.5 by 2050
Amenity available like education, medical, Transport communications, banks, power supply, Agricultural Credit Societies, Approach by pucca road	Rural population density, SC-ST population %, % marginal workers to total workers, Land use land cover as NDVI	Mean *kharif* rainfall (mm)(June, July, August, September) Mean *rabi* rainfall (mm) (December, January, February and March)	Projected *kharif* rain (mm) HadGEM2-AO) based on represented concentration pathways 8.5 by 2050; Projected *rabi* rain (mm) HadGEM2-AO) based on represented concentration pathways 8.5 by 2050
Available water capacity, Hydraulic conductivity, soil organic C, soil pH, soil electrical conductivity	%Agricultural labourers to total workers	Mean altitude (MSL) from SRTM database, Distance from sea or creeks	

Experiment: Silicon fertilizer evaluation for the amelioration of salinity stress in wet and *rabi* seasons of the coastal saline environment of West Bengal ICAR-IRRI Collaborative Project (S. K. Sarangi)

The coastal region close to the marshy *Sunderban* area of West Bengal faces waterlogging at an early stage of crop establishment and high salinity due to the coastal tidal rivers at the later reproduction phase during the Wet season. Whereas, *Rabi* season exhibits soil salinization problem similar to the inland soil salinity. Specific these tolerant rice varieties (STRVs) have been already identified for cultivation in these areas for different cropping seasons. Silicon (Si) is a beneficial nutrient for rice. The soil of the Indo-Gangetic plain is rich in Si, but due to interaction with soil cation and anions maximum Si getsconverted into the insoluble salts.

The plant height was affected by the method and dose of silicon application. The highest mean plant height (153.6 cm) was observed when 50% of the Si dose applied as a foliar spray at 10 days of water logging and rest 50% as a foliar spray before panicle initiation stage (Table 54). Plant height increased from 143.5 cm without silicon application to 152.8 cm with 62.1 kg Si ha^{-1}. Among the yield attributes panicles per hill was increased due to the application of silicon. The number of empty spikelets per panicle was significantly higher in susceptible variety Sabita than tolerant Amal-Mana.

The grain and straw yields were significantly affected by the silicon dose. It was observed that due to the application of silicon fertilizer the grain and straw yield were increased

Table 61: Effect of Si fertilizer application method and doses on plant height at maturity (cm) and yield attributingtraits in an on-station experiment conducted during Wet season 2019 at ICAR-CSSRI RRS Canning Town, West Bengal, India

Treatments	Plant height (cm)	Panicles $hill^{-1}$	Grains $panicle^{-1}$	Empty spikelets $panicle^{-1}$	1000 grain weight (g)
Main-plot: Rice varieties (V)					
Amal-Mana	149.4	13	136	34	27.51
Sabita	146.0	13	135	41	27.87
LSD0.05	NS#	NS	NS	6.2	NS
Sub-plot: Method of application					
M1	144.2	13	135	38	27.86
M2	145.3	13	136	37	28.11
M3	153.6	13	135	38	27.09
LSD0.05	4.9	NS	NS	NS	NS
Sub-sub plot: Dose of silicon (kg ha^{-1})					
F1 (0)	143.5	11	132	38	27.97
F2 (24.2)	145.5	12	137	34	28.16
F3 (41.05)	148.4	13	138	40	28.03
F4 (50.06)	148.4	13	135	37	27.73
F5 (62.1)	152.8	13	136	38	26.56
LSD0.05	3.4	0.9	NS	NS	NS

#NS, not-significant; M1: 100% basal with the recommended dose of fertilizers (RDF), M2: 75% basal with RDF + 25% foliar at maximum tillering, M3: 50% foliar spray during 10-12 days after waterlogging + 50% foliar spray before panicle initiation

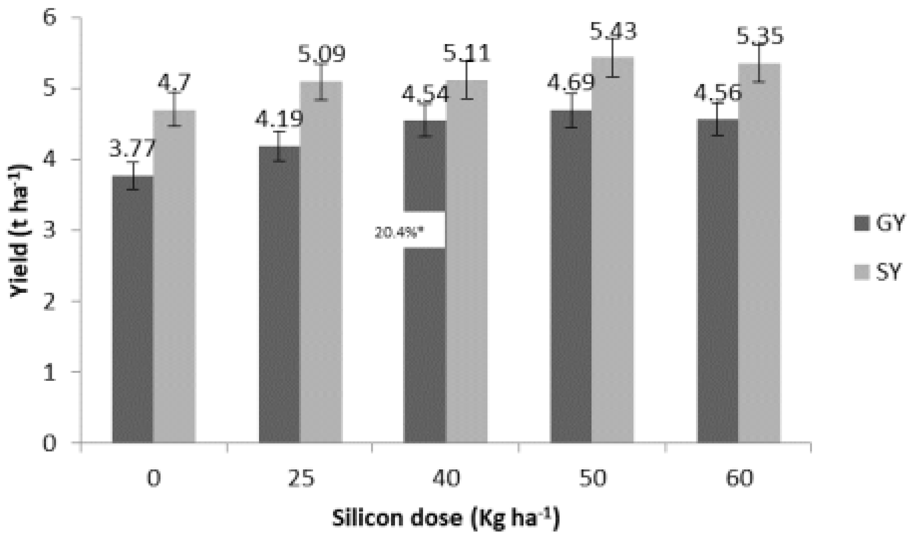


Fig. 58. Grain Yield (GY) and straw yield (SY) as influenced due to the application of Si fertilizer in an on-station experiment conducted at ICAR-CSSRI RRS Canning Town, West Bengal, India during wet season 2019. '*' represents the significance level (P≥0.05) over the control (0 kg Si ha^{-1}).

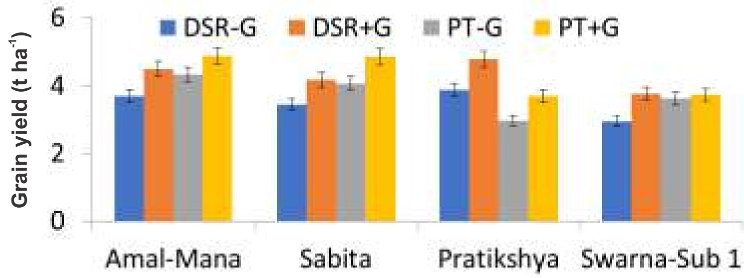


Fig. 59. Yield of different rice varieties under different establishment and management practices

from 11-24% and 8-16%, respectively. However, the grain yield response was upto 50 kg Si ha^{-1} (Fig.58).

Experiment: Evaluation of SUB 1 gene introgressed rice genotypes under dual (salinity and submergence) stress in rainfed lowlands (*kharif* 2019).

During the *kharif* 2019 six SUB 1 gene introgressed rice varieties viz. Ciherang – Sub 1, CR 1009 – Sub 1, BR 11 – Sub 1, Samba – Sub 1, IR 64 – Sub 1, Swarna – Sub 1 along with SR 26B (local check) were evaluated with dual stress of submergence and salinity. The crop was submerged due to heavy rain during August 2019 for about 2 weeks. Soil salinity (EC_e) during the reproductive stage of the crop was 9.1 dS m^{-1}. Highest grain yield of 2.5 t ha^{-1} was obtained from CR 1009 Sub 1, which was at par with Samba Sub 1 (2.4 t ha^{-1}). The local variety SR 26B produced grain yield of 2.2 t ha^{-1}.

Experiment: Developing risk reducing practices to minimize the salinity stress in DSR in coastal salt affected areas.

During *kharif* 2019, an experiment was conducted with four main plot treatments viz. DSR without gap filling (DSR-G), DSR with gap filing to replace mortality due to salinity (DSR+G), puddled transplanted rice without gap-filling after flooding (PTR-G) and puddled transplanted with gap-filling after flooding (PTR+G). The sub-plot consisted of four rice varieties viz. Amal-Mana, Sabita, Pratikshya and Swarna-Sub 1. The experiment was conducted in a split plot design with three replication.

There was a deficit rainfall during July 2019 (213.6 mm) as compared to long-term average of 2001-18 (417.7 mm), whereas during August 2019 the rainfall was excess (458 mm) as compared to long-term average (377.8 mm). There was mortality of seedling due to salinity in DSR plots (EC_e 7.73 dS m^{-1}) in July 2019 and due to submergence in puddled transplanted plots in August 2019. Therefore, the grain yield significantly increased due to gap filling (Fig. 59).

ACIAR Project: Cropping systems intensification in the salt affected coastal zones of Bangladesh and West Bengal, India (Sukanta K. Sarangi, D. Burman, U. K. Mandal, S. Mandal and K .K Mahanta)

This project funded by Australian Centre for International Agricultural Research (ACIAR) was implemented both during wet (*kharif*) and dry (*boro*) seasons in the farmers' fields. The project is implemented both in India and Bangladesh. CSSRI, RRS, Canning Town is implementing the project at the Sonagaon village in the Gosaba island of South 24

ACIAR *Project site at Gosaba Island, Sundarbans*

Parganas district including 199 male and 136 female farmers covering about 18 crops to increase cropping intensity through introduction of improved management practices, new crops and varieties.

River (surrounding the Gosaba island) water salinity is very high thoroughout the year 16.8 – 47.7 dS m^{-1}. The salinity of water in the drainage channel (locally called Nayanjuli) was variable (<0.5 dS m^{-1} to > 10 dS m^{-1}). Ground water salinity observed in the Gosaba island through piezometers was also saline.

Intensification of waterlogged paddy field

Intensification of waterlogged paddy field was done through cultivation of vegetables in bags filled with soil and farm yard manure. The study was conducted in 12 farmers' fields consisting of 6 female and 6 male farmers and there BC ratio was found from 1.63 to 4.46

Zero-tillage potato cultivation with paddy straw mulching – An innovative practice for cropping system intensification in the salt affected coastal region

Zero tilled paddy straw mulched potato cultivation technology developed under this project found to be a sustainable practice for the cropping system intensification in the coastal saline region. The soil properties studied after three years reveal that there is increase in organic carbon, available N and P due to this (Table 62).

Drip irrigation with different mulching materials were also studied there was a significant saving of labour and irrigation water due to these practices compared to the conventional flood irrigation practiced by farmers. The weed biomass was the lowest when drip irrigation is combined with plastic mulching. However, paddy straw mulching also significantly reduced the weed biomass compared to farmers practice.

Intensification of waterlogged paddy field for vegetable cultivation during *kharif* 2019

Ground and surface water study under the ACIAR Project

The observations from five numbers of piezometers installed in January 2017 at 20 feet below ground level reveal that the ground water in the Gosaba island is highly saline with average salinity of 10.3 dS m^{-1}. There was seasonal fluctuation of ground water depth in the study site. However, the water table never goes beyond 2.0 m throughout the year.

Quality (salinity and pH) of surface water resources from ten different sources (Gosaba Ghat, Durgaduani river, Gomar river, Nayanjuli, Sluice gate, Tube well, Tap water, 3 number of ponds) were monitored in the Sonagaon village. The water salinity of all the rivers is saline throughout the year round (16.8 – 47.7 dS m^{-1}), and was highest during March - May (> 30 dS m^{-1}). The salinity of pond water was lowest among different sources of water (Fig.60).

Table 62: Effect of zero tillage (ZT) with paddy straw mulching (PSM) on soil properties

Treatments	Organic carbon (%)	Bulk density (Mg m^{-3})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T1: Ridge sowing	0.39c	1.49a	140.8c	10.96b	265.5
T2: ZT +9 t ha^{-1} PSM	0.42b	1.46b	154.8ab	11.44b	264.5
T3: T2 + foliar spray	0.42b	1.46b	152.6b	11.48b	265.1
T4: ZT +12 t ha^{-1} PSM	0.44a	1.44c	155.0ab	11.44b	265.1
T5: T4 + foliar spray	0.44a	1.44c	155.8ab	12.26a	266.0
T6: ZT +15 t ha^{-1} PSM	0.45a	1.43d	159.0a	12.82a	264.9
T7: T6 + foliar spray	0.45a	1.43d	159.4a	12.90a	265.3

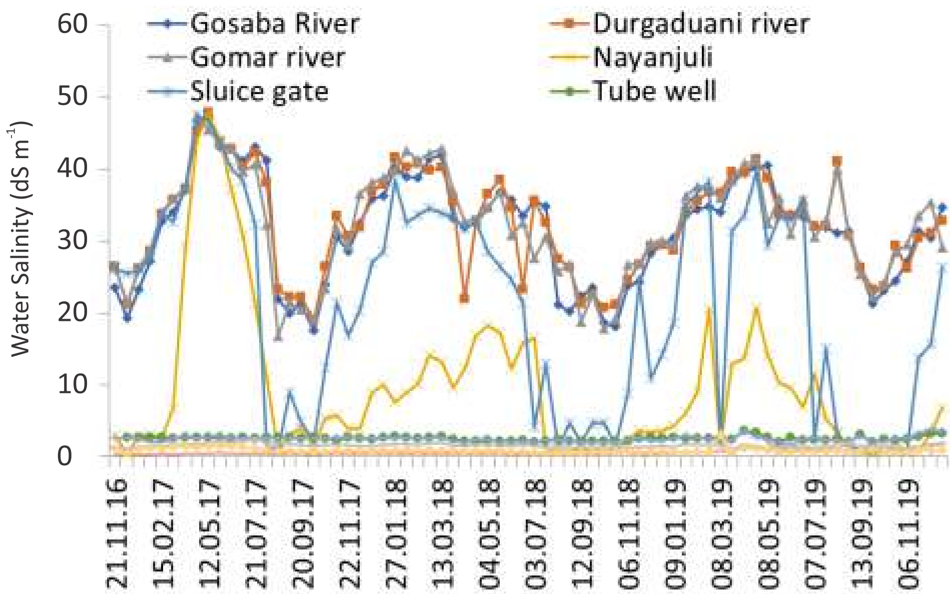


Fig. 60: Salinity of surface water resoureces of Sonagaon village during 2016-19 in the Gosaba

Development of salt-water balance model

A simple time-stepping model of water and salt stores and flows for Gosaba island as well as similar situations in coastal Bangladesh (called polders) developed. This model deals with the transfers of water and salt amongst the soil-plant continuum, the atmosphere, the ground water, the ponds and canals which drain the island, and the surrounding rivers. A Monte-Carlo sensitivity analysis of the model shows that the results are sensitive to the key model parameters. In general, the results are more sensitive to parameters governing the transfers of salt, and less sensitive to those governing the availability of water. This model will be useful for investigating new water and salt management procedures, and for investigating the impacts of climate change, by modifying the input data to form appropriate scenarios.

AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture

Amelioration of iron deficiency in direct seeded /aerobic rice grown on reclaimed sodic soil (B.L. Meena, R.K. Fagodiya, R.L. Meena, M.J. Kaledhonkar and P.C. Sharma)

Aerobic rice (direct seeded rice) is grown under non-puddled, nonflooded and non-saturated soil conditions similar to other upland crops. Micronutrient deficiency, especially iron (Fe) is more serious nutritional problem in DSR. It may be more pronounced in partially reclaimed sodic soils. In view of these facts, a field experiment was conducted at ICAR-CSSRI, Karnal to evaluate yield response to iron nutrition. Results indicated that the DTPA extractable Fe of soils at time of harvest of rice crop was influenced by Fe application methods (Table 63). The DTPA extractable Fe in the soil was significantly increased due to soil application of Fe over control while, as expected, foliar application of Fe did not bring any change. The highest content of NH_4OAc extractable Fe

Table 63: Soil extractable-Fe in soils as influenced by the methods of iron application at the harvest of rice (CSR 60)

Treatments			DTPA-Fe (mg kg^{-1})	% increase over control	NH_4OAc-Fe (mg kg^{-1})	% increase over control
T1	:	Control (no Fe application)	4.86	-	2.50	-
T2	:	30 kg Fe through $FeSO_4$	5.41	11.3	2.66	6.40
T3	:	40 kg Fe through $FeSO_4$	5.83	19.9	2.85	13.9
T4	:	50 kg Fe through $FeSO_4$	6.12	26.0	2.93	17.0
T5	:	FS of 1.5% $FeSO_4.7H_2O$	4.94	1.65	2.54	1.53
T6	:	FS of 3% $FeSO_4.7H_2O$	4.94	1.71	2.54	1.60
T7	:	FS of 0.5% Fe-EDTA	4.97	2.26	2.56	2.40
T8	:	FS of 0.2% Fe-EDDHA	5.07	4.25	2.61	4.53
T9	:	FS of 0.2% Fe-DTPA	4.90	0.89	2.52	0.67
		CD (p=0.05)	0.76		0.25	

Performance of Wheat under aerobic rice-wheat system in soil application of 40 kg Fe ha^{-1}

was 2.93 mg kg^{-1} under soil application of 50 kg Fe ha^{-1} which was significantly higher than control. Like DTPA, NH_4OAc-Fe was similar under soil application of Fe and foliar application of Fe treatment. However, NH_4OAc reagent extracted proportionately lower amounts of Fe under various treatments as compared to the DTPA. The mean grain yield of wheat (KRL-210) was significantly higher under 3 foliar sprays of 0.5% Fe-EDTA (62.4 q ha^{-1}) compared to control (56.0 q ha^{-1}). Soil application did not significantly influence the yield of wheat. On the basis of these results, soil application of Fe through $FeSO_4$ has a potential of getting readily converted into unavailable form, yet there was a marginal increase in available Fe (DTPA and NH_4OAc extractable) content in partially reclaimed sodic soils.

Survey and characterization of underground irrigation waters of Jodhpur district (Bikaner Centre)

Total 170 water samples from 121 villages i.e. 19 villages of Balesar,13 villages of Bap, 23 villages of Denchu, 23 villages of Lohawat, 22 villages of Phalodi and 21 villages Shergarh tehsils of Jodhpur district were collected and analyzed for various chemical characteristics (EC, pH, cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}), anions (CO_3^{-}, HCO_3^{-}, Cl^{-} and SO_4^{2-}), Floride (F^{-}) and Nitrate (NO_3^{-}). Surface soil samples were also collected from the fields irrigated with corresponding water and analyzed for their characterization.

About 100, 62.5, 100, 100, 72.42 and 93.33 per cent water samples in Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils had RSC in the range of < 2.5 meq l^{-1}, respectively. As regard to salinity, groundwater samples having EC < 2 dS m^{-1} were 41.94, 6.25, 12.50, 71.88, 10.34 and 3.33 per cent in Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils, respectively. Further 29.03,0, 31.25, 3.13, 24.14 and 30.00 per cent water samples were in the range of EC 2 to 3 dS m^{-1} in these tehsils, respectively. The 25.81, 12.50, 28.13, 15.63, 27.59, 10.00 and 3.23, 81.25, 28.13, 9.38, 37.33, 56.67 per cent water samples had EC 3 to 4 and >4 dS m^{-1} in Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils, respectively.

The concentration of Fluoride in water samples ranged from 0.02 to 1.34 (mean 0.46), 0.02 to 1.85 (mean 0.75), 0.04 to 0.85 (mean 0.47), 0.30 to 0.90 (mean 0.56), 0.03 to 1.50 (mean 0.63) and 0.02 to 2.52 (mean 0.71) mg l^{-1}, whereas, Nitrate content of water samples ranged from 1.10 to 114.40 (mean 52.67), 5.30 to 53.10 (mean 33.92), 1.50 to 128.20 (mean 31.79), 2.10 to 130.50 (mean 42.56), 2.70 to 120.60 (mean 32.93), and 1.40 to123.00 (mean 46.65) mg l^{-1}, respectively for Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils of Jodhpur district.

Table 64. Per cent water samples under different categories of water quality in different tehsils of Jodhpur district

S.N	Water quality category	Name of tehsils					
		Balesar	Bap	Denchu	Lohawat	Phalodi	Shergarh
1.	Good 38.71	6.25	12.90	71.87	10.34	3.33	
2.	Marginally saline	58.06	6.25	58.06	18.75	41.38	33.33
3.	Saline	3.23	-	3.23	-	-	3.33
4.	High- SAR saline	-	62.50	25.81	9.38	20.69	56.68
5.	Marginally alkali	-	-	-	-	-	3.33
6.	Alkali -	-	-	-	-	-	
7.	Highly alkali	-	25.00	-	-	27.59	-

The range of chemical characteristics of soil samples irrigated with corresponding tube well waters of different tehsils of Jodhpur district indicated that pH_2 of soil samples in Balesar tehsil varied from 8.57 to 9.32, Bap tehsil from 8.80 to 9.57, Denchu tehsil varied from 8.34 to 9.25, Lohawat tehsil from 7.50 to 9.53, Phalodi tehsil varied from 8.48 to 9.83 and Shergarh tehsils from 8.57 to 9.92, whereas, the corresponding EC_2 ranged from 0.08 to 0.70; 0.18 to 1.53; 0.2 to 1.07; 0.07 to 0.73; 0.11 to 1.12 and 0.16 to 0.78 dS m^{-1}, respectively in Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils.

Survey and characterization of ground waters of Faridabad district for irrigation (Hisar Centre)

Faridabad district of Haryana is divided into two blocks, namely, Faridabad and Ballabgarh. Total 118 groundwater samples were collected randomly from Ballabgarh block while 100 groundwater samples were collected randomly from Faridabad block. In the Faridabad district, electrical conductivity (EC) ranged from 0.50 to 9.91 dS m^{-1} with a mean of 2.57dS m^{-1}. It was observed that in Faridabad district, 188 samples had EC 0-4 dS m^{-1}. 77 samples had EC ranges from 4 to 10 dS m^{-1}, 29 samples had EC ranges from 8-10 dS m^{-1}.

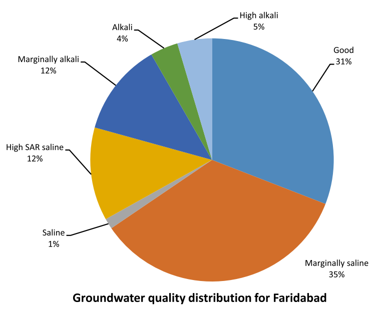


Fig.61.Quality of groundwater (percent) in Faridabad district

In case of anions, chloride was the dominant anion with maximum the concentration of chlorides in groundwater samples varied from 1.90 to 68.0 me l^{-1} with the mean value of 12.95 me l^{-1}. The concentration of bicarbonates in groundwater samples varied from 0.20 to 15.20 me l^{-1} with a mean value of 5.03 me l^{-1}. The mean values for CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} were found to be 1.47, 5.03, 12.95 and 4.47 me l^{-1}, respectively. The concentration of sodium in groundwater samples varied from 2.60 to 63.20 me l^{-1} with an average value of 16.35 me l^{-1}, followed by magnesium (1.50 to 26.10 me l^{-1}) and calcium (5.50to 8.10 me l^{-1}). Mean values for Na^+, Mg^{2+}, Ca^{2+} and K^+ were 16.35, 6.16, 2.09 and 0.27 me l^{-1}, respectively. According to AICRP classification, it was found that 30.9 percent samples were of good quality, 48.4 percent saline and 20.7 percent alkali in nature (Fig. 61). Out of the saline water, 34.6, 1.4 and 12.4 percent were in marginally saline, saline and high SAR saline, respectively. In alkali group 12.4, 3.7 and 4.6 percent were in marginally alkali, alkali and high alkali, respectively. Out of seven categories of water, maximum 34.6 percent of samples were found in marginally saline followed by good quality (30.6 percent) and minimum 1.4 percent were found in saline category.

Groundwater quality map for Faridabad district according to AICRP criteria was prepared to study its spatial variability in the district (Fig.62). In the district, 30.9 percent samples are under good category but spatial variable map of block indicates less area under good quality. This is due to higher concentration of tubewells in that area and accordingly more samples were collected from that area. Good category groundwater is 29% in Ballabgarh block and 33% in Faridabad block of the district and highly scattered in other blocks. Maximum saline water 50.0% was found in Faridabad block whereas maximum alkali 37.6% water was found in Ballabgarh block. Area of the district having EC < 2 dS m^{-1} can come under good quality category but among these area where SAR < 10 and RSC ≥ 2.5 me l^{-1} will come under marginally alkali and alkali. Most of the area where EC is more than 4 dS m^{-1} went under high SAR saline in comparison to saline condition, whereas, in both condition EC is more than 4 dS m dS m^{-1}. With this fact area under high SAR saline is increased and area under saline condition is reduced. There is a little problem of alkalinity in groundwater of the district because marginally alkali and alkali categories were observed very scattered with small polygons.

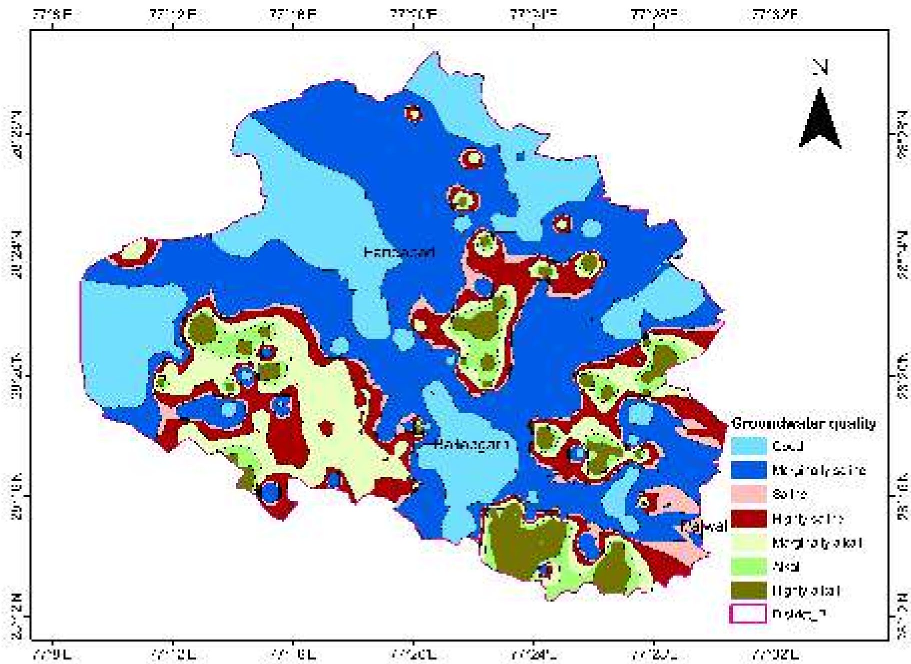


Fig.62. Groundwater quality map for Faridabad district according to AICRP criteria

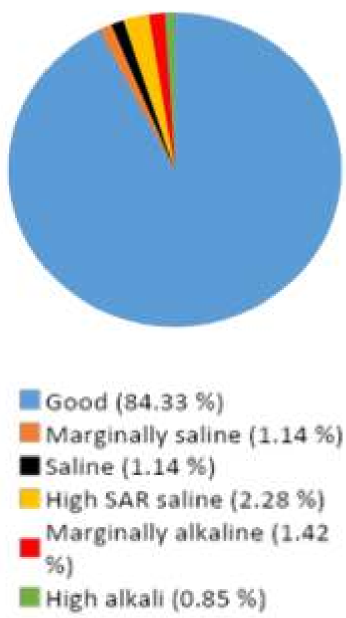


Fig. 63. Classification of ground water samples in Kerala for irrigation

Survey, characterization and mapping of ground water quality in the coastal areas of Kerala (Vytilla)

The survey and collection of ground water samples was initiated on 2014-15 to assess the ground water quality in the coastal areas of eleven districts of Kerala viz. Thiruvanamthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragode. Geo-referenced ground water samples were collected from ground water monitoring wells according to details given by Central Ground Water Board (CGWB), Trivandrum and also from nearby cultivated fields. In case of remaining districts viz, Idukki, Palakkad and Wayanad data was collected from CGWB to classify the ground water quality. The survey, collection and analysis of ground water samples of all the districts were completed. To assess the salinity status of study area, samples were analyzed for pH, electrical conductivity, carbonate, bicarbonate, chloride, sulphate, sodium, potassium, calcium, magnesium and boron. Quality parameters like, SAR and RSC were calculated. Classification of water quality was done on the basis of EC, SAR and RSC according to ICAR-CSSRI.

Analysis of the two hundred and thirty three ground water samples from all districts revealed some of the general observations which are given below (Fig. 63). Out of 351 samples of ground water analyzed, 296 were in good category, four each in marginally saline and saline category respectively. Twenty eight samples were marginally alkaline and two samples were highly alkaline in nature. As a whole in Kerala, 84.33 %, 1.14 %, 1.14 %, 2.28 %, 1.42 % and 0.85 % fall under good, marginally saline, saline, high SAR saline, marginally alkaline and high alkali category of ground water quality. Preparation of ground water quality maps of Thiruvanathapuram and Ernakulam districts were completed. In other districts, the preparation of maps is under progress.

Assessment of efficacy of organic amendments for sustainable crop production under rice-wheat cropping system in sodic soil (Kanpur)

This experiment was conducted at Research farm, Dalipnagar, Kanpur with the objectives to find out the suitable combination of organic and inorganic inputs for sustainable crop production in sodic conditions during 2016 to 2019. The treatments comprised of T_1- 50% GR; T_2- 25% GR (Gypsum Requirement) + rice straw @5 t ha^{-1}; T_3- 25% GR + GM @5 t ha^{-1}; T_4- 25% GR + GM (Green Manure) @5 t ha^{-1} + Microbial Culture (MC); T_5- 25% GR + Poultry Manure (PM) @3 t ha^{-1}; T_6- 25% GR + City Waste Manure (CWM) @5 t ha^{-1} and T_7 - Control. Rice variety CSR 36 and wheat variety KRL 210 were sown during kharif and rabi season. The initial soil status was pH 9.50, EC (0.94 dS m^{-1}), ESP 48.20 and OC 0.21%. The average grain and straw yield of rice varied from 24.48-42.37 and 29.48-50.89 q ha^{-1} respectively. The maximum yield of grain (42.37 q ha^{-1}) and straw (50.89 q ha^{-1}) was obtained from 25%GR + Poultry manure @ 3 t ha^{-1} treatment followed by 25% GR + GM @ 5 t ha^{-1} + Microbial culture and 25% GR + City Waste Manure @5 t ha^{-1} while minimum yield was received from control plot.

The average grain and straw yield of wheat varied from 19.59-36.78 and 24.13-44.73 q ha^{-1} respectively. The maximum yield of grain (36.78 q ha^{-1}) and straw (44.73 q ha^{-1}) was obtained from 25% GR + Poultry manure @ 3 t ha^{-1} treatment followed by 25% GR + GM @5 t ha^{-1} + Microbial culture and 25% GR + City Waste Manure @ 5 t ha^{-1} while minimum yield was received from control plot.

The maximum changes in pH, electrical conductivity, exchangeable sodium percentage (ESP) and organic carbon (OC) in 50% GR treated plot followed by 25% GR + Poultry manure @3t ha^{-1}. and 25% GR + GM @ 5 t ha^{-1} + Microbial culture than other treatments.

Performance of flower/medicinal plants with saline irrigation water through drip system (Bapatla)

The flower crops like chrysanthemum and marygold and also medicinal crop tulsi were grown on coastal sandy soil at Bapatla with saline water irrigation through drip. Initially

Table 65: Irrigation water salinity with respect to different yield levels of crops

Yield Level	Chrysanthemum		Marygold		Tulasi	
	EC_{iw} of flowers plant^{-1}	flowers plant^{-1} ECiw	Flowers plant^{-1}	EC_{iw}	Biomass (t ha^{-1})	EC_{iw}
100	96.8	0.5	158.6	0.4	8.6	0.9
90	87.12	1.5	142.7	1.4	7.74	3.0
80	77.44	2.6	126.9	2.4	6.88	5.0
75	72.6	3.1	119.0	2.9	6.45	6.0
70	67.76	3.7	111.0	3.5	6.02	7.0
60	58.08	4.7	95.2	4.5	5.16	9.0
50	48.4	5.8	79.3	5.5	4.3	11.0
40	38.72	6.9	63.4	6.5	3.44	13.0
30	29.04	7.9	47.6	7.6	2.58	15.0
20	19.36	9.0	31.7	8.6	1.72	17.1
10	9.68	10.1	15.9	9.6	0.86	19.1
0	0	11.1	0.0	10.6	0	21.1

Table 66. Effect of organic treatments on yield parameters of okra grown on raised bed

Treatments	Fruit weight (g)	Fruit Number	Fruit yield plant^{-1} (g)	Fruit yield ha^{-1} (t)
Control	9.0^{a}	10.2^{a}	106.6^{a}	5.93^{a}
Biogel (Bioconsortia + Seaweed extract)	11.5^{c}	11.4^{b}	126.5^{b}	6.96^{bc}
Biogel+ Panchagavya	12.9^{d}	11.8^{b}	140.0^{c}	7.70^{c}
Panchagavya	11.7^{c}	11.6^{b}	125.5^{b}	6.90^{bc}
Bioconsortia	10.6^{b}	12.0^{b}	121.6^{b}	6.75^{b}
CD (0.05)	0.945	1.051	15.024	0.823

soil was non-saline with pH 7.1 and EC_e as 0.5 dS m^{-1}. The crops were irrigated with waters with different salinity such as 0.6, 2, 4, 6, 8 dS m^{-1}. Results indicated that chrysanthemum recorded 96.8 flowers per plant at 0.6 dS m^{-1} and reduced to 68.1 flowers per plant at 8.0 dS m^{-1} by recording 30.9 flowers per plant. Marygold registered 158.6 flowers plant^{-1} at 0.6 and reduced to 71.8 at ECiw of 8.0 dS m^{-1} with 44.7 flowers plant^{-1}. For both, chrysanthemum and marygold 50% yields were obtained at water salinity level of 5.8 and 5.5 dS m^{-1}, respectively. However, Tulasi recorded 8.6 t ha^{-1} of biomass at 0.6 dS m^{-1} and reduced to 5.6 t ha^{-1} at 8.0 dS m^{-1} and there was a reduction of 35.2%. It clearly showed that tulsi was more tolerant to salinity as compared to chrysanthemum and marigold. The salinity build up in soil at different salinity levels after harvest of the crop was ranged between 0.8 to 3.2 dS m^{-1}.

Irrigation water salinity with respect to different yield levels starting from 100 to 0% based on irrigation water salinity yield relation in case of chrysanthemum, marygold and tulsi are given in Table 65. The 50% yield compared to yield at good quality irrigation water can be obtained at 5.8, 5.5 and 11.0 dS m^{-1} for chrysanthemum, marygold and tulsi, respectively. It suggested that Tulasi is most tolerant among three crops.

Effect of organics on okra grown on raised bed (Port Blair)

An experiment, to assess the effects of saline tolerant PGPR, prepared as Biogel (bioconsortia + seaweed extract) and other organics on okra on a raised bed system was conducted during monsoon season (July- October) of 2019. Raised bed system (alternate land management) has been found useful for vegetable cultivation under lowland condition and hence the same was selected under this experiment. The results showed that organic treatments significantly increased number of fruits, fruit weight and per plant fruit yield ($p > 0.05$) (Table 66). Biogel + panchagavya was found to be superior over all other organic treatments. It increased fruit yield by 31% than control. Although biogel formulation, bioconsortia and panchagavya were at par for all other yield parameters, saline tolerant PGPR in biogel formulation significantly increased fruit weight by 27% and fruit yield by 18.7% over control. The results demonstrated the potential of saline tolerant PGPR in biogel formulation either alone or in combination with panchagavya for improving crop performance under island condition.

Technology Assessed and Transfer

Sub-Surface Drainage Technology

Technical guidance, monitoring and evaluation of large-scale SSD projects in Haryana

Six new sites at Rithal, Madina Gindhran and Samar Gopalpur (Rohtakdistrict), Mandkola (Palwal), Hussainpur (Mewat)and Nathusary Chopta (Sirsa)with waterlogged saline area of 3,800 ha were jointly identified during 2019-20 based on the feasibility report for SSD system under Haryana Operational Pilot Project (HOPP), Govt. of Haryana. These new sites were characterized by shallow water table(Depth ≤ 1.5 m), moderate to high soil salinity (EC_e> 8 dS m^{-1}) and groundwater salinity (EC_{gw}> 2 dS m^{-1}) with availability of surface drain for disposing saline drainage water. Topographic surveys at these sites have been recommended to be conducted for designing of SSD systems by HOPP. No new design of SSD system was technically evaluated for HOPP as the designs of five SSD sitesfor 2,405 ha were already approved for implementation. During 2019-20, SSD systems in 200 ha were installed at Gangana (110 ha) and Kathurasites (90 ha) under Jind and Sonipat-III SSD projects. Up to June 2019, a total of 11,044 ha waterlogged saline area in Haryana has been reclaimed under 18 SSD projects benefitting 7,948 farmers. However, annual installation rate in Haryana is quite slow which needs to be accelerated to meet farmers' expectation through modernizing HOPP infrastructure and manpower or through project outsourcing to drainage firm/contractors in order to address land degradation neutral status of the country by 2030.Monitoring and evaluation study of five SSD sitesat Gharwal, Katwara, Siwana Mal, MokhraKheri and Kharkhara under Sonipat-II & III, Jind, and Rohtak-I and II SSD projects, respectively, with 67 drainage blocks covering 2,443 ha area and 1,863 beneficiary farmers were conducted for improvement in soil salinity and crop yield. The average yields of paddy, cotton and wheat crops increased by 42-97, 65-200and 32-125% and 15-35, 20-55 and 35-95%, respectively, for adequate pumping (200-400 hours)and partial pumping (100-200 hours) operations by farmers to achieve full or partial reclamative/maintenance salt leaching in drainage blocks. Adequate pumping was achieved in 36% of the blocks. TheSSD technology has transformed the barren waterlogged saline lands into good croplands in 2-3 year period and reduced the soil salinity (EC_e) from 15-38 to 2-8dS m^{-1}. It can be conclusively stated that SSD projects significantly enhanced crop yields and doubled the farmers' income with adequate pumping operation for full reclamative salt leaching.

SSD technology in heavy soils in Maharastra, Karnataka and Gujarat states

Three large-scale SSD projects- RECLAIM-I, II &III, were taken up by Govt. of Maharashtra under TDET and RKVY schemes for reclamation of waterlogged saline heavy soils. A total of 3,065 ha affected area in Sangli district was reclaimed with SSD system with 30 m drain spacing forsmall and marginal farmers. Consultancy services to RECLAIM-I, II & III SSD projects were provided by the institute through M/s Rex Polyextrusion PvtLtd, Sangliduring the period. As a result of encouraging performance of SSD projects in reclaiming waterlogged saline heavy soils and significantly enhancing cane productivity, individual farmers initiated installing the SSD system in their farms (<5 ha) by their own investment. In recent years, sugar factories in Sangli and Kolhapur districts have also played a major role in funding for reclamation of waterlogged saline Vertisols through farmers' cooperative societies for installation of SSD in Maharashtra and Karnataka through consultancy firm/drainage contractors. Consultancy services on evaluation and approval of designs and drawings of new SSD projects, drainage material testing, and stakeholders' training and meeting were provided to M/s Astral Poly Technik Ltd(Astral Pipes) Sangli (Maharashtra) during 2019-20. Generally, open drains were not constructed by Govt. in the farmers' cooperative lift irrigation schemes along the River Krishna and its tributaries in Maharashtra and Karnataka to dispose runoff/drainage water to the stream/river. Therefore, pipe main drain is adopted as anintegral part of SSD projects. Four designs and drawings of 3 farmers' cooperative society funded SSD projects with 20 m drain spacing and total area of 590.2 ha at Terwad Zone-I & II, Majrewadi, and Shirati in ShirolTaluka(Kolhapur) district were evaluated as per the national drainage guidelines and approved for implementation.

In order to address the excessive drainage of water and nutrients from conventional SSD system, acontrolled drainage approach was adopted to save irrigation water and nutrients. Nine farmers' cooperative society funded controlled SSD projects with 20 m spacing and pipe main drain in total area of 2,404 ha with 3,745 beneficiary farmers (Project cost- Rs. 5,467 lakhs) were approved and being implemented semi-mechanically in Kolhapur district during 2018-19 and 2019-20 by farmers' cooperativel and reclamation societies through CSSRI trained drainage contractors under supervision of three sugar factories and Astral Pipes with technical support from ICAR-CSSRI. The loan amount was released to nine farmers' cooperative societies for SSD projects by three cooperative banks. In the controlled drainage system, 80 mm diameter PVC Single Wall Corrugated (SWC) perforated pipes wrapped with suitable synthetic filter, and 100 mm diameter non-perforated PVC SWC(IS 9271:2004 & 2010) were used as lateral and collector drains, respectively.The lateral spacing of 15 or 20 m was chosen based on the severity of saline-sodic condition in soils. Drainage water from the project area is discharged through gravity outlet to the stream/river. The controlled drainage was applied by installing additional collector pipe for every 2.50-4.00 ha area (for 4-6 farmers of a family) with a control valve at the end of collector pipe inside the manhole (900 mm dia RCC pipe) for regulating discharge from each collector by turning valve as per the need by farmers to save irrigation water and nutrients. Pipe main drain was laid using HDPE Double Wall Corrugated (DWC) pipes (IS 16098 Part 2: 2013) with diameter varying from 135 to 500 mm towards the outlet.

Waterlogged saline black soil and semi-mechanical installation of SSD system in Arjunwadin ShirolTaluka(Kolhapur district)

The SSD work has been completed in about 675 ha up to June 2019 out of 2,404 ha project area and the lateral drain laying work was in progress while the pipe main drains in 7 projects have been completed except Majrewadi and Terwad-I & II. From the chemical analysis of monthly drainage water samples from two sites (Shedshal and Bubnal)with 20 m spacing, it was observed that the EC and SAR of drainage water decreased from 28.1 to 4.8 dS m^{-1} and 56.6 to 9.5, respectively, from April to November, 2018, reflecting considerable removal of soluble salts by leaching. Similarly, soil EC2.5 at 8 locations along the collector decreased from 9.9-24.0 to 5.4-16.8dS m^{-1}(by 58% average). The cane yield increased from 33.7-51.4 t ha^{-1} (Pre-project) to 78.5-97.0 t ha^{-1} during the first year of controlled SSD and the highest yield would be achieved in next 2-3 years. The SSD technology package has also been implemented successfully through PPP (Public-private partnership) mode or project outsourcing in Maharashtra, and Karnataka states realizing its significant benefits and impact on improvement of soil salinity, crop yield and farmers' income. The cost of installing SSD system is Rs. 148,500 and 174,000 ha^{-1} for 20 and 15 m spacing, respectively, andadditional cost of HDPE pipe main drain is Rs. 45,000-62,500 ha^{-1}. In Gujarat state, salinity of drainage water and sugarcane crop growth of a SSD project was monitored at Adadarasite in Bharuch district. Periodical pumping of saline water from the sump by the farmer resulted in increase of EC of drainage water from 4.9 to 7.3 dS m^{-1} during summer months while soil EC_e of upper 60 cm layer reduced from 8.1 - 9.85 to 3.35 - 5.57 dS m^{-1} during this period reflecting removal of excess salts from the affected fields. This has indicated the effective salt removal by the SSD system. Sugarcane crop was not grown at Adadara SSD site prior to SSD system and however, farmers started cultivating sugarcane after one year of SSD installation and healthy sugarcane crop conditionwas observed and resulted in the average yield of 75.0 t ha^{-1} fromthe entire fields.

A study was conducted to evaluate the effect of different lateral spacings on sugarcane yield and soil salinity in SSD projects. From the economic analysis (Table 67), it was revealed higher net returns in 15 m spacing and net returns decreases with increasing lateral spacing. Increasing yield in 15 m lateral spacing in SSD projects leads to the reduction in cost of production of sugarcane crop by Rs. 304 and Rs. 346 as compared to 20 m and 30 m spacings, respectively in the study area. Overall study indicated the lesser lateral spacing has economic advantage as compared to the higher spacing. A total of 3,065 ha affected area was reclaimed with SSD system with 30 m spacing in Sangli district. Few of these systems were later converted into 20 or 15 m spacing on farmers' request. All new SSD projects in Maharashtra and Karnataka are planned with 15 m lateral spacing with controlled drainage and pipe main drain.

Table 67: Economics of sugarcane cultivation with different lateral spacings in SSD projects

Parameter	Lateral spacing in SSD system			Advantage of 15 m spacing over	
	15 m (n=21)	20 m (n=3)	30 m (n=1)	20 m	30 m
Yield (t ha^{-1})	127.50	108.33	102.50	19.17	25.00
Gross Returns (Rs. ha^{-1})	384,253	333,141	305,076	51,112	79,177
Cost of cultivation (Rs.ha^{-1})	285,365	275,420	264,829	9,946	20,536
Net Returns (Rs. ha^{-1})	98,888	57,722	40,246	41,166	58,642
Cost of production (Rs t^{-1})	2,238	2,542	2,584	-304	-346
Input-Output Ratio	1.35	1.21	1.15	0.14	0.19
Employment generated (Man days/ha $annum^{-1}$)	212	207	203	5.64	9.76
Wage earnings from farm employment (Rs./ha $annum^{-1}$)	53,074	51,664	50,635	1,410	2,439

Pilot study on vertical drainage

About 120 ha of waterlogged saline land located near Sikrona village on Qabulpur Bangar-Sikrona Road in Ballabhgarh block of Faridabad district was selected as the study site. A network of 12 drainage tubewells at 120-134 m spacing along Sikrona drain was planned for controlling water table and soil salinity under Gurgaon canal command. Twelve drainage tubewells with 30.5 cm bore size were drilled at 120-134 m spacing up to 22 m (72 feet) deep based on the bore lithology of the study site. Three 200 mm diameter PVC perforated casing pipes of 6 m long each and a 4.27 m blind pipe (including 0.61m above the ground) were lowered into the tubewell and then medium grade round gravel pack material was filled in between inter-spacing. Soil salinity at Sikrona site changed from 39.6 to 8.58 dS m^{-1} (0-15 cm layer) and from 40.2 to 10.67 dS m^{-1} (15-30 cm depth layer) by pumping operation and salt leaching by monsoon rainfall. Salinity of canal water was changed slightly from 1.24 to 1.20 dS m^{-1} and similarly, salinity of groundwater changed slightly from 11.05 to 11.00 dS m^{-1}. Water table in the project area was improved from 0.60 to 0.92-1.18 m below the ground level. Paddy yield in the first year increased to 3.1 t ha^{-1} (by 20-25%) due to lowering of water table and partial salt leaching from the soil profile. The vertical drainage is beneficial to farmers in the project area who are satisfied with project performance. However, there is drain pollution problem for downstream farmers and vertical drainage may not be a good option when groundwater salinity exceeds 6 dS m^{-1}.

Revival of village ponds in saline vertisol areas

Harvesting of rain water and revival of village ponds for increasing water productivity is the impending need of the hour. Two village ponds in Samni and Sudi villages of Bharuch district suffering from siltation problem were selected for this study. Pond silt was found to be rich in nutrients and may be used as manure for soil conditioning. Data analysis revealed that soil pH ranged from 8.1-9.0, EC_e from 0.29-2.70 dS m^{-1} and SAR from 0.4-3.2 in case of Samni pond soil; while the corresponding values for Sudi pond soil were 8.0-9.0, 0.29-5.80 dS m^{-1} and 0.5-13.8. The dykes of ponds of both villages were planted with about 264 and 670 tree species including fruit trees. Our interventions had positive impact on various parameters related to village pond like level of pollution/contamination, water harvesting and water conservation, quality of water, different uses of water and water productivity, ecological and environmental benefits. Water quality in pond as well as in the surrounding tubewells and borewells was found to improve as evidenced through water quality analysis.

Recharge structures as localized drainage options in sodic soils

Cavity type individual farmer's based recharge structure was installed at four locations in low lying areas of Kaithal district under Farmer FIRST Project for evaluating their effectiveness in facilitating the localized drainage option and sustainable crop production. The installed structures were quite effective in saving the submerged crops particularly during the periods of intense rain in addition to augmenting groundwater and improving its quality. The groundwater table rose to an extent of 2-3 m beneath the structure during monsoon month compared to summer months. The improvement in groundwater quality was also observed in surrounding areas as a consequence of reduction in RSC by 2-3 meq l^{-1} compared to the values at the time of installation of the structure. A heavy rainfall (~150 mm) resulted in 35-40% crop damage in open-fields which was reduced down to 5-15% due to provision of recharge structure, significantly decreasing the additional cost towards re-transplanting and compensated the yield loss. In order to assess the impact of installed structure on ground water quality at spatial scale, ground water samples were collected from the distance of 10, 30, 60 and 90 m (through piezometers) from the actual recharging points for estimation of RSC. The RSC of the samples collected from 30 m distance showed slightly lesser or almost same RSC. The structure did not have any influence on groundwater quality beyond 30m from the actual recharging point. However, the effect of structure on groundwater resources is directly associated with number and amount of recharging event taking place during the monsoon months. If more rainwater is recharged, there is possibility that improvement in water quality will certainly be more profound and to larger extent covering more areas. The economic analysis revealed that the establishment of groundwater recharge structure has a potential risk reduction capacity by saving the crops during the periods of adverse rainfall situations. Though the initial capital investment cost was relatively high for installation of recharge structure, the study revealed that the investment can be expected back within 2 years (payback period) of installation. Considering the life of recharge structure as 20 years and discount rate of 10 per cent per annum, the net present value (NPV) was estimated to be Rs. 33,57,091 with a benefit cost ratio (BCR) of 1.93 and an internal rate of returns (IRR) of 145 per cent. On the other hand, the farmers achieved lesser net returns (Rs. 69,588 ha^{-1}) and benefit cost ratio (1.87) where no structure was installed. The significantly higher IRR, BCR, NPV and lesser payback period clearly indicated that the economic feasibility of investment on recharge structure for providing drainage option under sodic environments.

Land modification models for waterlogged sodic soils

Waterlogging and salt build up in the crop root zone are the major problems in Sharda Sahayak Canal Command, irrigating about 17.80 lakh ha area in 16 districts of Uttar Pradesh. As waterlogged sodic soils seldom respond to gypsum application, different land modification modules based on harvesting and management of canal seepage water for multipurpose use were developed under farmers participatory mode on 0.6 ha land in Patawakhera village of Lucknow district. Significant reductions in surface and sub surface soil pH were recorded under land shaping models. The pH of the pond water was almost same during the period of 2015-19. The EC of the water was less than <1 dS m^{-1} during five years. CO_3^- and HCO_3^-, the major sources of alkalinity varied from 0 to 2.07 me l^{-1} and 4.06 to 8.12 me l^{-1}, respectively. Ca content in water slightly increased from 1.50 me l^{-1} in 2014 to 2.12 me l^{-1} in 2018. Cl content was decreased over the time and minimum value (1.0 me l^{-1}) was recorded in 2019. From 0.60 ha land, the beneficiaries received net income of Rs 250747 in 2019. The maximum income was received during the month of April. The model has also boosted the land and water productivity remarkably and has helped in checking further secondary salinization of the area. The system may bring back more than one lakh ha of barren unproductive land under cultivation in canal command area of Uttar Pradesh. Initial success prompted us to replicate the land modification based Integrated Farming System Model on other farmers' field facing similar problems. Land and water productivity of different crops grown over old pond based integrated farming system models were calculated for different crops. It may be seen that Mr. Ghasita Ram from Patwakheda obtained yield potential of wheat, onion, grass and fish as 6114, 11520, 15100 and 3308 kg ha^{-1} for which water use efficiency were 382.14, 384.00, 1006.67 and 33.07 kg/ha-cm; water productivity 66.30, 57.60, 50.30 and, 39.69 Rs/m^3 and land productivity were 0.61, 1.52, 1.51 and 0.33 kg/m^2, respectively. Mr. Dinesh from Patwakheda obtained yield potential of rice, sponge gourd, cow pea, brinjal, tomato and fish as 4960, 43387, 17760, 62533, 113267 and 3662 kg ha^{-1} with corresponding water use efficiency of 248.00, 1314.75, 444.00, 1202.53, 1936.18 and 33.29 kg/ha-cm, water productivity of 46.25, 236.65, 146.52, 240.51, 425.96 and 43.27 Rs/m^3 and land productivity of 0.50, 4.34, 1.78, 6.25, 11.33 and 0.37 kg/m^2, respectively.

Mr. Jitendra from Lalaikheda village reported yield potential of Tomato and water melon as 116071 and 23214 kg ha^{-1} which resulted in water use efficiency of 1842.40 and 1289.68 kg/ha-cm, water productivity of 368.48 and 290.17 Rs/m^3 and land productivity of 11.60 and 2.32 kg/m^2, respectively. Mr. Sher Bahadur of Salempur Achaka village with normal soil obtained yield potential of mentha, fodder and fish as 182 l, 45455 kg ha^{-1} and 8531 kg/ha with corresponding water use efficiency of 3.030, 2272.72 and 77.92 kg/ha-cm, water productivity of 45.45, 113.63 and 77.92 Rs/m^3 and land productivity as 0.02, 4.54 and 0.86 kg/m^2, respectively.

Crop performance in IFS Model

Farm-level impact of such land modification models was also analysed by identifying and estimating different indicators like cropping intensity, level of crop diversification, employment opportunities, etc. The models were utilised to grow crops throughout the year, hence increasing the cropping intensity (from 125% to over 250-300%), crop diversification (from 0.24 to 0.86 of Simpson crop diversification index) and providing employment to the whole family throughout the year (Table 68). Despite these benefits, there are some obstacles that need to be overcome to upscale this technology. Availably of land in suitable plot sizes (1.0 ha for crop-fish based interventions and 0.50 ha for fish-crop based interventions) remains an important bottleneck. Besides, willingness of farmers having land but not sure how much land to be converted, land owners having larger plots but reluctant to convert land for fisheries as rearing fish is a social taboo, farmers were willing but land was not in their name or it was shared with multiple ownership, were some of the key determinants for large scale implementation of such models in the study area. This challenge can be addressed through aggregation of land by attracting private investment. As the land are highly degraded farmers were willing to leased-out their land to the investors and therefore such models can be promoted through public, public-private or private investment.

Table 68. Farm-level impact of land modification models at demonstration field

Indicators	With Land Modification Model	Without Land Modification Model	Remarks
Cropping pattern (choice)	Rice, wheat, vegetables, fruits, spices, mentha, fodder, potato	Rice, wheat, mentha	Any crops can be taken in LMM
Cropping intensity (%)	250 to above 300	125	Increased more than double
Crop diversification (Simpson Index)	Very high (0.86)	Low (0.24)	Multiple crops choice
Employment (man-days)	Year round	55-70 days	Gainful engagement
Income (Rs/year)	1.45 to 3.5 lakh	negative to meager	Increased many folds and continuing benefits
Crop productivity (t/ha system yield)	3.08 to 7.78	1.5 to 2.0	Increased and benefits continuing
Risk (% yield losses)	Low	Very high (45-62)	Often returns are negative, high instability
Asset creation	35000 to 55000	meager	Buying livestock, bike, pucca house etc
Externalities	Positive	Neutral to negative	LMM improved quality of other land too

ICAR-FUSICONT – bio-formulation for successful management of banana fusarium wilt disease

The pandemic of banana fusarium wilt disease in the commercial banana cultivation covering 7 districts in Uttar Pradesh and 5 districts of Bihar threatened the cultivation of G-9 banana in the country. The proliferation and devastation of the disease was very high such that it could disrupt the cultivation by its rapid spread across regions. ICAR-Central Soil Salinity Research Institute (CSSRI), RRS, Lucknow and ICAR-Central Institute of Sub-tropical Horticulture (CISH) characterized the hot spots of the disease through mapping the hot spots and initiated containment measures to avoid proliferation.

Studies were made to assess the potentials of biological control using 3 *Trichoderma*isolates obtained from abiotic and biotic stressed rhizosphere and was evaluated for *in-vitro* ability to antagonize the pathogenic fungus *Fusarium oxysporum f.* sp. *cubense*Tropical Race 4 (Foc TR-4) followed by pot and field evaluation by formulating it into a bio-formulation ICAR-FUSCONT with suitable multiplication media and application protocol.The CSR-T-3 isolate of *Trichoderma reesei* based bio-formulation (ICAR-FUSICONT) significantly restricted the mycelia growth of the Foc TR-4 (85.14%) under in-vitro studies. The disease severity index was recorded to be 0.75 and 1.14 in pot and field studies, respectivelyhas been found to explicit antagonistic property.The mechanism involved in attributing tolerance was characterized using LCMS and gene expression studies that identified specific antifungal compounds like peptabiols, fengycin, Xyloglucan and Iturin C produced in the host to induce tolerance. The collaborative research enabled the introduction and validation of the community empowered disease management in about 252 acres of the hotspot region and also restricted the proliferation of the disease to other districts of the country.

Impact of the technology in the control of the disease

Farmers-Scientist Particpatory Evaluation program with the experts from the country

Table 69: Effect of the IACR-FUSICONT on Fusarium wilt and growth of banana plantlets under field experiment in hot spot region of Uttar Pradesh

Treatment	Plant height (cm)	Girth(cm)	No. of leaves	Leaf area (cm^2)	Yield (kg $plant^{-1}$)	No. of hands	Disease incidence (%)	Disease severity index
CSR-T-3	230.73a	43.9a	7.86a	73.13a	30.57a	8.14a	10.58a	1.14a
	(± 4.70)	(±7.33)	(±0.38)	(±7.14)	(±3.60)	(±0.69)	(±4.64)	(±0.69)
Control	214.76b	36.1a	6.71b	51.84b	16.29b	7.71a	46.50b	3.46b
	(±2.73)	(±9.72)	(±0.76)	(±6.40)	(±6.13)	(±1.11)	(±18.33)	(±0.51)

Values are the means of ten replicates. Means in the columns followed by the same letter are not significantly different according to paired t test at P=0.05. Values in the parentheses indicate the standard deviation of the mean

Before Adoption of ICAR-FUSICONT

After adoption of ICAR-FUSICONT

were organized for validating the results. Sh.Anand Kumar Apte, progressive farmer of the Katrauli village, U.P. whose field was affected with the disease last year, briefed that he was about to leave the banana plantation when he witnessed the disease in his plantation but on adoption of ICAR-FUSICONT technology he could achieve 98% control of the disease and obtained an average yield of 30 kg $plant^{-1}$. Simalarly, Sh. Shoba Ram, Sh. Shalik Ram of the Magalsi village whose fields were affected with more than 40 percent during the initial joint survey along with scientist from National Research Centre (Banana) saved their next year crop in the same site to 90% due to ICAR-FUSICONT technology adoption.

Cropping systems intensification in coastal saline soils

Recently, several interventions were made to improve the wellbeing of farming communities in highly saline coastal areas of West Bengal state. For example, under Australian Centre for International Agricultural Research (ACIAR) funded project operational in Sonagaon village of South 24 Parganas district, 199 male and 136 female farmers were benefitted by technological interventions *viz.*, introduction of improved management practices, new crops and varieties for improving their food and income security. Intensification of waterlogged paddy field was done through cultivation of vegetables in bags filled with soil and farm yard manure. The study was conducted in 12 farmers' fields consisting of 6 female and 6 male farmers and there BC ratio was found from 1.63 to 4.46. Similarly, zero tilled paddy straw mulched potato cultivation technology was developed and found to be a sustainable practice for the cropping system intensification in this area. Soil properties studied after three years reveal that there is increase in organic carbon, available N and P due to this. Drip irrigation with different mulching materials were also studied there was a significant saving of labour and irrigation water due to these practices compared to the conventional flood irrigation

Intensification of waterlogged paddy field for vegetable cultivation during kharif 2019

practiced by farmers. Paddy straw mulching also significantly reduced the weed biomass compared to farmers practice.

Alternative amendments for alkali soils

Reliance formulated sulphur: Elemental Sulphur-based formulation was developed in collaboration with Reliance Industries Ltd., Mumbai, as an alternative technology for reclamation of sodic soils. Formulation applied 21 days prior to rice transplanting led to significant decline in $pH_{1:2}$. Efficiency of reclamation and crop performance in controlled field experiment at Karnal, Lucknow and Indore as well as farmers' participatory evaluation in Kaithal (Haryana), Patiala (Punjab), and Etah (UP) were superior or at par with gypsum applied on equivalent basis (GR 50). Yield advantage of S based formulation (RFS) application in pre-kharif season before sowing the crop at different farmers field in Haryana, Punjab, Uttar Pradesh, and Madhy Pradesh compared to control were highly significant (rice wheat, cotton and sugarcane). This response varies with the severity of sodicity, crop and variety grown.

Farmer participatory trial in Jaunpur (UP)

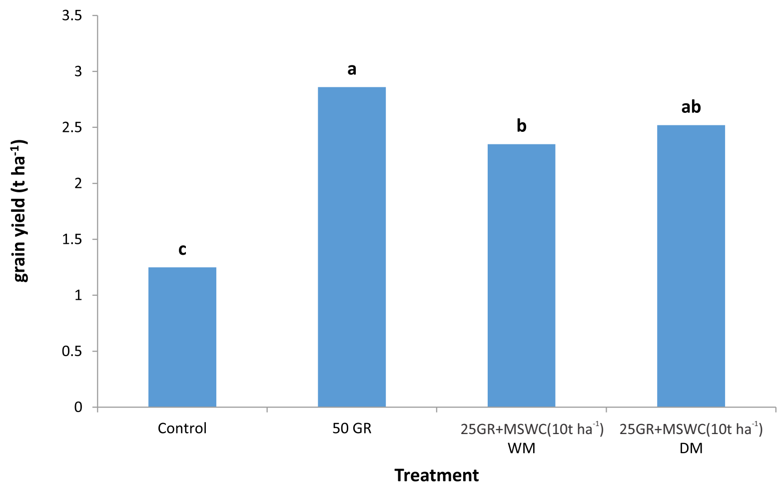


Fig 64. Total grain yield (t ha^{-1}) of rice crop (CSR-30) at farmer's field in Kaithal.

Municipal solid waste compost: Urban wastes such as sewage sludge and municipal solid waste compost in conjunction with gypsum have potential to reduce the soil sodicity. Selected treatment combinations [control, 50GR, 25GR+Compost 10 t ha^{-1} and Wet Mixing (25GR + C10WM), 25GR+Compost 10 t ha^{-1} Dry Mixing (25GR + C10DM)] were evaluated at farmers' field in Kaithal district of Haryana. Salt tolerant rice variety (CSR-30) was transplanted and changes in soil properties and yield increase were observed. The initial soil pH_2 was 9.37, EC_2 0.92 dS m^{-1} and gypsum requirement of 13.0 t ha^{-1}. There was significant increase of rice grain yield over contol. The yield of salt-tolerent rice variety CSR-30 (2.52 t ha^{-1}) was at par to 50 GR. Plant height, panicle length and productive tillers were also significantly higher in amended plots.

Impact of salt tolerant varieties in terms of additional food grain production and revenue generation: During the year 2019-20, about 0.8 t basmati rice, 1.2 t nonbasmati

Table 70: Estimated impact of the salt tolerant varieties of rice, wheat and mustard during the year 2019-20.

Crop/variety	Multiplication ratio	Production year	DAC indent of breeder seed (q)	Certified seed (q)#	Seed already sold (q)as certified seed/TL seed	Total seed (q) [E+F]	Estimated area coverage (ha)$	Estimated produce (t) [Based on average productivity of crops in tones]@	MSPs (Rs./q)**	Estimated value of produce (Crore Rs.)
A	B	C	D	E	F	G	H	I	J	K
Basmati CSR 30	1:80	2019	8.0	51200	92.0	51292	169263.6	338527.2	1770	599.19
Non Basmati (CSR 36, CSR 43, CSR 46, CSR 56, CSR 60)		2019	12.0	76800	13.0	76813	253482.9	506965.8	1750	887.19
Wheat (KRL 210, KRL 213)	1:20	2018-19	96.0	38400	317.6	38717.6	38717.6	116152.8	1840	213.72
Mustard (CS 58)	1:100	2018-19	0.55	5500	9.83	5509.83	92014.16	92014.16	4200	386.46
Total			116.55	171900	432.43	172332.43	553478.26	1053659.96		2086.56

**http://cacp.dacnet.nic.in/ViewContents.aspx?Input=1&PageId=36&KeyId=0
#Multiplication of seed from breeder to foundation and foundation to certified seed
$Total seed (q) is multiplied with factor (area covered by one quintal seed); Rice=3.3, Wheat=1, Mustard=16.7
@ Average productivity of Rice= 2t/ ha; Wheat= 3t/ ha, Mustard= 1t/ ha

rice, 9.6 t wheat and 0.055 t Indian mustard Breeder seeds of salt tolerant varieties were produced and distributed to various seed multiplication agencies, farmers and other stakeholders. In addition TL seeds (9.2 t of Basmati CSR 30, 1.3 t non basmati and 31.76 t wheat) were produced and distributed to farmers of different states. The total estimated area coverage by these salt tolerant varieties of rice, wheat and mustard was 0.55 Million ha. The value of additional production obtained due to adoption of ICAR-CSSRI salt tolerant varieties of rice, wheat and mustard during 2019-20 would be 1.05 million tonnes giving estimated revenue of Rs 2086.56 Crores at the national level (Table 70).

Frontline demonstrations on wheat under NFSM

Twenty-five demonstrations were conducted on direct sowing of wheat with Happy Seeder sown in Kathwar village of Kaithal district. Salt tolerant wheat variety KRL 210 was sown both under conventional and demonstrated plots. The soil pH ranged from 8.6 to 9.3, EC from 0.39 to 0.84 dS m^{-1} and water RSC ranged from 3.2to 5.5meq/l.An overall yield of 40.2 q ha^{-1} (range 3.5 – 4.5 t ha^{-1})was recorded under Happy seeder sown wheat with yield superiority of 3.2% as against the farmers practice. In addition, lesser incidence of *Phalaris minor*, water savings and lesser lodging under aberrant weather situations was also observed under Happyseeder sown wheat.

Adaptive strategies in salt affected agroecosystems of India: Top-to-bottom and bottom-to-up perspectives (Ranjay K. Singh, Anshuman Singh, R.K.Yadav, Parveen Kumar and P.C. Sharma)

Introduction

Relentless degradation of soil and water resources which, in extreme cases, can cause land desertification remains a significant global concern. There are broadly two approaches in adapting and mitigating salinity induced stresses i.e. *planned* and *autonomous*. Research bringing together the *top-down* and *bottom-up* narratives is lacking, yet to do so could provide valuable insights for adaptation and identify areas in which policy support and investment are needed. Looking to the importance of such approaches, this study was conducted with an objective to know the trends in *planned* and *autonomous* local adaptation strategies against salinity led stressors in India.The data were collected from secondary sources accessed from Indian institutions. A total of 129 literatures were explored using snow-ball sampling method for aperiod of 20 years (2000 to 2019). If a literature indicating an adaptive practice being applied by farmers to manage risks induced by salinity was given score '1' otherwise '0', and in case of absence. The adaptation were placed according to the types of salinity induced stresses and adaptation typologies (planned-top-bottom or autonomous-bottom-up). Appling square-root method, data were transformed to eliminate and un-even distribution patterns. Data were analyzed using Friedman test to drawthe inference from this study.

Results

1. Adaptation in managing risks imposed by waterlogged saline soils and waters

The results indicated that sub-surface drainage (including surface drainage also) was observed to be a numerically significant and promising *planned* (*top-bottom*) adaptation among farmers in reducing risk caused by waterlogged salinity in India, however, salt tolerant crop varieties were also at par (Table 71).

Table 71: Adaptation strategies applied by Indian farmers in managing salinity induced stressors

Adaptation strategies	Practices	Ecological stressors# (Mean of ranks)			Across the ecological stressors
		Waterlogged saline soils and waters	Saline-sodic soils and waters	Sodic soils and waters	
Planned	Sub-surface drainage (including drainage)	8.70a	-	3.95c	7.62bc
	Salt tolerant crops varieties	7.97ab	3.90c	12.52a	12.47a
	Enhancing capacity for efficient decision making	5.77abc	4.12c	8.95ab	9.92ab
	Agronomic practices	5.62bc	4.62c	6.80bc	7.65bc
	Land shaping	5.25bc	9.15ab	6.45bc	4.90cd
	Diversification	5.00bc	6.65abc	6.97bc	6.52bcd
	Agroforestry and agri-horti system	4.30bc	7.12abc	4.27c	4.77 cd
	Groundwater recharge	3.25C	5.92bc	7.45bc	6.87bcd
	Gypsum	-	8.97ab	9.10ab	7.07bcd
Autonomous	Local crops and varieties	5.00bc	6.02bc	5.97bc	6.67bcd
	Local agronomic practices	4.12c	4.45c	8.85ab	9.47ab
	Local agroforestry and agri-horti system	-	7.12abc	4.15c	3.30d
	Community knowledge (indigenous institutions, knowledge network, social migration, etc.)	-	9.92a	5.55bc	3.72cd
Friedman's statistics	Q (Observed value)*	75.08	93.29	112.50	113.41
	Q (Critical value)	16.91	19.67	21.03	21.03
	p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

*Ties have been detected in the data and the appropriate corrections have been applied
#: Level of significance (alpha 0.05)
- These practices were absent in corresponding stresses

The sharpening knowledge and skills (capacity development) by farmers to take efficient decision on managing risks induced by salinity in waterlogged areas was recorded to be numerically lower but statistically in the same group as earlier planned interventions (SSD and varieties). It was important to learn those agronomic practices(manipulations in irrigation methods, sowing techniques, zero or minimum tillage operations, etc.), land shaping, diversification and agroforestry and agri-horti system were different *planned* strategiesthose differ significantly from earlier described *planned* strategies in managing risks imposed by waterlogged saline soil and waters.Interestingly, local crops and varieties (landraces and farmers' varieties) found to be an *autonomous* (*bottom-up*) adaptive practice applied by farmers (mostly in coastal regions) in reducing risks was numerically lower but demonstrated at par (Table 71).

2. Adaptation in managing risks imposed by saline-sodic soils and waters

Community knowledge (indigenous institutions, knowledge network, social migration, etc.) emerged as a significant robust adaptive practice (*autonomous*) among farmers which was at par to the land shaping (followed to modify land use system), gypsum (applied reducing higher pH in saline-sodic soils) technology and diversification (*planned adaptation*) practices in managing risks imposed by saline-sodic soils and waters (Table 71). The agroforestry/and agri-horti (both on private and community lands) was found at par both in *planned* and *autonomous* strategies, being applied by farmers in reducing such salinity risks (Table 71).

3. Adaptation in managing risks imposed by sodic soils and waters

It was observed that practices including salt tolerant crops varieties, gypsum technology, capacity development to take efficient decisions (*planned* strategies) and applying local crops varieties (landraces and farmers' developed varieties/cropping systems) (*autonomous* strategy) were significantly at parto each other in vogue among the farmers while managing risk imposed by sodic soils and waters (Table 71). Results showed that ground water recharge, diversification process, agronomic practices, land shaping (*planned* strategies) and community knowledge (*autonomous*)practices were numerically different but at par to each other in moderating risks resulted by sodic soils and waters. The agroforestry, both in *planned* and *autonomous* levels, and SSD were non-significant to each other and demonstrated equal strength in adaptation strategies among the farmers.

Conclusions

It has been concluded that in waterlogged saline soils and waters induced stresses, sub-surface drainage (including drainage), salt tolerant crops varieties and enhancing capacity to take efficient decision were promising *planned*adaptation strategies along with the local crop and varieties as an *autonomous* strategy. In contrast community knowledge (indigenous institutions, knowledge network, social migration, exchange, pooling of resources, etc.) emerged as *autonomous* strategy along with land shaping and gypsum technologies (*planned strategies*), and agroforestry and agri-horti system (both in *planned* and *autonomous* strategies) in reducing risks imposed by saline-sodic soils and waters. The salt tolerant crops varieties and gyp[sum emerged as planned adaptation strategy in managing risk caused by sodic soils and waters. Across the salinity induced stresses, the salt tolerant crops varieties, and capacity development (*planned*) and local agronomic practices emerged significant adaptation strategies to reduce the risks associated with crop cultivation (livelihood).

Farmer FIRST Project "Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains"

Techno-economic evaluation of recharge structure as localized drainage option in sodic agro-ecosystems

The low infiltration capacity of sodic soils and alkaline irrigation water are the main limiting factors in sustaining crop production under salt affected agro-ecosystems. The extreme rains aggravate the chances of crop failure further, due to water stagnation for prolonged period under sodic lands. ICAR-Central Soil Salinity Research Institute, Karnal, designed, developed and installed the cavity type individual farmer's based recharge structure at four locations in low lying areas of adopted villages (under Farmer FIRST Project) of Kaithal district for evaluating their effectiveness in facilitating the localized drainage option and sustainable crop production. The installed structures were quite effective in saving the submerged crops particularly during the periods of intense rain in addition to augmenting groundwater and improving its quality. The groundwater table rose to an extent of 2-3 m beneath the structure during monsoon month compared to summer months. The improvement in groundwater quality was also observed in surrounding areas as a consequence of reduction in RSC by 2-3 meq l^{-1} compared to the values at the time of installation of the structure.A heavy rainfall (~150 mm) resulted in 35-40% crop damage in open-fields which was reduced down to 5-15% due to provision of recharge structure, significantly decreasing the additional cost towards re-transplanting and compensated the yield loss.

Table 72. Economic analysis of groundwater recharge structure

Sl. No.	Particulars	Unit	Without Recharge structure	With Recharge structure	Difference (%)
1.	Capital cost of recharge structure (including installation cost)	Rs	-	2,50,000	-
2.	Annual operational and maintenance cost	Rs	-	5,000	-
3.	Life of recharge structure	Years	20*	20	-
4.	Crop damage due to intense rainfall**	%	35-40	5-15	-
5.	Yield reduction due to delayed re-transplantation in rice crop considering 5 ha vulnerable area	%	15-20	2-5	-
6.	Harvested yield @ soil pH_2~9				-
a.	Rice cv. Pusa 1121	q ha^{-1}	24.00	28.95	20.63
b.	Wheat cv. KRL 210	q ha^{-1}	40.00	40.00	Nil
7.	Market price @ 2017-18				-
	a. Rice cv. Pusa 1121	Rs q^{-1}	3,250	3,250	Nil
	b. Wheat cv. KRL 210	Rs q^{-1}	1,735	1,735	Nil
8.	Discount rate	%	10	10	Nil
9.	Cost of cultivation***	Rs ha^{-1} $annum^{-1}$	80,250	78,750	-1.87
10.	Gross returns	Rs ha^{-1} $annum^{-1}$	1,49,838	1,63,488	9.11
11.	Net returns	Rs ha^{-1} $annum^{-1}$	69,588	84,738	21.77
12.	Discounted total cost	Rs	34,16,067	36,02,216	5.45
13.	Discounted total benefit	Rs	63,78,256	69,59,306	9.11
14.	Net present value (NPV)	Rs	29,62,188	33,57,091	13.33
15.	Benefit cost ratio (BCR)	-	1.87	1.93	3.21
16.	Internal rate of return (IRR)	%	-	145	-
17.	Pay Back period (PBP)	Years	-	2	-

*considered only for estimation of cost and returns and not as project life, **paddy crop was re-transplanted later by spending an additional cost of Rs 5000 and Rs 7500 per ha in with and without recharge structure. ***only variable cost was taken into account.

In order to assess the impact of installed structure on ground water quality at spatial scale, ground water samples were collected from the distance of 10, 30, 60 and 90 m (through piezometers) from the actual recharging points for estimation of RSC. The RSC of the samples collected from 30 m distance showed slightly lesser or almost same RSC. The structure did not have any influence on groundwater quality beyond 30m from the actual recharging point. However, the effect of structure on groundwater resources is directly associated with number and amount of recharging event taking place during the monsoon months. If more rainwater is recharged, there is possibility that improvement in water quality will certainly be more profound and to larger extent covering more areas.

The economic analysis revealed that the establishment of groundwater recharge structure has a potential risk reduction capacity by saving the crops during the periods of adverse rainfall situations. Though the initial capital investment cost was relatively high for installation of recharge structure, the study revealed that the investment can be expected back within 2 years (payback period) of installation. Considering the life of recharge structure as 20 years and discount rate of 10 per cent per annum, the net present value (NPV) was estimated to be Rs. 33,57,091 with a benefit cost ratio (BCR) of 1.93 and an internal rate of returns (IRR) of 145 per cent (Table 2). On the other hand, the farmers achieved lesser net returns (Rs. 69,588 ha^{-1}) and benefit cost ratio (1.87) where no structure was installed. The significantly higher IRR, BCR, NPV and lesser payback period clearly indicated that the economic feasibility of investment on recharge structure for providing drainage option under sodic environments.

Management strategies for reclamation of sodic soils and neutralization of residual alkalinity in irrigation waters: Effect of pressmud application in rice-wheat production system

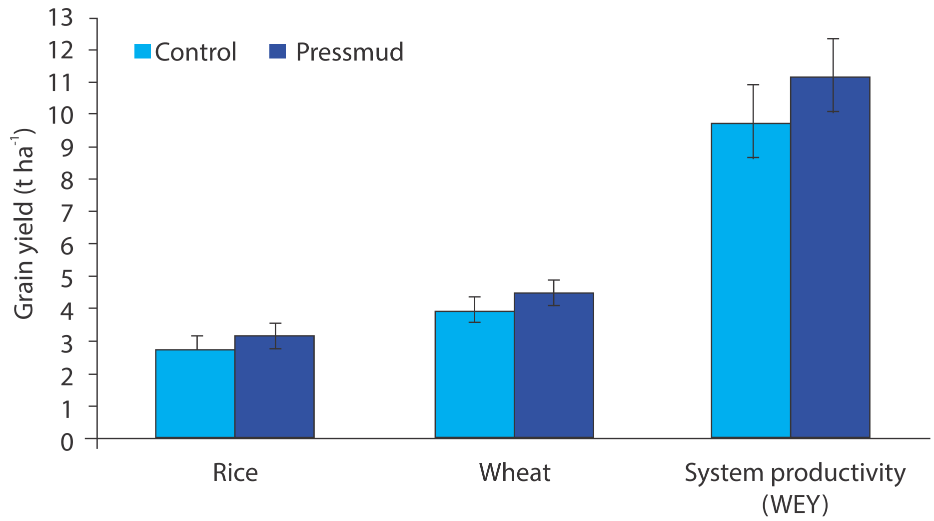
Pressmud, an organic waste by-product of sugar industries enhances organic matter content of soil, improves soil physical conditions, acts as a soil conditioner and valuable nutrient source for macro and important micronutrients.To evaluate the effect of pressmud application, farmers' participatory research trials were carried out involving two treatments; (a) Unamended control (farmers' practice; FP) and (b) Pressmud application @ 10 t ha^{-1} (PM) on dry weight basis.

Significant change in plant water status (RWC and MII), gas exchange parameters (Pn, gS, E, Fv/Fm and YII), biochemical parameters (P and CC) and Na/K concentration (shoot and root) was noticed in both rice and wheat crops under pressmud ameliorated plots, reflecting its effectiveness in reducing the adverse impact of residual alkalinity in irrigation water and soil sodicity compared to without neutralization alkali water irrigated plots (farmer's practice). Pressmud application increased leaf RWC from 82 to 85% in rice and 73 to 81% in wheat whereas MII reduced by 11.7 % in rice and 13.1% in wheat compared to unamended control. Significantly higher values for photosynthetic and chlorophyll indices viz., Pn (23.27 and 20.53 μmol CO_2 $m^{-2}s^{-1}$), gS (2.27 and 1.33mol H_2O $m^{-2}s^{-1}$), E (9.49 and 2.59m mol H_2O $m^{-2}s^{-1}$), Fv/Fm (0.61 and 0.58) and YII (0.55 and 0.56) were observed for rice and wheat crops, respectively due to pressmud application. Reduction in proline content to the extent of ~20% in rice and ~18% in wheat was noticed while chlorophyll content improved by ~22% in rice and ~24% in wheat when pressmud was applied. Pressmud applied plots exhibited exhibited good control on accumulation of toxic ions (Na^+) and maintained higher concentration of essential ions (K^+). Lower ionic (Na^+/K^+) concentration was observed in both shoot and root portions where pressmud was applied.

Remarkable reduction in productive tillers (15%), grains per panicle (13%) and 1000-grain weight (5%) was recorded in rice where no amendment was used for reclamation/neutralization purpose to mitigate the adverse impact of sodicity stress. The tillers sterility increased from 5.2 to 6.6% and unfilled grains per panicle increased from 8.0 to 9.6 under high RSC irrigation water induced sodification (farmers' practice). In wheat, pressmud amelioration increased number of productive tillers/mrl (13%), spikelets per spike (8%), grains per earhead (10%) and 1000-grain weight (2%) compared to farmers' managed plots.

Mean grain yields of both rice and wheat harvested over 37 locations strongly ($P<0.05$) reflected the influence of pressmud application (Fig. 65) elucidating yield improvement to the tune of 15.3% (0.41 t ha^{-1}) in rice, 14.4% (0.55 t ha^{-1}) in wheat and 14.9% (1.42 t ha^{-1}) in system productivity (wheat equivalent yield) compared to when no amendment was used (farmer's practice). Pressmud application apart from its ameliorative action enhanced the nutrient availability in soil-plant continuum, improved soil physical conditions,increased water infiltration and aggregation. Incorporation of pressmud increased the soil atmospheric CO_2 concentration by producing organic acids which in

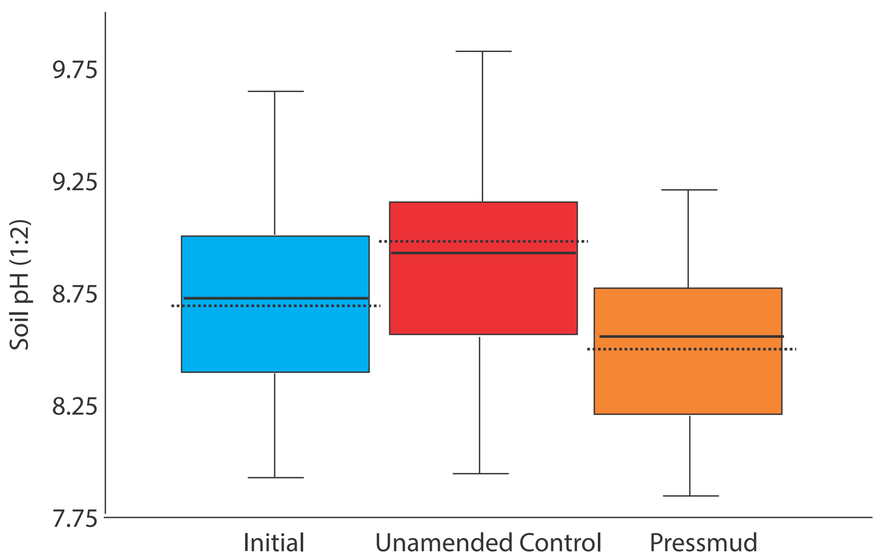
Fig. 65. Effect of pressmud application on grain yield of rice, wheat and system productivity (wheat equivalent yield). Capped lines indicate standard error of the mean



turn resulted in increased solubility of native $CaCO_3$ and other calcic minerals.

Irrigation with high RSC_{iw} waters (1.6-7.6 me L^{-1}) without using amendment (FP) induced build up in soil sodicity and increased soil pH of 8.85 (averaged over 37 locations) was recorded against the initial mean value of 8.68. Magnitude of reduction in soil pH under pressmud ameliorated plots invariably increased with the increase in soil sodification. The decomposition of pressmudneutralized alkalinity and favoured dissolution of native carbonate minerals declining soil pH to the extent of 0.07-0.44 units with a mean reduction of 0.21 units compared to initial value.

Fig. 66. Change in soil pH due to continued irrigation with high RSCiw and pressmud application at selected farmers' sites (N=37). Bars represent quartiles with median and spread, and dotted lines represent mean. Capped lines indicate standard error of the mean.



MISCELLANEOUS


ICAR-CSSRI

Trainings in India and Abroad

Sr.	Name and Designation	Subject	Duration	Place
1.	Dr. Sagar D. Vibhute, Scientist	Winter School on "Recent Advances in Micro-Irrigation & Fertigation Systems for Improved Input Use Efficiency of Open and Covered Cultivation through Engineering Interventions"	03.01.2019-23.01.2019	ICAR-CIAE, Bhopal
2.	Dr. S. K. Sarangi Principal Scientist	Electromagnetic (EM) Soil Survey of the Project 'Cropping Systems Intensifications in the Salt-Affected Coastal Zone of Bangladesh and West Bengal, India'	13.01.2019-19.01.2019	Khulna, Bangladesh
3.	Dr. Awtar Singh Scientist	"Precision Nitrogen Nutrition in Wheat: Integrating Genetics, Root	29.01.2019-31.01.2019	ICAR-IIWBR, Karnal
		Phenotyping and Precision Agronomy for Improving Nitrogen Use Efficiency"	07.03.2019-12.03.2019	BISA-CIMMYT, Ludhiana
4.	Sh. Vinod Kumar Technical Officer	Motivation, Positive Thinking and Communication Skill for Technical staff	13.03.2019-19.03.2019	ICAR-IISWC Dehradun
5.	Dr. Parveen Kumar Principal Scientist	SAARC Regional Training on 'Smart Agricultural Water Management Interventions for Enhancing Water Productivity & Resilience in South Asia.	18.06.2019-22.06.2019	ICAR-IIWM, Bhubaneswar
6.	Dr. Sagar D. Vibhute, Scientist	Advanced Irrigation Systems	19.08.2019 - 21.08.2019	NIPHM, Hyderabad
7.	Dr. Y.P. Singh Principal Scientist	Enhancing resilience and productivity of rice-based system through precision agronomy, machine learning and ICT based tools.	24.08.2019 - 26.08.2019	Chandigarh
8.	Dr. Kailash Prajapat	Farm Equipment for Plant Health Management	27.08.2019-29.08. 2019	NIPHM, Hyderabad
9.	Dr. H.S. Jat, Principal Scientist	To attend the International Conference on Wheat Diversity & Human Health	20.09.2019-24.09.2019	Istanbul, Turkey
10.	Dr. Bisweswar Gorain, Scientist	CAFT training on "Current Challenges and Strategies for Management of Soil Health & Sustainable Productivity"	11.09.2019-01.10.2019	JNKVV, Jabalpur (MP)
11.	Sh. Akanksha Vishwakarma, T1	Advancement in Soil, Water and Plant Analysis Techniques using Sophisticated Equipment with Respect to Salinity and Sodicity Management	16.09.2019 - 21.09.2019	ICAR-CSSRI, Karnal
12.	Dr. S. Mandal Principal Scientist	Participated in the International Conference of Australia Pacific Extension Network (APEN) 2019 Conference on Extension's Role in Climate, Rural Industry and Community Challenges	11.09.2019-13.09.2019	Darwin, Northern Territory, Australia
13.	Dr. S. K. Sarangi Principal Scientist	Good Agricultural Practices in Spraying	23.09.2019-30.09.2019	NIPHM, Hyderabad
14.	Dr Ashim Datta	7th International Symposium on Soil Organic Matter	06.10.2019-11.10.2019	Adelaide, Australia
15.	Raju, R.	National Dialogue on Land use for Integrated Livestock Development	01.11.2019-02.11.2019	NAAS Complex, New Delhi
16.	Dr. Madhu Choudhary Sr. Sceintist	"Advance Technologies for Bio fertilizers & Bio pesticides production for profitable and sustainable agriculture.	08.11.2019-28.11.2019	MPUA &T, Udaipur
17.	Dr. T. D. Lama	Geographical Information System (GIS) Approach in Soil, Water and Plant Health Management	03.12.2019-23.12.2019	NIPHM, Hyderabad

Deputation of Scientists Abroad

Sr.	Name and Designation	Subject	Duration	Place
1.	Dr. S. K. Sarangi Principal Scientist	Workshop on Data Analysis, Interpretation and Presentation of the Project 'Cropping Systems Intensifications in the Salt-Affected Coastal Zone of Bangladesh & West Bengal, India	13.01.2019-9.01.2019	Khulna, Bangladesh
2	Dr. R.K. Singh Principal Scientist	Commonwealth Chevening CRISP Fellowship 2019	23.04.2019-29.06.2019	University of Oxford, U.K.
3	Dr. Raj Mukhopadhyay, Scientist	Third International Conference on Bioresources, Energy Environment and Materials Technology 2019	12.06.2019-15.06.2019	Hong Kong Polytechnic University
4	Dr. P.C. Sharma Director	1st International wheat Congress	21.07.2019-26.07.2019	Canada
5.	Dr. Gajender Sr. Scientist Dr. Nurjary Baskar Scientist	For Execution Research and Experiment on ICAR-CSSRI-JIRCAS Project	01.09.2019-14.09.2019	Akita, Japan
6.	Dr. S. Mandal Scientist	International Conference of Australia Pacific Extension Network (APEN) 2019	12.09.2019-13.09.2019	Darwin, Australia
7.	Dr. Jogindra Singh Scientist	Training on "Basic Experimental Design and Data Analysis using STAR"	07.10.2019-11.10.2019	IRRI Philipines
8	Dr. Ashim Datta, Scientist	7th International Symposium on Soil Organic Matter	06.11.2019-11.11.2019	Adelaide, Australia
9	Dr. H.S. Jat Principal Scientist	International Conference on Wheat Diversity & Human Health	22.10.2019-24.10.2019	Istanbul Turkey
10.	Dr. S. K. Sarangi Principal Scientist	Third International Tropical Agricultural (TropAg) Conference	09.11.2019-14.11.2019	Brisbane, Australia
11	Dr. Krishnamurthy, SL Scientist	Global Forum on Innovation for Marginal Environments, 2019	20.11.2019-21.11.2019	Dubai
12.	Dr. D. Burman Principal Scientist	23rd International Congress on Modelling and Simulation (MODSIM2019)	01.12.2019-06.12.2019	Canberra, Australia

Awards and Recognitions

- Dr. H.S. Jat received National award: Golden Jubilee Award for Excellence- 2019 by the Fertilizer Association of India (FAI), New Delhi for best Fertilizer Use Research in the Country during 2nd December 2019.
- Dr. Raj Mukhopadhyay received Clay Mineral Bursary award from Mineralogical Groups of Mineralogical Society of Great Britain & Ireland
- Dr. S. Mandal received Early Career Sponsorship from ACIAR for attending and presenting research paper during International Conference on 'Extension's Role in Climate, Rural Industry and Community Challenges', 11-13 September 2019, Darwin, Australia
- Dr Ashim Dutta received International Travel fellowship from Science and Engineering Research Board (SERB)-DST, Govt. of India, New Delhi for participating in the 7th International Symposium on Soil Organic Matter, held in Hilton Adelaide, Adelaide, Australia during 6-11th October, 2019
- Dr. Ranjay Kumar Singh conferred Commonwealth-Chevening Fellowship for postdoctoral held in University of Oxford, UK, during 223rd April, 2019.
- Dr. R.K. Singh, conferred NAAS Felloship (Agril. Extension) on 1st January 2019
- Dr. Satyendra Kumar received Indian Society of Agricultural Engineering (ISAE) JAE Best Paper Award
- Dr. A.K. Bhardwaj got Best Paper Award in Joint International Conference by SCSI-ISCO-WASWAC, 5-9 November, 2019, New Delhi, India.
- Dr. Parvender Sheoran conferred Fellow of the Indian Society of Oilseeds Research, Hyderabad
- Dr. Parvender Sheoran conferred Fellow of the Indian Society of Weed Science, Jabalpur

Linkages and collaborations

Collaborative Programmes at Main Institute, Karnal

International Collaboration

- Stress Tolerant Rice for Poor Farmers of Africa and South Asia (IRRI-BMGF)
- Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTL for Drought, Submergence and Salt Tolerance (DBT, India)
- Developing of Sustainable Resource Management System in the Water-Vulnerable Area in India (JIRCAS, Japan)
- CV Raman Fellow Visiting Scientist from Soil and Water Department, Faculty of Agriculture, Cairo University, Egypt
- CIMMYT, IRRI, DoAFW, Haryana and Punjab, ICAR institutes
- DST Funded Project "North Indian Centre for Water Technology Research in Agriculture" with PAU and WTC, ICAR-IARI, ICAR-CSSRI, HPKV, HP, SKUAST-J, Jammu as collaborative Institutes.

National Collaborations

- Transgenics in Crops- Salinity Tolerance in Rice: Functional Genomics Component (funding ICAR, New Delhi)
- Monitoring and Evaluation of Large-Scale Subsurface Drainage Projects in the State of Haryana (HOPP, Department of Agriculture, Haryana)
- Multi-locational Evaluation of Bread Wheat Germplasm (funding by NBPGR, New Delhi)
- AMAAS-Application of Micro-organism in Agriculture and Allied Sectors (ICAR, New Delhi)
- Intellectual Property Management and Transfer/Commercialization of Agricultural Technology System (funding by ICAR, New Delhi)
- Development and Validation of Multi-Trait allele specific SNP panel for High Throughput Genotyping of Breeding Populations in Soybean (ICAR-CSSRI, Karnal and ICAR-IISR, Indore).
- QTL Mapping and Identification of Markers linked to Salinity Tolerance in Chickpea (*Cicer arietinum* L.) (ICAR-CSSRI, Karnal and JAV, Junagadh)
- Enhancement of Genetic Potential of Moongbean and Lentil in multi Season and Different Cropping System Adaptation (ICAR-CSSRI and ICAR-IARI, New Delhi).
- ICAR-NRRI, Cuttack and ICAR-IASRI, New Delhi partners in NASF funded project.
- ICAR-IIWBR, Karnal, ICAR-NBPGR, New Delhi
- DST Funded Project "North Indian Centre for Water Technology Research in Agriculture" with PAU and WTC, ICAR-IARI, ICAR-CSSRI, HPKV, HP, SKUAST-J, Jammu as collaborative Institutes.
- Methodology for Real-time Assessment of Salt Affected Soils in Ghaghar Plain of Haryana using Hyper-spectral Remote Sensing (SERB+DST Funded)
- Haryana State Forest Department
- Indian Oil Corporation Ltd. Refinery Panipat, Haryana
- Chaudhary Charan Singh Haryana Agriculture University, Hisar, Haryana
- NHRDF, RRS Karnal
- Potato Technology Centre, Shamgarh

Collaborative Programmes at Regional Research Stations

Canning Town

International Collaborations

- IRRI- for ICAR-IRRI collaborative project on Development of climate smart practices for climate resilient varieties; and Crop and natural resource management for stress tolerant rice in West Bengal
- CSIRO, Murdoch University, Australia – for project on cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India
- Bangladesh Agricultural Research Institute, Bangladesh Rice Research Institute, Khulna University - for project on cropping system intensification in the salt affected coastal zones of Bangladesh and West Bengal, India

National Collaborations

- Coastal Salinity Tolerant Variety Trial (CSTVT) with ICAR-IIRS, Hyderabad and ICAR-NRRI , Cuttack.
- ACIAR Funded Project (with BCKV, West Bengal)
- Partner in Inter-Institutional Project (NRSA-RRSC– East, Kolkata) (ISRO)
- Partner in Inter-Institutional Project (ICAR-NBSS&LUP, Kolkata Centre)
- Dissemination of Technologies, organized exposure visits and Farmers-Scientist Interaction Programme (Department of Agriculture, Government of West Bengal)
- Dissemination of technologies, organized exposure visits and farmers-scientist interaction programme (Department of Soil Conservation, Government of West Bengal).
- ACIAR Funded Project (Tagore Society for Rural Development, West Bengal)
- NGO: PRASARI- Training Programme.
- Consultancy Project NGO (Human Development Center) (HDC)

Lucknow

International Collaborations

- Future Rainfed Lowland Rice Systems in Eastern India (Development of Crop and Nutrient Management Practices in Rice) (ICAR –W3) (IRRI).

National Collaborations

- Utilization of Fly Ash for Increasing Crop Productivity by Improving Hydro-Physical Behavior of Sodic Soils of Uttar Pradesh (DST)
- Assessment of Municipal Solid Waste in Conjunction with Chemical Amendments for Harnessing Productivity Potential of Salt Affected Soils (UPCAR).
- G. B. Pant Polytechnic College, Lucknow
- Bansal Institute of Engineering and Technology, Lucknow
- Linkages also developed with different KVKs in the state for assessing the Halo-CRD a bioformulation developed for decomposition of crop residue.

Bharuch

National Collaborations

- Navsari Agricultural University, Navsari
- Anand Agricultural University, Anand
- Junagadh Agricultural University, Junagadh
- ICAR-Central Institute of Cotton Research, Nagpur
- College of Agriculture, NAU, Bharuch
- Main Cotton Research Station, NAU, Surat.
- Regional Cotton Research Station, NAU, Bharuch
- Gujarat Narmada Valley Fertilizer and Chemicals ltd. Bharuch
- VIKAS-NGO, Ahmedabad.
- ATAPI Seva Foundation, NGO Jambusar
- ICAR-Indian Institute of Water Management, Bhubaneshwar
- Bidhan Chandra Krishi Visva Vidyalaya, Kalyani (West Bengal)
- Water Technology Centre, TNAU, Coimbatore (TN)
- Krishi Vigyan Kendra, Surat, Dist. Surat
- Krishi Vigyan Kendra, Dediapada, Dist. Narmada
- Krishi Vigyan Kendra, Chaswad, Dist. Bharuch
- Krishi Vigyan Kendra, Vyara, Dist. Tapi
- ICAR Indian Institute of Wheat and Barley Research, Karnal
- All India Coordinated Cotton Improvement project , Coimbatore
- Sardar Sarovar Narmada Nigam Limited, Gandhinagar

NEW LINKAGES WITH NATIONAL AND INTERNATIONAL AGENCIES

- Recent Space Technologies and Image Interpretations for Mapping and Characterizing Salinity Affected Areas with Higher Accuracies with National Remote Sensing Centre (NRSC), Hyderabad, State Remote Sensing Application Centres (RSAC) and ICAR-NBSS&LUP, Nagpur
- Academic linkages with Institute of Environmental Studies, Kurukshetra University, Kurukshetra, Haryana; Department of Biotechnology, Maharishi Markandeshwer University, Mullana, Haryana; Deenbandhu Chhotu Ram University of Science & Technology, Murthal, Haryana and ICAR-NDRI, Karnal, Haryana for Post Graduate teaching and research
- Project Director, NCP, IGBP, IIRS, NRSA, Department of Space, Dehradun, Uttrakhand
- CCSHAU, Hisar, Haryana for collaborative research
- Research Institute of Theoretical & Applied Physical Chemistry (INIFTA), La Plata, Argentina (funding from UNESCO-TWAS-CONICETS) for collaborative research.
- Development of efficient and cost effective materials for remediation of salt-affected soils with Centre for Environmental Science and Engineering (CESE), Indian Institute of Technology, Kanpur, India.
- SHIATS, Allahabad (U.P.)
- JIRCAS, Tsukuba, Japan

Publications

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Participation in Conference/Seminar/Symposium/Workshop

Name	Title	Place	Period
Dr. Sanjay Arora Principal Scientist	28th National Conference on Farmer friendly soil and water conservation technologies for mitigating climate change impact	Udhagamandalam, Tamil Nadu	31.01.2019-02.02.2019
Dr. Sagar Vibhute, Scientist	Winter School on "Recent Advances in Micro-Irrigation and Fertigation Systems for Improved Input Use Efficiency of Open and Covered Cultivation through Engineering Interventions"	ICAR-CIAE, Bhopal	03-01.2019-23.01.2019
Dr. M.J. Kaledhonkar Principal Scientist	Seminar on Waterlogging and Salinity Organized by Agriculture Department, Haryana	Chandigarh	11.01.2019
Dr. P.C. Sharma Director Dr. M.J. Kaledhonkar PS	Annual Conference of Vice Chancellors of Agricultural Univiersities & Directors of ICAR Institutes	NASC Complex, Pusa, New Delhi	31.01.2019-01.02. 2019
Dr. Ashwani Kumar Scientist	International Symposium "Innopreneurship: A need of Sustainable Agriculture"	HAU, Hisar CCS	02.02.2019-03.02. 2019
Dr. Anil R. Chinchmalatpure	XXV meeting of the ICAR Regional Committee VI	AAU Anand	04.02.2019- 05.02.2019
Dr. M.J. Kaledhonkar Principal Scientist Dr.RL Meena Principal Scientist Dr. BL Meena Scientist	26th Biennial Workshop of AICRP on SAS&USW	ICAR-CSSRI, Karnal	05.02.2019-06.02.2019
All Scientists	Golden Jubilee International Salinity Conference	Karnal	07.02.2019-09.02.2019
Dr.M.J. Kaledhonka Principal Scientist Dr. B.L. Meena Scientist	Training-Cum-Workshop on Unit Level Data Repository for AICRP	ICAR-IASRI, New Delhi	25.02.2019-26.02. 2019
Dr. Krishnamurthy, S. L. Scientist	54th All India Annual Rice Group Meetings	Hyderabad	30.05.2019-02.06.2020
Dr. R. Mukhopadhyay Scientist	3rd International Conference on Bio-resources, Energy, Environment and Materials Technology	Hong Kong Polytechnic University, Hong Kong	12.06.2019-15.06.2019
Dr. D.S. Bundela Principal Scientist Dr. M.J. Kaledhonkar Principal Scientist	National Workshop on Sustainability of Indian Agriculture: Methodology and Indicators	ICAR- NIAP, New Delhi	18.06.2019-19.06.2019
Dr. Uttam Kumar Mandal Principal Scientist	Attended NICRA Technical Review Workshop of NRM Institutes under Strategic Research Component	NASC, New Delhi	25.07.2019-26.07. 2019
Dr. S. K. Sarangi Principal Scientist	Participated in the QRT meeting of All India Co-ordinated Rice Improvement Project (AICRIP) of Eastern Zone	BCKV, Kalyani, West Bengal	29.07.2019-30.07.2019
Dr. Anil R. Chinchmalatpure Principal Scientist Dr.Shrvan Kumar, PS Dr.Sagar Vibhute Scientist	One day workshop on "Priority setting, monitoring and evaluation (PME) of Agril Research Projects"	ICAR-DMAPR, Boriyavi	03.08.2019
Dr. R.K. Fagodiya, Scientist	Training on Analysis of Experimental Data	ICAR-NAARM, Hyderabad	22.08.2019-27.08.2019
Dr. S. K. Sarangi Principal Scientist	International workshop on "Enhancing resilience and productivity of rice-based system through precision agronomy, machine learning and ICT based tools"	Chandigarh	24.08.2019-26.08.2019
Dr. M.J. Kaledhonkar Principal Scientist Dr. D.S. Bundela Principal Scientist	National workshop on Agricultural Sustainability Indicators: Methods and weight determination	Amity University, Noida	31.08.2019
Dr. Anil R. Chinchmalatpure Principal Scientist	Global Organic Convention	Nagpur	14.09.2019-17.09.2019
Dr. R Mukhopadhyay Scientist	International Workshop on Groundwater Flow and Contaminant Transport Modelling using HYDRUS-3D	IIT, Mandi	09.09.2019-11.09.2019

Dr. M.J. Kaledhonkar Principal Scientist	National Conference on Climate Smart Agriculture for Livelihood Security: Challenges and Opportunities	TNAU, Tiruchirappalli	13.09.2019-14.09.2019
Dr. Raj Kumar (AF) Sientist	AICARP Workshop on Agroforestry	Coimbatore	18.09.2019-20.09.2019
Dr. U.K. Mandal, Principal Scientist	Workshop on Water Conservation and Livelihood Enhancement in Indian Sundarbans at Panchayat and Rural Development Department	Saltlake, Kolkata	19.09.2019
Dr. D.S. Bundela Principal Scientist	6th India Water Week International Conference-2019: Water Cooperation - Coping with 21st Century Challengess	Vigyan Bhawan, New Delhi	24.09.2019 - 28.09.2019
Dr. P. Chandra Principal Scientst Dr. D.S. Bundela Principal Scientist	International Conference on Recent Advances in Agricultural, Environmental and Applied Sciences for Global Development (RAAEASGD-2019).		27.09.2019
Dr. Jaffer Yousuf Dar, Scientist	NAHEP National Workshop on 'Inland Saline Aquaculture,	ICAR-CIFE, Rohtak	05.10.2019- 06.10.2019
Dr. Raj Mukhopadhyay Scientist	Environmental Challenges and Eco-friendly Technologies/Practices		
Dr. U.K. Mondal Principal Scientist	Workshop on 'Carbon management in Soils through Resource Conservation Technologies (RCT): Issues and Strategies.	BCKV, Kalyani, West Bengal	02.11.2019
Dr. Sanjay Arora, Principal Scientist	International Conference on Soil and Water Resources Management for	NASC Complex,	05.11.2019-09.11. 2019
Dr. A.K. Singh Principal Scientist	Climate Smart Agriculture, Global Food and Livelihood Security	New Delhi	
Dr. Sanjay Arora Principal Scientist Dr. B L Meena Scientist	84th Annual Convention of ISSS	BHU, Varanasi	15.11.2019- 18.11.2019
Dr. D.S. Bundela Principal Scientist	Management Development Programme on Leadership Development (Pre-RMP Programme)	ICAR-NAARM, Hyderabad	02.12.2019- 13.12.2019
	Consultation Workshop on "Conjunctive use of water in India: Current status and way forward"	ICAR NASC Complex, New Delhi	16.12. 2019
Dr. U. K. Mandal, Principal Scientist	Attended Seventh NICRA Annual Review Workshop	NASC, New Delhi	17.12.2019-18.12.2019
Dr. Parveen Kumar, PS	Seminar on 'Restructuring of Primary and Secondary Education to address the issue of 'Education Curriculum weaning students from farmers and farming community'	ICAR-NDRI, Karnal	20. 12.2019

List of On-going Projects

Institute Funded Projects

Priority area - Data Base on Salt Affected Soils & Poor Quality Waters

1. NRMACSSRISIL201700500929. Spectral characterizations of saline soil located at Nain experimental farm of ICAR-CSSRI in Panipat district of Haryana. (Arijit Burman, R. Srivastava, A.K. Mandal, Jogendra Singh and R.K. Yadav)

2. NRMACSSRISIL201800100954. Mapping and characterization of salt affected soils in Uttar Pradesh using remote sensing and GIS. (A.K. Mandal, Arijit Barman, R.K. Yadav V.K. Mishra, Sanjay Arora, S.K. Jha, M.J. Kaledhonkar and P.C. Sharma)

Priority Area - Reclamation and Management of Alkali Soils

3. NRMACSSRISIL201501300889. Impact of secondary salinization and other stressors on agricultural systems: constraints analysis in South-Western Punjab. (R.K. Singh, Satyendra Kumar, Anshuman Singh and Nirmalendu Basak)

4. NRMACSSRISIL201600400902. Farmer participatory enterprise mix diversification on reclaimed sodic land (Gajender, R. Raju, A.K. Rai, R.K. Yadav, Madhu Choudhary, Raj Kumar, Anil Kumar, Dar Jaffer Yusuf and K.S. Kadian)

5. NRMACSSRISIL201600100899. Characterization and application of sewage sludge and municipal solid waste compost for reclamation of sodic soils. (Parul Sundha, A.K. Rai, Gajender, Nirmalendu Basak and Priyanka Chandra)

6. NRMACSSRISIL201700100925. Isolation, identification and assessment of salt tolerant zinc solubilising bacteria for enhancing availability and use efficiency of zinc in salt affected soils. (Awtar Singh, R.K. Yadav, A.K. Rai and Madhu Choudhary)

7. NRMACSSRISIL201700200926.Dynamics of nitrogen and organic matter fractions in soils under long-term conservation agriculture in reclaimed sodic soil. (Ashim Datta, Madhu Choudhary and P.C. Sharma)

8. NRMACSSRISIL201700300927.Sustainable nutrient management strategies for partially reclaimed salt affected soils. (Ajay Kumar Bhardwaj, Priyanka Chandra and Bhaskar Narjary)

9. NRMACSSRISIL201700600930. Development of endo-rhizospheric fungal consortia to increase salt tolerance in crops. (Priyanka Chandra, Awtar Singh and Kailash Prajapat)

10. NRMACSSRISIL201701500939. Planned adaptations and co-production of adaptive knowledge to agro-ecological stressors: Perspectives of multi-stakeholders of North-Western India. (Ranjay K. Singh, Anshuman Singh, R.K. Yadav, Parveen Kumar and P.C. Sharma)

11. NRMACSSRISIL201800200955. Amelioration of iron deficiency in direct seeded/aerobic rice in reclaimed sodic s soils. (Babu Lal Meena, Ram Kishor Fagodiya, R.L. Meena, M.J. Kaledhonkar and P.C. Sharma)

12. NRMACSSRISIL201801700969. Developing of soil quality indices for sodic soil under different reclamation strategies (Nirmalendu Basak, Arvind Kumar Rai, Parul Sundha, R.L. Meena, R.K. Yadav and P.C. Sharma)

13. NRMACSSRISIL201802200974. Rice-wheat system performances and dynamics of salt and water under contrasting tillage, residue and irrigation management practices. (H.S. Jat, Ashim Datta, Madhu Choudhary, Satyendra Kumar and P.C. Sharma)

Priority Area - Drainage Investigations and Performance Studies

14. NRMACSSRISIL2014001000868. Impact assessment of subsurface drainage technology in canal command areas of Karnataka. [(R. Raju, Aslam Latif Pathan and Thimmappa K.]

15. NRMACSSRISIL201501400890. Performance evaluation of subsurface drainage systems in Haryana and to implement interventions for improving operational performance and impact. (D.S. Bundela, Bhaskar Narjary Aslam Latif Pathan and R. Raju)

16. NRMACSSRISIL201701000934. Developing guidelines for suitability of geosynthetic filter materials for Sub-Surface Drainage systems in different agro-climatic. (A.L. Pathan, R.S. Tolia and D.S. Bundela)

17. NRMACSSRISIL201701100935. Studies on salt load dynamics of drainage water and improvement in soil salinity in sub surface sites in Haryana, (R.S. Tolia, A.L. Pathan, Kailash Prajapat and D.S. Bundela)

Priority Area - Management of Marginal Quality Waters

18. NRMACSSRISIL201400700865. Conjunctive water use strategies with conservation tillage and mulching for improving productivity of salt affected soils under limited fresh water irrigation.(Arvind Kumar Rai, Nirmalendu Basak, Satyendra Kumar, Bhaskar Narjari and Gajender)

19. NRMACSSRISIL201501500891. Assessing use of press mud/press mud compost in gypsum beds for neutralization of RSC in irrigation water. (R.K. Yadav, Satyendra Kumar, Parul Sundha and Madhu Choudhary)

20. NRMACSSRISIL201502100897. Isolation, identification and evaluation of plant growth promoting bacteria for mitigating salinity stress in crops. (Madhu Choudhary, Gajender, Awtar Singh and T. Damodaran)

21. NRMACSSRISIL201700900933. Development of salinity yield relations for different crops under micro-irrigation for updating water quality guidelines. (Ram Kishor Fagodiya, B.L. Meena, R.L. Meena, M.J. Kaledhonkar, D.S. Bundela and P.C. Sharma)

22. NRMACSSRISIL201802100973. Salinity management and modeling under drip Irrigation, raised bed and mulch for optimum yield. (Bhaskar Narjary, Satyendra Kumar and R.K Fagodiya)

Priority Area - Crop Improvement for Salinity, Alkalinity and Waterlogging Stresses

23. NRMACSSRISIL201500800884. Identification of high yielding and salt tolerant genotypes in pomegranate. (Raj Kumar, R.K. Yadav, Anita Mann and Anshuman Singh)

24. NRMACSSRISIL201501100887. Development of rice genotypes for salt tolerance in rice: Conventional and Molecular approaches. (Krishnamurthy, S.L., P.C. Sharma, Y.P. Singh and S.K. Sarangi)

25. NRMACSSRISIL201700400928. Development of Soybean [*Glycine max* (l.) Merrillis] genotypes for higher yield under Salt Stress. (Vijayata Singh and S.K. Sanwal)

26. NRMACSSRISIL201700700931. Development of salt tolerant and high yielding Indian Mustard (*Brassica juncea* L.Czern & Coss) genotypes using Classical and Modern breeding approaches. (Jogendra Singh, P.C. Sharma and Vijayata Singh)

27. NRMACSSRISIL201700800932. Morpho-physiological characterization and standardization of agronomic practices of quinoa (*Chenopoium quinoa*) for salt affected ecosystems. (Kailash Prajapat, S. K. Sanwal and P.C. Sharma)

28. NRMACSSRISIL201701300937. Wheat improvement for salt and waterlogging tolerance thorugh conventional and molecular approaches. (Arvind Kumar, P.C. Sharma, Ashwani Kumar, Indivar Prasad and Y.P. Singh)

29. NRMACSSRISIL201800300956. Identification of salt tolerant genotypes in jamun (*Syzygium cumini* L. Skeels) (Anshuman Singh and Ashwani Kumar)

30. NRMACSSRISIL201801800970. Genetic improvement of chickpea for salt tolerance through conventional and molecular breeding approaches. (S.K. Sanwal, Vijayata Singh and Anita Maan)

31. NRMACSSRISIL201802300975. Screening of potato genotypes for higher tuber yield under salinity stress- (Parveen Kumar, V.K. Gupta, PS (VB), CPRS, Modipuram)

Priority Area - Agroforestry in Salt Affected Soils

32. NRMACSSRISIL201701200936. Evaluation of potential Olive germplasm for salt affected soils. (Manish Kumar and Rakesh Banyal)

33. NRMACSSRISIL201701300938 Enhancing productivity potential of saline soils through agroforestry interventions. (R. Banyal, A.K. Bhardwaj, Parveen Kumar, Raj Kumar and Rahul Singh Tolia)

34. NRMACSSRISIL201800400957. Improvement of *Melia dubia* for salt tolerance through selection approach. (Raj Kumar, Rakesh Banyal and Awtar Sing)

Priority Area - Reclamation and Management of Coastal Saline Soils

35. NRMACSSRISIL201401100869. Long term impact of land shaping techniques on soil and water quality and productivity of coastal degraded land. (D. Burman, U.K. Mandal, S.K. Sarangi, S. Mandal, K.K. Mahanta and S. Raut)

36. NRMACSSRISIL201600500903. Conservation agriculture for rice-maize cropping system in coastal saline region. (S.K. Sarangi, U.K. Mandal, K.K. Mahanta and T.D. Lama)

37. NRMACSSRISIL201600600904. Role of soil salinity and land uses on status and characteristics of organic matter under different landforms in coastal ecosystem. (Shishir Raut and T.D. Lama)

38. NRMACSSRISIL201600700905. Assessment and coping strategies of agricultural risk under coastal region of West Bengal – a social-economic analysis. (Subhasis Mandal, U.K. Mandal and T.D. Lama)

39. NRMACSSRISIL201600800906. Assessing carbon sequestration potential of conservation tillage practices under rice based cropping systems in coastal saline soils. (U.K. Mandal, D. Burman, S.K. Sarangi and T.D. Lama)

40. NRMACSSRISIL201600900907. Impact of deficit irrigation on salt dynamics and crop productivity in coastal saline soils. (T. D. Lama, D. Burman, S. K. Sarangi and K.K. Mahanta)

41. NRMACSSRISIL201801100964. Evaluation of different micro-irrigation systems for rabi rice in coastal salt affected soils. (K.K. Mahanta, S.K. Sarangi, U.K. Mandal, D. Burman and S.Mandal)

Priority Area - Reclamation and Management of Salt Affected Vertisols

42. NRMACSSRISIL201601000908. Cost effective drainage in waterlogged saline Vertisols for improving crop productivity in Gujarat. (Sagar Vibhute D., Anil R. Chinchmalatpure, David Camus. D and M.J. Kaledhonkar)

43. NRMACSSRISIL201601100909. Maximization of yield and factor productivity through integrated nutrient management in desi cotton based cropping systems in saline vertisols. (Shrvan Kumar, David Camus. D, Bisweswar Gorain and Anil R. Chinchmalatpure)

44. NRMACSSRISIL201800500958. Conjunctive use of saline groundwater and surface water in Vertisols for improving water productivity under drip irrigated wheat. (Sagar D. Vibhute, Anil R. Chinchmalatpure, Shrvan Kumar and Bisweswar Gorain)

45. NRMACSSRISIL201800600959. Pulpwood-based silvipastoral systems for saline Vertisols. (David Camus D, Shrvan Kumar and Bisweswar Gorain)

46. NRMACSSRISIL201800700960. Assessment and mapping of salt affected soils of Gujarat using remote sensing and GIS. (Anil R. Chinchmalatpure, Shrvan Kumar, Bisweswar Gorain, A.K. Mandal, M.J. Kaledhonkar, Arijit Barman and scientist from AICRP –Indore centre)

47. NRMACSSRISIL201800800961.Development of Desi cotton genotypes (*G. herbaceum* and *G. arboreum*) for salt affected Vertisols. (Shrvan Kumar, Anil R. Chinchmalatpure and P.C. Sharma)

Priority Area - Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains

48. NRMACSSRISIL201601200910. Breeding of salt tolerant polyembryony mango rootstocks and assessment of bio-efficacy of the microbial formulations in control of *Fusarium* wilt of banana and guava.{(T. Damodaran (PI), V.K. Mishra and S.K. Jha, S. Rajan and Umesh. (CISH, Lucknow)}

49. NRMACSSRISIL201601300911. Bio-augmenting crop residues degradation for nutrient cycling through efficient microbes to enhance productivity of salt affected soils. (Sanjay Arora, Y.P. Singh and A.K. Singh)

50. NRMACSSRISIL201601400912. Feasibility of marine gypsum an alternative source of mineral gypsum for the reclamation of sodic soils. (S. K. Jha, V.K. Mishra T. Damodaran and Y.P. Singh)

51. NRMACSSRISIL201800900962. Development of soil moisture sensor to automate solar PV based irrigation system in salt affected soils. (Atul Kumar Singh, C.L. Verma A.K. Bhardwaj, V.K. Mishra and Anju Kumari Singh (GBPP, Lucknow))

52. NRMACSSRISIL201801900971. Managing soil sodicity and waterlogging problems in permanent land modification modules under Sarada Sahyak canal

command area. (V.K. Mishra, C.L. Verma, Y.P. Singh S.K. Jha, T. Damodran, M.J. Kaledhonkar and P.C. Sharma)

Externally Funded Research Projects

1. Stress tolerant rice for poor farmers in Africa and South Asia (STRASA Phase 3). Krishnamurthy S.L, P.C. Sharma, D. Burman, S.K. Sarangi, S. Mandal, Vinay Kumar Mishra and Y.P. Singh)- BMGF

2. Intellectual property management transfer/commercialization of agricultural technologies renamed as NAIF. (Parveen Kumar, Anita Mann, Rakesh Banyal, Raju R. and Bhaskar Narjary) – ICAR

3. NRMACSSRICOP201500400880. Climate change mitigation and adaptation strategies for salt affected soils. (Ajay K. Bhardwaj, Ranbir Singh, R.K. Singh, Rakesh Banyal, R.K. Fagodiya, U.K. Mandal, Shishir Raut, K.K. Mahanta and V.K. Mishra)- NICRA, ICAR

4. NRMACSSRISOL201501600892. Molecular genetic analysis of resistance/tolerance in rice, wheat, chickpea and mustard including sheath blight complex genomics. [(Rice: component 1): Krishnamurthy, S.L. and P.C. Sharma, (Chickpea: component 3): P.C. Sharma, Anita Mann and Jogendra Singh, (Mustard: component 4): P.C. Sharma, Jogendra Singh and Vijayata Singh)] – ICAR, New Delhi

5. NRMACSSRISOL201502200898. CRP on Conservation Agriculture 'Productive utilization of salt affected soils through conservation agriculture". (Ranbir Singh, Arvind Kumar Rai, Parvender and Aslam Latif Pathan)-ICAR

6. NRMACSSRISOL201601500913. Strategic Research Platform on Climate Smart Agriculture "Developing and defining climate smart agricultural practices portfolios in South Asia". (P.C. Sharma, Ashim Datta and Madhu Chaudhary) ICAR-CCAFS

7. NRMACSSRISOL201601600914. Perceived climatic variability & agricultural adaptations by material resource-poor farmers in salt affected agro-ecosystems: Implications for food & livelihood security. [Ranjay K. Singh, Anshuman Singh, Satyendra Kumar, Pervender and Dheeraj Singh, KVK, Pali (CAZRI)]-ICAR

8. NRMACSSRISOL201601800916. Efficient groundwater management for enhancing adaptive capacity to climate change in sugarcane based farming system. [Satyendra Kumar(CCPI) and Aslam Latif Pathan]-ICAR

9. NRMACSSRISOL201602000918. CRP on water "Evaluation of Irrigation System and Improvement Strategies for Higher Water Productivity in Canal Command". (Chhedi Lal Verma, A.K. Singh, Dr. Y.P. Singh, Sanjay Arora, T. Damodaran, V. K. Mishra S.K. Jha and C.S. Singh)

10. NRMACSSRICOP201602100919. CRP on water "Groundwater contamination due to geogenic factors and industrial effluents and its impact on food chain" (Anil R. Chinchmalatpure, David Camus D. and Shrvan Kumar)-ICAR

11. NRMACSSRICOP201602200920. Cropping System intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India (LWR/2014/73/KGF). (S. K. Sarangi, D. Burman, U. K. Mandal, Subhasis Mandal and K.K. Mahanta)- ACIAR.

12. NRMACSSRICOP201602300921. Piloting and up-scaling an innovative underground approach for mitigating urban floods and improving rural water security in South Asia (V.K. Mishra, C.L. Verma and S.K. Jha) –IWMI

13. NRMACSSRICOL201602400922. Developing the alternate strategies for reclamation of sodic soils. [Arvind Kumar Rai, Nirmalendu Basak, R. L. Meena, R. K. Yadav, P.C. Sharma, Parul Sundha, S.K. Jha and U.R. Khandkar, AICRP (MSUSWA), Indore]- RIL

14. NRMACSSRISOL201602500923.Mineral nutrient diagnostic and site specific nutrient management demonstrations to improve agricultural productivity of salt affected soils in Haryana.(Anita Mann, R.K Yadav, Parvender, Ashwani Kumar and B.L. Meena) -RKVY

15. NRMACSSRISOL201602600924. Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains. {(Parvender, R.K. Singh, Satyendra Kumar, Arvind Kumar, R. Raju, Arijit Burman, Kailash Prajapat, Dar Jaffer Yusuf and K. Punnusamy (NDRI)}- Farmer FIRST ICAR

16. NRMACSSRICOL201701600940. Developing low cost ameliorating amendments for reclamation of sodic soils by suing municipal solid waste. (Gajender, R.K. Yadav, Madhu Choudhary, Bhaskar Narjary, Ashim Datta and Parul Sundha) -DST

17. NRMACSSRICOL201701700941. Potential gene mining from salt tolerant grasses for improvement of stress tolerance in crops. {(Anita Mann, Ashwani Kumar, Arvind Kumar, B.L. Meena, Monendra Grover & D.C. Mishra (IASRI, New Delhi), and Parameswaran C. (NRRI, Cuttack)}-NASF-ICAR

18. NRMACSSRICOL201701800942. Developing alternatives to gypsum using nanotechnology-based approaches for efficient and cost-effective reclamation of sodic soils. (Ajay Kumar Bhardwaj)-LBS Award

19. NRMACSSRICOL201701900943. Agricultural livelihood in Eastern coastal region of India under climate and environmental Risk (Subhasis Mandal) --LBS Award project

20. NRMACSSRICOL201702000944. Phyto-remediation potential of selected halophytes for salt affected lands of Haryana. (Ashwani Kumar, Arvind Kumar, B.L. Meena and Anita Mann) –RKVY

21. NRMACSSRICOL201702100945. Identification of salt tolerant scion and rootstocks in mango and low chill temperate fruits. (Rajkumar, Anshuman Singh, Ashwani Kumar, R.K. Yadav and P.C. Sharma)- RKVY

22. NRMACSSRICOL201702200946. CRP on Agro-Biodiversity- Sub. Project 1. Characterization, Multiplication and evaluation for important biotic and abiotic traits of plant genetic resources of selected crops (NBPGR) Component II (Biotic and abiotic evaluation) under sub-project-I (Arvind Kumar and P.C. Sharma)-ICAR

23. NRMACSSRICOL201702300947. Network project on Functional Genomics and genetic modification in crops (NPFGGM) salt tolerance in rice. (S.L. Krishnamurthy and P.C. Sharma) – ICAR- NPTC, New Delhi

24. NRMACSSRICOL201702400948. CRP on Agro-Biodiversity—Component 2 - Evaluation of rice germplasm accessions against biotic/abiotic stresses. (Krishnamurthy S.L. and P.C. Sharma)-ICAR

25. NRMACSSRICOL201702500949. Development of High Zinc rice varieties.(Krishnamurthy S.L. and P.C. Sharma)-IRRI

26. NRMACSSRISIL201600200900. Impact of *Eucalyptus* plantations in waterlogged saline ecologies in Indo Gangetic plains. (R. Banyal, Ajay K. Bhardwaj, R.K. Singh, Gajender and Ashlam Latif Pathan)

27. NRMACSSRICOL201702600950. HOPP Project "Technical guidance on monitoring & evaluation of large scale SSD projects in Haryana"{Team Leader: PC Sharma, D.S. Bundela (PI) Team A: Satyendra Kumar, Aslam Pathan, Arijit Barman and Kailash Prajapat and Team B: R.L. Meena, Bhaskar Narjary, R. Raju, and Rahul Singh Tolia, R.K. Fagodiya, Raj Mukhopadhyay and Dar Jaffer Yusuf)

28. NRMACSSRICOL201702700951. Network project on AMAAS "Harnessing the rhizosphere diversity with dynamic substrate to inccduce tolerance to biotic and biotic stress for commercial cultivation of agri-horticultural crops in partially reclaimed sodic soils. (T. Damodaran, V.K. Mishra and S.K. Jha)

29. NRMACSSRICOL201702800952. Management of harvested rainwater for enhancing water productivity and revival of village pond through scientific interventions in saline vertisol area of Gujarat. (Anil R. Chinchmalatpure, Shrvan Kumar and Sagar Vibhute D.)-DST

30. NRMACSSRICOL201801000963. Assessing potential of microbial enriched municipal solid waste compost for improving soil health and sustaining productivity of sodic soils. (Y.P. Singh, Sanjay Arora, V.K. Mishra and Atul K. Singh)-CST,UP

31. NRMACSSRISOL201801200964. From QTL to Variety: Genomics assisted introgression and field evaluation of rice varieties with genes/QTLs for yield under Drought, Flood and Salt stress. (Krishnamurthy S.L. and P.C. Sharma)

32. NRMACSSRISOL201801300965. Development of sustainable resource management systems in water vulnerable regions of India. ((Team Leader; P.C. Sharma, Dr. R.K. Yadav (PI), D.S. Bundela, Satyendra Kumar, Bhaskar Narjary, Gajender and A.K. Rai) Funded by ICAR-JIRCAS, Japan

33. NRMACSSRISOL201801600968. Development of Energy Efficient and Environment Protective Aquaculture Technologies for Degraded Soil. (D.S. Bundela, Raj Mukhopadhyay and Dar Jaffer Yusuf) (Funded by NAHEP) Lead Center is CIFE Mumbai.

34. NRMACSSRISOL201802000972. Identification of traits, genes, physiological mechanisms to develop climate smart varieties for unfavourable environment. (Krishnamurthy S.L. and P.C. Sharma) -ICAR-IRRI

Collaborative Projects

1. Land use options for enhancing productivity and improving livelihood in Bali Island of Sundarbans. [(S. Mandal) (NBSSLUP-Kolkata, CSSRI, RRS-Canning Town and CIFA – Kalyani)]

2. Characterization and mining genetic variability in sugarcane germplasm against abiotic stress (Salinity/Alkalinity and low temperature) under subtropical India (Karnal). [(Ashwani Kumar, Co-PI) collaboration with ICAR-SBI,RRS, Karnal)]

3. Exploration of medicinal and aromatic plants cultivation under different cropping systems and on marginal and degraded lands of semi-arid regions of India. {(Anil R. Chinchmalatpure, Co-PI) collaboration with ICAR-DMAPR, Anand, Gujarat)

4. Studies on bio-optical response of rice genotypes under varying levels of soil salinity [T. D. Lama, S.K. Sarangi and K. Chandrasekar (NRSA-Regional Remote Sensing Centre – East, Kolkata)]-ISRO

Consultancy

1. Subsurface Drainage for Heavy Soils of Maharashtra, Karnataka, Gujarat, AP & Telangana (Team Leader: Dr. P.C. Sharma, Dr. D.S. Bundela (PI), Dr. Satyendra Kumar, Dr. Anil Chinchmalatpure, Dr. R. Raju, Dr. Aslam Pathan, Dr. Sagar Vibhute and Dr. Rahul Singh Tolia)

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

3. M/s Gujarat Narmada Valley Fertilizer and Chemicals Ltd, Bharuch Gujarat

4. Astral-Rex Consultancy on subsurface drainage for heavy soils in Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Telangana (Dr. P.C. Sharma, Team Leader and Dr. D.S. Bundela, PI)

INSTITUTE ACTIVITIES

Institute Joint Staff Council Meeting

The institute Joint staff council meeting was held at ICAR-CSSRI, Karnal on 11th March, 2019 under the Chairmanship of Dr. P.C. Sharma, Director. It was attended by Dr. R.K. Yadav, Head, SCM, Div., Dr. S.K. Sanwal, Head (A) CI, Div. Sh. Abhishek Srivastava, SAO, Dr, Pankaj Kumar, SAO, Sh. Sunil Kumar, FAO, Sh. N.K. Vaid, OIC, Estate and Sh. Tarun Kumar, Sh. Suresh Pal Rana, Sh. Purshotam Lal, Sh. Devender Kumar, Sh. Zile Singh and Sh. Sukhbir Singh. The members discussed the various agenda items and other related issues for the welfare of the Institute staff at length and settled various issues systematically and amicably.

IJSC meeting in progress

Institute Management Committee Meeting

The 43rd Institute Management Committee meeting was held on 23rd March, 2019 at Karnal and was attended by the following IMC Members.

1.	Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal.	Chairman
2.	Dr. Padamni Sawain Head, Principal Scientist,ICAR-NRRI, Cuttack	Member
3.	Sh. Hem Chand Kaushik, V&PO, Kokrana	Member
4.	Dr. Mehar Chand, Gahlaut, V. Sahole, Distt. Palwal	Member
5.	Sh. Rajnesh Kumar, FAO, ICAR-NBAGR, FAO	Member
6.	Sh. Abhishek Srivastava, SAO, ICAR-CSSRI, Karnal.	Member Sec.

The Meeting started with the confirmation of the proceedings of the last meeting held on 6th March, 2018. Subsequently, the research achievements of different Divisions, Regional Research Stations and Project Coordinating Unit were discussed for the period of May-December, 2018. This was followed by discussion on other activities carried out during May-December. 2018. These included activities by the Institute Rajbhasha Committee, different trainings and Kisan Gosthis organized during the period, the issues related to staff position, Institute budget and expenditure, sale of farm produce, publications, linkages and collaborationsand the activities related to 'Swachh Bharat Abhiyaan' and 'Mera Gaon Mera Gaurav' programme.

IMC meeting in progress

Research Advisory Committee (RAC) meeting

The 22nd meeting of the Research Advisory Committee (RAC), constituted vide Council letter No. NRM/9-2/2019-IA-II dated 8th March 2019, held during 5-6 August, 2019 at ICAR-CSSRI, Karnal, under the Chairmanship of Dr. A.K. Sikka, Ex-Deputy Director General (NRM), ICAR, and currently IWMI Representative-India & Principal Researcher, IWMI. Other members present were Dr. Yadavinder Singh, INSA Senior Scientist, PAU, Dr. R.K. Jhorar, Dean, College of Agricultural Engineering and Technology, CCS HAU, Dr. N.S. Bains, Director Research, PAU, Dr. A.K. Mehta, Ex-ADG (Agricultural Extension), ICAR, Dr. S. K. Chaudhari, ADG (SWM), ICAR, Dr. P.C. Sharma, Director, ICAR-CSSRI and Dr. Ajay Kumar Bhardwaj, Principal Scientist and Member Secretary, RAC. The committee reviewed the last year research activates and advised for the future research work. All Heads of Divisions/Stations, Project Coordinator and Scientists of the Institute participated in this Meeting.

RAC members at experimental sites

Workshop, Seminar, Training, Foundation Day and Kisan Mela organised

Dr. S.K. Chaudhari addressing the participants

Biennial Workshop of AICRP on SAS&USW

Biennial Workshop of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture was organized at ICAR-CSSRI, Karnal during 5-6 Feb. 2019. Dr. P.C. Sharma, Director, ICAR-CSSRI was the Chief Guest for inaugural function and he said that technologies for management of salt affected soils and salty waters developed by this institute and AICRP are promising and scientists should give emphasis on increasing income of farmers along with crop productivity. Dr. M.J. Kaledhonkar Project Coordinator informed that 12 centres of the AICRP work in different agro-climatic regions of the country for development of databases of salt affected soils and poor quality ground waters, reclamation of management of alkali and saline soils/ waters, alternate land uses, integrated farming system models for such soils and screening of crop varieties for salinity tolerance. He summarized research output for different themes. The Chief Scientists/Nodal Officers of AICRP Centres presented progress of on-going research work and discussed future research programmes during the workshop. Dr. D.K. Sharma, Ex. Director, ICAR-CSSRI and Dr. S.K. Gupta, Former Project Coordinator gave valuable comments as ICAR nominated experts. In concluding session on 6th Feb., Dr. S.K. Chaudhari, ADG (SWM), Chief Guest appreciated good work done by AICRP centres and advised to work hard to fulfill farmers' expectations as benefit cost ratio for management of salt affected soils is relatively higher compared to other degraded soils. Besides, scientists from AICRP centres, heads and scientists from ICAR-CSSRI attended the workshop.

Golden Jubilee International Salinity Conference

Golden Jubilee International Salinity Conference was held at ICAR-Central Soil Salinity Research Institute, Karnal during 7-9 Feb. 2019. Prof. Ramesh Chand, Hon'ble Member, NITI Aayog delivered the valedictory address. He complimented ICAR-CSSRI for its illustrious journey of five decades leading to the productive use of about 2.14 Million ha salt affected area in environmentally harsh conditions. He said that although ICAR-CSSRI continues to be one of the global leaders in agricultural salinity management, its glorious achievements should not lead to complacence; especially at a time when natural


Dr. Ramesh Chand addressing the validatory function

resources are shrinking at a rapid rate while food demands are growing and diversifying. He opined that consistent with the national priorities, all possible efforts should be made for converting the waste into wealth (i.e. conversion of municipal solid wastes into compost) for enhancing soil resilience and crop productivity. He noted that rampant burning of rice residues in the North-Western India is a major concern which needs to be managed by developing doable technologies. He said that integrated farming systems comprising of crop, horticulture, fish and livestock components could be the keys to enhancing farmers' incomes while ensuring environmental sustainability. Dr. S. K. Chaudhari, ADG (SWM), ICAR, New Delhi opined that ICAR-CSSRI has made outstanding contributions to applied research leading to the huge impact of technologies like gypsum based package and salt tolerant cultivars. Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal and President, ISSSWQ in his welcome address said that large scale promotion of sub-surface drainage and land shaping technologies, development of multiple stress tolerant crop cultivars and management of sub-surface sodicity and high pH in the reclaimed sodic areas through conservation agriculture based sustainable intensification practices will be the major focus of salinity research in the coming years. Recommendations of different technical sessions of GJISC-2019 were presented and some publications released on this occasion. A total of 275 delegates from 17 countries, CGAIR institutions, ICAR institutes, SAUs, State Line Departments and Farmers participated in this event.

Foundation Day

ICAR-CSSRI, Karnal celebrated its 51st Foundation Day on 19th March 2019 Chief Guest Dr. Ashok Dalwai (IAS), Chief Executive Officer, National Rainfed Area Authority, Ministry of


Dr. Ashok Dalwai delivering the foundation day lecture

Agriculture & Farmers Welfare (Govt of India), New Delhi, in his foundation day lecture, raised the issue of sustainable management of soil and water resources, and exhorted the need of integrated policy and planning to be executed in collaborative manner with all the stakeholders. He also shared the facts about how the policy of Soil Health Card has reduced cost of cultivation (8-10%) and increased the benefits of farmers (5- 8%). He opined that degraded lands can be sustainably managed if science and policy are coherently aligned according to the need. He suggested the pressing need for 'income revolution' instead of Green Revolution. Dr. Gurbachan Singh, Ex-Chairman, Agricultural Scientist Recruitment Board presided over the function and emphasized that the pace of reclamation in alkali soils in country is satisfactory; however more speedy management of saline soils is the need of hour which can only be possible when state agencies are more active. On this occasion Dr. Gurbachan Singh was conferred the Patron of Indian Society of Soil Salinity and Water Quality (ISSSWQ). Special Guest Padam Shri Kamal Singh Chauhan flagged the issue of sustainable management of natural resources using combination of farmers' knowledge and formal sciences. Dr. P. C. Sharma, Director ICAR-CSSRI, Karnal welcomed all the dignitaries and highlighted salient achievements of institute including total area reclaimed, role of institutional technology and science in supporting national and state policies and overall farmers' development.

National Productivity Week

The ICAR-CSSRI, Karnal celebrated the 'National Productivity Week' during 12-18 February, 2019 with the aim to enhance agricultural productivity by facilitating adoption of appropriate technologies developed by the institute and use of more efficient crop production practices. In this regard, a group of 10 agriculture officers of different state departments of north India and a group of 50 farmers Uttar Pradesh were sensitized on adoption of farming system practices through one day training on February 13, 2019. In this training, aspects like resource conservation, resource recycling, integrated nutrient and pest management, entrepreneurship and cooperative marketing as well as the constraints faced by the farmers were discussed.


Prof. Radhe Shyam Sharma delivering the lecture

Since value creation and improvement in quality of work also fall in the domain of productivity and sustainability, the institute organized a special talk on "Value Creation at Work Place" for all the Institute employees on 18th February 2019 by Prof. Radhey Shyam Sharma, ex-Vice Chancellor of Ch. Devi Lal University, Sirsa (Haryana). Prof. Sharma informed that values increase knowledge and understanding and create unity in the country. He emphasized upon identification of suitable Role Models for the society to inculcate good value system among the people. He cited several examples of successful personalities known to him who still adopt the traditional value system inspite of their busy schedule. Prof. Sharma covered the topics like role clarity and self confidence, integrity and honesty, responsibility and discipline, time and mind management, team work and feedback, *etc.*Dr. P.C. Sharma, Director of ICAR-CSSRI, Karnal called upon the employees of the Institute to adopt good value system at work place in order to improve organizational efficiency and work output.

Kharif Kisan Mela

The Institute organized Kharif Kisan Mela on 16th March 2019 at Habri village in Kaithal District of Haryana in which 500 farmers from Habri and adjoining villages (Saanch, Hazwana, Barsana and Sikander Kheri) participated. These villages have been adopted by the Institute under Mera Gaon Mera Gaurav programme. The Mela was inaugurated by

Dr. Samar Singh addressing the farmers

Dr. Samar Singh, Regional Director, Uchani Centre of Haryana Agriculture University, Hisar. In his address, Dr. Singh emphasized on conservation of soil and water for environmental safety. He advised the farmers to use balanced fertilizers and green manuers for maintaining soil health and obtaining optimum crop yields. He also urged the farmers to adopt integrated farming system through crop diversification and use of micro-irrigation techniques.

Dr. P.C. Sharma, Director ICAR-CSSRI, Karnal apprised the farmers about the achievements and technologies of CSSRI. He informed that about 2.14 Mha of land area has been reclaimed out of total 6.74 Mha salt affected areas in the country. The reclaimed lands are contributing around 16 million tons of foodgrains to the national food basket. Dr. Sharma urged the farmers to adopt the salt tolerant varieties developed by the Institute for higher yields in salt affected soils. On this occasion, a Kisan Gosthi was also organized in which experts delivered the lectures on control of *Phalaris minor* weed, management of sodic soil and water, pest control in rice crop and salt tolerant rice and wheat varieties.

The Mela witnessed 18 exhibition stalls put up by local pesticide and farm machinery firms. Farmers' producer organizations displayed their respective products to the visiting farmers. On this occasion ICAR-CSSRI also put up its exhibition stalls and organized free-of-cost on-the-spot testing of soil and water samples. On this occasion, 11 progressive farmers of the area were felicitated.

Van mahotsav

Dr. M.L. Jat planting of tree

Van Mahotsav were celebrated on 8th August, 2019 in collaboration of Haryana State Forest Department. On this occasion, over 300 saplings of different trees and shrubs were planted. Dr M.L. Jat, Chief Guest applauded the role of trees in human life. Dr. P.C. Sharma, Director, ICAR-CSSRI said that Institute is celebrating Van Mahotsav every year to keep its commitment towards society. There is need to plant more and more trees for checking the global warming. At the outset, Dr Rakesh Banyal, Coordinator of the event briefed about the objectives of program.

MANAGE sponsored training programme

MANAGE sponsored training programme on "Technologies for Doubling Farmer's Income on Salt Affected Soils" during August 19-23, 2019 in which 15 trainees from State Departments, ICAR Institutes and SAUs participated. The trainees were trained on 4 major aspects viz., identification and characterization of salt affected soils and water,

Chief Guest with participants

reclamation of salt affected soils and poor quality waters, salt tolerant crop varieties and alternate land use systems for productive utilization of salt affected soils. A field/study visit was also conducted for the trainees for one day during the training programme during which the trainees were given exposure to technologies developed by ICAR-CSSRI, Karnal, Model Dairy Farm of ICAR-NDRI, Karnal, seed processing unit of ICAR-IARI RRS, Karnal and commercial fish production farm of a progressive farmer in Karnal.

Training on functional characterization of differential gene expression under salt stress

Three days short training on ***"Functional characterization of Differential Gene Expression under Salt Stress"*** was conducted at ICAR-CSSRI, Karnal from 11-13 September 2019. Training was inaugurated by Dr P.C. Sharma, Director, ICAR-CSSRI, he briefly explained about various technologies developed by CSSRI for reclamation of saline and sodic soils. He informed approximately 2.14 M ha area has been reclaimed through these technologies. A total of 29 participants from various academic institutes attended this training. During three days programme, lectures along with hands-on practical's covering the topics from an exposure to NGS data and itsbiological interpretation, differential gene expression with validation, functional characterization under salt stress etc were covered. One day session was held at ICAR-IASRI, New Delhi, where the participants were exposed to various bioinformatics softwares for NGS data analysis.

Director along with participants

Rabi kisan mela

Rabi kisan mela was organized by the institute in collaboration with Department of Agriculture and Farmers' Welfare, Govt. of Haryana at Netaji Subhash Chandra Stadium, Palwal on 13th September, 2019. Shri Mehar Chand Gehlot, Vice Chairman, Livestock Development Board and member IMC, ICAR-CSSRI, Karnal Haryana was the Chief Guest of the Mela. In his inaugural remark, he said that ICAR-CSSRI, Karnal is playing a pivotal role in improving agricultural productivity in salt and water stressed regions of the country. He observed that farmers of the region need to adopt integrated farming

A view of Rabi Kisan Mela at Palwal

systems developed by ICAR-CSSRI, Karnal to obtain regular income while conserving the precious natural resources. Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal, in his welcome address, presented an overview of improved salt tolerant varieties, doable salinity management and resource conservation technologies to achieve the goals of higher productivity, natural resource conservation and climate change adaptation. About 2500 farmers participated in Kisan Mela, which showcased improved technologies for salinity management, crop diversification, integrated farming, horticultural crops and mushroom cultivation. Free analysis of soil and water samples; exhibition of improved agricultural technologies developed by ICAR institutes, government agencies and private companies; sale of high yielding, salt tolerant seeds of wheat and mustard, and Farmer-Scientist Goshthi were the main attractions of the Mela. Five innovative farmers were also felicitated on this occasion.

Hindi Pakhwada

Hindi Pakhwada was organized at ICAR-CSSRI Karnal during 14-28 September, 2019. Dr. Rekha Sharma, Principal Pt. Chiranjilal Sharma Govt. P.G. College, Karnal inaugurated the program. In her address, she appreciated the works being done in Hindi by the Institute and requested audience to adopt Hindi language in day to day working. Dr. P.C Sharma, Director, ICAR said use of Hindi is increasing day by day in internet and even

Dr. Rekha Sharma delivered a lecture on Hindi Pakhwada our Government representatives are addressing in Hindi in different gatherings at global level. During the Pakhwara, different competitions such as *Ashu Bhashan, Nibandh Lekhan, Aavedan Patra Lakhan,Prashanottari, Pratiyogita and Hindi Geet Antakshari* were organized. ICAR-CSSRI, RRS, Bharuch celebrated Hindi week during 13-19 September 2019 during which events like computer Unicode Hindi typing, letter writing, Hindi essay competition, and elocution were organized and all the staff participated in these events.

Model Training Course

Director along with trainees

A Model Training Course entitled "Advancements in Soil, Water and Plant Analysis Techniques using Sophisticated Equipment with respect to Salinity and Sodicity Management" was held during 16-21 September, 2019 at ICAR-CSSRI Karnal. The main purpose of this training program was to impart exposer to the participants regarding soil, water and plant analysis techniques using various sophisticated instruments. During the training course, 75% time was allotted for lab practical work and 25% for theoretical and field visits. During the program, hand-on lab exercises was conducted on characterization of irrigation water and practical assessment of electrical conductivity, total dissolved solids, residual sodium carbonate (RSC), sodium adsorption ratio (SAR) and specific ion determination using ion chromatograph (IC).

CCS NIAM Sponsored Training Programme

The Institute organized 3 days training programme sponsored by CCS National Institute of Agricultural Marketing, Jaipur on "Innovative Marketing Practices for Enhancing Farmers Income in Salt Affected Regions" during 18-20th September, 2019. A total of 30 progressive farmers/agri-entrepreneurs from 20 villages covering seven districts of Haryana and Punjab states participated in the training programme. During the three days training programme, a total of 19 resource persons delivered their lectures/conducted field visits (12 lectures delivered in the class room and 7 field visits with spot lecture). The trainees were acquainted with several aspects of agricultural marketing *viz.,*technologies for enhancing farmers' income in salt affected regions, Govt. policies and schemes related to agricultural marketing and innovative marketing practices to be followed for fetching higher income. In field/study visit, the trainees were given exposure to technologies developed by ICAR-CSSRI, Karnal.

Participants along with chief guest

Dr. Manoj Nardev Singh Secretary General AARDO with participants

International Training Programme on "Use of Poor Quality Water in Agriculture"

A short-term International Capacity Building Programme on "Use of Poor Quality Water in Agriculture" was organized at ICAR-CSSRI, Karnal, India during 23 October to 05 November 2019. This programme was jointly sponsored by AARDO and Ministry of Rural Development, Govt. of India. Nine delegates from AARDO member countries (Malaysia, Malawi, Morocco, R.O. China, Sri Lanka, Syria, Tunisia, Zambia) are participated. The programme was inaugurated by Dr. Gurbachan Singh, Ex Chairman, ASRB, New Delhi. The programme was divided into plenary sessions of presentations on various issues of poor quality water, and hands on practical trainings and field visits to apprise the delegates on parameters of poor quality water and management issues. The hands on practical trainings were; in situ examination of salt affected soil profile for reclamation and management, gypsum/amendments requirement in reclamation of sodic soil and irrigation water, assessment of poor quality parameters as EC, TDS, RSC, SAR and specific ions in irrigation water and bioremediation of poor quality water etc.

Valedictory Function was held on 5th November 2019. Dr Manoj Nardeo Singh, Secretary General, AARDO and the Chief Guest, highlighted the problems of poor quality water in AARDO member countries and the relevance of this capacity building programme for sustainable use of poor quality water in these countries. Dr. P. C. Sharma, Director ICAR-CSSRI described the achievements of CSSRI, and its vast experience in organizing such training programmes.

Farmers' Training Programme

ICAR-CSSRI in collaboration with Haryana Land Reclamation and Development Corporation (HLRDC organized 5 one day's training programme on "Management of alkali soils and water" for Capacity Building of Stakeholders under Pilot Project for reclamation and sustainable management of alkali soils and adoption of rainwater recharging in Nilokheri Block of District Karnal during November-December, 2019. This training programme was attended by 200 farmers from sodicity affected villages of Nilokheri block. Participating farmer trainees were exposed to techniques of identifying and reclaiming sodic soils, ways and methods of managing of alkali (high RSC) water, salt tolerant crop varieties for the region, etc. The trainees were also exposed to live field experiments, multi-enterprise farming model, conservation agriculture based crop diversification, etc..

Director felicitating the farmers

Swachh Bharat Mission

ICAR-CSSRI, Karnal celebrated Swachhata Pakhwada from 16th to 31st December, 2019 under the 'Swachh Bharat Mission' Programme. All the Institute employee participated actively in various cleanliness activities organized on the institute campus, schools and in nearby villages. On first day, a cleanliness drive was organized on the main campus. In this order the cleaning of the institute campus and offices were also done. On this occasion we made awareness about the composting of biodegradable waste/ kitchen waste. We also make aware about the curb the use of singe use plastic waste. We also organized the swachhata programme in the MGMG villages of the institute. On 20th December 2019, we organized the poster, seminar and workshop programme in the institute involving the students and employees. In this order several cleanliness drive and programme were organized in the Majura, Dabri, Pundrak, Dadupur Rodan and Kalampura villages and more than 2000 people were participated. In this order, on 30th December 2019 a big programme was


Swachh Bharat Mision

organized in the Govt. High School of Kalam Pura by Dr. Anil Kumar, Dr. Ashwani Kumar (Nodal officer, Swachhata Pakhwada), Dr. Ram Kishor Fagodia and his team. Dr. Prabodh Chandra Sharma, Director, ICAR-CSSRI, Karnl was the Chief Guest of the Programme. On this occasion, one painting and one quiz competition was organized for the school children. This programme was attended by the about 250 villagers and students. Director, ICSSR-CSSRI, Karnal distributed the awards and certificates to the winners of the events and donated two dustbins to the school. On the last day of the programme a Wide coverage of different activities organized during Swacchta Pakhwara found prominent place in local print and electronic media.

Farmer's Day

The Institute organized farmers' day on 23rd December, 2019 on the eve of birth anniversary of Late Prime Minister Chaudhary Charan Singh. Hon'able Union Minister of State for Agriculture and Farmers Welfare Sh. Kailash Chaudhary graced this occasion as Chief Guest. He visits the several experimental site of the Institute. Later on, he addressed the gathering of scientists, farmers and other staff. He told that there has been an important role of scientists and farmers for ensuring food security in the country. He observed that researchers, developmental agencies and agri-entrepreneurs will have to work together in order to make farming a profitable occupation. The farmers have to come forward to undertake agri-enterprises.

Dr. P. C. Sharma, Director, ICAR-CSSRI apprised the gatherings regarding the role and achievements of the Institute in developing technologies and salt tolerant varieties for the management of salt affected soils. Later on, Hon'able Minister visited Nadana village in the NiloKheri block which is one of the adopted villages of CSSRI to showcase the crop residue management and conservation agriculture technologies. This village is now totally free from residue burning by the farmers. Addressing a gathering of 500 farmers including 100 farmers from Punjab in this village, the Honorable Minister expressed distress over crop residue burning in North India and asked the farmers to use the machineries available for *in situ* management of crop residue. He told that by adopting such practices there will be improvement in the general health of soil and environment. CSSRI RRS, Bharuach celebrated Kisan Diwas on 14th November 2019 in which 70 farmers and officials from agricultural department, Agricultural College Bharuch, NABARD, various NGO and KVK participated. Certificate to two progressive farmers and seed of KRL 210 distributed to 28 farmers under MGMG program.

Sh. Kailash Chaudhary addressing the farmers

List of Scientific, Technical and Administrative Personnel

Parbodh Chander Sharma, Ph.D., Director

Division of Soil and Crop Management

R.K. Yadav, Ph.D., Head

A.K. Mandal, Ph.D.

Ranbir Singh, Ph.D.

Parveen Kumar, Ph.D.

A.K. Rai, Ph.D.

H.S. Jat, Ph.D.

A.K. Bhardwaj, Ph.D.

Rakesh Banyal, Ph.D.

Gajender Yadav, Ph.D.

Madhu Chaudhary, Ph. D.

Anshuman Singh, Ph.D.

Nirmalendu Basak, Ph.D.

Ashim Dutta, Ph.D..

Parul Sundha, Ph.D.

Rajkumar, Ph.D. (11.02.2019)[a]

Rajkumar, Ph.D. (18.11.2019)[b]

Raj Kumar, Ph.D

Arijit Burman, Ph.D.

Awtar Singh, Ph.D

Priyanka Chandra, Ph.D.

Manish Kumar, M.Sc

Raj Mukhopadhyay, Ph.D.

Technical Officers

Naresh Kumar, Ph. D.

Raj Kumar (31.10.2018)[c]

Dilbag Singh

Division of Crop Improvement

S.K. Sanwal, Ph.D. Head, (A)

Anita Mann, Ph.D.

S.L.Krishna Murthy, Ph.D

Joginder Singh, Ph.D.

Ashwani Kumar, Ph.D

Arvind Kumar, Ph.D.

Vineeth TV, M.Sc.

Ravi Kiran, M.Sc.

Vijayata Singh, Ph.D.

Lokesh Kumar B.M.

Division of Irrigation and Drainage Engineering

D.S. Bundela, Ph.D., Head

Satyender Kumar, Ph.D.

Bhaskar Nurjury,Ph.D.

Pathan Aslam Latif , M.Tech.

Dar Jaffer, M.Sc.

Technical Officers

Rajiv Kumar, M.Sc.

S.K. Dahiya

Dharam Pal Kansia, M.Lib.

Mohinder Pal (31.12.2019)[a]

Division of Social Science Research

Anil Kumar, Ph.D. Head (A)

R.K. Singh, Ph.D.

Parvender Sheoran, Ph. D.

R. Raju, Ph.D

Kailash Prajapat, Ph.D.

Bhagya Vijayan

Kiran Kumara, Ph.D (26.11.2019)[a]

AICRP (Saline Water)

M.J. Kaledhonkar, Ph.D., P.C.

R.L. Meena, Ph.D.

Babu Lal Meena, Ph.D.

Technical Officers

Anil Kumar Sharma, M.A.

Regional Research Station, Canning Town

D. Burman, Ph. D., Head (A)

S.K. Sarangi, Ph. D.

Subhasis Mandal, Ph. D.

U.K. Mandal, Ph.D.

Shishir Raut, Ph. D.

K.K. Mahanta, Ph. D.

T.D. Lama, Ph.D.

Technical officers

D. Pal, Ph. D.

N.B. Mondal, Diploma

Sivaji Roy, M.Sc

P.K. Dhar, B. Sc.

S. Mandal, B.Sc.

A.K. Pramanik

L.K. Nayak,

D. Mukherjee

D. Banerjee

Regional Research Station, Bharuch

Anil R. Chinchmalatpure, Ph.D., Head

Sharwan Kumar, Ph.D

Indivar Parshad, M.Sc.

Monika Shukla, M.Sc.

David Cames D., M.Sc.

Vibuti Sagar, M.Tech.

Bisweshwar Gorain, M.Sc.

Technical Officer

M.V.S. Rajeshwar Rao, M.Sc. (31.12.2019)[a]

Akshay Kumar

Regional Research Station, Lucknow

V.K. Mishra, Ph.D. Head (A)

Y.P. Singh, Ph.D.

Chhedi Lal Verma, Ph.D.

T. Damodaran, Ph.D.

Atul Kumar Singh, Ph.D.

Sanjay Arora, Ph.D.

S.K. Jha, Ph.D.

Arjun Singh, Ph.D. (24.12.2019)[b]

Technical Officers

C.S. Singh, Ph.D.

Hari Mohan Verma, M.Tech.

Administrative and Supporting Section

Administration

Abhishek Srivastava, SAO (8.3.2019)[a]

Pankaj Kumar (11.3.2019)[b]

Pankaj Kumar (20.7.2019)[a]

Alok Kumar (26.07.2019)[b]

Sunil Kumar, FAO (6.3.2019)[b]

Ishwar Dayal, AO

Tarun Kumar, Asstt. Admn. Officer

Ranjeet Singh, Asstt. Admn. Officer

Dinesh Gugnani, PS

Santra Devi, PS

Rita Ahuja, PS

RTI Cell

Parvender Sheoran, Ph.D., CPIO

Rajeev Kumar, M.Sc.

Vinod Kumar, M.A.

Transparency Officer

Dr. A.K. Rai

Priortizing, Monitoring and Evaluation (PME) and Institute Technology Management Unit (ITMU)

H.S. Jat, Ph.D

Technical Officer

Vinod Kumar, M.A.

Publication and Supporting Services Unit

H.S. Jat, Ph.D. , CO

Anshuman Singh, Ph. D., OIC

Technical Officer

Madan Singh, M.A.

Hindi Cell

A.K. Srivastava, SAO,OIC (8.3.2019)[b]

Technical Officer

S.K. Tyagi, Ph.D

Director Cell

Sunita Malhotra, PS

Public Relation Officer

Anil Kumar Sharma, M.A.

Farm Section

Jai Parkash, M.Sc., Farm Manager

Chander Gupt

Jaswant Singh

Library

Meena Luthra, M.A., M. Lib. Sci., OIC,

Medical Unit

Dr. (Mrs.) Mahathi Parkash, M.B.B.S.,OIC (31.12.2019)[b]

Sunita Dhingra

Chanchal Rani

Geeta Rani

Estate Section

N.K. Vaid, M.Tech. OIC (Estate Civil)

S.K. Dahiya, OIC, Security

Ashwani Kumar, Diploma

Kulbir Singh, Diploma

* Superscripts a, b and c refer to date of relieving, joining and superannuation, respectively.

ICAR-CSSRI Staff Position

Statement showing the total number of employees and the number of Scheduled Castes (SC)/Scheduled Tribes (ST) as on 31.3.2019.

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	-	81	81	22	11.11	3	4.16
Lowest rung of Class-1	-	5	5	-	-	-	-
Class-II		52	52	15	-	-	-
Class-III	23	92	92	14	15.83	11	9.16
Class-IV (excluding sweepers)	4	40	44	11	25	4	9.09
Class-IV (only sweepers)	-	1	1	1	100	-	-
Total	27	231	231	52	16.25	18	7.5

Statement of Scheduled Castes (SC) and Scheduled Tribes (ST)

Statement showing the number of reserved vacancies filled by Scheduled Castes (SC)/ Scheduled Tribes (ST) as on 31.12.2019.

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 2019

Main Institute, Karnal

During the year 2019, a total rainfall of 504.3 mm was recorded at Agro-met Observatory at Karnal as compared to the mean annual rainfall of 751.9 mm (for the last 48 years). The year was a deficient rainfall year (67% of the long-term mean annual rainfall) whereas the year 2018 was anexcess rainfall year (183.6% of the long-term mean annual rainfall). The maximum monthly rainfall of 244.8 mm was recorded during July. During the monsoon season, the highest rainstorm 71.6 mm was recorded on 15-16thJuly and the second highest of 58.4mm on 18thAug. During January and February, there was a good amount of rainfall of 28.8 mm and 20.8 mm which substantially met the irrigation demand of *Rabi* crops leading to bumper *Rabi* crop growth. There was 7.4 mm winter rainfall (March) as compared to the last year no-winter rainfall. Scanty winter rainfall resulted in increase of irrigation demands for different *Rabi* crops during February and March, which were either met from canal water or groundwater or both, particularly for wheat crop. There were 46 rainy days as compared to 59days during the last year.

The minimum and maximum air temperatures, 1.5 °Cand 44.4 °C were recorded on 28thDecember and 11thJune, respectively. The air relative humidity was the lowest (11%) on 28th May while the highest (100%) was recorded on several occasions during the year. The highest soil temperatures at 5 and10 cm depth were 42.0 and 41.0 °Con 30-31st May and 11th June. The lowest values at same depths were recorded as 7.0 and 7.5-8.0 °C on 27-30thJan. (5 and 10 cm). The total open pan evaporation during the year was 1476.6 mm, which is more than 2.93 times of the annual rainfall. The lowest evaporation of 0.2 mm was recorded on 14th December and the highest of 13.0 mm was on 29thApril. The average sunshine hours per day were 6.6. The highest and lowest vapour pressure values were 30.0mm and 5.9 mm on 31stJuly and 30thDecember, respectively. The average wind speed was 5.5 km per hour. The monthly weather parameters recorded at Agro-meteorological Observatory, ICAR-CSSRI, Karnal (Haryana) for the year 2019 are presented in Table 1.

Weather Report 2019 Bharuach

Agro-meteorological observations (Table 2) recorded at Regional Cotton Research Station, NAU, Bharuch during 2019 revealed that this region received normal rainfall of 1203 mm spread over 53 days. Season's highest rainfall 325.2 mm was received during August followed by 296.6 mm, 279.6 mm and 243.2 mm in the month of July, September and June 2019, respectively. Maximum air temperature ranged from 29.5 °C (January) to 40.4°C (April) and minimum air temperature varied from 12.6°C (January) to 22.4°C (Jun). Pan evaporation varied from 2.9 mm day^{-1} to 10.5 mm day^{-1} during the year. The average bright sunshine hours varied from 2.5 to 10.2 hr/day. Mean relative humidity varied from 36 per cent during March to 83 per cent in Aug/Sep. The average wind speed varied from 1.6kmph to 12.1kmph during the year.

Weather Report 2019 Canning Town

The onset of southwest monsoon was on 26th July, 2019. Total annual rainfall of 1999.9 mm was recorded by the meteorological unit of this institute during 2019, the maximum of 458.0 mm rainfall and 23 rainy days were recorded in the month of August. Rainfall received in the month of august was higher compared to normal (49 years average rainfall for the month of July is 372 mm), causing flooding in the rice fields in the coastal areas of West Bengal. This affected the smooth growth of transplanted rice during the initial period of the *kharif* season. Due to meagre/slight rain after the monsoon period supplemental irrigation was essential for cultivation of *rabi* crops. There was total 74 rainy days in this year, which helped the farming system but due to delay of monsoon of this year, the production was not improved significantly. The average daily sunshine hours were moderate. The minimum temperature reaches its lowest (total mean monthly average 11.2°C) in the month of January. The average mean monthly temperature of 18.9°C in January rises very rapidly to 31.5°C in the month of April. The relative humidity remains quite high throughout the year, which causes several problems of infestation in seeds, pest and diseases. Heavy Rainfall was recorded on 9.11.19 (31.8 mm) and 10.11.2019(198.4mm) due to very severe Cyclonic Storm *Bulbul*, and also heavy rainfall was recorded on 4-5-2019 (67.4mm) due to heavy cyclonic storm *Fani*(Table3).

Table 1: Mean monthly weather parameters for the year 2019 recorded at the Agro-meteorological Observatory, ICAR-CSSRI, Karnal

Latitude: 29° 43' N — Altitude : 245 m above the Mean Sea Level
Longitude: 76° 58' E — I Time : 0722/0830 hours IST
II Time : 1422 hours IST

Month	Temperature, °C							Vapour pressure (mm of Hg)		Relative Humidity (%)		Max. Temp, °C		Min. Temp, °C	
	Max.	Min.	Grass Min.	Dry bulb		Wet bulb						High/ date	Low/ date	High/ date	Low/ date
				I	II	I	II	I	II	I	II				
Jan.	19.0	5.8	-	6.9	18.5	6.8	13.9	7.4	9.2	98	57	24.4/21	15.2/05	12.0/21	3.4/01
Feb.	20.4	9.1	-	10.3	19.6	10.0	15.7	9.2	11.1	96	65	28.0/28	15.0/03	14.0/22	5.0/28
Mar.	25.1	11.0	-	12.9	24.8	12.3	18.8	10.5	12.8	93	55	34.0/31	18.0/03	16.4/20	5.0/01
Apr.	35.4	18.6	-	22.0	35.1	18.9	22.5	14.3	12.8	75	31	40.5/28	31.2/02	20.6/08	13.0/01
May	38.6	21.8	-	26.2	38.0	20.3	23.3	14.4	12.6	57	27	44.0/31	33.0/16	26.4/31	18.0/05
Jun.	38.6	26.2	-	28.9	37.7	24.3	26.9	23.4	20.2	68	43	44.4/11	28.0/19	29.0/02	22.0/18
Jul.	33.1	26.3	-	27.4	31.6	26.2	27.9	24.8	25.5	90	74	40.0/01	26.0/17	29.4/04	23.6/18
Aug.	33.0	26.1	-	27.6	31.5	26.9	37.0	26.2	26.9	94	78	36.0/29	29.4/19	27.6/08	25.2/20
Sept.	33.1	25.0	-	26.3	32.0	25.8	27.8	24.6	25.5	96	72	35.4/12	27.4/30	26.8/05	22.8/28
Oct.	31.2	18.2	-	19.6	30.4	19.4	24.0	16.9	18.6	98	57	32.8/13	29.0/30	22.0/01	16.4/31
Nov.	27.1	13.4	-	14.4	26.0	18.7	19.4	11.7	13.0	94	51	31.0/01	18.4/29	17.0/02	9.8/12
Dec.	16.7	7.4	-	8.3	15.8	8.1	12.8	12.8	8.1	99	72	23.2/01	9.0/26	10.0/01	1.5/28
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	**29.3**	**17.4**	-	**19.2**	**28.4**	**18.1**	**22.5**	**16.4**	**16.4**	**88**	**57**	-	-	-	-

Month	Soil Temperature, °C (Depth-wise)						Rainfall*			Evaporation		Sunshine (hr/day)	Wind Speed (km/hr)
	5 cm		10 cm		20 cm								
	I	II	I	II	I	II	Monthly (mm)	No of rain days	Heavy/ date	mm/ day	mm/ month		
Jan.	9.2	15.7	10.0	14.5	10.7	13.6	28.8	03	16.8/22	1.4	43.1	5.4	3.1
Feb.	9.5	17.5	10.5	16.5	11.5	15.5	20.8	06	10.2/2.7	1.6	46.1	7.8	5.1
Mar.	15.2	23.5	16.1	22.5	16.1	20.1	7.4	02	5.4/03	3.2	98.0	7.2	3.2
Apr.	22.6	32.2	23.7	31.2	#	#	7.8	02	6.8/26	6.8	204.6	8.6	10.9
May	26.0	36.0	26.9	35.3	#	#	20.6	05	9.2/03	9.3	289.0	9.6	8.9
Jun.	30.3	37.4	31.2	36.7	#	#	18.3	05	6.4/21	9.0	271.4	9.6	12.4
Jul.	28.0	33.2	28.7	32.3	28.9	30.9	244.8	09	71.6/15-16	4.7	127.3	4.9	10.8
Aug.	27.3	35.1	27.8	33.8	29.2	32.8	101.2	07	58.4/17	3.4	102.0	5.9	2.0
Sept.	26.8	37.0	27.7	36.3	29.8	34.0	13.4	03	9.6/22	3.6	107.0	6.4	3.0
Oct.	20.4	35.3	20.9	32.9	24.4	28.6	2.0	01	2.0/02	2.8	88.1	5.7	1.9
Nov.	14.9	28.6	15.7	26.4	18.5	22.4	15.0	01	15.0/28	2.3	68.7	4.8	2.6
Dec.	8.5	18.0	9.1	16.4	11.5	13.1	24.2	02	15.8/12	1.0	31.3	3.4	2.3
Total	-	-	-	-	-	-	-	**46**	-	-	**1476.6**	-	-
Average	**19.9**	**29.1**	**20.7**	**27.9**	**20.1**	**23.4**	-	-	-	**4.3**	-	**6.6**	**5.5**

Note: Rainfall < 2 mm is drizzle or trace.*
 # 20 cm deep soil thermometer was broken by stray dogs

Table 2: Monthly average agro-meteorological parameters at Bharuch during 2018

Month	Air Temperature (^{o}C)		Rainfall (mm)	Total rainy days	Avg. Relative humidity (M+E) (%)	Vapour pressure(mm)		Wind speed (km/hr)	Sunshine (hr/day)	EPan (mmpd)
	Max	Min				M	E			
January	29.5	12.6	0.0	0	42	8.7	7.2	3.4	9.0	4.9
February	31.0	15.8	0.0	0	40	9.0	8.7	3.1	8.6	7.2
March	34.4	18.6	0.0	0	36	10.9	9.2	3.1	8.9	8.1
April	40.4	24.6	0.0	0	45	18.8	12.8	1.6	9.2	10.5
May	39.8	26.6	0.0	0	54	22.3	18.4	7.9	10.2	10.4
June	36.4	27.4	243.2	9	67	25.4	21.6	12.1	6.9	8.8
July	33.0	26.3	296.6	17	78	25.3	24.4	10.1	4.5	5.1
August	30.4	25.4	325.2	10	83	24.1	23.2	6.1	3.2	2.9
September	31.4	25.6	279.6	13	83	24.3	24.0	3.9	2.5	2.9
October	33.7	23.9	49.9	3	63	20.5	18.4	3.3	6.3	5.7
November	33.0	21.5	8.0	1	60	17.5	15.8	2.9	6.8	6.1
December	30.0	17.1	0.0	0	61	13.0	15.2	3.1	7.0	4.6
Total			1203	53						

Table 3: Mean monthly weather parameters at Canning Town (Latitude 22015 N, longitude 88040 E, altitude (amsl) 3.0 m) during the year-2019

Month	TEMPERATURE(°C)			RH (I) (%)	RH (II)(%)	Rainfall (mm)	Rainy Days (no.)	Evaporation (mm)	Av. WIND (km h^{-1})	BSSH (day^{-1})
	MAX.	MIN.	MEAN							
Jan	26.1	11.8	18.9	77	43	0.0	1.4	6.3	1.9	0.0
Feb	29.1	16.0	22.5	78	52	187.6	2.8	5.7	2.8	4.0
Mar	31.4	21.7	26.5	79	54	66.6	3.8	6.8	3.7	2.0
Apr	34.9	25.0	30.0	77	58	99.2	6.5	7.0	5.6	4.0
May	35.9	27.1	31.5	78	63	83.8	7.9	8.2	10.1	3.0
Jun	35.1	27.5	31.3	79	69	129.8	6.5	6.1	6.4	6.0
Jul	34.3	27.1	30.7	83	75	213.6	4.2	4.7	6.3	10.0
Aug	32.6	26.5	29.6	91	81	458.0	1.0	4.1	4.7	23.0
Sep	31.8	26.5	29.1	88	79	324.1	2.0	4.8	4.4	13.0
Oct	32.2	24.9	28.5	87	80	195.0	2.0	6.5	2.2	6.0
Nov	29.6	20.3	24.9	88	89	230.2	1.9	6.8	2.3	2.0
Dec	25.3	14.9	20.1	90	91	12.0	1.5	5.6	2.0	1.0
Total	378.3	269.3	323.6	997	833	1999.9	41.5	72.6	52.4	74.0
mean	31.5	22.4	27.0	83	69		3.4	6.1	4.4	

Max. temp. = 38.0 0C on 18.05.2019,14.06.2019, 17.7.19 718.7.19
Min. temp. = 9.0 0C on 30.01.2019
Max. rainfall= 198.4 mm on 10.11.19

ICAR-Central Soil Salinity Research Institute

Karnal, Haryana-132 001