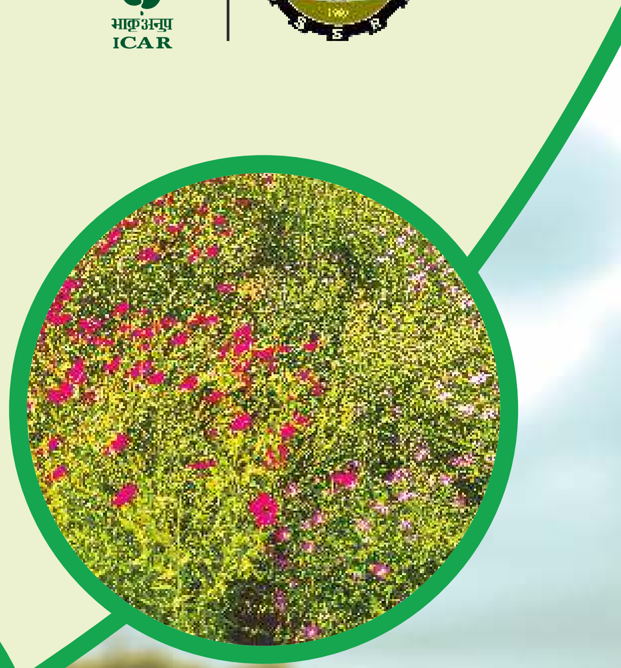
# वार्षिक प्रतिवेदन

# ANNUAL REPORT 2020



**ICAR-Central Soil Salinity Research Institute**

Karnal, Haryana- 132001

2020

# वार्षिक प्रतिवेदन

# Annual Report 2020

ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE

KARNAL - 132001 (HARYANA)

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Quinoa, Rice and Linseed (Left to Right)

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# Mandate

1

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

2

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

3

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

4

Centre for training in salinity researches in the country

# Preface

Soil salinity is one of the major and widespread challenges in the recent era that hinders global food security and environmental sustainability in the arid and semi-arid regions of the world that severely affects the global agricultural production and biodiversity. Globally, more than 900 million hectares of land, accounting for nearly 20% of the total agricultural land and 33% of the irrigated agricultural lands is affected by salinity. Furthermore, waterlogged and coastal areas are vulnerable to salinity development often due to sea water intrusion and inundation, which again relate to global climate change. The salt stress in soil is becoming prominent due to the ever-increasing global population pressure, intensive agricultural practices and climate change over decades. New challenges are set to be faced either due to changing climate or land use anomalies, leading to exponential increase in the area under salinity in the coming decades. 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 SDGs. The land restoration practices remain vital to human well-being: an area that reflects our unending commitment to the society. We, at ICAR-CSSRI, try to bring cheers on farmers' faces in salt-affected areas.

The Annual Report for the year 2020 brings out some major achievements in the areas of technology development and dissemination to the farmers' fields. Some major research breakthroughs during the period under report were: Management of salt affected soils through Cut-Soiler technology; MSWC: An alternate amendment sources for sodic soil reclamation; Halo-CRD: A liquid bioformulation for faster decomposition of crop residues; CSR-GROW-SURE: A bio-consortia for enhancing the productivity of agri-horticultural crops in salt affected soils; Quinoa: a new promising crop for saline areas; CSC057 & CSC025: Promising salt tolerant, high yielding desi cotton (*Gossypium herbaceumL.*) lines for saline Vertisols; and Sustainable intensification of rice based systems for coastal saline area.

During the year 2020, under Mera gaon Mera Gauraw a total of 180 demonstrations were conducted with 20.0 quintal seed of salt tolerant wheat KRL-210 and 8.9 quintal seed of Basmati rice CSR 30 and Amol Mana in salt affected soils of Haryana, Punjab, Uttar Pradesh and West Bengal. During this period, under SC-SP programme, 453 demonstrations for the capacity building of 1400 marginalized schedule caste farmers were conducted. Seeds (47.40 qt) of salt tolerant and normal varieties of different crops: rice, wheat, mustard and vegetables, 70 agrochemical spray pump, Biofertilizers, chemical fertilizers (21.13 qt) and agricultural implements were distributed to further strengthen their activities. A total of 1200 saplings of mango and jamun were given for diversification to 182 farmers. To strengthen livestock component, animal mat (44 farmers) and animal mineral mixture (41 qt; 50 farmers) were provided to the farmers.

'Swachhta Abhiyan' was organized from 16$^{th}$-31$^{st}$ December 2020 in which awareness programmes and cleanliness drives were organized within and outside the Institute premises to sensitize the people about Clean India Mission. Different teams of Scientists, Administrative and Technical Staff were constituted for implementing the *Swachhta* activities as per guidelines received from the council. These teams organized mass awareness programmes in 6 villages involving about 370 households on waste segregation, composting of organic waste, hazards of plastic and role of cleanliness in human health etc. A workshop on "Complete sanitation: a step forwards towards Developed Nation" was also organized in which Prof. Radhey Shyam Sharma, Ex-VC, GJU, Hisar delivered a talk. At closing ceremony, Mrs. Renu Bala Gupta, Mayor, Karnal applauded the role of CSSRI in Swachh Bharat Mission and emphasized on need of sensitizing people for complete sanitation which would lead to a clean and healthy Nation.

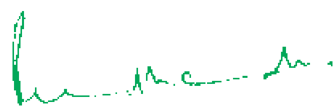
ICAR- CSSRI in collaboration with International Centre for Biosaline Agriculture (ICBA) organized an international salinity webinar "Resilient Agriculture in Saline Environments under Changing Climate" on November 3, 2020. The webinar was inaugurated by Dr. Trilochan Mohapatra, Director General, ICAR & Secretary DARE, Govt. of India, New Delhi and Dr. Ismahane Elouafi, DG, ICBA, Dubai delivered the inaugural remarks on this occasion. Dr. S.K. Chaudhari, DDG (NRM), ICAR, New Delhi summarized the deliberations of presenters and highlighted the major issues needed for reclamation and management of salt affected soils. This Webinar received 967 registrations, out of which 554 joined as attendees including 17 panelists. About 200 people took advantages of this seminar on live streaming on YouTube.

'Hindi Pakhwada' was organized at ICAR-CSSRI, Karnal during 14-28 September, 2020. Training programs organised during 2020 included 8 Days Model Training Course sponsored by Directorate of Extension, Ministry of Agriculture & Farmers' Welfare, Govt. of India, New Delhi on "Livelihood Security of Farmers through Technological Interventions in Salt Affected Soils" (31 Jan - 7 Feb), ATMA Maharashtra sponsored 4 days (24-27 February) training programme on "Management of Salt affected Soils and Poor Quality Irrigation Water of Maharashtra" and Skill India development training programme during 24 Feb - 19 March). Institute Research Committee (IRC) meeting was held from 20-25 Jan, 12 -13 Feb and 3-4 July 2020 under the Chairmanship of Dr. P.C. Sharma, Director, ICAR-CSSRI, to review the progress of the ongoing research projects and to take up new research project proposals at the main institute, and its three regional research stations at Bharuch (Gujarat), Canning Town (West Bengal) and Lucknow (U.P.). Total 89 projects, 51 institute funded and 38 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 on 17$^{th}$ September 2020 under the chairmanship of Dr. A.K. Sikka, Former DDG, NRM, ICAR, New Delhi.

The Institute organised Mahila Kisan Diwas on 15th October 2020 in Budhanpur village of Karnal district. On this occasion, around 60 farm women were present and participated in the deliberation. Institute is consistently working for the welfare of the farmers to enable them for self employment and self reliance. The institute was instrumental in formation of "CSSRI Navya Mahila Self Help Group" consisting of 16 member SC women in Budhanpur village in the leadership of Smt. Kavita. Institute provided them technical guidance and logistic support in the form of sewing machine (50 women) that helped in enhance their income (16 members' income Rs. 24310) by making local cloths and mask.

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. Hanuman Sahay Jat, Dr. Madhu Choudhary and Sh. Yudhvir Singh Ahlawat in compilation, editing and timely printing of the Annual Report are commendable. I thank my colleagues for providing the material for the timely publication of the report.

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



(Parbodh Chander Sharma)

Director

# सारांश

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

## कट–सॉइलर तकनीक के माध्यम से लवण प्रभावित मृदा का प्रबंधन

कट–सॉइलर एक ऐसी मशीन है जो वी–आकार में मिट्टी की सतह को काटती व ऊपर उठाती है साथ ही मशीन इस कट चैनल को मिट्टी के साथ सतह पर बिखरे भूसे और अवशेषों से भर देती है। इस तरह की कट–सॉइलर द्वारा बनाई गयी लाइनें जल प्रवाह के लिए जल निकासी चैनलों के रूप में काम करती हैं और इस प्रकार सतह के जलभराव और मिट्टी की लवणता का प्रबंधन करने में सहायता करती हैं। कट–सॉइलर खेतो में चलते समय बिखरे हुए भूसे, अवशेषों या बचे हुए तनों की सामग्री का उपयोग और प्रबंधन करती है। यह जमीन की सतह पर पड़े अवशेषों को लगभग 40–60 से.मी. नीचे की उप–सतह में निर्मित कट–सोइलर लाइन में डालता है। कट–सोइलर लवण प्रबंधन एवं जल निकास तकनीक की लागत कम है और इसका इस्तेमाल छोटे स्तर पर किसान के प्रत्येक खेत में किया जा सकता हैं। यह सतह पर विद्यमान अवशेषों और पुआल का उपयोग करता है, इसलिए फसल अवशेष जलने को कम करने में मदद मिल सकती है। कट–सॉइलरः आईसीएआर–जिरकास–सीएसएसआरआई (ICAR-JIRCAS-CSSRI) संयुक्त अनुसंधान परियोजना के तहत कम लागत पर उप सतही मृदा लवणता सुधार के लिए जापान से कट–सॉइलर मशीन भारत में उपयोग के लिए लायी गई है। कट–सॉइलर तकनीक जापान के जल भराव क्षेत्रों का सुधार करने में सक्षम पायी गयी है, उत्तर भारत के मैदानी क्षेत्रों में यह मशीन उप–सतही क्षारीय भूमि प्रबंधन में भी कारगर हो सकती है। केन्द्रीय मृदा लवणता अनुसंधान संस्थान – सीएसएसआरआई एवं अंर्तराष्ट्रीय कृषि अनुसंधान केन्द्र, जापान – जिरकास ने भारत के सतही जल भराव एवं लवण प्रभावत क्षेत्रों के कम लागत से समुचित प्रबंधन के लिए एक परस्पर सहयोगी परियोजना प्रारंभ की है। कट–सोईलर द्वारा किए गए तरजीही जल प्रवाह का लवण, जल एवं पोषक तत्वों की उपस्थिति एवं गतिशीलता में उपयोगिता का मुल्यांकन एवं मानकीकृत करने के लिए संस्थान के नैण प्रायोगिक फार्म (पानीपत) एवं गांव बुधमोर (पटियाला), पंजाब में किसान के खेत पर अध्ययन प्रगति पर है।

## नगरीय ठोस अपशिष्ट खादः क्षारीय मृदा सुधार के लिए वैकल्पिक संशोधन स्रोत

शहरी कचरा जैसे कि वाहितमल अवयंक और नगरीय ठोस अपशिष्ट खाद (एमएसडब्ल्यूसी) को जिप्सम के साथ मिलाकर प्रयोग करने से मृदा की क्षारीयता कम होती है। क्षारीय मृदा एकत्र कर (पीएच 9.59–10.11) सीएसएसआरआई परिसर, करनाल में क्षारीय मृदा सुधार पर शोध किया गया। धान की फसल की कटाई के बाद मिट्टी के नमूनों के मृदा जल संतृप्ति पेस्ट का विश्लेषण किया गया था। 25जीआर + एमएसडब्ल्यूसी/वाहितमल अवयंक के अनुप्रयोग से क्षारीय मिट्टी के पीएच में 0.06–1.3 इकाई गिरावट दर्ज की गयी। हरियाणा के कैथल जिले में किसान की क्षारीय मिट्टी का प्रारंभ में पीएच 9.37, विद्युत चालकता 0.92 dS $m^{-1}$ और जिप्सम आवश्यकता 13.0 टन प्रति हेक्टेयर थी। जारी शोध कार्य के अंतर्गत जिप्सम के साथ नगरीय ठोस अपशिष्ट खाद के उपचार के बाद लवण–सहनशील बासमती धान की किस्म CSR-30 के उत्पादन में बिना उपचारित खेत की उपज की तुलना में उल्लेखनीय (4.78 टन प्रति हेक्टेयर) वृद्धि हुई। धान की पैदावार लगभग 50 GR जिप्सम उपचार के बराबर थी। गेहूँ (KRL-210) की उपज नियंत्रण (1.0 टन प्रति हेक्टेयर) की तुलना में 25जीआर / कार्बनिक संशोधन (2.0–2.3 टन प्रति हेक्टेयर) में अधिक दर्ज की गई। खाद के उपचार के साथ मिट्टी के किण्वक गतिविधि (डीएचए) में वृद्धि दर्ज की गयी। धान की फसल के बाद वर्ष 2019–20 के दौरान रोगजनकों जैसे ई. कोलाई, क्लेबसिएला, साल्मोनेला, शिगेला और एंटरोबैक्टर के आकलन में समय के साथ गिरावट दर्ज की गयी। 16 विभिन्न एंटीबायोटिक दवाओं के साथ खाद उपचारित भूखंडों में मौजूद रोगजनकों के लिए किए गए एंटीबायोटिक डिस्क परीक्षण से शहरी अपशिष्ट खाद के मृदा उपचार से सार्वजनिक स्वास्थ्य पर प्रतिकूल प्रभाव को कम आंका गया।

## किनोवाः लवणग्रस्त क्षेत्रों के लिये संभाव्य सफल

लगातार लवणीय जल से सिंचाई करने से मृदा में लवणों की सान्द्रता बढ़ती जाती है और कुछ समय बाद मृदा के लवणता स्तर में फसलों की सहनशील क्षमता से अधिक बढ़ोत्तरी होने से भूमि में फसल उत्पादन करना मुश्किल हो जाता है। ऐसी परिस्थिति में इस प्रकार की लवणीय भूमि एवं लवणीय सिंचाई जल के साथ कुछ विशेष लवण सहनशील फसलों अथवा वृक्षों के साथ जैव लवणीय खेती एक अच्छा विकल्प हो सकता है। इस प्रकार की कई फसल प्रजातियाँ प्राकृतिक रूप से पाई जाती हैं जो लवणता जैसे अजैविक तनावों के प्रति सहनशील होने के साथ–साथ आर्थिक रूप से भी महत्वपूर्ण हैं। किनोवा (चिनोपोडियम किनोवा) एक ऐसी ही वैकल्पिक लवणमृदोद्भिद फसल है जो कई प्रकार के अजैविक तनावों (लवणता, सूखा, पाला आदि) के प्रति सहनशील होने के साथ–साथ उत्कृष्ट पौष्टिक दाना होने के कारण इसे विश्व स्तर पर विशेष पहचान मिली है। किनोवा के दाने कई प्रकार के खनिज (कैल्शियम, फास्फोरस, मैग्नीशियम, लोहा व जिंक), विटामिन (सी1, बी9, सी व ई1) से भरपूर, प्रचुर मात्रा में प्राकृतिक आक्सीकरण अवरोधी तत्व तथा प्रोटीन (14–20 प्रतिशत) युक्त होते हैं। इस प्रकार किनोवा के दाने जो कि प्रोटीन से भरपूर होते हैं, प्रोटीन कुपोषण से निपटने में महत्वपूर्ण हो सकते हैं। किनोवा की बहुउपयोगिता तथा भारत के लवण प्रभावित क्षेत्रों में इसकी खेती की संभावना को देखते हुए इसके जननद्रव्यों का 8–24 डेसीसीमन / मी. तक के लवणता वाले सिंचाई जल पर अध्ययन किया गया। इस अध्ययन में कुछ जननद्रव्यों से अधिक सोडियम अधिशोषण अनुपात युक्त 24 डेसीसीमन / मी. की लवणता पर भी 6.2 से 7.0 ग्राम / पौधा उपज प्राप्त हुई। प्रक्षेत्र प्रयोग में 6–8 डेसीसीमन / मी. विद्युत चालकता (ई.सी.2) युक्त मृदा में 30 कि. प्रति हैक्टर के लगभग उपज प्राप्त हुई जो इसकी लवणीय मृदा में खेती की संभावना को दर्शाती है। हालांकि बहुत छोटे दाने होने के कारण लवणीय मृदा में उपयुक्त अंकुरण की समस्या देखी गई। संस्थान द्वारा इसकी खेती की देश के विभिन्न कृषि पारिस्थितिकी क्षेत्रों के अन्तर्गत संभावना के मूल्यांकन के लिए भी प्रयोग जारी हैं।

## हेलो–सीआरडीः फसल अवशेषों के तेजी से अपघटन के लिए एक तरल जैव फोर्मूलेशन

भारत के गंगा के मैदानी क्षेत्रों में फसल की कटाई के बाद भारी मात्रा में धान के ठूंठ एवं भूसे को विघटन के लिए छोड़ दिया जाता है और इसमे से अधिकांश खेत में सामान्य और लवण प्रभावित मिट्टी के क्षेत्र में अनुपयोगी रहता है। किसाने द्वारा अपनाई जाने वाली सबसे आम प्रथा अवशेषों को जला देना है। विशेष रूप से उन क्षेत्रो में जहां अगली फसल कम समय में उगाई जाती है, जिसमे अवशेषों को मिट्टी में सड़न के लिए कम समय मिलता है। जलाने के विकल्प के रूप में धान के भूसे के प्रबंधन के विकल्प जैसे हैप्पी सीडर, रिवर्सिबल डिस्क हल आदि द्वारा अवशेषों को मिट्टी में मिलाना महंगा रहता हैं। इसलिए फसल अवशेषों के तेजी से अपघटन के लिए कुशल जीवाणुओं की पहचान करने का प्रयास किया गया। लवण सहिष्णु सेल्युलोज और लिग्निन डिग्रेड़िग बैक्टीरिया को विभिन्न स्रोतों से अलग किया गया। शिवरी फार्म में ऊपर मिट्टी पर धान के बचे हुए ठूंठों पर तीन कुशल उपभेदो का परीक्षण व्यक्तिगत रूप से कुशल उपभेदों के कल्चर के स्प्रे के माध्यम से किया गया और समय के साथ ठूंठ एवं भूसे के उपघटन पर उनके प्रदर्शन की तुलना करने के लिए मट्ठे के साथ संयोजन किया गया। माइक्रोबियल कल्चर स्ट्रेन सीडीएम–1 और सीडीएम्भ–2 ने 35 दिनों के बाद ठूंठ के वजन को 39.2, 31.9 और 40.1 प्रतिशत कम कर दिया, जबकि लैक्टोबैसिलस युक्त मट्ठे के साथ सीडीएम 3 स्ट्रेन में यह 35 दिनों के बाद केवल पानी की तुलना में 418 से घटकर 208 ग्राम प्रति वर्ग मीटर हो गया। मट्ठे के साथ विघटनकारी बैक्टीरिया के कन्सोर्टिया के प्रयोग के परिणामस्वरूप ठूंठ के प्रारंभिक वजन की तुलना मे ठूंठ के वजन में 46.7% की कमी आई। मट्ठे के साथ कन्सोर्टिया के टीकाकरण के बाद 35 दिनों में अवशेष सामग्री (ठूंठ और पुआल) का कार्बनःनाइट्रोजन अनुपात 66.5:1 से घटकर 24:1 हो गया। यह देखा गया कि सीडीएम कन्सोर्टिया के टीकाकरण से अधिकतम 59.8% की कमी आई। उपभेदों के बीच, मट्ठे के साथ सीडीएम–2 ने 35 दिनों के बाद C:N अनुपात को 58.6% तक कम कर दिया फसल अवशेषों के लिए डीकंपोजर के रूप में जैव–फार्मूलेशन "हेलो–सीआरडी" के रूप मे उपयुक्त मानकीकृत मीडिया में हेलोफिलिक लिगनो–सेलुलोलिटिक जीवाणु के साथ पौधों की वृद्धि को बढावा देने वाले दो कुशल बैक्टीरिया का कन्सोर्टिया तैयार किया गया।

## सी.एस.आर.– ग्रो–श्योरः कृषि–बागवानी की उत्पादकता बढ़ाने के लिए एक जैव पदार्थ

सी.एस.आर.– ग्रो–श्योर नामक जैव पदार्थ का प्रयोग लवण प्रभावित क्षेत्रों में बागवानी की फसलों की उत्पादकता को बढ़ाने के लिए किया जाता है। सी.एस.आर.–ग्रो–श्योर एक विशेष प्रकार के लवण सहिष्णु जीवाणुओं द्वारा निर्मित CSR-M16 *(बैसिलस लिचेनिफॉर्मिस)*, CSR-A11 *(लिस्नीबैसिलस फ्यूसीफॉर्मिस)*, CSR-A16 *(लिस्नीबैसिलस स्फेरिकस)* जैव पदार्थ विकसित किया गया है। इस जैव पदार्थ को विकसित करने के लिए सीएसआर मीडिया को संशोधित कर चार जीवाणुओ को मिलाकर एक जैव–पदार्थ को निर्मित किया गया है, मीडिया आईपीआर संरक्षण के तहत पेटेंटेड है। भा.कृ.अनु.प.– सी.एस.एस.आर.आई.– क्षेत्रीय अनुसंधान केंद्र– लखनऊ के सोडिक प्रायोगिक अनुसंधान फार्म पर जिस मृदा का पीएच 9.14–9.30 है उस मृदा में टमाटर की नयी प्रजाति एनएस 585 में वृद्धि और उपज के मानकों के लिए इस जैव पदार्थ के फॉर्मुलेशन का मूल्यांकन किया गया था। परिक्षण में पाया गया की पहले से प्राप्त CSR-BIO के परिणाम की अपेक्षा वर्तमान में सी.एस.आर.– ग्रो–श्योर अधिक प्रभावकारी पाया गया है। CSR -M16, CSR-A11 और CSR-A16 के जीवाणुओं से निर्मित कंसोर्टिया द्वारा सी.एस.आर. –ग्रो–श्योर जैव–पदार्थ का सोडिक मिट्टी में पीएच 9.2 पर केले की खेती में सफलता पूर्वक परीक्षण एवं मूल्यांकन किया गया। इस फॉर्मुलेशन का प्रयोग उत्तर प्रदेश के समेशी गॉव में जहाँ ऊसर एवं अधिक जल भराव वाले क्षेत्र में सब्जी की फसलों में किया गया था। इसके अलावा सीएसएसआरआई, करनाल में भी इसका मूल्यांकन DSR धान की फसल में भी किया गया इससे धान की फसल में उत्पादकता के साथ 25% नत्रजन की आपूर्ति को भी बढ़ता है।

## सी.एस.सी.057 (CSC 057) एवं सी.एस.सी. 025 (CSC 025)ः लवणीय काली मृदाओं हेतु देसी कपास *(गोसिपियम हर्बेसियम)* की लवण सहिष्णु एवं अधिक उपज देने वाली दो उत्कृष्ट नवीनतम किस्में

भा.कृ.अ.प.-केंद्रीय मृदा लवणता अनुसंधान संस्थान के भरूच स्थित क्षेत्रीय अनुसन्धान केंद्र का एक महत्वपूर्ण शोध कार्यक्षेत्र गुजरात के लवण प्रभावित काली मृदाओं के लिए देसी कपास की किस्मों का विकास करना है। केंद्र पर देसी कपास का अध्ययन किया जा रहा है जिसमें एफ-8 पीढ़ी में 100 गोसिपियम आर्बोरियम की लाइनें, एफ-9 पीढ़ी में 90 गोसिपियम हर्बेसियम की लाइनें, 64 विभिन्न जनकों से उत्पन्न समष्टियां, पितृ पंक्तियाँ एवं प्रजनन चक्र के विभिन्न चरणों में विद्यमान लाइनें सम्मिलित हैं। क्षेत्रीय अनुसंधान केंद्र, भरूच के समनी अनुसंधान फार्म की लवणीय मृदा (मृदा की विद्युत चालकता = 8.0-9.0 डेसी सिमेन्स प्रति मीटर; पीएच मान = 8.0) में चार वर्षों तक (2016-19) कुल 90 गोसिपियम हर्बेसियम लाइनों का प्रचलित विमोचित किस्म गुजरात कपास-23 (G-Cot-23, जोनल एवं स्थानीय नियंत्रण किस्म) के साथ मूल्यांकन किया गया। इन परीक्षणों के फलस्वरूप चिन्हित दो उत्कृष्ट प्रविष्टियों ( CSC057 और CSC025) का 2018-19 में अखिल भारतीय समन्वित कपास सुधार परियोजना (AICCIP) के अंतर्गत बहुस्थानिक परीक्षण कई स्थानों जैसे भा.कृ.अ.प.-केंद्रीय मृदा लवणता अनुसंधान संस्थान, क्षेत्रीय अनुसंधान केंद्र भरूच; नवसारी कृषि विश्वविद्यालय के क्षेत्रीय कपास अनुसंधान केन्द्र, भरूच; मुख्य कपास अनुसंधान केंद्र, नवसारी कृषि विश्वविद्यालय, सूरत और क्षेत्रीय कपास अनुसंधान केन्द्र, आनंद कृषि विश्वविद्यालय, विरमगाम, अहमदाबाद पर भी किया गया। इन किस्मों में प्रति पौधे बॉल की संख्या, बॉल का वजन, बीज उपज (SCY), जिनिंग आउट टर्न (GOT), पोटैशियमः सोडियम आयन अनुपात, रेशे की उच्च मध्य औसत लंबाई (UHML), टेनेसिटी और माइक्रोनियर मूल्यों से संबंधित आंकड़े दर्ज कर व्यवस्थित रूप से विश्लेषण किया गया। फलस्वरूप, दो बेहतर लाइनों CSC057 और CSC025 की पहचान की गई, जिनसे चार साल में जोनल चेक (G-Cot23) की तुलना में क्रमशः 30% और 28% अधिक बीज की उपज प्राप्त हुई। CSC057 का प्रदर्शन अखिल भारतीय समन्वित कपास सुधार परियोजना के प्रारंभिक मूल्यांकन परीक्षण (IET 32 b, 2018-19) में भी सराहनीय था, जिसमें विभिन्न परिस्थितियों वाले चार स्थानों पर स्थानीय चेक और जोनल चेक की तुलना में औसतन 8.6% अधिक उपज प्राप्त हुआ। प्रयोग के चार वर्षों के दौरान पत्ते के ऊतकों का औसत पोटैशियमः सोडियम अनुपात जोनल चेक (3.98) की तुलना में CSC057 और CSC025 के लिए यह क्रमशः 6.8 और 10.18 था। इन किस्मों ने बॉल की संख्या और बॉल वजन जैसे अन्य महत्वपूर्ण विशेषताओं के लिए भी सभी वर्षों में समान प्रवृत्ति दिखाई। CSC057 और CSC025 के रेशे की गुणवत्ता जोनल चेक के बराबर या थोड़ी बेहतर थी। कुल मिलाकर, CSC057 और CSC025 पिछले कुछ वर्षों में जोनल चेक और स्थानीय चेक से लगातार बेहतर प्रदर्शन कर रहे हैं इसलिए गुजरात के लवणीय काली मृदाओं में बेहतर उच्च उपज वाले लवण सहिष्णु किस्मों की विकास की दिशा में संभावित लाइनें हो सकती हैं।

## तटीय लवणीय क्षेत्र के लिए धान आधारित प्रणालियों का सतत गहनीकरण

बाढ़, सूखा और लवणता जैसे अजैविक दबावों के कारण भारत के तटीय क्षेत्र में कृषि प्रणाली अत्यधिक जोखिम वाली है। मिट्टी और पानी की बढ़ती लवणता और सूखे के दौरान अच्छी गुणवत्ता वाले सिंचाई पानी की कमी और बारिश के मौसम में भारी वर्षा के कारण जलभराव की स्थिति के कारण खेती बेहद चुनौतीपूर्ण हो जाती हैं। इस क्षेत्र की कृषि उत्पादकता को बढ़ाने के लिए चावल–मक्का, चावल–आलू, चावल–हरा चना, चावल–आलू–हरा चना, चावल–प्याज, चावल–सूरजमुखी, चावल–सरसों और सब्जियां–सब्जी–सब्जियां जैसी फसल प्रणालियां प्रथाओं के विशिष्ट उन्नत पैकेज को अपनाने के साथ आशाजनक पाए गए हैं। तनाव सहिष्णु / उपयुक्त किस्मों जैसे उन्नत प्रबंधन प्रथाओं, हरी खाद के माध्यम से मिट्टी के स्वास्थ्य में

सुधार, अम्लीय लवणीय मिट्टी में सुधार के लिए रॉक फॉस्फेट/चूने का उपयोग, मिट्टी की नमी के संरक्षण और खरपतवार नियंत्रण के लिए मल्चिंग, प्लास्टिक/धान की पुआल मल्चिंग के साथ सोलर ड्रिप सिंचाई जैसे जल संरक्षण तकनीकों ने फसलों की औसत पैदावार में 20–101% की वृद्धि की और पारंपरिक प्रथाओं की तुलना में केवल ड्रिप के तहत सिंचाई के पानी को 40% और ड्रिप+मल्च्ड परिस्थितियों में 60% तक बचाया। जलभराव वाली मिट्टी में धान की उपज को प्रभावित किए बिना मिट्टी से भरे बैगों में सब्जियां जैसे कि रिज लौकी, करेला, ककड़ी उगाई जाती है। जीरो टिलेज प्लांटिंग, धान की पुआल मल्चिंग, इंटरक्रॉपिंग जैसी नवीन प्रबंधन प्रथाओं को अपनाना, मोनो–क्रॉप्ड तटीय लवणीय मिट्टी में कई फसलें उगाना संभव है और फसल की तीव्रता को 200% से अधिक तक बढ़ाया जा सकता है।

## CSR 76: उच्च गुणवा युक्त लवण सहनशील धान की किस्म

लाइन IET 27070, CSR 2748441–195 (CSR76) को संस्थान में क्रॉस CSR 27/MI48 से विकसित किया गया और नमक तनाव की स्थिति के तहत मूल्यांकन किया गया। इस कल्चर ने हरी पर्णसमूह के साथ नमक तनाव की स्थितियों में अच्छी पैदावार तथा वृद्धि दर्ज की। बेहतर प्रदर्शन के आधार पर, IET 27070 को उत्तर प्रदेश राज्य परीक्षण के लिए नामांकित किया गया जिसमें 2017, 2018 और 2019 के दौरान IET 27070 ने उत्तर प्रदेश की ऊसर भूमि में बेहतर प्रदर्शन किया और अधिकांश मौकों को परीक्षण के शीर्ष रैंक वाली प्रविष्टियों में से एक माना गया और सभी जांचों में प्रभावशाली उपज दर्ज की। इसी प्रकार, उत्तर प्रदेश की ऊसर मृदाओं के तहत दो वर्षों (2017 और 2018) में एआईसीआरपी के माध्यम से इस प्रविष्टि का भी एएलटी और आईएसटीवीटी में परीक्षण किया गया जिसमे चेक किस्मो जोकि FL478, उपज चेक (जया), संवेदनशील जाँच (पूसा44), राष्ट्रीय सोडिक चेक (CSR 36) CSR10, क्वालिफाइंग वैरायटी 1 (IET27072) और क्वालिफाइंग वैराइटी 2 (IET 27069) थी जिसके मुकाबले इसने क्रमशः 103%, 41%, 40%, 6%, 17%, 23% और 9% श्रेष्ठता दिखाई। इसलिए सीएसआर 2748441–195 (CSR76) का प्रदर्शन उत्तर प्रदेश के राज्यों में सोडिसिटी के तहत आशाजनक था। CSR76 पत्ती और नैक ब्लास्ट और बैक्टीरियल लीफ ब्लाइट के प्रति मध्यम प्रतिरोधी है तथा हॉपर (ब्राउन और ग्रीन), पित्त मिज और केस वर्म के प्रति मध्यम सहिष्णु है। इसमें हाई हलिंग (76.7%), मिलिंग रिकवरी (68.6%), लंबे बोल्ड अनाज, 7.0 की क्षार प्रसार मूल्य के साथ अच्छा खाना पकाने की गुणवत्ता, एमाइलोज सामग्री (27.22%) और मध्यम जयल स्थिरता (24.5 मिमी) है जोकी उत्कृष्ट खाना पकाने की गुणवत्ता के संकेत हैं।

## पुरस्कार एवं मान्यताएं

- डॉ. एस.एल. कृष्णामूर्ति को वर्ष 2020 के लिए जापान के कृषि, वानिकी और मत्स्य पालन मंत्रालय (ऍमएफफ) और जापान इंटरनेशनल रिसर्च सेंटर फॉर एग्रीकल्चरल साइंसेज (जिरकास) द्वारा युवा कृषि शोधकर्ताओं–जापान अंतर्राष्ट्रीय पुरस्कार (जापानी पुरस्कार) से सम्मानित किया गया।
- डॉ. एस.एल. कृष्णामूर्ति को वर्ष 2020 के लिए राष्ट्रीय कृषि विज्ञान अकादमी, नई दिल्ली ने एसोसिएट फेलो से सम्मानित किया गया।
- डॉ. एस.एल. कृष्णामूर्ति को 2020 में भारतीय आनुवंशिकी एवं पादप प्रजनन संस्था के फेलो से सम्मानित किया गया।
- डॉ. जोगेंद्र सिंह को डॉ. राम अवतार शिक्षा समिति द्वारा कृषि एवं सम्बंधित विज्ञान के क्षेत्र में समग्र उपलब्धियों के लिए युवा वैज्ञानिक पुरस्कार–2019 से सम्मानित किया गया।
- श्री डार जाफर यूसुफ को डॉक्टरेट (पीएच.डी.) की डिग्री के लिए नेताजी सुभाष–आईसीएआर अंतर्राष्ट्रीय फैलोशिप से सम्मानित किया गया।

- डॉ. वी.के. मिश्रा को वर्ष 2020 के लिए राष्ट्रीय कृषि विज्ञान अकादमी (एनएएएस) के फेलो से सम्मानित किया गया।
- डॉ. सुभाशीष मंडल को डीडीजी (कृषि विस्तार) द्वारा पश्चिम बंगाल के हुगली जिले में आर्य परियोजना के तहत जिला निगरानी समिति के सदस्य के रूप में नामित किया गया।
- डॉ. एच.एस. जाट, डॉ. असीम दत्ता, डॉ. मधु चौधरी, डॉ. सुरेश कुमार ककरालियां, डॉ. मनोज कुमार गोरा, डॉ. एम.एल. जाट एवं डॉ. पी.सी. शर्मा को नगर राजभाषा कार्यान्वयन समिति, करनाल, हरियाणा के द्वारा फोल्डर श्रेणी में आलेख "जलवायु स्मार्ट खेती/क्लाईमेट स्मार्ट एग्रीकल्चर– खाद्य एवं पौषण सुरक्षा को बनाये रखनें के लिए कृषि की एक उन्नत तकनीक" के लिए वर्ष 2020 में प्रथम पुरस्कार से नवाजा गया।
- डॉ. मधु चौधरी, डॉ. कैलाश प्रजापत, डॉ. मनीषा कौशिक एवं डॉ. एच.एस. जाट को नगर राजभाषा कार्यान्वयन समिति, करनाल, हरियाणा के द्वारा बुकलेट/प्रशिक्षण पुस्तिका श्रेणी में बुलेटिन "लवणग्रस्त मृदाओं हेतु उन्नत कृषि क्रियाएँ" के लिए वर्ष 2020 में प्रथम पुरस्कार से नवाजा गया।
- डॉ. प्रबोध चन्द्र शर्मा, डॉ. अंशुमान सिंह एवं श्री मदन सिंह को नगर राजभाषा कार्यान्वयन समिति, करनाल, हरियाणा के द्वारा समाचार पत्र/न्यूज लैटर श्रेणी में "लवणता समाचार, जनवरी – जून, 2019" के लिए वर्ष 2020 में द्वितीय पुरस्कार से नवाजा गया।

## कार्यशाला

- भारत सरकार के कृषि और किसान कल्याण मंत्रालय के विस्तार निदेशालय विभाग द्वारा प्रायोजित "लवण प्रभावित मिट्टी में तकनीकी हस्तक्षेप के माध्यम से किसानों की आजीविका सुरक्षा" पर मॉडल प्रशिक्षण पाठ्यक्रम का आयोजन 31 जनवरी से 7 फरवरी, 2020 तक किया गया।
- आईसीएआर–सीएसएसआरआई, करनाल में 24–27 फरवरी, 2020 के दौरान "महाराष्ट्र की लवण प्रभावित मिट्टी और निम्न गुणवत्ता वाले सिंचाई जल का प्रबंधन" पर प्रशिक्षण कार्यक्रम आयोजित किया गया।
- आईसीएआर–सीएसएसआरआई, करनाल में 24 फरवरी से 19 मार्च के दौरान "तकनीकी सहायकों के लिए मिट्टी और जल परीक्षण प्रयोगशाला" पर कौशल विकास प्रशिक्षण का आयोजन किया गया ।
- एसीआईएआर, ऑस्ट्रेलिया द्वारा प्रायोजित परियोजना के तहत सोनागांव के गोसाबा गांव में ड्यूल ईएम का 26 फरवरी 2020 को सर्वेक्षण किया गया।
- आईसीएआर–सीएसएसआरआई, संस्थान ने 1 मार्च 2020 को अपना 52वां स्थापना दिवस मनाया।
- गाजर घास *(पार्थीनियम स्पीशीज)* खरपतवार के दुष्प्रभावों के बारे में लोगों को जागरूक करने के लिए 16–22 अगस्त 2020 को पार्थीनियम सप्ताह का आयोजन किया गया।
- संस्थान में 14 से 28 सितंबर, 2020 तक हिंदी पखवाड़ा का आयोजन किया गया।
- संस्थान ने करनाल जिले के गांव बुधनपुर में 15 अक्टूबर 2020 को महिला किसान दिवस का आयोजन किया।
- आईसीएआर–सीएसएसआरआई ने इंटरनेशनल सेंटर फॉर बायोसैलाइन एग्रीकल्चर (आईसीबीए) के सहयोग से 3 नवंबर, 2020 को एक अंतर्राष्ट्रीय वेबिनार "बदलते जलवायु के तहत लवणता वातावरण में प्रतिरोधक कृषि" का आयोजन किया।

- स्वच्छ भारत मिशन के बारे में लोगों को जागरूक करने के लिए संस्थान परिसर के भीतर और बाहर जागरूकता के लिए संस्थान ने 16 से 31 दिसंबर 2020 तक स्वच्छता अभियान का आयोजन किया।
- मेरा गांव मेरा गौरव (एमजीएमजी) और एससी–एसपी कार्यक्रम के तहत विभिन्न गतिविधियों और कार्यक्रमों का आयोजन किया गया।

## क्षेत्र प्रदर्शनी व भ्रमण

वर्ष 2020 के दौरान कृषि में लवणग्रस्त मृदा के सुधार और प्रबंधन व निम्न कोटि जल के उपयोग पर विभिन्न अनुसंधान संस्थानों और विकास अभिकरणों में एक प्रदर्शनी लगाई गई। 798 हितधारकों ने संस्थान के सूचना प्रौद्योगिकी केन्द्र व प्रायोगिक फार्म का दौरा किया जिसमे 356 किसान, 380 विद्यार्थी, 50 प्रसारकर्मी और वस्तु विषय विशेषज्ञ, 12 भारतीय व विदेशी वैज्ञानिक आए थे।

## किसान सलाहकार सेवा

किसानों की मृदा लवणता, क्षारीयता व जल गुणवत्ता संबंधित समस्याओं के त्वरित और समुचित समाधान हेतु संस्थान के 18001801014 नम्बर पर निःशुल्क फोन सेवा चल रही है। वर्ष 2020 के दौरान देश के विभिन्न क्षेत्रों से कृषि संबंधित समस्याओं संबंधित 152 कॉल प्राप्त हुई और संस्थान के वैज्ञानिकों द्वारा इन समस्याओं के निदान हेतु वैज्ञानिक उपाय सुझाए गए।

## अंतर्राष्ट्रीय सहयोग

- जलवायु परिवर्तन, कृषि एवं खाद्य सुरक्षा (सीसीएएफएस) (सीआईएमएमवाईटी, मैक्सिको)
- उच्च जिंक चावल की किस्मों का विकास, वर्षा आधारित पारिस्थितिकी में विशेष खोज, चावल के दाने और पोषण की गुणवत्ताः कम आर्सेनिक वाले चावल, चावल में बायोएक्टिव्स और कम जीआई वाले चावल (आईआरआरआई)
- भारत के जल संवेदनशील क्षेत्रों में सतत संसाधन प्रबंधन प्रणालियों का विकास (जेआईआरसीएएस)।
- जलवायु स्मार्ट प्रबंधन प्रणालियां (आईआरआरआई)
- बांग्लादेश और पश्चिम बंगाल (भारत) के लवण प्रभावित तटीय क्षेत्रों में फसल प्रणाली सघनता (एसीआईएआर, ऑस्ट्रेलिया)
- आरटीएफ–डीसीएस फेलोशिप विजिटिंग साइंटिस्ट– डॉ. अहमद मोहम्मद एलसैयद अब्दुल्ला, कृषि प्राध्यापक, दमनहौर विश्वविद्यालय, मिस्र

## प्रकाशन

- संस्थान द्वारा प्रमुख जरनलों में 127 अनुसंधान आलेख के साथ–साथ 33 पुस्तक/मैनुअल/अध्याय, 21 तकनीकी बुलेटिन/फोल्डर/प्रचलित आलेख छपवाये गये और 20 आलेख सेमीनार/सिमपोसिया एवं कानफ्रेन्सों में प्रस्तुत किये गये।

# Executive Summary


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

### Management of salt affected soils through Cut-Soiler technology

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. Such cut-soiler lines serve as drainage channels and thus have potential to manage surface waterlogging and soil salinity. Simultaneously it can be helpful in surface residue management and reducing the residue burning in NW Indo-Gangetic plains. This technology could serve as remunerative alternative for management of salt affected soils in India. Looking to the feasibility and applicability of Cut-soiler technology, ICAR-CSSRI and JIRCAS initiated a collaborative project to provide sustainable resource management system for waterlogged saline soils of India. To see the effect of cut-soiler drainage on salt and water dynamics under fluctuating water table along with an irrigation experiment are undertaken at ICAR-CSSRI, Karnal. Different artificial conditions were created in lysimeters to study effects of the technology in different conditions with variable inputs. The desalinization effect of Cut-soiler was observed in saline (6.73 to 5.5 $dSm^{-1}$) and heavy textured soils (0.86 to 0.34 $dSm^{-1}$). The Cut-soiler technology reduced soil salinity and thus increased yield (23-34%) of both pearl millet and mustard crops. Construction of Cut-soiler led to an improvement of crop yield which was due to reduced (18%) salt accumulation during dry season. After 12 months of trial at Village Budhmor, Patiala, Punjab, it has shown decrease in soil ESP by ~ 18.3% at 40 cm depth up to a lateral distance of ~0.7 m from cut-soiler line. Grain and biological yield of wheat also increased with decreasing Cut-soiler spacing.

### MSWC: An alternate amendment source for sodic soil reclamation

Utilization of municipal solid waste compost (MSWC) and sewage sludge (SS) in conjunction with gypsum is emerging alternative in reducing the problem of soil sodicity. The sodic soil reclamation experiment was carried out in lysimeter at CSSRI campus with sodic soils of varying texture and pH ($pH_2$ 9.59-10.11). Application of 25 % Gypsum requirement (GR) + MSWC/SS decreased soil $pH_2$ to the tune of 0.06-1.3 units. Simultaneously, the experiment was carried out at farmers' field in Kaithal, Haryana in sodic soil ( $pH_2$ 9.37) with gypsum requirement of 13.0 t $ha^{-1}$ with application of municipal solid waste compost (MSWC). In the treated plots, higher (30-50%) grain yield of rice and wheat was recorded. However, the yield of salt-tolerent rice variety CSR-30 was at par to 50 GR (4.75 t $ha^{-1}$) in compost treated soils (4.78 t $ha^{-1}$) in conjunction with 25% GR. The yield of wheat (KRL-210) in compost amended plots was significantly higher (2.0- 2.3 t $ha^{-1}$) compared to control (1.0 t $ha^{-1}$). The DHA enzyme acitvity was found higher with repeated application of compost. Estimation of pathogens *viz.*, *E. coli, Klebsiella, Salmonella, Shigella and Enterobacter* during 2019-20 after rice crop revealed the declining trend over the period of time. The antibiotic disc diffusion test carried out for pathogens present in the compost treated plots for 16 different antibiotics revealed their low risk to public health associated with city waste compost application in agriculture.

### Quinoa: a new promising crop for saline areas

Nature has provided certain crop plant species that are naturally tolerant to wide range of abiotic stresses. Use of such plants which have economic value too, can be a feasible option to bring these soils under cultivation in short time span. Quinoa (*Chenopodium quinoa* Wild) is one of the such promising facultative halophyte which has been recognized recently for endurance in multiple abiotic stresses (drought, salinity, frost etc.) and for exceptional nutritional quality grain, has a high potential for saline and drought prone areas. The grains are rich source of proteins (14-20%), minerals (Ca, P, Mg, Fe and Zn), vitamins (B1, B9, C and E) and oil containing large amounts of linoleate. The preliminary results of experiments on evaluation of quinoa germplasm at ICAR-CSSRI, Karnal showed that some germplasm produced satisfactory grain yield of about 6.2 to 7.0 g/plant under high SAR irrigation water salinity of 24 $dSm^{-1}$. Under field conditions, grain yield of more than 3.0 Mg $ha^{-1}$ was obtained in the saline soil of 6-8 $dSm^{-1}$ $EC_2$. Efforts are being made to explore the more genetic variability for salt affected agro-ecosystem of the country with standardization of management practices.

### Halo-CRD: A liquid boiformulation for faster decomposition of crop residues

In Indo-Gangetic Plains, huge quantities of rice straw are left for disposal after harvest of the crop and most of this remains unutilized in the field of normal and salt affected soils. The most common practice adopted by farmers is burning, especially in areas where the succeeding crop is grown in a short time thus allowing less time for its incorporation into soil for decomposition. Alternative to burning, rice straw management options like Happy Seeder, Reversible Disc Plough etc. remain costlier for its incorporation into the soil. An attempt was therefore made to identify the efficient microbes for faster decomposition of crop residues. Salt tolerant cellulose and lignin degrading bacteria were isolated from different sources. Three efficient strains were tested on left over stubbles of paddy on sodic soil at Shivri farm through spray of culture broth of the efficient strains individually and in combination with whey to compare their performance on degradation of the stubbles and straw with respect to time. The microbial culture strains CDM1 and CDM2 reduced the stubble weight by 39.2, 31.9 and 40.1% after 35 days while with whey having Lactobacillus strain it reduced from 418 to 208 g/$m^2$ in CDM3 strain as compared to only water after 35 days. Inoculums of consortia of CDMs along with whey resulted in decrease in stubble weight by 46.7% compared to the initial weight of stubble. The C:N ratio of the residue material (stubbles and straw) decreased to maximum of 24:1 from 66.5:1 in 35 days after inoculation of consortia with whey. It was observed that there was maximum reduction of 59.8% with inoculation of CDM consortia. Among the strains, CDM2 with whey reduced the C:N ratio to the extent of 58.6% after 35 days. The consortia of two efficient and compatible halophilic bacterial lingo-cellulolytic strains having plant growth promotion traits were prepared in suitable standardized media as bio-formulation 'Halo-CRD' as decomposer for crop residues.

### CSR-GROW-SURE: A bio-consortia for enhancing the productivity of agri-horticultural crops in salt affected soils

CSR GROW-SURE is a unique bio-stimulant that has been developed using the highly efficient salt tolerant bacteria strains CSR-M-16 *(Bacillus licheniformis)*, CSR-A-11 *(Lysnibacillus fusiformis)*, CSR-A-16 *(Lysnibacillus sphaericus)* obtained from high stress rhizosphere cultured in a unique modified CSR medium which is under IPR protection. The four bacterial strains were made into consortia and cultured on a patent protected media. The formulation was assessed for growth and yield parameters in tomato var.NS585 grown in sodic soils of pH 9.14-9.30 in field experiment conducted at the sodic soil experimental research farm of CSSRI, Regional Research Station, Lucknow in field and pot experiment. The results clearly showed 10 percent more efficacy of the current consortia than the earlier CSR-BIO. The results were further evaluated in banana CSR GROW-SURE comprising of the bacterial microbial consortia of CSR-M16, CSR-A11 and CSR-A16 resulted in successful cultivation of banana in partially reclaimed sodic soils of pH 9.2. The formulation was further validated in farmers field experiment at Samesi in UP in waterlogged sodic soils for two years. It was also evaluated at CSSRI, Karnal in DSR rice against the efficacy of 25% more Nitrogen dosage to increase the productivity of rice under DSR system.

### CSC 057 and CSC 025: Two promising salt tolerant, high yielding desi cotton (*Gossypium herbaceumL.)* lines in saline Vertisols

Development of desi cotton varieties for salt affected Vertisols is a new venture. A total of 90 *G. herbaceum* lines along with released variety G.Cot-23 (zonal and local check) were evaluated under salt stress conditions at experimental farm, Samni (ECe = 8.0-9.0 $dSm^{-1}$; pH=8.0) over a period of four years (2016-19). Moreover, two very promising lines (CSC057 and CSC025) identified from these trials were also tested in the All India Coordinated Cotton Improvement Project (AICCIP), 2018-19 at multiple locations. Data pertaining to number of bolls per plant, boll weight, seed cotton yield (SCY), Ginning out turn (GOT), K/Na ratio, Upper half mean length (UHML), tenacity and micronaire values were recorded and analyzed systematically. Identified promising lines, CSC057 and CSC025 which showed a mean of 30% and 28% seed cotton yield advantage over zonal check (G.Cot-23) across four years, respectively. The performance of CSC057 was also commendable in the AICCIP, Initial evaluation trial (IET 32b, 2018-19), showing a mean yield advantage of 8.6%

over local checks and zonal check (G.Cot-23) across 4 locations of varying characteristics. The quality attributes of CSC057 and CSC025 were at par or slightly superior to that of ZC G.Cot-23 which make them potential candidates for superior high yielding salt tolerant varieties in saline Vertisols.

### Sustainable intensification of rice based systems for coastal saline area

Agricultural system in the coastal region of India is highly risk prone due to abiotic stresses like flooding, drought and salinity. As a result, farming becomes extremely challenging due to soil and water salinity build up and shortage of good quality irrigation water during dry months and waterlogged situation due to heavy rainfall in wet season. To enhance the agricultural productivity of this region, cropping systems such as rice-maize, rice-potato, rice-green gram, rice-potato-green gram, rice-onion, rice-sunflower, rice-mustard and vegetables-vegetables-vegetables have been found promising with adoption of specific improved package of practices. Improved management practices such as stress tolerant/suitable varieties, improving soil health through green manuring, application of rock phosphate/ lime for amelioration of acid saline soils, mulching for conservation of soil moisture and weed control, water conservation practices such as solar drip irrigation with plastic/paddy straw mulching increased the mean yields of crops by 20 - 101% and save irrigation water by 40% under only drip and 60% under drip + mulched conditions over conventional practices. Climbing types of vegetables such as ridge gourd, bitter gourd, cucumber is grown in soil filled bags without affecting the yield of rice in waterlogged rice soils. Adoption of innovative management practices such as zero tillage planting, paddy straw mulching, intercropping, it is possible to grow multiple crops in the mono-cropped coastal saline soils and cropping intensity could be increased to more than 200%.

### CSR 76: A promising salt tolerant rice variety

The line IET 27070, CSR 2748441-195 (CSR76) was developed from the cross CSR 27/MI48 at ICAR-CSSRI, Karnal and was evaluated under salt stress situation. This culture recorded good yield under salt stress situations with green foliage, erect flag leaf and long slender grains with complete panicle excertion. Based on its superior performance, IET 27070 was nominated to Uttar Pradesh state trails and evaluated in state trials (2017-19) and national AICRP AL&ISTVT trial (2017 and 2018) wherein it was promoted based on its overall superior performance over the best yielding checks in respective years of testing. All through the testing years i.e. 2017, 2018 and 2019, IET27070 performed better in sodic soils of Uttar Pradesh and majority of occasions figured among the top ranked entries of the trial and recorded impressive yield gain over all the checks. Similarly, this entry was also tested in AL&ISTVT through AICRP (RICE) in two years (2017 and 2018) under sodic soils of Uttar Pradesh. It showed yield superiority of 15%, 46%, 19% and 29% over CSR 36 (National best check), NARANDRA USAR- 2009 (local check), qualifying variety 1 (NDRK 50059) and qualifying variety 2 (CSR-2748-4441-193), respectively. Therefore CSR 2748441-195 (CSR76) was promising in the states of Uttar Pradesh under sodicity. The CSR 2748441-195 (CSR76) is recommended by the SVRC for its release in UP and it will certainly increase rice yields in sodic areas of Uttar Pradesh. During 2017 and 2018, the CSR 2748441-195 (CSR76) was also evaluated through AICRP (rice) across the sodic stress locations of Uttar Pradesh (Gautambuddanagar and Masoda). It showed yield superiority of 103%, 41%, 40%,6%, 17%, 23% and 9% over checks FL478, yield check (Jaya), sensitive check (Pusa44), national sodic check (CSR 36), Check CSR10, Qualifying Variety 1 (IET27072) and Qualifying Variety 2 (IET 27069), respectively. Therefore, CSR 2748441-195 (CSR76) was promising in the states of Uttar Pradesh under Sodicity. CSR 2748441-195 (CSR76) is moderately resistant against leaf and neck blast and Bacterial leaf blight and moderately tolerant to Hoppers (Brown and Green), gall midge, case worm. It has high hulling (76.7%), milling recovery (68.6%), long bold grains, good cooking quality with alkali spreading value of 7.0, amylose content (27.22%) and medium gel consistency (24.0 mm). The above values are indicative of excellent cooking quality of IET 27070.

## Awards and Recognitions

- Dr. S.L. Krishnamurthy was awarded Japan International Award for Young Agricultural Researchers (Japanese Award) by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan and Japan International Research Center for Agricultural Sciences (JIRCAS) for the year 2020.
- Dr. S.L. Krishnamurthy was awarded Associate fellow of National Academy of Agricultural Sciences, New Delhi for the year 2020.
- Dr. S.L. Krishnamurthy was awarded Fellow of Indian Society of Genetic and Plant Breeding in 2020.
- Dr. Jogendra Singh received Young Scientist Award-2019 for overall achievements and accomplishment in the field of Agriculture & Allied Science by Dr. Ram Avatar Shiksha Samiti (Reg. No. 265, 2007-08 under Society Registration act XXI of 1860), Pilibhit, Uttar Pradesh.
- Netaji Subhas-ICAR International Fellowships (NS-ICAR IFs) conferred to Mr. Dar Jaffer Yousuf for pursuing Doctoral degree.
- Dr. V.K. Mishra, Awarded Fellow of National Academy of Agricultural Sciences (NAAS) for the year 2020.
- Dr. Subhasis Mondal received Special Recognition as Member of District Monitoring Committee under ARYA Project, Hooghly district of West Bengal, nominated by DDG (Agril. Extension) on 19 December 2020.
- Dr. H.S. Jat, Dr. Ashim Datta, Dr. Madhu Choudhary, Dr. S.K. Kakraliya, Dr. M.K. Gora, Dr. M.L. Jat and Dr. P.C Sharma were awarded first prize for "जलवायु स्मार्ट खेती/क्लाईमेट स्मार्ट एग्रीकल्चर– खाद्य एवं पौषण सुरक्षा को बनाये रखनें के लिए कृषि की एक उन्नत तकनीक" in Hindi Folder category by *Nagar Rajbhasha Kaariyenavyan Samiti, Karnal.*
- Dr. Madhu Choudhary, Dr. Kailash Prajapat, Dr. Manisha Kaushik and Dr. H.S. Jat were awarded first prize for "लवणग्रस्त मृदाओं हेतु उन्नत कृषि क्रियाएँ" in Hindi Bulletin category by *Nagar Rajbhasha Kaariyenavyan Samiti, Karnal.*
- Dr. P.C. Sharma, Dr. Anshuman Singh and Sh. Madan Singh were awarded second prize for "लवणता समाचार, जनवरी – जून, 2019" in News Letter category by *Nagar Rajbhasha Kaariyenavyan Samiti, Karnal.*

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

- Model Training Course sponsored by Directorate of Extension, Ministry of Agriculture & Farmers' Welfare, Govt. of India, New Delhi on "Livelihood Security of Farmers through Technological Interventions in Salt Affected Soils" from 31 January to 07 February 2020.
- Training programme on "Management of Salt affected Soils and Poor Quality Irrigation Water of Maharashtra" was organized during 24-27 February, 2020 at ICAR-CSSRI, Karnal.
- The Institute organized Skill Development Training on 'Soil and Water Testing Lab for Technical Assistant' during 24 February to 19 March, 2020.
- DUAL EM Survey conducted under ACIAR, Australia funded project at Sonagaon village, Gosaba on 26 February 2020.
- ICAR-CSSRI, Karnal celebrated its 52$^{nd}$ Foundation Day on 1$^{st}$ March 2020.
- Parthenium week' was organized from 16-22 August 2020 to sensitize the people about the ill-effects of carrot grass *(Parthenium spp)* weed.

- Hindi Pakhwada was organized at ICAR-CSSRI Karnal from $14^{th}$ to $28^{th}$ September 2020.
- The Institute organised Mahila Kisan Diwas on 15th October 2020 in Budhanpur village of Karnal district.
- ICAR- CSSRI in collaboration with International Centre for Biosaline Agriculture (ICBA) organized an International salinity webinar "Resilient Agriculture in Saline Environments under Changing Climate" on November 3, 2020.
- Institute organized 'Swachhta Abhiyan' from 16-31 December 2020 to create awareness and cleanliness drives within and outside the Institute premises to sensitize the people about clean India Mission.
- Various activities and functions were organized under Mera Gaon Mera Gaurav (MGMG) and SC-SP Programme.

### Field Exhibition and Visit

During 2020, one exhibition was organized at Kachchwa village to portray the improved technologies for the reclamation and management of salt-affected soils and poor quality waters. A total of 798 stakeholders including 356 farmers, 380 students, 50 extension workers and 12 scientists from India and abroad visited Institute Technology Information Centre and experimental farms to learn about the technologies commercialized and being developed.

### Farmers' Advisory Services

During the year 2020, a total of 152 agro-advisories were provided on soil testing, salinity and alkalinity management, salt tolerant crop varieties, crop management practices, animal husbandry, horticultural crops, and nutrient management were provided to the farmers through TOLL Free Number 1800 180 1014. Besides, fortnightly advisories on crop and soil management for salt affected areas were given to 528 farmers associated through WhatsApp groups with the institute International Collaboration.

### International Collaboration

- Climate change agriculture and food security (CCAFS)- (Funding CIMMYT)
- Development of high Zinc rice varieties; Trait discovery rain fed ecology; Rice grain quality and nutritional quality: Low arsenic rice, Bioactives in rice and Low GI rice (Funding IRRI)
- Development of Sustainable Resource Management Systems in Water Vulnerable Regions of India (Funding JIRCAS)
- Climate smart management practices (Funding IRRI)
- Cropping system intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India (Funding ACIAR Australia)
- RTF-DCS Fellowship to visiting scientist Dr Ahmed Mohammed Elsayed Abdallah, Faculty of Agriculture, Damanhour university, Egypt.

### Publications

The Institute published 127 research papers in peer reviewed journals, 33 Book/Manual/ Chapter, 21 Technical Bulletins/Folder/popular articles. Besides, 20 papers were presented in different National and International Seminar/Symposia and Conferences.

# Introduction

## Historical Perspective

ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) is a premier research institute dedicated to pursue interdisciplinary researches on salinity/alkalinity management and use of poor quality irrigation waters in different agro-ecological zones of the country. Government of India constituted an Indo-American team to assist the Indian Council of Agricultural Research in developing a comprehensive water management programme for the country. As a follow up of these recommendations, Central Soil Salinity Research Institute was established under 4$^{th}$ Five Year Plan period. The Institute started functioning at Hisar (Haryana) on 1$^{st}$ March, 1969. Later on, it was shifted to Karnal in October, 1969. In February 1970, the Central Rice Research Station, Canning Town, West Bengal was transferred to CSSRI, Karnal to conduct the research on problems of coastal salinity. Another Regional Research Station for carrying out research on problems of inland salinity prevailing in the black soils region of western parts of the country started functioning at Anand (Gujarat) from February, 1989. As per recommendations of the QRT, the station was shifted from Anand to Bharuch in April 2003. Keeping in view the need of undertaking research to manage alkali soils of Central and Eastern Gangetic Plains having surface drainage congestion and high water table conditions, another Regional Research Station was established during October, 1999 at Lucknow. The Coordinating Unit of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture is located at the Institute with a network of eight research centres located in different agro-ecological regions of the country (Agra, Bapatala, Bikaner, Gangawati, Hisar, Indore, Kanpur and Tiruchirapalli). In 2014, four new voluntary centres have started functioning at Bathinda (Punjab), Panvel (Maharastra), Vytilla (Kerela) and Port Blair (Andaman & Nicobar Islands).

Over the years, Institute has grown into an internationally recognized esteemed centre of excellence in salinity research. Multidisciplinary research activities at the main institute are being strengthened through four research divisions. The major research activities in the Division of Soil and Crop Management include preparation and digitization of database on salt affected soils besides periodic assessment of state of soil resources, developing alternate amendments for the reclamation of alkali soils besides developing technologies for the optimal management of gypsum amended alkali soils and the use of high RSC and saline waters for crop production. Focus on conservation agriculture based management practices in cereal systems to address the secondary salinization. In the post reclamation phase, focus is on developing climate smart agriculture, and development of farming system models for marginal farmers. Agro-forestry and horticulture on salt affected soils is another area of focus that includes multipurpose tree species, fruit plants, vegetables and seed spices. Scaling of individual farmer based groundwater recharge technologies, subsurface drainage for amelioration of waterlogged saline soils and development of methodology for large scale soil mapping through non-destructive soil mapping using EM-38 and GIS are some of the major issues being addressed by the Division of Irrigation and Drainage Engineering. Development of high yielding genotypes tolerant to salinity, alkalinity and water logging stresses in rice, wheat, mustard and chickpea through conventional breeding and modern molecular and physiological approaches are the major focus areas of the Division of Crop Improvement. The Division of Social Science Research identifies the constraints hampering adoption of land reclamation technologies and their impact on rural development.

The Institute has developed technologies for the chemical amendment based reclamation of alkali soils, reclamation of saline soils through subsurface drainage, development and release of salt tolerant crop varieties of rice, wheat and mustard and the biological reclamation of salt affected soils through salt tolerant multipurpose trees. A microbial consortia namely CSR- GROW SURE as a plant growth enhancer and Halo- CRD as a residue decomposer has been developed. Land shaping technologies for the productive utilization of waterlogged sodic soils and coastal saline soils have been advocated for scaling in domain area. Nearly 2.14 million ha salt affected lands have been reclaimed using these technologies and put to productive use. It has been estimated that reclaimed area is contributing about 17 million tonnes food grains to the national pool. For waterlogged saline soils, subsurface drainage technology developed by the Institute initially for Haryana has been widely adopted and replicated in Rajasthan, Gujarat, Andhra Pradesh, Maharashtra and Karnataka. So far, about 72,000 ha waterlogged saline areas have been reclaimed, through institutional and private modes. Artificial groundwater recharge is another area of interest for the region with depleting water table. Besides, the technologies are also being developed for the salt affected areas of Vertisols and coastal regions of the country. Conservation agriculture based management technologies are developed by the institute for reclaimed sodic soils to conserve natural resources and to improve soil and environmental quality.

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

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

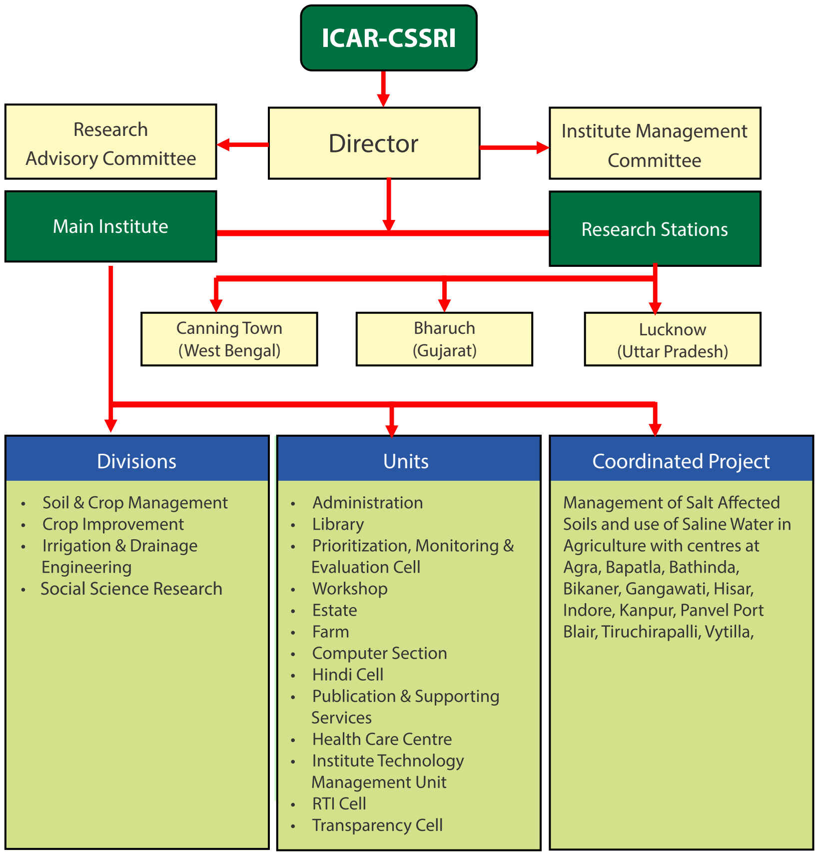
## Mandate

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

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

# Organogram

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




### Research Farm, Karnal

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

Productivity of crops at CSSRI farm

| Crop | Variety | Average yield (t $ha^{-1}$) |
|---|---|---|
| | *Rabi 2019 - 20* | |
| *Wheat* | *KRL-210* | *5.02* |
| | *KRL-213* | *5.15* |
| | *KRL-283* | *5.17* |
| *Mustard** | *CS 58* | *1.64* |
| | *CS 60* | *1.27* |
| | *CS 56* | *1.47* |
| | *CS 54* | *1.95* |
| *Chick Pea* | *Karnal chana 1* | *2.1* |
| | *Kharif 2020* | |
| Paddy | CSR 30 | 3.09 |
| | CSR 56 | 6.12 |
| | CSR 60 | 6.34 |
| | PB1509 | 5.74 |

*Breeder Seed Production

to provide quality of seed of salt tolerant varieties to the farmers. During the period under report, the farm unit generated revenue of Rs. 92 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. 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 $mmol^{1/2}L^{-1/2}$) also 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 been conducting 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. Some experiments have also been established for accessing different strategies like conjunctive/cyclic use of saline water through border or drip irrigation method and cut-soiler operated crop residue filled low cost preferential sub-surface drainage to manage soil salinity. 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 (Rs. in lakhs) during the year 2020-21 under Plan and Non-Plan budget is presented below:

| Head | Progressive Expenditure (other than NEH & TSP expenditure) | Progressive Expenditure (TSP) | Progressive Expenditure (NEH) | Grand Progressive Expenditure |
|---|---|---|---|---|
| Capital (Grant for creation of capital assets) | 194.68 | - | - | 188.65 |
| Establishment Expenses (grant in aid-salaries) | 2525.83 | - | - | 2513.25 |
| Grant in aid general | 1415.85 | - | - | 1379.12 |
| **Grand Total** | 4136.36 | - | - | 4081.02 |
| 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 | 71 | 10 | 12 |
| Technical | 112 | 74 | 38 | 34 |
| Administrative | 56 | 36 | 20 | 36 |
| Skilled Supporting Staff | 48 | 37 | 11 | 23 |
| **Total** | **297** | **218** | **79** | **27** |

### Library

Library plays a crucial role in supporting the research and academic programmes of the Institute. It identifies, evaluates, procures, processes and then makes these learning resources available to the faculty and students to meet their teaching and research needs. Library has always been striving hard to meet the expectations of its users. ICAR-CSSRI library is well furnished, fully air-conditioned and equipped with four computers, one server and two UPS. The Institute library has rare and large collection of Technical, Scientific books, Journals, Reports and other publications. Library possesses Indian and Foreign publications related to the fields of Water Management, Soil Salinity, Drainage, Alkalinity, Water Resources, etc. to achieve the mandate of the institute. Presently, the library has total collection of 15736 books including Hindi books. A separate section is maintained for Hindi books. There are 8451 bound volumes of the Journals. It has a rich collection of special publications of FAO, IRRI, UNESCO, ILRI, ICID, IFPRI, ASA, ASAE which fulfill the needs of scientists, researchers, teachers and students. About 162 theses on subjects relating to Soil Science, Agric. Engg., Water Management, etc. are available in the library. Annual Reports from the different Institutes, Agricultural Universities are being received from time to time.

### e-Services

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

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

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

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

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

## Documentation and other Services

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

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

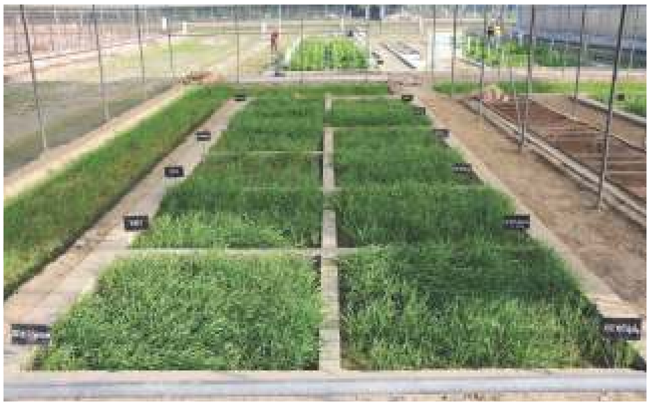
## Laboratories

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

## Allied Facilities

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

# RESEARCH ACHIEVEMENTS



# Database on Salt Affected Soils

**Development of digital methodology for low cost real time assessment of salt affected soils in Haryana using hyper-spectral remote sensing data** (A.K. Mandal, Arijit Barman, Bhaskar Narjary, R.K. Yadav and P.C. Sharma)

Hyper-spectral remote sensing data in the visible and infrared wavebands (ranges 350 to 2350 nm) were used for precise delineation of salt affected soils. The objective is to characterize the spectral behavior of salt affected soils for further delineation using space borne remote sensing multispectral data. Prior to the soil characterization, the spectral pattern of salts: carbonates, bicarbonate, chloride and sulfates of sodium, calcium and magnesium, were analyzed based on their occurring in the salt-affected soils. Spectral curves were generated for technical grade sodium chloride, calcium chloride and magnesium chloride salts and the result indicated a high reflectance (80 to 90%) of sodium chloride (NaCl) which dips at 1400 and 1900 nm apparently due to hygroscopic nature of salt. Similar characteristics were notices for $CaCl_2$ and $MgCl_2$ showing abrupt changes, 10-40% of reflectance, between 900, 1400 and 1900 nm. The increase of absorption may be ascribed due to water absorption in the salts after exposed to atmospheric condition. The patterns were more complex when compared between $CaSO_4$ and $CaCl_2$ where sharp changes were noticed for 900, 1400, 1600 and 1900 nm (Fig.1). A uniform spectral signature of $CaCO_3$ indicated that it is relatively unaffected due to atmospheric interference. The reflectance of $Na_2CO_3$ and $NaHCO_3$ indicated a sharp decline at the 1350 nm. $Na_2CO_3$ showed higher reflectance than $NaHCO_3$ beyond 1350 nm band.

The spectral signatures for two highly sodic soils (pH 10 to11, ECe 2.1 to 21.5 dS $m^{-1}$, $CO_3^-$ 6.0-18.0 me $L^{-1}$, $HCO_3^-$ 7.0-58.0 me $L^{-1}$ and $Cl^-$ 10.0-65.0 me $L^{-1}$) indicated an increase in reflectance from 350 to 2350 nm with the changes at 800, 1400, 1910 and 2200 nm, respectively. The data at surface (0-15 cm) and sub-surface (15-30 cm) depths indicated a change (20%) due to the differences in salt content and sodicity. Lower reflectance in highly sodic soils may be ascribed due to higher degradation, more dispersion, lighter soil color and higher moisture content in the sub-surface depths. Similar phenomenon is also noticed when the reflectance data was compared between two other soils where differences in the Ca + Mg content (4.0 to 44.0 me $L^{-1}$) and ECe levels (2.5 to 26.7 dS $m^{-1}$) indicated higher reflectance of surface soils with low salt content than soil at sub-surface depth and higher salt content. The reflectance value of a sodic soil at surface and sub-surface depths showed little difference (<10%), though a significant differences of soil pH (10.5 to 10.74) and ECe (10.4 to 26.4 dS $m^{-1}$) is noted between two depths. The reflectance data of a saline soil (pH 8.38 to 8.68, ECe 32.2 to 59.3 dS $m^{-1}$) indicated a slight higher at sub-surface depth than the surface, apparently due to similar soil moisture conditions. The reflectance values when compared between a saline and a sodic soil, revealed a relatively higher (~20%) value for a sodic soil than a saline soil.

The results indicated complex reflectance characteristics of salts that vary with the molecular associations, structural differences and hygroscopic nature. The reflectance patterns in salt affected soils were almost similar both at surface and sub-surface depths and between saline and sodic characters. The intricate association of salts and soil particles, organic matter and sesquioxides and their roles on reflectance behavior in soils needs to be studied for clear understanding of spatial characteristics of salt affected soils. Similar

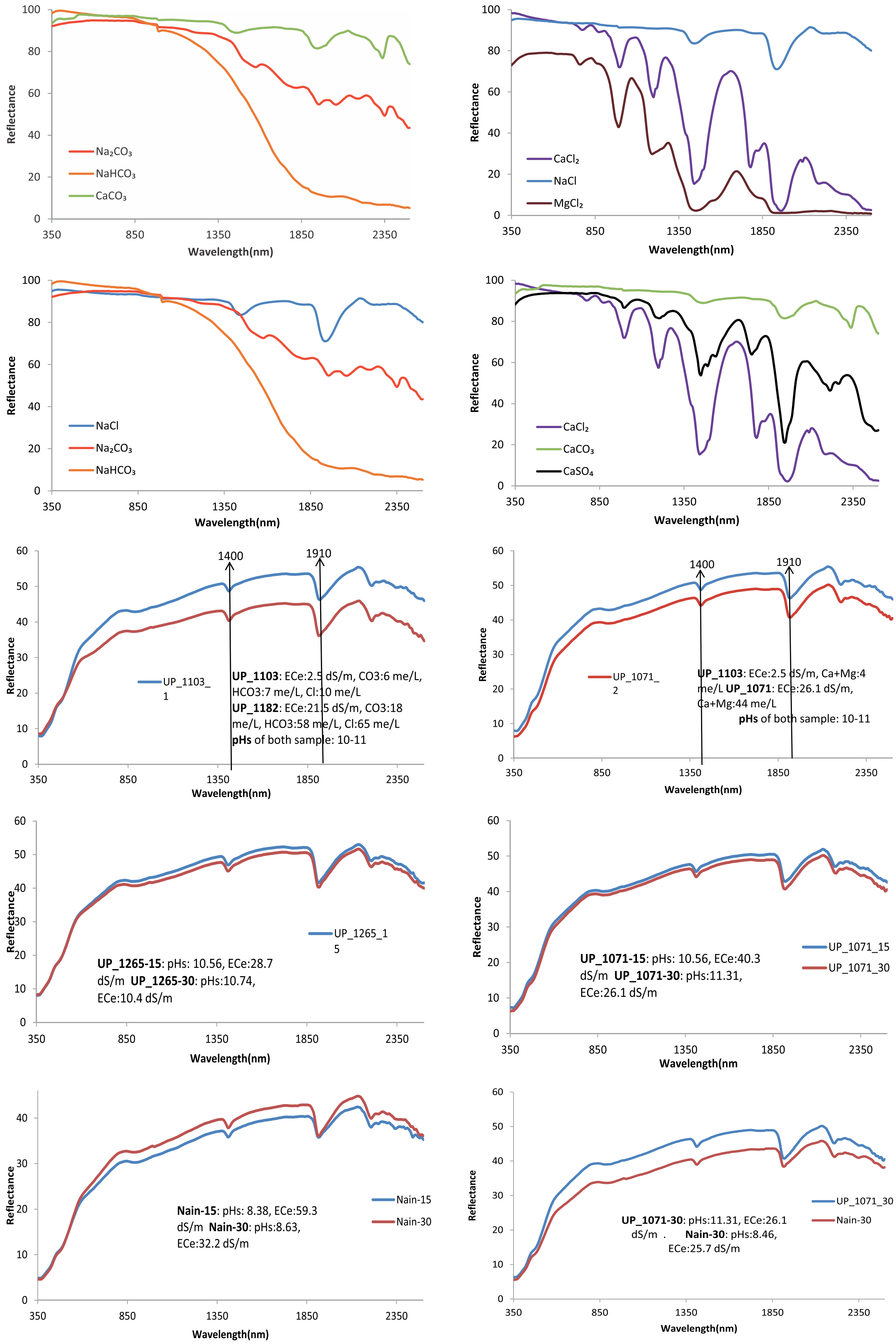



Fig1. Spectral characteristics of salts and soils from UP and Nain farm

studies are also required to establish the impact of interventions due to land reclamation, both in saline and sodic soils. A methodology for real time assessment of soil salinity may be evolved to pursue further research on complex affected soils in irrigated regions.

**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)

Spectral characterization of saline soil collected during *prekharif*(after harvest of wheat) was done to understand the effect of salt composition on spectral behaviour or reflectance. We observed that spectral reflectance value reduced with increase of soil $EC_e$ value from 2.74 to 56.72 dS $m^{-1}$. Simultaneously increase of soil $EC_e$ and $pH_s$ reduce the soil reflectance value at various wavelengths across the spectrum but prominent absorption drop was found at 1410, 1910 and 2210 nm. But at only 1910 nm waveband saline soil and saline sodic soil can be separated due to presence of high $CaCO_3$ in saline sodic soil. Soil reflectance value also reduced with increase of SAR value due to dissolving of humicsubstances which turns the soil colour into blackish nature (Fig. 2).

Increase of solution sodium and chlorine concentration reduced the soil reflectance value, but the high concentration of Ca and Mg with low Na concentration reduced the reflectance value. This behaviour can be seen in the curve of Na concentration of 100 – 200 me $L^{-1}$ at figure 2. But increase of both Ca+Mg and Na concentration increase the reflectance value and this behaviour can be seen in the curve of $Cl^-$ concentration of >200 me $L^{-1}$ at Fig. 3.

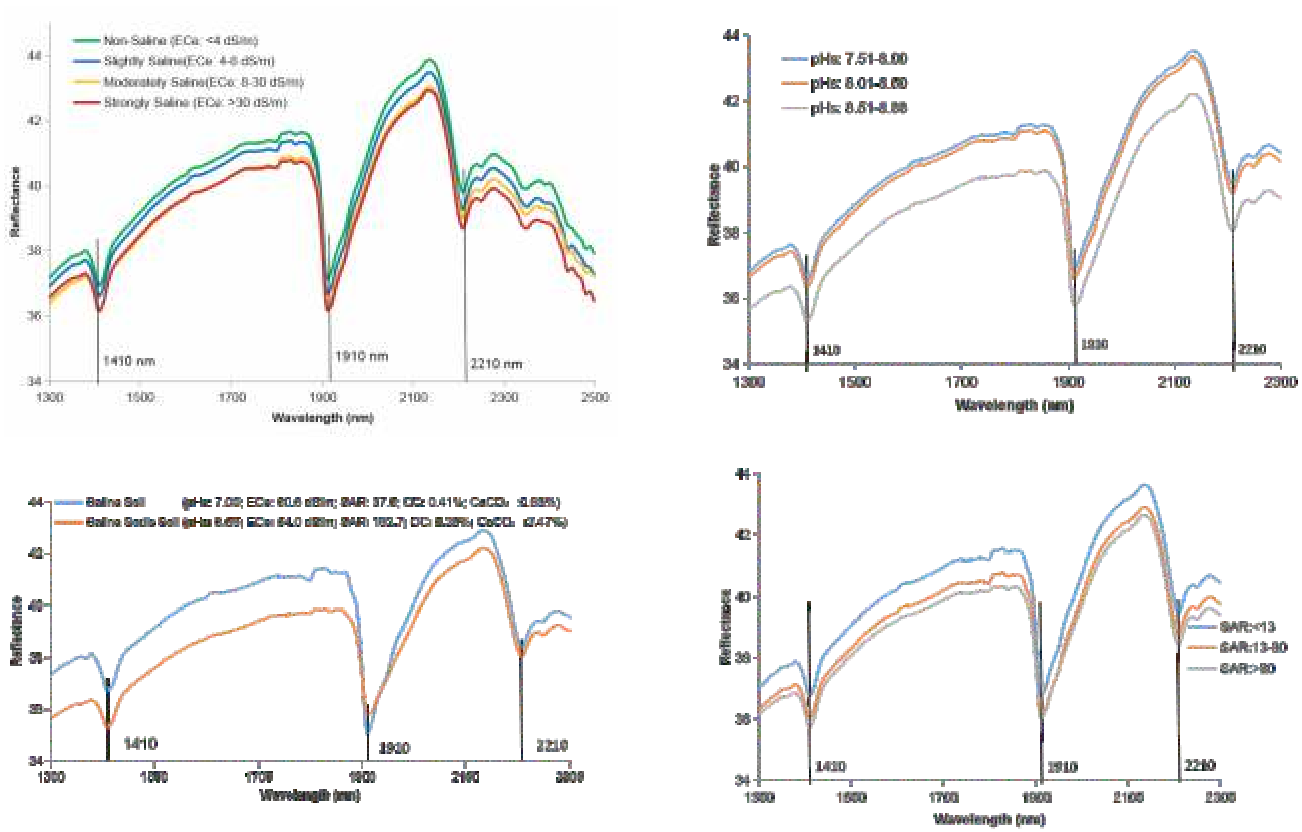



Fig 2. Spectral behaviour with change in ECe, pHs, SAS type and SAR value

Table 1. Salt affected soil characteristic in soil profile

| | ECe (dS $m^{-1}$) | $pH_s$ | $Cl^-$ (me $L^{-1}$) | $SO_4^{2-}$-S (me $L^{-1}$) | $Na^+$ (me $L^{-1}$) | Ca+Mg (me $L^{-1}$) | SAR |
|---|---|---|---|---|---|---|---|
| P4-15 | 70.3 | 6.68 | 707.5 | 31.1 | 839.13 | 579.60 | 49.3 |
| P4-30 | 24.6 | 7.14 | 172.4 | 23.1 | 281.30 | 102.67 | 39.3 |
| P4-45 | 8.55 | 7.88 | 47.2 | 13.8 | 55.65 | 67.90 | 9.6 |
| P4-60 | 10.58 | 7.95 | 55.9 | 12.9 | 57.17 | 81.14 | 9.0 |
| P4-75 | 7.11 | 8.22 | 33.0 | 13.5 | 65.43 | 36.43 | 15.3 |
| P4-90 | 5.89 | 8.2 | 25.2 | 9.0 | 50.87 | 24.84 | 14.4 |
| P4-110 | 5.14 | 8.7 | 22.9 | 5.1 | 44.35 | 16.56 | 15.4 |
| P4-120 | 6.72 | 8.71 | 30.7 | 4.3 | 34.78 | 19.87 | 11.0 |

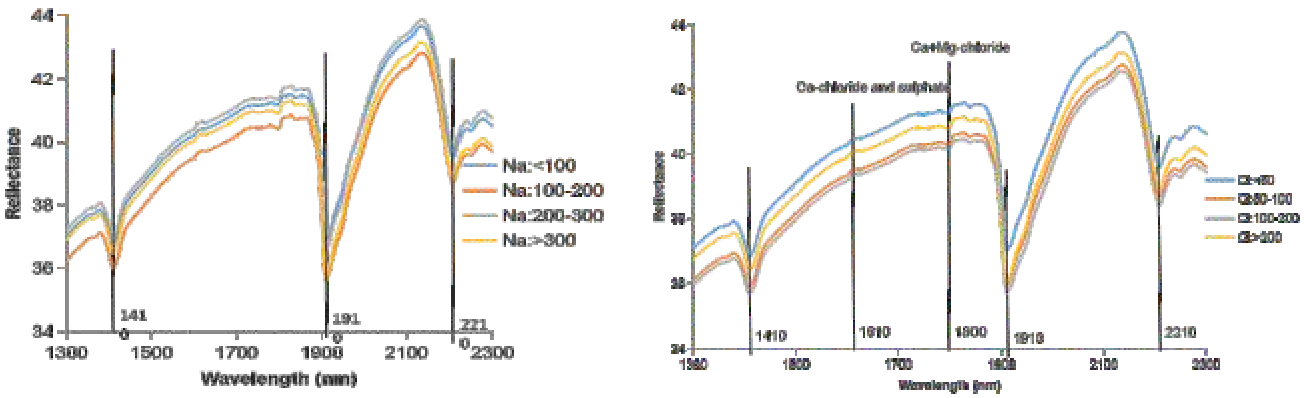



Fig 3. Spectral behaviour with change in Na+ and Cl- value

The physico-chemical property of this soil profile is presented in Table 1. Very strong soil salinity ($EC_e$:70dS $m^{-1}$) was observed at 0-15cm soil depth while slight salinity ($EC_e$:6 dS $m^{-1}$) was recorded at 1.1 - 1.2 m soil depth. Slight soil sodicity ($pH_s$:8) was observed at 0.9 to 1.2 m soil depth. Soil of root depth (0-30 cm) is dominated by $Na^+$, Ca+Mg, $Cl^-$ and $SO_4^{2-}$ with SAR of 44.3 mmol$^{1/2}$ $L^{-1/2}$.

**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)

Salt affected soils (SAS) can be assessed in Ghaghar plain of Haryana by geostatistical modelling and that can be monitored periodically by hyperspectral data with minimum

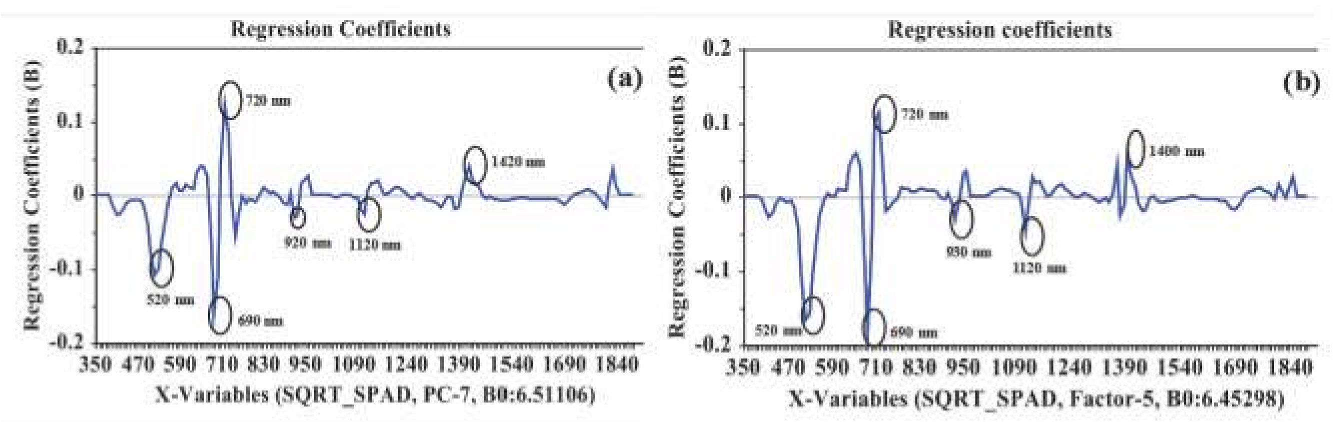



Fig 4. (a) PCRand (b) PLSR regression coefficient for SPAD at different waveband

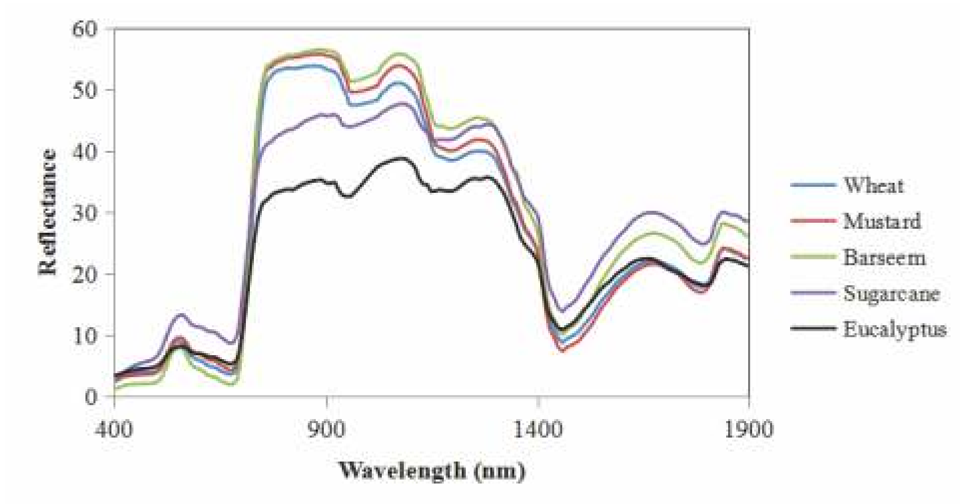



Fig 5. Reflectance spectra of field crops grown under study area of salt affected soils

ground truth. The vegetative growth is effected by high salinity/alkalinity. Monitoring of vegetative status indirectly help to asses the SAS. The significant waveband of SPAD value was identified at 520, 690, 720, 930, 1120 and 1420 nm from both PCR and PLSR spectral model (Fig. 4).

There is significant spectral variation among field crops. The spectral reflectance is increased with increasing healthy leaf at NIR region. The mustard leaf structure is different than wheat leaf at NIR region where reflectance is higher for mustard over wheat leaf (Fig. 5). It explain the difference in spongy mesophyll leaf structure. The reflectance spectra is reduced at NIR region when plant are exposed in salinity/alkalinity stress.

The hyperspectral data can be directly used to assess the SAS as reflectance spectra has more effect in the region of 1410, 1910 and 2210 nm. The ground truth data (445 soil

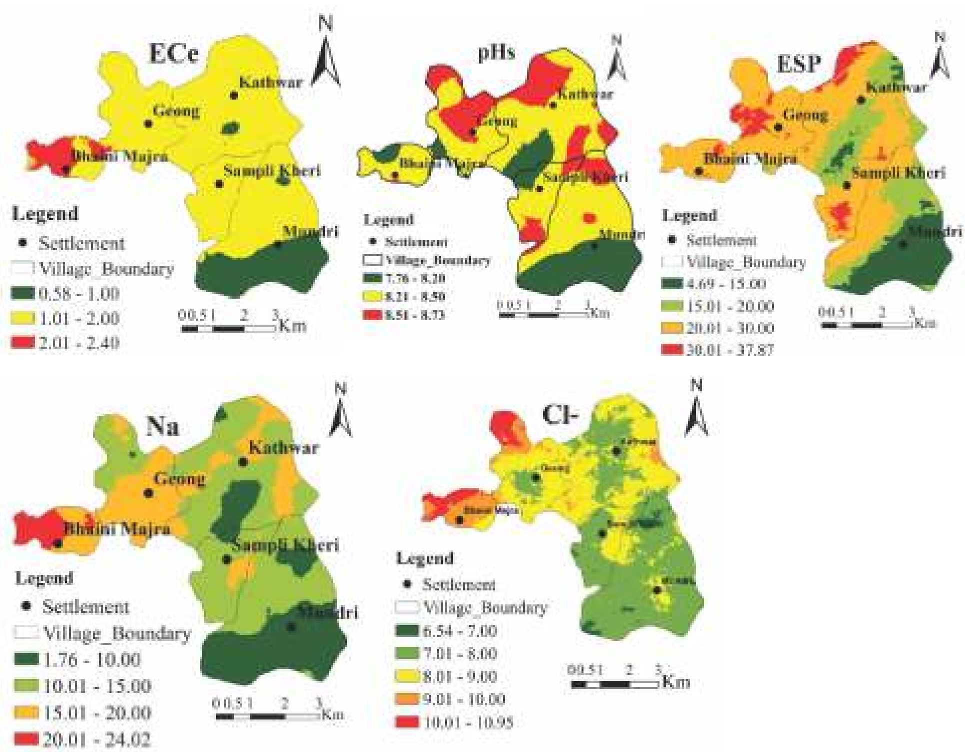



Fig 6. Spatial variation of ECe, pHs, ESP, $Na^+$ and $Cl^-$ of salt affected soils under study

samples) were analysed and used for prediction of unknown site by geostatisticalapproach which will be correlated with predicted SAS parameter by hyperspectral data. Different thematic map of ECe, pHs, ESP, $Na^{+}$ and $Cl^{-}$ were prepared by ordinary kriging method (Fig. 6).

A total of 21.5% area showed sodic nature of soil ($pH_s$:8.52 – 8.73) and the ESP value of <15 was distributed in 16.7% area. Surface soil salinity was not observed ($EC_e$<4) in the study area. The sodium and chloride concentration ranged from 1.76 to 24 .02 me $L^{-1}$ and 6.54 to 9.0 me $L^{-1}$, respectively, is characterized as four category. A total of 47.4% and 49.1% area of surface soil covered by only one category of sodium (10 – 15 me $L^{-1}$) and chloride (7 – 8 me $L^{-1}$) content (Table 2).

Table 2. Frequency distribution of SAS parameters

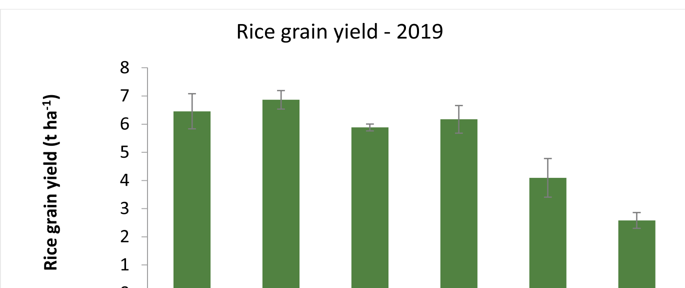
| Soil Parameters | Rating | Area (ha) | % of total area |
|---|---|---|---|
| ECe(dS $m^{-1}$) | 0.58-1 | 499.2 | 15.4 |
| | 1-2 | 2578.3 | 79.7 |
| | 2-2.4 | 159.5 | 4.9 |
| pHs | 7.76-8.2 | 698.7 | 21.6 |
| | 8.2-8.5 | 1842.0 | 56.9 |
| | 8.5-8.73 | 696.3 | 21.5 |
| $Na^{+}$(me $L^{-1}$) | 1.76-10 | 780.8 | 24.1 |
| | 10-15 | 1533.9 | 47.4 |
| | 15-20 | 799.4 | 24.7 |
| | 20-24.02 | 122.9 | 3.8 |
| $Cl^{-}$(me $L^{-1}$) | 6.54-7 | 52.1 | 1.6 |
| | 7.01-8 | 1587.9 | 49.1 |
| | 8.01-9 | 1169.9 | 36.1 |
| | 9.01-10.94 | 427.0 | 13.2 |
| ESP (%) | 4.69-15 | 539.2 | 16.7 |
| | 15.01-20 | 680.3 | 21.0 |
| | 20.01-30 | 1803.0 | 55.7 |
| | 30.01-37.86 | 214.4 | 6.6 |

# 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)

Productivity of rice-wheat cropping system (RWCS) in Indo-Gangetic Region is either stagnating or decreasing with several associated problem such as declining water table, causing nutrient imbalance, emerging deficiencies micronutrients, and crop residue burning. Problems multiply several folds in the areas with salt affected soils. This calls for upgrading of water, nutrient and energy use efficiency through better management of land and water resources to sustain agriculture in this 'food bowl' of the country. Keeping these constraints in view, a field experiment has been continuing from 2006 with revised treatments from 2011 to evaluate the effect of resource conservation strategies viz., tillage, residue and irrigation methods for enhancing crop productivity and sustaining soil health in semi-reclaimed sodic soils. Conventional farmers practice *i.e.* transplanted rice (TPR) and conventional wheat sowing (CVW) *vis-à-vis* nine adopted resource conservation treatments were imposed. Rice variety CSR46 and wheat variety HD 2967 were taken as test crops.

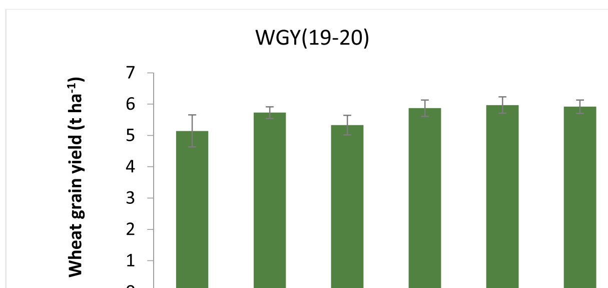
Highest grain yield of rice (6.87 t $ha^{-1}$) was recorded in transplanted rice with wheat residue incorporation (TPR+RI) followed by TPR without residue incorporation (6.46 t $ha^{-1}$) (Fig. 7). Crop residue incorporation in transplanted rice gave 6.35% additional yield compared to conventional transplanted rice without residue incorporation. Direct seeded rice in reduced tillage with wheat residue incorporation (DSR+RT+RI) produced grain yield 6.17 t $ha^{-1}$ which was 4.49% lower than TPR along with saving of 23.66% irrigation water and 19.34% electricity compared to TPR. Highest grain yield (5.97 t $ha^{-1}$) of wheat was recorded under zero tillage wheat without rice residue (ZTW) which is 16.15 % higher than conventional wheat sowing CVW method (5.14 $tha^{1}$) (Fig. 8). Likewise, wheat under zero tillage with anchored rice residue (ZTW+RA) produced grain yield 5.92 t $ha^{-1}$, which was 15.18% higher than conventional wheat practice. Incorporation of rice residue under reduced tillage gave additional 10.13% grain yield than reduced tillage without




| | TPR | TPR+RI | DSR+RT | DSR+RT +RI | DSR+ZT | DSR+ZT +RA |
|---|---|---|---|---|---|---|
| RGY-2019 | 6.46 | 6.87 | 5.88 | 6.17 | 4.10 | 2.58 |

Fig 7. Effects of tillage and residue management on rice grain yield

TPR = Transplanted rice; RI= Wheat residue incorporation; DSR= Direct seeded rice; RT = Reduced tillage; ZT= Zero tillage; RA = Wheat residue anchored




| | CVW | CVW+ RI | RTW | RTW+ RI | ZTW | ZTW+ RA |
|---|---|---|---|---|---|---|
| WGY(19-20) | 5.14 | 5.73 | 5.33 | 5.87 | 5.97 | 5.92 |

Fig 8. Effects of tillage and residue management on grain yield of wheat

CVW = Conventional wheat tillage; RI= Rice residue incorporation; RTW = Reduced tillage wheat; ZTW= Zero tillage wheat; RA = Rice residue anchored rice residue. No significant difference in wheat grain yield was found under zero tillage with anchored rice residue (ZTW+RA) and without residue (ZTW).

Sprinkler irrigation system in wheat under zero tillage with 100% rice residue produced grain yield 6.29 t $ha^{-1}$ with highest nutrient use efficiency (NUE) of 83.87 kg grain $kg^{-1}$ N along with saving of 46.34% irrigation water and 50% nitrogen (161.6 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 6.26 t $ha^{-1}$ along with saving of 68.55% of irrigation water than conventional transplanted rice. Saving of 19.2% nitrogen (compared to recommended dose of 150 kg $ha^{-1}$) along with highest NUE (51.65 kg grain $kg^{-1}$ N) was also reported in this treatment. Drip irrigation in zero tilled wheat with 100% rice residue produced grain yield of 6.54 t $ha^{-1}$, highest NUE 58.04 kg grain $kg^{-1}$ N along with saving of 57.08 % irrigation water and 25% nitrogen (~80.8 kg urea $ha^{-1}$) compared to conventional wheat practice. Drip irrigation system in DSR under reduced tillage produced grain yield 6.07 t $ha^{-1}$ with NUE of 42.43 kg grain $kg^{-1}$ N and irrigation water productivity of 2.22 kg grain $m^{-3}$ along with saving of 73.58% irrigation water and 55.69% electricity compared to conventional transplanted rice.

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

Integrated nutrient management experiments were started with ten treatments replicated four times in randomized block design. The treatments are- $T_1$=Control (without organic and inorganic fertilizer, O), $T_2$= $N_{180}P_{22}K_0Zn_5$ (Farmer's practice; FP), $T_3$= $N_{180}P_{39}K_{63}Zn_7$ (F), $T_4$= $N_{100}P_{16}K_{26}$ + Moong (LE), $T_5$= $N_{100}P_{16}K_{26}$ + green manuring with *Sesbania aculeate* before rice transplanting (GM), $T_6$= $N_{100}P_{16}K_{26}$ + FYM @10t $ha^{-1}$ before

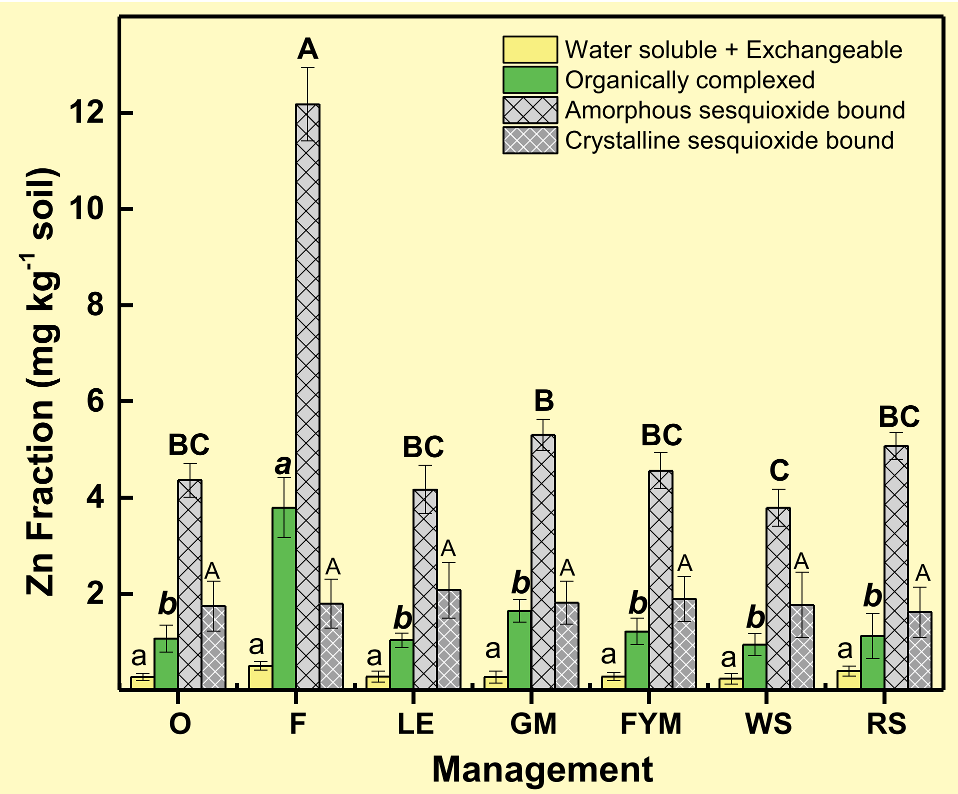



Fig 9. Effects of inorganic fertilizer Zinc (Zn) addition compared to no zinc addition on the zinc fractions in the soil under different management. Management: F= 100% inorganic N, P, K, Zn fertilizers only , INM= Integrated nutrient management (55% inorganic N, P, K fertilizer + organic amendment). Error bars denote ± 1SE. Similar colored and patterned bars followed by same digits are not significantly different at $P \leq 0.05$ .

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 (DBW-17) sowing in $T_8$ treatment. Before rice transplanting, greengram seeds (SML 668) were sown in first fortnight of May in the specified plots and incorporated in situ after two pickings of pods. Similarly, dhaincha (*Sesbania aculeate*) as green manure crop was sown in May in the plots of $T_5$ treatment. At the age of 45 days, it was harvested, weighed and incorporated *in situ* in the specified plots before rice transplanting. Farm yard manure (FYM) and wheat straw (WS) were added in soil 15 and 30 days before rice transplanting, respectively. Rice (Pusa-44) seedlings (30 days old) were transplanted in first week of July at 20 cm × 15 cm spacing. One third of N and full doses of other macro and micro nutrients were applied at 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). The fractions of Zn were determined in the soil using the methodology given by Murthy, 1982 and modified by Mandal and Mandal, 1986. Twelve years of addition of Zinc (Zn) fertilizer in the F treatment, compared to O where no inputs (inorganic or organic) and to integrated nutrient management (INM) treatments, resulted in the total soil pool significantly yet the contributions to different fractions were different (Fig. 9). The addition of $ZnSO_4$ fertilizer contributed the maximum to amorphous sesquioxide bound fraction followed by the organically complexed and crystalline sesquioxide bound fractions. While there was highly significant increase in the amorphous sesquioxide bound fraction and organically complexed fraction, there were no significant differences in the water soluble and exchangeable fractions.

**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)

Application of sewage sludge and municipal solid waste compost in conjunction with gypsum are low cost alternate amendment sources of sodic soils. An experiment was carried out at farmers' field in Kaithal, Haryana in sodic soil with initial soil $pH_2$ 9.37, $EC_2$ 0.92 dS $m^{-1}$ and gypsum requirement of 13.0 t $ha^{-1}$ with repeated appication of city waste compost (C). The treatments of the experiment were: control, gypsum @ 50 per cent of gypsum requirement (50GR), 25GR + compost 10 t $ha^{-1}$ one time application (25GR + C10OTA), 25GR + compost 10 t $ha^{-1}$ repeated application (25GR + C10RA).

There was significant increase of rice grain yield (CSR-30) over contol (1.84 t $ha^{-1}$). The yield of salt-tolerent rice variety CSR-30 was at par to 50 GR (4.75 t $ha^{-1}$) in compost treated soils (4.78 t $ha^{-1}$) in conjunction with 25% GR (Fig. 10). Repeated application of municipal solid waste compost had insignificant affect over 50GR and one time applcation of city compost on the yield of rice. However, dehyrogenase acitvity was enhanced in soil treatment with repeated application of compost.

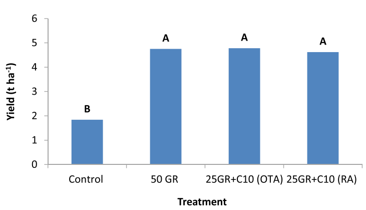
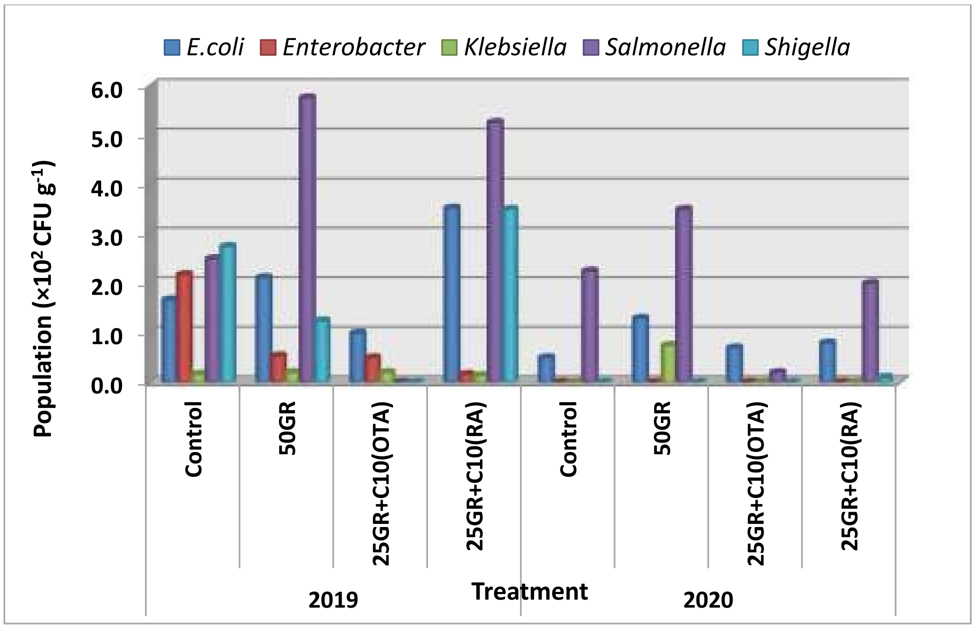



Fig 10. Effect of treatments on total grain yield (t $ha^{-1}$) of rice crop

Application of city waste compost and sewage sludge is often associated with existence of pathogens. Estimation of pathogens *viz*., *E. coli, Klebsiella, Salmonella, Shigella and Enterobacter* was done during 2019-20 after rice crop. Their population declined over the

Fig 11. Estimation of pathogens present in compost treated plots




period of time (Fig. 11). However, their population remained below the environmental concerns. The antibiotic disc diffusion test carried out for pathogens present in the compost treated plots revealed their susceptibility to 16 different antibiotics. This test further revealed low risk to public health associated with city waste compost application in agriculture.

## Elemental S based formulations-an alternate to gypsum in reclamation of sodic soil

(A.K. Rai, Nirmalendu Basak, Rameshwar Lal 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. Response of the rice plant to different reclamation strategies were evaluated at different plant growth stages. Rice root biomass production responded to change in soil pH. Root

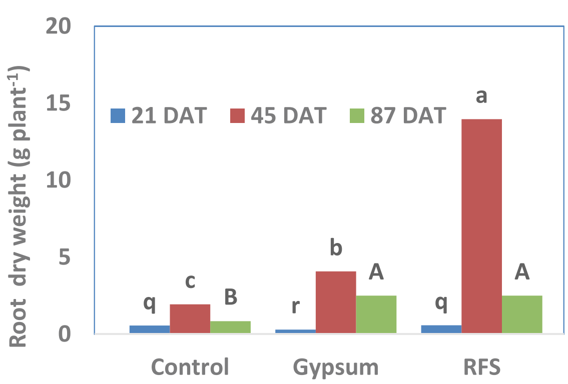



Fig 12. Effect of different amendments on the root biomass production at different growth stages

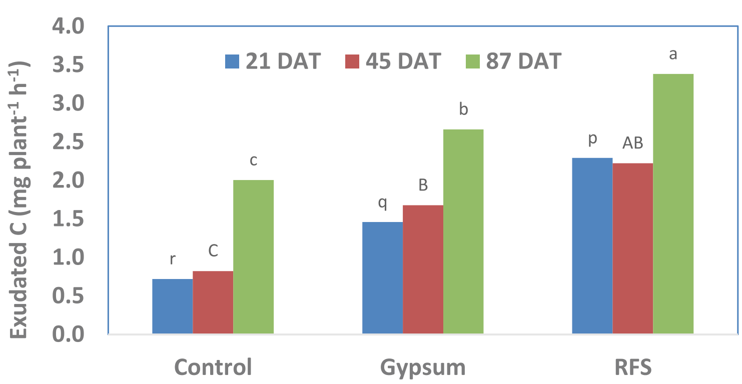
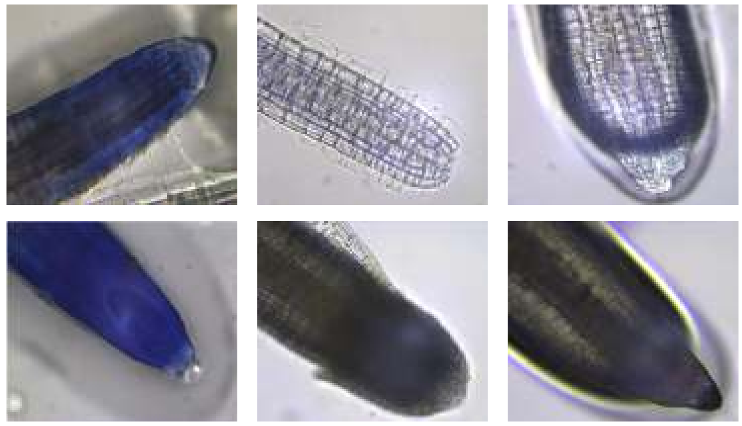



Fig 13. Effect of different amendments on the Evans blue staining of the roots from surface and subsurface soils.

Effect of different amendments on the carbon exudation in soil at different growth stages

**Surface soil**

**Subsurface soil**



**Control** **Gypsum** **RFS**

biomass production significantly greater in soil treated with different amendments compared to control. Root biomass was maximum at 45 days after transplanting, thereafter it declined at 87 day after transplanting (Fig. 12). Exudation of the carbon in the rhizosphere also vary with reclamation strategies. It was maximum in RFS followed by gypsum and control (Fig. 13). Carbon exudation increased with the crop growth. Roots also showed varied Evans blue staining. In surface soil root tips of the rice plant grown in control showed intense staining as compared to gypsum and RFS, indicating alleviation of stress in gypsum and RFS treated soil. However, in subsurface soil root tips staining was relatively more intense in gypsum compared to RFS.

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

The sodic land reclamation in the country is primarily based on the use of gypsum amendment. The success to bring about 3.77 mha sodic lands under cultivation heavily depends upon the success of alternate reclamation strategies. Recognizing the role of flue gas desulfurized gypsum (FGDG) in reclamation of sodic soil as an alternate to mine gypsum, CSSRI and NTPC has jointly initiated a collaborative project to study the efficiency and efficacy of FGDG and monitoring of the heavy metal(s) uptake, crop growth and quality of soil and water in FGDG amended soils.

Bulk soil required for sodicity reclamation study from five different locations of Haryana state were processed and filled in different lysimeters upto 100 cm depth. The soils leachate collection cups were installed at 15 and 30 cm depth and change in the leachate composition was monitored weekly. Soil columns in lysimeters were allowed to settle for soil biological activity and natural compaction for 30 days. Thereafter, gypsum and FGDG were applied as per the gypsum requirement in micro-lysimeters and lysimeters in moist condition and allowed to react for 30 days in soil. Thereafter, 30 days old rice seedlings (*cv.* CSR-56) were planted in the first week of July 2020.

View of lysimeter and micro-lysimeter experiments with FGD gypsum amendments

After harvesting of rice crop, $pH_s$ of the soil saturation extract significantly declined compared to control and fallow (Fig.14). The highest soil $pH_s$ reductions was recorded in 100FGDG followed by 75FGDG, 50FGDG> 50GR gypsum. The $SAR_e$ level of leachate collected from lysimeters at regular intervals attained peak at 21 days after transplanting of rice thereafter a gradual decrement was observed in level of $SAR_e$ in all cultivated plots.

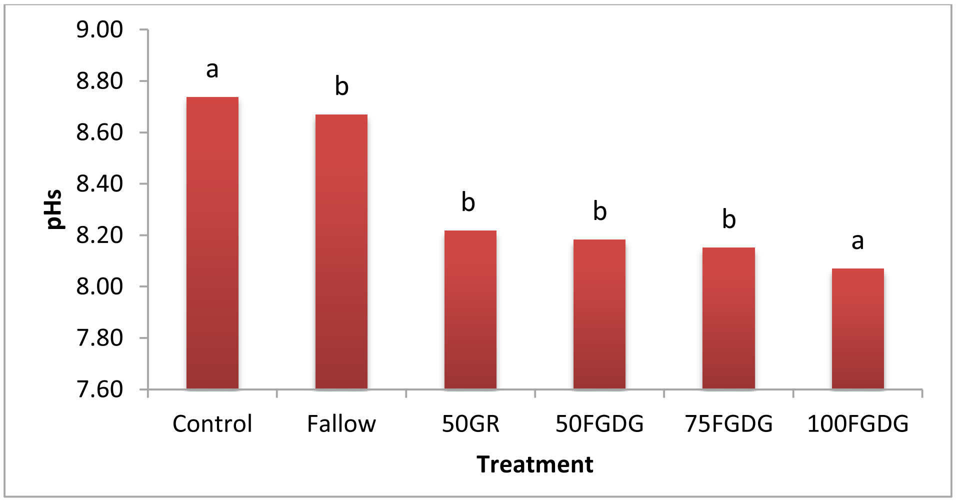



Fig 14. Change in pHs of soil after rice crop (2020)

Application of gypsum and FGDG supply soluble $Ca^{2+}$ with progress of reclamation and exhibited lower values of $SAR_e$ in lechates. However, fallow showed a lower concentration of SARe upto 54 days of transplanting of rice due to slow or non-performing of exchange reaction. Higher plant biomass was recorded in the FGDG treated plots.

**Developing portfolios for resource use efficient and climate smart future cropping system in reclaimed sodic lands of North-West India** (P.C. Sharma, Ashim Datta and Madhu Choudhary)

During kharif 2020, rice yield was significantly higher in scenario 2 (7 t $ha^{-1}$) followed by scenario 1 (6.85 t $ha^{-1}$) and lowest in scenario 3 (6.35 t $ha^{-1}$). The yield of rice was higher by ~9.3% in scenario 2 over scenario 3. About 7% higher maize yield was recorded in scenario

Table 3. Yield and water use under different scenarios during rice/maize 2020

| Scenario | Systems | Residue management | Productivity (t $ha^{-1}$) | Irrigation water (mm $ha^{-1}$) | Water productivity (kg $m^{-3}$) |
|---|---|---|---|---|---|
| I- farmers practice | Rice-wheat (CT/TPR) | No residue | 6.85 | 1742 | 0.39 |
| II- partial CA based | Rice-wheat-mungbean (TPR-ZT-ZT) | Full (100%) rice & mungbean and anchored wheat | 7.00 | 1738 | 0.40 |
| III- full CA based | Rice-wheat-mungbean (ZT-ZT-ZT) | Full (100%) rice and mungbean; anchored wheat | 6.35 | 1691 | 0.38 |
| IV- full CA based | Maize-wheat-mungbean (ZT-ZT-ZT) | Maize (65%) and full mungbean and anchored wheat | 8.36 | 169 | 4.95 |
| V-full CA+ based with SSD | Rice-wheat-mungbean (ZT-ZT-ZT) | Full (100%) rice and mungbean; anchored wheat | 6.65 | 1073 | 0.62 |
| VI-full CA+ based with SSD | Maize-wheat-mungbean (ZT-ZT-ZT) | Maize (65%) and full mungbean and anchored wheat | 8.99 | 103 | 8.73 |

Table 4. Yield and water use under different scenarios during kharif season 2020

| Treatments | Tillage | Wheat equivalent Yield (t /ha) | Irrigation water (mm ha-1) |
|---|---|---|---|
| Rice-Wheat-Fallow | Conventional tillage (CT) | 6.55 | 2209 |
| Rice-Wheat-Fallow | CT DSR-ZT | 6.25 | 2136 |
| Rice-Wheat-Mungbean | ZT | 6.37 | 2100 |
| Maize-Mustard-Mungbean | Permanent Beds (PBs) | 9.40 | 236 |
| Maize-Wheat-Mungbean | PBs | 10.89 | 200 |
| Soybean-Wheat-Mungbean | PBs | 2.62* | 162 |
| Pigeonpea-Wheat-Mungbean | PBs | 0.69** | 82 |

*soybean and **pigeon pea yield (t/ha)

CSSRI-CCAFS Research Platform

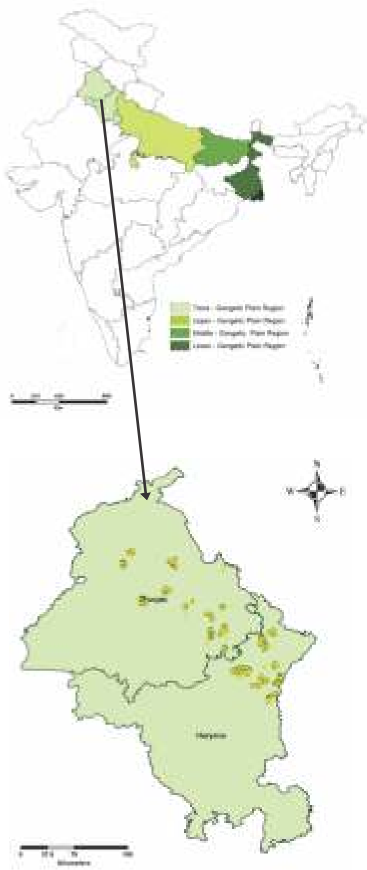
6 over scenario 4 (Table 3). In rice, irrigation water application was highest in scenario 1 (1742 mm $ha^{-1}$) and lowest in scenario 6 (103 mm $ha^{-1}$). The water productivity was significantly higher in scenario 6 (8.73 kg grain $m^{-3}$ water) over scenario 1.

In another experiment significantly higher wheat equivalent yield was recorded in PBM-PBW-PBMb treatment (10.89 t $ha^{-1}$) followed by PBM-PBMs-PBMb (9.40 t $ha^{-1}$).

Highest irrigation water was applied in CTR-CTW (2209 mm $ha^{-1}$) followed by CTDSR-ZT (2136 mm $ha^{-1}$), ZTDSR-ZTW-ZTMb (2100 mm $ha^{-1}$) and PBM-PBM-PBMb (236 mm $ha^{-1}$) treatments (Table 4).

**Sub-project: Filling data gaps with big data stacks to support climate smart agriculture in South Asia** (H.S. Jat and P.C. Sharma)

The crop production in present time is not only addressing the food security concerns, rather addressing the food security in profitable and environmentally sustainable way. Many climates smart agriculture practices are formulated and validated in the research fields and their effectiveness is also established, but their ground level adoption is still unknown. So, contrary to the traditional top-down approach of agronomic field experimentations is no more acceptable by farmers. Therefore, nowadays bottom-up approach of research is popularized more, because it provides an opportunity for benchmarking; i) to know the limitation in crop productivity at ground level, ii) to show the sustainable path way of crop production, iii) to understand about the lower adoption of a technology and iv) to identify the important drivers, their interaction and influence on crop productivity. The Rice-wheat (RW) system in north western Indo-Gangetic plains is popularly called as bread basket of India and is always a focal point for ensuring future food security in an economically and environmentally sustainable way. The broad dimension of sustainable assessment requires an intensive data collection including management data, crop cut, economics, resource use and socio-economic data. So, for



Location of the surveyed rice fields in the states of Haryana and Punjab.

this ground level study, data are required, which can be collected using various means including the data collection in digital platform, which poses advantage in saving time, making the surveys efficient and less prone to errors. Open data kit (ODK) is an android based application, free and simple to use. It can be used without internet once the form is downloaded from the server and response can be saved with out internet use, later after verification can be uploaded to server. The facility of capturing the geo-coordinates with a desired level of precision, text and numeric data and photos makes it a valuable tool in the data driven agronomic research approach. The ODK activities was started under the umbrella of CGIAR-CCAFS project in selected districts of the Haryana and Punjab from Kharif 2019 and Rabi 2019-20, respectively. During the Kharif 2019, a information on sample size of 1050 was collected for both crop cut and survey, while during Kharif 2020 crop cut was conducted in only 24.7% of the surveyed plots. Similarly, the data on crop cut for the wheat was 37% of the surveyed plots. For the plots where crop cut was done, all the information related to management, socioeconomic conditions were asked from the crop cut field along with the geo-coordinates recorded from the center of the crop cut field. The plots where only survey was done, the yield and agronomic information from the largest plot was asked, further the geo-coordinates of the largest plots were recorded.

A large database of individual farmer crop data was used to decompose rice yield gaps in rice-wheat cropping system of Haryana and Punjab to investigate the scope to reduce the inputs (especially N) without compromising crop yield. Based on Stochastic frontier analysis, rice yield gaps were found in the range of 20–30% of the potential yield (Yp) in rice-wheat cropping systems. The input efficiency and resource yield gaps was very small (< 10% of Yp), however, the technology yield gap was 10-20% of Yp. The yield gaps were associated with high input viz., irrigation water and fertilizer nitrogen. The N partial factor productivity (PFP-N) for the rice was ~50 and 40 kg grain kg$^{-1}$ N with efficient and inefficient N management in rice-wheat system. Resource yield gaps are the result of overuse of inputs and less efficiency that indicate little scope to improve the space, time and form of inputs applied. Thus, there is considerable scope to improve N-use efficiency in this region through 4R-stewardship. Site-specific nutrient management must be popularized for future sustainable rice production in the Northwestern IGP of India.

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

Rice –wheat is high water requiring system and alkaline water use induced stress brings several metabolic and physiological changes in plants, depending upon the extent of the stress through the amount and frequency of alkaline water applied to the crop. Seed growth in the seed-filling period is determined by several abiotic stresses of prevailing environmental conditions, *i.e.* temperature, rainfall and light. In this study the effect of differential alkalinity induced by RSC water application during crop growth and seed development on seed quality of rice wheat and subsequent ability to germinate is being investigated. The experiment is being conducted in lysimeters at the experimental farm of the ICAR-Central Soil Salinity Research Institute, Karnal, India. The irrigation water treatments consisted of two types of alkali waters having similar amount of salts (total electrolyte concentration, TEC 30 me L$^{-1}$) and sodium adsorption ratio (SARiw 10 mmol L$^{-1}$) but varying in residual sodium carbonate, RSC (5 me L$^{-1}$ and 10 me L$^{-1}$), and when latter was ameliorated to neutralize RSC equivalent to 5 me L$^{-1}$ with either sulfuric acid or gypsum.

Table 5. Initial soil chemical properties under different RSC induced alkalinity treatments

| Treatment | ECE (dS $m^{-1}$) | pHs | Na (ppm) | CEC (meq $100g^{-1}$) | $HCO_3$ (ppm) |
|---|---|---|---|---|---|
| **Control (Good Quality)** | $0.74^{b}$ | $8.02^{d}$ | $83.90^{c}$ | 62.71 | 0.63 |
| **RSC 5** | $1.91^{a}$ | $8.90^{b}$ | $382.60^{ab}$ | 52.57 | 0.66 |
| **RSC 10** | $1.51^{ab}$ | $9.09^{a}$ | $463.67^{a}$ | 24.85 | 0.83 |
| **RSC_10_5_H2SO4** | $1.76^{a}$ | $8.64^{c}$ | $333.50^{b}$ | 56.6 | 0.69 |
| **RSC_10_5_Gypsum** | $2.23^{a}$ | $8.65^{c}$ | $323.67^{b}$ | 61.73 | 0.88 |
| **SE(d)** | 0.31 | 0.06 | 45.63 | 23.06 | 0.15 |
| **LSD at 5% 0.86** | 0.18 | 126.7 | NS | NS | |

These treatments were compared to irrigation with good quality water as control. The experiment was conducted with rice cvs CSR 60 and PR 126. Various basic chemical characteristics of surface 15 cm soil, including ECe, pHs, sodium, CEC and $HCO_3$ content are given in Table 5. The soil pH (varying between 8.02 and 9.09 in surface 15 cm) was the maximum with RSC 10 and this was followed by RSC 5 and those ameliorated with either sulfuric or gypsum which maintained a little lower pH than RSC 5.

Seed moisture content was estimated on the fresh weight basis using the high-constant-temperature-oven method with ground seed (ISTA, 2020). The seed moisture dry down trend was similar across the RSC treatments, but the rate was faster in Var. PR 126. Seed moisture content declined from over 50% to below 20% between 7 and 30 DAA in cvs PR 126, whereas cvs CSR 60 had taken 53-40 DAA for declination of moisture content from 50% to 20% (Fig. 15). Mean seed dry weight was calculated from fresh weight and moisture content. The average seed weight (mg) was reduced significantly at RSC 5 and further at RSC 10. The mean seed weight of CSR 60 was significantly higher than the PR 126 across the treatments (Fig. 16). The overall reduction in mean seed dry weight from Control to RSC 10 was ~18.5% in Cv PR126 and ~15% in Cv. CSR 60.

In cv. CSR 60, the mean seed weight of control was 39.12 mg, whereas the mean seed weights of RSC 10 was 33.5 mg. The mean seed weight of RSC 5 and RSC 10 neutralized with $H_2SO_4$ and Gypsum was 35.32, 36.28 and 36.67 mg, respectively. The control treatment seed had taken 18 DAA to attain maximum seed weight, whereas RSC 10 treatment had taken 28 for the same. All other treatments had taken 23 DAA to attain maximum seed weight. In cv. PR 126, the mean seed weight of control was 31.66 mg,

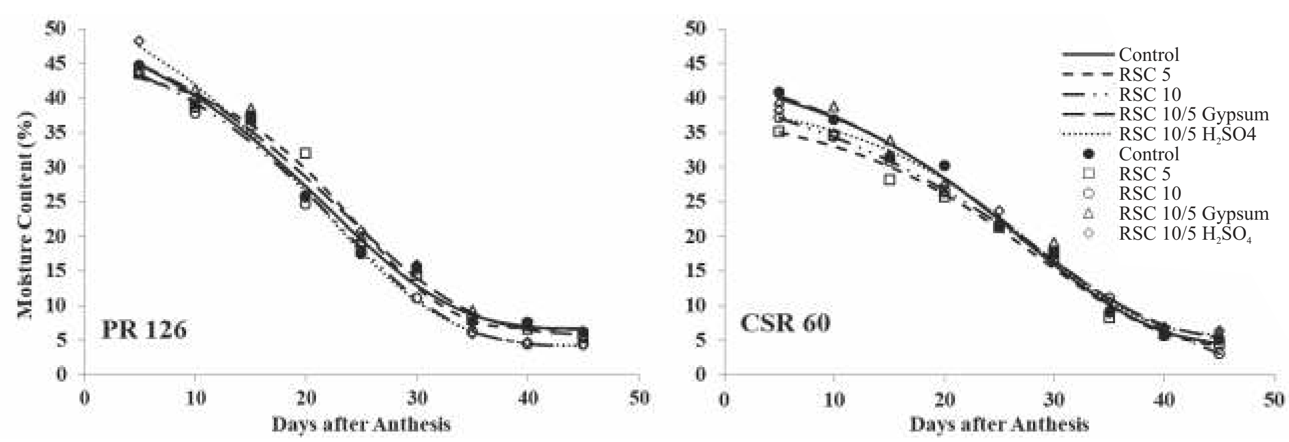



Fig 15. Changes in moisture content of fresh seeds of rice cv. PR 126 and CSR 60 in differential RSC induced alkali water irrigation regimes.

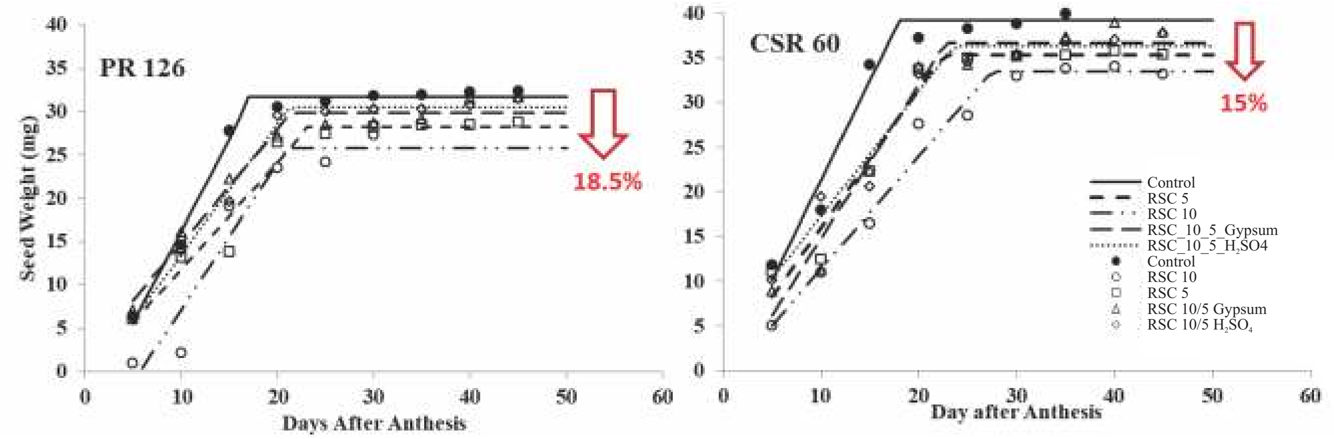



Fig 16. Changes in seed filling period and mean seed dry weight (mg) of rice cv. PR 126 and CSR 60 in differential RSC induced alkali water irrigation regimes.

whereas the mean seed weight of RSC 10 was 25.8 mg. The mean seed weights of RSC 5 and RSC 10 neutralized with H2So4 and Gypsum were 28.24, 30.53 and 29.87 mg, respectively. The control treatment seed had taken 17 DAA to attain maximum seed weight, whereas RSC 10 treatment had taken 21 for the same. All other treatments had taken 22-23 DAA to attain maximum seed weight.

**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 sustainability of this rice-wheat (RW) system continues on the cost of natural resource degradation in the IGP since last 5 decades. Traditional cultivation (intensive tillage coupled with water ponding in transplanted rice) of RW system consumes large amount (1800-2400 mm) of irrigation water, and is energy and labor intensive, and deteriorates soil health. The sustainability of the RW production systems of South Asia has become a major concern owing to alarming depletion of water table, stagnating or declining productivity growth and diminishing economic returns. Since the early 1970s, there has been a steady increase in the depth to the groundwater in most of the RW area of North-West (NW) India and later on start decreasing. Furthermore, climate change also increases future water demand globally by about 40% of the water needed for irrigation without global warming thereby reducing water availability in areas where irrigation is most needed. Under the emerging scenario of acute shortages of ground water, in future it is imperative that we focus our efforts to develop alternative approaches for saving water use in irrigated RW system in NW India. Dry seeded rice (DSR) has been identified as one of the alternative to puddled transplanted rice (PTR) in RW system to address the issues of rising labor, water and energy scarcity in NW India. Other agronomic practices to save irrigation water in RW system include cultivation of short duration cultivars, shifting planting time of rice towards period of low evaporation demand, zero tillage and crop residue mulching. The other approaches suggested saving water and increase water productivity (WP) in different crops includes change from flood irrigation systems to micro-irrigation systems. Under salt affected soils, the effect of micro-irrigation (subsurface drip irrigation) on salt dynamics and soil moisture distribution pattern is unknown. Therefore, to advocate the subsurface drip irrigation (SSDI) in salt affected areas, there is a urgent need is felt to understand the effect of salt on crop productivity and

Table 6. Effect of different crop management scenarios on RW system grain yield, irrigation water use and net returns (2019-20).

| Scenario | Residue management | System Yield ($t\ ha^{-1}$) | System Irrigation ($mm\ ha^{-1}$) | System Net Returns ($INR\ ha^{-1}$) |
|---|---|---|---|---|
| **ScI:** Rice-wheat CT (-R) | All residue removed | 8.48 | 1348 | 69147 |
| **ScII:** Rice-wheat CT (+R) | 50% rice and anchored wheat residue incorporated | 6.73 | 1306 | 37243 |
| **ScIII:** Rice-wheat ZT (-R) | All residue removed | 9.01 | 989 | 100769 |
| **ScIV:** Rice-wheatZT (+R) | 100% rice and anchored wheat residue retained | 9.80 | 992 | 115126 |
| **ScV:** Rice-wheatZT (-R) + SDI | All residue removed | 9.23 | 481 | 109237 |
| **ScVI:** Rice-wheatZT (+R) + SDI | Same as ScIV | 10.36 | 477 | 129949 |
| **ScVII:** Rice-wheat-mungbean ZT (-R) + SDI | All residue removed | 11.63* | 595* | 139098* |
| **ScVIII:** Rice-wheat-mungbean ZT (+R) + SDI | Same as ScIV and full mungbean residue retained | 11.65* | 590* | 139065* |

*Where,* CT: conventional-till rice; ZT: zero-till; -R: without residue; +R: with residue; SDI: sub-surface drip irrigation; * Mungbean yield

profitability of RW system in lieu of saving ground water in NW India. The study on subsurface drip irrigation (SSDI) in cereal crops especially RW system is of new kind. In salt affected soils, how salt behaves and have influence on the systems productivity and profitability is unknown. Therefore, we hypothesized that development of SSDI technology will reduce the salt effect in root zone, reduce irrigation water consumption, and increase input use efficiency in CA based rice-wheat system.

The highest grain yield was recorded with the integration of mungbean in to RW system with SDI irrigation. Inclusion of mungbean increased the system yield by 19% at the same management level under CA- based systems. Almost 37% higher yield was recorded with ScVII and ScVIII irrespective of residue management. Zero-tillage and SDI system increased the system yield by 2.19 t $ha^{-1}$ at the same management level (Table 6). The lower grain yield of RW system was recorded with ScII where it was grown under CT condition with residue incorporation.

The conventional RW system consumed highest (~1327 mm) amount of irrigation water with flood irrigation, whereas ZT with flood and ZT with SDI consumed ~990 and 479 mm or irrigation water, respectively (Table 6). With SDI system, 56% irrigation water was saved in maize-wheat-mungbean system (average of ScVII and VIII) under CA- based management practices. Integration of mungbean with SDI increased the net returns by 100% compared to farmers' practice.

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

The sustainability of the intensive cereal production systems of South Asia has become a major concern owing to alarming depletion of groundwater table, stagnating or declining productivity growth, degrading soil health and environmental quality, and diminishing farm profitability. Developing and defining climate smart agriculture practices (CSAPs) for crops and cropping systems is the new avenues for site-specific research for development (R4D) in IGP to achieve the systems' sustainability while conserving natural resources in the context of climatic change scenario. IRRI- CSA flagship project-2 in Indian IGP was implemented for designing next generation resource efficient, productive and sustainable cereal systems suited to current climatic and socio-economic settings under salt affected agroecosystems (saline, sodic, coastal). A larger number of CSAPs related to water, nutrient, carbon, energy etc. have been deployed in rice based systems.

Among the two rice varieties, CSR 88 performed better than CSR 91 under all types of tillage, crop establishment and water management methods. Highest yield of was recorded with CT- Vattar (5.27 t $ha^{-1}$) ZT-DSR (5.05 t $ha^{-1}$) in CSR 91, However, CSR 88 recorded the higher yield with rice furrow planting (6.78 t $ha^{-1}$) and bed planting (6.51 t $ha^{-1}$) and at par with PTR (6.81 t $ha^{-1}$). Irrigation water application was highest in puddled transplanted rice (PTR) i.e. Sc1 (2050 mm $ha^{-1}$) followed by DSR (dry and vattar) (1600-1820 mm $ha^{-1}$) and lowest under furrow and bed planting methods (1250-1300 mm $ha^{-1}$). The irrigation water use was decreased by 11-22% and 37-39% under DSR and bed planting methods, respectively compared to PTR. From the data, it is evident that plant growth and yields reduced significantly with the increasing sodicity levels. Maximum plant growth and yield was obtained with $S_1$ sodicity level (pH 8.0) and it reduced significantly with increasing sodicity levels. 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 other treatment. Highest grain yield of rice-wheat system was recorded with treatment $T_3$ (75% RDF+ Halo Azo+ Halo PSB + Halo Zinc) and it was at par with $T_4$ (75% RDF+CSR-Bio+ Zinc sulphate @ 25 kg $ha^{-1}$). Application of 60 kg K $ha^{-1}$ in 3 splits (50% as basal, 25% top dressing at 30 days after transplanting and remaining 25% as top dressing at panicle initiation stage produced significantly higher grain yield over application of full dose of K as basal. During kharif 2020, plant height was not affected either by variety, method of application or silicon dose. However, the grain yield was significantly affected by silicon dose. Highest grain yield of 6.02 t $ha^{-1}$ was observed with application of highest dose of 62 kg Si $ha^{-1}$. Observation on lodging tolerance was recorded by a prostate tester at maturity. The lodging tolerance of Amal-Mana was 0.31 kg $cm^{-1}$, which was higher than Sabita (0.21 kg $cm^{-1}$). The lodging tolerance of rice increased with increasing dose of silicon fertilizer. However, the lodging tolerance was at par (0.27 kg $cm^{-1}$) with 50 and 62 kg Si $ha^{-1}$.

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

The conventional systems created problems of high production cost, low input-use efficiency, decline in groundwater, deterioration in soil health, and environmental pollution. The intensive use of water in conventional puddled transplanted rice (CT-TPR) cultivation in northwest IGP is depleting aquifers at the rate of 11-13 $km^2$ annually. Therefore, it has been imperative to use conservation agricultural techniques for sustained production. The conventional system of rice production (CT-TPR) in this region is basically water, labour and energy intensive, adversely affecting the environment Therefore, to sustain the long term production of rice, more efficient alternative methods of rice productions are needed. For this, Dry direct Seeded Rice (DSR) is the technology which is water, labour and energy efficient along with eco-friendly characteristics and can be a potential alternative to CT-TPR. The risk reducing practices to minimize the salinity

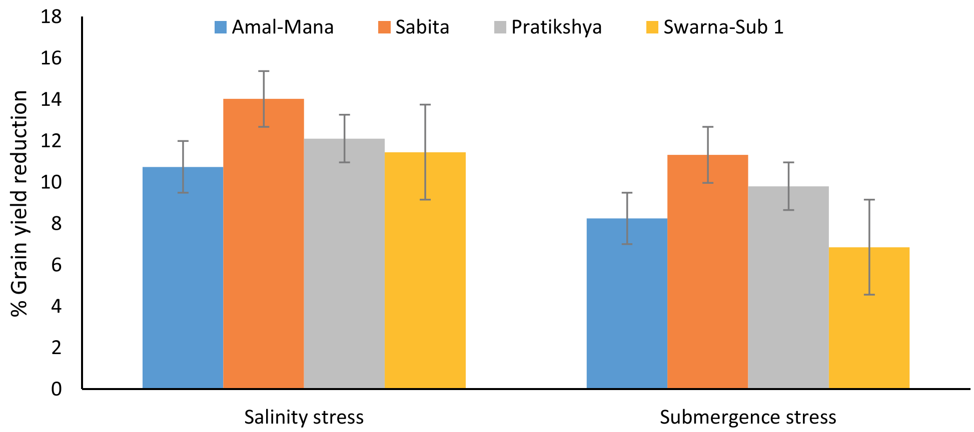



Fig 17. Yield of different rice varieties under different establishment and management practices

stress in DSR is evaluated under coastal salt affected areas of West Bengal. During the *kharif* 2020, gap filling increased the grain yield of both direct seeded rice (DSR) and puddled transplanted rice (PTR). Averaged over four varieties (Amal-Mana, Sabita, Pratikshya and Swarna-Sub1), gap filling increased grain yield of rice by 13.6% in DSR and 9.9% in PTR (Fig. 17). Salinity stress resulted a grain yield loss of 10.7-14.0%, while due to submergence, the yield penalty varied between 8.3 – 11.3% depending upon the variety. Due to submergence, lowest (8.3%) yield loss was observed in Amal-Mana and highest (11.3%) was observed in Sabita.

Under anaerobic germination, 116 genotypes were tested for germination and, four genotypes out of these 116 genotypes did not germinate. Germination, root length and shoot length were measured on 15$^{th}$ day after sowing. The lines IR127795-820-1-2-1 (IQ 34) and IR127795-1020-1-1-3 (IQ 40) were identified as superior genotypes with 100% germination capacity with highest seedling vigor of 32%, followed by IR 127795-820-1-2-2 (IQ 35) with 98% germination and 31% seedling vigor. A total of 60 rice genotypes were screened by direct seeding in K*harif* 2020 with plot size of 10m$^2$ with 3 replication. Out of 60 genotypes, maximum grain yield was observed in CSR MAGIC 167 (5.61 t ha$^{-1}$) followed by PET-27 (5.52 t ha$^{-1}$), CSR58 (5.23 t ha$^{-1}$) and minimum yield was observed in CSR 62 (2.23 t ha$^{-1}$). Out of 8 DSR genotypes, maximum grain yield was observed in CSR 86 (6.19 t ha$^{-1}$) followed by CSR 88 (6.06 t ha$^{-1}$).

## Developing soil quality indices for sodic soil under different reclamation strategies

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

Gypsum (Gyp) and conjunctive application of elemental sulphur formulation (RFS), pressmud, acids, acid-formers, pyrites, phosphogypsum, fly ash, bio-augmented material and aluminum chloride are generally recommended for sodic soils reclamation.

Table 7. Effect of amendments on soil pHs in 0-15 cm soil depth

| Amendments categories | Patiala, Punjab | Barwah, Indore | Mundri, Haryana |
|---|---|---|---|
| Control | 8.54A | 8.94AB | 7.84A |
| Gyp50 | 8.30B | 8.97A | 7.80AB |
| Gyp:RFS ratio1 | 8.15C | 8.54BC | 7.77AB |
| Gyp:RFS ratio2 | 8.18BC | 8.31CD | 7.83AB |
| Gyp:RFS ratio3 | 8.18BC | 8.23CD | 7.70B |
| Gyp:RFS ratio4 | 8.08C | 8.11D | 7.54C |

**Numbers followed by different uppercase letters significantly different at P ≤ 0.05 by DMRT for separation of mean*

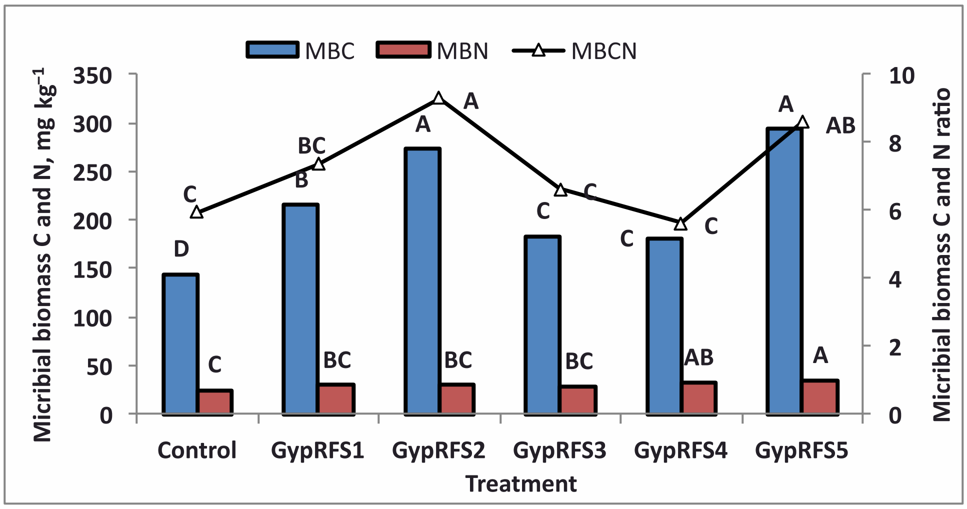



Fig 18. Impact of amendments on soil microbial biomass C and N (mg kg-1) after rice 2020 in Mundri, Haryana in 0-15 cm soil (Numbers followed by different uppercase letters significantly different at P ≤ 0.05 by DMRT for separation of mean); GypRFS1, GypRFS2, GypRFS3, GypRFS4 and GypRFS5 denote the several Gyp:RFS ratios.

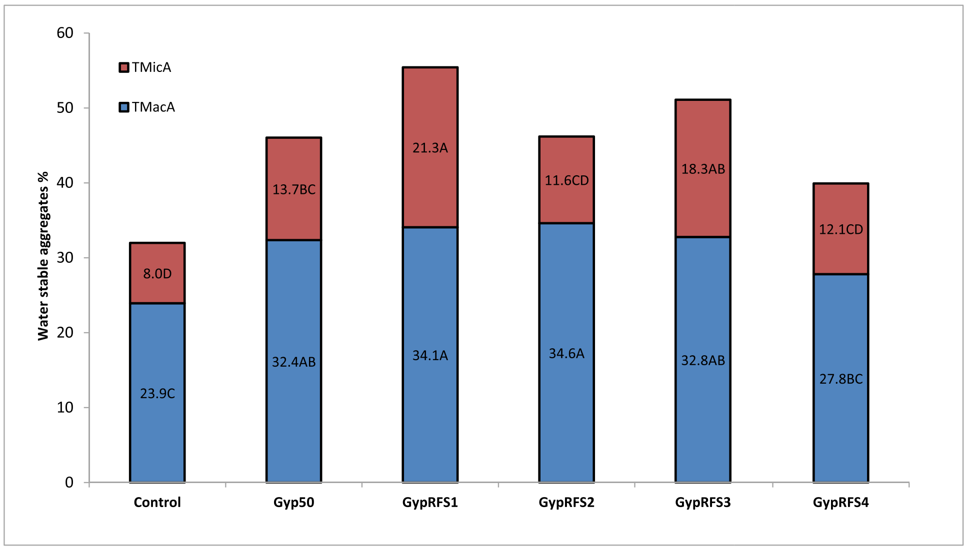



Fig 19. Distribution of macro (TMacA) and micro aggregates (TMicA) (µm) into different size classes as influenced by different amendments after rice 2020 (after fourth crop rotations) (Numbers followed by different uppercase letters significantly different at P ≤ 0.05 by DMRT for separation of mean); GypRFS1, GypRFS2, GypRFS3 and GypRFS4 denote the several Gyp:RFS ratios.

However, inherent soil bio-physical environment, initial soil sodicity and available water quality use for cultural practices have immense role on the process of reclamation. The progress of soil reclamation mainly is represented by measuring the pH of soil water saturation paste extract ($pH_s$), electrical conductivity of soil water saturation paste extract ($EC_e$) and exchangeable sodium per cent (ESP). However, after application of chemical amendments, soil chemical & biological properties show early response rather than the soil physical attributes. Soil pHs declined for all the experiment sites with application of amendments RFS or its conjunctive application with Gyp. The improvement of soil chemical properties have captured by changes in soil pHs (Table 7). However, decrement of pHs were greater in Budhmore (Punjab) followed by Indore (MP) and Mundri (Haryana). Soil microbial biomass carbon (MBC) and nitrogen (MBN) and their ratio (Fig. 18) improved in soils amended with RFS/GypRFS compared to unamended soil. Sole application of RFS /or it's conjunctive application with Gyp increased soil macro and micro aggregates compared to unamanded control (Fig. 19). It also improved saturated hydraulic conductivity in Kaithal, Haryana. Amending soil with RFS/or it's conjunctive application with Gyp improved rice grain yield at all locations.

# 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, P.R. Bhatnagar and P.C. Sharma)

### Identification of new sites

Three sites at Dighal and Dhaur (Jhajjar district) and Sarupgarh (Charkhi Dadri district) for new sub surface drainage (SSD) projects were jointly identified by a team of ICAR-CSSRI and HOPP (Haryana Operational Pilot Project) Cell, Govt. of Haryana with a total waterlogged saline area of 480 ha during 2020 on the basis of site feasibility criteria. These sites were characterized by waterlogged condition (water table depth, 0.55-1.30 m), moderate to very high soil salinity ($EC_{e,}$ 8.9-43.7 dS $m^{-1}$), moderate groundwater salinity ($EC_{gw,}$ 2.28-6.7 dS $m^{-1}$) and availability of adjoining surface drain (except Sarupgarh) for disposing off saline drainage water safely.

### Evaluation of designs of SSD and vertical drainage

The HOPP-prepared designs of SSD systems for 18 drainage blocks under Rohtak-III and IV SSD projects viz. nine blocks each of Rithal site (RI-7 to 16) and Chandi site (Ch-1 to 9) covering total area of 712.1 ha were technically evaluated using Cavelaars's equations (Table 8). The length of lateral pipes and drained area by various collectors for 18 drainage blocks were found to be within the permissible limits of lateral length and drained area by collector sizes of 160, 200, 250 and 294 mm as per the National Drainage Guidelines. The layouts of the systems were found appropriate by taking advantage of the natural land slope so as to keep excavation minimum. Therefore, the designs of 18 drainage blocks were technically approved.

The HOPP-prepared designs of vertical drainage systems at four sites- Shakar Mandori, Shahpuria, Darba Kalan and Manak Diwan under Sirsa Pilot Project were technical evaluated for the feasibility for reclamation of waterlogged saline soils (Table 9). From technical design data of four sites, drainage tubewell with 12" dia bore and depth up to 70-80 feet was designed without cavity formation. Perforated PVC screen case pipe of 250 mm dia was to be lowered. The discharge of each UGPL line from single/multiple tubewells were found to be within the maximum discharge capacity. Layout of the tubewell networks was also appropriate. A 5 hp solar submersible pump set with 5.0-7.5 lps discharge and 25-30 m head is sufficient with regular pumping of about 8-11 hours. The proposed HDPE underground pipe lines (UGPL) of 140 and 200 mm dia @ 3.2 kg $cm^{-2}$ pressure at 4-5 feet deep with nominal slope were appropriate for disposing off saline drainage water into open drains. Total length of UGPL pipes at Shakar Mandori and Shahpuria sites is 17,879 m and 2,545 m. A 7.5 hp solar submersible pump set is provided at sump well near open drains to dispose saline water delivery into surface drain. Outlet protection structure for each UGPL line is provided. The designs and layouts of drainage tubewells at Shakar Mandori and Shahpuria sites were in conformity with the drainage tubewell guidelines and therefore, were technically approved for the feasibility study. Due to significant overlap of area of SSD systems installed and vertical drainage systems proposed at Darba Kalan and Manak Diwan sites, rehabilitation of both the SSD systems was recommended and the vertical drainage systems were dropped.

Table 8. Hydraulic evaluation of designs of 18 drainage blocks under two SSD projects

| S No | SSD Block | Gross area (ha) | Net area (ha) | Lateral pipe size (mm) | Actual lateral length used (m) | Permissible lateral length (m) | Actual drained area (ha) by collector pipe size (mm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 160 | 200 | 250 | 294 |
| **Rohtak-III SSD Project (Rithal)** | | | | | | | | | | |
| 1. | RI-07 | 40.0 | 38.5 | 80 | 134-510** | 692.34** | 13.96 | 28.03 | 38.48 | -- |
| 2. | RI-08 | 40.0 | 37.2 | 80 | 469-536* & 270** | 621.50* 692.34** | 15.47 | 28.14 | 37.18 | -- |
| 3. | RI-09 | 46.0 | 39.9 | 80 | 67-335* | 621.50* | 15.50 | 28.39 | -- | 39.86 |
| 4. | RI-10 | 53.0 | 47.7 | 80 | 235-302* | 621.50* | 15.91 | 27.98 | -- | 47.72 |
| 5. | RI-11 | 56.0 | 57.7 | 80 | 90-300** | 621.50* | 10.85 | 27.14 | -- | 57.69 |
| 6. | RI-12 | 64.0 | 60.5 | 80 | 270-390** | 692.34** | 15.68 | 28.74 | | 60.50 |
| 7. | RI-13 | 40.0 | 35.0 | 80 | 168* & 180-270** | 621.50* 692.34** | 15.48 | 29.95 | 34.99 | -- |
| 8. | RI-14 | 39.0 | 37.0 | 80 | 168-503*& 150-330** | 621.50* 692.34** | 12.08 | 27.56 | 37.00 | -- |
| 9. | RI-15 | 67.0 | 60.7 | 80 | 60-480** | 692.34** | 15.28 | 31.76 | -- | 60.70 |
| **Sub-total** | | **445.0** | **414.2** | | | | | | | |
| **Rohtak-IV SSD Project (Chandi)** | | | | | | | | | | |
| 10. | Ch-01 | 39.0 | 32.5 | 80 | 168-502* | 621.50* | 7.57 | 24.89 | 32.53 | -- |
| 11. | Ch-02 | 14.0 | 11.8 | 80 | 34-268* | 621.50* | 11.80 | -- | -- | -- |
| 12. | Ch-03 | 30.0 | 27.3 | 80 | 300-650** | 692.34** | -- | 27.34 | -- | -- |
| 13. | Ch-04 | 40.0 | 36.4 | 80 | 60-450** | 692.34** | 15.68 | 26.33 | 36.45 | |
| 14. | Ch-05 | 40.0 | 31.9 | 80 | 120-600*& 90-250** | 621.50* 692.34** | 12.45 | 22.77 | 31.93 | -- |
| 15. | Ch-06 | 38.0 | 33.6 | 80 | 90-210** | 692.34** | 13.27 | 25.33 | 33.57 | |
| 16. | Ch-07 | 48.0 | 42.2 | 80 | 150-270** | 692.34** | 16.88 | 28.14 | -- | 42.21 |
| 17. | Ch-08 | 36.0 | 30.2 | 80 | 150** | 692.34** | 14.07 | 24.12 | 30.15 | -- |
| 18. | Ch-09 | 59.0 | 52.0 | 80 | 90-270** | 692.34** | 18.09 | 36.18 | -- | 52.66 |
| **Sub-total** | | **344.0** | **297.9** | | | | | | | |
| | **Total** | **789.0** | **712.1** | | | | | | | |

(Note: 60 m* and 67 m** lateral drain spacing based on field orientation; Maximum areas drained by 160, 200, 250 and 294 mm collector pipe sizes as 17.13, 30.17, 44.62 and 64.10 ha)

Table 9. Detailed information of the proposed Sirsa vertical drainage pilot project

| Site no | Name of the site | Area (ha) | No of tubewells | UGPL collector lines | | No of storage sump wells |
|---|---|---|---|---|---|---|
| | | | | No. | Total length (m) | |
| 1. | Shakar Mandori | 421 | 28 | 7 | 17,879 | 6 |
| 2. | Shahpuria | 165 | 11 | 8 | 2,545 | 2 |
| 3. | Darba Kalan | 302 | 20 | 9 | 7,630 | 7 |
| 4. | Manak Diwan | 106 | 07 | 2 | 3,320 | 2 |
| | **Total** | **994** | **66** | **26** | **31,374** | **17** |

Field testing of tractor powered agricultural trencher and JCB machine

### M&E of five SSD projects

Monitoring and evaluation (M&E) 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 SSD projects, respectively, were conducted during the year. Field data were partially collected and information on the Rabi and Kharif crop yields were collected from the beneficiary farmers through mobile phones due to Covid-19 pandemic. The average yields of paddy, cotton and wheat crops increased by 44-99, 63-197 and 35-126% and 17-37, 21-87 and 38-77%, respectively, for adequate and partial pumping operations done by farmers for achieving full or partial reclamative salt leaching. Out of 67 drainage blocks, adequate pumping was achieved in 25 blocks (37%).

### Feasibility of installation of a Shallow SSD System

In order to adapt new design criteria for lowering drainage discharge volume for environmental sustainability, a shallow SSD system was designed with drain depth up to 2.0 m including collector. Thus, feasibility of tractor powered trencher and hydraulic excavator machine was tested in waterlogged saline conditions. An agricultural trencher/trench digger (Delta make, 2.7 m boom length, 2.0 m digging depth and 0.26 m width) operated by a 60 hp tractor (New Holland model 3630 Plus TRX) was field tested for digging trenches and laying pipes in severe waterlogged saline soils (Water table, 1.0-1.2 m deep) at Kathura site (Sonipat). The trench was dug up to 21-24 m long with 0.30 m width and 1.9 m depth. After lapse of almost 15 minutes, side walls of the trench collapsed and filled back almost entire trench in 21-30 minutes. The field test repeated three times but failed due to complete trench backfilling. However, the machine test was successful in fields having water table > 2.0 deep. Field testing of a backhoe loader machine, (JCB odel 4DX, ~90 hp), was conducted for digging trenches at Kathura site. The machine could dig trench up to 21 m long, 2 m deep and 50 m width, but the insignificant side wall collapse of trench was observed due to increased trench width and the trench was subsequently cleaned. A new shallow SSD system for a drainage block (JH-III-D-1) was designed for land locked Dujana site covering an area of 5.17 ha under Jhajjar-III SSD project for the feasibility study with 34 m drain spacing and depth up to 2.0 m including collector (Fig 20). The installation of a sump well and collector line was completed using backhoe loader machine (JCB model 4DX) at Dujana and the lateral lines were installed in the area up to June 2020 when the water table depth was more than 1.6 m at the time of installation and the collector was installed with pumping for dewatering. However, some difficulty was observed to install lateral and collector pipes in water table depth less than 1.6 m without dewatering pumping. The time-series M&E data could not be collected due to covid-19 pandemic.

### Feasibility of vertical drainage systems

Feasibility on vertical drainage systems installed at Sikrona site (Faridabad) and Singhwa Khas site (Rohtak) was assessed by resulting salinities of drain and canal water at disposal points during two years. Drainage tubewell networks of 12 and 14 each in 120 and 145 ha affected areas were installed at two sites to control water table and soil and water salinity. The tubewells with depth up to 22 m were made operational with 5 hp solar submersible pump sets to dispose off saline drainage water into Sikrona drain and Jui feeder canal, respectively, through UGPL lines. Pumping operations in various combinations were performed and the time series data along with water and soil

Fig 20. Design of a new shallow SSD system at Dujana

samples were collected and analysed. When all pump sets (100%) were running, soil salinity (ECe) of Sikrona and Singhwa Khas sites reduced from 39.6 to 8.58, and 62.0 to 9.04 d S $m^{-1}$ in two years of pumping. Water table in the both project areas improved from 0.60 to 1.28 m and 0.65 to 1.42 m below the ground level. The water salinity of the Jui feeder canal and Gurgaon canal varied from 0.31 to 1.24 dS $m^{-1}$ whereas salinity of groundwater varied 4.71 to 11.05 dS $m^{-1}$ at both the sites. The study revealed that the paddy and wheat yield increased from 3.11 to 3.8 and 3.42 to 4.71 ton $ha^{-1}$ at both sites due to lowering of water table. When all solar pump sets were running at Sikrona site, the water salinity of Sikrona drain varied 2.13-3.11, 4.27-6.24 and 8.6-12.5 dS $m^{-1}$ downstream of the disposal point with full, half and quarter supply drain discharge (Fig. 21). Salinity of the drain water increased (2.13-12.51 dS $m^{-1}$) and caused severe drain water pollution and soil salinization at downstream by use of drain water for irrigation. The salinity of canal water marginally increased (0.32-0.39) with full and half canal supplies and was not degraded at all thorough the year. Therefore, vertical drainage system with large disposal capacity (>400 cusecs) is a feasible option for reclaiming waterlogged saline soils. On the other hand, vertical drainage at Sikrona was not feasible resulting in higher drain water salinity after the disposal point in Sikrona drain.

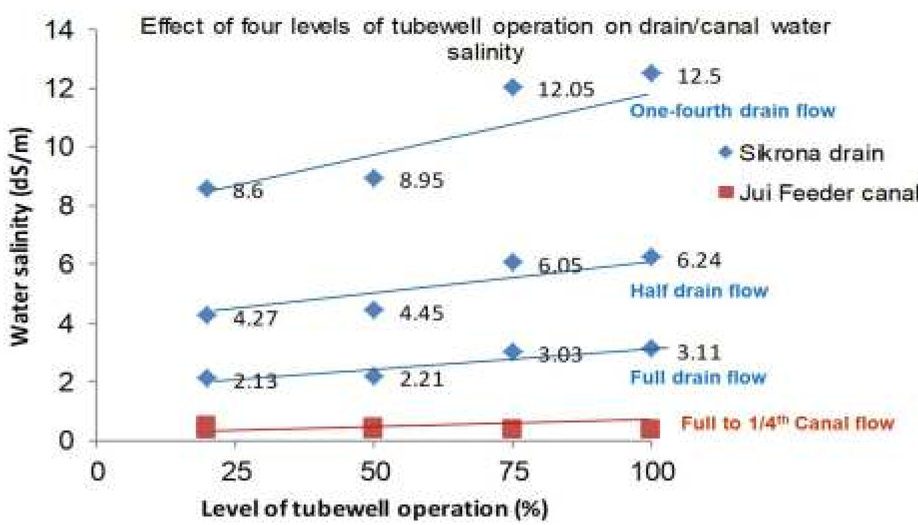



Fig 21. Effect of tubewell operations on drain/canal water salinity with three flow conditions.

Installation of SSD work with hydraulic excavator in Kolhapur and inspection chamber with controlled drainage structure installed in the field.

**Astral consultancy on sub surface drainage for reclamation of waterlogged and saline heavy soils** (D.S. Bundela, Anil Cinchmalatpure, R. Raju, R.K. Fagodiya, Sagar Vibhute and P.C. Sharma)

Consultancy services on site identification, design and approval of new projects, drainage material testing, pre-drainage investigations and topographic surveys, etc. for Maharashtra and Karnataka states were provided to M/s Astral Poly Technik Ltd (Astral Pipes), Ahmedabad (Gujarat) during 2020. Six new SSD projects (80 to 250 ha) with total area of 1,980 ha in Sangli, Kolhapur, Pune and Ahmednagar districts (Maharashtra) were jointly identified and recommended for topographic surveys and pre-drainage investigations and designing of SSD systems with controlled drainage and pipe main drain for reclamation of waterlogged saline black soils. M/s Shreedatta Sugar, Sharad Sugar, Gurudatta Sugar and Rajaram Bapu sugar factories and Directorate of Irrigation Research & Development (DIRD), Water Resources Department have played the leading role in project formulation, financing and monitoring. To address the excessive drainage of irrigation water and nitrogen fertilizer from conventional SSD projects, controlled drainage approach was applied to nine farmers' society funded SSD projects with 20 m spacing in total area of 2,404 ha with 3,745 beneficiary farmers. During the year, SSD work with controlled drainage was implemented in 484 ha in three projects and in 1159 ha in five projects up to Dec 2020. The projects were implemented through semi-mechanically in Kolhapur district by farmers' land reclamation cooperative societies through CSSRI trained drainage contractors under supervision of consultancy firm (M/s Astral Pipes) with technical support from ICAR-CSSRI. In the controlled drainage design, a ball based control valve structure was designed and installed at the end of collector pipe for every 2.50-4.00 ha area (4-6 farmers) inside a RCC pipe inspection chamber. Efficient drain water management practices were developed by regulating drainage discharge during each irrigation in sugarcane for 5-7 days from every collector by rotating valve suitably by farmers to save irrigation water and nitrogen. The drainage water from the project area was discharged in controlled manner to a large open drain through the gravity outlet. Drainage water management practices in controlled SSD systems completed in five projects were adopted and the time series data were collected for monitoring of water quality. The EC and SAR of drainage water from five projects decreased from 28.6 to 4.51 dS $m^{-1}$ and 55.3 to 9.2dS $m^{-1}$, respectively, from April 2018 to March 2020 which reflects the significant removal of soluble salts by leaching. After March, monitoring data could not be collected due to Covid-19 pandemic. Similarly, the soil $EC_e$ at different locations along the collector lines decreased from 9.8-24.7 to 5.2-16.7 dS $m^{-1}$ (by 57% average) and the $pH_s$ was increased by ~1.0 due to salt leaching during the first two years. It resulted in savings of 15-18% water and 10% urea fertilizer. The cane yield increased from 33.7-51.4 t $ha^{-1}$ (Pre-project) to 81.4-117.0 t $ha^{-1}$ during the first two years of controlled SSD system.

**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)

BIS standards based methodologies for testing the suitability of non-woven and woven geosynthetic filters were developed to ensure the optimal quality of drainage filter fabrics for different agro-climatic regions of the country in order to prevent clogging of

Table 10. Test results of four non-woven synthetic geotextile filters

| S No | Parameter | Reference Value/Guideline | Sample-wise Test Results | | | |
|---|---|---|---|---|---|---|
| | Filter Sample ID | --- | NWCA-3 | NWCA-4 | PPGT-1 | PPGT-2 |
| 1. | Material type | Polypropylene | Not tested chemically | | | |
| 2. | Category | Non-woven | Non-woven | | | |
| 3. | Appearance | Regular | Regular | | | |
| 4. | Strip width for 80 mm pipe | 310 mm | 321 | 322 | 325 | 324 |
| 5. | Thickness | > 3 mm | 4.90 | 4.21 | 3.75 | 4.99 |
| 6. | Mass per unit area (gsm) | >300 g $m^{-2}$ | 407 | 370 | 360 | 520 |
| 7. | Apparent opening size (O90) | >300 micron | 390 | 340 | 165 | 160 |

Table 11. Test results of woven nylon sock filter

| S. No. | Test Parameter | Reference Value/ Guideline | Test Results (WCA-3) |
|---|---|---|---|
| i) | Material | Nylon | Nylon |
| ii) | Category | Woven | Woven |
| iii) | Appearance | Regular | Regular |
| iv) | Thickness | ≤ 1 mm | 0.30 |
| v) | Pore size (mesh) | ≤ 60 mesh | 42 |

drain pipes of SSD systems. During the year, four 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 results showed that two non-woven polypropylene filter samples (NWCA-1 & 2) from *M/s CA Polytech Pvt Ltd*, Gaziabad met all three criteria and were recommended for use in SSD projects in Haryana (Table 10) whereas two non-woven polypropylene filter samples from *M/s Parishudh Fibres (P) Ltd,* Jaipur failed to meet the apparent opening size (O90) criterion and were not recommended to use. Further, one woven nylon sock filter samples (WCA-1) collected from M/s *CA Polytech Pvt Ltd*, was tested for their suitability for collector pipes in terms of thickness, mass per unit area and pore size (mesh< 60) and met all three criteria and was recommended for use in SSD projects in Haryana (Table 11). These methodologies have worked well for suitability of geosynthetic filters for waterlogged saline alluvial soils in North-west India, and criteria value for non-woven geosynthetic filters for waterlogged saline heavy soils were 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)

Saline groundwater within the crop root-zone restricts plant growth drastically. The improvement in physico-chemical condition is inevitable for sustainable crop production in waterlogged saline environment. Subsurface drainage (SSD), an effective technology practised extensively, can be an effective option for amelioration of waterlogged saline irrigated soils. However, proper design, installation and operational management of SSD system are the key factors in success of the SSD

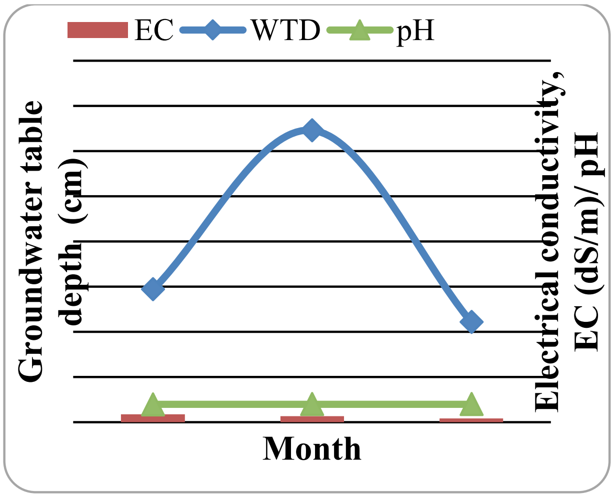



Fig 22. Temporal changes in water table and salinity in observation well of functional block-2

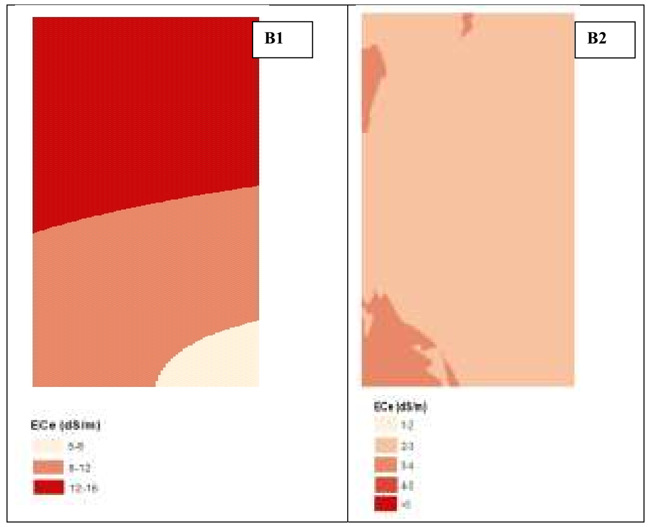



Fig 23. Spatial soil salinity map of non functional (B1) and functional (B2) SSD blocks

project in the field. Improper design and management may lead to accelerated losses of irrigation water, nitrogen and other nutrients and water quality issues at the downstream open drains. Further, irrigation water quality from canal, open drain or drainage effluent reuse affects soil salinity of the project area which needs to be monitored regularly. In order to evaluate the performance of installed subsurface drainage system, soil and water quality was monitored on spatio-temporal scale at Kahni SSD site situated in Rohtak district of Haryana. For this purpose, SSD block-2 was considered as operational with farmers own efforts and the performance indicators were compared with SSD block-1 where pumping was not started yet.

The impact of SSD system on water table depth and improvement in water quality can be visualized from the data presented in Fig. 22. The water level was at about 59 cm below the ground level (bgl) in the month of January 2020, which went down to 129 cm bgl in the month of May 2020. During the rainy season of 2020, water level build-up started due to irrigation in rice and rainfall received, which was recorded as 44.4 cm in October 2020. This shows the declining trend for water level during the post-monsoon period. Despite of continuous pumping operation of SSD block, water table fluctuation varied with the season. The upward movement of groundwater level during the 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, relatively higher groundwater level in adjoining SSD blocks might have limited the real benefit of continuous pumping in SSD block-2. From the Fig. 22, it is clear that EC value of water samples collected from the observation wells installed in the functional SSD block decreased from 3.56 dS $m^{-1}$ (January, 2020) to 1.77 dS $m^{-1}$ (October, 2020). The continuous decline in electrical conductivity value shows the benefit of SSD system. Mapping of soil salinity reveals that soil salinity (0-90 cm depth) in the functional block (B2) was less than 4 dS $m^{-1}$ while salinity level in the entire non-functional block (B1) was found $\geq$4 $dSm^{-1}$ (Fig 23). The soil salinity level of > 8 $dSm^{-1}$ was found in about 50% area of block- B1 which is considered as very high for good crop production.

**Salinity management through drip irrigation, raised bed and mulch condition for crop production** (Bhaskar Narjary, Satyendra Kumar, R.K. Fagodiya and Raj Mukhopadhyay)

For effective utilization of saline water and sustainability of the environment, there is a need to shift from conventional to resource efficient technologies. Based on these, a project was initiated with drip irrigation in raised bed and flat bed with mulch treatment in salt-affected soils. The experiment was conducted at Nain Experimental Farm (Panipat) with two treatments in main plot i.e drip irrigated flat bed and raised bed system and 4 saline irrigation water treatments comprising EC of 12, 9, 6 dS $m^{-1}$ and best available water (~ 4 dS $m^{-1}$) in the farm combination in subplots in pearl millet-wheat cropping system. In wheat season 2019-20, significant difference in the biomass and yield was observed with saline water irrigation treatments. In saline irrigation treatments, the highest grain and biomass (5.07 and 14.05 t $ha^{-1}$) was observed in the plots irrigated with low saline water (BAW~4 dS $m^{-1}$), followed by 6 dS $m^{-1}$ saline water (4.84 and 12.86 t $ha^{-1}$), followed by 9 dS $m^{-1}$ saline water (4.55 and 11.49 t $ha^{-1}$) and least in 12 dS $m^{-1}$ (4.39 and 10.18 t $ha^{-1}$). The significant reduction in biomass and yield observed in saline irrigation treatments was mainly due to salinity stress and reduction on osmotic pressure in plant root zone. In between the main plots, the highest biomass and grain yield was recorded in the raised bed plots (12.44 and 4.74 t $ha^{-1}$) as compared to the flat bed plots (6.79 and 11.85 t $ha^{-1}$). Irrigation water productivity (t-ha/cm) was more in the raised bed system (2.71) than flat bed system (2.68). In saline irrigation treatments, the highest irrigation water productivity (2.91) was observed in the plots irrigated with low saline water (BAW~4 dS $m^{-1}$), followed by 6 dS $m^{-1}$ saline water (2.76), and followed by 9 dS $m^{-1}$ saline water (2.6) and least in 12 dS $m^{-1}$ (2.51). In the *Kharif* season pearl millet (2020), no significant difference in yield was observed in the raised bed and flat bed systems, but significant difference was recorded in saline irrigation treatments (Table 12). In saline irrigation treatments, the highest grain yield (2.89 t $ha^{-1}$) was observed in the plots irrigated with low saline water (BAW~4 dS $m^{-1}$), followed by 6 dS $m^{-1}$ saline water (2.53 t $ha^{-1}$), followed by 9 dS $m^{-1}$ saline water (2.08 t $ha^{-1}$) and the least in 12 dS $m^{-1}$ (1.88 t $ha^{-1}$).

Table 12. Effect of saline drip irrigation water on yield, biomass and water productivity in pearl millet–wheat cropping system under raised bed and flat bed in saline environment

| Wheat Yield (t $ha^{-1}$) | | | | | Pearl Millet Yield (t $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Salinity (dS $m^{-1}$) | | | | Salinity (dS $m^{-1}$) | | | |
| Factor | BAW (EC< 4) | 6 EC | 9 EC | 12 EC | BAW (< 4EC) | 6 EC | 9EC | 12 EC |
| Raised bed | 5.18 | 4.91 | 4.55 | 4.3 | 2.95 | 2.43 | 2.08 | 1.89 |
| Flat bed | 4.96 | 4.77 | 4.55 | 4.48 | 2.82 | 2.64 | 2.09 | 1.87 |
| Wheat Biomass t $ha^{-1}$) | | | | | Pearl Millet Biomass (t $ha^{-1}$) | | | |
| | Salinity (dS $m^{-1}$) | | | | Salinity (dS $m^{-1}$) | | | |
| BAW (EC < 4) | 6 EC | 9 EC | 12 EC | BAW (EC < 4) | 6 EC | 9EC | 12 EC | |
| Raised bed | 14.29 | 13.33 | 11.79 | 10.36 | 7.17 | 6.7 | 6.04 | 4.78 |
| Flat bed | 13.81 | 12.38 | 11.19 | 10 | 5.97 | 5.49 | 5.48 | 4.72 |
| Wheat Irrigation Water Use efficiency (t-ha/cm) | | | | | Pearl Millet Irrigation Water Use efficiency (t-ha/cm) | | | |
| | Salinity (dS $m^{-1}$) | | | | Salinity (dS $m^{-1}$) | | | |
| Factor | BAW (EC < 4) | 6 EC | 9 EC | 12 EC | BAW (EC < 4) | 6 EC | 9EC | 12 EC |
| Raised bed | 0.296 | 0.281 | 0.26 | 0.246 | 7.87 | 6.47 | 5.53 | 5.03 |
| Flat bed | 0.283 | 0.273 | 0.26 | 0.256 | 7.52 | 7.04 | 5.57 | 4.98 |

**Methodology for rapid detection, characterization and 3-D representation and risk zone identification of salinity hot spots in Rohtak district** (Bhaskar Narjary, Raj Mukhopadhyay, Arijit Barman and D.S. Bundela)

Soil salinity monitoring is prerequisite for preventing soil salinization and to take timely decisions on reclamation and salinity management. Remote sensing technology provides a viable and cost-effective alternative to traditional field work due to its large area coverage, multiple spectra information and nearly constant observation. However, soil salinity area detected by optical remote sensing needs lots of measured soil salinity data for validation of results. This was time consuming, labor intensive and expensive. The major constraint is related to the nature of the satellite images, which do not allow extracting information from the third dimension of the 3-D soil body e.g., where salts concentrate in subsoil. Electromagnetic induction technique (EMI) is a rapid and reliable technology for determining soil electrical conductivity and has been used for several soil salinity studies. Using electromagnetic induction techniques, more information can be gathered in a less time than obtained from a single sampling point. Based on this hypothesis, a research work has been taken up to develop methodologies for soil salinity determination using optical remote sensing and geophysical electromagnetic induction techniques. Rohtak district, Haryana, one of most salt-affected district in India was selected for this purpose. For rapid detection of salinity through remote sensing and electromagnetic techniques in Rohtak district, a base map was prepared (1:50,000 scale) and delineated important features such as settlements, road, railways, forest and canal (Fig. 24). SRTM DEM covering the Rohtak district was processed and important features i.e. natural stream lines, slope, 3D view and contour map of the study area was extracted. Landsat-8 and Resourcesat LISS-4 satellite imageries were processed for false colour composite (FCC) and the supervised and unsupervised classification was done (Fig. 25). For rapid detection and risk zone of salinity identification in Rohtak district, Landsat-8, Resourcesat LISS-4 and sentinel-2 imageries of 2018, 2019 and 2020 were processed for the atmospheric and radiometric correction. The FCC and surface reflectance of each imagery was extracted and the classification (supervised and

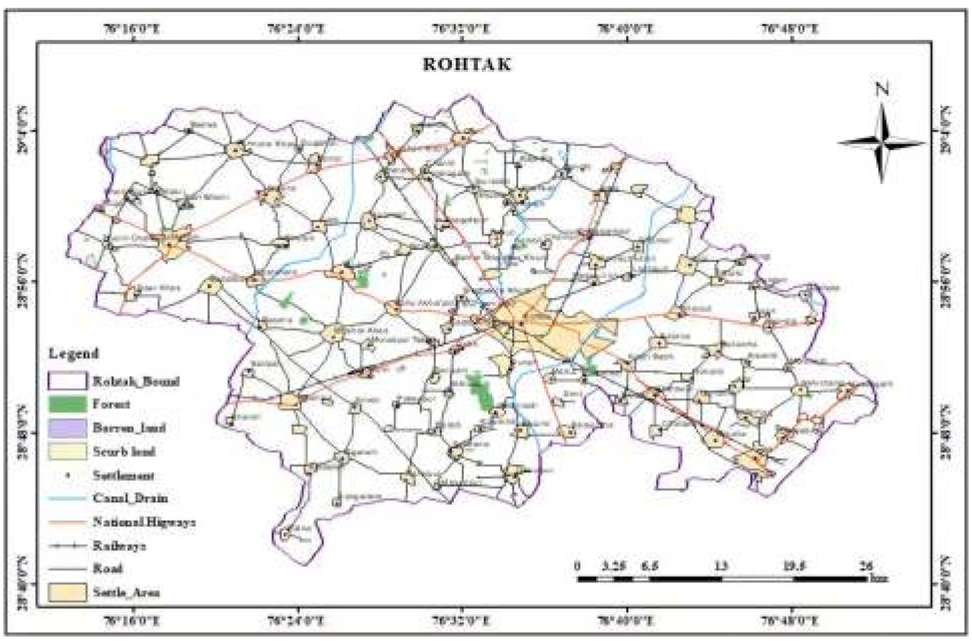



Fig 24. Base/topographic map of Rohtak district showing different features-road, railways, forest and canal etc.

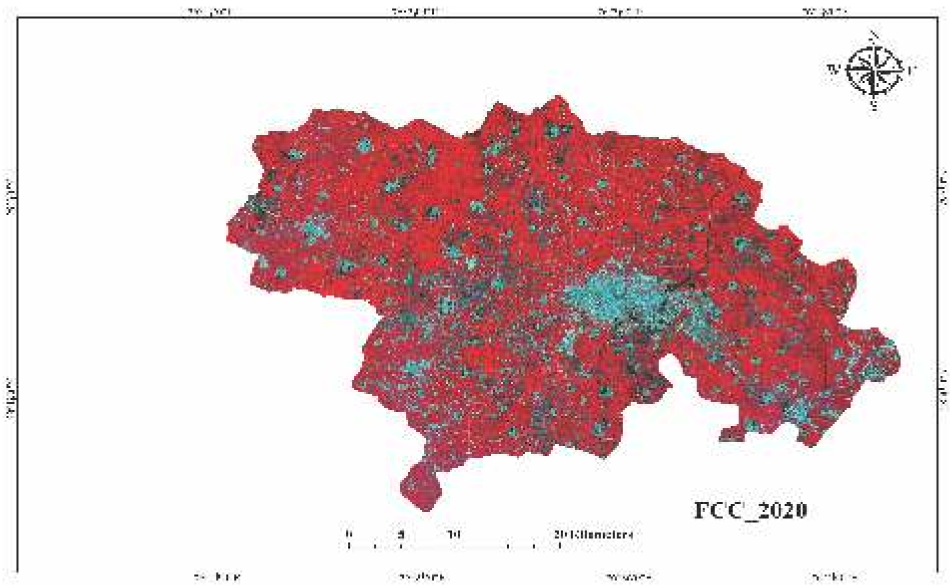



Fig 25. False Color composite map of Rohtak District, Haryana, India in March, 2020.

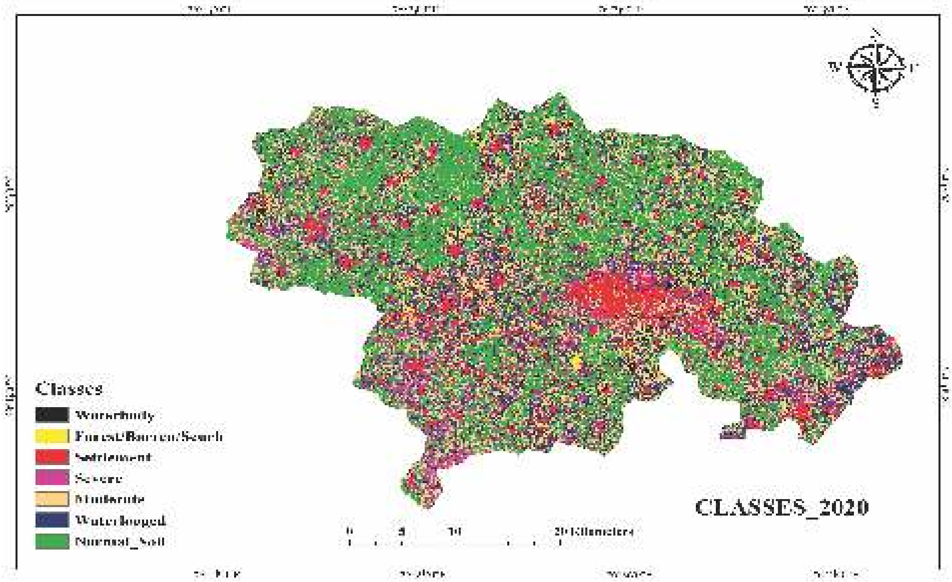



Fig 26. Land use and land cover classification map of Rohtak District, Haryana

unsupervised) was done (Fig. 26). 30 salinity Indices namely NDVI, NDSI, Normalized brightness index, VSSI etc were prepared which have the potentiality to estimate salinity from satellite data. Electromagnetic induction survey (EMI) for rapid assessment of soil salinity was carried out at Kahni, Rohtak. EMI reading in Vertical mode ranges between 4-34.4 dS $m^{-1}$ and horizontal mode ranges between 3.3-39.1 dS $m^{-1}$.

**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 of 24 crops (vegetables, cereals, oilseeds and others) from four AICRP (SAS&USW) Centres at Agra, Bapatla, Bikaner, and Hisar working on use of saline groundwater for irrigation were collected. Overall 359 observations (238 related to drip irrigation and 121 related to surface irrigation) were considered for estimation of the mean crop yield under drip and surface irrigation. Overall, the mean crop yield was 57% higher under drip (14.56 t $ha^{-1}$) as compared to surface irrigation (9.23 t $ha^{-1}$)

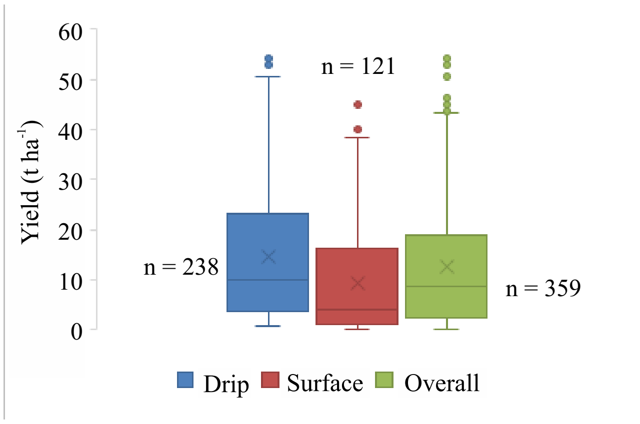



Fig 27. Crop yield under drip, surface, and overall (drip + surface) irrigation methods using poor quality saline water.

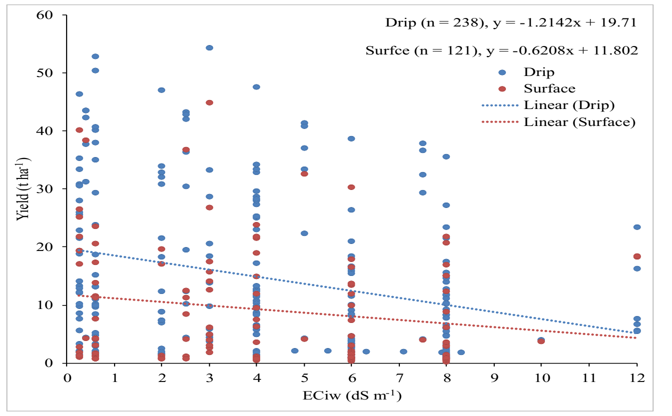



Fig 28. Salinity-yield relations between crop yield and irrigation water salinity under drip and surface irrigation.

using saline water (Fig. 27). Salinity-yield relationhips between the crop yield and irrigation water salinity were developed and salinity values for 90, 75 and 50% relative yields were worked out (Fig. 28). The salinity limits of irrigation water for 90, 75 and 50% relative yields were higher in drip irrigation (5.4, 7.2, and 10.6 dS $m^{-1}$) as compared to the surface irrigation (4.7, 6.9, and 10.2 dS $m^{-1}$). The comparative study of drip and surface irrigation methods showed that crops tolerated higher level of water salinity under drip irrigation. This indicated that crops respond differentially to water salinity under drip and surface irrigation methods. The results can be helpful for the development of guidelines for the use of poor quality groundwater for irrigation using drip system.

### Long-term impact of SSD system on clay mineralogical transformation, physico-chemical properties and hyperspectral signatures of waterlogged saline soils under Inceptisol and Vertisol (Raj Mukhopadhyay, Bhaskar Narjary and Arijit Barman)

Soil salinity, a major component of land degradation, is considered as one of the prime global challenges in the 21st century. The extent of saline soils in India is 2.95 million hectare (Mha) out of which Maharashtra and Haryana covers around 0.2 Mha and 48,000 ha, respectively. Sub surface drainage (SSD) is one of the most important technologies to reclaim waterlogged saline soils. The basic information on clay mineralogical characteristics along with variable physico-chemical nature of these waterlogged saline soils before and after implementation of SSD system is lacking. Additionally, the information is unavailable on the old SSD sites where SSD performance has been stopped and there is a strong rebuild-up of soil salinity. Keeping the above views, five sites were selected under Inceptisol of Haryana where SSD system has been

Table 13. ECe (dS $m^{-1}$) and pHs of profile soil samples of different long-term SSD sites

| Depth (cm) | Sampla (15 years) | | Jagsi (12 years) | | Siwana Mal (8 years) | | Kahni (2 years) | | Kahni (without SSD) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ECe | pHs | ECe | pHs | ECe | pHs | ECe | pHs | ECe | pHs |
| 0-15 | 5.25±0.1 | 8.04±0.05 | 1.39±0.15 | 7.83±0.05 | 1.23±0.09 | 7.97±0.05 | 3.79±0.5 | 7.74±0.10 | 16.96±2.57 | 7.50±0.02 |
| 15-30 | 4.09±0.05 | 8.07±0.08 | 1.01±0.07 | 7.75±0.04 | 0.96±0.04 | 7.85±0.04 | 3.32±0.1 | 7.83±0.03 | 6.98±0.09 | 7.73±0.02 |
| 30-60 | 3.47±0.15 | 8.03±0.02 | 0.88±0.07 | 7.77±0.03 | 0.92±0.03 | 7.64±0.05 | 4.04±0.06 | 7.86±0.05 | 4.06±0.2 | 7.59±0.03 |
| 60-90 | 3.62±0.6 | 8.05±0.02 | 0.87±±0.04 | 7.58±0.06 | 1.00±0.03 | 7.71±0.06 | 3.49±0.04 | 7.70±0.04 | 3.92±0.4 | 7.51±0.04 |
| 90-120 | - | - | 0.85±0.04 | 7.53±0.03 | 1.10±0.09 | 7.77±0.04 | 3.22±0.1 | 7.56±0.06 | 3.18±0.2 | 7.48±0.02 |

'-' indicates unavailability of data due to shallow water table '±' indicates standard deviation

Soil profile of waterlogged saline soil in Kahni, Rohtak

performed namely: Sampla (15 years old), Kahni (2 years old), Kahni (control: without SSD) in Rohtak district, Siwana Mal (8 years old) in Jind district and Jagsi (12 years old) in Sonipat. The $EC_e$ of the soil profile in Sampla varied from 5.25 to 3.62 dS $m^{-1}$ in surface soil (0-15 cm) to the deeper soil profile (60-90 cm), while the $pH_s$ (>8.0) didn't vary significantly throughout the soil profile (Table 13). This suggested that there is a strong rebuild up of salinity has occurred in Sampla due to non-performance of SSD pumping since 2000. In contrast, SSD is still being performed on regular basis in Jagsi and Siwana Mal and the $EC_e$ of those sites were well below the range of waterlogged saline soils. The $EC_e$ of Jagsi and Siwana Mall varied from 1.39 to 0.89 and 1.23 to 1.10 dS $m^{-1}$ throughout the soil profile, respectively (Table 13). However, the $pH_s$ of these two sites were below 8.0. The SSD has just started working in Kanhi, Rohtak since 2018 and the initial $EC_e$ of the waterlogged saline soil varied from ~17.0 to 3.0 dS $m^{-1}$ from surface to deeper soil profile. The implementation of SSD has reduced the soil $EC_e$ to 3.79 dS $m^{-1}$ of the surface soil (0-15 cm), while the $pH_s$ of the site remain almost unchanged throughout the soil profile. This study indicates that the pumping of SSD should be performed on regular basis in order to avoid rebuild up of soil salinity and needs further investigation of those older sites which have already been reclaimed long ago.

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

Natural farming' refers to a farming approach that emphasizes the importance of co-production of crops relying on easily available 'ingredients' to build up soil fertility and microbial population. The approach is built on the 'four wheels' of Low Budget Natural Farming (LBNF)- (1) stimulation of microbial activity to make nutrients available to plants and protect against pathogens using a microbial inoculum, '*jivamrita*'; (2) supply of plant nutrients through organic fertilizer prepared using 'indigenous' cow dung, cow urine, jaggery and pulse meal, '*ghanajivamrita*'; (3) production of stabilized soil organic matter and conservation of top-soil by mulching '*acchadana*' and (4) soil aeration ('*whapahasa*') by improving soil structure and reducing tillage. The inputs made from locally

Experimental view of different scenarios of LBNF project at Research Farm, Karnal

available materials like cow dung and urine, pulse flour, buttermilk etc., therefore, farmers can easily arrange the raw materials and make these inputs on their own farms that will ultimately reduce the cost of external high cost chemicals used for farming. Many of the farmers reported to get benefitted with the adoption of the LBNF, but no scientific study is available regarding this. Hence, a field experiment was initiated at four locations for comparing the conventional farming (chemical inputs) system with LBNF treatments in order to evaluate the fulfilments of nutrient demand (macro and micro nutrients), yield gap and soil quality under different cropping systems of different agro-ecological regions of India.

### Karnal (Haryana)

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

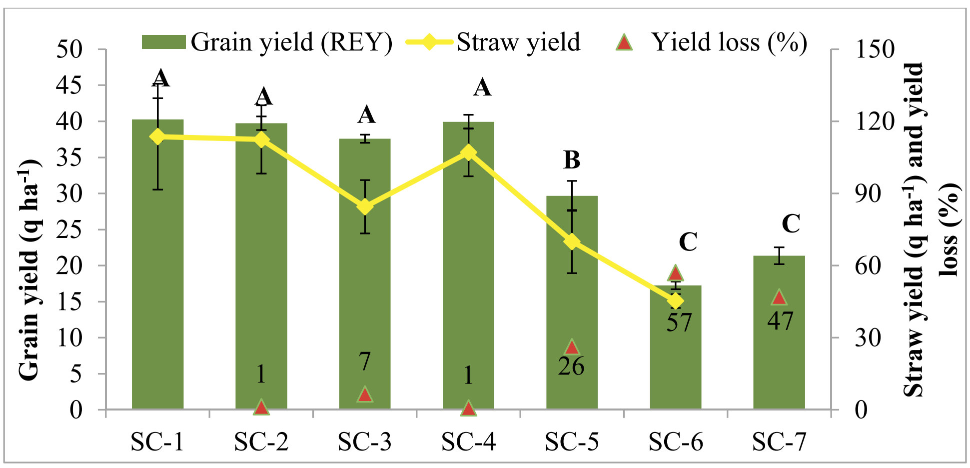



Fig 29. Straw, rice equivalent grain yield (q ha$^{-1}$) and yield loss (%) under different scenarios

Maize (CT)- ZTW- ZTD with full residue retention and nutrients source through LBNF components. The experimental results for the *Kharif* season (rice and maize) suggested that the grain yield under Sc-1, 2, 3 and 4 was at par and ranged between 3.76 to 4.027 t $ha^{-1}$. However, under Sc-5, Sc-6 and Sc-7 of LBNF components, the grain yield lowered significantly by 26, 57 and 47%, respectively, as compared to the conventional R-W system (Sc-1) (Fig. 29). Under Sc-7 the maize yield was converted into rice equivalent yield (REY). Similarly, rice straw yield under Sc-1, Sc-2 and Sc-4 was in the range of 10.7-11.4 t $ha^{-1}$. However, the lowest straw yield (4.5 t $ha^{-1}$) was observed under Sc-6 with direct seeded rice under LBNF components as nutrient source followed by Sc-5 with transplanted rice under LBNF components (7.0 t $ha^{-1}$) and Sc-3 (8.4 t $ha^{-1}$) (Fig. 29).

### Lucknow (UP)

A field experiment of the LBNF project was conducted with rice (CSR-46) at the Shivari Research Farm of ICAR-CSSRI RRS Lucknow. Six treatments among which 2 treatments (viz; Sc-1 and Sc-2) were based on recommended chemical input-based farming practices whereas 4 treatments viz Sc3 (LBNF component only), Sc4 (LBNF component + Green Mannuring), Sc5 (LBNF component + CSSRI bioformulations) and Sc6 (LBNF component + Dhaincha + CSSRI bioformulations) were based on package and practices of natural farming were taken. The soil oxidizable organic carbon (OC) and available nitrogen content were having similar levels under Sc-4, 6, 1 and 5 initially whereas Sc-3 had the highest level of OC. In terms of available N content, Sc-1 had the highest level of available N whereas remaining scenarios had similar levels of available N). Soil enzymatic activity in terms of dehydrogenase activity was found to be most sensitive in defining the effect of application of natural farming components as well as chemical inputs in soil microbial biomass changes. It was found that initial levels of dehydrogenase activity in all the selected treatments were similar,the recorded dehydrogenase activities ranged from ~54 to 76.9 International Unit (IU). The scenarios receiving natural farming components registered the highest increase in the dehydrogenase activity and among them Sc-4 (125.26 IU) and Sc-6 (124.56 IU) had the statistically significant increase in dehydrogenase activities. The results of the dehydrogenase activity imply that incorporation of Jivamrit in the soil has an influence on enriching the soil microbial population *vis a vis* improvement in soil organic matter reserves. Hence, Jivamrit was acting as soil conditioner for improving overall health of the soil. The grain yield per plot obtained after the completion

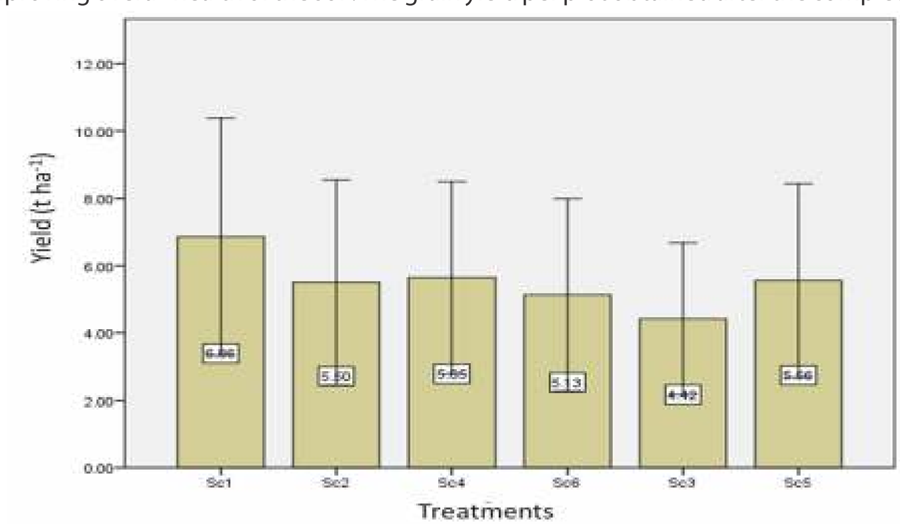



Fig 30. Crop yield obtained under various treatments of chemical based farming and natural farming based agriculture practices

of the field experiment indicated that Sc-1 (chemical farming control) showed the maximum yield of approximately 6.8 t (±3.9) $ha^{-1}$, whereas Sc-4 (among LBNF) showed the highest yield of 5.64 t (±3.2) t $ha^{-1}$ (Fig 30).

## Canning (West Bengal)

A field experiment was initiated during the *Kharif* 2020 at ICAR-CSSRI RRS, Canning Town to evaluate the components of Low Budget Natural Farming under coastal agro-ecosystem. The experiment consisted of the following scenarios- S1: Rice-Maize-Fallow (CT-CT) (Rice-transplanted, maize-dibbling, all residue removed, Nutrient: farmers' recommendation); S2: Rice-Maize-Dhaincha (CT-ZT-ZT) (Rice-transplanted, maize-dibbling, dhaincha-broadcast; full rice and maize leaf residue retained, dhaincha incorporated; rice – RDF, maize – RDF); S3: Rice-Maize (CT-ZT) (Rice-DSR, maize-dibbling, full rice and maize leaf residue retained; rice – RDF, maize – RDF (N through FYM + CSSRI Formulation)); S4: Rice-Maize (CT-ZT) (Rice-DSR, maize-dibbling, full rice and maize leaf residue retained, Nutrient: 50% through organic & 50% through inorganic); S5: Rice-Maize-Dhaincha (CT-ZT-ZT) (Rice-transplanted, maize-dibbling, dhaincha-broadcast, full rice and maize leaf residue retained, dhaincha incorporated; Nutrients – Nil; Low budget natural farming (LBNF)); S6: Rice-Maize-Dhaincha (ZT-ZT-ZT) (Rice- unpuddled transplanted, maize-dibbling, dhaincha-broadcast, full rice and maize leaf residue retained, dhaincha retained; Nutrients – Nil; Low budget natural farming (LBNF); S7: Rice-Maize-Dhaincha (CT-CT-CT) (Rice-transplanted, maize-dibbling, dhaincha-broadcast, anchored rice and maize leaf residue retained, dhaincha incorporated; Nutrients: rice – 50% RDF, maize – 50% RDF; Low budget natural farming (LBNF). The plot size was 6.5 m × 11.5 m. In addition, one large plot of 10 m x 50 m was also used for laying out of scenario S5. The soil of the experimental site had pH of 6.9 and ECe of 4.85 dS $m^{-1}$ which is highly variable being the lowest during rainy season and the highest during the dry season. The organic carbon content in the soil was 0.78% and was low in available N (208.6 kg $ha^{-1}$), medium in available phosphorus (16.4 kg $ha^{-1}$) and high in available potassium (570 kg $ha^{-1}$). During the *Kharif* 2020, rice (Amalmana) was grown as per the seven scenarios. It was observed

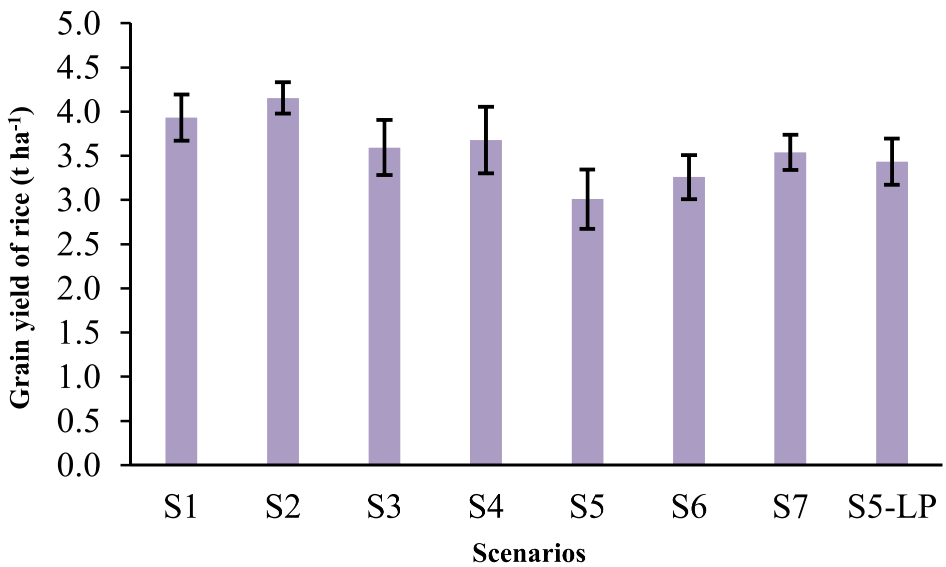



Fig 31. Grain yield of rice (variety – Amalmana) under differrent scenarios

that the highest grain yield of rice was obtained under Scenario S2 (4.15 t ha$^{-1}$) followed by Scenario S1 (3.93 t ha$^{-1}$). The lowest yield was obtained in Scenario S5 with LBNF components (3.01 t ha$^{-1}$) (Fig. 31). Addition of N @ 50% RDF along with LBNF components gave slightly better yield (3.54 t ha$^{-1}$) as compared to S5 and S6 (3.26 t ha$^{-1}$) scenarios with LBNF components. It was also observed that in Scenario S5 (S5-LP) laid out in a larger plot of 500 m$^2$, the yield obtained was relatively higher (3.43 t ha$^{-1}$) in comparison to S5. However, there was no significant difference in the yield obtained under various scenarios.

### Bharuch (Gujarat)

An experiment was planned with randomized block design with three replications and six treatments with a plot size of 500 m$^2$ area. Two cropping systems- cotton-fallow and sorghum-wheat were taken with farmer's practice (using chemical fertilizers and insecticides) and conventional tillage, so these two treatments will act as control to get compared with LBNF treatments. These two cropping systems were also taken up with LBNF practices i.e. green manuring, crop and nutrient management with LBNF components with minimum tillage. Same cropping systems with LBNF treatments also were taken with conventional tillage to evaluate feasibility of minimum tillage in *Vertisols*. Details of the treatments are given in Table 14.

Waterlogged field during the Kharif 2020

### Kharif Season Experiment

In the *kharif* 2020, dhaincha crop for the green manuring was sown in the month of June 2020. Sowings of cotton and sorghum crops were delayed (first week of August 2020) due to heavy rainfall (167 mm) in the month of July. Again after sowing there was continuous and heavy rainfall in the month of August 2020 (376 mm with 20 rainy days). Due to heavy rainfall and low infiltration rate of the *Vertisols,* waterlogging condition was prevailed for prolong duration in the experimental area. Provision for the drainage in the field was also tried but it didn't work and the *kharif* crops failed due to submergence.

Table 14. Details of the treatments at Bharuch (Gujarat)

| Scenarios (SC) | Crop Rotations | Tillage | Mulching with green manure crop | Nutrient (NPK) Management | |
|---|---|---|---|---|---|
| | | | | Quantity (kg ha$^{-1}$) | Source |
| SC-1 | Cotton-fallow | Conventional tillage | - | 80:40:00 | 100% through chemical fertilizers |
| SC-2 | Sorghum-wheat | Conventional tillage | - | Sorghum: 80:40:00 Wheat: 120:60:00 | 100% through chemical fertilizers |
| SC-3 | Cotton-fallow | Conventional tillage | Green manure mulching | According to LBNF recommendations | LBNF Components |
| SC-4 | Cotton-fallow | Minimum tillage | Green manure mulching | According to LBNF recommendations | LBNF Components |
| SC-5 | Sorghum-wheat | Conventional tillage | Green manure mulching | According to LBNF recommendations | LBNF Components |
| SC-6 | Sorghum-wheat | Minimum tillage | Green manure mulching | According to LBNF recommendations | LBNF Components |

# 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 (A.K. Rai, Nirmalendu Basak, Satyendra Kumar, Bhaskar Narjary and Gajender Yadav)

Conservation tillage, deficit irrigation (DSI) and crop residue mulching approaches were effective in managing the crop water requirement with 40% saving of irrigation water and reduced salt loading under saline water irrigation (ECiw 16 dS $m^{-1}$). Low water requiring cropping system with rainfed kharif and irrigated rabi responded to application of high saline SAR water application. Wheat yield showed declining pattern of yield with increasing amount of water application. Though yield reduction was non-significant in wheat, but residual effect of high SAR saline water application was evident on performance of the subsequent rainfed sorghum. The 100WR caused significant reduction in the green and dry forage yield compared to 80WR and 60WR. Effect of mulching was visible on the both the component crops with significant increase in the yield of the wheat and sorghum under mulching compared to no mulch (Table 15). Tillage had non-significant effect on yield. But, wheat yield was lower and sorghum yield was greater in ZT compared to other tillage practices. High saline water irrigation led to the increase in salinity of the 100WR compared to deficit (80 and 60WR) saline water irrigation (Table 16). Mulch showed significantly lower ECe compared to no mulch. High SAR water application caused slight increase in soil pHs compared to the

Table 15. Effect of tillage, irrigation and mulch on the yield of sorghum and wheat

| Treatments | Wheat grain (t $ha^{-1}$) | Sorghum grain (t $ha^{-1}$) | Sorghum dry fodder yield (t $ha^{-1}$) |
|---|---|---|---|
| **Tillage** | | | |
| ZT-RT | 4.333 | 37.856 | 12.727 |
| CT-CT | 4.750 | 33.233 | 11.277 |
| ZT-ZT | 4.022 | 44.278 | 14.995 |
| SEm± | 0.613 | 4.914 | 1.651 |
| CD | NS | NS | NS |
| Irrigation | | | |
| 100WR | 4.139 | 36.5B | 12.285B |
| 80WR | 4.222 | 39.322A | 13.315A |
| 60WR | 4.444 | 39.544A | 13.399A |
| SEm± | 0.427 | 3.571 | 1.236 |
| CD | NS | 2.15 | 1.024 |
| Mulch | | | |
| No Mulch | 4.037B | 32.985B | 11.115B |
| Mulch | 4.50A | 43.926A | 14.884A |
| SEm± | 0.349 | 2.916 | 1.009 |
| CD | 0.513 | 5.955 | 2.061 |

Different letters (A, B) denote significant differences ($P \leq 0.05$, DMRT). WR-Percent water requirement.

Table 16. Influence of tillage, mulch and saline irrigation on soil pHs and ECe (dS $m^{-1}$) after sorghum harvest

| Treatments<br>Tillage | pHs | ECe (dS $m^{-1}$) | SARe |
|---|---|---|---|
| ZT-RT | 8.18B | 6.25 | 9.71 |
| CT-CT | 8.42A | 5.77 | 11.28 |
| ZT-ZT | 8.30AB | 6.51 | 10.75 |
| SEm± | 0.06 | 0.47 | 0.96 |
| CD | 0.16 | NS | NS |
| Irrigation | | | |
| 100 WR | 8.29 | 6.72 | 10.45 |
| 80 WR | 8.33 | 5.92 | 10.36 |
| 60 WR | 8.29 | 5.89 | 10.93 |
| SEm± | 0.03 | 0.62 | 0.72 |
| CD | 0.07 | 1.27 | 1.48 |
| Mulch | | | |
| No Mulch | 8.28 | 6.72A | 11.11 |
| Mulch | 8.33 | 5.63B | 10.04 |
| SEm± | 0.03 | 0.51 | 0.59 |
| CD | 0.05 | 1.04 | 1.21 |
| Analysis of variance | | | |
| Tillage | * | NS | NS |
| Irrigation | NS | NS | NS |
| Mulch | NS | * | NS |
| Irrigation*Mulch | NS | NS | NS |
| Tillage*Irrigation | * | NS | NS |
| Tillage*Mulch | NS | NS | NS |
| Tillage*Irrigation*Mulch | * | NS | NS |

Different letters (A, B) denote significant differences ($p \leq 0.05$, DMRT). WR-Percent water requirement; * significant ($p<0.05$); NS non-significant.

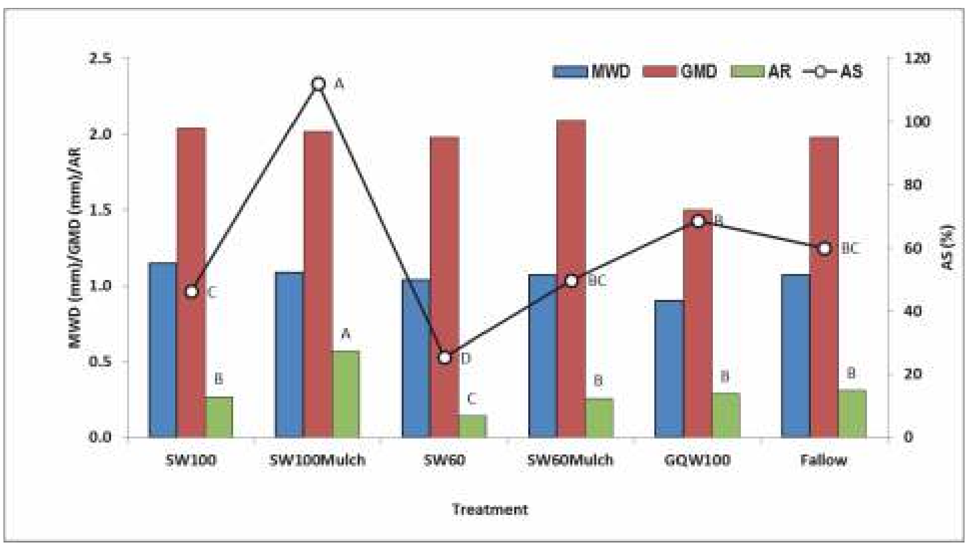



Fig 32. Effect of tillage, mulching and saline irrigation on soil aggregation after 6 years of sorghum-wheat cropping in surface soil (0-0.15 m). (SW100-saline water 100WR; SW100Mulch-saline water 100WR + mulch; SW60- saline water 60WR; SW60Mulch- saline water 60WR + mulch; GQW100-good quality water 100WR; Different letters (A, B) denote significant differences ($p \leq 0.05$, DMRT)

initial values (8.2). After six years of the cropping under sorghum-wheat cropping system effect of saline water irrigation and mulching under ZT was evaluated in comparison to fallow and good quality water irrigation without mulch with conventional tillage. Distribution of the aggregate was affected by saline irrigation and mulching. Good quality water application had aggregate distribution similar to fallow field. MWD and GMD was not affected by tillage, saline water irrigation and mulch. But aggregate stability and aggregate ratios were greater in 100WR + mulch compared to other treatments (Fig. 32). The treatments showed higher TOC in macro aggregate compared to micro-aggregate.

**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)

Worldwide occurrence of zinc deficiency in crops has drawn the attention of researchers for improving zinc availability to crops by adopting different management strategies like zinc fertilization, genetic biofortification, appropriate crop rotations and application of zinc solubilizing microbes. In this context, a study was initiated for enhancing zinc nutrition to crops utilizing zinc solubilizing bacteria under salt-affected soils. Based on the results of controlled experiments, *Bacillus paramycoides* strain MCCC 1A04098 (solubilize inorganic compound of zinc in broth,) was selected for evaluation in rice crop under field conditions at two sites. Soil $pH_2$ and DTPA zinc at site-I and site II were 9.1 & 8.2; 2.57 and 1.41 mg $kg^{-1}$, respectively. The varieties i.e. PR-126 at Site I and CSR-30 at Site II were taken. Treatments included $T_1$: control, $T_2$: substrate (similar quantity used for inoculation of *Bacillus paramycoides*), $T_3$: *Bacillus paramycoides*, $T_4$: $T_1$ + zinc sulphate (5 kg zinc), $T_5$: $T_2$ + zinc sulphate (5 kg zinc) and $T_6$: $T_3$ + zinc sulphate. At site 1, all the 6 treatments evaluated, however at site II, only the first three treatments evaluated. Grain yield and zinc uptake were superior at site II compared to the site I. Grain yield and zinc uptake did not differ significantly among treatments at both sites (Fig. 33). It might be because native zinc solubilizing microbes contributing equally for zinc solubilization under treatments of control and substrate at both the sites. Furthermore, the initial DTPA zinc in soils was under higher range, therefore crop did not respond to additional zinc.

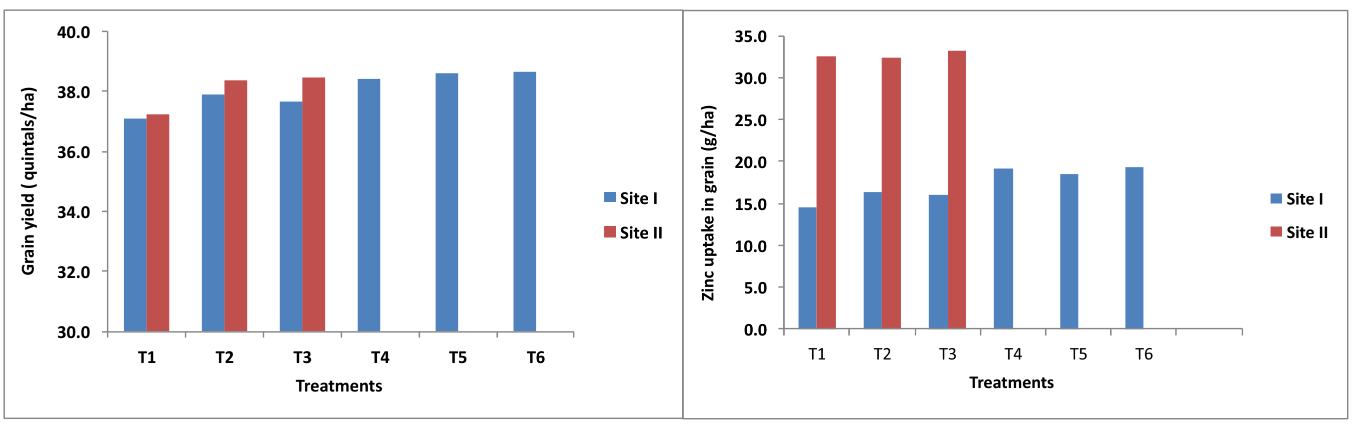



Fig 33. Effect of *bacillus paramycoides* on grain yield and zinc uptake in rice

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

Tomato (NS 4266) seedlings of 40 days old were transplanted on 27 Sept. 2020 in polyhouse beds of 75 cm width with 70 cm spacing between two beds. The seedlings were planted in two rows in each bed. The row to row spacing was maintained at 45 cm in double drip line treatment and 30 cm in single drip line treatments while plant to plant spacing was kept 30 cm in both treatments. Saline water treatments were started at 15 DAP. Water soluble fertilizers NPK (19:19:19) and (0:0:50) were mixed well in overhead water tanks of 300 litres capacity. Calcium nitrate and Magnesium sulphate nutrients were applied twice a month and micronutrient mixture was sprayed twice a month. The observations on number of fruits and fruit yield were recorded with each harvesting and observations on fruit length, fruit width, fruit wt/fruit, TSS, and self life span of fruits at room temperature were recorded at regular intervals. Plant height, stem girth and root length was recorded at the end of final harvesting of fruits.

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

The data were analysed statistical using Tukeys test and perusal of data showed that number of fruits/plant, fruit weight/fruit, fruit length and fruit width were found at par with covering of plastic mulch cover while fruit wt/plant was observed significantly higher in no mulch treatment. Plant height (cm) at harvest of tomato plants differ non-significantly and it was 530.25 and 531.29 cm with no mulch and mulch cover respectively. The mean number of fruits/plant 61.6 and 60.1, fruit wt./fruit was 46.7 and 47.7 g, fruit length was 4.65 and 4.74 cm, fruit width was 5.42 and 5.35 cm respectively with no mulch and mulch cover. Fruit wt./plant was 3.14 and 2.87 kg was significantly different with no mulch and mulch cover. As a result of higher number of fruits and fruit weight/plant, fruit yield (t $ha^{-1}$) of tomato was higher with no mulch (129.35 t $ha^{-1}$) as compared to mulch cover (128.85 t $ha^{-1}$) though it was non-significant. TSS (%) of tomato fruits was found non-significantly higher with mulch cover and it was 5.18 and 5.21% with no mulch and mulch cover treatments.

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

After establishments of seedlings for 15 days, saline water irrigation was initiated. Data showed that except tomato fruit length, all other attributes and fruit yield differ significantly with these treatments. No. of fruits was significantly higher with treatment $T_6$ : $EC_{iw}$ 9 dS $m^{-1}$ + DDL) which produced 65.8 fruits/plant followed by 65.44 and 62.9 with treatments $T_4$: $EC_{iw}$ 3 dS $m^{-1}$ + DDL and $T_3$ : $EC_{iw}$ 39 dS $m^{-1}$ + SDL respectively. Fruit weight (g) per fruit was also found significantly higher (50.58 g) with treatment $T_6$ : $EC_{iw}$ 9 dS $m^{-1}$ + DDL) followed by 48.29, 46.99 and 46.8 g with application of $T_1$, $T_4$ and $T_3$ treatments respectively. Fruit weight (kg) per plant was higher with treatment $T_5$ (3.42 kg) which was at par with $T_6$ (3.32 kg) as compared to other treatments. Fruit length differ non-significantly and it ranged between 4.55 cm – 4.82 cm in different treatments. Fruit width differ significantly and it was higher with $T_1$ (5.58 cm) which was at par with the fruit width observed with $T_3$ –$T_6$ treatments except $T_2$. Plant height was measured maximum with $T_2$ (543.75 cm) and significantly minimum with $T_6$ (504.13 cm) Plant height was at par with $T_2$-$T_5$ treatments. It means application of saline water of $EC_{iw}$ 9 dS $m^{-1}$ hindered the normal growth of the plant but there was no significant effect on no. of fruits, fruit

Table 17. Effect of mulching and saline water irrigation with single and double dripline system on growth, yield and yield attributes of tomato under naturally ventilated polyhouse conditions.

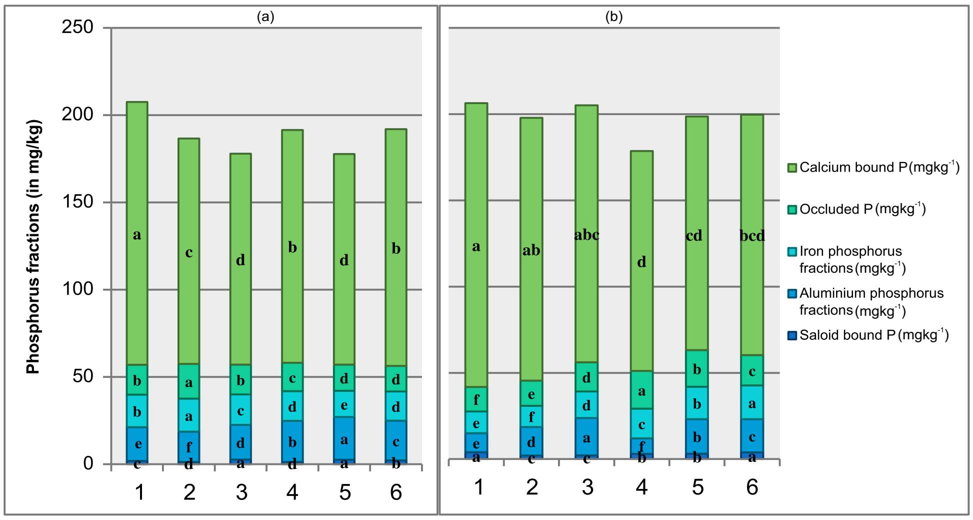
| Treatments | Plant height (cm) | No. of fruits/plant | Fruit Weight (g) | Fruit weight/plant (kg) | Fruit length (cm) | Fruit width (cm) | Fruit yield (t ha-1) | TSS (%) |
|---|---|---|---|---|---|---|---|---|
| Mulching | | | | | | | | |
| No mulch | 530.2 | 61.6 | 46.7 | 3.14a | 4.65 | 5.42 | 129.3 | 5.18 |
| Mulch | 531.3 | 60.1 | 47.7 | 2.87b | 4.74 | 5.35 | 128.8 | 5.21 |
| Saline water irrigation + Dripline (Signle/Double) | | | | | | | | |
| ECiw 3 ds/m-SDL | 508.9$^{bc}$ | 55.9$^{c}$ | 48.3$^{ab}$ | 2.7$^{dc}$ | 4.82 | 5.58$^{a}$ | 121.3$^{cd}$ | 5.01$^{c}$ |
| ECiw 6 ds/m-SDL | 543.7$^{a}$ | 55.9$^{c}$ | 45.8$^{bc}$ | 2.56$^{c}$ | 4.61 | 5.17$^{b}$ | 114.9$^{d}$ | 5.03$^{c}$ |
| ECiw 9 ds/m-SDL | 538.1$^{a}$ | 62.9$^{ab}$ | 46.8$^{bc}$ | 2.94$^{cd}$ | 4.81 | 5.5$^{ab}$ | 132.3$^{c}$ | 5.11$^{bc}$ |
| ECiw 3 ds/m-SDL | 556.9$^{a}$ | 65.4$^{a}$ | 47.0$^{bc}$ | 3.08$^{bc}$ | 4.76 | 5.54$^{ab}$ | 138.4$^{ab}$ | 5.24$^{abc}$ |
| ECiw 6 ds/m-SDL | 532.9$^{ab}$ | 59.2$^{bc}$ | 44.8$^{c}$ | 3.42$^{a}$ | 4.55 | 5.19$^{ab}$ | 118.9$^{cd}$ | 5.45$^{a}$ |
| ECiw 9 ds/m-SDL | 504.1$^{c}$ | 65.8$^{a}$ | 50.6$^{a}$ | 3.32$^{ab}$ | 4.64 | 5.32$^{ab}$ | 148.9$^{a}$ | 5.34$^{ab}$ |

weight and fruit yield. Tomato fruit yield differ significantly with different treatments and it was observed that significantly highest fruit yield (148.91 t $ha^{-1}$) was produced with double dripline irrigation and treatments $T_6$: $EC_{iw}$ 9 dS $m^{-1}$ + DDL followed by $T_4$: $EC_{iw}$ 3 dS $m^{-1}$ + DDL (138.45 t $ha^{-1}$) and $T_3$: $EC_{iw}$ 9 dS $m^{-1}$ + SDL (132.05 t $ha^{-1}$). TSS (%) was observed significantly higher in double dripline treatments combined with saline water irrigation and maximum TSS was with observed with $T_5$ (5.45) which was at par with $T_4$ (5.24) and $T_6$ (5.34) treatments (Table 17).

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

Vesicular-Arbuscular Mycorrhiza (VAM) has been shown to promote plant growth and salinity tolerance by many researchers. They promote salinity tolerance by employing various mechanisms, such as enhancing nutrient acquisition, producing plant growth hormones, improving rhizospheric and soil conditions, altering the physiological and biochemical properties of the host and defending roots against soil-borne pathogens. This may lead to increased plant growth and subsequent dilution of toxic ion effect. These benefits of VAM have prompted it to be a suitable candidate for bio-amelioration of saline soils. Hence, an experiment was carried out to evaluate the efficacy of mycorrhiza and salt tolerant *Trichoderma* culture in normal, saline ($EC_e$~8ds $m^{-1}$) and sodic soil ($pH_2$~ 8.6) on wheat and sorghum crops with these treatments (T1: Control; T2: recommended dose of Fertilizer; T3: VAM1+ *Trichoderma*; T4: VAM2+ *Trichoderma*; T5: VAM1+ *Trichoderma*+ $P_{50}$; T6: VAM2 +*Trichoderma* + $P_{50}$). The results of the experiment demonstrated that VAM and *Trichoderma* cultures showed the ability to solubilize phosphorus in normal, saline as well as sodic soils and making it available for crops. In saline soil, T1 (control treatment), the available phosphorus was 12.66 $kgha^{-1}$ which increased upto 14.19 $kgha^{-1}$ in T2 (recommended dose of fertilizer) and which was followed by T5 (13.66 $kgha^{-1}$) (VAM1+ *Trichoderma*+ $P_{50}$). Similarly in the sodic soil, available phosphorus was highest 14.11 $kgha^{-1}$ following T3 (13.66 $kgha^{-1}$) while in T1, it was 11.57 $kgha^{-1}$. VAM and *Trichoderma* also enhance the phosphorus uptake in sorghum and wheat in comparison to control. However, the results were significantly lower than the recommended dose of fertilizer. The mycorrhizal root colonization was also determined. It was assessed by visual observation of fungal colonization in roots. Roots were digested with 10% KOH and

Fig 34. Results demonstrating the effect of Vesicular-Arbuscular Mycorrhizal (VAM) and Trichoderma on different fractions of phosphorus in (a) normal soil (b) saline soil.




1- Control ; 2- recommended dose of Fertilizer; 3- VAM 1+Trichoderma; 4 -VAM2+Trichoderma; 5- VAM 1+ Trichoderma+Fertilizer P50; 6- VAM 2+ Trichoderma +Fertilizer P50

stained with trypan blue and colonization was assessed under microscope. The results of microscopy revealed the fungal colonization inside the roots. Different form of phosphorus in soil was also evaluated and effect of fungi on it was studied. The calcium bound phosphorus was found to be most abundant in both normal and saline soil. Effect of treatment was highest on calcium bound phosphorus as compare to other forms (Fig. 34). Saloid-bound P was generally considered as solution P and it was easily available to plants. Among other inorganic P fractions, saloid-bound P recorded the lowest value. While other forms, Aluminum bound P (Al–P), iron phosphorus fraction (Fe–P) and occluded P remained unaffected by the treatments (Fig. 34).

**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 Yadav, Bhasker Najary and P. C. Sharma)

The problem of salinity especially in poorly drained saline soils is increasing. It needs an 'On farm technology' solution that can be adopted at individual farm/farmer level. Development of low-cost preferential subsurface drainage (PSSD) and irrigation technology in salt-affected fields for sustainable agricultural production are thrust areas of ICAR- Central Soil Salinity Research Institute (CSSRI), Karnal. Cut-soiler machine uses and manages surface scattered crop straw/residue while running on the field. It cuts soil in V-shape. It may help in managing surface water logging, soil salinity, crop residues burning and sub-surface sodicity. In this back ground, ICAR-CSSRI Karnal and Japan International Research Center for Agricultural Sciences (JIRCAS) initiated a collaborative research project to develop sustainable resource management system for water vulnerable and saline arid regions of India. At CSSRI, our research focus is on the development of alternative low cost PSSD in conjunction with efficient irrigation management in saline conditions to evaluate its utility on salt leaching, water saving and nutrient dynamics in field and lysimeter conditions.

The study is being conducted at three locations, simultaneously. The effect of cut-soiler drainage on salt and water dynamics under fluctuating water table along with an irrigation experiment are undertaken at ICAR- Central Soil Salinity Research Institute, Karnal. The field experiment on optimum spacing of construction line by a material-filled subsurface drain machine (Cut-soiler) in salinized fields of arid zone is under progress at Nain Experimental Farm of ICAR-CSSRI at Panipat, Haryana. The feasibly trial effectiveness of Cut Soiler for precision alkalinity management being conducted at five sites in farmers' field in Pattijhugia, kharabgarh and Budhmor villages of Patiala (Punjab).

### Optimum spacing of construction line by a material-filled subsurface drain machine (Cut-soiler) in salinized fields of arid zone

Regular monitoring of weather at Nain farm was recorded by HOBO weather station. In this year, precipitation remained relatively small during rainy as well as October to December. The average Aridity Index was about 0.32 that was 0.44 for year 2018 and 0.20 for the year 2019. GS3 sensors, installed at six depths on regular intervals of 0.32, 0.94 and 1.25 m between material filled variable distance interval Cut-soiler operation lies, were used to continuously record the characteristics of horizontal and vertical water movement, actual electrical conductivity and temperature after each rainfall and/or irrigation in natural field conditions of Nain experimental farm. Construction of Cut-soiler lines prevented salt accumulation especially during dry season and thus reduced the soil salinity in comparison to without Cut-soiler (Fig. 35). Analysis of soil samples for EC, pH, soil moisture, carbonates and bicarbonates suggested that EC ranged 1.14 to 21.82 dS $m^{-1}$ and pH varies from 7.1 to 8.88. The Cut-soiler based preferential drainage reduced soil salinity and thus increased yield of pearl-millet crop. The highest pearl-millet yield (1.81 t $ha^{-1}$) was recorded in 2.5 m spacing followed by 5.0 m (1.39 t $ha^{-1}$), 7.5m (1.22 t $ha^{-1}$) and 10 m (1.16 t $ha^{-1}$) spacing over control (0.89 t $ha^{-1}$).

### Salt and water dynamics in fluctuating shallow saline water table conditions under Cut-soiler drainage: Lysimeter studies

Cut-soiler operation reduced actual soil EC peak, measured by 5TE sensors, at 12 and 50 cm depth decreased by 18.7 and 38.2%, respectively during dry season and rainy season. Cut-soiler operation was found to remove soil salinity ~38.2 % during July to August 2019 (Table 18). Across variable salinity water irrigation, the Cut-soiler operation reduced soil salinity from 3.07 to 2.76 $dSm^{-1}$ during *kharif* season. The trend of decrease in soil salinity remained similar among all i.e 4, 8 and 12 $dSm^{-1}$ irrigation water salinity levels. Salt and water dynamics was also monitored for four irrigation methods *i.e.* border irrigation (Conventional; BI), every furrow irrigation (EFI), and fixed skip furrow irrigation (FSFI) was

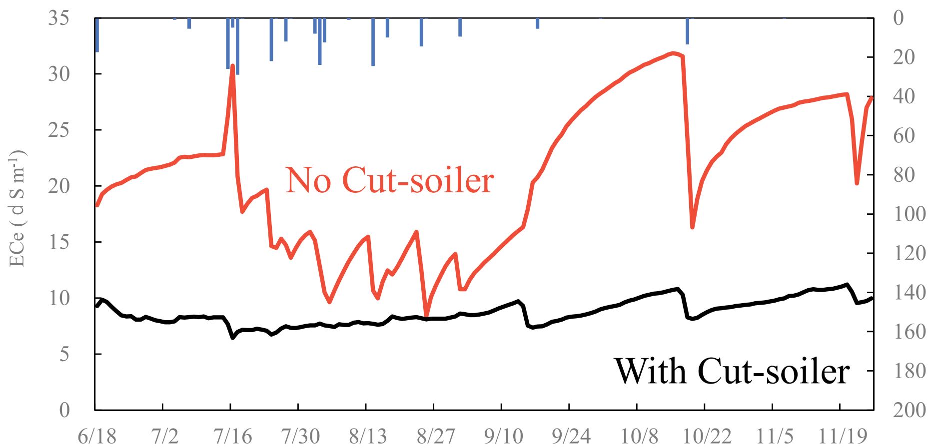



Fig 35. Temporal changes in soil salinity (dS $m^{-1}$) in Cut-soiler and without Cut-soiler plots at Nain Farm Panipat.

Table 18. The reduction in soil salinity with Cut soiler at 12 cm and 50 cm depths

| Peak soil EC ($dSm^{-1}$) at 12 cm depth in dry season | | | |
|---|---|---|---|
| Date | Without Cut-soiler | With Cut-soiler | Reduction Rate (%) |
| 17 Nov 2018 | 7.1 | 6.1 | 14.1 |
| 13 Dec 2018 | 4.9 | 3.4 | 30.9 |
| 25 Jan 2019 | 6.4 | 5.7 | 10.9 |
| Average | 6.1 | 5.1 | 18.7 |
| **Peak soil EC ($dSm^{-1}$) at 50 cm depth in dry season** | | | |
| Duration | Without Cut-soiler | With Cut-soiler | Reduction Rate (%) |
| 04 Jul- 20 Aug | 5.1 | 3.2 | 38.2 |

monitored by 5TE sensors. These were installed at 15, 25, 35, 50, 70 cm depths from the center of ridge and/or 25, 35 cm depths under furrow.

In BI and EFI, the volumetric water content (VWC) remained almost similar and ranged between 0.1 - 0.3 $m^3 m^{-3}$. However, it was lower in surface layer 15cm than the deeper soil depth (50cm). It varied between 0.1-0.2 $m^3m^{-3}$ and consistently maintained at 0.3 $m^3 m^{-3}$ in surface in 15 and 50 cm depth, respectively under FSFI. However, higher bulk soil EC was observed in BI and EFI in comparison to FSFI. As far as water saving was concerned, the EFI and FSFI saved 10 and 55% irrigation water as compared to BI. Even, EFI and FSFI did not cause significant reduction in mustard yield in comparison to BI.

### Feasibly trial on managing sub-surface sodicity: village Budhmor, Patiala, (Punjab)

The Cut soiler was run at 2.5, 5.0 and 10.0 m spacing with straw as surface residue, gypsum and straw+ gypsum. Gypsum and rice straw filled Cut-soiler operation at a depth of 40 cm reduced soil pH and ESP up to lateral distance of 0.7 m from Cut-soiler line (Table 19). Grain and biological yield of wheat increased by ~12% in 2.5 m spacing over control. Rice straw residue and gypsum filled Cut-soiler run at four new sites in farmers' field in Pattijhungia, Kharabgarh and Budhmor villages of Patiala (Punjab).

### Cut-soiler PSSD feasibility in saline Vertisols (Bharuch, Gujarat)


Material filled Cut-soiler based PSSD in Vertisols at CSSRI, RRS, Bharuch Samni Farm.

To study the feasibility of material filled Cut-soiler operation based preferential drainage in combating waterlogging in Vertisols, a field experiment was started at Samani Farm of CSSRI, RRS, Bharuch. Locally available sugarcane bagasse and cotton stalks filled 60 cm deep Cut–soiler lines were constructed at spacing of 2.5, 5.0 and 7.5 m. Spatial-temporal changes in salt and water dynamics and cracking behavior of saline Vertisols will be monitored in due course of time.

Table 19. The effect of spacing of Cut-soiler on soil (ESP %) and wheat yield.

| Cut-soiler spacing | Grain yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Soil ESP (%) at different interval between Cut-soiler lines | | |
|---|---|---|---|---|---|
| | | | 1/8 | 1/4 | 1/5 |
| Control | 4.08 | 9.07 | 24.4 | 23.8 | 24.2 |
| 2.5 m | 4.83 | 10.28 | 18.6 | 20.7 | 23.4 |
| 5.0 m | 4.52 | 9.91 | 20.3 | 21.9 | 24.1 |
| 10.0 m | 4.12 | 8.96 | 22.8 | 23.6 | 23.9 |
| CD (p=0.05) | 0.58 | 1.02 | -- | -- | -- |

# Crop Improvement for Salinity, Alkalinity and Waterlogged Stresses

**Genetic improvement of rice genotypes for salt tolerance using Conventional and Molecular breeding methods** (S. L. Krishnamurthy, P. C. Sharma, B M Lokeshkumar, H S Jat, Y. P. Singh and Vineeth TV)

This project aims at identification of salt tolerant donors from different backgrounds its utilisation breeding of new salt tolerant genotypes. It also aims to development, evaluation and dissemination of better salt tolerant rice genotypes through station trails and AICRP trails. To achieve the objectives, following trials were conducted and the breeding material was advanced during *Kharif* 2020.

### A. National trail

#### a) IVT-Alkaline and Inland Saline Tolerant Variety Trial-2020

The IVT-Alkaline and Inland Saline Tolerant Variety Trial (IVT-AL&ISTVT) comprised of 20 entries including check variety (CSR 36, CSR 23, CSR 10, Pusa 44 and FL-478) and one local check (LC) which were evaluated across four salt stress locations in Random Block Design with three replications. Three entries namely 4607, 4617 and 4616 were performed very well under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36 across 4 locations. The entry 4607 performing better under saline microplot and saline field condition (Nain farm) with an average yield of 3.95 t $ha^{-1}$.

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

The AVT-Alkaline and Inland Saline Tolerant Variety Trial (AVT-AL&ISTVT) comprising of 16 entries including check variety (CSR 36, CSR 23, CSR 10, Pusa 44 and FL-478) ) and one local check which were tested across four salt stress locations in Random Block Design with three replications. The two entries namely 4512 and 4505 were performed very well under both saline and sodic condition over the saline check CSR 27 and sodic check CSR 36. The entry 4505 performing better under saline microplot and saline field condition (Nain Farm) with an average yield of 4.08 t $ha^{-1}$.

#### c) IVT and AVT Basmati Varietal Trial-2020

The IVT-BT trail comprising of 20 entries including check varieties (Pusa Basmati 1, Taroari Basmati, Pusa Basmati 1121 and Basmati CSR30 (Local check) were tested in Random Block Design with three replications in CSSRI Karnal. The three entries namely, 1919, 1916 and 1913 were top performing entries with the yield of 6.87 t $ha^{-1}$, 6.6 t $ha^{-1}$ and 6.47 t $ha^{-1}$, respectively. Similarly The AVT-BT trail comprising of 32 entries including check variety (Pusa Basmati 1, Taroari Basmati, Pusa Basmati 1121 Basmati CSR30 (Local check) were tested in Random Block Design with three replications in CSSRI Karnal. The three entries namely 1802, 1809 and 1808 were top performing entries with an average yield of 6.63 t $ha^{-1}$, 6.53 t $ha^{-1}$ and 6.37 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 and to enhance the genetic variation and to transfer the salt tolerance in high yielding varieties. Many numbers of segregating populations were screened under high salinity ($EC_{iw}$ ~ 12 dS $m^{-1}$) in micro plots and stress field. The top performing progenies were selected from each segregating population for further screening/evaluation in the next cropping season.

### Evaluation of basmati lines from different background

A total of 202 genotypes of different basmati background were evaluated in 10 $m^2$ area under normal fields at CSSRI Karnal. Genotypes CSR BT-131 shows highest grain yield 6.45 t $ha^{-1}$ with plant height 105 cm and plant duration 100 days. The grain yield ranged from 1.22 t $ha^{-1}$ (CSR BT-72) to 6.45 t $ha^{-1}$ (CSR BT-131) with mean 3.53 t $ha^{-1}$. The top 10 best performing genotypes were presented in Table 20.

### 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 (7.5 q) CSR36 (7.0 q), CSR 43 (7.0 q), CSR 46 (7.0 q), CSR49 (1.0q), CSR52 (4.0q), CSR56 (7.0q), CSR60(7.0q), was produced to meet the demand of seed producing agencies as per DAC (Department of Agriculture and Cooperation) during 2020.

### Rice entries nominated to AICRP during 2020

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

1. **NILs trail:** CSR179-11-11 (PUSA44+saltol), CSR179-11-263 (PUSA44+saltol), CSR179-11-243 (PUSA44+saltol), CSR179-11-215 (PUSA44+saltol), CSR189-11-2 (Sarjoo52+saltol), CSR189-11-80 (Sarjoo52+saltol), and CSR189-11-87 (Sarjoo52 + saltol).
2. **CSTVT**: CSR2019IRBD78, CSR YET 5, CSR YET 16, CSR YET 79 and CSR 2748-44
3. **Medium slender Trail:** CSR27SM66,CSR27SM160,CSR27SM59,CSR27SM117 and CSR27SM132
4. **AL&ISTVT trail :**CSR YET 8, CSR YET 59, CSR TPB 159, CSR CPB 69, CSR MAGIC 157, CSR MAGIC 167 and CSR YET 55
5. **Bio fortification trail:** CSR HZR 17-42, CSR HZR 17-23, CSR HZR 17-21, ,CSR HZR 17-8 and CSR HZR 17-22
6. **Basmati trail:**CSR 90, CSR 86, CSRCPB 55 and CSR 84

Table 20. Best performing basmati lines under normal condition

| Genotype | Days to 50% Flowering | Plant Height (cm) | Yield (t $ha^{-1}$) |
|---|---|---|---|
| CSR BT-131 | 100 | 105 | 6.45 |
| CSR BT-146 | 94 | 92 | 6.34 |
| CSR BT-42 | 107 | 93 | 6.29 |
| CSR BT-172 | 113 | 119 | 6.20 |
| CSR BT-119 | 102 | 104 | 6.18 |
| CSR BT-115 | 87 | 101 | 5.96 |
| CSR BT-116 | 85 | 109 | 5.90 |
| CSR BT-227 | 108 | 122 | 5.86 |
| CSR BT-178 | 102 | 125 | 5.80 |
| CSR BT-199 | 109 | 116 | 5.70 |

### Salt tolerant rice variety CSR76:

The rice variety CSR76 was developed from the cross CSR 27/MI48. It was recommended (SVRC) during 2020 for the sodic soils of Uttar Pradesh. It tolerates soil Sodicity up to $pH_2$ 9.6. It possessed long slender grains and takes 130 days for maturity. This is a semi dwarf culture (100 cm), with green foliage; erect flag leaf, compact panicle with complete exertion. Quality wise it showed high head rice recovery (76.7 %), desirable alkali spreading value (7.0) and intermediate amylase content (27.22 %). This variety yields 6.5 t $ha^{-1}$ under non stress and 4.0 t $ha^{-1}$ under salt stress situation.

### Saline and alkaline tolerant rice genetic stock CSR59:

Developed and registered rice genetic stock CSR59 tolerant to salinity and alkalinity. This line could be used as donor for development of high yielding rice varieties with long slender with lesser use of resources. This Germplasm can be used as a genetic stock for future breeding programmes aiming at development of high yielding salt tolerant rice varieties for saline and alkaline soils.

### Network project on functional genomics and genetic modification in crop (NPFGGM): Salt Tolerance in Rice (ICAR funded) (S.L. Krishnamurthy and P.C. Sharma)

The main aim of this project is to map the important genomic regions / QTLs controlling salt tolerance traits in rice. This involves collaborative work between CSSRI (for phenotyping) and NRC on Plant Biotechnology, New Delhi (for genotyping). A total of 140 RILs developed from cross combination of PUSA 44 × CSR 27. A total of 140 genotypes were phenotyped in two environments [Normal (field) and moderate salinity ($EC_{iw}$~8.0 dS $m^{-1}$) micro plots] during *Kharif* 2020.The grain yield was ranged from 1.55 t $ha^{-1}$ (G-117) to 6.73 t $ha^{-1}$ (G-140) with mean 2.57 t $ha^{-1}$ under normal, whereas, the range of grain yield from 1000 (G-60, G-138, G-4, G-135) to 3.27 t $ha^{-1}$ (G-48) with mean 1.8 t $ha^{-1}$ under saline stress condition. The highest grain yield was 6.73 t $ha^{-1}$ in G-140 and 3.27 t $ha^{-1}$ in G-48 under normal and saline stress respectively. The top performing RILs lines based on grain yield under normal and moderate salinity stress are presented in Table 21. The RIL G-179 genotypes performed with grain yield of 6.35 t $ha^{-1}$ under normal and 1.95 t $ha^{-1}$ under saline condition.

Table 21. Top performing RILs under normal and saline condition

| Sl. No. | Normal | | Saline | |
|---|---|---|---|---|
| | Genotype | Grain yield (t $ha^{-1}$) | Genotype | Grain yield (t $ha^{-1}$) |
| 1 | G-140 | 6.73 | G-48 | 3.27 |
| 2 | G-42 | 5.59 | G-112 | 3.17 |
| 3 | G-54 | 5.31 | G-42 | 2.97 |
| 4 | G-139 | 4.86 | G-53 | 2.88 |
| 5 | G-15 | 4.85 | G-40 | 2.88 |
| 6 | G-85 | 4.81 | G-107 | 2.83 |
| 7 | G-96 | 4.56 | G-54 | 2.82 |
| 8 | G-48 | 4.44 | G-74 | 2.78 |
| 9 | G-53 | 4.42 | G-46 | 2.77 |
| 10 | G-122 | 4.35 | G-105 | 2.75 |

Table 22. Summary statistics for root length and shoot length recorded on 924 rice genotypes

| Parameter | Vigour score | Root length (cm) | Shoot length (cm) |
|---|---|---|---|
| Mean | 6.97 | 4.25 | 19.10 |
| Maximum | 9.0 | 14.33 | 34.33 |
| Minimum | 3.0 | 1 | 5 |

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

The main objective of this project is to screening of rice Germplasm under salinity stress at seedling stage. A total of 498 genotypes including two checks (IR 29- sensitive check and FL478- tolerant check) were phenotyped for seedling stage salinity tolerance in 2020. Out of these, 16 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 ~ 10.0 dS $m^{-1}$) on $14^{th}$ day after sowing by adding NaCl salt. Standard Evaluation Score (SES), root and shoot lengths were measured on $28^{th}$ day after sowing. The mean, maximum and minimum values of the recorded traits during 2020 are presented in Table 22.

Vigour score (SES) ranged from 3 to 9 under saline conditions. Nearly 48 genotypes were found tolerant (score-3), 189 genotypes were moderately tolerant (score-5), 123 were moderately sensitive (score-7) and 120 genotypes were highly sensitive (score-9). Shoot length and root length were reduced in salinized condition. Root length ranged from 6.13 cm to 34.6 cm with a mean of 17.42 cm. The range of shot length is from 16.4 cm to 80.27 cm with a mean of 50.12.

**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. 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. True $F_{1s}$ were identified and used them in back cross breeding progamme in all three recurrent parents (Sarjoo 52, PR 114 and PUSA 44), separate lyto transfer the salinity tolerance QTL for reproductive stage. To produce $BC_3F_1$ population, $BC_2F_1$ progenies of three populations (Sarjoo 52/CSR 27, PR 114/CSR 27 and PUSA44/CSR 27 were subjected to molecular marker-assisted selection and back cross to recipient parents in *Kharif* season 2020. $BC_2F_1$s will be used as male parent and recipient parent of last year was used as female parent in cross. Recipient parents (Pusa44, PR114 and Sarjoo 52) were sown and transplanted in five staggered dates to synchronize the flowering with the $B_2F_1$ population (Table 23). 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.

Table 23. Staggeredsowing of parents $BC_2F_1$progenies Kharif 2020

| Parents | Activity | 1st | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|---|
| **Sarjoo52** | Sowing | 7/06/2020 | 13/06/2020 | 19/06/2020 | 26/06/2020 | 2/07/2020 |
| **(Recipient)** | Transplanting | 2/07/2020 | 10/07/2020 | 15/07/2020 | 23/07/2020 | 30/07/2020 |
| **Pusa44** | | | | | | |
| **(Recipient)** | Sowing | 7/06/2020 | 13/06/2020 | 19/06/2020 | 26/06/2020 | 2/07/2020 |
| | Transplanting | 2/07/2020 | 10/07/2020 | 15/07/2020 | 23/07/2020 | 30/07/2020 |
| **PR114 (Recipient)** | Sowing | 7/06/2020 | 13/06/2020 | 19/06/2020 | 26/06/2020 | 2/07/2020 |
| | Transplanting | 2/07/2020 | 10/07/2020 | 15/07/2020 | 23/07/2020 | 30/07/2020 |
| **$BC_2F_1$ (Donor)** | Sowing | | | 19/06/2020 | 26/06/2020 | |
| | Transplanting | | | 15/07/2020 | 23/07/2020 | |

Table 24. Summary of generation to generation forwarding of materials from $F_1$ to $BC_3F_1$

| Sr. No. | Crosses | Number of $F_1$ seeds obtained | Number of $BC_1F_1$ plants screened for MAS | Number of MAS plants obtained $BC_1F_1$ | Number of seeds obtained $BC_2F_1$ | Number of $BC_2F_1$ plants screened for MAS | Number of MAS plants obtained $BC_2F_1$ | Number of seeds obtained $BC_3F_1$ |
|---|---|---|---|---|---|---|---|---|
| 1. | Pusa 44/CSR27 | 446 | 46 | 21 | 423 | 350 | 25 | 2853 |
| 2. | PR114/CSR27 | 288 | 96 | 17 | 371 | 267 | 23 | 2033 |
| 3. | Sarjoo52/CSR27 | 228 | 121 | 37 | 277 | 250 | 19 | 2175 |

A total of 350, 267 and 250 $BC_2F_1$ plants from PUSA 44 X CSR 27, PR 114 X CSR 27 and Sarjoo 52 X CSR 27 respectively were subjected to marker assisted screening using RM3395,

HVSSR8-25, RM22722 and RM22713 foreground markers and Hvssr8-12 and Hvssr8-35 back ground markers. About 25, 23 and 19 plants were selected and used for backcrossing to generate $BC_3F_1$seeds. After maturity the $BC_3F_1$seeds were harvested from the recurrent and stored at refrigerated condition. A total of 2853, 2033 and 2175seeds were obtained from Pusa44/CSR27, PR114/CSR27 and Sarjoo 52/CSR27, respectively (Table 24).

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

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

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

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 2 environments {normal and saline stresses (EC~ 6) during *Kharif* 2020.The grain yield (gm/plant) ranged from 12 (RIL 90) - 22.81 (RIL 46) and 5 (RIL 172)-14.5 (RIL118) under normal and moderate salinity, respectively. The RIL46 shows the highest grain yield followed by RIL 1, RIL131, and RIL134 over CSR20 under normal stress. The top performing RILs under normal and saline stress were

Table 25. Summary statistics for root length and shoot length recorded on 924 rice genotypes

| S.N | Grain yield in Normal (gm/plant) | | Grain yield in saline stress (gm/plant) | |
|---|---|---|---|---|
| 1 | RIL46 | 23 | RIL118 | 14.5 |
| 2 | RIL1 | 22 | RIL116 | 14.1 |
| 3 | RIL131 | 20 | RIL112 | 13.3 |
| 4 | RIL134 | 20 | RIL121 | 13.2 |
| 5 | CSR20 | 19 | RIL134 | 13.2 |
| 6 | RIL64 | 19 | RIL111 | 13.1 |
| 7 | RIL117 | 18 | RIL117 | 13 |
| 8 | VSR156 | 18 | RIL128 | 13 |
| 9 | RIL47 | 18 | RIL119 | 12.9 |
| 10 | RIL28 | 18 | RIL126 | 12.9 |

presented in table 25. Under saline stress, the RIL 118 showed the highest grain yield and followed by RIL 116, RIL112, RIL121, RIL134, RIL11, RIL117, RIL128, RIL119 and RIL126.

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

A total of 47 rice genotypes were evaluated in two replication at ICAR-CSSRI, Karnal. The traits which were recorded are Days to 50% flowering with mean of 111 days, plant height with average of 114.1cm, average panicle length of 27.16 cm, productive tiller per plant is 11.27 and average grain yield of 4.39 t $ha^{-1}$ (Table 26). Based on the grain yield the following entries IR15M1293, IR15M1053, R14M124, IR15M1302 and IR15M1315 recorded the highest grain yield. The entry IR15M1293 recorded highest yield of 6.5 t $ha^{-1}$ followed by entry IR15M1053 (6.2 t $ha^{-1}$). Entry R14M124 recorded yield of 5.9 t $ha^{-1}$ while entry IR15M1302 and IR15M1315 has recorded almost same yield of 5.8 t $ha^{-1}$. Seeds of all entries were sent to IIRR Hyderabad to estimate the Zn content.

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

A total of 26 rice entries were evaluated in arsenic prone area at CSSRI RRS canning town in randomized block design with three replications. Observations on the days to flowering, maturity, plant height, tillers per hill, panicles per hill, grain and straw yields were recorded. The data with results are presented here. The flowering duration varied from 77 – 107 days. The entries IARS 13, IARS 15 and IARS 24 flowered in 77 days, closely followed by IARS 7 and IARS 26, which flowered in 79 days. IARS 21 took maximum of 107 days to flower. The mean flowering duration of all the entries was 89 days. The plant height varied

Table 26. Mean, maximum and minimum values for Grain yield (t $ha^{-1}$) and yield contributing character

| Parameter | Days 50% | Plant Height(cm) | Panicle Length(cm) | Productive tiller per plant | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| Mean | 111 | 114.1 | 27.16 | 11 | 4.39 |
| Maximum | 151 | 130.5 | 33.5 | 17 | 6.57 |
| Minimum | 94 | 91.75 | 21.25 | 8 | 1.01 |

Table 27: Performance of rice genotypes evaluated at arsenic prone area of canning town during 2020

| Entry No. | Plant height (cm) | Tillers/hill | Panicles/hill | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|
| **IARS 3** | 167.3 | 7 | 7 | 3.77 |
| **IARS 4** | 82.7 | 10 | 10 | 1.19 |
| **IARS 5** | 121.3 | 12 | 12 | 3.10 |
| **IARS 6** | 90.3 | 6 | 6 | 0.68 |
| **IARS 7** | 138.7 | 7 | 7 | 0.70 |
| **IARS 9** | 102.3 | 9 | 9 | 1.69 |
| **IARS 10** | 156.0 | 7 | 7 | 3.18 |
| **IARS 11** | 96.3 | 10 | 10 | 1.46 |
| **IARS 12** | 141.7 | 10 | 10 | 1.27 |
| **IARS 13** | 112.7 | 17 | 17 | 0.53 |
| **IARS 14** | 111.3 | 14 | 14 | 1.90 |
| **IARS 15** | 127.7 | 16 | 16 | 0.55 |
| **IARS 16** | 116.3 | 12 | 12 | 4.12 |
| **IARS 18** | 160.7 | 12 | 12 | 3.76 |
| **IARS 19** | 144.3 | 12 | 12 | 1.32 |
| **IARS 20** | 158.0 | 7 | 7 | 1.31 |
| **IARS 21** | 109.7 | 5 | 5 | 2.67 |
| **IARS 22** | 133.0 | 7 | 7 | 2.82 |
| **IARS 23** | 153.7 | 11 | 10 | 4.75 |
| **IARS 24** | 126.7 | 10 | 10 | 4.04 |
| **IARS 25** | 100.0 | 5 | 5 | 1.41 |
| **IARS 26** | 117.0 | 8 | 8 | 3.25 |
| **IARS 27** | 120.7 | 13 | 13 | 3.69 |
| **IARS 28** | 116.3 | 13 | 13 | 3.05 |
| **IARS 29** | 100.0 | 17 | 17 | 3.13 |
| **IARS 30** | 109.7 | 10 | 10 | 3.50 |

There was variation in the grain yield of entries from 0.53 – 4.75 t $ha^{-1}$ with the highest grain yield (4.75 t $ha^{-1}$) in IARS 23. The grain yield was greater than 3 t $ha^{-1}$ in the entries IARS 3, IARS 5, IARS 10, IARS 16, IARS 18, IARS 23, IARS 24, IARS 26, IARS 27, IARS 28, IARS 29 and IARS 30.

from 82.7 – 167.3 cm (Table 27). The shortest plant height (82.7 cm) was observed in IARS 4, while the tallest plant height (167.3 cm) was recorded in IARS 3. The plant height of IARS 3, IARS 10, IARS 18, IARS 20 and IARS 23 was greater than 150 cm. While in case of entries IARS 4, IARS 6 and IARS 11, the plant height was less than 100 cm. The number of tillers per hill and panicles per hill was almost same in all the entries. The panicles per hill varied from 5 - 17 per hill, with lowest number of tillers or panicles per hill recorded in entries IARS 21 and IARS 25. The number of panicles per hill was maximum (17) in IARS 13 and IARS 29.

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

A set of 330 genotypes of 3K panel of rice from IRRI was screened in hydroponics using Yoshida culture solution, under controlled glasshouse conditions at CSSRI, Karnal. The line FL 478 was used as tolerant check and IR 29 as susceptible check. The data was

Table 28. List of genotypes exhibiting tolerant and moderately tolerant reaction to salinity

| SES score 3 (Tolerant lines) | SES score 5 (moderately tolerant lines) |
|---|---|
| 1. MODDAI KARUPPAN ::IRGC 15465 -1 | 1. YA NONG ZAO 4 :: IRGC 63908 - 1 |
| 2. KALU ILANKALAYAN ::IRGC | 2. SIMUL KHURI :: IRGC 35154 -1 |
| 3. KARUTHA SEENATI :: 15515-2 | 3. NOROI ::IRGC 31611-1 |
| 4. ARC 15873 :: IRGC 43250-1 | 4. JAO LEUANG :: IRGC 65866 -1 |
| 5. LINANGAN :: IRGC 47255-2 | 5. JIN JUN DAO :: IRGC 59710 -1 |
| 6. TOC 5430 ::IRGC 70487-1 | 6. BANTA TIMA ::IRGC 69474-1 |
| 7. KHAO CHUAN CHOM 452 :: IRGC 36571 -1 | 7. YEBAWYIN ::IRGC 33885-1 |
| 8. PARA NELLU :: IRGC 50009 -1 | 8. BARIK KUDI ::IRGC 52807 -1 |
| 9. RADEN KARAMUNTING ::IRGC | 9. CHAM LEK :: IRGC 89387 -1 |
| 10. CT 23 ::GERVEX 1488 -C1 | 10. ANDEL::IRGC 17153-2 |
| 11. DELI 2::IRGC 80313-1 | 11. LWANKHAN::IRGC 33330-1 |
| 12. CHIH SHEN LI ::IRGC 1306 -1 | 12. JIA GEN :: IRGC 79654 -1 |
| | 13. ARC 12079 ::IRGC 21888 -1 |
| | 14. MANSARA DHAN :: IRGC 86940-1 |
| | 15. KHAO NON :: IRGC 30051 -1 |
| | 16. ARC 6015 :: IRGC 20314-2 |
| | 17. DAHARNAGRA :: IRGC 45465 |
| | 18. OVAL RED 29 B 601 :: IRGC 38130 -2 |

recorded after the complete death of susceptible check under salt stress. To evaluate the salinity tolerance of 330 genotypes, for two traits shoot length was measured from the base of the plant to the tip of the longest leaf while root length was measured from the base of the plant to the tip of the longest root. Genotypes with SES scores (salt injury score) between 1 and 5 were considered as highly tolerant, tolerant, and moderately tolerant respectively, where as 7-9 were reported as susceptible and highly susceptible. A total of twelve genotypes responded extremely well under saline condition with SES score of 3 while 21 genotypes came out to moderately salt tolerant with SES score of 5 (Table 28). The remaining genotypes were highly affected by high salt concentration in the nutrient medium and salt. A total of 58 (Antenna Pannel) rice genotypes were evaluated for grain yield and related characters during kharif2020 under normal and saline microplot (EC ~ 6 dS $m^{-1}$) condition at ICAR-CSSRI, Karnal. The data on days to 50 %

Table 29. Grain yield and yield contributing character were presented mean, maximum and minimum under normal condition

| Parameter | Days 50% | Plant Height(cm) | Panicle Length(cm) | Tiller per plant | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| Mean | 88 | 114.052 | 26.0862 | 15.1121 | 4.009 |
| Maximum | 114 | 181.5 | 79 | 35 | 7.178 |
| Minimum | 62 | 73.5 | 18 | 8.5 | 1.147 |

Table 30. Grain yield and yield contributing character were presented mean, maximum and minimum under saline micro plot condition

| Parameter | Days 50% | Plant Height(cm) | Panicle Length(cm) | Tiller per plant | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| Mean | 89 | 90.18 | 20.84 | 12.20 | 2.430 |
| Maximum | 120 | 135.36 | 24.86 | 21.68 | 4.754 |
| Minimum | 68 | 58.96 | 13.18 | 6.46 | 0.273 |

flowering, plant height, panicle length tiller per plant and grain yield was recorded and presented in Table 29 and Table 30. The entry GSR IR2-9-R1-SU3-Y2, MG 2::IRGC 79837-1, TEQING, Nerica L-19 and Sahel 108 has recorded the highest yield among other entries under normal condition.Maximum grain yield was observed in entry GSR IR2-9-R1-SU3-Y2 (1.778 t $ha^{-1}$) followed by entry MG 2::IRGC 79837-1. Entries TEQING and Nerica L-19 were shown grain yield of 6.4 and 6.3 tons per hectare. At saline stress, range of days to 50 per cent flowering from 68 (Supa) days - 120 days (Jamir) with an average of 89 days. The plant height ranged from 58.69 cm to 135.36 cm with the mean plant height of 90.18 *cm*. The number of productive tillers per plant ranged from 6 to 21 among the 58 rice genotypes.The panicle length varied from 13cm to 24cm among the 58 rice genotypes (Table 30). Based on the grain yield per plot the entry IRRI147, Sahel 108, IR 93340:14-B-21-17-12-1RGA-2RGA-1-B-B, MTU1010 and TEQING has recorded the highest yield among other entries. The entry IRRI 147 recorded highest yield of 4.754 t $ha^{-1}$ followed by entry Sahel 108 (4.72 t $ha^{-1}$). Entry IR 93340:14-B-21-17-12-1RGA-2RGA-1-B-B recorded yield of 4.5 t $ha^{-1}$ while entry MTU1010 recorded yield of 4.3 and TEQING has recorded yield of 4.1 t $ha^{-1}$ under salinity stress condition of CSSRI salinity.

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

The major goal of the project was to improve and develop disease resistant high yielding salt and waterlogging tolerant wheat genotypes. To achieve to goal following activities were undertaken during the cropping season 2019-2020.

#### Entries contributed under IPPSN 2019-20

During the cropping season, thirty five promising wheat entries were sent for evaluation against rust diseases in Initial Plant Pathological Screening Nursery (IPPSN).Out of 35 entries KRL 1912 was promoted to NIVT-1B-IR-TS-TAS and KRL 1914 was promoted to NIVT-1A-IR-TS-TAS, 2020-21.

#### Hybridization and generation advancement:

To transfer the salt tolerance from elite or released cultivars (KRL 3-4, KRL 99, KRL 210, KRL213, KRL 283, KRL19, KRL1-4, KRL119, KRL2-10, KRL 12, KRL 327, KRL330, KRL621, KRL283) developed at CSSRI, Karnal in elite, popular varieties ( PBW 778, DBW 222, HD 3118, HD 3043,DBW 252, HS 626, HS 627, DBW 187, PBW 760, PBW 667,PBW 621, PBW 777, PBW 757, DBW 246, WH 1310, WH1127, HD 3121, HD 3132) which carrying the gene pyramids for resistance to rust and other major diseases, 900 ear heads were emasculated and hybridized, which comprised of 150 cross combinations. Apart from these 792 new cross combinations were attempted to create the variability for desired traits. After harvesting of hybrids variable number of seed set were threshed.

| Number of seed set | Number of cross combinations |
|---|---|
| >100 | 10 |
| 51-100 | 124 |
| 31 -50 | 225 |
| 11-30 | 355 |
| 5-10 | 228 |
| Total | 942 |

During the year 2020-21, a total of 350 new cross combination involving different targeted donors were advanced to diversify base, improving tolerance against disease resistance, waterlogging tolerance and salt tolerance. Under segregation generation $F_2$ (142 Crosses), $F_3$ (44 Crosses), $F_4$(42 Crosses), $F_5$ (33 Crosses) and $F_6$ (89 Crosses) were advanced under intensive selections pressure of rust diseases. Selections were made on the basis on disease resistance and agro-morphological traits during the rabi season 2020-21.

### Development and advancement of mapping populations for salt tolerance

During the cropping season three mapping populations namely IC564103-A/Kharchia 65 (population size 290 in $F_4$ generation), HD2985/Kharchia Local (population size 360 in $F_3$ generation) and KRL 283/IC 401976 (size 120 in $F_5$ generation) were advanced.

### Evaluation of wheat varieties for salt stress in Microplots

During the cropping season 2019-20, twenty three wheat varieties were evaluated under four environments (Control, Saline: irrigation with saline water of 10 $EC_{iw}$, Low Sodic; $pH_2$ 9.2 ± 0.13 and High Sodic: $pH_2$ 9.5 ± 0.17) for their *per se* performance in micro plots. Genotypes were evaluated in CRBD with three replications. In control condition genotype DBW 187 attained the highest yield followed by HI 1620, HI 1612, HD 3226, Dharwad dry, KRL 210 and K 1317 however with saline irrigations, genotype KRL 210 attained the highest yield followed by KRL 99, DBW 173, K 1317, KRL 423 and HD 3226, least grain yield was attained by the genotype PBW 550 and PBW 757. Under sodic environment maximum yield was attained by the genotype KRL 99 followed by KRL 210, DBW 187, Kh.65, PBW 752 and DBW 173. However sodic environment the genotypes HD 2985, PBW 757, UAS 334, PBW 550, RAJ 4120 and Dharwad dry did not produced any economic yield, they may be treated as highly sensitive genotypes.

### Breeder/ nucleus seed production and seed multiplication

Breeder seed of CSSRI varieties KRL 210, KRL 213 and KRL 283 and nucleus seed of five released varieties KRL 1-4, KRL19, KRL 210, KRL 213, KRL 283 and 20 advanced lines was produced at CSSRI experimental farm for use in the next cropping season. During the crop season, 35 entries of IPPSN and SATSN, and three entries contributed in NIVTs (KRL 1810, KRL 1803 and KRL 1808) were also multiplied. In addition, the seed of important germplasm such as Kharchia 65, KRL 99, KRL 3-4 and Kharchia local was multiplied to meet out the demand as checks.

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

The project was initiated with the objective to improve existing salt tolerant lines with reference to grain yield, grain colour, disease resistance and other physiological and morphological characters and to develop salt tolerant lines for different stress situations. A number of experiments related to wheat breeding programme were laid down during the project period in microplots, sodic soils of ICAR-CSSRI farm, saline soils of Nain farm and other reclaimed soils during November-December 2021.

Following wheat entries were nominated to different trials for 2020-21

1. NIVT-1A-IR-TS-TAS, 2020-21: KRL1914
2. NIVT-1B-IR-TS-TAS, 2020-21: KRL1912
3. Haryana State Varietal Trial: KRL 370, KRL 386, KRL 377, KRL 283, KRL 423, KRL 1803
4. U.P State Varietal Development Programme: KRL 1803, KRL 423, KRL 370, KRL 377, KRL 386
5. SATSN 2019-20: KRL 2001, KRL 2006, KRL 2012, KRL 2017, KRL 2018, KRL 2021, KRL 2022, KRL 2028, KRL 2031, KRL 2032

6. IPPSN2019-20: KRL 2002, KRL 2003, KRL 2004, KRL 2005, KRL 2007, KRL 2008, KRL 2009, KRL 2010, KRL 2011, KRL 2014, KRL 2015, KRL 2016, KRL 2019, KRL 2020, KRL 2023, KRL 2024, KRL 2026, KRL 2027, KRL 2030, KRL 2033, KRL 2034, KRL 2035, KRL 2036, KRL 2037,KRL 2038

### Breeder/ nucleus seed production and seed multiplication

Breeder seed of CSSRI varieties KRL 210 (20.10q), KRL 213 (2.0q) and KRL 283 (15.95 q) were distributed to various public and private seed producing agencies. Breeder seed of KRL 210 (5.40q), KRL 213 (0.50 q) and KRL 283 (2.20 q) varieties was also provided to the seed production unit for the production of truthful labelled (TL) seed.

### Screening of salt tolerant germplasm for known rust resistant molecular markers

Deployment of rust resistant cultivars has been the most economical and environmentally friendly strategy to control rust diseases. Rust pathogens are continuously evolving and acquiring virulence to more resistance genes. So mining of resistance genes in salt tolerant cultivars to identify the genotypes with multiple rust resistance genes was initiated. To keep in mind this objective molecular identification of rust resistance genes in 41 wheat lines was done by a number of molecular markers (*Yr18/Lr34/Sr57 (csLV34), Lr19-Sr25 (GB), Yr9/Lr26/Sr31 (iag95-STS), Lr24/Sr24 (Sr24#50), Yr15/Yr24 (GWM11 and BARC8), Lr68 (CsGs-STS), Sr2 (GWM533), Sr28 (wPt7004), Lr32 (WMC43), Yr10 (psp3000), Yr15 (gwm11), Yr36 (Yr36_13104), Yr 5(Yr5_insertion),Lr 67(CFD71* and*Lr 67 PLUSHSUT)*.

### Molecular Identification of *Yr18/Lr34/Sr57* gene complex

Molecular marker csLV34 was used to amplify *Yr18/Lr34/Sr57* gene complex. In preliminary study, presence of csLV34 gives 150 bp amplicon which is present in eleven wheat genotypes KRL 283, KRL 213, KRL 1-4, KRL 99, KRL 2001, KRL 2009, KRL 2011, KRL 2024, KRL 2025, KRL 2026, and KRL 2027. Presence of the 229 bp amplicon indicates the absence of *Lr34* gene complex (Fig. 36).

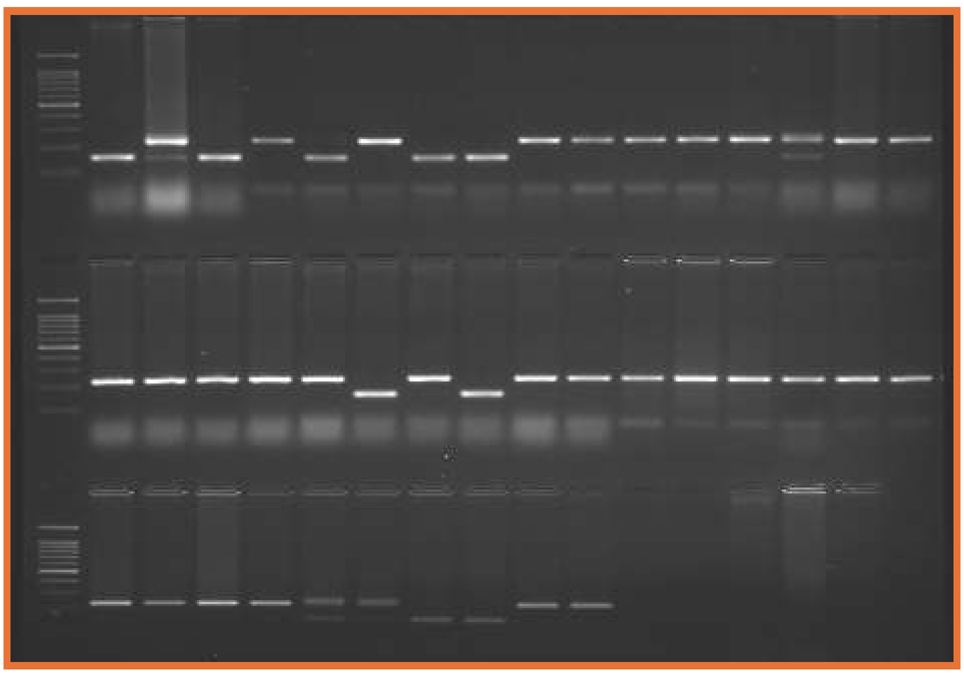


Fig 36. PCR amplification of Yr18/Lr34/Sr57 via molecular marker csLV34

Table 31. Analysis of variance of the studied traits in 812 accessions under alkaline environment experiment conducted during 2019-20

| Source of Variation | Df | Mean squares | | | |
|---|---|---|---|---|---|
| | | Biomass | Grain yield | Tillers | Plant height |
| Block | **13** | 14972.7** | 263.476 | 2283.62 | 53.27 |
| Entries | **814** | 45132.9*** | 5256.43*** | 6170.46** | 267.301*** |
| Checks | **2** | 85686.6*** | 18203.5*** | 53714.4*** | 5247.45*** |
| Accessions | **811** | 41067.7*** | 4783*** | 5795.88** | 255.28*** |
| Checks vs. accessions | **1** | 3260892*** | 363308*** | 214864*** | 56.012 |
| Error | **26** | 4761.08 | 256.268 | 2216.48 | 49.269 |
| **Ci – Vi (CD at 5%)** | | 174.63 | 40.51 | 119.15 | 17.76 |
| **Source of Variation** | **Df** | **Spike length** | **Spikelets per spike** | **Days to maturity** | **Days to heading** |
| Block | **13** | 0.59 | 1.12 | 6.67 | 3.10* |
| Entries | **814** | 1.18 | 3.16* | 53.57*** | 194.04*** |
| Checks | **2** | 6.88** | 12.29** | 24.50 | 24.60*** |
| Accessions | **811** | 1.17 | 3.00 | 51.45*** | 185.19*** |
| Checks vs. accessions | **1** | 3.89 | 113.02*** | 1834.82*** | 7713.73*** |
| Error | **26** | 0.93 | 1.82 | 9.17 | 1.41*** |
| **Ci – Vi (CD at 5%)** | | 2.44 | 3.42 | 7.66 | 3.01 |

* Significant at 5% level of significance; ** Significant at 1% level of significance ; *** Significant at 0.1% level of significance

**Consortium Research Platform on Agrobiodiversity (CRP-AB) "Sub-project1. 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)

During the cropping season a sets of 812 accessions of bread wheat was received from NBPGR, New Delhi for the screening of salt tolerance. Out of 812 accessions, 263 were indigenously collection of Uttarakhand state, 477 accessions of Himachal Pradesh and 72 of Jammu and Kashmir. Under Indigenous collection, maximum accessions shared from Himachal Pradesh state followed by Uttarakhand. During the experiment quantitative data on days to 50 % flowering, days to maturity, number of effective tillers, plant height, spike length, spikelet's per spike grain yield and above ground biomass (gram per 2 meter row length) was recorded and entered into spread sheet and structured thematically.

All the accessions of bread wheat were evaluated in Augmented Randomized Block Design with 14 blocks under sodic soils (pH2 9.12±0.23). A total of three salt tolerant national checks namely, Kharchia 65, KRL 19 and KRL210 were used and randomized within 58 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, spikelet's per spike, grain yield (gram per 2 meter running row length)and above ground biomass (gram per 2 meter row length) were recorded. Significant differences were observed among accessions for all characters studied except spike length, spikelet's per spike (Table 31). Among checks versus accessions all the character showed significant difference for all the 812 wheat germplasm accessions except the trait spike length. This indicates the existence of good amount variability for yield and yield contributing traits in germplasm set. Which can be exploit through selection and hybridization in further

Table 32: List of salt tolerant accessions superior to best Check (KRL 210) based on critical difference

| S.NO. | Accessions Name | Adjusted Grain yield (g)$^{-2m}$ row length | Collection Id | |
|---|---|---|---|---|
| | | | District | State |
| 1. | IC0421937 | 375.83 | Solan | HP |
| 2. | IC0282865 | 341.16 | Dehradun | Uttarakhand |
| 3. | IC0252407 | 320.16 | - | Uttarakhand |
| 4. | IC0328652 | 319.86 | L&S | HP |
| 5. | IC0421880 | 317.03 | Solan | HP |
| 7. | IC0316098 | 315.36 | Udham Singh Nagar | Uttarakhand |
| 8. | IC0329507 | 307.46 | Kullu | HP |
| 9. | IC0421915 | 304.23 | Solan | HP |
| 10. | IC0260878 | 302.83 | Rudrapryag | Uttarakhand |
| 11. | IC0316093 | 300.56 | Udham Singh Nagar | Uttarakhand |
| 12. | IC0316095 | 300.36 | Udham Singh Nagar | Uttarakhand |
| 13. | IC0341417 | 296.16 | Uttarkashi | Uttarakhand |
| | (CD at 5%) | 40.51 | | |

breeding program to improve the salt tolerance of wheat. Based on the mean performance over the blocks, Check KRL 210 was the top performing check followed by KRL 19 and Kharchia 65 respectively in alkaline environment.

Based on the critical differences only 48 accessions were observed significantly superior from salt tolerant checks (Kharchia 65). Out of 48 accessions, 34 accessions were significantly superior to KRL 19, while ever only 13 accessions were significantly superior from best salt tolerant check KRL 210. Information of identified salt tolerant accessions is given in Table 32.

### 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 (PYT) in saline soils andsemi– reclaimed alkali soils

Fifty three advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 and RH 749) were evaluated in PYT for seed yield in screening trial in saline soils (ECe 11-16 dS m$^{-1}$) at Nain Farm (Distt. Panipat). Seed yield ranged from 0.52 to 2.53 t ha$^{-1}$ (Mean 1.30 t ha$^{-1}$, CD $_{(0.05\%)}$ 1.17 t). Four lines gave significantly higher yield over the best check CS 60 (1.93 t ha$^{-1}$) with CS 2009-437 (2.53 t ha$^{-1}$) followed by CS 2009-216 (2.32 t ha$^{-1}$) recording maximum seed yield. Further, 53advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 and RH 749) were evaluated in PYT for seed yield in screening trial in reclaimed alkali soils (*p*H 8.5 to 9.3) at Karnal. Seed yield ranged from 0.93 to 2.18 t ha$^{-1}$ (Mean 1.53 t ha$^{-1}$, CD $_{(0.05\%)}$ 0.55 t). Five lines gave significantly higher yield over the best check CS 60 (1.88 t ha$^{-1}$) with CS 2002-95 (2.18 t ha$^{-1}$) followed by CS 2009-315 (2.02t ha$^{-1}$) recording maximum seed yield.

### Developmentand Evaluation of advanced breeding lines (YET) in saline and semi– reclaimed alkali soils

A total of 53 advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 and RH 749) were evaluated in YET for seed yield in screening trial in saline soils (ECe 11-

16 dS $m^{-1}$) at Nain Farm (Distt. Panipat). Seed yield ranged from 0.30 to 2.05 t $ha^{-1}$ (Mean 1.05 t $ha^{-1}$, CD $_{(0.05\%)}$ 1.09 t). The one line found superior over best check CS 60 (1.93 t $ha^{-1}$) with CS 2004-112 (2.05 t $ha^{-1}$) followed by check equivalent yield of CS 2005-125 (1. 93 t $ha^{-1}$). Further, 53 advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 and RH 749) were evaluated in YET for seed yield in screening trial in reclaimed alkali soils (*p*H 8.5 to 9.3) at Karnal. Seed yield ranged from 1.00 to 2.27 t $ha^{-1}$ (Mean 1.71 t $ha^{-1}$, CD $_{(0.05\%)}$ 1.00 t). The 14 line found superior over best check CS 60 (1.88 t $ha^{-1}$) with CS 2009-192 (2.27 t $ha^{-1}$) followed by CS 2009-215 (2.19 t $ha^{-1}$) recording maximum seed yield.

### Development and Evaluation of advanced breeding line ($F_{10}$, $F_{12}$ and $F_{13}$) of Mustard in saline and semi– reclaimed alkali soils

Forty advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 and RH 749) were evaluated in $F_{10}$ generation for seed yield in saline soils (ECe 11-16 dS $m^{-1}$) at Nain Farm (Distt. Panipat). Seed yield ranged from 0.27 to 2.21 t $ha^{-1}$ (Mean 1.05 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.50 t). Three line gave significantly higher seed yield over the best check CS 60 (1.93 t $ha^{-1}$) with CS 22000-7-1(2.21 t $ha^{-1}$) followed by CS 19000-4-3 (2.11 t $ha^{-1}$) recording maximum seed yield. Further, 40advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 and RH 749) were evaluated in $F_{10}$ generation for seed yield in reclaimed alkali soils (*p*H 8.5 to 9.3) at Karnal. Seed yield ranged from 1.35 to 2.42 t $ha^{-1}$ (Mean 1.88 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.26 t). The 17 lines gave significantly higher seed yield over the best check CS 60 (1.88 t $ha^{-1}$) with CS 22000-7-2(2.42 t $ha^{-1}$) followed by CS 19000-4-5(2.38 t $ha^{-1}$) recording maximum seed yield.

Forty seven advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 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). Seed yield ranged from 0.49 to 2.49 t $ha^{-1}$ (Mean 1.35 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.89 t). Five lines gave significantly higher seed yield over the best check CS 60 (1.93 t $ha^{-1}$) with CS 2013-60 (2.12 t $ha^{-1}$) followed by CS 2013-1 (2.07 t $ha^{-1}$) recording maximum seed yield. Further, 47advanced breeding lines including five checks (Kranti, CS 58, Giriraj,CS 60 and RH 749) were evaluated in $F_{12}$ generation for seed yield in reclaimed alkali soils (*p*H 8.5 to 9.3) at Karnal. Seed yield ranged from 1.27 to 2.12 t $ha^{-1}$ (Mean 1.67 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.25 t). Seven lines gave significantly higher seed yield over the best check CS 60 (1.88 t $ha^{-1}$) with CS 2013-66 (2.12 t $ha^{-1}$) followed by CS 2013-41 (2.05 t $ha^{-1}$) recording maximum seed yield.

Sixty eight advanced breeding lines including five checks (Kranti,CS 58,Giriraj,CS 60 and RH 749) were evaluated in $F_{13}$ generation for seed yield in saline soils (ECe 11-16 dS $m^{-1}$) at Nain Farm (Distt. Panipat). Seed yield ranged from 0.30 to 2.72 t $ha^{-1}$ (Mean 1.50 t $ha^{-1}$, CD $_{(0.05\%)}$0.73 t). Ten lines gave significantly higher seed yield over the best check CS 60 (1.93 t $ha^{-1}$) with CS 2009-332 (2.72 t $ha^{-1}$) followed by CS 2009-118 (2.56 t $ha^{-1}$) recording maximum seed yield. Further, 68 advanced breeding lines including five checks (Kranti,CS 58,Giriraj,CS 60 andRH 749)were evaluated in $F_{13}$generation for seed yield in reclaimed alkali soils (*p*H 8.5 to 9.3) at Karnal. Seed yield ranged from 0.84 to 2.30 t $ha^{-1}$ (Mean 1.65 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.35 t). Seven lines gave higher seed yield over the best check CS 60 (1.88 t $ha^{-1}$)with CS 2004-119 (2.30 t $ha^{-1}$) followed by CS 2009-208 (2.15 t $ha^{-1}$) recording maximum seed yield.

### Development and Evaluation of Multistress tolerance advanced breeding line ($BC_6$) in saline and semi–reclaimed alkali soils

The objective behind these crosses was to develop multistress (Salinity, Heat, Drought and Frost)tolerant mustard genotypeswith higher yield. Thirty fouradvanced breeding lines including three checks (Kranti,GirirajandCS 60)were evaluated in $BC_6F_4$generation for seed yield in sodic soils (*p*H 9.3) at Karnal. Seed yield ranged from 1.33 to 2.07 t $ha^{-1}$ (Mean 1.6 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.27 t). Three lines gave significantly higher seed yield over the best check CS 60 (1.88 t $ha^{-1}$)withQ 2061-41 x CS 56-1 (2.07 t $ha^{-1}$) followed by CS 54 xQ 2061-41(2.04 t $ha^{-1}$).

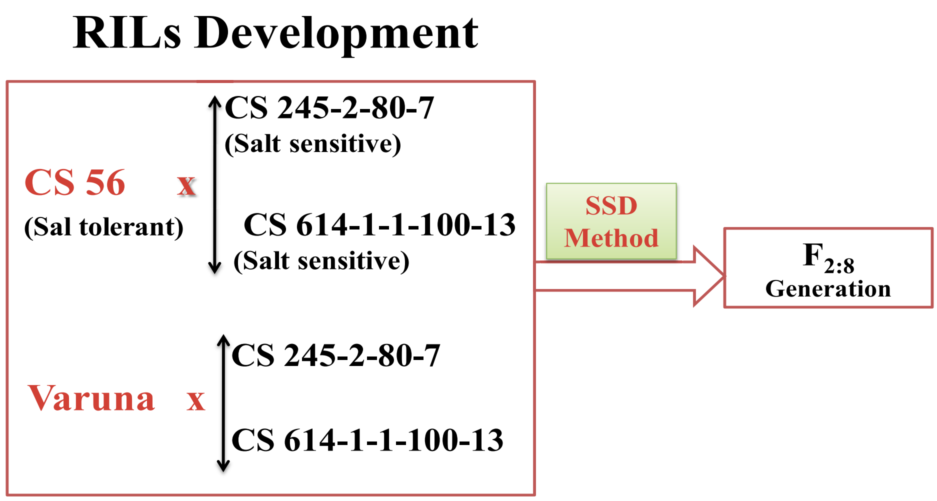
Similarly,34 advanced breeding lines including three checks (Kranti,GirirajandCS 60)were evaluated in $BC_6F_4$generation for seed yield in saline soils (ECe 11-16 dS $m^{-1}$) at Nain Farm (Distt. Panipat). Seed yield ranged from 1.29 to 1.96 t $ha^{-1}$ (Mean 1.58 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.59 t). Four lines gave significantly higher seed yield over the best check CS 60 (1.80 t $ha^{-1}$)with RH 781 x CS 54(1.96 t $ha^{-1}$) followed by CS 204-2-2 x Q 2061-41 (1.91 t $ha^{-1}$).

### Monitoring and Evaluation of promising salt tolerant strains of Indian Mustard (Brassica juncea) in AICRP on Rapeseed Mustard Salinity/Alkalinity Trial -2019-20

A total of eightentries were evaluated in IVT under saline condition (ECe 11.0 dS $m^{-1}$) at experimental farm Nain (Distt. Panipat) and alkali condition (*p*H 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 1.422 to 1.977 t $ha^{-1}$ (Mean 1.648 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.298 t) at Nain, while it ranged from 1.398 to 1.919 t $ha^{-1}$ (Mean 1.590 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.338 t) under high alkaline conditions (*p*H 9.3) at Karnal. Entry CSCN-19-8 (1.977 and 1.919 t $ha^{-1}$) followed by CSCN-19-7 (1.737 and 1.703 t $ha^{-1}$) showed highest seed yield over the saline/alkali conditions (Table 33).

Table 33. Performance of mustard strains in IVT (saline/alkaline conditions)-2019-20

| S. No. | Code | Strain | Seed yield (t/ha) | | | 1000-Seed wt. (g) | | Oil Content (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | PNP | KAR | Mean | PNP | KAR | PNP | KAR |
| 1 | CSCN-19-1 | CS-54 (Check) | 1.621 | 1.588 | 1.605 | 5.0 | 4.7 | 38.9 | 38.6 |
| 2 | CSCN-19-2 | CS 2009-313 | 1.422 | 1.398 | 1.410 | 4.4 | 5.0 | 38.2 | 38.6 |
| 3 | CSCN-19-3 | Giriraj (Check) | 1.471 | 1.390 | 1.431 | 5.1 | 5.3 | 38.6 | 38.8 |
| 4 | CSCN-19-4 | CS 2007-165 | 1.581 | 1.520 | 1.551 | 4.4 | 4.9 | 39.0 | 39.0 |
| 5 | CSCN-19-5 | Kranti (NC) | 1.593 | 1.581 | 1.587 | 3.4 | 3.7 | 38.9 | 38.6 |
| 6 | CSCN-19-6 | CS 2002-99 | 1.483 | 1.319 | 1.401 | 3.9 | 4.4 | 39.1 | 39.0 |
| 7 | CSCN-19-7 | CS 60 (LR) | 1.737 | 1.703 | 1.720 | 4.3 | 4.4 | 39.3 | 39.0 |
| 8 | **CSCN-19-8** | **CS 2005-143** | **1.977** | **1.919** | **1.948** | **4.7** | **5.1** | **39.1** | **38.6** |
| | | **GM** | 1.648 | 1.590 | | | | | |
| | | **CD (5%)** | 0.298 | 0.338 | | | | | |
| | | **DOS** | 18/10/19 | 12/10/19 | | | | | |
| | | **C.V.** | 10.3 | 12.1 | | | | | |
| | | **ECe (dS $m^{-1}$)/ pH** | 12 | 9.3 | | | | | |




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

During the year 2019-20, a total of 1.55 t breeder seed (graded) of Indian mustard varieties; CS 52 (0.050 t), CS 54 (0.20 t), CS 56 (0.10 t), CS 58 (0.60 t) and CS 60 (0.60 t) was produced for distribution to central and state govt. agencies.

**Output During Period Under Report**

- Developed and submitted genotypes CS 2005-143 to AICRP on Rapeseed & mustard for AVT-1 Salinity/Alkalinity trial-2020-21.
- Developed and submitted two genotypes (CS 2002-99 and CS 2005-143) of mustard for 1$^{st}$ year screening in the UP State Adaptive Trial under Sodic condition-2020-21.
- Developed and submitted five genotypes (CS 700-2-1-4, CS 508-1P2, CS 900-1-2-2-1-3, CS 13000-3-1-1-4-2, CS 2005-137) of mustard for 2$^{nd}$ year screening in the UP State Adaptive Trial under Sodic condition-2020-21.
- Developed and submitted four genotypes (CS 13000-3-2-2-5-2, CS 15000-1-1-1-4-2, CS 2002-70, RIL87) of mustard for 3$^{rd}$ year screening in the UP State Adaptive Trial under Sodic condition-2020-21.
- Developed 4 Recombinant Inbred Lines (RILs) population (250 lines of each) in $F_8$ generation according to objectives of project.

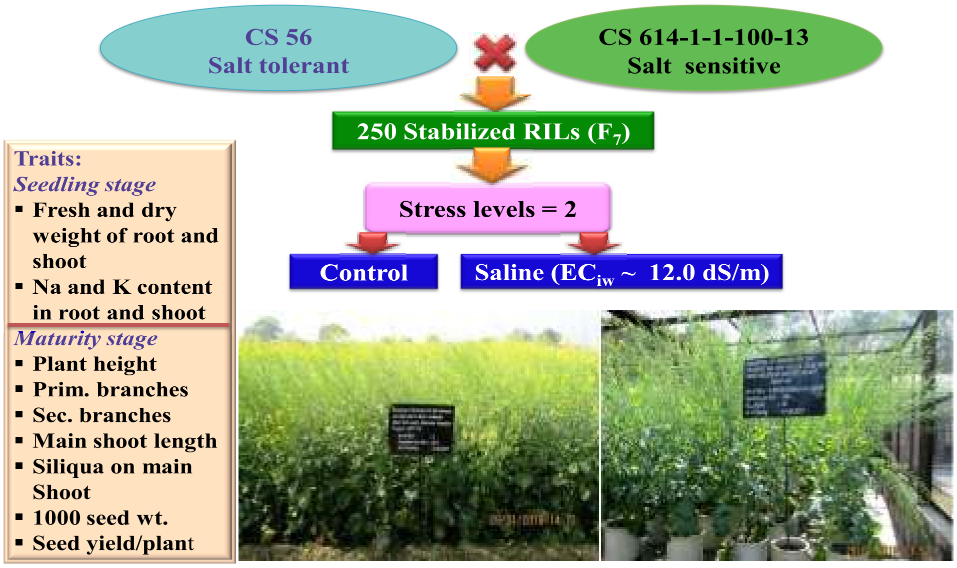
**Molecular approaches for mapping of novel gene(s)/ QTL(s) for resistance/ tolerance to different stresses in Rice, Wheat, Chickpea and Indian Mustard including sheath blight complex genomics and resistance mechanisms. Component 4: Indian Mustard** (Jogendra Singh, P.C. Sharma and Vijayata Singh)

**Objective1. Development of genetic and genomic resources for facilitating research on salt tolerance in Indian mustard**

**Advancement of RILs**

Two hundred fifty two Recombinant Inbred Lines (RILs) including their parents (CS 56 and CS 614-1-1-100-13) were sown in October 2019 and advanced $F_7$ generation in to $F_8$ using single siliqua decent method.

*Phenotyping of mapping populations*




## Phenotyping of mapping populations

Two hundred fifty two RILs including their parents (CS 56 and CS 614-1-1-100-13) were sown under normal and salinity ($EC_{iw}$ 12 dS $m^{-1}$) conditions for phenotyping. The plant height of the parental lines CS 614-1-1-100-13 and CS 56 was 186.7 and 194.5 cm respectively under normal and 166.7 and 174.0 cm saline ($EC_{iw}$ 12 dS $m^{-1}$) conditions. The height of RILs ranged from 161-248 cm under normal and 134.5-207.3 cm under saline soils respectively. The number of primary branches of RILs ranged from 3.5 to 8.5 and 4.0 to 6.7 under normal and saline soils, respectively. The number of primary branches of the parental lines CS 56 and CS 614-1-1-100-13 was 8.5 and 5.0 under normal and 7.3 and 4.7 in saline conditions. The number of secondary branches of RILs ranged from 7.0 to 18.5 and 5.5 to 16.3 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 19.5 and 10.5 under normal and 14.3 and 7.3 in saline conditions. The main shoot length of RILs ranged from 62.1- 100.2 cm under normal and 45.0- 81.3 cm under saline conditions, respectively. The main shoot length of the parental lines CS 56 and CS 614-1-1-100-13 was 87.0 and 77.5 cm under normal and 58.0 and 43.7 cm in saline conditions. The number of siliqua on main shoot of RILs ranged from 42.0-78.0 under normal and 36.0- 59.0 under saline conditions, respectively. The number of siliqua on main shoot of the parental lines CS 56 and CS 614-1-1-100-13 was 58.0 and 57.0 under normal and 47.0 and 33.7 in saline conditions. The test weight of RILs range varies from 3.55-7.30g and 3.10-5.3g under normal and saline conditions, respectively. The parental lines CS 56 and CS 614-1-1-100-13 displayed test weight of 5.2 and 5.0g under normal and 4.7 and 3.9g in saline conditions. The yield/plant of RIL ranged from 23.7 to 59.0g and 3.73 to 27.50g under normal and saline conditions, respectively. The parental lines CS 56 and CS 614-1-1-100-13 displayed yield of 50.2 and 31.2g under normal and 24.8 and 8.1g in saline conditions.

## Objective 2. Identification of QTLs/genes for tolerance to salinity stress

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 are being used for genotyping of RILs and tagging QTLs for salt tolerance in Indian Mustard.

## Objective 3. Understanding physiological and biochemical bases of salinity tolerance

The net photosynthesis, stomatal conductance, water use efficiency and transpiration rate decreased significantly ($P<0.05$) in the all genotypes evaluated at higher salinity ($EC_{iw}$ 12 dS $m^{-1}$) as compared to control.The highest reduction in photosynthesis rate at 12 dS $m^{-1}$ was recorded in CS 614-4-1-4-100-13 (90.04%), while the lowest reduction was recorded in CS 52-SPS-1-2012 (50.03%) followed byCS 54 (55.47%) compared to control. Similarly, highest reduction in stomatal conductance was noted in CS 614-4-1-4-100-13 (80.05%) while CS 52-SPS-1-2012 (30.10%) displayed lowest reduction at $EC_{iw}$12 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. The highest reduction in transpiration rate was recorded in CS 614-4-1-4-100-13 (64.51%), while CS 52-SPS-1-2012 displayed the lowest reduction (40.05%), at $EC_{iw}$ 12 dS $m^{-1}$compared to control. Further, the increasing salinity, also significantly 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 (83.59%) while CS 52-SPS-1-2012 (11.71%) displayed the lowest at $EC_{iw}$ 12 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 salinitywas recorded in CS 614-4-1-4-100-13 (40.22%), while CS 52-SPS-1-2012 (20.52%) displayed the lowest, compared to control. At the higher salinity ($EC_{iw}$ 12 dS $m^{-1}$) shoot and root tissues of CS 614-4-1-4-100-13 accumulated the highest amount of $Na^+$ (4.5 and 7.1 times, respectively,) compared to control. On the contrary, lowest $Na^+$ concentration in shoot and root was recorded in CS 52-SPS-1-2012 (2.3 times) and Pusa bold (3.0 times). Further, $Na^+/K^+$ ratio of the shoot and root was significantly lowest in the salt tolerant mutant CS 52-SPS-1-2012 (1.04 and 2.01, respectively), whereas, the ratio was highest in the salt susceptible mutant CS 614-4-1-4-100-13 (2.4 and 5.00) followed by Pusa bold (2.03 and 4.84) for shoot and root, respectively, across the salinity levels.

### Other outcomes

Developed and registered Indian mustard germplasm **CS 52-SPS-1-2012 (IC0630607 & INGR19082)** as national genetic stocks under National Bureau of Plant Genetic Resources (NBPGR)for unique traits *viz.* salinity tolerant up to $EC_e$ 15 dS $m^{-1}$, alkalinity tolerant up to pH 9.5, high 1000-Seed weight (8-9g) and high photosynthetic efficiency under salinity.

| Name of Genotype | CS 52-SPS-1-2012 |
|---|---|
| Parentage | Mutant of CS 54 |
| **Unique traits** | |
| Salinity tolerance (ECe dS/m) | Up to 15.0 |
| Sodicity tolerance (pH) | Up to 9.5 |
| High 1000- Seed weight | 8.0-9.0 g |
| Photosynthetic efficiency under salinity | High |


Certificate
Plant Germplasm Registration

Member-Secretary
PGRC

Chairman, PGRC

Mustard Genotype CS52-SPS-1-2012

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

### Phenotyping of mapping populationunder alkaline condition

A total of 330 RILs along with parents (BG-1103 x Karnal Chana-1) were evaluated under normal and sodic (pH 9.3±0.1) environments during rabi season of 2019-20. All the lines were germinated under alkalinity but 49 lines didn't survive after germination. The range, mean and per cent reduction of different traits for RIL population were recorded (Table 34). High mean seed yield and other related traits performance was noticed under normal soil as compared to alkalinestress. The flowering and maturity was early under stress condition. The mean plant height was 64.36 and 55.68 cm under control & alkalinity and there was a 13.49 % reduction under alkaline condition. The seed yield/plant was the most sensitive trait and reduced by 38.19 % under alkaline environment (Table 34). The seed yield (g) ranged from 17.42(RIL106) to 53.64g (RIL225) under control and 4.30(RIL79) to 36.54 g(RIL276) under alkalinecondition. On the basis of higher yield 10 best lines from each treatment were selected. 100 seed wt. was also affected by alkalinity and it was reduced about 15.70%. $Na^+$ content under alkalinity in both root and shoot ranged from 2.06-3.39% and 0.74-1.06 % and it was 60.89 & 50.0 % higher than control.

### Characterization of advance material and varieties under alkaline environment

Twenty six lines/varieties were sown along with check CSG 8962 (Karnal Chana-1) in microplots for evaluation in control and saline ($EC_{iw}$ 6 dS $m^{-1}$) conditions for seed yield and other yield contributing traits. 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, 100 seed weight $Na^+$and $K^+$ content in root and shoot. All the genotypes were earlier for days to 50% flowering under saline condition as compared to control. Under salt stress, earliest flowering was recorded in genotype GG2 and HK2 (89 days) followed by HC-1 and GG3. These lines showed mean yield of 43.23 g under control condition which reduced 47.88 % under saline condition. Genotype H-09-96 Showed higher yield followed by KC1 x S7 and H-07-120 under control as well as saline condition (Fig. 37). Under saline condition, minimum reduction was recorded for H-08-71 (35.66%) followed by H-10-41 (39.69%) and S7 x KC1 (40.17). 100 seed weight is also reduced with salinity but reduction varies from 2.17% in HK-4 to 41.36% in C-235. Interestingly, it was also noted that line HK-4 had the highest 100 grain weight under control as well as saline

Table 34. Mean performance of the 330 RILs and parents under normal and alkaline condition for different traits.

| S. No. | Characters | Mean | | Range | | % reduction |
|---|---|---|---|---|---|---|
| | | Control | pH 9.3±0.1 | Control | pH 9.3±0.1 | pH 9.3±0.1 |
| 1 | Days to 50% flowering | 102.66 | 92.18 | 80-118 | 72-116 | 10.20 |
| 2 | Days to 50% maturity | 146.42 | 139.8 | 128-156 | 122-151 | 4.52 |
| 3 | Plant height (cm) | 64.36 | 55.68 | 53.4-71.2.2 | 43.24-66.3 | 13.49 |
| 4 | Yield/plant (g) | 44.14 | 27.28 | 17.42-53.64 | 4.30-36.54 | 38.19 |
| 5 | 100 seed wt. (g) | 17.32 | 14.60 | 12.60-21.24 | 8.12-18.32 | 15.70 |
| 6 | Root Na+ (%) | 1.79 | 2.88 | 1.33-1.96 | 2.06-3.39 | -60.89 |
| 7 | Root K+ (%) | 1.69 | 1.47 | 1.44-1.87 | 1.30-1.63 | 13.01 |
| 8 | Shoot Na+ (%) | 0.54 | 0.81 | 0.42-0.67 | 0.74-1.06 | -50 |
| 9 | Shoot K+ (%) | 2.02 | 1.61 | 1.68-2.34 | 1.49-1.81 | 29.20 |

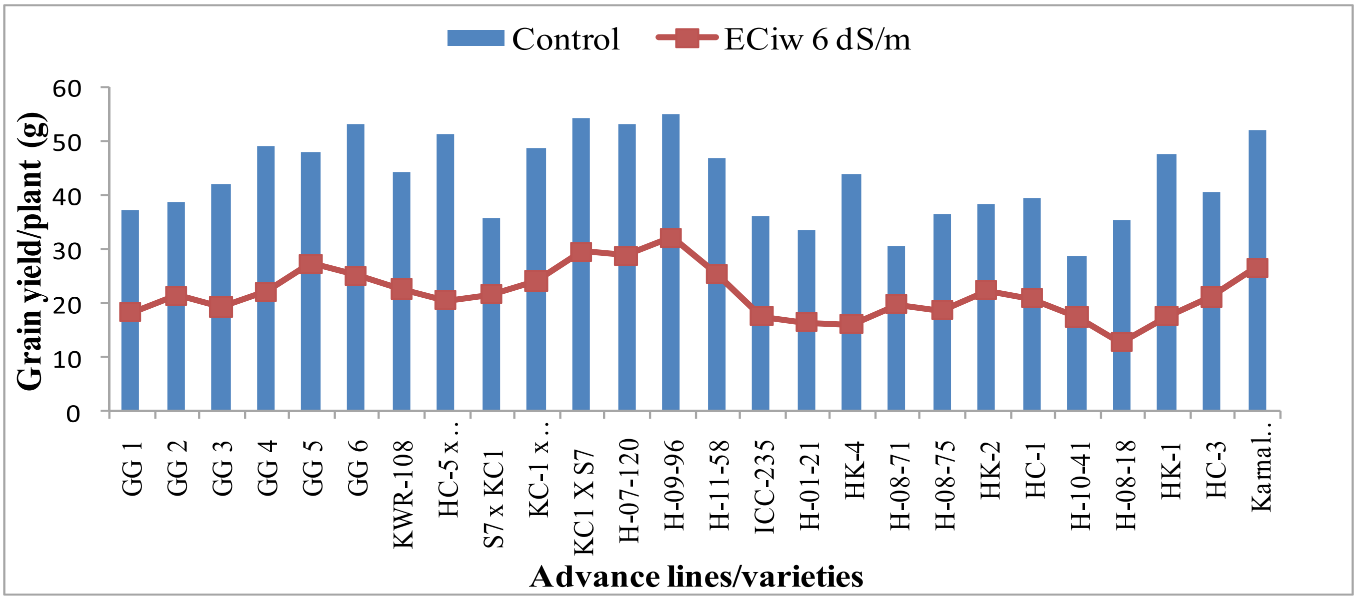


Fig 37. Yield potential of different lines/varieties under control and saline condition.

condition, followed by HK-2 and HK-1 under control and HK-2 and HC-3 under saline condition. Chlorophyll content varies from 2.06 to 4.08 mg $g^{-1}$ with mean values of3.17 mg $g^{-1}$ under control. While under salinity stress mean chlorophyll content reduced by 28.07% with a range of 1.62 to 2.98 mg $g^{-1}$. Maximum reduction under salinity was noted in GG1 (45.08%) whereas GG5 showed the minimum reduction of 6.45%. Three to six times higher proline content was recorded under saline condition in comparison to control. Proline content ranged from 16.78to 96.4µg $g^{-1}$ under salinity stress. Maximum increase for proline content was recorded in H-09-96 followed by HC-3 and KC1 x S7.

### Crossing of salt tolerant lines with prominent varieties.

High yielding salt sensitive varieties were selected for crossing with salt tolerant genotypes. A total of 12 cross combination were made and pods were harvested and will be evaluated in next year.

### Maintenance of germplasm and parental lines

A total of 276 germplasm lines and 24 parental lines were maintained for their use in future breeding programme.

### Breeder seed production

During 2020, 3.5 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 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, plant height (cm), seed yield/plant, 100 seed weight, total chlorophyll, proline and ionic analysis.

Days to 50% flowering ranged from 71-130 and 70-126 respectively under control and saline condition. Under stress condition, flowering was early and it was 5.39 %. The RIL82 has earliest flowering followed by RIL58 and RIL53. The plant height of 163 RILs ranged from 61.0 to 97.0, and 60.0 to 94.5 cm, respectively under control and saline. There was 2.86% reduction in plant height under stress compared to control condition (Table 35). The mean yield/plant was 25.70 g in control while it was 7.77 g in stress. It ranged from 2.09 to 83.61 and 1.27 to 23.56 g, respectively under control and saline condition. There was reduction in yield/plant under salinity and it was 69.77 % less than control. The RIL115 has maximum yield followed by RIL83, RIL4, RIL62, RIL69 and RIL29 under saline condition. The 100 seed weight of these RILs ranged from 10.48 to 24.42 g, and 7.06 to 19.6 g, respectively under control and saline condition. There was major reduction in 100 seed weight in salinity condition compared to control condition. The overall growth in saline environment was comparatively less. The number of branches in saline environment was very low compared to control.

### Phenotyping of lines received from IARI, New Delhi

A total of 14 lines received from IARI, New Delhi were sown along with check CSG 8962 (Karnal Chana-1) in microplots for evaluationin control and saline ($EC_{iw}$ 6 dS $m^{-1}$) conditions for seed yield and other yield contributing traits. The saline irrigation of $EC_{iw}$ 6 dS $m^{-1}$ was given at 30, 60 and 90 days after sowing. Under stress condition the flowering was early and days to maturity were also reduced in all the genotypes in comparison to control. Earliest flowering was noted in genotype ILC 0 (Lativia) and SBD-377 under saline condition. These lines showed mean yield of 42.93g under control condition which reduced by 64.64% under saline environment. ICCV-10 and SBD-377 showed higher yield

Table 35. Mean, range and percent reduction of different characters of 163 recombinant inbred lines evaluated at salinity ECiw 6 dS $m^{-1}$.

| S. No. | Characters | Mean | | Range | | % reduction |
|---|---|---|---|---|---|---|
| | | Control | ECiw 6 dS $m^{-1}$ | Control | ECiw 6 dS $m^{-1}$ | over control |
| 1 | Days to 50% Flowering | 109.03 | 103.15 | 71-130 | 70-126 | 5.39 |
| 2 | Plant height (cm) | 79.50 | 77.23 | 61.0-97.0 | 60.0-94.5 | 2.86 |
| 3 | Yield/Plant (g) | 25.70 | 7.77 | 2.09-83.61 | 1.27-23.56 | 69.77 |
| 4 | 100 Seed weight (g) | 16.20 | 12.58 | 10.48-24.42 | 7.06-19.6 | 22.35 |
| 5 | Total chlorophyll (mg/g FW) | 3.13 | 2.78 | 2.66-4.06 | 1.44-3.46 | 11.18 |
| 6 | Proline (ug/g FW) | 47.01 | 217.42 | 9.76-179.12 | 34.93-677.76 | -362.5 |
| 7 | Root Na+ (%) | 0.683 | 3.14 | 0.350-1.196 | 1.913-5.29 | -359.7 |
| 8 | Root K+ (%) | 1.006 | 0.577 | 0.262-2.659 | 0.188-1.113 | 42.64 |
| 9 | Shoot Na+ (%) | 0.281 | 1.005 | 0.173-0.391 | 0.380-2.630 | -257.6 |
| 10 | Shoot K+ (%) | 2.596 | 1.454 | 1.309-4.310 | 0.543-2.792 | 43.99 |

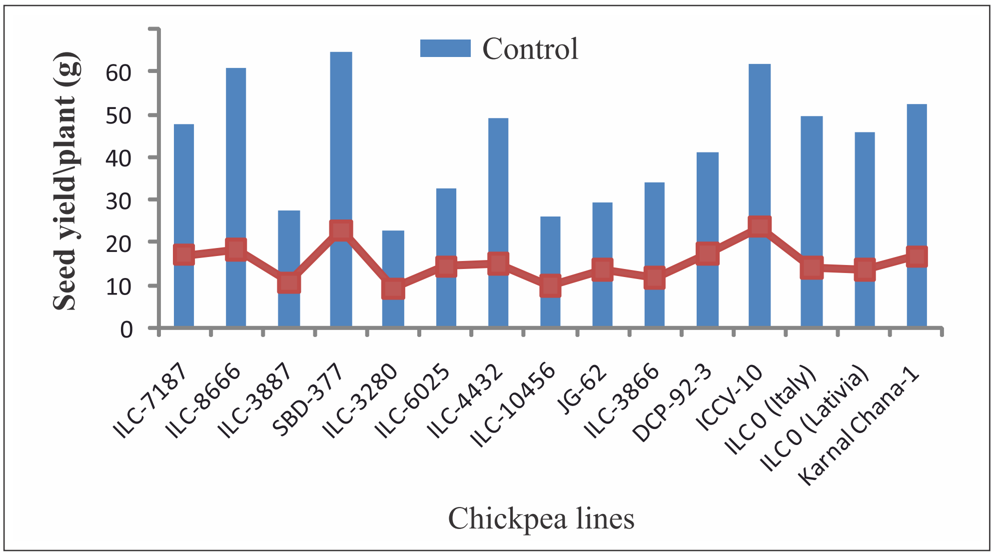



Fig 38. Yield potential of different lines of chickpea under control and saline environments.

under saline environment but the per cent reduction was lowest in JG-62 (53.65%) followed by ILC-6025 (55.7%) and DCP-92-3 (57.87%) and ILC-3280 (58.9%) (Fig. 38). 100 seed weight is also reduced with salinity but reduction varies from 1.38 % (SBD-377) to 45.74% (ILC-3866). Interestingly, it was also noted that lines SBD-377 had the highest 100 grain weight under control as well as saline condition, followed by ICCV-10 and ILC 0 (Lativia). Under salinity stress mean chlorophyll reduced by 17.42 % with a range of 2.20 to 2.98 mg $g^{-1}$. Proline content varies from 26.71 µg $g^{-1}$ to 258.69 µg $g^{-1}$ under salinity.

**Response of onion and garlic varieties under salt stress** (S.K. Sanwal and B.K. Dubey)

### Onion

Sixteen onion varieties were transplanted in microplots in January, 2020 under normal and saline condition (ECiw 4 & 7 dS $m^{-1}$) with the objectives to find out salt tolerant varieties. Increaszed soil salinity decreased the yield per plant, bulb diameter and TSS% in all the evaluated genotypes. Highest yield per plant was observed in NHRDF Red (L-28) (100.50 g) followed by BhimaKiran under control and saline environments (Fig. 39).

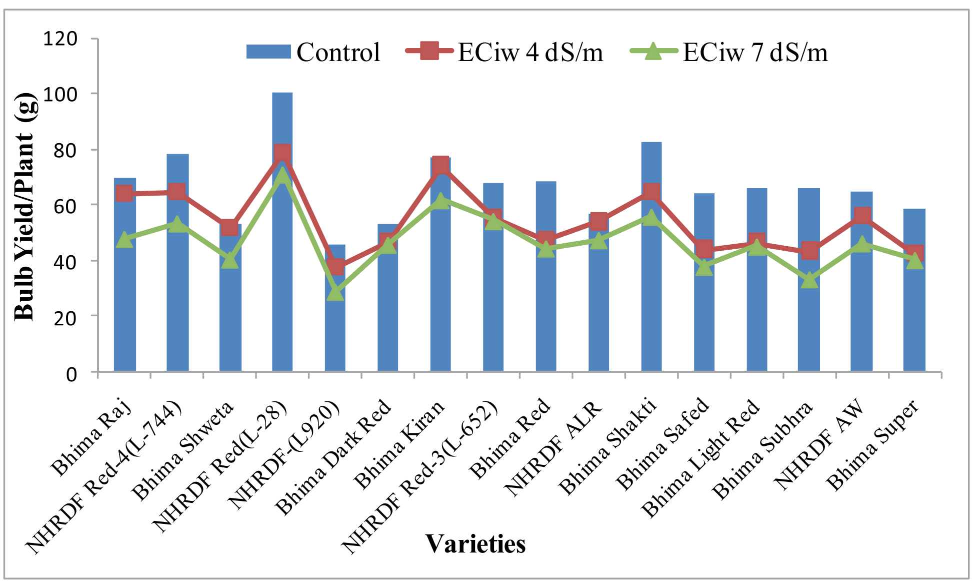



Fig 39.Performance of different onion varieties under saline environment.

Maximum reduction for yield per plant was seen in BhimaShubhra (34.18% and 49.68%) followed by BhimaSafed (30.92% and 40.94%) and Bhima Red (30.44% and 35.06%) at ECiw 4 &7 dS $m^{-1}$ in comparison to normal condition. Highest bulb diameter was observed in NHRDF Red (L-28), followed by NHRDF Red-4 (L-744) under control and saline conditions. Maximum reduction for bulb diameter was observed in BhimaSafed i.e. 17.02% and 19.54% at ECiw 4 and 7 dS $m^{-1}$ compared to control. Total soluble solid (TSS) percent was maximum in NHRDF ALR which is 15.30%, 14.90% and 14.20% and minimum in Bhima Dark Red (11.20%), Bhima Raj (11.90%) and Bhima Red (10.40%) under normal, 4.0 EC and 7.0 EC, respectively. No differences were seen for Bhima Raj, NHRDF AW and Bhima Super for TSS% under normal and at ECiw 4 dS $m^{-1}$ salinity level. Minimum reduction was observed in Bhima Light Red (0.36%) and BhimaShweta (0.39%) at 4.0 EC and in BhimaShweta (3.88%) and Bhima Super (4.92%) at 7.0 EC compared to control.

Na/K ratio was higher in roots than shoot and bulb in all the tested varieties. There was a positive correlation between salinity and Na/K ratio in root, shoot and bulb. Bhima Light Red and NHRDF Red (L-28) have lowest Na/K ratio in roots while NHRDF ALR has lowest Na/K ratio in shoots.

## Garlic

Twelve garlic varieties were sown under control, saline (ECiw 4 & 7 dS $m^{-1}$) and alkaline ($pH_2$ 9.0 & 9.5) condition in Oct. 2019 in microplot (salinity) and field (alkaline) to find out the salt tolerant genotypes. With increase in soil salinity, there was a decrease in the yield per plant, bulb diameter and TSS% in all the evaluated genotypes. Highest yield per plant was observed in Yamuna Safed (G-1) (27.34 g) followed by Yamuna Safed-3 (G-282) (25.12 G) and Yamuna Purple-10 (G-404) (25.06 g) and lowest yield was recorded in Bhima Purple (9.94 g) under normal condition.

At ECiw 4.0 dS $m^{-1}$, Yamuna Purple-10 (G-404) (24.62 g) recorded highest yield followed by Yamuna Safed-4 (G-323) (22.08 g) and Yamuna Safed-3 (G-282) (21.82 g) while at ECiw 7.0 dS $m^{-1}$, highest yield was recorded from Yamuna Safed-3 (G-282) (21.84 g) followed by Yamuna Purple-10 (G-404) (21.00 g) (Fig. 40).

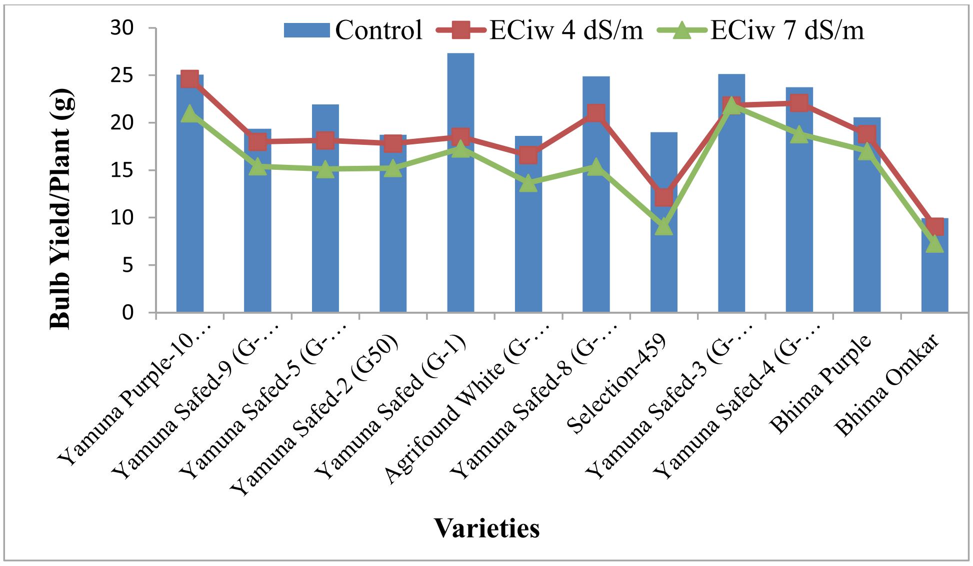



Fig 40. Performance of different garlic varieties under saline condition.

Under alkaline condition, highest yield/plant was observed in Bhima Purple (30.54 g) followed by Yamuna Safed-3 (G-282) (29.46 g) and Yamuna Safed-4 (G-323) (29.37 g) under normal condition. At higher alkalinity ($pH_2$ 9.5) maximum yield/plant was recorded from Yamuna Purple-10 (G-404) (24.48 g) followed by Yamuna Safed-3 (G-282) (22.97 g) and YamunaSafed (G-1) (20.62 g).

Highest polar diameter of bulb was observed in Yamuna Safed-8 (G-384) (4.9), Agrifound White (G-41) (4.07) and Yamuna Safed-8 (G-384) (3.68) and lowest in Bhima Purple. Highest equatorial diameter of bulb was observed in Yamuna Safed-8 (G-384) (4.70) followed by Yamuna Safed-3 (G-282) and Yamuna Safed (G-1) while at higher alkalinity ($pH_2$ 9.5), Yamuna Safed-3 has maximum equatorial diameter followed by Yamuna Safed-4.

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

### Phenotyping of linseed germplasms under salt stress environment

A total of 2612 lines along with five checks i.e T-397, Shekhar, Hira, Mukta&Shubhra were sown under control, saline and alkaline field from 26-31 Oct. 2020in 28 blocks under augmented design. Each line was sown in single row of 2 m length and 45x10 cm spacing was kept between row to row and plant to plant. Each block has 95 lines and five checks. Due to higher salinity (ECe 10.24-12.49 dS $m^{-1}$) of the selected field at Nain Farm, Panipat there was no germination and again irrigation was done with low saline water. After irrigation, sampling was done and the salinity was in the range of 8.62-10.16 dS $m^{-1}$. Then

Table 36. Soil and germination status of control, alkaline and saline field.

| Type of soil | Soil parameters | | Germination status | | | |
|---|---|---|---|---|---|---|
| | ECe (dS $m^{-1}$) | $pH_2$ | No. of lines germinated | Lines not germinated (<5 plants) | Lines having poor germination | Percent germination |
| Normal | 0.12 | 7.85 | 2605 | 7 | Nil | 99.73 |
| Alkaline | 0.16 | 9.3-9.5 | 2579 | 33 | 275 | 98.73 |
| Saline | 8.62-10.16 | 8.12 | 2505 | 107 | 551 | 95.90 |

Linseed germplasm germination in normal and alkaline field

Salt tolerant Lentil variety PDL-1

Salt tolerant Lentil variety PSL-9

re-sowing was done on 15th Nov. Germination data was recorded and it was found that under saline condition, 107 lines were not germinated while 551 lines have poor germination having <5 plants (Table 36). In alkaline field ($pH_2$ 9.4±0.2) the germination was slow as compare to normal field and 33 lines were not germinated while 275 lines have poor germination having <5 plants. In normal soil condition, the germination was very good except 7 lines (EC0041667, EC0041737, EC0541207, EC80490, EC00541224, EC0041742, EC0080490) did not germinated. Presently crop is in vegetative growth stage and data recording on early vigour index and days to 50% flowering are in progress.

**Development and release of salt tolerant varieties of Lentil PDL-1 and PSL-9** (Vijayta Singh, S.K. Sanwal and P.C. Sharma)

These lentil varieties were developed with collaboration of IARI New Delhi, for the medium salt prone soil and water of the NWP and NEP region (Punjab, Haryana, Delhi, Rajasthan, Uttar Pradesh, Bihar, Orissa, West Bengal and Assam) and recommended by CVRC in 84th Meeting held on 10th July, 2020.

**Salt tolerant Lentil variety PDL-1 :** It has a plant height of 30–32 cm, flowering on 75–80 days, maturity of 103–118 days, 57 pods / plant, 1.9 g weight of 100 seeds. Its yield is 1.1–1.6 t $ha^{-1}$ in saline-affected soil (up to ECe 6 dS $m^{-1}$) and alkalinity (up to pH 9.0) and 2.5–3.0 t $ha^{-1}$ in normal soil.

**Salt tolerant Lentil variety PSL-9 :** This variety has a plant height of 31-33 cm, flowering on 69-77 days, maturity of 108-116 days, weight of 62 pods / plant, 2.6 g of 100 seeds. Its yield is 1.1–1.5 t $ha^{-1}$ in saline-affected soil (up to ECe 6 dS $m^{-1}$) and alkalinity (up to pH 9.0) and 2.0–2.5 t $ha^{-1}$ in normal soil.

**Development of high density linkage map and tagging salinity tolerance in lentil using genotyping-by-sequencing approach for improving salt tolerance** (Vijayata Singh and S.K. Sanwal)

The main aim of this project is to advance the $F_4$ mapping population for development of $F_7$ RILs population for salt tolerance, to phenotype the $F_7$ RILs mapping population for salt tolerance under controlled saline microplots/ field conditions and to map the QTLs using various traits for salt tolerance at seedling and reproductive stages.

**Molecular mapping for salinity stress tolerance at seedling stage**

The parents sensitive (L-4147 and L-4076) and salt-tolerant (PDL-1 and PSL-9), $F_1$, $F_2$, $F_3$ and backcross populations were assayed in salt solution at 120 mM NaCl for assessing salinity stress tolerance based on seedling survival and a Fluorescein diacetate (FDA) signal (Fig. 41). The $F_{1s}$ were found tolerant to salinity stress indicating their dominance over the sensitive ones. The $F_2$ segregation fitted well with the expected monogenic frequency ratio of salt- tolerant: salt-sensitive plants, which indicates that salinity stress tolerance is governed by a single dominant gene. This was also confirmed in $F_3$ and backcross segregation data. Allelism test supported the hypothesis that the same gene was conferring stress tolerance in tolerant genotypes (PDL-1 and PSL-9). This matched with major QTL of seedling survival under salinity stress. Four hundred and ninety-five SSR markers were analyzed for polymorphism and 11 of them were found polymorphic between the parents. Among eleven polymorphic markers, seven were associated with seedling survival under salinity stress. The QTL of this trait was mapped within a map

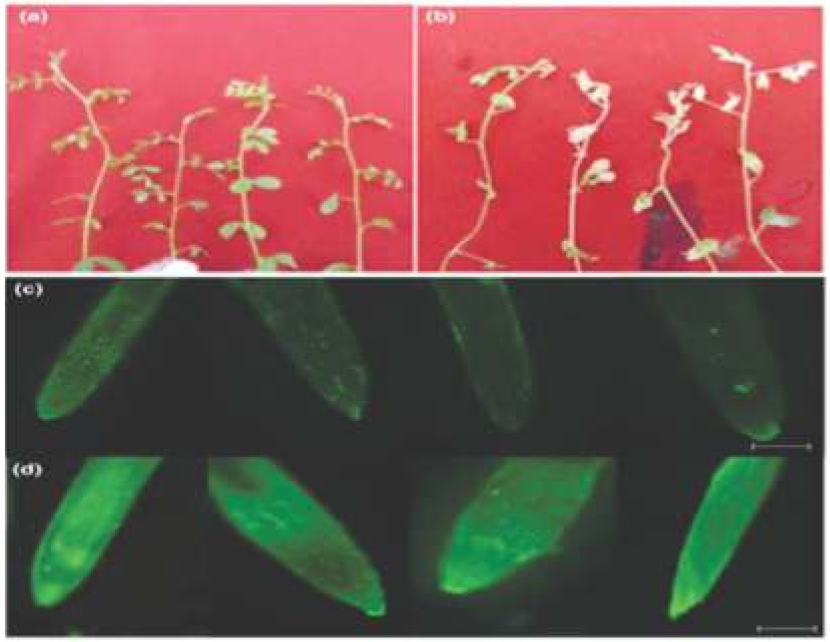



Fig 41. Phenotyping of tolerant and sensitive F2 individuals in response to salinity stress (120 mM) for seedling survival (a, b0 and FDA based on Fluorescent signals (c, d) under hydroponic assay

distance of 133.02 cm in $F_2$mapping population (L-4147 X PDL-1) and it was found located on linkage group 1 (LG_1) and explained phenotypic variance of 65.6%. This report on QTL mapping should be useful for dissection ofcandidate genes and development of molecular markers for improvement of salinity stress tolerance in lentil.

On the basis of genetic analysis of $F_1$,$F_2$,$F_3$and back- cross populations, it is suggested that a single major gene is associated with seedling survival and FDA based fluorescent signals in lentil and governs its salinity tolerance. Bulk segregant analysis proved to be a simple and less timeconsuming approach to salinity stress tolerance when linked with a molecular marker system. A salinity stress tolerance locus, *qS_ss* was found linked with seven SSR markers including PBA_LC_1752, PBA_LC_1288, PBA_LC_1684, PBA_LC_1480, LC_04, PBA_LC_1563 and PBA_LC_1526. Simple sequences repeat markers such as LC_04 and PBA- LC-1563 had proximity with seedling survival on the linkage map. These markers can be used in future molecular breeding program for transferring salinity tolerance genes in lentil. However, there is a need to employ more PCR-based markers to saturate the map and confer salinity tolerance to the locus present in the sources PDL-1 and PSL-9.

**Genetic improvement of Lentil (*Lens culinaris* Medikus) for salt tolerance using conventional and molecular breeding approaches** (Vijayata Singh, Jogendra Singh and P.C. Sharma)

The main aim of this project is to development of salt tolerant lentil genotypes, identification of donors for salt tolerance to introgress into high yielding cultivars of lentil and development of mapping population from the most contrasting parental line for salt tolerance QTL identification. Screening advanced breeding line (germplasm, cultivars, segregating generations and elite line) under salinity ECe 7 and $EC_{iw}$ 7-10 dS $m^{-1}$) and sodicity ($pH_2$ 9.3) for target traits along with high seed yield during 2020-21 for morpho-physiologiical traits and crop is yet to be harvest. Crossing most contrasting parents to develop RILs for mapping of QTLs governing salinity and sodicity tolerance and selecting true to type crosses. Introgression of salt tolerance from identified donors in to elite Lentil genotypes for development of pre-breeding lines.

### *Monitoring and Evaluation of promising salt tolerant entries of Lentil in AICRP on MULLaRP-2020*

A total of 23 entries were evaluated under saline condition (ECe 6-7 dS $m^{-1}$) at experimental farm Nain (Distt, Panipat). Significant differences were observed in seed yield amongst the genotypes evaluated under salinity. Under salinity stress, seed yield ranged from 0.651 to 2.551 t $ha^{-1}$ (Mean 1.622 t $ha^{-1}$, CD $_{(0.05\%)}$ 0.294 t $ha^{-1}$) at Nain, Panipat. Entry SL-20-123 (2.551 t $ha^{-1}$) showed highest seed yield followed by SL-20-107 (2.318 t $ha^{-1}$) under salinity.

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

Initially the salt-specific transcriptome libraries were prepared from *Urochondra setulosa*, *Dichanthium annulatum* through de novo sequencing at EC 30, 40 and 50 dS $m^{-1}$ while that of salt tolerant rice, CSR-10 at EC 12 & 18 dS $m^{-1}$ salt treatments. In *Urochondra*, an average of 345,729 transcripts were differentially expressed while in *Dichanthium* an average of 147,851 transcripts were expressed. In Rice, an average of 128,567 transcripts were differentially expressed. The differentially expressed genes involved in salt tolerance mechanisms were identified at three salt concentrations. The transcripts were involved in various pathways as shown in the table 37.

Based on DEGs analysis, the four genes involved in SOS pathway in the salt tolerant grass halophyte, *Urochondra setulosa* were identified asV-type proton ATPase (Urochondra_DN29474_c0_g1_i1) with log2fold value of 4.36, CBL-interacting protein kinase (Urochondra_DN39224_c0_g1_i2) with log2fold value of 1.53, Sodium/hydrogen exchanger (Urochondra_DN33781_c0_g1_i1) with log2fold value of 3.50 and Calcineurin B-like protein 4 (Urochondra_DN35326_c1_g1_i3) with log2 fold value of 2.16.

Similarly, the genes involved in ROS scavenging include the following:

1. Catalase (*Urochondra*_DN29893_c0_g1_i1) log2fold= 1.11
2. Superoxide dismutase (*Urochondra*_DN36187_c0_g2_i5) log2fold= 1.8
3. L-ascorbate peroxidase (*Urochondra*_DN34366_c0_g1_i1) log2fold= 3.89
4. Monodehydro ascorbate reductase (*Urochondra*_DN48599_c0_g1_i1) log2fold= 1.79
5. Glutathione reductase (*Urochondra*_DN37694_c0_g2_i1) log2fold= 1.52

Table 37. Pathway specific DEGs involved in salt tolerance mechanism

| Pathway | No. of transcripts | |
|---|---|---|
| | Up-regulated | Down-regulated |
| Response to oxidative stress | 68 | 35 |
| Signal transduction | 71 | 28 |
| MAPK pathway | 37 | 8 |
| Ion transport | 38 | 17 |
| Defense response | 66 | 58 |
| Photosynthesis | 17 | 41 |
| Cell wall organization | 131 | 20 |
| Cell redox homeostasis | 30 | 37 |
| Carbohydrate metabolic process | 233 | 127 |
| Sequence-specific DNA binding transcription factor | 195 | 131 |

Also, the genes involved in MAPK pathway include the following:

1. Protein phosphatase 2C (*Urochondra*_DN30190_c0_g2_i2) log2fold= 5.43
2. Serine/threonine-protein kinase (*Urochondra*_DN34126_c1_g1_i6) log2fold= 3.25
3. Catalase (*Urochondra*_DN29893_c0_g1_i1) log2fold= 1.11
4. MAP kinase3 (*Urochondra*_DN36586_c0_g1_i2) log2fold= -4.22

The validated differentially expressed genes involved in salt tolerance pathways namely, dehydrin/LEA group 2-like protein, sodium/hydrogen exchanger, transcription factor DREB, trehalose-6-phosphate synthase, calmodulin-binding protein, pyrroline-5-carbosylate synthase etc from grass halophytes were randomly selected for transformation into Rice. Thirty-four differentially expressed genes (DEGs) in *Urochondra* and *Dicanthium*showing high level of expression during salt stress was compared with DEGs in CSR10 for salinity stress during reproductive stage @12 and 18 dsm$^{-1}$. The analysis showed two genes involved in trehalose metabolism *(Trehalose 6-P synthase, Trehalose 6-P Phosphatase*) were co-expressed both in *Urochondra* and *Dicanthium* at salt stress >18 dsm$^{-1}$. The complete coding sequence of *Urochondra* Dehydrin gene identified through RACE was cloned in pCAMBIA1304 binary vector and transformation of these genes in CSR 10 is in progress at ICAR-NRRI Cuttack.

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

A pot experiment was conducted to evaluate the response of nano-fertilizers in rice-wheat cropping system under salt stress (sodicity/salinity). Total treatments were 9 as

**T1 – Control; T2 – Full N through Urea (3-splits); T3 – 1/3rd through Urea + 1/3rd through Urea +1/3rd through Nano-N (33% replacement); T4–1/3rd through Urea + 1/3rd through Urea + Nano-N (50:50) +1/3rd through Nano-N (50% replacement); T5–1/3rd through Urea + 1/3rd through Nano-N +1/3rd through Nano-N (66% replacement); T6 –100% RDN through Nano-N (Basal + Foliar spray); T7 – 1/3rd through Urea + 1/3rd through Urea + Nano-N (50:50) +1/3rd through Nano-N (50% replacement) + Nano-Zn + Nano-Cu; T8 – T7 + Sagarika; T9 – T7 + Sagarika + Biofertilizers.

**Note :** The recommended dose of nitrogen (RDN) for CSR 30 Basmati: 60 kg N/ha; for PB 1121: 90 kg N/ha

### Physiological traits

Replacing 50% N through nano-Nitrogen along with nano-Zn and nano-Cu supplementation resulted into 12.11% and 7.18% plant height enhancement in CSR 30 Basmati and PB 1121, respectively compared to conventional approach (RDN application through urea). In normal soils, the application of Nano-N resulted in to the improvement of the relative water content by 0.23% (T3), 0.95% (T4) and 3.38% (T5) in CSR 30 and about 0.70% (T3), 0.55% (T4) and 2.40% (T5) in PB 1121 as compared to RDN application through urea (T2). In addition, basal application of sagarika (T8) and sagarika + seed inoculation with biofertilizer (T9) resulted in enhanced RWC as compared to RDN application through urea (T2) for both varieties. The level of enhancement was higher under sodic and saline soils. Before application of Nano-N the mean percent reduction of chlorophyll content in sodic soils was about 13.89% in

Table 38. Effect of salt stress and nitrogen application on grain yield of two rice varieties

| Treatment abbreviations | Treatment | Grain yield (g/plant)Ŧ | | | | | |
|---|---|---|---|---|---|---|---|
| | | CSR 30 Basmati | | | Pusa 1121 | | |
| | | Control (pH~8.0 ±0.2) (ECe~ 0.6 dS/m) | Sodic soil (pH~9.0 ± 0.2) | Saline soil (ECe~6.0 ±0.2 dS/m) | Control (pH~8.0 ±0.2) (ECe~ 0.6 dS/m) | Sodic soil (pH~9.0 ± 0.2) | Saline soil (ECe~6.0 ±0.2 dS/m) |
| **T1** | Control (No-nitrogen) | 4.28 | 2.43 | 2.24 | 5.59 | 3.23 | 1.11 |
| **T2** | Full N through Urea (3-splits) | 11.74 | 9.87 | 8.64 | 12.29 | 9.67 | 8.57 |
| **T3** | 1/3rd through Urea + 1/3rd through Urea +1/3rd through Nano-N **(33% replacement)** | 11.93 | 10.09 | 8.78 | 12.52 | 9.83 | 8.75 |
| **T4** | 1/3rd through Urea + 1/3rd through Urea + Nano-N (50:50) +1/3rd through Nano-N **(50% replacement)** | 12.29 | 10.57 | 9.19 | 12.78 | 10.27 | 8.98 |
| **T5** | 1/3rd through Urea + 1/3rd through Nano-N +1/3rd through Nano-N **(66% replacement)** | 12.27 | 10.77 | 9.45 | 12.81 | 10.40 | 9.27 |
| **T6** | 100% RDN through Nano-N (Basal + Foliar spray) | 9.39 | 8.07 | 6.69 | 10.87 | 8.46 | 7.06 |
| **T7** | T4 +Nano-Zn + Nano-Cu | 12.42 | 10.60 | 9.22 | 12.93 | 10.58 | 9.32 |
| **T8** | T7 + Sagarika @ 25 kg/ha (granular) | 12.73 | 10.98 | 9.57 | 13.37 | 10.69 | 9.43 |
| **T9** | T8 + Biofertilizer | 12.78 | 11.09 | 9.61 | 13.52 | 11.13 | 9.80 |
| | **General mean** | 11.09[A] | 9.39[B] | 8.15[B] | 11.85[A] | 9.36[B] | 8.03[C] |
| | **CV%** | Stress (S): 18.1; N treatments (N): 12.8 | | | Stress (S): 5.6; N treatments (N): 10.1 | | |
| | **HSD @ 5%** | S: 1.67; N: 1.87; S× N: NS | | | S:0.53; N: 1.51; S× N: NS | | |

Ŧrepresents mean data of 12 pooled measurements (4 replications × 3 plants/replicate)

CSR30 and 13.67% in PB 1121 while 21.08% in CSR30 and 23.06% in PB 1121 in case of saline soils in comparison to normal soils. Before application of Nano-N the mean percent reduction of photosynthetic rate in sodic soils was about 14.35% in CSR 30 and 17.46% in PB 1121 while 18.08% in CSR30 and 25.61% in PB 1121 in case of saline soils in comparison to normal soils. The application of Nano-N resulted the mean percent reduction of photosynthetic rate in sodic soils to the tune of 16.09% in CSR30 and 28.78% in PB 1121 while 43.17% in CSR30 and 46.26% in PB 1121 in case of saline soils.

### Yield

The effects of stress treatments as well as nitrogen treatments were found significant in both the test varieties, but the interactive effect was non-significant (Table 38). Yield improvement to the tune of 1.6% (T3), 4.7% (T4), and 4.5% (T5) in CSR 30 Basmati and -1.8% (T3), 4.0% (T4) and 4.2% (T5) in PB 1121 was observed with 33%, 50% and 66% replacement of conventionally applied N (urea) through nano-nitrogen, respectively. Replacing 100% N through nano-N (T6) imparted 20% and 12% yield reduction in CSR 30 Basmati and PB 1121, respectively; suggesting the need of basal N application through urea only. Supplementing nano-Zn and nano-Cu with 50% N replacement through nano-nitrogen (T7) had 5.8% and 5.2% yield advantage in CSR 30 Basmati and PB 1121, respectively compared to conventional approach (T2). Basal application of sagarika (T8) and sagarika + seed inoculation with biofertilizer (T9) gave 8.4% and 8.9% yield advantage in CSR 30 Basmati and 8.8% and 10.0% in PB 1121, respectively.

In sodic soils, yield improvement to the tune of 2.2% (T3), 7.1% (T4), and 9.1% (T5) in CSR 30 Basmati and 1.7% (T3), 6.2% (T4) and 7.5% (T5) in PB 1121 was observed with 33%, 50% and 66% replacement of conventionally applied N (urea) through nano-nitrogen, respectively. Replacing 100% N through nano-N (T6) imparted 18.2% and 12.6% yield reduction in CSR 30 Basmati and PB 1121, respectively. Supplementing nano-Zn and nano-Cu with 50% N replacement through nano-nitrogen (T7) had 7.4% and 9.4% yield advantage in CSR 30 Basmati and PB 1121, respectively compared to conventional approach (T2). Basal application of sagarika (T8) and sagarika + seed inoculation with biofertilizer (T9) gave 11.2% and 12.4% yield advantage in CSR 30 Basmati and 10.5% and 15.1% in PB 1121, respectively. On an average, yield reduction to the tune of 15% in CSR 30 Basmati and 21% in PB 1121 was observed due to sodicity stress in compared to normal soils.

In saline soils, yield improvement of 1.6% (T3), 6.4% (T4) and 9.4% (T5) in CSR 30 Basmati and 2.1% (T3), 4.8% (T4) and 8.2% (T5) in PB 1121 was observed with 33%, 50% and 66% replacement of conventionally applied N (urea) through nano-nitrogen, respectively. Replacing 100% N through nano-N (T6) imparted 22.6% and 17.6% yield reduction in CSR 30 Basmati and PB 1121, respectively. Supplementing other nano fertilizer *viz*., nano-Zn and nano-Cu with 50% N replacement through nano-nitrogen (T7) resulted 6.7% and 8.8% yield advantage in CSR 30 Basmati and PB 1121, respectively compared to conventional approach (T2). Basal application of sagarika (T8) and sagarika + seed inoculation with biofertilizer (T9) gave 10.8% and 11.2% yield advantage in CSR 30 Basmati and 10.0% and 14.4% in PB 1121, respectively. On an average, yield reduction to the tune of 27% in CSR 30 Basmati and 32% in PB 1121 was observed due to sodicity and salinity stress in compared to normal soils.

**Morpho-physiological characterization and standardization of agronomic practices of quinoa (*Chenopodium quinoa*) for salt affected ecosystems** (Kailash Prajapat, S.K. Sanwal and P.C. Sharma)

Quinoa (*Chenopodium quinoa*) is a new crop for India. It is a natural salt tolerant semi-halophyte in nature which as potential to be grown in dry-land salinity affected areas of the country. However, its potential germplasm and cultivation practices to be followed have not been standardized so far in the country. A field experiment was therefore conducted at ICAR-CSSRI, Nain Farm, Panipat (Haryana) in saline soil ($EC_2$ 6-8 dS $m^{-1}$) to evaluate the performance of two salt tolerant germplasm (EC507740 and Local collection, LC) under various row spacing (30 cm and 45 cm) and seeding density (6, 8 and 10 kg $ha^{-1}$). The experiment was executed in randomized block design. Results showed that germplasm LC recorded tallest plants than EC507740 (Table 39). However, both the germplasm remained statistically at par in terms of branches $plant^{-1}$ and grain yield $ha^{-1}$. Among the row spacing, there was non-significant variation in plant height and branches $plant^{-1}$, while sowing at 30 cm row spacing recorded significantly highest grain yield (4.04 t $ha^{-1}$) than sowing at 45 cm row spacing. Increasing seeding density significantly increased the plant height of quinoa being highest with 10 kg $ha^{-1}$ seed rate. There was

Table 39. Performance of quinoa under different row spacing and seeding rate in saline soil

| Treatments | Plant height at maturity (cm) | No. of branches plant$^{-1}$ | Grain yield (t ha$^{-1}$) |
|---|---|---|---|
| **Germplasm** | | | |
| EC507740 | 119.7 | 16.3 | 3.71 |
| LC | 129.9 | 14.7 | 3.33 |
| SEm± | 1.8 | 0.4 | 0.11 |
| LSD (0.05) | 8.2 | NS | NS |
| **Row spacing** | | | |
| 30 cm | 123.8 | 15.3 | 4.04 |
| 45 cm | 125.8 | 15.7 | 3.00 |
| SEm± | 1.8 | 0.4 | 0.11 |
| LSD (0.05) | NS | NS | 0.34 |
| **Seeding rate (kgha$^{-1}$)** | | | |
| 6 | 121.3 | 16.5 | 3.20 |
| 8 | 123.4 | 15.3 | 3.63 |
| 10 | 129.6 | 14.7 | 3.74 |
| SEm± | 1.5 | 0.4 | 0.135 |
| LSD (0.05) | 2.2 | 1.3 | 0.420 |

NS: Non-significant

Quinoa in saline soil

decrease in no. of branches plant$^{-1}$ with an increase in seeding density and seeding @ 10 kg ha$^{-1}$ recorded significantly lower no. of branches plant$^{-1}$ compared to seeding @ 6 kg ha$^{-1}$. Grain yield of quinoa significantly increased with increased seeding rate up to 8 kg ha$^{-1}$ (3.63 t ha$^{-1}$) and further increase in seed rate to 10 kg ha$^{-1}$ resulted in non-significant improvement in grain yield of quinoa.

To explore the genetic diversity in quinoa for salt tolerance, 120 germplasm were acquired from ICAR-NBPGR, New Delhi. They were sown in the normal soil conditions for multiplication purpose during 2019-20. Among the 120 germplasm sown, only 31 germplasm could germinate and multiplied. The grain yield ranged from 1.4 g plant$^{-1}$ to 55 g plant$^{-1}$ among these germplasm.

# Alternate Land Use

### Enhancing productivity potential of saline soils through agroforestry interventions (Rakesh Banyal, Ajay K. Bhardwaj, Parveen Kumar and Raj Kumar)

An experiment for developing agroforestry systems based on *Eucalyptus tereticornis* (Clone 413) and *Melia composita* with optimization of saline irrigation and understanding the behaviour of five agroforestry trees (*Eucalyptus tereticornis*, *Melia composita*, *Azadirachta indica*, *Dalbergia sissoo* and *Terminalia arjuna*) in terms of biometric gains and reclamation aspect in shallow saline situations is being undertaken. *Eucalyptus* and *Melia* gave average survival of 98.5 and 73.3 per cent, respectively after six year of experimentation and decreased with the increase in the saline irrigation. Growth parameters (plant height, DBH and crown spread) were higher with BAW ($I_1$: best available water) irrigation regime. Reduction rate in plant height was higher to the tune of 16 and 12.3 percent in rainfed condition ($I_5$) and ECiw 12dS $m^{-1}$ ($I_4$) than (BAW: $I_1$) in *Eucalyptus*. The higher reduction rate was observed in DBH (34.7%) and crown spread (34.8%) while comparing $I_5$ to $I_1$. In *Melia,* reduction was 13.4% in plant height, 24% in DBH and 30% in crown spread under $I_4$ than $I_1$ (Fig. 42). Survival and growth accumulation in trees with companion crops (*Eucalyptus*+crop: $LU_2$ and *Melia*+crop: $LU_3$) was low compared to trees growing in sole landuse (sole tree: $LU_1$). In $I_1$, 7.29, 5.85 and 13.3% reduction was reported in plant height, DBH and crown spread in $LU_2$ than $LU_1$. Higher mustard yield was reported in $I_1$ compared to saline irrigation regimes and further decreased to 83% in $LU_2$ and 41.3% in $LU_3$ compared to $LU_1$. Pearl millet yield was reduced to 81.1% in $LU_2$ and 56.7% in $LU_3$ compared to $LU_1$.

Leaf litter collector in *Melia* based agroforestry system

Leaf litter production was higher during autumn (1st Oct.-15th Nov.) and winter (16th Nov.-31st Dec.) seasons. Trees managed under $I_1$ gave higher (2.16 kg/*Eucalyptus* tree and 4.32 kg/*Melia* tree) leaf litter with lowest in $I_4$ (1.26 kg/*Eucalyptus* tree and 2.34 kg/*Melia* tree). Saline water irrigated plots showed higher salt accumulation than $I_1$. Soil ECe was minimum (4.14 dS $m^{-1}$) in $I_1D_1$(0+15cm)+$LU_3$ and maximum (12.82 dS $m^{-1}$)) in $I_4D_2$(15-30 cm)+$LU_2$ after mustard harvest. Soil pHs was low under the trees ($LU_2$ and $LU_3$) than the sole crop landuse ($LU_1$) in both the seasons. The other soil chemical attributes viz. organic

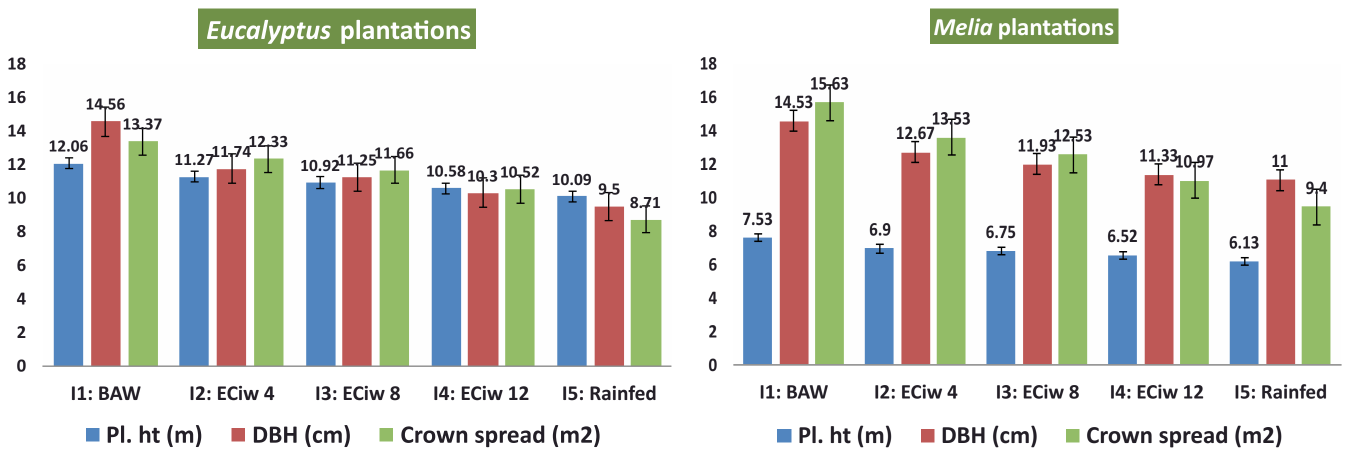



Fig 42. Growth trends of Eucalyptus and Melia plantations under irrigation regimes

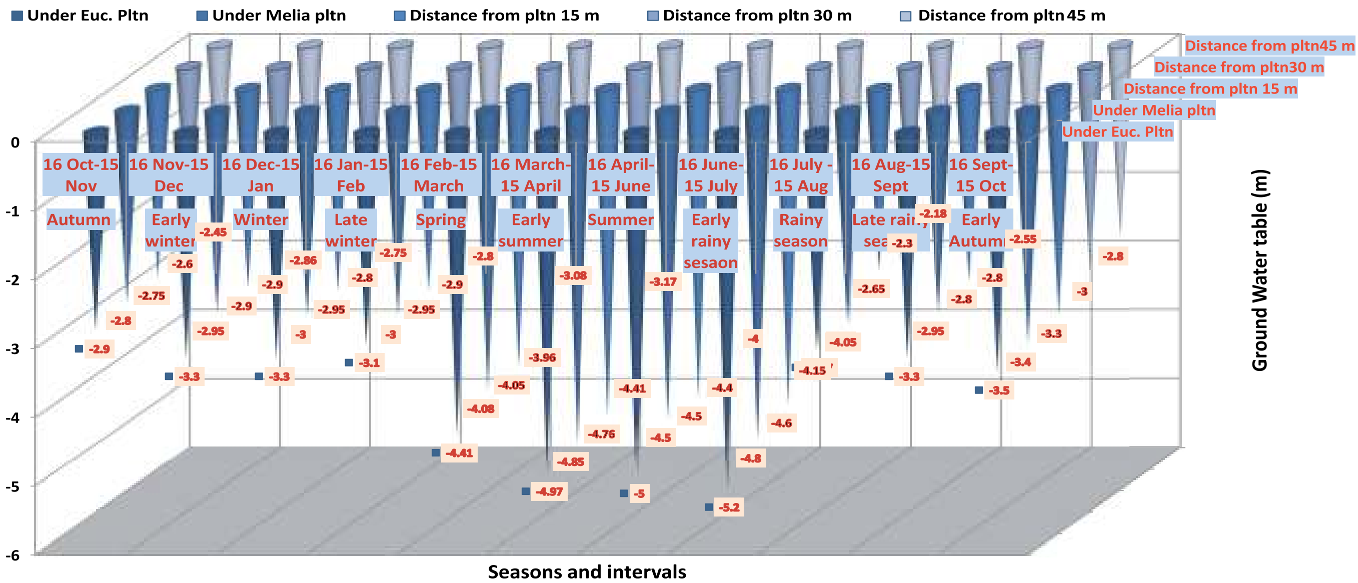



Fig 43. Ground water table fluctuations with and without plantations under shallow saline areas

*Eucalyptus* plantations in shallow saline soils

carbon, available N, P and K were higher under trees (*Eucalyptus* and *Melia*) than sole crop. Ground water table (g.w.t.) under *Eucalyptus* and *Melia* plantations was at higher depths round the year than the adjoining bare areas without trees. The average g.w.t. depth was 3.83, 3.58, 3.47, 2.92 and 2.97 m under *Eucalyptus* (first two points) and then 15, 30 and 45 m distance from the plantations (Fig. 43). Quality of ground water was moderately saline but better under *Melia* (5.90 dS $m^{-1}$) than *Eucalyptus* (7.60 dS $m^{-1}$) and from other points of piezometers without plantations. Best available water ($I_1$) individually while compared with saline irrigation emerged as best one in developing agroforestry systems in shallow saline conditions. Upto ECiw 8 dS $m^{-1}$ ($I_3$), the reduction in growth was low but after this the decline was steep in $I_4$ and $I_5$. Productivity of companion crops declined drastically during 6$^{th}$ year of agroforestry system comparing to previous years. Among five agroforestry trees, *Eucalyptus* emerged as better option in greening saline lands based on establishment and growth attributes. *Eucalyptus* gave highest performance value (4.46) followed by Neem (3.30), *Dalbergia* (3.16), *Melia* (2.58) and Arjun (1.70) which showed the better adaptability and better returns in terms of biometric outputs.

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

Systematic study has been conceptualized and initiated for screening of potential olive cultivars to saline and sodic environment in which eight cultivars (*Arbequina*, *Koroneiki*, *Barnea*, *Picual*, *Coratina*, *Frantoio*, *Picholine* and *Leccino*) were evaluated 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 in eighteen months aged saplings.

It was observed that *Arbequina* gave highest (97%) survival among all the cultivars with lowest (39.5%) in *Picholine* cultivar. Survival rate in all the tested cultivars regulated with the salinity level in irrigation water, consistently decreased from 5 to 10 dS $m^{-1}$. Among all the cultivars, *Arbequina* was the only cultivar which gave lowest 4.70 and 4.20 per cent reduction in plant height and collar diameter at ECiw 10 dS $m^{-1}$. Similarly, number of branches showed consistent reduction in numbers with the increase in salinity level with

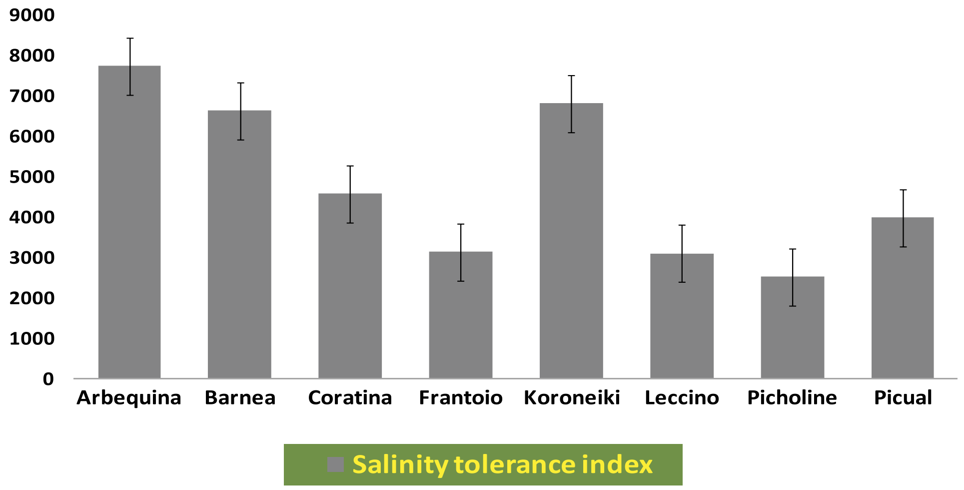



Fig 44. Salinity tolerance index of Olive cultivars in saline environment

lowest in *Arbequina*. Proline accumulation was higher (40-45%) in *Arbequina* compared to *Leccino* and *Picholine* (salt sensitive cultivars). All the olive cultivars showed the ability to maintain an appropriate $Na^{2+}/K^{+}$ ratio in leaf. $K^{+}$ accumulation was reduced to the tune of 26 to 48 per cent at higher salinity regime (10 dS $m^{-1}$) across the cultivars. *Arbequina* cultivar showed 43 per cent reduction in photosynthesis rate at higher salinity compared to control. *Arbequina* gave 61 per cent less chlorophyll content at ECiw 10 dS $m^{-1}$ compared to normal irrigation water. Higher relative water content (RWC) at higher salinity levels caused osmotic stress in plants, thereby gave low values of growth traits. The ranking order under salinity was *Arbequina> Koroneiki> Barnea> Picual> Coratina> Frantoio> picholine> Leccino*. *Arbequina* cultivar emerged as better performer in respect of growth, physiological and biochemical traits among all the Olive cultivars under pH levels right from 8.2 to 9.4 based on growth traits. At higher pH, relative stress injury (RSI) was more because of reduction in water uptake. The order of cultivar performance in sodic environment was *Arbequina> Koroneiki> Leccino> Barnea> Frantoio> Picual> Coratina> picholine*.

*Arbequina* emerged as best cultivar, giving highest average (7742) tolerance index among the all the tested cultivars with lowest (2518) in *Picholine* cultivar (Fig. 44). *Barnea*, *Koroneiki* and *Arbequina* emerged as the best cultivars after two years of survival and growth, out-planted in partially reclaimed sodic lands.

**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 quality planting material of *Melia dubia* for the salt affected soils. It is hypothesized that the growth and productivity of *M. dubia* could be improved if genetically superior planting material were used for agroforestry programme. Therefore, in this study, we examined the alkalinity tolerance of twenty-five genotypes of *Melia dubia* at pH 9, to elucidate the salt tolerance mechanism, and to screen genotypes for the improved salt tolerance. Under salt stress, plant height and collar diameter growth were decreased by 8%-29% and 2.4%-31%, respectively, in all the twenty-five *Melia* genotypes. Maximum growth (height and collar diameter) was recorded for MDSSS02 & MDSSS13 genotypes in control and for MDSSS06 & MDSSS21 genotypes at pH 9. Genotypes displayed substantial differences for leaf $Na^{+}$ ions accumulation under alkali stress from 3.3 ppm in MDSS15 to 1.35 ppm in MDSS02, while $K^{+}/Na^{+}$ ratio was ranged from 14.4 in MDSS02 to 3.0 in MDSS15. Salt tolerance was

Germplam testing of Melia tree for alkalinity tolerance under field conditions.

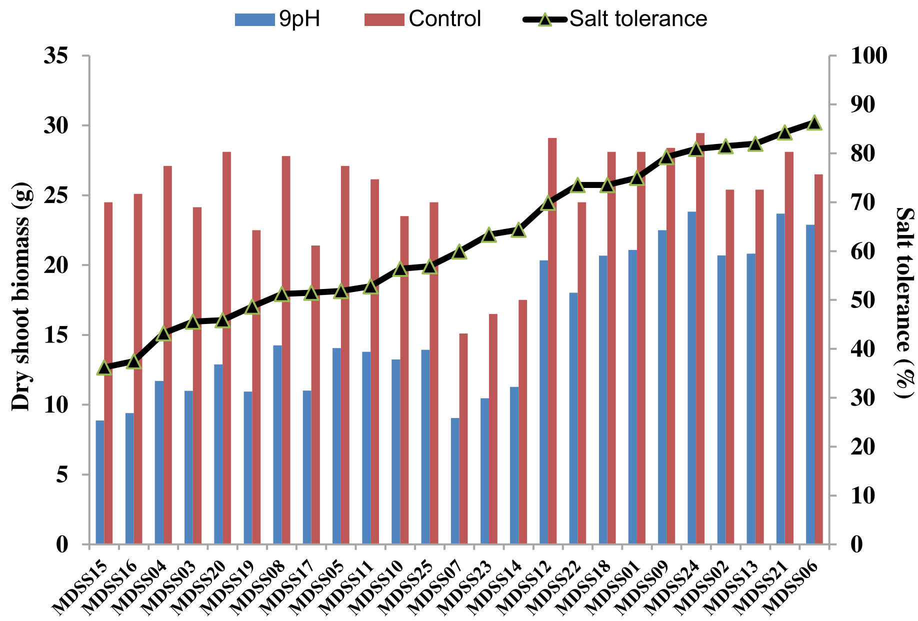



Fig 45. Shoot dry weight (bars) and salt tolerance (line-scatter plot) of 25 genotypes of Melia dubia.

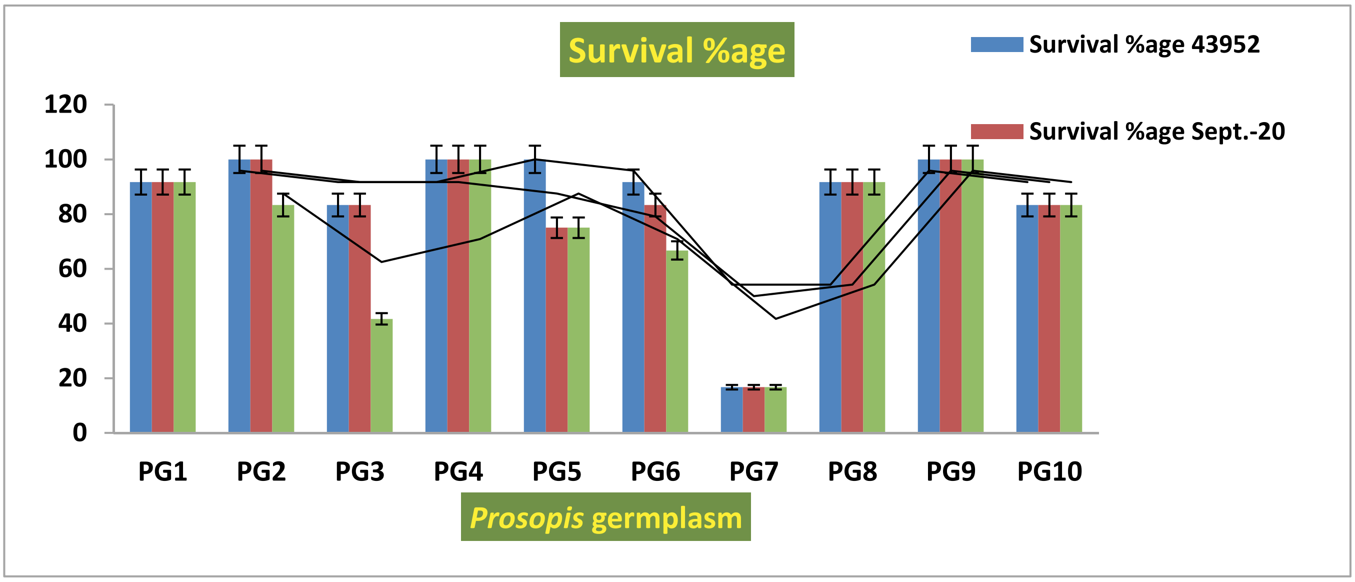
determined from the plant biomass in salt treatment as percent of control. Genotypes showed high variation for salt tolerance ranging from 36% (MDSS15) to 86% (MDSS06), and the existing poplar genotype (MDSS20) showed the salt tolerance of 45.5% (Fig. 45). Correlations were derived to determine the relationships between the various plant growth parameters and cations concentration. $Na^{+}$ concentration in shoots showed highly negative ($P<0.05$) correlation with growth traits (seedling height, diameter and, shoot biomass) under salt stress. The cluster analysis validated the alkalinity response of genotypes and classified germplasm into the sensitive, moderately tolerant, and tolerant category each consisting of nine, eleven, and five genotypes, respectively. Among the genotypes, MDSS06, MDSS13, and MDSS21 produced greater growth, biomass, and depicted high salt tolerance which indicate immense potential of these genotypes in the alkali soils, and hence recommend for commercial plantations in salt affected soils.

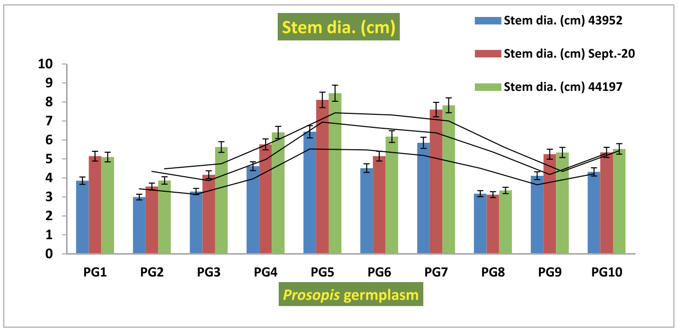
**Physiological and biochemical mechanisms of salt tolerance in guinea grass** (Raj Kumar)

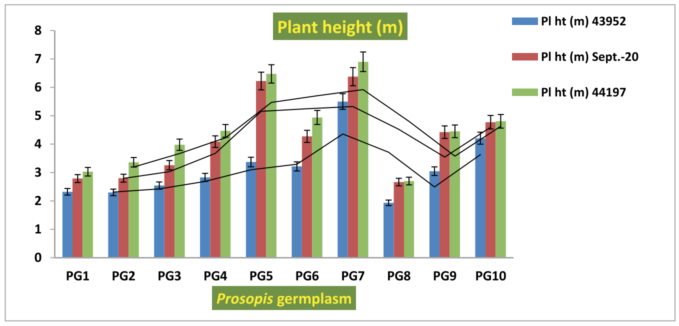
This project was initiated in collaboration with ICAR-IGFRI to screen and identify guinea grass lines for differential salt tolerance and to characterize the salt tolerant adaptive mechanisms in guinea grass at physiological and biochemical levels. During 2020, two varieties (BG-1, DGG-1) of Guinea grass were tested in field conditions to assess species salinity tolerance potential. Results showed that guinea grass varieties BG-1 and DGG-1 yielded total green biomass of 1.42 and 0.73 kg per plant, respectively, under saline soil

Table 40. Growth, biomass, and biochemical parameters of guinea grass varieties under saline soil conditions

| Variety | Plant height (cm) | Leaves per plant (no.) | Tiller per plant (no.) | Total green biomass per plant (kg) | Shoot $Na^{+}$ (%) | Shoot $K^{+}$ (%) |
|---|---|---|---|---|---|---|
| DGG-1 | 120.2±11.4 | 80.2±33.1 | 12.0±6.1 | 1.42±0.13 | 1.45±0.12 | 1.10±0.08 |
| BG-1 | 95.1±7.6 | 37.3±18.7 | 9.3±2.0 | 0.73±0.08 | 1.52±0.15 | 1.01±0.11 |




PG1: Prosopis cineraria; PG2: P. cineraria; PG3: P. cineraria; PG4: P. juliflora; PG5: P. juliflora; PG6: P. pallida; PG7: P. pallida; PG8:P. cineraria; PG9: P. laevingata and PG10: P. juliflora

Fig 46. Survival and growth trends of Prosopis germplasm during third year of out-planting

(ECe 8) conditions (Table 40). Shoot $Na^+/K^+$ ratio was observed higher DGG-1 (1.10), compared to BG-1 (1.01). Further screening of Guinea grass lines for salinity tolerance is progress in the field conditions. From results, it can be concluded that guinea grass can be grown in saline soils, and BG-1 and DGG-1 varieties can be considered for cultivation in moderately saline soils.

**Development of *Prosopis* germplasm bank** (Rakesh Banyal)

Prosopis germplasm bank

The growth traits were recorded in three quarters (four months period) in whole year for understanding the biometric increment pattern of different genotypes planted in the germplasm bank (Fig. 46). All the ten planted genotypes showed good survival ranged from 16.7 to 100 percent. $PG_4$, $PG_9$ and $PG_2$ outscored in survival percentage during third year of plantations. Plant height was maximum (6.26 m) in $PG_7$ and minimum (2.43 m) in $PG_8$ genotype. $PG_5$, $PG_7$ and $PG_4$ gave higher values of stem diameter compared to other seven genotypes. The three best performer genotypes based on growth traits were $PG_7$, $PG_5$, $PG_4$ and $PG_{10}$ at the age of three years. More number of *Prosopis* genotypes will be added to the germplasm bank down the road for conservation and improvement purposes at ICAR-CSSRI, Karnal, Haryana.

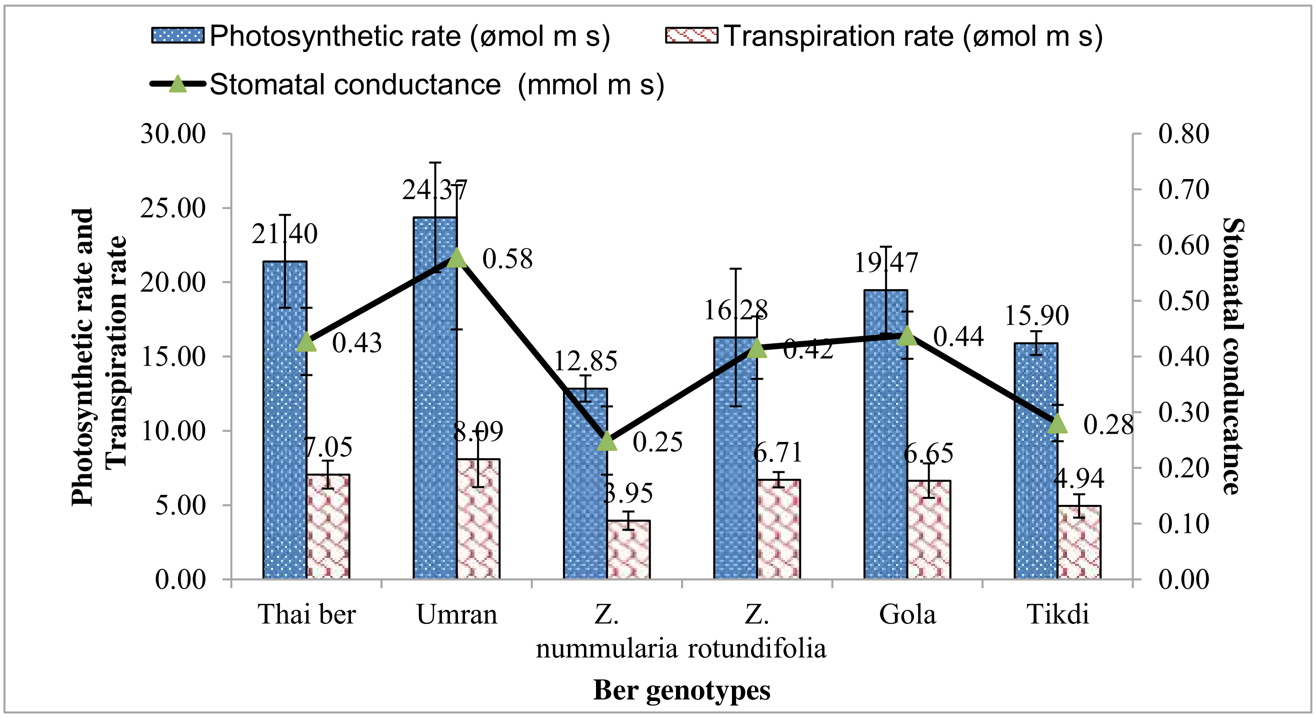


Fig 47. Photosynthetic and transpiration rate of ber genotypes.

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

The old and senile *ber* orchard in an area of approximately 3.5 acre (410 *ber* trees) at CSSRI experimental farm was unproductive and non-economical. Therefore, to rejuvenate this old and unproductive *ber* orchard through top working was begun during 2020. Initially beheading of these trees two feet above from the ground level was carried out during the month of May. After one month sprouting started and new branches emerged from the remaining lower parts of the trunk. The process of budding was carried out during the last week of July and first week of August by using the buds of improved scion cultivars like 'Thai apple ber', 'Tikdi', 'Gola' and 'Umran' on the newly sprouted shoots. On an average about 10 buddings were done per tree on different branches. Out these buds approximately 70 per cent were survived. Besides, gap filling was done by using the species of Ziziphus, namely '*Z. nummularia*' and '*Z. rotundifolia*'. The physiological parameters like photosynthetic rate (µmol $m^{-2}s^{-1}$), transpiration rate (µmol $m^{-2}s^{-1}$) and stomatal conductance (µmol $m^{-2}s^{-1}$) were recorded in various genotypes of *ber* as shown in Fig. 47. The maximum photosynthetic rate (24.37 µmol $m^{-2}s^{-1}$) was recorded in 'Umran' followed by 'Thai apple ber' (21.40 µmol $m^{-2}s^{-1}$). Similarly, the maximum transpiration rate (8.09 µmol $m^{-2}s^{-1}$) was recorded in 'Umran' followed by 'Thai apple ber' (7.05 µmol $m^{-2}s^{-1}$). The maximum stomatal conductance (0.58 µmol $m^{-2}s^{-1}$) was recorded in 'Umran' followed by 'Gola' (0.44 µmol $m^{-2}s^{-1}$), respectively.

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

Fruits of sixteen cultivars of sapota were collected and the fruit parameters like fruit length (mm), breadth (mm), weight (g), fruit water content (%), number of seeds and TSS ($^{0}$B) were recorded as shown in Table 41. The maximum fruit breadth (61.50 mm) was recorded in CSRS-10 followed by CSRS-16 (60.17 mm). Similarly, maximum fruit length

Table 41. Effects of high soil pH on physiological parameters in leaves.

| Genotypes | Fruit Breadth (mm) | Fruit Length (mm) | Fruit Weight (g) | Fruit Moisture content (%) | No of Seeds per fruit | TSS ($^0$B) |
|---|---|---|---|---|---|---|
| CSRS-1 | 44.40BC | 46.16F | 51.18D | 70.59 | 2.00 | 24.93 |
| CSRS-2 | 52.10$^{ABC}$ | 47.79$^{EF}$ | 80.79$^{BCD}$ | 72.93 | 1.67 | 19.70 |
| CSRS-3 | 55.33$^{ABC}$ | 58.91$^{BCD}$ | 95.97$^{AB}$ | 73.59 | 1.67 | 23.03 |
| CSRS-4 | 48.91$^{ABC}$ | 64.48$^{ABC}$ | 90.73$^{ABC}$ | 71.58 | 2.00 | 24.13 |
| CSRS-5 | 48.37$^{ABC}$ | 52.75$^{DEF}$ | 71.67$^{BCD}$ | 71.57 | 2.00 | 26.50 |
| CSRS-6 | 44.56$^{ABC}$ | 44.59$^{F}$ | 54.83$^{CD}$ | 70.19 | 1.33 | 21.10 |
| CSRS-7 | 48.56$^{ABC}$ | 55.11$^{CDEF}$ | 72.85$^{BCD}$ | 71.54 | 1.67 | 26.07 |
| CSRS-8 | 45.93$^{ABC}$ | 51.11$^{DEF}$ | 64.52$^{BCD}$ | 70.59 | 2.00 | 25.80 |
| CSRS-9 | 49.86$^{ABC}$ | 47.48$^{EF}$ | 68.22$^{BCD}$ | 69.90 | 1.67 | 18.67 |
| CSRS-10 | 61.50$^{A}$ | 71.27$^{A}$ | 123.00$^{A}$ | 73.53 | 2.00 | 25.07 |
| CSRS-11 | 49.07$^{ABC}$ | 50.27$^{DEF}$ | 64.47$^{BCD}$ | 72.72 | 2.33 | 25.55 |
| CSRS-12 | 41.37$^{C}$ | 58.87$^{BCD}$ | 54.74$^{CD}$ | 70.83 | 2.67 | 25.27 |
| CSRS-13 | 47.20$^{ABC}$ | 57.97$^{BCDE}$ | 76.48B$^{CD}$ | 74.06 | 2.67 | 18.00 |
| CSRS-14 | 50.84$^{ABC}$ | 57.82$^{BCDE}$ | 80.96B$^{CD}$ | 72.05 | 2.33 | 23.37 |
| CSRS-15 | 49.60$^{ABC}$ | 67.03$^{AB}$ | 91.26$^{ABC}$ | 70.79 | 2.67 | 23.00 |
| CSRS-16 | 60.17$^{AB}$ | 44.60$^{F}$ | 73.64$^{BCD}$ | 73.48 | 2.33 | 26.33 |
| LSD@5% | 16.981 | 10.913 | 36.7 | NS | NS | NS |

(71.27mm) was recorded in CSRS-10 followed by CSRS-15 (67.03mm). Similarly, maximum fruit weight (123g) was recorded in CSRS-10 followed by CSRS-3 (95.97). Although, the parameters like fruit moisture content varies from (69.90 to 74.06%) and non-significantly differ among various cultivars. Similarly, parameters number of seeds per fruit and TSS ($^0$B) also differ no significantly. Furthermore, twelve cultivars have been transplanted to pots and treated with RSCiw for evaluation against salinity tolerance. Four cultivars have been under evaluation at ECiw ≤ 2 dS $m^{-1}$, ECiw ≤ 4 dS $m^{-1}$, ECiw ≤ 8 dS $m^{-1}$, ECiw ≤ 12 dS $m^{-1}$ and ECiw ≤ 16 dS $m^{-1}$ to find out the tolerant cultivars. Reyan or khirni seeds have been collected and under evaluation to find out the salt tolerance limit of this most commonly used rootstock in sapota plants multiplication.

**Identification of salt tolerant genotypes in Jamun *(Syzygium cumini L.* Skeels)**
(Rajkumar and Ashwani Kumar)

The physiological parameters like chlorophyll content, transpiration rate, photosynthetic rate, RWC and stomatal conductance were recorded in ten genotypes of Jamun namely 'Ajmer-2', 'Denkanal', 'Gumla', 'Ajmer-1', 'Jorhat', 'Jind-1', 'Bhruch-2', 'Patna-1', 'Jamshedpur' and 'Ajmer-3' and depicted in Table 42. The maximum chlorophyll content was observed in 'Ajmer-2' (2.25mg $g^{-1}$) followed by 'Gumla' (1.59 mg $g^{-1}$). However, maximum transpiration rate (0.54 µmol $m^{-2}s^{-1}$) was recorded in 'Ajmer-3' followed by 'Jamshedpur' (0.48 µmol $m^{-2}s^{-1}$), respectively. The maximum photosynthetic rate (2.64 µmol $m^{-2}s^{-1}$) was recorded in 'Ajmer-2' followed by (1.33 µmol $m^{-2}s^{-1}$) in 'Jind-1'. The relative water content in the leaves showed that maximum RWC (75.20%) was recorded in 'Patna-1' followed by 'Gumla' (74.91%). The maximum stomatal conductance (10.22 µmol $m^{-2}s^{-1}$) was recorded in genotype 'Ajmer-2' followed by 'Bhruch-2' (8.98 µmol $m^{-2}s^{-1}$). These plants have been transplanted in pots

Table 42. Physiological traits in various jamun genotypes

| Genotypes | Chlorophyll content (mg g$^{-1}$) | Transpiration rate (µmol m$^{-2}$ s$^{-1}$) | Photosynthetic rate (µmol m$^{-2}$ s$^{-1}$) | RWC (%) | Stomatal conductance (µmol m$^{-2}$ s$^{-1}$) |
|---|---|---|---|---|---|
| Ajmer-2 | 2.25$^{A}$ | 0.25$^{CDE}$ | 2.64$^{A}$ | 71.79$^{AB}$ | 10.22$^{A}$ |
| Denkanal | 1.44$^{BC}$ | 0.18$^{DE}$ | 0.76$^{CD}$ | 72.12$^{AB}$ | 6.67$^{CDE}$ |
| Gumla | 1.59$^{B}$ | 0.09$^{E}$ | 1.08$^{BCD}$ | 74.91$^{A}$ | 7.70$^{BCD}$ |
| Ajmer-1 | 1.54$^{BC}$ | 0.12D$^{E}$ | 0.62$^{D}$ | 63.36$^{D}$ | 8.37$^{ABC}$ |
| Jorhat | 1.44$^{BC}$ | 0.30$^{BCD}$ | 0.96$^{BCD}$ | 65.94$^{CD}$ | 5.25$^{EF}$ |
| Jind-1 | 1.37$^{CD}$ | 0.25$^{CDE}$ | 1.33$^{B}$ | 70.22$^{ABC}$ | 4.66$^{EF}$ |
| Bhruch-2 | 1.54$^{BC}$ | 0.11$^{E}$ | 1.17$^{BC}$ | 66.03$^{CD}$ | 8.98$^{AB}$ |
| Patna-1 | 1.23$^{DE}$ | 0.40$^{ABC}$ | 0.87$^{BCD}$ | 75.20$^{A}$ | 5.73$^{DEF}$ |
| Jamshedpur | 1.37$^{CD}$ | 0.48$^{AB}$ | 1.14$^{BC}$ | 68.69$^{BCD}$ | 4.05$^{F}$ |
| Ajmer-3 | 1.11$^{E}$ | 0.54$^{A}$ | 0.83$^{CD}$ | 68.37$^{BCD}$ | 6.13$^{DEF}$ |
| LSD (P=0.05) | 0.1842 | 0.1864 | 0.4727 | 5.6571 | 2.2335 |

and residual sodium carbonate (RSC) irrigation water treatments have been applied to find out the tolerance limit of these genotypes.

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

Four genotypes of mango were transplanted in pots and physiological parameters like chlorophyll content, transpiration rate, photosynthetic rate, RWC and stomatal conductance were recorded and depicted in Table 43. The maximum chlorophyll content (2.34 mg g$^{-1}$) was recorded in 'Kurukkan' followed by 'Indonesia' (2.15 mg g$^{-1}$). However, maximum transpiration rate (1.20 µmol m$^{-2}$ s$^{-1}$) was recorded in '*M. odorata*' followed by 'Indonesia' (0.86 µmol m$^{-2}$ s$^{-1}$). Similarly, the maximum photosynthetic rate (5.22 µmol m$^{-2}$ s$^{-1}$) was recorded in '*M. odorata*' followed by (3.46 µmol m$^{-2}$ s$^{-1}$) in genotype 'Kurukkan'. The relative water content in the leaves of these genotypes showed that maximum RWC (78.95%) was recorded in 'Kurukkan' followed by 'Indonesia' (78.31 %). The SPAD data showed that maximum SPAD value (36.27) was recorded in 'Kurukkan' followed by genotype '*M. zeylanica*' (27.37). These plants of these genotypes have been transplanted in pots and residual sodium carbonate (RSC) irrigation water treatments have been applied to find out the tolerance limit.

Table 43. Various physiological parameters in different mango genotypes

| Genotypes | Chlorophyll content (mg g$^{-1}$) | Transpiration rate (µmol m$^{-2}$ s$^{-1}$) | Photosynthetic rate (µmol m$^{-2}$ s$^{-1}$) | RWC (%) | SPAD | Stomatal conductance (µmol m$^{-2}$ s$^{-1}$) |
|---|---|---|---|---|---|---|
| M. zeylanica | 1.93BC | 0.63B | 1.81C | 74.89B | 27.37AB | 0.04 |
| Kurukkan | 2.34A | 0.64B | 3.46B | 78.95A | 36.27A | 0.03 |
| Indonesia | 2.15AB | 0.86B | 3.18B | 78.31A | 26.93AB | 0.04 |
| M. odorata | 1.81C | 1.20A | 5.22A | 65.53C | 20.30B | 0.05 |
| LSD (P=0.05) | 0.2465 | 0.3036 | 1.0741 | 3.2766 | 13.002 | NS |

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

**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)

Application of organic matter in sodic soils could accelerate salt leaching; decrease both the exchangeable sodium percentage and electrical conductivity, and increase water infiltration, water holding capacity and aggregate stability. Furthermore, 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.

Field experiments consisted of six treatments viz. $T_1$- Control (no amendments), $T_2$- Gypsum @50%GR, $T_3$- Un-enriched MSW compost @10 t ha$^{-1}$, $T_4$- Enriched MSW compost @10t ha$^{-1}$, $T_5$- Gypsum @25%GR + Un-enriched MSW compost @10 t ha$^{-1}$ and $T_6$- Gypsum @ 25% GR + Enriched MSW compost @10t ha$^{-1}$ was conducted on a sodic soil (pH 9.2, EC 1.14dS m$^{-1}$, ESP 48, OC 0.30%) during 2019-20 at ICAR-CSSRI, Research farm, Shivri, Lucknow to test the efficacy of microbial enriched municipal solid waste compost in conjunction with reduced dose of gypsum on soil amelioration and sustaining productivity of rice-wheat cropping system.

Salt tolerant variety of wheat 'KRL283' was grown in the experiment and recommended dose of fertilizers (120kg N: 60kg P: 40kg K ha$^{-1}$) was applied uniformly in all the treatments. Data given in Table 44 revealed that the maximum plant height was recorded with treatment $T_5$ but it was statistically at par with other treatments. Spike density, grains/spike, 1000 grain weight were significantly higher in treatment $T_6$ over rest of the treatments. Highest straw and grain yields were obtained in treatment $T_6$ where enriched MSW compost @10t ha$^{-1}$ + 25%GR gypsum was applied in the soil. Harvest index was also higher in treatment $T_6$ which was significantly higher over $T_1$ but statistically at par with rest of the treatments (Table 44).

Table 44. Crop growth, yield attributing characters and yield of wheat crop under different treatments

| Treatments | Plant height (cm) | Spike density m$^{-2}$ | Grains /spike | 1000grain weight (g) | Straw yield (t ha$^{-1}$) | Grain yield (t ha$^{-1}$) | HI |
|---|---|---|---|---|---|---|---|
| T1- Control (No amendments) | 69.20 | 363.40 | 30.95 | 32.20 | 3.906 | 1.860 | 32.26 |
| T2- Gypsum @50%GR | 76.12 | 388.22 | 33.70 | 41.81 | 5.111 | 3.250 | 38.88 |
| T3- Un-enriched MSW compost @10 t ha$^{-1}$ | 77.90 | 341.30 | 30.95 | 38.52 | 3.888 | 2.430 | 38.51 |
| T4- Enriched MSW compost @10t ha$^{-1}$ | 76.22 | 343.90 | 32.25 | 30.40 | 3.952 | 2.472 | 38.46 |
| T5- Gypsum @25% GR + un-enriched MSW compost @10 t ha$^{-1}$ | 83.55 | 391.32 | 33.50 | 40.90 | 5.071 | 3.230 | 38.91 |
| T6- Gypsum @ 25% GR + Enriched MSW compost @10t ha$^{-1}$ | 74.87 | 394.20 | 35.10 | 43.15 | 6.154 | 3.925 | 38.91 |
| CD (p=0.05) | ns | 9.23 | 3.12 | 0.53 | 6.23 | 3.26 | |

Table 45. Crop growth and yield attributing characters of rice under different treatments

| Treatments | Plant height (cm) | Tillers $hill^{-1}$ | Panicle density ($m^{-2}$) | Spikelet fertility (%) | Grains $panicle^{-1}$ | 1000grain weight (g) | Grain yield ($t\ ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| T1- Control (No amendments) | 111.22 | 9.65 | 286.0 | 73.2 | 114.30 | 22.22 | 4.21 |
| T2- Gypsum @50%GR | 124.40 | 16.47 | 389.6 | 87.5 | 132.22 | 26.62 | 5.27 |
| T3- Un-enriched MSW compost @10 t ha-1 | 123.43 | 11.65 | 345.0 | 76.3 | 126.02 | 24.62 | 4.51 |
| T4- Enriched MSW compost @10t ha-1 | 122.35 | 12.80 | 359.1 | 81.2 | 129.62 | 23.55 | 4.70 |
| T5- Gypsum @25%GR + un-enriched MSW compost @10 t ha-1 | 123.40 | 13.42 | 381.0 | 85.3 | 138.05 | 25.37 | 5.17 |
| T6- Gypsum @ 25% GR + Enriched MSW compost @10t ha-1 | 123.40 | 14.77 | 387.9 | 85.8 | 138.30 | 25.95 | 5.45 |
| CD (p=0.05) | ns | 3.12 | 11.23 | 5.23 | 5.32 | ns | 0.32 |

After harvesting of wheat rice 'CSR 46' was transplanted in the same plots. All the relevant observations related to plant growth, yield attributing characters and yields were recorded. From the data given in Table 45, it is revealed that there was no significant difference in plant height due to application of either inorganic amendment alone or in combination with organic amendments. However, productive tillers/hill and panicle density were significantly higher with treatment $T_2$ over $T_1$, $T_3$ and $T_4$ but statistically at par with $T_5$ and $T_6$. Highest spikelet fertility was recorded with $T_2$ which was significantly higher over $T_1$, $T_3$ and $T_4$ but at par with $T_5$ and $T_6$. Significanty higher numbers of grains per panicle were recorded in treatment $T_6$ where enriched MSW compost was applied in combination with reduced dose of gypsum but it was at par with $T_5$. Grain yield increased with addition of organic amendments over the sole application of inorganic amendment. Highest grain yield was recorded with treatment $T_6$ which was at par with $T_2$ and $T_5$ but significantly higher over $T_1$, $T_3$ and $T_4$.

**Effect of integrated nutrient management on productivity potential of Rice-wheat cropping system under different sodicity levels** (Y.P. Singh and V.K. Mishra)

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 ($pH_2$) 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% recommended dose of fertilizers (RDF) (120:60:40 (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 $ha^{-1}$ was conducted in split plot design with a plot size of $25m^2$.As per treatment wheat seed was treated with different microbial inoculants two hour before sowing, dried in shed and sown in the field.

From the data, it is evident that the highest grain yield (3.21t $ha^{-1}$) was recorded with treatment $T_3$ which was significantly higher over $T_1$ and $T_2$ but statistically at par with $T_4$. Significant interaction between sodicity levels and INM was observed in grain yield. Maximum grain yield was observed with treatment $S_1T_3$ (Table 46).

Table 46. Grain yield (t $ha^{-1}$) of salt tolerant variety of wheat (KRL 283) under different sodicity levels and integrated nutrient management practices

| Sodicity levels | Integrated nutrient management | | | | Mean |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| $S_1$ | 3.43 | 3.40 | 3.52 | 3.34 | 3.42 |
| $S_2$ | 3.12 | 3.13 | 3.32 | 3.14 | 3.18 |
| $S_3$ | 2.76 | 2.80 | 3.06 | 2.84 | 2.86 |
| $S_4$ | 2.64 | 2.46 | 2.93 | 2.74 | 2.69 |
| Mean | 2.99 | 2.95 | 3.21 | 3.01 | |
| CD(p=0.05)for sodicity levels | 0.21 | | | | |
| CD(p=0.05)for nutrient management | 0.13 | | | | |
| CD(p=0.05)for S x N | 0.32 | | | | |

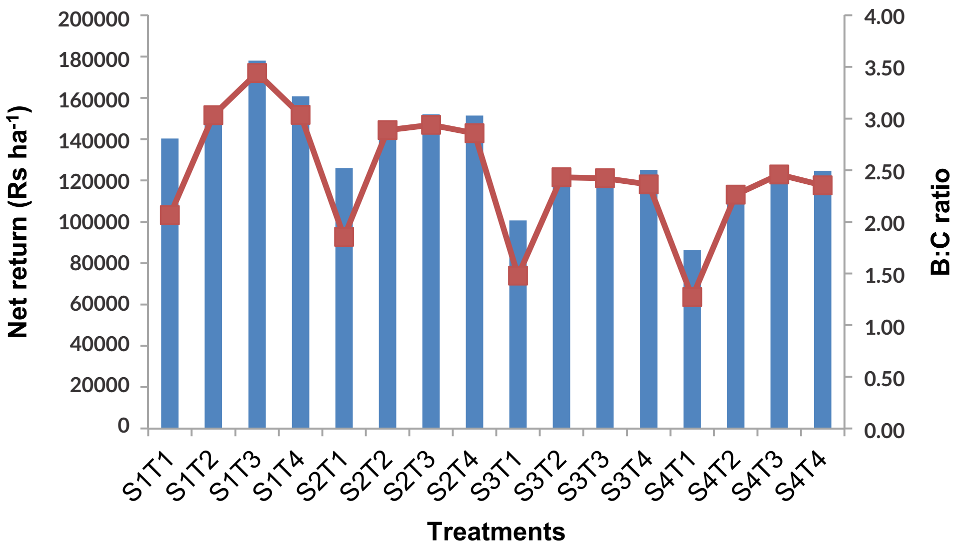
Performance of KRL 283 wheat under different sodicity levels and integerated nutrient management

After harvesting of wheat salt tolerant variety of rice CSR 46 was transplanted on 10.07.2020 with the same treatments. From the data, it is evident that the grain yield reduced with increasing sodicity. The highest reduction in yield was observed in between $S_1$ and $S_2$ sodicity levels. The highest grain yield was recorded with $S_1$ sodicity level at all the nutrient management treatments which was significantly higher over S2, $S_3$, and $S_4$ sodicity levels. Application of reduced dose of NPK with integration of Halo Azo, Halo PSB and Halo zinc ($T_3$) produced significantly higher grain yield at all the sodicity levels over the treatment $T_1$ and $T_2$ but at par with $T_4$. Significant interaction between sodicity levels and nutrient management treatments on grain yield was also observed (Table 47).

Table 47. Grain yield (t $ha^{-1}$) of CSR 46 under different sodicity levels and integrated nutrient management practices

| Sodicity levels | Integrated nutrient management | | | | Mean |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| $S_1$ | 5.26 | 4.25 | 5.23 | 5.19 | 4.98 |
| $S_2$ | 4.52 | 3.92 | 4.66 | 4.64 | 4.43 |
| $S_3$ | 4.55 | 3.36 | 4.56 | 4.48 | 4.23 |
| $S_4$ | 4.43 | 3.27 | 4.53 | 4.32 | 4.13 |
| Mean | 4.69 | 3.70 | 4.74 | 4.65 | |
| CD(p=0.05) for sodicity levels | 0.13 | | | | |
| CD(p=0.05) for nutrient management | 0.22 | | | | |
| CD(p=0.05) for SxN | 0.32 | | | | |

Fig 48. Net returns and B:C ratio of Rice-wheat cropping system under different integerated nutrient management treatments




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. 48).

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

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. Therefore, under sodicity stress, improving the K-nutritional status of plants alleviates the detrimental effects of $Na^+$. As higher levels of NaCl cause K-deficiency, this may be one of the factors of oxidative stress. 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 experiments consisting of four sowing/transplanting windows viz. $W_1$- 15th Nov., $W_2$-30th Nov., $W_3$-15th Dec., $W_4$- 30th Dec. for wheat and $W_1$-5th July,

Table 48. Effect of transplanting windows and mode of K application on grain yield of wheat under rainfed condition in partially reclaimed sodic soils

| Transplanting windows | Treatments | | | | Mean |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| W1 | 3.22 | 3.35 | 3.59 | 3.42 | 3.40 |
| W2 | 2.94 | 3.06 | 3.22 | 3.07 | 3.07 |
| W3 | 2.39 | 2.54 | 2.83 | 2.91 | 2.67 |
| W4 | 1.78 | 2.17 | 2.36 | 2.26 | 2.14 |
| Mean | 4.92 | 4.81 | 5.40 | 5.16 | |
| CD (p=0.05) for windows | 0.23 | | | | |
| CD (p=0.05) for treatments | 0.32 | | | | |
| CD(p=0.05) for W x T | 0.43 | | | | |

Table 49. Effect of transplanting windows and mode of K application on grain yield of rice under rainfed condition in partially reclaimed sodic soils

| Transplanting windows | Integrated nutrient management | | | | Mean |
|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| W1 | 4.40 | 4.22 | 5.12 | 4.12 | 4.45 |
| W2 | 5.42 | 5.30 | 5.50 | 5.80 | 5.51 |
| W3 | 4.85 | 5.32 | 5.65 | 5.40 | 5.30 |
| W4 | 4.23 | 3.50 | 3.82 | 4.15 | 3.91 |
| Mean | 4.71 | 4.57 | 5.02 | 4.85 | |
| CD (P=0.05) | 0.13 | | | | |
| CD (p=0.05) for treatments | 0.40 | | | | |
| CD(p=0.05) for W x T | ns | | | | |

$W_2$-15$^{th}$ July , $W_3$-25$^{th}$ July and $W_4$-5$^{th}$ August for rice as main plot treatment and four levels and methods of potassium (K) application viz. $T_1$- 40kg K ha$^{-1}$ as basal,$T_2$-40kg K ha$^{-1}$ 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 were conducted in split plot design at ICAR-CSSRI, RRS, Lucknow during Rabi 2019-20 and Kharif 2020 with the objective to evaluate the impact of elevated temperature and rainfall pattern on productivity of rice and wheat in sodic soil under rainfed conditions. Recommended dose of Nitrogen and phosphorus were applied uniformly in all the treatments. Highest grain yield of wheat was obtained from treatment $W_1T_3$ where wheat crop was sown on 15$^{th}$ November with 60kg K ha$^{-1}$ applied in 3 splits (50% as basal, 25% top dressing at 30days after transplanting and remaining 25% as top dressing at spike initiation stage. However, there was no significant difference in $W_1$ and $W_2$ (Table 48).

After harvesting of wheat rice crop (CSR 46) was transplanted under different transplanting windows. The highest grain yield of rice was obtained from treatment $W_2T_3$ where rice was transplanted on 15$^{th}$ 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 49).

**Microbially mediated paddy and wheat crop residue decomposition to enhance nutrient recycling and soil health management** (Sanjay Arora, Y.P. Singh and A.K. Singh)

The samples of sodic soil, decayed wood, compost and rotten organic waste were collected for isolation of ligno-cellulolytic fungi. The fungal isolation was performed on Czapek Dox agar and Rose Bengal chloramphenicol agar selective media. Total colony forming units on the two media were 507 and 376 of which 128 discrete colonies were purified (Fig. 49). Based on morphological colony characteristics *viz*. growth, size, colour 97 fungal isolates were further purified through subculturing method on the respective media. Primary screening of isolates for their cellulolytic and lignolytic potential was done by qualitative plate assay on the basis of zone formation in carboxymethyl cellulose and tannic acid agar plates using two modified compositions of both the media.

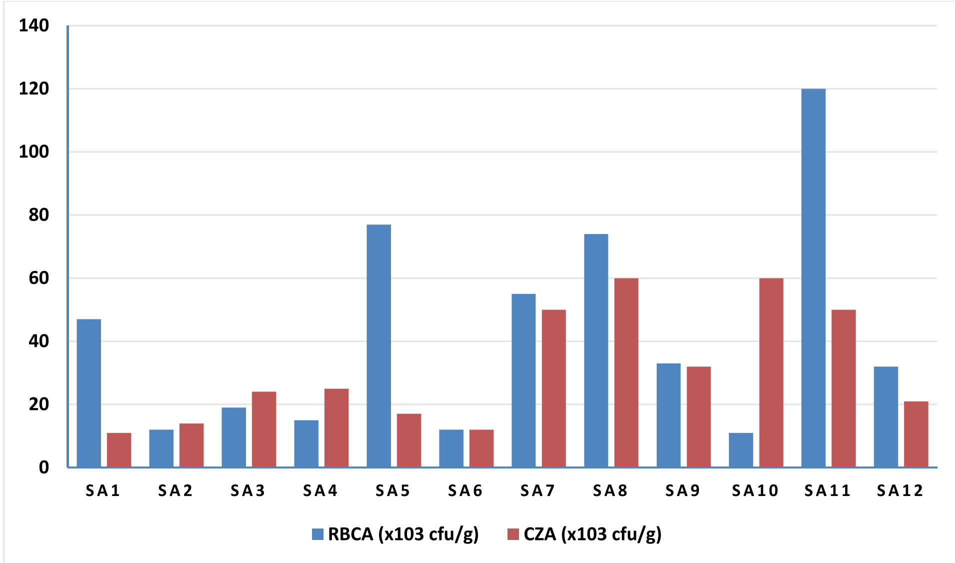
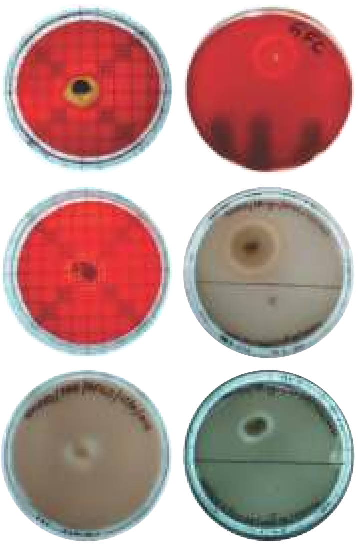



Fig 49. Isolation of different fungal isolates from samples



Primary screening of cellulose and lignin degrading fungi

Out of 97 fungal isolates, 72 isolates were screened for the cellulolytic activity using the CMC agar media and found that 29 fungal isolates showed positive result for the production of cellulase enzyme by forming clear zone around colony. Tannic acid agar media was used for the qualitative assay of polyphenol oxidase enzyme production by fungal isolates. Out of 72, 16 isolates showed clear zone around colony with brown pigment on the modified tannic acid agar plates which contain tannic acid as a sole carbon source (photo). This primary screening indicated that the fungal isolates are capable to decompose the polyphenolic complex structure possessed by lignin for their consumption in absence of any other carbon source.

Further, it is indicative that these fungal isolates might show some promising result in terms of lignocellulolytic activity that may be useful in degradation of crop residues.

**Combating sub-soil sodicity constraints of central indo-gangetic plains of Uttar Pradesh for enhancing crop productivity (UPCAR Funded)** (V.K. Mishra, S.K. Jha and Y.P. Singh)

It has been noticed that in spite of the technological intervention of sodic soil management, the yields of the many crops are not up to the country/state demand because of the highly dispersed nature of sub surface soil and poor organic carbon content. This is mainly because, the conventional method of sodic soil reclamation include mixing of gypsum @ 50 % GR to 7.5 cm soil depth and was considered adequate for rice–wheat cropping system taking into account the self reclamation to the deeper depth through mobilization of soil $Ca^{2+}$ under ponded rice. However, this procedure is inefficient to reclaim the subsurface sodicity in heavy textured, highly dispersed, and in presence of hard pan. The mobilized $Ca^{2+}$ under ponded rice gets restricted within shallow depth due to high clay, silt content and dispersed soil matrix at sub-surface soil layers. This results in poor hydraulic conductivity of the soil and the real efficacy of gypsum application gets reduced due to formation of $CaCO_3$ in presence of dissolved $CO_3^{--}$ and $HCO_3^-$ in soil solution. In the past, no attempts have been made for management of sub surface sodicity in relation to field crops, though only few attempts of deep ploughing, agar whole method, pit method plantation in sodic land have been initiated, that too confined very much to horticultural crops.

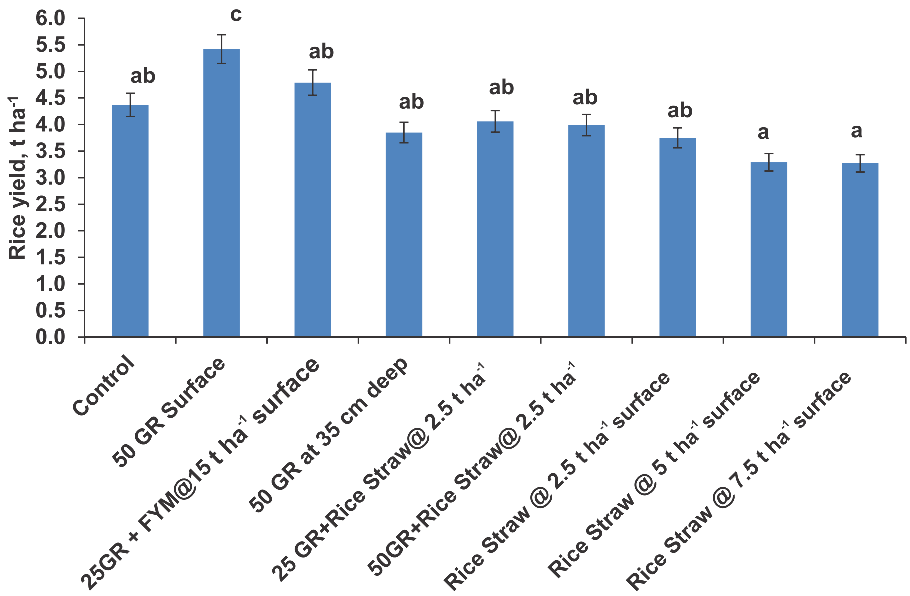



Fig 50. Rice yield under different treatments

Keeping this view in mind, a field experiment was conducted on partially reclaimed sodic soil of Shivri farm Lucknow under UPCAR funded project for the management of sub surface sodicity constraints and for boosting up the productivity of rice and wheat in such soils. The experiment started in the kharif season in 2020, involving nine treatments and three replications on plot size of 48 $m^2$ (6 m X 8 m), using a randomized block design. Following the experimental lay-out, the plots were ploughed to fine tilth and based on the gypsum requirement (GR), determined in the laboratory, the required doses of gypsum was applied as per the treatments:- The treatments were: T1– Control; T2 – 50 GR gypsum at surface; T3 – 25 GR +15 t $ha^{-1}$ FYM at surface; T4 – 50 GR at 35 cm depth; T5 - 25 GR +placing rice straw @ 2.5 t $ha^{-1}$ at 35 cm depth; T6 – 50 GR +placement of rice straw @ 2.5 t $ha^{-1}$ at 35 cm depth; T7 – placement of rice straw @ 2.5 t $ha^{-1}$ at 35 cm depth; T8 – placement of rice straw @ 5 t $ha^{-1}$ at 35 cm depth; T9 – placement of rice straw @ 7.5 t $ha^{-1}$ at 35 cm depth. In the treatments, where gypsum and/or rice straw was placed at the sub-surface, trenches of 50 cm wide were made to the depth of 35 cm and placed the rice straw. The distance between the trenches were kept to 50 cm.

A view of the channel showing placement of rice straw

The irrigation water was applied to each plot after gypsum and rice straw application and ponding of water was maintained for about 15 days. After 15 days of reaction time, 30 days old rice seedlings (cv CSR-36) were transplanted as a first crop at 20 cm and 15 cm between rows and hills, respectively. The full dose of P (60 kg $P_2O_5$), K (40 kg $K_2O$) and 50 % of recommended doses of N (75 kg N) $ha^{-1}$ were applied as basal. The remaining amount of N was applied at the time of tillering (30 days after transplanting) and panicle initiation (75 days after transplanting) in equal proportions. The performance of the crop is shown in Fig. 50.

The rice was harvested and the grain yield was recorded. Maximum grain yield of 5.42 t $ha^{-1}$ was recorded in the treatment where 50 GR gypsum was applied at the surface (50 GR surface) Fig. 50. The treatments where rice straw was placed at the soil depth of 35 cm @ 5t $ha^{-1}$ and 7.5 t $ha^{-1}$ recorded numerically lowest yield compared to control. This might be probably due to appearance of high pH sub-surface soil to the surface in the process of manual digging of the channels and leveling.

Table 50. Physico-chemical characteristics of soil after rice harvest

| Treatments | $pH_2$ | $EC_2$ | O.C. % |
|---|---|---|---|
| Control | 9.23 | 0.61 | 0.32 |
| 50 GR surface | 8.89 | 0.70 | 0.32 |
| 25 GR+FYM@15 t $ha^{-1}$ surface | 8.96 | 0.66 | 0.38 |
| 50 GR at 35 cm depth | 9.2 | 0.72 | 0.31 |
| 25 GR+rice straw @ 2.5 t $ha^{-1}$ | 9.3 | 0.72 | 0.29 |
| 50 GR + rice straw @ 2.5 t $ha^{-1}$ | 9.36 | 0.60 | 0.27 |
| Rice straw @ 2.5 t $ha^{-1}$ | 9.47 | 0.71 | 0.28 |
| Rice straw @ 5 t $ha^{-1}$ | 9.29 | 0.81 | 0.3 |
| Rice straw @ 7.5 t $ha^{-1}$ | 9.32 | 0.74 | 0.28 |

The soil samples (0-15 cm) were collected after rice harvest was subjected to physico-chemical analysis. The average pH of the soil varied from 8.89 to 9.47 with maximum pH reduction observed in 50 GR surface with respect to control (Table 50). The organic carbon did not show any significant change among the treatments.

**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. The field of wheat was recorded, although the wheat yield was found to be numerically higher in 50 GR MG (3.35 t $ha^{-1}$), it was statistically on par with 50 GR GYP (3.28 t $ha^{-1}$) and 25 GR GYP+25 GR MG (3.06 t $ha^{-1}$). In control, only 0.58 t $ha^{-1}$) wheat yield was recorded (Fig. 51). The soil samples collected after wheat harvest were subjected to physico-chemical analysis. With respect to control, the pH was reduced significantly in the treatments 50 GRMG which was

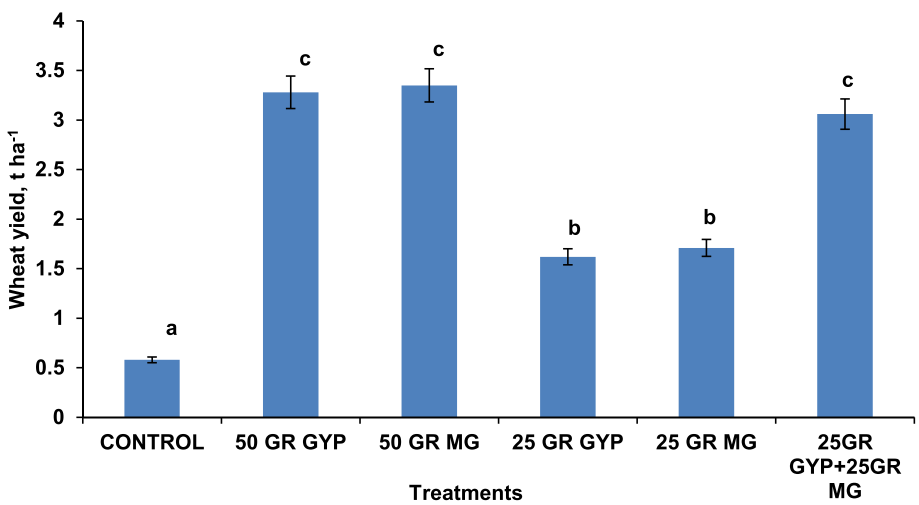



Fig 51. Effect of marine gypsum on grain yield of

Table 51. Physico-chemical characteristics of soil after rice harvest

| Treatments | pH | EC(1:2) | O.C.% |
|---|---|---|---|
| Control | 10.08[c] | 0.76[a] | 0.1[a] |
| 50 GR GYP | 9.12[a] | 0.93[ab] | 0.28[bc] |
| 50 GR MG | 9.07[a] | 1.01[b] | 0.36[c] |
| 25 GR GYP | 9.50[b] | 0.77[ab] | 0.24[b] |
| 25 GR MG | 9.46[b] | 0.91[ab] | 0.27[bc] |
| 25GR GYP+25GR MG | 9.13a | 0.97ab | 0.34bc |

Different letters represent significant differences at a p<0.05.

statistically on par to 50 GR GYP and 25 GR GYP+25 GR MG. The organic carbon percentage found to increase in all the treatments compared to control whereas no significant difference in electrical conductivity ($EC_2$) was noticed among the treatments (Table 51).

The relationship between Ca adsorbed on to the solid phase (soil) and soil solution is presented in Fig. 52. The exchange isotherm of Ca in soil saturated with Na depicted a C-shaped curve which meant that the ions are non-specifically adsorbed on to the exchange site. The amount of Ca was found to increase in both the exchange and solution phase and reached maximum at Ca concentration of 1400 mg L-1 (35 mmol L-1) of equilibrating solution. The distribution coefficient (Kd) value of Ca in soil saturated with Na varied between 3.93 and 8.57 L kg-1. The ionic strength of the equilibrating solutions (µ = 1/2∑CiZi2) was also calculated and a relationship between ionic strength and activity coefficient was plotted which revealed an increase in the ionic strength of solution with the decrease of activity coefficient. The Vanselow activity coefficient (KV) for the (Na-Ca) binary exchange reaction (2Na-X + Ca2+ = Ca-X +2 Na+) was found to be less than unity, which meant that Na is proffered for the exchange reaction compared to Ca.The study proposed that marine gypsum could be an alternative to mineral gypsum in the management of degraded sodic soils in absence and/or paucity of agricultural grade mineral gypsum.

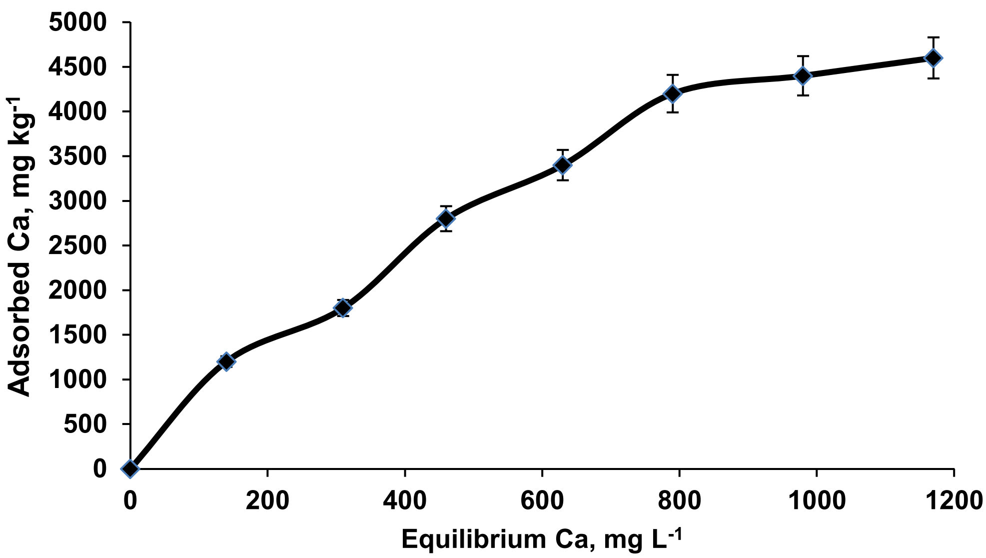



Fig 52. Isotherms of Ca in Na-Ca binary exchange systems in studied

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

### Sharda Sahayak Canal Command

Canal command faced problems of waterlogging and sodicity five years after the commissioning of the canal. Water and land productivity in waterlogged pockets coupled with sodicity remained low throughout the year. A study was initiated in Sharda Sahayak Canal System to work out major production constraints in selected minor of Sharda Sahayak Canal Command and for the evaluation of pond based IFS Model in waterlogged sodic conditions

### Models Under Study

One Pond Based Integrated Farming System Model (PBIFSM) was located at Mahraura, Raebareli with pond area of 2330 $m^2$ and elevated field bed area of 2730 $m^2$. Other models considered in this study were located in Patwakheda and Lalaikheda. The area under pond was 1300 $m^2$ and elevated field bed area was 1635 $m^2$ under the control of Ghasita Ram and pond area of 1300 $m^2$ and elevated field bed area of was controlled by Dinesh in Patwakheda village of Lucknow district. Beneficiary farmer of Lalaikheda model is Jitendra Singh. The area under pond was 2356 $m^2$ and elevated field bed area was 2336 $m^2$.

### Crop Performance

Crop performance grown over the elevated field bed and fish are shown in the pictures. Karuna Shankar took wheat (KRL 210) over an area of 0.165 ha and garlic over an area of 0.0062 ha during Rabi 2019-20 and rice over an area 0.18 ha during Kharif 2020. Wheat yield obtained was 3.94 t $ha^{-1}$ resulting to water use efficiency, water productivity and land productivity as 437.71 kg/ha-cm, Rs. 84.26 $m^{-3}$ and 0.394 kg $ha^{-1}$, respectively. Reported garlic yield was 7.74 t $ha^{-1}$ resulting to water use efficiency, water productivity and land productivity as 430.11 kg/ha-cm, Rs. 516.12 $m^{-3}$ and 0.774 kg $ha^{-1}$, respectively. Similarly rice crop (CSR 36) grown over an area of 0.18 ha during 2020 gave the yield potential of 3.5 t $ha^{-1}$ with corresponding water use efficiency, water productivity and land productivity as 291.66 kg/ha-cm, Rs. 46.67 $m^{-3}$ and 0.350 kg $ha^{-1}$, respectively. Intensive fish farming was initiated this year with pangasius fish. Artificial feed was given to the fish. The production of fish was 10.44 t $ha^{-1}$ with water use efficiency, water productivity and land productivity as 34.78 kg/ha-cm, Rs. 31.70 $m^{-3}$ and 1.04 kg $ha^{-1}$, respectively.

Ghasita Ram from Patwakheda obtained yield potential of potato, peas, sugar beet, spongegourd and brinjal as 18.00, 9.79, 1.36 and 20.60 t $ha^{-1}$ for which water use efficiency were 3000.00, 1088.00, 1133.33, 1018.51 and 1287.50 kg/ha-cm; water productivity 600.00, 10.88, 226.66, 203.66 and 257.00 Rs $m^{-3}$ and land productivity were 1.833, 1.800, 0.979, 1.360 and 2.060 kg $m^{-2}$, respectively. Yield potential of mentha was calculated as 97 liter $ha^{-1}$ resulting to water use efficiency, water productivity, land productivity and B:C ratio of 2.43 liter/ha-cm, 29.14 Rs $m^{-3}$, 0.012 liter $m^{-2}$ and 4.78, respectively. The productivity potential of fish and corresponding water use efficiency, water and land productivity were 3.04 t $ha^{-1}$, 30.43 kg/ha-cm, 39.56 Rs $m^{-3}$ and 0.30 kg $m^{-2}$, respectively. The productivity of the menthe was recorded as 97 liter $ha^{-1}$. The benefit cost ratios of potato, peas, sugarbeet, sponge gourd, brinjal and fish were worked out as 4.91, 8.05, 4.45, 5.14, 5.37 and 8.70, respectively.

Dinesh from Patwakheda obtained yield potential of pea, tomato, coriander-mix, radish-mix and spinach-mix as 7.25, 4.27, 2.86, 6.13 and 2.10 t $ha^{-1}$, respectively. Corresponding water use efficiency, water and land productivity were observed to be 805.56, 1108.23, 952.33, 680.667 and 2042.00 kg/ha-cm; 399.01, 110.82, 288.76, 244.88, 129.37 Rs $m^{-3}$ and 0.725, 4.267, 0.286, 0.613 and 0.210 kg $m^{-2}$, respectively. The B:C ratios of pea, tomato, coriander-mix, radish-mix and spinach-mix were 5.55, 4.72, 4.09, 6.90 and 1.94, respectively. Kharif vegetables namely sponge gourd, bottle gourd, pumpkin and cow pea gave yield of 21.79, 23.57, 4.27 and 11.48 t $ha^{-1}$ with corresponding water use efficiency, water and land productivity as 681.18, 962.10, 1108.23 and 478.33 kg/ha-cm; 136.24, 96.21, 110.82 and 119.58 Rs $m^{-3}$, and 2.180, 2.360, 4.267 and 1.148 kg/ m2, respectively. The fish yield, water use efficiency, water and land productivity were obtained as 3.25 t $ha^{-1}$, 32.50 kg/ha-cm, Rs.42.30 $m^{-3}$ and 0.325 kg $m^{-2}$, respectively. B:C ratio of pea, tomato, coriander-mix, radish-mix, spinach-mix, sponge gourd, bottle gourd, pumpkin, cow pea, brinjal and fish were 5.55, 4.72, 4.09, 6.90, 1.94, 5.14, 4.15, 6.58, 3.76, 4.95 and 9.55, respectively.

## Crop performance at IFS Models

### Modeling of Salt Accumulation

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. Following evaporation model was developed for estimating evaporation from soil surface in response to water table depth.

$$E_y = \frac{1}{\frac{1}{E_p} + \alpha\, y^{\beta}} \qquad (1)$$

Where,

Ey= evaporated depth of water against water table depth of y

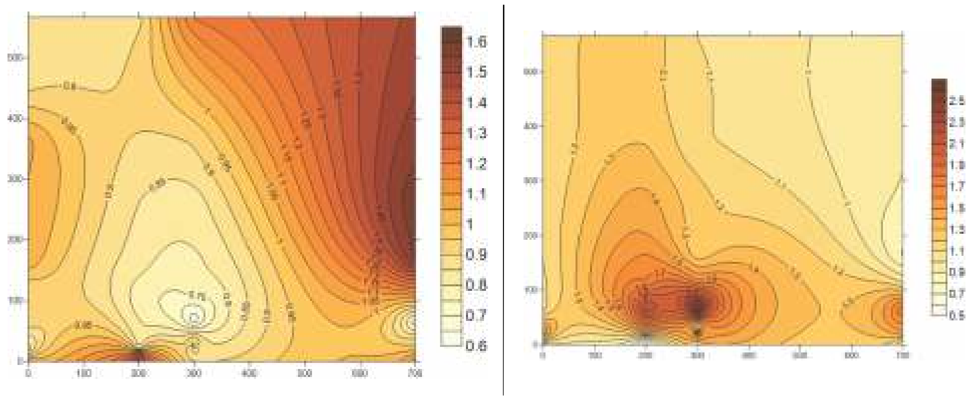
yβ= appropriated depth of water table

α and β are the model constants

If the electrical conductivity of water is ECw, salt concentration can be calculated by introducing a salt coefficient as Sw=λs.ECw in Eqn. (1) as below.

$$E_y = \frac{\lambda_s . EC_w}{\frac{1}{E_p} + \alpha\, y^{\beta}} \qquad (2)$$

Water table depths recorded on daily basis for year 2003-04 in four rows across the canal at Kashrawan village of Bachhrawan block of district Raebareli were utilized for calculation of salt accumulation. Water table contours of whole field and corresponding salt accumulation contours for the month of June 2004 are shown in Fig. 53a and 53b. Salt accumulation on soil surface on the first line during the month of October 2003 were calculated as 0.116, 0.149, 0.175, 0.213, 0.275, 0.270, 0.155, 0.145, 0.173, 0.170, 0.170 and 0.178 ppm and during June 2004 were 0.685, 1.033, 1.179, 1.336, 1.667, 1.610, 1.064, 1.082, 1.100, 1.113, 1.100 and 1.143 ppm at the points 0, 5, 10, 15, 20, 25, 65, 117, 165, 265, Fig 53. Water table fluctations and salt accumulation.




(a) Water depth contour during June 04

(b) Salt accumulation contour during June 04

Construction of rain water storage tanks.

Water tank covered with plastic sheet during mid July 2020

Water quality towards October 2020 end

365 and 455 m away from the canal, respectively. Similarly month wise salt accumulations were calculated for all points located over four observational lines. Salt accumulation was more pronounced in the closure vicinity of the canal.

## Rain Water Harvesting, Storage, Use and Recharge in Fluoride Affected Area of U.P.

(C.L. Verma, S.K. Jha and A.K. Jha)

Presence of high levels of fluoride in drinking water causes damage to the human dental and skeletal systems. Ground water is being used directly for human consumption in rural areas without any prior test and treatments. It is the main source of fluoride ingestion in rural areas. Rain water is a good source of water with almost no salt and fluoride in it. The area with sufficient rainfall has potential for rain water storage and dilution of fluoride in drinking water. Roof top harvesting, storage, use and ground water recharge for dilution of fluoride in ground water is a simple solution. The present study was taken up for remediation of fluoride contaminated water in Unnao district of U.P. in high risk zone with the following objectives.

### Rain Water Storage Structure

Two rain water storage structures (2.0 m x1.5 m x 1.5 m) were constructed under the study (photo). One structure was constructed in the premise of Central Soil Salinity Research Institute Regional Research Station Lucknow for detailed investigations of water quality and losses due to evaporation and seepage. Another rain water storage tank was constructed at Marksnagar village in Unnao district. Rain water harvested from roof top was conveyed to the storage tank through 100 mm PVC pipe. After covering the tank with concrete cover it was further covered with a thin polythene sheet putting soil all around (photo). EC of the stored water at the end or October month was observed to be 0.933 dS $m^{-1}$ and pH was 8.04. The water was transparent in the tank with very good appearance. The EC and pH of rain water measured during the month of July 2020 were 0.0644 dS $m^{-1}$ and 5.62, respectively.

### Evaporation Loss

Evaporation loss with plastic shield cover was measured as 0.33 mm $day^{-1}$ over a period 100 days. The temperature during this period is higher. The tank was opened on 28.10.2020 and water depth was measured on daily basis till 18.01.2021. Variation of water depth in tank with time is shown in Fig. 54. The rate of water loss during the month November to January was worked out as 0.17 mm $day^{-1}$ without cover. Properly

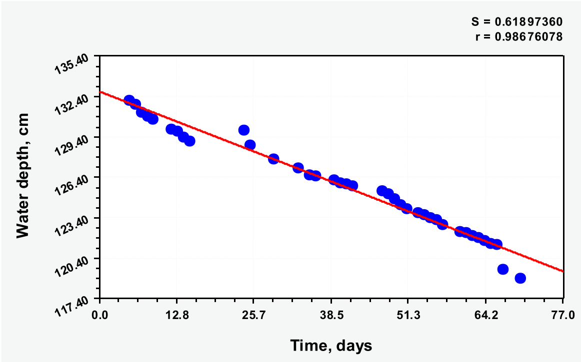



Fig 54. Evaporation loss pattern from rain water storage tank

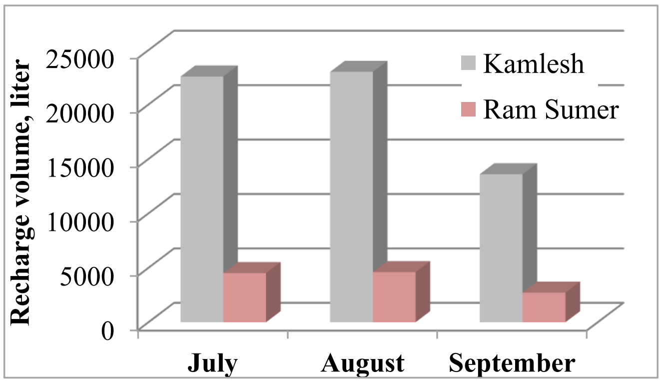



Fig 55. Monthly rainwater recharge vol. at Sirsahakheda village.

constructed rain water storage tank has potential to store rain water with minimum losses through proper care.

### Ground Water Recharge and Fluoride Dilution

For recharging ground water through roof top harvested rain water was collected through the roof top drain outlet and diverted to open recharge well with a flexible plastic pipe. Rain water capturing efficiency was considered as 95%. Two wells in the closer vicinity were recharged using the rain water from the roofs of Kamlesh (90 $m^2$) and Ram Sumer (18 $m^2$). The recharge volumes were 22572 23000 and 13595 liter for Kamlesh well and 4514, 4600 and 2719 liter for Ram Sumer well, respectively during the month of July, August and September. Thus overall monthly recharge volumes become 27086, 27600 and 16314 liter for July, August and September, respectively (Fig. 55). Total recharge of 71000 liter of roof top harvested rain water reduced the fluoride concentration of hand pump located in the close vicinity of the recharge well from 2.31 ppm (June 2020) to 1.13 ppm (October 2020).

### Dynamic Use Planning of Roof Top Harvested Rainwater

The planning of simultaneous use, storage and harvesting of rain water is termed as dynamic use planning of roof top harvested rain water in fluoride affected area. A family of five members would require about 15 liter of good quality drinking water @ 3 liter per person on daily basis. The total volume required for a month would be 450 liter. During four month rainy season the roof top harvested rain water could be used and stored simultaneously. During dry months only the stored water is required to be used for drinking purpose. Volume of rain water required for eight dry months becomes 3600 liter. Considering fluoride concentration in ground water as 3 ppm, mixing of the same with same volume of rain water would double the available volume of drinking water keeping the fluoride in the limit of 1.5 ppm. Thus to fulfil the water requirement of 3600 liter in mix mode a storage volume of 1800 liter would be needed. Therefore a storage tank of 2000 liter capacity would be sufficient to meet the daily need of drinking water if fluoride concentration in available ground water is 3 ppm. Plastic tank is much easy to install, link with rainwater harvesting system and safe guard the quality of stored water over a long period of time.

# 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)

Salinity being temporal in nature, day by day the extent of area under salinisation is changing due to one or other factors and therefore it becomes highly essential to monitor and report the extent of salt affected soils for taking control over it by using different technologies available for reclamation and management. 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 samples were collected from 688 different geo-referenced sites of different districts of Gujarat *viz*., Bharuch (89), Surat (60), Anand (9), Navsari (4), Vadodara (10), Tapi (9), Narmada (1), Ahmedabad (30), Kheda (22), Bhavnagar (54), Surendranagar (58), Mehsana (57),Patan (21) and Kutch (264) till March 2020. The samples were collected from different depths to ascertain the possibility of sub-surface salinity. Soils of these sites varied in texture, structure, colour, relief and showed different cropping systems and management practices. The collected soil samples were analyzed for $EC_2$, ECe, $pH_2$, pHs as well as soluble cations and anions. Out of 296 geo-referenced soil samples analysed for 0-15 cm depth, 221 samples (74%) recorded $EC_e$ less than or equal to 4 dS $m^{-1}$ whereas, 11% samples fall in the range of 4-8 dS $m^{-1}$ salinity and 15% samples fall in the range of >8.0 dS $m^{-1}$ salinity. This analysis suggests that saline area is about 26% and normal area is about 74%. The data showed the predominance of subsurface salinity (Table 52). Likewise, in 0-15 cm depth, 19 (6.41%) of the 296 samples analyzed had pHs>8.2 whereas in 90-120 cm, 27 out of 173 analyzed soil

Table 52. Number of analyzed soil samples in different soil salinity category (ECe)

| Depth (cm) | No. of samples | | | |
|---|---|---|---|---|
| | < 4dS $m^{-1}$ | 4-8 dS $m^{-1}$ | >8 dS $m^{-1}$ | Total samples analyzed |
| 0-15 | 221 (74) | 32 (11) | 43 (15) | 296 |
| 15-30 | 230 (78) | 18 (6) | 483 (16) | 296 |
| 30-60 | 210 (76) | 18 (7) | 47 (17) | 275 |
| 60-90 | 132 (72) | 10 (5) | 42 (23) | 184 |
| 90-120 | 117 (68) | 15 (8) | 41 (19) | 173 |

Table 53. Number of analyzed soil samples in different soil pHs category

| Depth (cm) | No. of samples | | No. of samples |
|---|---|---|---|
| | pHs< 8.2 | pHs> 8.2 | |
| 0-15 | 277 | 19 | 296 |
| 15-30 | 267 | 29 | 296 |
| 30-60 | 248 | 27 | 275 |
| 60-90 | 160 | 24 | 184 |
| 90-120 | 145 | 28 | 173 |

samples (15.60%) recorded pHs>8.2 suggesting higher pH in the sub-surface layers of soil profile (Table 53). The data on soluble cation and anions revealedthat among cationsthe dominance of $Na^{+}$ followed by $Mg^{2+}$, $Ca^{2+}$, and $K^{+}$ and among anions $Cl^{-}$ > $SO_4^{2-}$ > $CO_3^{2-}$ > $HCO_3^{-}$.

**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) to agricultural land has several beneficial effects similar to other organic manures. Micronutrients always have been ignored in general nutrient management plan. Deficiency of zinc in soil is increased in India due to extensive use of NPK without application of micronutrients. By combining some approaches of integrated nutrient management (INM) and application of micronutrients, yield of field crops can be enhanced and sustainability of the system can be secured. The idea of inclusion of some other crops in the cotton mono-crop system along with INM has been used for maximization of crop yield. Keeping this in view, experiment was planned with split plot with three cropping systems of cotton in two years crop rotation; C1- Cotton mono-cropped, C2-Cotton-Sorghum-Wheat and C3-Cotton-Pigeonpea-Wheat in main plot and five treatments of INM in sub plots as: 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.

Among INM treatments under cotton mono-cropped system (C1) for 4th year, results revealed N5 treatment recorded significantly higher values of yield parameters *i.e.* plant height (144.3 cm), No. of branches/plant (27.9), No. of Bolls/plant (41.2); cotton yield/plant (77.93 g), stalk yield/plant (143.3 g), cotton yield/plot (2.69 kg), stover yield /plot (6.43 g), cotton yield (12.45 q $ha^{-1}$) and stover yield/ha (29.8 q $ha^{-1}$) than other treatments, which was statistically at par with treatments N2 and N1 (data not given).

Yield analysis of wheat crop components under C2 cropping system revealed that at 90 days after sowing (DAS) the maximum plant height (83.1 cm) and maximum dry weight biomass (4.65 g) were observed under the treatment N5 followed by the treatments N2 and N1. Similarly significantly higher values of yield parameters *i.e.* 1000-seed weight (44.47 g), wheat grain yield/plant (6.46 g), grain yield/plot (7.11 kg), straw yield /plot (23.14 kg), grain yield /ha (28.23 q $ha^{-1}$) and straw yield/ha (91.83 q $ha^{-1}$) was obtained with treatment N5 which was statistically at par with treatments N2 and N1 (data not given).

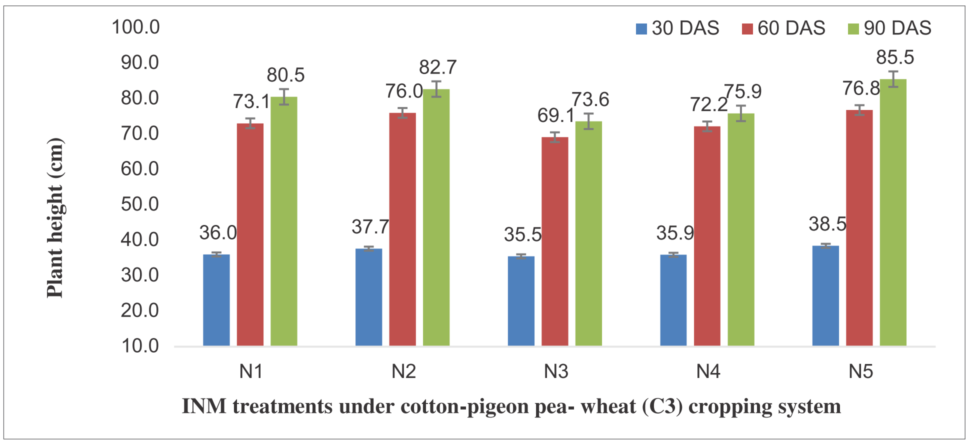



Fig 56. Plant height of wheat (C3) affected by various INM treatment.

Table 54. Wheat yield parameters affected by various INM treatment under cotton-pigeon pea-wheat cropping system (C3) in 2nd rotation.

| Treatments | No. of tillers/ plant | 1000-seed wt. (g) | Grain yield/ plant (g) | Grain yield (kg/plot) | Straw yield (kg/plot) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| N1 | 7.57 | 42.24 | 5.98 | 7.09 | 22.54 | 2.81 | 8.94 |
| N2 | 7.83 | 43.62 | 6.53 | 7.12 | 24.00 | 2.83 | 9.52 |
| N3 | 7.30 | 39.19 | 5.50 | 5.59 | 18.18 | 2.22 | 7.21 |
| N4 | 7.63 | 41.32 | 5.85 | 6.38 | 20.94 | 2.53 | 8.31 |
| N5 | 7.90 | 44.82 | 6.56 | 7.39 | 24.84 | 2.93 | 9.86 |
| Mean | 7.65 | 42.24 | 6.08 | 6.71 | 22.10 | 2.66 | 8.77 |
| LSD0.05 | NS | 2.77 | 0.70 | 0.99 | 3.73 | 0.39 | 1.48 |

Similarly the yield analysis of wheat crop components under C3 cropping system revealed that at 90 DAS maximum plant height (85.5 cm) was observed under the treatment N5 followed by treatments N2 and N1 (Fig. 56). Similar results were also obtained under cotton-pigeon pea-wheat cropping system for 4th year (Table 54)

Soil analysis revealed that soil $pH_2$ and $EC_2$ were non-significant among different cropping system. Under C1 system, soil $pH_2$ and $EC_2$ were in the range of 7.29-7.35 and 0.47-0.69 dS $m^{-1}$, respectively at 0-15 cm surface layer. Under C1, C2 and C3 cropping system in surface layer, maximum organic carbon content (0.685%, 0.667% and 0.742%, respectively), available nitrogen (339.0 kg $ha^{-1}$, 323.1 kg $ha^{-1}$ and 353.0 kg $ha^{-1}$, respectively) and phosphorus (40.1 kg $ha^{-1}$, 37.0 kg $ha^{-1}$ and 43.4 kg $ha^{-1}$) were found in the treatment N5 which was statistically at par with the treaments N2 and N4. Among different cropping system, cotton-pigeon pea-wheat cropping system (C3) have higher magnitude of organic carbon content, available nitrogen and phosphorus content which was followed by cotton mono cropping system (C1). Minimum fertility status was obtained by cotton-sorghum-wheat cropping system (C2).

Another experiment was conducted to evaluate the microbial formulations (Halo-Azo, Halo–PSB and Both mix) under different its combinations in *rabi* season wheat (var. KRL 210) crop at Bharuch condition for two years (2018 and 2019) with five treatment combinations:

Table 55. Wheat yield parameters under different microbial formulations treatments.

| Treatments | Plant height (cm) | No. of tillers/ plant | 1000-seed wt (g) | Grain yield (kg/plot) | Straw yield (kg/plot) | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| T1 | 65.8 | 8.27 | 40.1 | 1.52 | 4.63 | 2.38 | 7.23 |
| T2 | 60.2 | 8.00 | 38.4 | 1.39 | 4.36 | 2.18 | 6.82 |
| T3 | 67.0 | 8.93 | 41.1 | 1.65 | 5.84 | 2.59 | 9.12 |
| T4 | 62.2 | 8.47 | 39.0 | 1.47 | 4.79 | 2.30 | 7.49 |
| T5 | 69.7 | 9.30 | 42.9 | 1.75 | 6.05 | 2.73 | 9.46 |
| Mean | 65.0 | 8.59 | 40.3 | 1.56 | 5.13 | 2.43 | 8.02 |
| LSD0.05 | 5.8 | NS | NS | 0.21 | 1.16 | 0.33 | 1.81 |

T1= Un-inoculated+VC @ 2.5 t $ha^{-1}$+100% RDF; T2= Un-inoculated+VC @ 2.5t $ha^{-1}$+75%RDF; T3=Halo-Azo incoculation+T2; T4= Halo-PSB incoculation+T2; and T5 =Halo-Azo + Halo-PSB incoculation+T2.

Results revealed that T5 treatment recorded maximum values of yield parameters *i.e.* No. of tillers/ plant (9.3); 1000-seed weight (42.9 g), grain yield/plot (1.75 kg), straw yield /plot (6.05 kg), grain yield /ha (27.3 q ha$^{-1}$) and straw yield/ha (94.6 q ha$^{-1}$) than other treatments, which was statistically at par with treatment T3 (Table 55).

**Cost effective drainage in waterlogged saline vertisols for improving crop productivity in gujarat** (Sagar D. Vibhute, Anil R. Chinchmalatpure, Vineeth T. V. and M. J. Kaledhonkar)

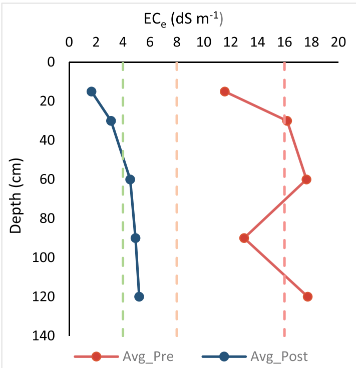



Fig 57. ECe variation at Adadara site

Growth of Sugarcane on reclaimed saline soil

Subsurface drainage technology (SSD) is one of most successful technologies for getting sustainable crop production in waterlogged and highly saline soils. Effect of SSD in Vertisols of Ukai kakrapar canal command area of Gujarat was studied at Adadara and Ghodadara villages. The SSD system was installed in February 2017 and its effect on desalination of soil profile and improvement in crop yield was studied after successful operation of the SSD system for 4 years. The SSD site at Adadara village has shown very good results due to periodic pumping of water but the situation has not improved much at Ghodadara site due to lack of pumping.

At Adadara site pre SSD average soil salinity was more than 10 dS m$^{-1}$ in all soil layers for top 120 cm soil profile and it was reduced by 9.9 dS m$^{-1}$ (86%), 13.1 dS m$^{-1}$ (81%), 13.1 dS m$^{-1}$ (74%) , 8.1 dS m$^{-1}$ (72%) and 12.5 dS m$^{-1}$ (71%) for 0-15, 15-30, 30-60, 60-90 and 90-120 cm soil layers, respectively (Fig. 57). Average soil salinity has come below 4 dS m$^{-1}$ for the top 30 cm layer whereas it was 4 to 5.2 dS m$^{-1}$ for the 30-120 cm soil layer.

The system was installed with 35 m lateral spacing (d) and soil salinity was also measured at a distance of 0.5 m, D/8 (4.375 m) , D/4 (8.75 m) and D/2 (17.5 m) from the centre of lateral pipe in order to study the horizontal effect of the system. The spatial variation in soil salinity is given in Table 56. It was observed that average ECe at 0.5 m distance from lateral pipe was below 4 dS m$^{-1}$ for entire top 120 cm soil profile whereas it was below 4 dS m$^{-1}$ for top 30 cm layer at distance of D/8, D/4 and D/2 from lateral pipe. In case of pHs, very slight spatial variation was observed. As far as crop performance is considered, sugarcane crop was not growing at Adadara site, however, after SSD installation sugarcane crop was successfully cultivated twice in rotation with fodder grasses. The sugarcane yield of 75 tonnes per hectare was achieved from the site and the growth of sugarcane on reclaimed saline soil is showed in the picture.

At Ghodadara SSD site soil salinity was reduced by 1.1 dS m$^{-1}$, 0.9 dS m$^{-1}$, 0.7 dS m$^{-1}$, 1.2 dS m$^{-1}$ and 0.6 dS m$^{-1}$ for 0-15, 15-30, 30-60, 60-90 and 90-120 cm soil layers, respectively but waterlogging condition is still persistent in the area. Spatial variation in soil salinity was also studied at the site (Table 57).

It was observed that soil ECe throughout the soil profile were below 4 dS m$^{-1}$ at all the locations. The pHs were also found within neutral range for all the samples.

Table 56. Spatial variation in Soil salinity at Adadara site

| Soil layer (cm) | ECe (dS m$^{-1}$) | | | | pHs | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.5 m | D/8 m | D/4 m | D/2 m | 0.5 m | D/8 m | D/4 m | D/2 m |
| 0-15 | 0.88 | 1.75 | 1.36 | 2.67 | 7.20 | 7.03 | 7.22 | 6.99 |
| 15-30 | 1.58 | 3.43 | 3.18 | 3.58 | 7.05 | 6.99 | 7.14 | 7.14 |
| 30-60 | 2.56 | 5.70 | 4.77 | 5.13 | 7.24 | 7.15 | 7.25 | 7.06 |
| 60-90 | 3.25 | 5.43 | 4.73 | 5.63 | 7.07 | 6.93 | 7.23 | 7.15 |
| 90-120 | 3.24 | 6.67 | 5.10 | 5.83 | 7.23 | 7.08 | 7.23 | 7.16 |

Table 57. Spatial variation in Soil salinity at Ghodadara site

| Soil layer (cm) | ECe (dS $m^{-1}$) | | | | pHs | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.5 m | D/8 m | D/4 m | D/2 m | 0.5 m | D/8 m | D/4 m | D/2 m |
| 0-15 | 0.9 | 1.19 | 1.13 | 1.18 | 6.72 | 7.16 | 7.1 | 7.15 |
| 15-30 | 0.9 | 1.15 | 1.7 | 1.62 | 6.95 | 6.96 | 7.12 | 7.16 |
| 30-60 | 4 | 0.89 | 0.78 | 1.56 | 7.24 | 7.2 | 7.1 | 7.25 |
| 60-90 | 1.25 | 1.22 | 0.76 | 1.56 | 7.25 | 7.04 | 7.12 | 7.22 |
| 90-120 | 1.26 | 1.3 | 1.43 | 1.35 | 7.2 | 7.05 | 7.15 | 7.22 |

**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)

Apart from saving freshwater resources, lesser salinity build-up is the major benefit in adopting conjunctive irrigation in saline environments of arid regions. Third year field experiment on conjunctive use of surface water and saline groundwater was carried out under drip irrigated wheat at Samni Experimental Farm of ICAR-CSSRI, Regional Research Station, Bharuch. Previous year treatments of cyclic mode of conjunctive irrigation were continued in this experiment and 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) along with one treatment of traditional border irrigation method ($I_6$) were undertaken. The data regarding different plant, soil and water parameters were periodically recorded during the study.

### Estimation of crop water requirement and irrigation scheduling

Average values of different weather parameters for preceding 10 years were considered for estimating the potential evapotranspiration ($ET_0$) and estimated values are given in Table 58.

Crop evapotranspiration ($ET_C$) values were calculated by multiplying $ET_0$ values by crop coefficient factor ($K_C$). $K_C$ values were taken as 0.35 for first 15 days, 0.75 for next 25 days, 1.15 for next 50 days and 0.45 for remaining days. Based upon the above values, daily irrigation requirement was calculated and the amount of water to be supplied during particular irrigation was calculated by multiplying irrigation interval and daily irrigation requirement. Irrigation intervals were kept at 7 days for the initial period and it was reduced to 4 days subsequently. The total amount of irrigation water applied during the entire season was 314 and 385 mm for drip irrigation and border irrigation, respectively.

### Yield attributes, yield and water productivity

Different parameters like grain yield, straw yield, 1000 grain weight and water productivity were measured and their values under different treatments are given in Table 59.

Table 58. Estimation of Potential Evapotranspiration

| Month | Max Temp (°C) | Min Temp (°C) | Humidity (%) | Wind Speed (km/d) | Sunshine (H) | Daily $ET_0$ (mm) |
|---|---|---|---|---|---|---|
| Nov - 2019 | 35 | 18.9 | 50 | 31 | 9 | 3.13 |
| Dec - 2019 | 28.6 | 13.4 | 48 | 70 | 8.2 | 2.89 |
| Jan - 2020 | 30.9 | 15.3 | 52 | 56 | 8.5 | 3.29 |
| Feb - 2020 | 33.6 | 18 | 46 | 60 | 8.5 | 3.70 |
| Mar - 2020 | 36.4 | 21.2 | 40 | 83 | 8.3 | 5.12 |

Table 59. Yield attributes, yield and water productivity of wheat under different treatments

| Treatment | 1000 grain weight (g) | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Water Productivity, (kg m$^{-3}$) |
|---|---|---|---|---|
| $I_1$ | 40.10$^{ab}$ | 4.42$^{abc}$ | 8.48$^{b}$ | 1.41$^{abc}$ |
| $I_2$ | 39.84$^{ab}$ | 3.89$^{bc}$ | 8.39$^{c}$ | 1.24$^{bc}$ |
| $I_3$ | 42.18$^{ab}$ | 4.6$^{ab}$ | 8.30$^{d}$ | 1.46$^{ab}$ |
| $I_4$ | 42.90$^{a}$ | 4.98$^{a}$ | 8.76$^{a}$ | 1.58$^{a}$ |
| $I_5$ | 38.70$^{b}$ | 3.80$^{c}$ | 8.46$^{bc}$ | 1.21$^{c}$ |
| $I_6$ | 39.11$^{ab}$ | 4.51$^{abc}$ | 8.74$^{a}$ | 1.17$^{c}$ |

Treatment $I_4$ was found to be superior in all aspects i.e. 1000 grain weight, grain yield, straw yield and water productivity. Treatment $I_6$ was statistically at par in case of grain yield, straw yield and 1000 grain weight but it has consumed 23% more water than $I_4$ and has lowest water productivity.

### Salt build up under different treatments

Soil salinity build-up in $I_1$ treatment was at par with $I_6$ treatment even after using 50% saline water. Highest salinity build up was observed in treatment $I_5$ in which ECe was increased by 5.7 dS m$^{-1}$ whereas lowest increase of 1.6 dS m$^{-1}$ observed in $I_4$ treatment. Moreover, depth-wise soil salinity assessment showed significant salinity build-up (almost 1.5 to 2 times higher) in top 0-30 cm soil layer as compared to lower soil layers in drip irrigation whereas salinity build up was uniform across all depths in case of controlled treatment of border irrigation.

### Relationship between $EC_e$ and $EC_2$

Soil samples collected before sowing and after harvesting for two seasons (2018-19 and 2019-20) were analysed for both $EC_e$ and $EC_2$ in order to develop relation between $EC_e$ and $EC_2$. Total 225 samples were analysed and it was found that the $EC_e$ is 2.46 times $EC_2$ and the relation has the coefficient of determination of 0.92.

**Pulpwood-based silvipastoral systems for saline vertisols** (Monika Shukla, Shrvan Kumar, Bisweswar Gorain and Vineeth T.V.)

Field studies were carried out to study the performance of tree seedlings under saline *Vertisols* condition at Samni Research farm, ICAR-CSSRI, RRS. Compared to microplot studies, the performance of tree seedlings under field conditions was poor, expect for *Eucalyptus camaldulensis* and *Acacia mangium*. Under microplot conditions, the survival rate of *Casuarina equisetifolia* was 100 percent under all levels of saline water irrigation (<2, 4, 8 and 12 dS m$^{-1}$) followed by *Leucaena leucocephala, Eucalyptus, Acacia mangium, Melia dubia* and *Dalbergia sissoo*. But under field conditions, *Acacia mangium* performed better followed by *Eucalyptus* and *Leucaena leucocephala*. There was full mortality in *Casuarina equisetifolia, Melia dubia* and *Dalbergia sissoo* under the field conditions (Table 60).

Intercropping of grasses like *Chloris gayana*, *Echinochloa crus-galli* and *Sporobolus marginatus* was planned to intercrop with these trees. Due to prolong waterlogged conditions in field, high mortality and poor growth of trees, forage intercropping was not possible in kharif season, 2020. Also to non-availability of seed/planting material of *Sporobolus marginatus* is there, so fodder Sorghum will be taken in its place. The sowing of the grasses has been planned in the month of February, 2021. Growth parameters of the

Table 60. Survival percentage of plant under nursery and field conditions.

| Species | Nursery (Irrigation water salinity) | | | | Survival under Field condition |
|---|---|---|---|---|---|
| | < 2 dS $m^{-1}$ | 4 dS $m^{-1}$ | 8 dS $m^{-1}$ | 12dS $m^{-1}$ | |
| *Acacia mangium* | 100 | 92 | 92 | 83 | 89 |
| *Eucalyptus camaldulensis* | 100 | 100 | 92 | 75 | 73 |
| *Leucaena leucocephala* | 100 | 100 | 100 | 83 | 20 |
| *Casuarina equisetifolia* | 100 | 100 | 100 | 100 | 0 |
| *Melia dubia* | 83 | 75 | 75 | 58 | 0 |
| *Dalbergia sissoo* | 92 | 75 | 58 | 0 | 0 |

Table 61. Survival, height and diameter at breast height (DBH) of Eucalyptus and Acacia mangium after transplanting.

| Tree species | Tree height (m) | DBH (cm) |
|---|---|---|
| *Eucalyptus camaldulensis* | 7.77 | 12.07 |
| *Acacia mangium* | 4.13 | 9.30 |
| *Leucaena leucocephala* | 1.43 | 2.23 |

Both these species can be recommended for planting in saline Vertisols – *Acacia mangium*, for its better survival rate and *Eucalyptus* for its better biomass production.

trees has been taken and the height of *Eucalyptus* ranged from 7.4 to 8.3 m and for *Acacia mangium*, it ranged from 3.6 to 4.9 m. Diameter at breast height was also higher in *Eucalyptus* (11.8 to 12.4 cm) than in *Acacia mangium* (9.0 to 9.8 cm). Height of *Leucaena leucocephala* ranged from 1.3 to 1.5 m with color diameter (2.1 to 2.3 cm) (Table 61).

**Performance of Indian mustard (*Brassica juncea*) under saline vertisols** (Monika Shukla, Vineeth T.V., Shrvan Kumar and Anil R. Chinchmalatpure)

The choice of crop grown in the bara tract having saline Vertisols is limited to salt tolerant crops only. In the *rabi* season due to non-availability of good quality water, only selected crops can be taken in irrigated condition. Ultimately the diversity of the farm reduced due to limited choice of crop to be grown. Therefore, any possibility for the use of saline water in *rabi* crops will increase the farm diversity and productivity of these areas. Farmers are not taking mustard crop in these areas due to non-availability of suitable varieties and lack of awareness. ICAR-CSSRI has developed six salt-tolerant varieties of Indian mustard, viz., CS52, CS54, CS56, CS58 and CS60, and they may be introduced as a new crop under these areas for improving livelihood of the farmers.

Whenever a new crop introduced in a region, an appropriate package of production practices must be developed. A suitable sowing date is very important aspect for good agronomic performance of any crop. Sowing time is the most vital nonmonetary input to achieve target yields in mustard. Keeping these points in view, the present study has been planned to find out suitable salt tolerant variety and the refinement of package of practices for mustard variety for saline Vertisols of Gujarat. The experiment was planned in Split plot design with three replications. The experimental trial is ongoing at the Samni Farm Bharuch. The details of the treatment are given below:

| A. Main Plot: Mustard Varieties | B. Sub Plot: Date of sowing |
|---|---|
| V1: Mustard CS 56 | D1: 10th October, D2: 20th October |
| V2: Mustard CS 58 | D3: 30th October, D4: 09th November |
| V3: Mustard CS 60 | D5: 19th November, D6: 29th November |

Table 62. Weekly data for maximum and minimum temperature of October and November

| Month | Week No. | Maximum Temperature | Minimum Temperature |
|---|---|---|---|
| **October** | 40 (01\10 to 07\10) | 34.3 | 25.2 |
| | 41 (8\10 to 14\10) | 36.3 | 24.1 |
| | 42 (15\10 to 21\10) | 36.2 | 26.1 |
| | 43 (22\10 to 28\10) | 35.5 | 23.6 |
| **November** | 44 (29\10 to 04\11) | 35.2 | 20.4 |
| | 45 (05\11 to 11\11) | 34.3 | 17.3 |
| | 46 (12\11 to 18\11) | 33.9 | 17.8 |
| | 47 (19\11 to 25\11) | 31.8 | 17.6 |
| **December** | 48 (26\11 to 02\12) | 31.9 | 18.1 |

**Progress of ongoing experiment:**

Due to late withdrawal of the monsoon, the field was not prepared upto 10$^{th}$ of October so this year first sowing of mustard started from 13$^{th}$ October and with 10 days interval sowings were done in 6 different dates upto 2$^{nd}$ December. All three varieties was sown with the spacing of 45 cm X 20 cm and 80:40 kg ha$^{-1}$ N and P has been applied to the crop. Nitrogen 50% as basal and 50% at the time of 1st irrigation has been applied. P has been supplied with SSP so sulphur requirement fulfilled with this. Irrigation has been given at the critical stages and whenever needed to the crop with available saline groundwater. In the initial three dates of sowing the crop was unable to establish due to higher temperature during October and mid of November (The data of the temperature is given in the Table 62) and some unidentified insect attack in the very initial seedling stage. At present only last three date of sown crops has been standing. Data recording for various agro-morphological parameters is going on.

**Effect of crop residues and their incorporation methods on crack management and yield in pigeon pea-wheat cropping system in saline vertisol of Gujarat** (Bisweswar Gorain, Anil R. Chinchmalatpure, Shrvan Kumar and Sagar Vibhute)

An experiment was conducted in a randomized complete block design (RCBD) to study the effect of crop residues *viz.*, sugarcane bagasse and paddy straw and their incorporation methods *viz.*, surface retention and soil incorporation on the cracking behaviour of saline vertisols of Gujarat in a pigeon pea (GJ-301)-wheat (KRL-210) cropping system. The experiment was taken up to address certain issues related to soil hydrology affected by cracks formed by the 2:1 type expanding (swell-shrink) clay minerals *e.g.* higher evaporation of water through cracks causing moisture deficit in soil profile, non-uniform wetting of soil profile, movement of irrigation water below crop root zone due to preferential flow of water through deep cracks and translocation of nutrient rich top soil to the deeper layers. The following treatments were imposed for this study after land preparation and just before sowing pigeon pea seeds: $T_1$: Fallow land (No crop and no residue),$T_2$: Crop (No residue),$T_3$: Paddy straw @5t ha$^{-1}$ surface retention,$T_4$: Paddy straw @5t ha$^{1}$ incorporation,$T_5$: Paddy straw @10t ha$^{1}$ surface retention,$T_6$: Paddy straw @10t ha$^{1}$ incorporation,$T_7$: Sugarcane bagasse @5t ha$^{1}$ surface retention,$T_8$: Sugarcane bagasse @5t ha$^{1}$ incorporation,$T_9$: Sugarcane bagasse @10t ha$^{1}$ surface retention and $T_{10}$:

Sugarcane bagasse @10t $ha^{1}$ surface incorporation. The textural analysis of the soil of experimental site revealed it to be clayey in nature (60% clay content). The field observations showed no significant difference in the crack length in the plots among the treatments. However, significant difference in crack width was observed between $T_{10}$ (0.28 m) and other treatments except $T_5$ (0.28 m) and $T_8$ (0.31 m) which were at par. The crack depth in $T_{10}$ was recorded to be 0.26 m which was at par with $T_5$, $T_7$, $T_8$ and $T_9$ but significantly different from other treatments. The surface area and crack volume in $T_{10}$ was recorded to be 1.63 $m^2$ and 0.23 $m^3$ as compared to 3.9 $m^2$ and 0.35 $m^3$ respectively in fallow plot suggesting ameliorative effect of crop residues on cracking behaviour. The organic carbon content in $T_1$ was 0.45% which was significantly lower than the other treatments due to addition of crop residues as well as leaf litter fall in the latter. The ECe (0-30 cm depth) of the treatments varied from 0.46 dS $m^{-1}$ in $T_5$ (Paddy straw @10t $ha^{1}$ surface retention) to 0.54 dS $m^{-1}$ in $T_1$(Fallow land; devoid of residue). The maximum dry bulk density (BDd) was recorded in $T_1$ (Fallow land) *i.e.* (1.35 g $cc^{1}$) which was significantly higher as compared to $T_6$ (Paddy straw @10t $ha^{1}$ incorporation); which recorded (1.26 g $cc^{1}$) and $T_{10}$ (Sugarcane bagasse @10t $ha^{1}$ surface incorporation) (1.23 g $cc^{1}$). The co-efficient of linear extensibility (COLE) and volumetric shrinkage (VS) values were 0.06 and 0.20 in $T_1$ whereas in $T_{10}$ the values were 0.07 and 0.23, respectively reflecting ameliorative effect of crop residues in development of cracks after 1 year of residue addition.

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

Cotton is an important cash crop globally, and it is increasingly grown on saline agro ecosystems. It is a moderately salt tolerant crop (threshold salinity 7.7 dS $m^{-1}$). Asiatic diploid cotton (*Gossypium herbaceum* and *Gossypium arboreum*) is the preferred candidate in certain highly saline, semiarid *Vertisols* of Gujarat state as compared to *Gossypium hirsutum* and Bt cotton. Nevertheless, there would be considerable decline in the productivity and quality of fiber with increasing soil salinization. Till date, there is no study on stability analysis of Asiatic cotton germplasm on salt affected *Vertisols* and this research gap has been the impetus for this project where a set of genotypes were evaluated under naturally saline *Vertisols*. The primary objective of the project is to identify salt tolerant, high yielding genotypes which are consistent across seasons so that they can be pushed to cotton varietal release pipeline.

About 100 stabilized (F7) *G. arboreum* and 90 stabilized (F8) *G. herbaceum* lines were screened on salt affected field condition ($EC_e$ of 4.93-8.29 dS $m^{-1}$) at experimental farm, Samni, Bharuch, Gujarat. The mean performance of top 20 *G. herbaceum* genotypes in comparison with local and zonal check (G Cot 23) for the last three years including the year 2019-20 is depicted in Table 63. These genotypes were selected on the basis of yield, fiber quality, leaf ion content and visual scoring data of past three years. Among the top 20 genotypes, three genotypes namely, CSC-025, CSC-057 and CSC-021 performed better than the zonal and local check G Cot 23 which showed 23, 7 and 4% yield advantage over the check variety respectively. Moreover, CSC-025 showed a much higher leaf K/Na ratio as compared to the check variety which confirms its improved ion homeostatic mechanism (Table 63).

Table 63. Superior *Gossypium herbaceum* genotypes based on the average performance for three years on salt affected *Vertisols*

| Genotype | SCY (q ha$^{-1}$) | | Yield advantage over LC & ZC (%) | Boll weight (g$^{-1}$) | | K/Na ratio | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **SE** | | **Mean** | **SE** | **mean** | **SE** |
| *CSC-043* | *9.9* | *0.36* | | *47* | *1.20* | *3.6* | *0.59* |
| CSC-047 | 12.2 | 0.20 | | 52 | 0.58 | 2.4 | 0.10 |
| CSC-049 | 11.0 | 1.36 | | 43 | 1.67 | 3.6 | 0.32 |
| CSC-053 | 8.3 | 0.97 | | 45 | 4.04 | 3.6 | 0.59 |
| CSC-057 | 15.8 | 1.40 | **6.73** | 57 | 2.33 | 5.6 | 0.66 |
| CSC-061 | 10.1 | 0.90 | | 44 | 2.33 | 3.2 | 0.42 |
| CSC-065 | 12.0 | 0.52 | | 48 | 2.31 | 3.8 | 0.83 |
| CSC-067 | 13.6 | 0.64 | | 47 | 0.88 | 4.4 | 0.89 |
| CSC-069 | 12.6 | 1.11 | | 38 | 0.58 | 4.4 | 0.97 |
| CSC-001 | 13.0 | 1.08 | | 48 | 1.20 | 5.4 | 0.60 |
| CSC-005 | 13.4 | 1.19 | | 46 | 1.53 | 5.6 | 0.53 |
| CSC-009 | 11.9 | 3.37 | | 49 | 5.51 | 4.3 | 0.19 |
| CSC-013 | 13.7 | 2.27 | | 56 | 4.26 | 4.5 | 0.43 |
| CSC-017 | 13.8 | 1.31 | | 50 | 1.76 | 4.2 | 0.48 |
| CSC-021 | 15.3 | 0.32 | **3.62** | 52 | 1.86 | 4.7 | 1.21 |
| CSC-025 | 18.2* | 0.38 | **22.83** | 60 | 1.45 | 9.6* | 1.16 |
| CSC-029 | 11.8 | 0.29 | | 49 | 1.33 | 4.8 | 0.35 |
| CSC-033 | 12.2 | 0.22 | | 47 | 0.67 | 3.7 | 0.50 |
| CSC-037 | 12.9 | 1.01 | | 47 | 2.96 | 3.5 | 0.32 |
| CSC-039 | 11.2 | 1.72 | | 44 | 4.49 | 4.8 | 0.64 |
| G Cot 23 (LC & ZC) | 14.8 | 1.42 | | 54 | 2.33 | 5.0 | 0.38 |
| | C.D. | 2.66 | | C.D. | 5.87 | C.D. | 1.06 |
| | SE(m) | 0.92 | | SE(m) | 2.04 | SE(m) | 0.37 |
| | SE(d) | 1.31 | | SE(d) | 2.89 | SE(d) | 0.52 |
| | C.V. | 12.61 | | C.V. | 7.27 | C.V. | 14.24 |

LC & ZC- Local check and zonal check; * Significant difference in comparison with LC & ZC at $P < .05$

Moreover, CSC-025 and CSC-057 also displayed better fiber quality as compared to the released check variety. Five genotypes namely, CSC-009, CSC-017, CSC-033, CSC-047 and CSC-061 showed improved fiber quality in terms of all three major quality indices like upper half mean length, uniformity index, micronaire and tenacity compared to the check variety.

Among the 98 *G. arboreum* genotypes, nine genotypes showed superior performance than local (G Cot 19) and zonal check (AKA 7). The genotype AR-90 showed the highest yield advantage (36%) over local and zonal check (Table 64). However, to our surprise, all these nine genotypes showed a lower K/Na ratio in its leaf tissue at boll formation stage which may be attributed to its tissue tolerance nature via. efficient compartmentation to less sensitive cellular organelles, which needs to be further studied (Table 64).

Apart from these stabilized lines, various *G. herbaceum* lines at different stages of their breeding cycle were evaluated on salt affected *Vertisols* and superior performing lines

Table 64. Superior *Gossypium arboreum* genotypes based on seed cotton yield and leaf ion content on salt affected *Vertisols.*

| Genotype | SCY (q ha-1) | Yield advantage over LC (%) | Yield advantage over ZC (%) | K/Na ratio |
|---|---|---|---|---|
| AR-54 | 15.15 | 31.5 | 31.5 | 1.00 |
| AR-64 | 14.13 | 22.7 | 22.7 | 1.85 |
| AR-67 | 14.49 | 25.8 | 25.8 | 0.95 |
| AR-72 | 14.03 | 21.7 | 21.7 | 1.36 |
| AR-74 | 15.39 | 33.6 | 33.6 | 1.09 |
| AR-78 | 13.50 | 17.2 | 17.2 | 0.90 |
| AR-81 | 12.48 | 8.3 | 8.3 | 1.52 |
| AR-89 | 14.49 | 25.8 | 25.8 | 1.17 |
| AR-90 | 15.66 | 35.9 | 35.9 | 1.60 |
| LC (G Cot 19) | 11.52 | - | 0 | 3.45 |
| ZC (AKA 7) | 11.52 | 0 | - | 1.06 |

*SCY-Seed cotton yield (quintal per hectare); LC-Local check; ZC-Zonal check

and individual plants (segregating $F_2$ population) were harvested separately and advanced. The Br 32b All India Coordinated Cotton Improvement trial for *herbaceum* cotton was also successfully carried out.

In the current season (2020-21), the same set of *G. herbaceum* and *G. arboreum* genotypes along with 12 other genotypes (total: 32 genotypes) are raised on normal, medium salt affected and highly salt affected fields in replicates for a holistic, comparative understanding of ionic, osmotic and oxidative modules of salt stress tolerance in these genotypes. The major limitation of the study is the absence of a separate All India coordinated trial for salt tolerance in cotton both at AICRP and Gujarat state level. This is a major obstacle in evaluating our superior desi cotton genotypes across multi environments, which is a prerequisite to release as crop variety.

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

In recent years, increasing industrialization, urbanization and developmental activities with the population explosion lead to generation of large amount of waste water from domestic, commercial, industrial and other sources. Industrial waste waters get directly discharged in to river, lake, nallas, and khadi and created new pollution problem. Industrial pollution is found in large amount in certain areas like, Surat, Vapi and Ankleshwar of Gujarat. 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.

### Monitoring of variations in salinity, pH and groundwater depth

Spatial and temporal variation of water salinity, pH and groundwater depth was monitored in the constructed recharge structures. Water salinity and pH in 100 tubewells in the study area also monitored. Date (Table 65) revealed that the maximum salinity of groundwater was 7.4 dS $m^{-1}$ and minimum was 0.19 dS $m^{-1}$. Similarly pH raged from 6.83 to 9.5 in water samples collected form 100 tubewells in the study area. The salinity and pH

Table 65. Mean EC and pH of ground water samples (100 nos) from study sites

| | EC (dS $m^{-1}$) | pH |
|---|---|---|
| Max | 7.40 | 9.50 |
| Min | 0.19 | 6.83 |
| Mean | 2.41 | 8.11 |
| SD | 1.77 | 0.65 |

Table 66. Ground water EC, pH and depth of recharge wells at study sites

| Village Name | EC (dS $m^{-1}$) | pH | Depth |
|---|---|---|---|
| Sakkarpur | 0.63 | 9.06 | 1.9 m |
| Kapodra | 0.51 | 8.12 | 2.3 m |
| Panoli | 1.6 | 7.96 | 1.5 m |
| Boidra | 3.6 | 7.21 | 1.5 m |

of the groundwater in the four recharged structures were 0.5 to 3.6 dS $m^{-1}$ and 7.2 to 9.1, respectively. The groundwater depth ranged from 1.5 to 2.3 m during the year (Table 66).

### Heavy metal content in groundwater

In pre-monsoon season (PRM), heavy metals like Cd (49 % of sampled sites), Co (43 %), Ni (31 %), Cr (27 %) and Mn (19 %) in groundwater were beyond desirable limit for irrigation purpose whereas in post-monsoon season (POM) only Cd (59 %) exceeded the limit. Heavy metal pollution index (HPI), is a rating method and an effective tool to assess the water quality with respect to heavy metals. HPI was calculated separately for each sampling sites in order to compare the heavy metal pollution load and seasonal variations in each selected sites. The HPI values were in the range of 59.3 to 1035.6 (mean 537.2) and 4.1 to 574.7 (mean 359.5) in the PRM and POM seasons, respectively. There was marked reduction in HPI values from PRM season to POM season at all the sampling sites (Fig. 58). High HPI values in the PRM season resulted from large number of industries coupled with indiscriminate disposal of not-so-well-treated effluents into the water flows. Low HPI values in the POM season are attributable to the dilution of heavy metals contained in the groundwater caused by rainfall. It is a significant finding that 82 % of sites in PRM season and 68 % of sites in POM season had HPI values above the critical value (100). Out of 40 villages surveyed in the study area, 31 were affected by heavy metal contamination. Pre-monsoon analysis showed that 22 villages were affected by cadmium, 24 by cobalt, 18 by nickel, 15 by chromium and 11by manganese. The total area under study was 590 sq. km. The area under cobalt which exceeded the recommended maximum concentration (mg $l^{-1}$) in irrigation water was 321 sq.km followed by cadmium in 270 sq.km, chromium in 51 sq.km, manganese in 30 sq.km and nickel in 23.5 sq.km.

### Risk prevention– entry into food chain

Efforts were made to reduce the uptake of heavy metals in commonly grown vegetable, Spinach (Palak) in the industrially dominant district of Bharuch, Gujarat to reduce its entry into the food chain. Combination of 1% Tourmaline and 2% vermicompost reduced accumulation of Cd in shoot and translocation from root to shoots in spinach whereas 1% tourmaline with 3% vermicompost reduced accumulation of heavy metals like Co, Cr, Cu and Fe in shoot and its translocation. Use of tourmaline along with rhizobacteria reduced both accumulation and translocation factor for Mn, Pb and among the crops, spinach had generally very high transfer factors, indicating that cultivation of this species, along with

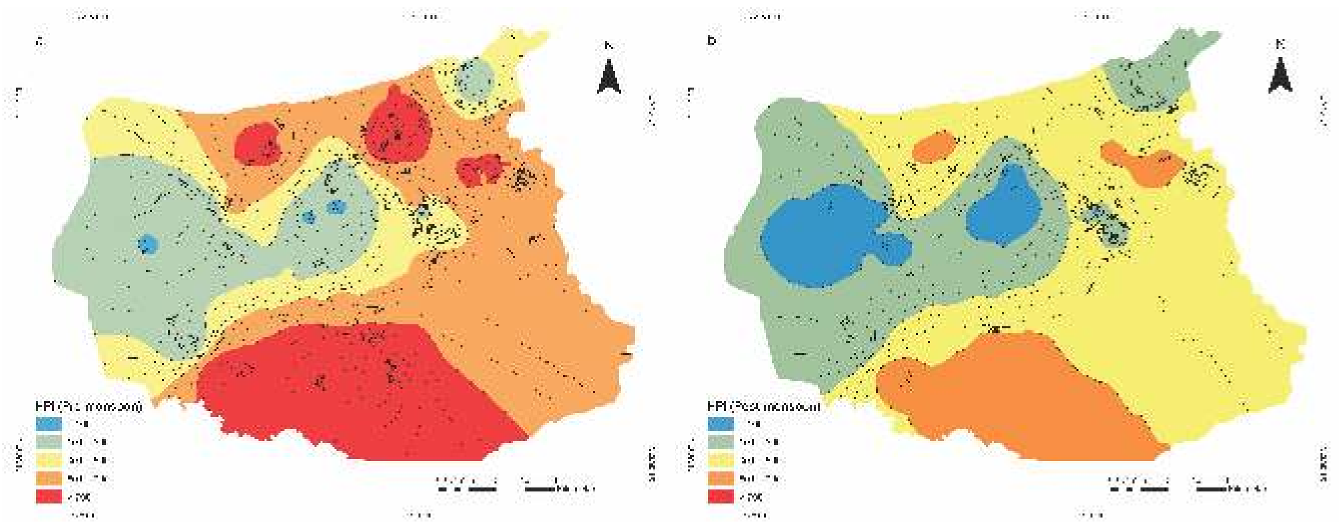


Fig 58. Map of Heavy metal pollution Index (a. PRM and b POM)

other leaf vegetables like lettuce, should be avoided on contaminated areas. Species with low translocation factor can be recommended for cropping. Heavy metal excluding crops like beans, potatoes or cereals should be preferred. Water management practices like use of drip irrigation for irrigating crops can reduce the quantity of irrigation water amount and thereby help in reducing the uptake of heavy metals by plants.

### Dilution through recharge structures

Groundwater recharge structures were installed in four villages viz. Kapodra, Boidra, Panoli and Sakkarpur in Bharuch district to study its viability in reducing the concentration of contaminants in groundwater. The heavy metal concentration was observed up to 57% lower concentration in recharged areas. Bharuch district having a rainfall of 800 to 900 mm, rain water harvesting in farm ponds can also be an option on a large scale.

### Effect of treated effluent from Aniline-ETP Plant of GNFC Unit II on growth and yield of Isabgol *(Plantago ovata* Forsk.*)* and properties of vertisols (Anil R. Chinchmalatpure, Sharvan Kumar, Sagar Vibhute, Bisweswar Gorain and P.C. Sharma)

Senna crop under treated effluent irrigation treatment

The Aniline-TDI plant of Gujarat Narmada Valley Fertilizer and Chemicals Ltd, Bharuch (GNFC Unit-II) primarily deals with the manufacturing of Toluene diisocyanate and Aniline. It has established a well-developed effluent treatment plant which produces about 500 $M^3$ of treated effluent from their Aniline unit. The analytical report of the treated effluent indicated that the effluents produced are less toxic as their chemical constituents are within acceptable limits. In order to understand the feasibility of using these effluents in this crop and their impact on soil properties, salinity development and crop production and produce quality over a long run, field trials were initiated to assess the suitability of the treated effluents.

Field experiment was initiated with the medicinal crop Isabgol and sowing was done in the month of December 2019 and good germination was established but because of menace of peacock in the premise of GNFC-Unit-II, shoots emerged from the plumule of isabgol seed, was eaten by the peacock and the entire shoots of Isabgol crop in the experimental plots were destroyed and hence we replaced the crop with another medicinal plant, Senna (*Cassia angustifolia*) and sowing of the crop was done on dated 07-

02-2020. The experiment was conducted with the application of nitrogen through urea and irrigation using treated effluent in factorial design with three replications. The treatments comprises of ($I_1$) best available water (BAW) as such *i.e.* effluent: BAW in 0:1 ratio; ($I_2$) effluent and BAW in 1:1 ratio; and ($I_3$) effluent as such i.e. effluent: BAW in 1:0 ratio with combination of four nitrogen levels doses ($N_1$= 0 kg N $ha^{-1}$; $N_2$= 40 kg N $ha^{-1}$, $N_3$=60 kg N $ha^{-1}$ and N4=80 kgN $ha^{-1}$). Soil samples analyzed for pHs and ECe from the experimental field at different depths (0-15, 15-30, 30-90, 90-120 cm). Soil pH values were ranged from 6.8-7.2, 6.6-7.3 and 6.7-7.4 for $I_1$, $I_2$ and $I_3$ treatments, respectively with mean values of 7.0, 7.0 and 7.1. Similarly ECe values ranged from 1.0-1.9 dS $m^{-1}$, 1.3 to 4.6 dS $m^{-1}$ and 0.9 to 4.1 dS $m^{-1}$, respectively for $I_1$, $I_2$ and $I_3$ treatments with mean values of 1.5 dS $m^{-1}$, 2.7 dS $m^{-1}$ and 2.4 dS $m^{-1}$. In $I_2$ and $I_3$ treatments, surface soil were having slightly higher electrical conductivity values (> 4.0 dS $m^{-1}$), while $I_1$ having lower values at surface layer.

The growth parameters like plant height, no of branches, fresh shoot and dry shoot weight were collected treatment wise and analyzed statistically but for shake of brevity data is not given. The data analysis for fresh leaf and dry leaf weight (Table 67) and yield of senna (Table 68) showed that the $I_3$ treatment showed higher yield and also other yield and growth parameters followed by $I_2$ treated plot. Treated effluent application has resulted in highest growth of Senna crop as compared to BAW suggesting the possibility of using the treated effluent as such for maximizing the yield which may be due to nutrient availability from the treated effluent. In case of nitrogen fertilizer application, the highest growth parameters and yield was found highest in case of 60 kg N $ha^{-1}$. Similarly the interaction effect of treated effluent irrigation with 60 kg N $ha^{-1}$ application has found beneficial which suggest that effluent is contributing to the nutrient requirement of the crop.

Table 67. Effect of treated effluent irrigation with nitrogen fertilizer on leaves of Senna crop

| **Treatments** | **Fresh leaf wt (g/plant)** | | | | | **Dry leaf wt (g/plant)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **$N_1$** | **$N_2$** | **$N_3$** | **$N_4$** | **Mean** | **$N_1$** | **$N_2$** | **$N_3$** | **$N_4$** | **Mean** |
| **$I_1$** | 23.88 | 24.13 | 25.99 | 25.52 | 24.88b | 11.19 | 12.16 | 12.96 | 12.58 | 12.22b |
| **$I_2$** | 24.7 | 26.1 | 32.0 | 28.1 | 27.7b | 11.6 | 12.7 | 15.5 | 14.8 | 13.6b |
| **$I_3$** | 35.3 | 36.5 | 39.4 | 37.8 | **37.3a** | 14.5 | 16.1 | 17.5 | 16.7 | **16.2a** |
| **Mean** | 27.96 | 28.91 | 32.46 | 30.47 | | 12.43b | 13.65ab | 15.32a | 14.69a | |
| | **LSD (0.05)** | | | | | **LSD (0.05)** | | | | |
| **Irrigation** | 4.14 | | | | | 2.33 | | | | |
| **Nutrient** | NS | | | | | NS | | | | |

Table 68. Effect of treated effluent irrigation with nitrogen fertilizer on seed yield of Senna crop

| **Treatments** | **Seed yield (g/plot)** | | | | | **Seed yield (q $ha^{-1}$)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **$N_1$** | **$N_2$** | **$N_3$** | **$N_4$** | **Mean** | **$N_1$** | **$N_2$** | **$N_3$** | **$N_4$** | **Mean** |
| **$I_1$** | 634.0 | 652.0 | 708.33 | 669.67 | 666.0c | 8.80 | 9.056 | 9.84 | 9.30 | 9.25c |
| **$I_2$** | 699.0 | 788.0 | 822.0 | 818.0 | 781.8b | 9.71 | 10.94 | 11.42 | 11.36 | 10.86b |
| **$I_3$** | 780.7 | 867.3 | 1078.0 | 879.0 | **901.3a** | 10.84 | 12.05 | 14.97 | 12.21 | **12.52a** |
| **Mean** | 704.56c | 769.11b | **869.44a** | 788.89b | | 9.79c | 10.68bc | 12.08a | 10.96b | |
| | **LSD (0.05)** | | | | | **LSD (0.05)** | | | | |
| Irrigation | 47.16 | | | | | 0.65 | | | | |
| Nutrient | 65.71 | | | | | 0.91 | | | | |

# Reclamation and Management of Coastal Saline Soils

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

The reclamation of saline soils involves basically the removal of salts from the saline soil through the processes of leaching with water and drainage. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (Sunhemp, Daincha, Kolingi) and or green leaf manuring also counteracts the effects of salinity. An experiment was conducted in an Inceptisol of Central Soil Salinity Research Institute, Canning Town research farm. The soil is clayey (16% sand, 30% silt and 54% clay). Four ameliorants namely poultry manure, farm yard manure (FYM), Acacia leaf and tank silt were used ($M_1$, $M_2$, $M_3$ & $M_4$). The design of the experiment was split plot with three replications where the ameliorants were put in the main plots and doses in the subplots. The doses were 2, 4, 6, 8, 10 and 12t $ha^{-1}$ ($T_1$, $T_2$, $T_3$, $T_4$, $T_5$ and $T_6$, respectively) on the basis of moist weight. The ameliorants were added in the plots and well mixed at 0-15 cm soil layer before onset of monsoon (February-March, 2020). The field was left undisturbed for near one year so that the ameliorants were well decomposed. Soil samples were collected from 0-15 cm without disturbing *in situ* soil conditions for determining bulk density. The saturated hydraulic, particles sizes, soil organic carbon, soil EC and soil pH (1:2 soil: water suspension) were also determined.

### Soil bulk density and hydraulic conductivity

Soil bulk density was found higher for the control, 1.43 $Mgm^{-3}$ soil than for all other amendment treatments were applied, averages of 1.36 (Table 69). Some differences in soil bulk density among amendment treatments were measured, for example, soil bulk density was higher for the green leaf manure treatment (1.42 $Mgm^{-3}$) than poultry manure treatment (1.28 $Mgm^{-3}$). There was a decrease in soil bulk density with the increase in amount of doses, 1.30 $Mgm^{-3}$ for 12 t $ha^{-1}$ amendments. Whereas, the value was 1.43 $Mgm^{-3}$ for 2 t $ha^{-1}$ amendment used. Changes in saturated hydraulic conductivity were also dependent on the treatment and doses (Table 69 and 70). The hydraulic conductivity values were little higher for FYM and poultry manure treatment (4.9-5.1 $cmh^{-1}$) than to green leaf manure and tank silt treatments (3.8-4.9 $cmh^{-1}$) for the soil. The saturated

Table 69. Effect of different ameliorants on soil bulk density and hydraulic conductivity

| Dose | B.D. (Mg $m^{-3}$) | H.C. (cm $h^{-1}$) |
|---|---|---|
| $T_1$ (2 t $ha^{-1}$) | 1.43 | 1.2 |
| $T_2$ (4 t $ha^{-1}$) | 1.40 | 2.0 |
| $T_3$ (6 t $ha^{-1}$) | 1.38 | 3.5 |
| $T_4$ (8 t $ha^{-1}$) | 1.34 | 4.6 |
| $T_5$ (10 t $ha^{-1}$) | 1.30 | 5.2 |
| $T_6$ (12 t $ha^{-1}$) | 1.30 | 5.5 |
| C.D. (p=0.05) | 0.15 | 1.28 |
| Interaction ameliorant X dose | ns | s |

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

Table 70. Effect of different ameliorant doses on soil bulk density and hydraulic conductivity

| Ameliorants* | B.D. (Mg $m^{-3}$) | H.C. (cm $h^{-1}$) |
|---|---|---|
| $M_1$ | 1.38 | 4.9 |
| $M_2$ | 1.42 | 3.8 |
| $M_3$ | 1.37 | 4.9 |
| $M_4$ | 1.28 | 5.1 |
| C.D. (p=0.05) | ns | ns |

*ns: non-significant*

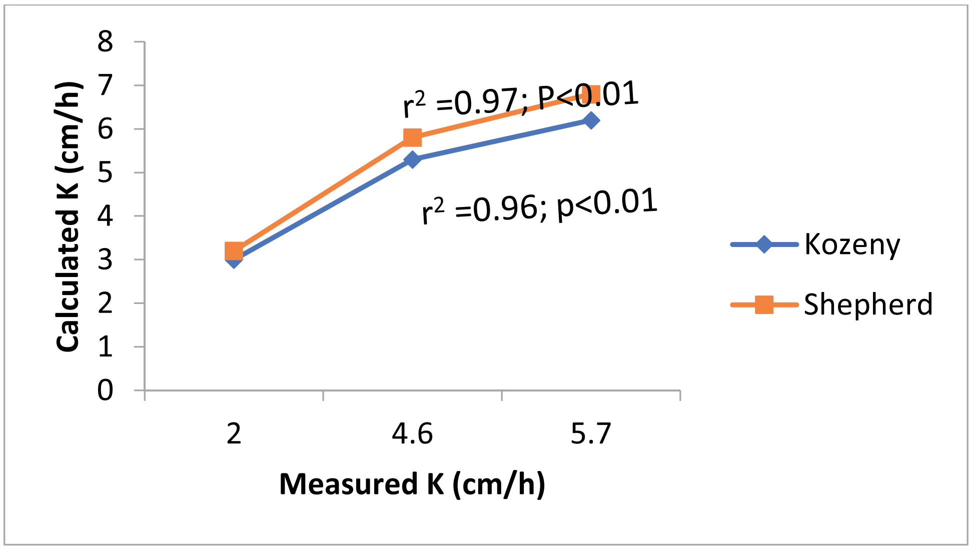
hydraulic conductivity was increased from 1.2 to 5.5 $cmh^{-1}$ when the doses increased from 2 to 12 t $ha^{-1}$. The use of different ameliorants did not bring about significant change in soil parameters like bulk density (B.D.) (avg. 1.36 $Mgm^{-3}$) and saturated hydraulic conductivity (H.C.) (4.7 $cmh^{-1}$) (Table 69). However, saturated HC for different plots treated with different doses of ameliorants differ significantly (C.D. $t_{0.05}$= 1.28 for the treated soil) (Table 70). The interaction effects of ameliorants and doses were also significant in bringing significant change in saturated hydraulic conductivity of soil.

The relationship between measured and calculated hydraulic conductivities using Kozeny-Carman equation was significant ($r^2$=0.96, p<0.01) (Fig. 59).

But the calculated values were slightly higher than measured values. Hydraulic conductivity values determined from Shepherd's equation were relatively higher than those that were measured in the laboratory using Kozeny-Carman equation. The relationship between the calculated (Shepherd's equation) and measured hydraulic conductivities was also significant ($r^2$ = 0.98 for soil) (Fig. 59). Correlation between percentage organic C and hydraulic conductivity of the soil was +0.62.

The EC (1:2 soil: water suspension) values of the soil varies from 3.1 to 2.3 dS $m^{-1}$ in the 2 t $ha^{-1}$ and 12 t $ha^{-1}$ FYM treated plots, respectively whereas the values varied from 3.0 to 1.8 dS $m^{-1}$ in the 2 t $ha^{-1}$ and 12 t $ha^{-1}$ green leaf manure treated plots. In general, with increase in ameliorant doses there was a decrease in EC values of soils.

Fig 59. Relation between calculated and measured hydraulic conductivities



## Evaluation of pressurized irrigation system for *rabi* rice in coastal salt affected soil

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

Rice is the staple food for rural people of coastal West Bengal and also the predominant crop in the coastal areas in both *kharif* and *rabi* seasons. Rice productivity here is low during *kharif* season as fields are submerged with excess runoff water and give little chance for water management and input applications. With the objective of improving productivity with less water, the experiment is carried out for drip irrigated aerated rice at CSSRI, RRS, Canning Town farm.

In the experiment, rice (var. DRR Dhan 44) an early duration, drought tolerant, high yielding and long slender grain variety suited both for transplanted and direct seeded aerobic cultivation with good weed competitive ability was taken as the test crop. The field was prepared by three ploughings with power tiller and leveling. As lateral to lateral spacing was 0.75 m and paddy is a closed spacing crop, the existing drip irrigation system was modified to make rice row to row spacing of about 15 cm. Seed sowing was done on 29.01.2020 both for DSR and Conventional experiment. The germination and growth was slow this year as winter was colder in comparison to the average temperature especially in DSR condition. The transplanting was done on 24$^{th}$ February, 2020. The ECe & pH of the soil obtained at the start of experimentation are given in Table 71. There was total four sub-plots. Treatments such as T1: Plastic mulch, T2: Straw mulch and T3: Control were given in each sub-plot. The plot size for the transplanted rice was 2.6m x 11 m, replicated thrice. The source of water was ground water of tubewell with depth of around 250 m. The salinity of ground water was 1.4 dS m$^{-1}$.

Table 71. ECe (dS m$^{-1}$) and pH of the soil in the root zone at start of cropping.

| Plot | Depth (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 0-20 | | 20-40 | | 40-60 | |
| | ECe (dS m$^{-1}$) | pH | ECe (dS m$^{-1}$) | pH | ECe (dS m$^{-1}$) | pH |
| 1 | 1.91 | 6.91 | 2.17 | 7.12 | 2.84 | 7.19 |
| 2 | 2.15 | 7.23 | 2.43 | 6.95 | 2.97 | 7.03 |
| 3 | 2.39 | 7.12 | 2.65 | 7.34 | 3.18 | 7.12 |
| 4 | 2.82 | 7.30 | 3.12 | 7.05 | 3.75 | 7.33 |

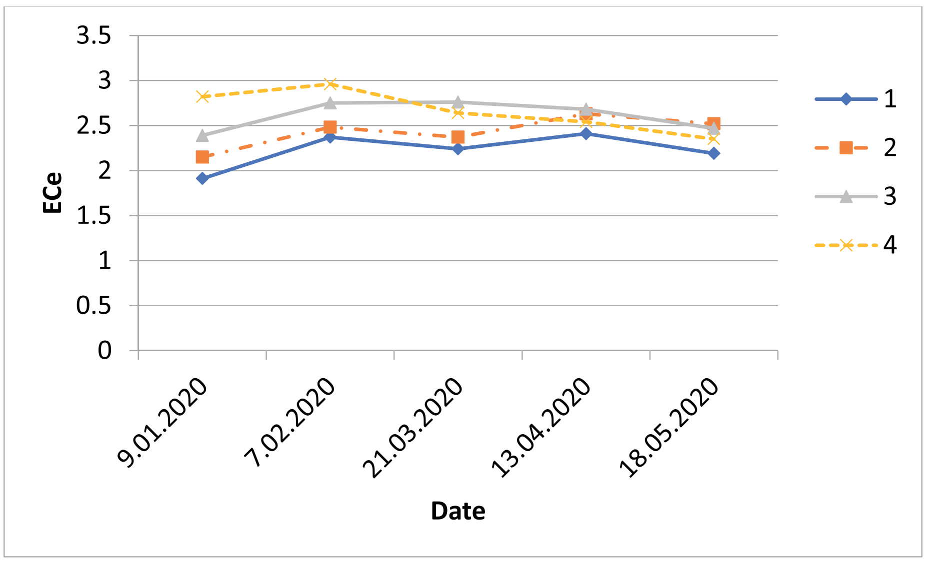



Fig 60. Relation between calculated and measured hydraulic conductivities

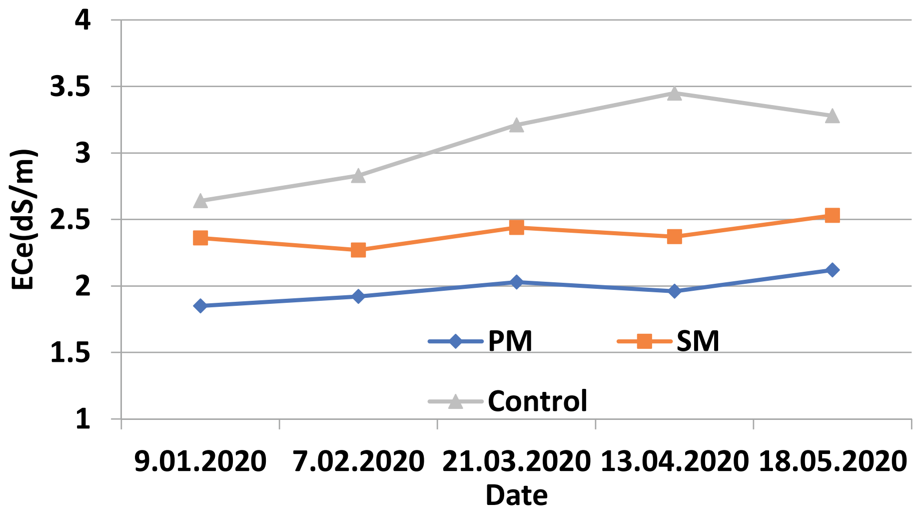



Fig 61. The soil salinity in the top layer(0~15 cm) under mulching conditions

Table 72. Comparison between transplanted and drip irrigated rice

| Item | Transplanted rice | Drip rice |
|---|---|---|
| Height(cm) | 126.56 | 76.43 |
| Tiller nos. | 14.11 | 8.26 |
| EBT | 13.88 | 7.25 |
| Root length(cm) | 20-30 | 10-17 |
| Yield (t ha-1) | 2.1 | 1.45 |
| Irrigation(cm) | 105 | 73 |

The soil salinity in the top layer (0~20 cm) for drip irrigated rice was within the range 2~3.5 dS $m^{-1}$ (Fig. 60). In transplanted rice plot, the soil salinity was below 3 throughout the cropping period. Post emergence herbicide Granite (Penoxsulam) was effective for controlling the weeds.

Growth of rice plants, flowering and fruiting were earlier in case of transplanted condition than aerated condition. Physiologically transplanted rice was superior for both root and shoot (Table 72).

The salinity in the plastic mulched condition was lowest in comparison to straw mulched and control conditions in DSR (Fig. 61). The amount of water required for aerated rice was about 31% less than transplanted rice (Table 72). The effects due to the imposition of treatments in the aerated rice were not noticeable. The growth and yield of rice under transplanted condition observed superior to aerated rice under drip irrigation. Due to the Cyclone Amphan on 20$^{th}$ May, 2020, there was loss in yield for both transplanted as well as drip irrigated rice. Hence, potential yield was not obtained for both conditions.

**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)

This research project was carried out 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 Sndarbans regions were collected during summer (March-June), *kharif* and *rabi* seasons. Different

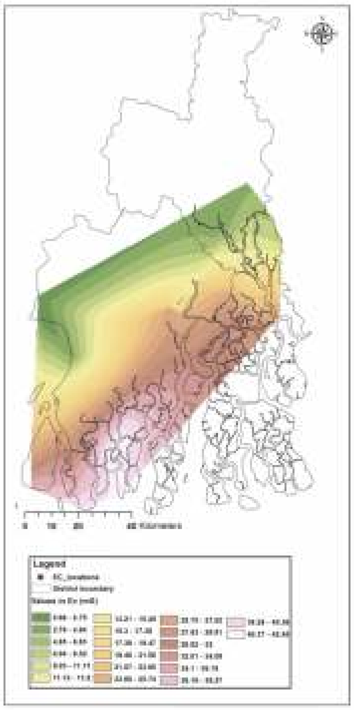


Fig 62. Surface water sanity map of Sundarbans during rabi season

water quality parameters like $EC_w$, pH, $Ca^{++}$, $Mg^{++}$, $Na^+$, $K^+$, $Cl^-$ and $SO_4^-$ were analyzed. The water quality parameters varied with locations, seasons and source. The surface salinity maps for *rabi* season was prepared using natural neighbor interpolation method (Fig. 62). The salinity of water was higher in the South and South-Eastern part of Sundarbans during *rabi* season. The spatial variation in water salinity for other seasons also followed the similar trend. In general salinity of surface water was lower during *kharif* season followed by *rabi* and summer seasons. However, salinity of river water at few locations in the Southern part of Sundarbans was higher compared to summer season. This could be due to more ingress of saline water from the sea and less received of rainfall during *rabi* season. Salinity of surface water varied from 1.41 - 34.56 $dSm^{-1}$, 0.34 to 30.60 $dSm^{-1}$ and 0.62 – 42.70 $dSm^{-1}$ during summer, *kharif* and *rabi* seasons, respectively. The spatio-temporal variation of other water quality parameters also followed the similar trend. The water quality of Hooghly river and drainage channel was found suitable for irrigation during all the seasons.

**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)

Rice (*Oryza sativa*) based cropping in the Asian region has been considered as one of the most significant agricultural practices that contribute to climate change due to high energy intensity and large carbon footprints (CF). To assess the contributions of rice-based cropping in lowland coastal ecosystems to environmental change, energy budgets, CF, exchange of $CO_2$ and fluxes of non-$CO_2$ greenhouse gases (GHGs) like $CH_4$ and $N_2O$ were determined for an array of conservation tillage based management. Static chamber gas chromatography-based methodology along with biometric data collection was used in a long-term field experiment following split-split plot design. The main plot treatment consisted of cropping system [rice-rice (RR) and rice-cotton (*Gossypium hirsutum*) (RC)], sub-plot treatment was tillage intensity [zero tillage (ZT), reduced tillage (RT), conventional tillage (CT)], and residue application [residue (R) and no residue (NR)] were considered as sub-sub plot treatments.A peak of $N_2O$ emissions were recorded as and when N-fertilizer (urea and DAP) was applied to the field. The peak value of $N_2O$ emission appears generally 3-4 days after the application of N fertilizer in case of NR whereas it took 6-7 days for R plots. The field with NR have more $N_2O$ emissions than R. The $N_2O$ emission from the cotton field was higher than rabi rice grown in the same season. $N_2O$ fluxes during kharif rice crop growth ranged from 0.42 to 0.61% of applied N fertilizer (@60 kg $ha^{-1}$); for rabi rice and cotton $N_2O$ fluxes varied from 0.47 to 0.72% and 0.91 to 1.27% of applied N (@120kg $ha^{-1}$). ZT recorded 7% and 12% less $N_2O$ emission than RT and CT; no significant difference in $N_2O$ between R and NR plots except in ZT where residue application reduced 38% $N_2O$ emission than NR plots (Table 73). $CH_4$ fluxes increased after rice transplanting reached its peak value near panicle differentiation. $CH_4$ flux was negligible for cotton except in few incidences when there was unseasonal rainfall.Overall zero tillage produced more $CH_4$ than RT and CT and also application of residue produced more $CH_4$ than no residue plots. We examined the diurnal and seasonal net ecosystem $CO_2$ fluxes pattern in rice-rice and rice-cotton systems and the mean daily NEE varied from 1.03 to -33.26 g $CO_2$ $m^{-2}$ per day for kharif rice whereas for rabi rice and cotton, NEE varied from 1.39 to -30.65 g $m^{-2}$ per day and 2.12 to -17.83 g $m^{-2}$ per day, respectively (Fig. 63). Most of the NEE values during

Greenhouse gas collection from rice field

Table 73. N2O, CH4, net ecosystem exchange of CO2 (NEE) and night CO2 flux or ecosystem respiration during kharif, rabi crop growing season and on annual basis under different tillage and residue treatments in rice-rice (RR) and rice-cotton (RC) systems (± standard error from mean, n = 3).

| Treat ment | $N_2O$ (kg ha$^{-1}$) emissions | | | $CH_4$ (kg ha$^{-1}$) emissions | | | NEE (kg ha$^{-1}$) | | | Night $CO_2$ flux or ecosystem respiration (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kharif | Rabi | Annual | Kharif | Rabi | Annual | Kharif | rabi | Annual | kharif | rabi | Annual |
| RR-ZTR | 0.253 ±0.021 | 0.569 ±0.045 | 0.910 ±0.071 | 155.6 ±7.33 | 121.8 ±5.45 | 277.5 ±14.6 | -15407.0 ±414.3 | -10634.7 ±311.6 | -23937.2 ±870.9 | 2250.5 ±122.4 | 1800.4 ±90.7 | 5489.2 ±224.7 |
| RR-ZTNR | 0.362 ±0.027 | 0.863 ±0.068 | 1.356 ±0.103 | 120.6 ±6.24 | 91.3 ±5.03 | 211.9 ±11.7 | -14193.6 ±367.2 | -9924.7 ±297.8 | -22651.7 ±812.4 | 1972.3 ±109.3 | 1552.1 ±77.4 | 4612.7 ±210.6 |
| RR-RTR | 0.306 ±0.024 | 0.821 ±0.066 | 1.214 ±0.093 | 140.1 ±6.82 | 127.0 ±6.17 | 267.1 ±14.1 | -16712.1 ±464.2 | -11915.7 ±351.8 | -26765.2 ±946.1 | 2523.9 ±142.5 | 2538.6 ±124.6 | 6484.5 ±311.2 |
| RR-RTNR | 0.309 ±0.024 | 0.858 ±0.068 | 1.253 ±0.096 | 109.5 ±5.11 | 96.2 ±4.71 | 205.8 ±11.3 | -15555.8 ±422.1 | -11285.2 ±336.5 | -25313.1 ±908.5 | 2194.1 ±123.4 | 2225.8 ±104.5 | 5736.5 ±246.5 |
| RR-CTR | 0.312 ±0.025 | 0.687 ±0.055 | 1.258 ±0.096 | 132.9 ±6.43 | 101.3 ±5.03 | 234.1 ±12.2 | -16854.3 ±471.3 | -11305.3 ±371 | -24915.4 ±872.5 | 3077.4 ±162.4 | 2206.4 ±103.9 | 7562.2 ±402.3 |
| RR-CTNR | 0.317 ±0.025 | 0.744 ±0.058 | 1.306 ±0.096 | 103.0 ±4.87 | 74.4 ±4.36 | 177.4 ±10.3 | -15632.8 ±425.3 | -10576.8 ±304.2 | -23624.4 ±852.6 | 2615.6 ±151.4 | 1957.1 ±96.8 | 6476.0 ±372.5 |
| RC-ZTR | 0.300 ±0.024 | 1.090 ±0.088 | 1.498 ±0.098 | 149.1 ±7.23 | 6.64 ±0.48 | 155.8 ±9.4 | -15106.1 ±404.8 | -3030.6 ±112.4 | -16490.6 ±776.8 | 2237.9 ±96.7 | 4118.3 ±182.6 | 7196.6 ±379.4 |
| RC-ZTNR | 0.364 ±0.027 | 1.520 ±0.112 | 1.966 ±0.11 | 118.8 ±5.04 | 4.58 ±0.42 | 123.4 ±7.4 | -13640.9 ±345.8 | -1045.4 ±46.5 | -13601.7 ±708.1 | 2018.2 ±94.7 | 3499.7 ±165.7 | 6166.0 ±344.1 |
| RC-RTR | 0.332 ±0.0224 | 1.302 ±0.101 | 1.808 ±0.13 | 137.2 ±6.66 | 4.79 ±0.46 | 141.9 ±8.2 | -16222.6 ±466.3 | -7330.9 ±272.4 | -21584.3 ±841.8 | 2651.2 ±107.5 | 5884.3 ±261.3 | 9840.6 ±422.5 |
| RC-RTNR | 0.345 ±0.025 | 1.324 ±0.102 | 1.842 ±0.13 | 111.7 ±5.17 | 4.61 ±0.41 | 116.4 ±6.7 | -15221.2 ±409.1 | -6053.2 ±212.3 | -19566.4 ±807.9 | 2399.4 ±100.7 | 4895.5 ±237.4 | 8419.0 ±407.9 |
| RC-CTR | 0.325 ±0.024 | 1.366 ±0.102 | 1.907 ±0.15 | 126.0 ±6.47 | 4.45 ±0.38 | 130.5 ±7.1 | -16613.1 ±426.7 | -7792.0 ±287.1 | -21589.6 ±861.7 | 3392.4 ±137.2 | 5977.6 ±271.3 | 10955.8 ±511.3 |
| RC-CTNR | 0.348 1.374 | ±0.026 ±0.108 | 1.915 ±0.15 | 96.5 ±5.03 | 4.35 ±0.39 | 100.8 ±5.3 | -15277.4 ±411.7 | -6866.7 ±244.5 | -19508.9 ±833.2 | 3043.7 ±128.4 | 5099.5 ±245.1 | 9549.9 ±496.3 |

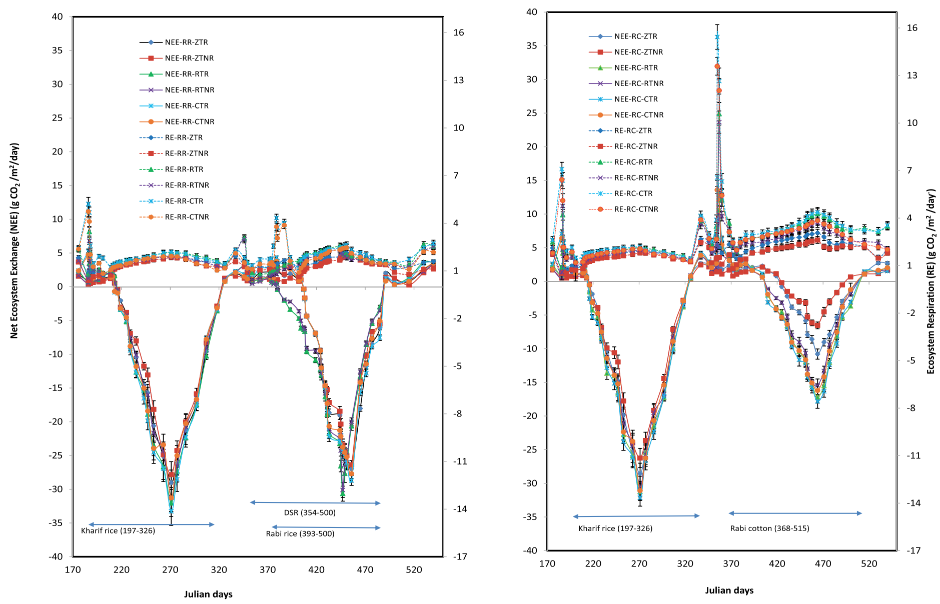



Fig 63. Daily mean net ecosystem exchange of $CO_2$ (NEE) and ecosystem respiration (RE) from under different tillage and residue treatments in rice-rice (RR) and rice-cotton (RC) systems. Error bars represent standard errors; n =3).

daytime were negative and positive during the night, indicating that the flooded rice ecosystem acted as a sink for $CO_2$ during the day and $CO_2$ source during the night. Same diurnal trend was also found for cotton crop. The cumulative annual NEE varied from -22.7 to -26.8 Mg $ha^{-1}yr^{-1}$ and -13.6 to -21.6 Mg $ha^{-1}yr^{-1}$ for rice-rice and rice-cotton system. NEE were higher during warm kharif seasons (-13.6 to -16.9 Mg $ha^{-1}$ for kharif rice) and lower during cooler rabi seasons (-9.9 to -11.9 Mg $ha^{-1}$ for rabi rice) (Table 73).

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

Soil salinity is a major constraint for cropping during dry season in coastal areas. However, dry-season cropping is attractive to many farmers with access to irrigation. Farmers in these areas with access to ground water irrigation grow *boro* rice, but with high input of irrigation water (>130cm) and low irrigation water productivity. In the coastal areas of India, rainfall is much higher than PET during the monsoon, when rice is the major crop, producing huge amount of paddy straw as well as carry over soil moisture for the subsequent crop. However, due to excess moisture after harvesting of rice, tillage is difficult under conventional practice, therefore, the establishment of rabi crops are delayed. Further, due to soil salinity development the crop performance is severely affected. Conventional tillage practice also needs higher irrigation water input for growing crops under saline soil. Keeping these facts in view, this research project was started from the kharif season of 2020. Rice variety Swarna-Sub 1 was sown in the nursery on 22.07.2020, transplanted on 28.08.2020 and the rice crop was harvested on 23.11.2020. The performance of kharif rice crop is given in Table 74.

Rabi crops (potato, mustard and garlic) under the experiment on conservation agriculture at Canning Town (2020-21)

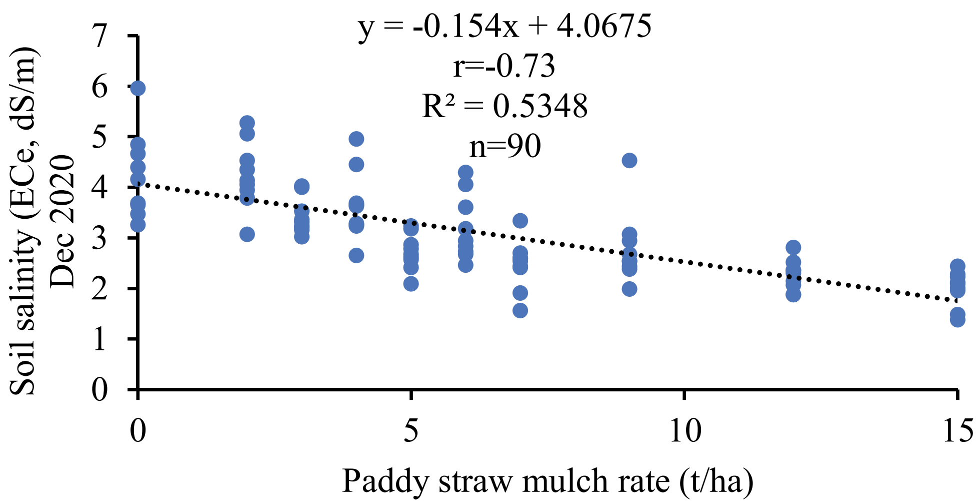
After the harvesting of the rice crop, the subsequent rabi crops (potato, mustard and garlic) were sown on 26.11.2020 under zero tillage practice. The varieties for potato, toria and garlic were Kufri Pukhraj, T 9 and Yamuna Safed 2 respectively. In the conventional practice (control) it took two weeks for tillage operations and seed bed preparations and the planting was done on 07.12.2020.

The experiment consists of three cropping systems viz. rice-mustard-green gram, rice-garlic-green gram and rice-potato-green gram. For mustard crop the treatments are conventional tillage (control), zero tillage (ZT) sowing with three spacings (20x10, 25x10 & 30x10 cm) and three mulch rates (2 t $ha^{-1}$, 4 t $ha^{-1}$ and 6t $ha^{-1}$). For garlic, the treatments

Table 74. Performance of rice (var. Swarna-Sub1) during kharif 2020

| Growth, yield & attributes | Mean | Range |
|---|---|---|
| Plant height (cm) | 112.7 | 110.0-116.7 |
| Hills/$m^2$ | 19 | 16-21 |
| Tillers/hill | 11 | 10-13 |
| Panicles/hill | 11 | 10-13 |
| Panicle length (cm) | 23.3 | 22.1-24.6 |
| Spikelets/panicle | 127 | 121-134 |
| Chaffs/panicle | 22 | 19-26 |
| Test weight (g) | 20.73 | 20.4-21.3 |
| Grain yield (t $ha^{-1}$) | 4.58 | 4.01-4.97 |
| Straw yield (t $ha^{-1}$) | 5.12 | 4.97-5.26 |
| Harvest Index | 0.47 | 0.44-0.49 |

Fig 64. Relation between paddy straw mulch rate and soil salinity during December 2020




are conventional tillage (control), ZT sowing with three spacings (20x10, 25x10 & 30x10 cm) and three mulch rates (3 t $ha^{-1}$, 5 t $ha^{-1}$ and 7 t $ha^{-1}$). Potato crop treatments are conventional ridge and furrow cultivation (control), ZT planting with three spacings (30x15, 45x15 & 60x15 cm) and three mulch rates (9 t $ha^{-1}$, 12 t $ha^{-1}$ and 15 t $ha^{-1}$). There were three replications of each treatment.

For the conservation treatments rice straw was used as mulch in the *rabi* crops and green gram stover left in the field. In the conventional practice all the crop residues are removed from the system. Soil salinity (ECe) was observed in the month of December 2020. In control plots soil salinity varied from 3.46 – 5.16 dS $m^{-1}$, whereas in paddy straw mulched plots it varied from 1.71 – 4.96 dS $m^{-1}$. Mean soil salinity in potato, garlic and mustard was 2.46, 2.99 and 3.84 dS $m^{-1}$ respectively. Soil salinity (ECe) had a negative correlation (r=-0.73) with amount (t $ha^{-1}$) of paddy straw mulching during December 2020 (Fig. 64).

**Coastal Saline Tolerant Variety Trial (CSTVT)** (S.K. Sarangi and Nitish Ranjan Prakash)

During the *kharif* season of 2020 under CSTVT two trials were conducted viz. (1) AVT 1-CSTVT and (2) AVT-2-NIL (CS). The details of the trials conducted are furnished in the Table 75.

The mean soil salinity of these trials were 6.43 dS $m^{-1}$ and 6.37 dS $m^{-1}$ for AVT 1-CSTVT and AVT-2-NIL (CS) respectively. Under AVT-1-CSTVT, out of 17 entries (Entry no. 4701 – 4717) highest grain yield of 5.11 t $ha^{-1}$ recorded from entry no. 4713 compared to 3.92 t $ha^{-1}$ from local check (Canning 7) at ECe of 6.43 dS $m^{-1}$. In AVT-2-NILCS, five entries (IET 28008, IET

Table 75. Details of Coastal Saline Tolerant Variety Trial – CSTVT at Canning Town during kharif 2020

| Particulars | AVT 1-CSTVT | AVT-2-NIL (CS) |
|---|---|---|
| No. of entries | 17 (IET 4701 - 4717) | 5 (IET28008, IET28010, IET28784, MTU |
| | | 1010, RP Bio 226) |
| Rep Spacing | 4 | 4 |
| Local Checks | Canning 7 | - |
| DOS | 10.07.2020 | 30.07.2020 |
| DOT | 10.08.2020 | 18.08.2020 |
| Plot size | 4.455 m2 | 3.24 m2 |

Coastal Saline Tolerant Variety Trial (CSTVT) under All India Co-ordinated Rice Improvement Project (AICRIP) at Canning Town during kharif 2020

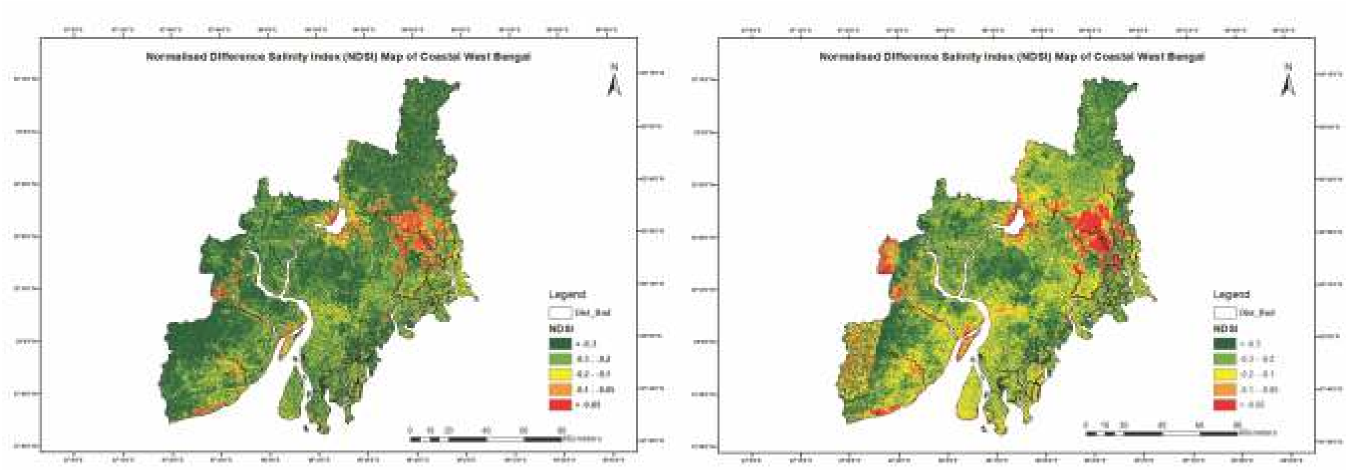
28010, IET 28784, MTU 1010 and RP Bio 226) were evaluated under 50% and 100% NPK. The highest grain yield of 4.86 t $ha^{-1}$ recorded from IET 28008 under 100% NPK.

**Seed production, maintenance and evaluation of rice germplasm** (S.K. Sarangi and Nitish Ranjan Prakash)

Seed production of released varieties of CSSRI under taken in *kharif* 2020. 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 2020. 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* 2020. 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-one 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))

Soil salinity is one of the major land degradation problems threatening agricultural production in the fragile coastal ecosystem. The salinity problem in soils is primarily due to the upward capillary movement water from the shallow brackish ground water. Besides, occasional inundation of the land with saline water from river or sea and over




(a) (b)

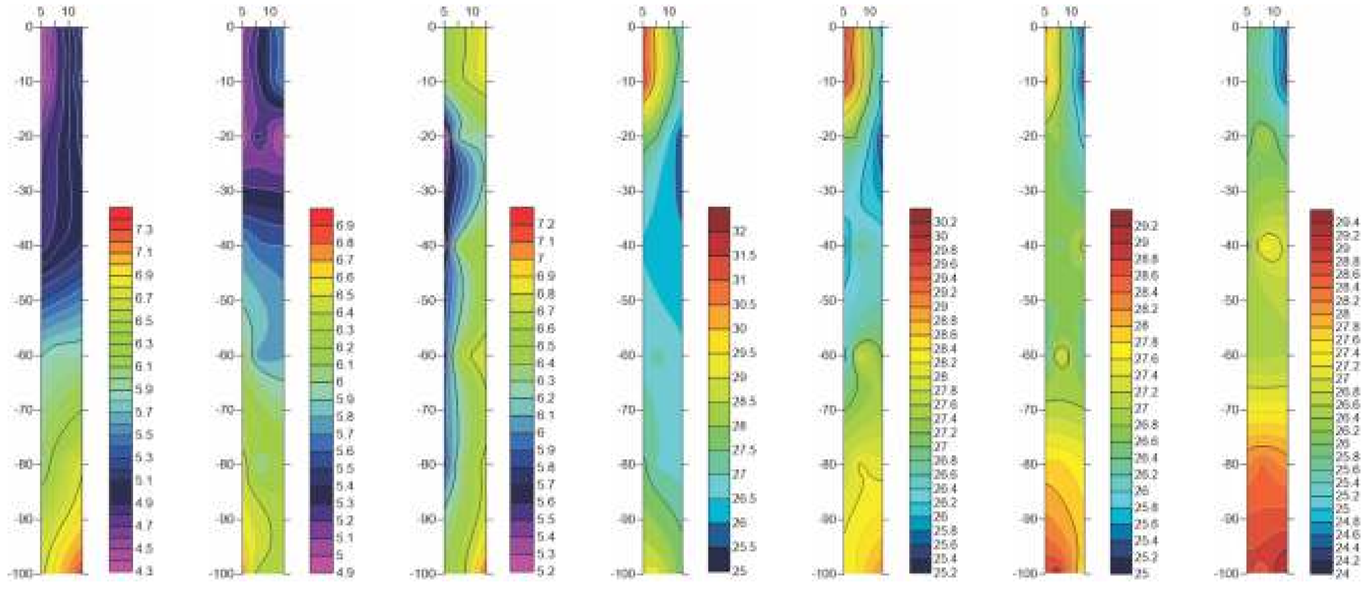
Fig 65. NDSI map of the coastal districts of West Bengal derived from (a) IRS-LISS III (b) Sentinel 2B data

exploitation of ground water from coastal aquifers leading to intrusion of saline sea water also contributes to the salt accumulation in these soils. Assessment and monitoring the extent of salt affected soils and the severity of soil salinity on a spatial scale to delineate areas affected by soil salinity are important to develop strategies for sustainable agricultural development. The present study was initiated to map and develop an updated database of salt affected soils in coastal West Bengal.

IRS-LISS III satellite imageries acquired during Feb-March 2018 and Sentinel 2B satellite imageries of March 2018 pertaining to the study area was processed using ERDAS imagine software. Reflectance values were derived for the satellite imageries and different salinity indices, namely, normalized difference salinity index (NDSI), crop response salinity index (CRSI), salinity indices (SI-1 & SI-2) and vegetation soil salinity index (VSSI) were computed. The satellite derived salinity indices were then correlated with the soil salinity (electrical conductivity of saturated extract, ECe) of the surface soil samples (0-15 cm) measured in the laboratory after collection from the field located in the two districts of South and North 24 Parganas. Among the salinity indices considered in the study, normalized difference salinity index (NDSI) was observed to have better correlation with the measured soil salinity values for both LISS III ($R^2$ = 0.36) and Sentinel 2B ($R^2$ = 0.32) satellite data. The NDSI map for the coastal part of West Bengal comprising the districts of North 24 Parganas, South 24 Parganas, Howrah and East Midnapore was generated in GIS environment (Fig. 65).

**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)

To study the salt dynamics and crop productivity under deficit irrigation in a heavy textured coastal soil, field experiment was conducted during rabi, 2019-20 in the research farm of RRS, Canning Town, West Bengal. The treatments consisted of three irrigation water quality levels (GW – good quality water, $EC_{iw}$ <2.0 $dSm^{-1}$, $SW_1$ - saline water with $EC_{iw}$ 4.0 $dSm^{-1}$ and $SW_2$ - saline water with $EC_{iw}$ 8.0 $dSm^{-1}$) 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. Maize and brinjal crops were grown following recommended agronomic practices. Soil $EC_e$ as well as moisture content was monitored at 0-10, 10-20, 20-40, 40-60,



(a) (b) (c) (d) (e) (f) (g)

Fig 66. Spatial variation of salinity under different salinity levels of irrigation water (a) Good water (b) ECiw - 4 dSm-1 and (c) ECiw - 8 dSm-1 and soil moisture at different irrigation levels (d) 125% CPE (e) 100% CPE (f) 75% CPE and (g) 50% CPE

60-80 and 80-100 cm depths at regular intervals. In maize crop, highest mean soil $EC_e$ of 6.22 $dSm^{-1}$ in 0-10 cm depth was recorded at 91 days after sowing (DAS) with the application of irrigation water having salinity level 8.0 $dSm^{-1}$ while in brinjal the highest $EC_e$ was 7.00 $dSm^{-1}$ at 112 days after transplanting (DAT). The corresponding soil $EC_e$ was 4.30 with good quality water and 4.99 with irrigation water having $EC_e$ of 4.0 $dSm^{-1}$ in maize and 4.73 and 5.04 $dSm^{-1}$ respectively in brinjal. The soil salinity was lower after the crop harvest as there was a rainfall in excess of 135 mm in the last week of May 2020, which could have led to leaching of the salts. In general, an increase in soil salinity on application of higher amounts of saline irrigation water was observed probably due to the introduction of more salts with the irrigation water, where as in plots irrigated with good quality water, the soil salinity increased with reducing amounts of water applied. The mean gravimetric soil moisture content after the crop harvest was highest (32.7 % in maize and 34.37 % in brinjal at 112 DAT) when irrigation was scheduled at 125% CPE, while it was lowest under deficit irrigation at 50% CPE (28.77 and 32.22% in maize and brinjal, respectively). The moisture content values were relatively higher due to the rainfall received during the period. The spatial distribution of soil salinity (Fig. 66 a, b & c) under different salinity levels of irrigation water revealed that with the increase in salinity of irrigation water, there was increase in soil salinity in the upper soil layer and with the increasing distance from the dripper. The soil moisture content also decreased with increasing distance from the dripper, and the zone with higher moisture content was smaller in the treatments receiving lower amount of irrigation water (Fig. 66 d, e, f & g).

Table 76 shows the crop productivity as influenced by irrigation and salinity treatments. Significantly highest kernel yield (3.26 t $ha^{-1}$) of maize was obtained at irrigation level of 125% CPE and the lowest with 50% CPE. The kernel yield at 100 and 75% CPE irrigation levels were at par statistically. Among the salinity treatments, highest kernel yield (3.21 t

Table 76. Effect of deficit irrigation and irrigation water salinity on crop productivity

| Treatments | Maize Kernel yield (t $ha^{-1}$) | | | | Brinjal Fruit yield (t $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | GW | $SW_1$ | $SW_2$ | Mean | GW | $SW_1$ | $SW_2$ | Mean |
| $I_1$ | 3.64 | 3.18 | 2.97 | 3.26a | 12.96 | 12.57 | 11.42 | 12.32a |
| $I_2$ | 3.54 | 2.98 | 2.84 | 3.12b | 12.54 | 12.16 | 10.14 | 11.61ab |
| $I_3$ | 3.08 | 2.87 | 2.53 | 2.82bc | 12.30 | 11.24 | 9.01 | 10.85bc |
| $I_4$ | 2.60 | 2.53 | 2.25 | 2.46d | 10.13 | 9.54 | 8.26 | 9.31d |
| Mean | 3.21a | 2.89ab | 2.65bc | | 11.98a | 11.38ab | 9.71c | |

Means with at least one letter common are not statistically significant

$ha^{-1}$) was obtained with good quality water, however, it was statistically at par with that obtained with irrigation water having 4.0 $dSm^{-1}$ salinity. In brinjal, the highest fruit yield was obtained with good quality water (14.46 t $ha^{-1}$), which was at par with irrigation water having 4.0 $dSm^{-1}$ salinity levels. Lowest yield of both the crops was obtained at the highest irrigation water salinity level of 8.0 $dSm^{-1}$. In maize significantly higher yield was obtained at the irrigation level of 125% CPE. In brinjal, the yield at irrigation level of 125% CPE was at par with that at 100% CPE. At 100 and 75% CPE in both the crops at par yields were obtained. Lower yield was obtained in brinjal as the crop was damaged due to the cyclone Amphan. Overall, deficit drip irrigation at 75% and 50% CPE reduced kernel yield of maize by 9.5 and 21.1% respectively, over irrigation at 100% CPE, whereas, fruit yield of brinjal was reduced by 6.6 and 19.9 %. 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 17.6 and 19.0%, respectively, over that obtained with good quality water. With 4 $dSm^{-1}$ irrigation water salinity the corresponding reduction in yield was by 10.2 and 5%, respectively.

**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)

An attempt has been made to delineate the coastal salt affected soils in India using satellite remote sensing. Coastal India is spread over nine states (West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, and Goa); two union territories (Puducherry and Daman & Diu) and two groups of islands (Andaman & Nicobar group in the Bay of Bengal and Lakshadeep and Minicoy group in the Arabian sea) covering within 73 districts. The Landsat-8, the most recently launched landsat satellite OLI (Operational Land imager) was used for the study. Cloud cover is a consistent problem in all topical regions. Because the aim of this study was to delineate the salt affected areas images need to be totally cloudless over the area of interest. These images were downloaded from the United States geological Survey (USGS) earthExplorer web site where archived satellite image data are available. The images were georeferenced. USGS supplies Landsat 8 images with basic georeferencing and district boundary map (georeferenced from the topo-sheet) was used for further georeferencing the image and extracted the study area. Absolute radiometric calibration was carried out for multi temporal studies in order to reduce the effects due to changes in atmospheric condition, solar angle and sensor view angle. These corrections involve the conversion of the digital number (DN) to the top of atmosphere reflectance that helps in

Table 77. Soil characteristics of Indian Sundarbans

| Parameter | Maximum | Minimum | Average | Standard deviation | Coefficient of variance |
|---|---|---|---|---|---|
| pH (1:2) | 8.17 | 3.96 | 5.72 | 0.903 | 15.79 |
| EC (1:2) (dS $m^{-1}$) | 13.85 | 0.103 | 1.52 | 1.68 | 110.68 |
| OC% | 1.25 | 0.224 | 0.791 | 0.253 | 32.06 |
| pHe | 8.69 | 3.6 | 6.78 | 0.86 | 12.7 |
| ECe (dS $m^{-1}$) | 36.34 | 0.273 | 4.26 | 4.66 | 109.4 |
| % silt | 50.4 | 6.4 | 26.2 | 5.6 | 21.4 |
| % clay | 63.4 | 21.8 | 49.1 | 8.01 | 16.3 |
| % sand | 71.8 | 8.7 | 24.7 | 10.2 | 41.2 |

the temporal analysis. The DN of all the images was converted to at-satellite spectral reflectance. Total 57 scenes of landsat-8 OLI was downloaded, georeferenced and converted to spectral reflectance. Images were classified using unsupervised classification in ERDAS software. Initially images were classified into 150 classes and then re-coded to broad 5 to 6 land use classes and Google earth was used for this purpose. The bare soils and agricultural land were extracted from each classified image to delineate the salt affected area. Three indices Normalized Difference Vegetation Index (NDVI), Salinity Index (SI) and Canopy Response Salinity Index (CRSI) were used for our study. All images were re-samples to a spatial resolution of 30 m.

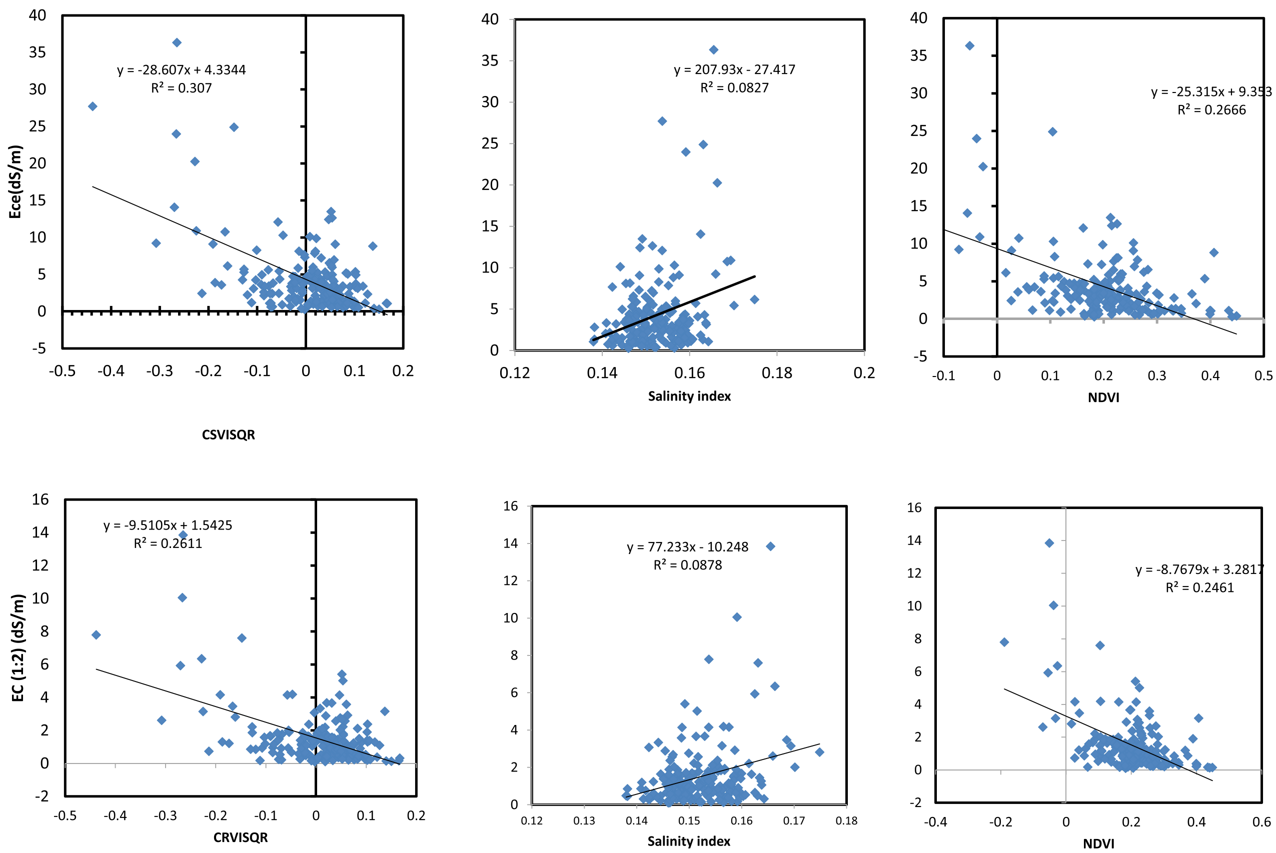



Fig 67. Relationship between ECe and EC (1:2) with NDVI, SI and square of CRVI (CRVISQR)

Table 78. Salt affected soils in Coastal India

| Sr. No. | State | Salt affected soils ($km^2$) |
|---|---|---|
| 1. | Gujarat | 6939.15 |
| 2. | Maharashtra | 916.29 |
| 3. | Goa | 23.34 |
| 4. | Karnataka | 18.204 |
| 5. | Kerala | 172.989 |
| 6. | Tamil Nadu | 171.14 |
| 7. | Andhra Pradesh | 534.31 |
| 8. | Odisha | 34.729 |
| 9. | West Bengal | 3852.2089 |
| 10. | Andaman & Nicobar and Lakshadweep islands | 46.647 |
| 11 | Total | 12709.0079 |

For ground truthing 192 soil samples from Indian Sundarbans considering one sample from each gram panchayat were collected. The soil characteristics were presented in Table 77. A relationship has been developed between NDVI, SI and square of CRVI (CRVISQR) with ECe and EC (1:2) (Fig. 67) and maximum $r^2$ ( 0.49) was found between ECe and square value of CRVI also the value of CRVISQR <0.08 was considered salt affected soils for the coastal region. We delineate salt affected soils based on square of CRVI <0.08 for each coastal state and state-wise area of salt affected area is presented in Table 78.

**ICAR-IRRI Collaborative Project - Sub project 2.1: Climate smart management practices: - Climate smart management practices - Evaluate silicon fertilizer for the amelioration of salinity stress in wet and rabi seasons of the coastal saline environment of West Bengal** (S.K. Sarangi)

During the *rabi* season (boro season) 2019-2020, the same experiment was conducted with different varieties **[**Canning 7 (tolerant) and IR29 (susceptible)] with Si fertilizer doses of 0 kg $ha^{-1}$, 75 kg sodium metasilicate $ha^{-1}$ (17.3 kg Si $ha^{-1}$), 105 kg sodium metasilicate $ha^{-1}$ (24.2 kg Si $ha^{-1}$), 170 kg sodium metasilicate $ha^{-1}$ (39.1 kg Si $ha^{-1}$) and 230 kg sodium metasilicate/ha (52.9 kg Si $ha^{-1}$) with three replications in a split-plot design. The source of Silica was sodium metasilicate.

Seeds of IR 29 and Canning 7 were sown in the nursery on 13 December 2019 and transplanting of 34 days old seedlings in the main field was done on 15 January 2020. Out of the two varieties, Canning 7 produced grain yield of 6.26 t $ha^{-1}$, significantly higher than IR 29 (4.19 t $ha^{-1}$). The grain yield of IR 29 increased from 3.69 t $ha^{-1}$ without Si application to 4.87 t/ha with application of 53 kg Si $ha^{-1}$. In Canning 7, the grain yield increased from 5.46 t/ha without Si application to 7.00 t $ha^{-1}$ with application of 53 kg Si $ha^{-1}$. The mean grain yield response due to 0, 17, 24, 39 and 53 kg Si $ha^{-1}$ was 4.58, 5.00, 5.07, 5.54 and 5.94 t $ha^{-1}$ respectively.

### *Kharif* 2020

During kharif 2020, the same experiment as conducted during kharif 2019 was continued. It was observed that plant height was not affected either by variety, method of application or silicon dose. However, the grain yield was significantly affected by silicon dose. Highest grain yield of 6.02 t ha-1 was observed with application of highest dose of

Observation on lodging tolerance in rice by prostate tester at different crop stages

Table 79. Effect of variety, method of application and silicon dose on performance of rice during kharif 2020 at Canning Town, West Bengal

| Treatments | Plant height (cm) | Lodging tolerance (kg cm-1) | Grain yield (t ha-1) |
|---|---|---|---|
| **Main-plot: Rice varieties (V)** | | | |
| Amal-Mana | 176.30 | 0.31 | 5.46 |
| Sabita | 179.95 | 0.21 | 4.38 |
| $LSD_{0.05}$ | NS# | 0.02 | NS |
| **Sub-plot: Method of application** | | | |
| M1 | 176.27 | 0.26 | 5.01 |
| M2 | 177.26 | 0.26 | 4.86 |
| M3 | 180.84 | 0.25 | 5.56 |
| $LSD_{0.05}$ | NS | NS | NS |
| **Sub-sub plot: Dose of silicon (kg ha-1)** | | | |
| F1 (0) | 176.54 | 0.24 | 4.38 |
| F2 (24.2) | 177.95 | 0.26 | 4.77 |
| F3 (41.05) | 179.47 | 0.26 | 5.14 |
| F4 (50.06) | 178.25 | 0.27 | 5.42 |
| F5 (62.1) | 178.38 | 0.27 | 6.02 |
| $LSD_{0.05}$ | NS | 0.01 | 0.48 |

62 kg Si $ha^{-1}$ (Table 79). Observation on lodging tolerance was recorded by a prostate tester at maturity. The lodging tolerance of Amal-Mana was 0.31 kg $cm^{-1}$, which was higher than Sabita (0.21 kg $cm^{-1}$). The lodging tolerance of rice increased with increasing dose of silicon fertilizer. However, the lodging tolerance was at par (0.27 kg $cm^{-1}$) with 50 and 62 kg Si $ha^{-1}$.

**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 ACIAR, Australia funded project, was implemented by ICAR-CSSRI, Regional Research Station (RRS), Canning Town during 2016-2020 in the farmers' fields (on-farm) of the Gosaba island of the Sundarbans as well as in the research farm (on-station) during the

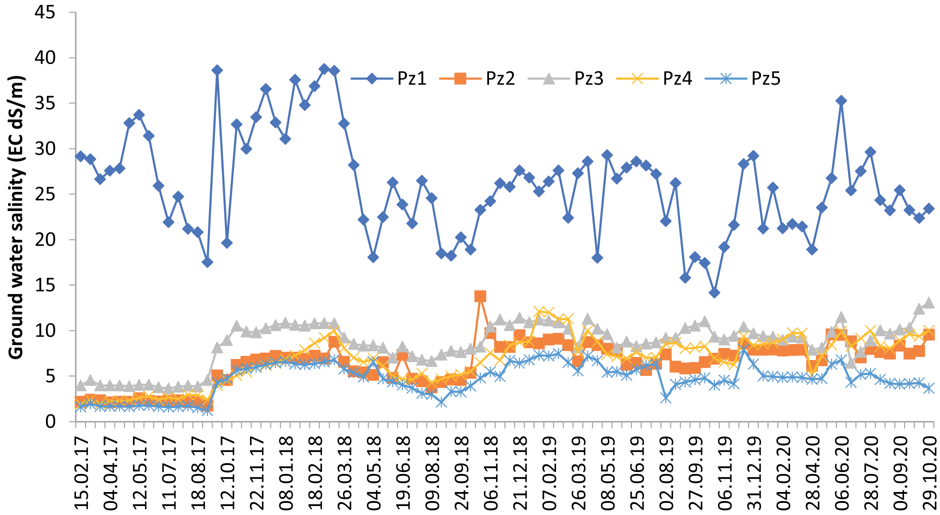



Fig 68. Ground water salinity of Gosaba Island, Sundarbans, West Bengal observed during February 2017 to October 2020

reported period. Project activities implemented in about 700 farmers' fields with field experiments to increase cropping intensity through introduction of improved management practices, new crops and varieties. New cropping systems for increasing cropping intensity with improved package of practices have been developed. Management practices for improving soil health such as green manuring, application of rock phosphate and lime for amelioration of acid saline soils, mulching for conservation of soil moisture and weed control, water conservation practices such as drip irrigation has been implemented in the project sites. Mulching practices (black, white, paddy straw and control), resulted in higher yield in vegetable crops (okra, cucumber and bitter gourd) compared to non-mulching. In vegetables mean yield was 43, 73 and 101% higher in paddy straw, white and black plastic mulching over control. Vegetables like Indian spinach, broccoli, knol-khol, chilli, cabbage, cauliflower, pumpkin, sweet potato and tomato are the most suitable crops. During *rabi* season maize, potato followed by green gram are suitable field crops. Zero tillage potato after rice is a very good option followed by green gram/onion/vegetables, there by cropping intensity can be increased to 300%. Rice cultivation practices including establishment techniques, suitable varieties and management practices for soils with low pH (acid saline soils) varying from 4.6 to 4.8 developed under the project for higher productivity, reducing risks as well as improving soil health. Data on the surface water (rivers, canals, drainage channels, ponds etc.) and ground water quality parameters in the island were collected for use in the salt water balance model developed under the project. The average depth of ground water in the island is closest to the surface during the wet season July-December (0.44 m) and farthest during dry season January-June (0.95 m), however, it never goes beyond 2 m depth. The mean salinity of the ground water is 10.5 dS $m^{-1}$observed during February 2017 to October 2020. The maximum and minimum ground water salinity was 38.7 dS $m^{-1}$ and 1.2 dS $m^{-1}$ respectively (Fig. 68).

Trainings on improved crops, varieties, cultivation practices etc. were imparted to about 685 farmers (470 male and 215 female) in 25 numbers of events. Developed technologies were demonstrated in different locations of the village, exhibited in different scientific forum and communicated in mass media. The detailed scientific interventions undertaken, feedback of the collaborating farmers and stakeholders were documented in the form of audio-visual programme for subsequent dissemination to the target

Table 80. Yield of vegetable crops and mungbean under paddy straw mulching and non-mulching during 2019-20 at Sonagaon village, Gosaba island of Sundarbans, West Bengal

| Crops | Varieties | Broccoli Equivalent Yield (t $ha^{-1}$)* | | |
|---|---|---|---|---|
| | | Non-Mulching | Mulching | Mean |
| Broccoli | Green comet | 28.14 | 33.52 | 30.83 |
| Onion | Sukh sagar | 8.17 | 12.42 | 10.29 |
| Garlic | Local | 11.43 | 17.73 | 14.58 |
| Okra | Ankita, Rohini | 23.16 | 24.88 | 24.02 |
| French bean | Harsha | 12.62 | 33.75 | 23.19 |
| Indian spinach | Ladna | 18.66 | 30.94 | 24.80 |
| Tomato | Deb | 18.16 | 26.67 | 22.42 |
| Pumpkin | Baidyabati, Aditya, Rana BSS 749 | 45.84 | 58.11 | 51.97 |
| Bitter gourd | Samurai 786 | 14.10 | 22.09 | 18.09 |
| Snake gourd | Jyothi, Kirti | 8.26 | 10.06 | 9.16 |
| Cucumber | Seven star | 14.28 | 23.76 | 19.02 |
| Chilli | Tejaswini | 19.77 | 29.67 | 24.72 |
| Mung bean | Sona moong | 4.85 | 6.24 | 5.54 |
| Mustard | Laxmi Gold-1001 | 1.81 | 2.72 | 2.26 |
| Cabbage | Green express | 18.00 | 31.28 | 24.64 |
| Cauliflower | Barkha | 12.69 | 35.68 | 24.18 |
| Knol-khol | Winner | 19.31 | 31.77 | 25.54 |
| Beetroot | Ruby ball | 21.33 | 24.33 | 22.83 |
| Sweet potato | Samrat | 32.27 | 37.83 | 35.05 |
| Mean | | 17.52 | 25.97 | 21.74 |
| Comparison | | LSD (P=0.05) | | |
| Two main-plot means (avg. over all subplot treatments) | | 2.87 | | |
| Two subplot means (avg. over all main-plot treatments) | | 1.29 | | |
| Two subplot means at the same main-plot treatments | | 3.66 | | |
| Two main-plot means at the same or different subplot treatments | | 3.84 | | |

*Price per kg of vegetables during 2019-20: Broccoli=₹18, Onion=₹25, Garlic=₹50, Okra=₹30, French bean=₹30, Indian spinach=₹15, Tomato=₹20, Pumpkin=₹20, Bitter gourd=₹40, Snake gourd=₹20, Cucumber=₹40, Chilli=₹40, Mung bean=₹70, Mustard=₹50, Cabbage=₹25, Cauliflower=₹20, Knol-khol=₹20, Beetroot=₹25, Sweet Potato=₹30

audience. Socio-economic analysis of the project activities was under taken for evaluation of economics of the cropping system and benefits accruing to the farming community of the salt affected coastal region of West Bengal.

During the *rabi* season of 2019-20 different vegetable crops and mungbean were evaluated under paddy straw mulching and non-mulching. The results of the study are given in Table 80. On average paddy straw mulching increased the yield of crops by 48% compared to non-mulching.

# 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)

The Direct Seeded Rice (DSR) also known as aerobic rice is a new production system in which rice is grown under non-puddled, non-flooded and non-saturated soil conditions as other upland crops. To address the Fe deficiency in DSR, an experiment was started at ICAR-CSSRI under DSR-wheat system with application of Fe through soil as well as foliar using amendments such as $FeSO_4.7H_2O$, Fe-EDTA and Fe-EDDHA. The rice crop (variety CSR-60) was grown under DSR. The soil and foliar application of iron fertilizers were done under 9 treatments with 3 replications and their effects of crop yield and iron content in grain as well as in husk are given in Table 81.

The field experiment results indicated that iron fertilization of aerobic rice proved useful in enhancing the grain yield. The highest mean grain yield of aerobic rice (CSR60) was 5.42 t $ha^{-1}$ in 3 foliar sprays of 0.2% Fe-EDDHA which was 9.58% higher compared to control. Among the soil application of Fe, the highest grain yield (5.37 t $ha^{-1}$) was recorded from the 50 kg Fe $ha^{-1}$ through ferrous sulphate, followed by 40 kg Fe (i.e. 5.25 t $ha^{-1}$) as compared to control. In case of soil application, highest iron content in grain of 8.02 mg $kg^{-1}$ was recorded under treatment of 50 kg Fe $ha^{-1}$ through $FeSO_4$. The same iron content was also recorded for Foliar sprays of 3% $FeSO_4.7H_2O$ (Thrice at 30, 45, 60 DAS). In general, husk iron content in rice followed similar trends as grain iron content. The iron content in soil improved with its application through $FeSO_4.7H_2O$. However, foliar application helped in reducing Fe deficiency in rice crop but did not influence soil iron content. Initial results indicated that foliar application foliar sprays of 3% $FeSO_4.7H_2O$ might be practical and economical solution to deal Fe deficiency in direct seeded rice.

Table 81. Effect of Fe fertilization on rice yield, Fe-grain and Fe-husk in case of DSR

| Treatments | Rice yield (t $ha^{-1}$) | Fe-grain (mg $kg^{-1}$) | Fe-husk (mg $kg^{-1}$) |
|---|---|---|---|
| T1 : Control (no Fe application) | 4.94 | 7.45 | 73.9 |
| T2 : 30 kg Fe $ha^{-1}$ through $FeSO_4$ | 5.13 | 7.71 | 79.0 |
| T3 : 40 kg Fe $ha^{-1}$ through $FeSO_4$ | 5.25 | 7.81 | 80.6 |
| T4 : 50 kg Fe $ha^{-1}$ through $FeSO_4$ | 5.37 | 8.02 | 81.6 |
| T5 : Foliar sprays of 1.5% $FeSO_4.7H_2O$ (Thrice at 30, 45, 60 DAS) | 5.15 | 7.70 | 78.5 |
| T6 : Foliar sprays of 3% $FeSO_4.7H_2O$ (Thrice at 30, 45, 60 DAS) | 5.33 | 8.02 | 80.1 |
| T7 : Foliar sprays of 0.5% Fe-EDTA (Thrice at 30, 45, 60 DAS) | 5.37 | 8.00 | 80.7 |
| T8 : Foliar sprays of 0.2% Fe-EDDHA (Thrice at 30, 45, 60 DAS) | 5.42 | 8.10 | 82.3 |
| T9 : Foliar sprays of 0.5% Fe-DTPA (Thrice at 30, 45, 60 DAS) | 5.03 | 7.54 | 76.0 |
| CD (p=0.05) | 0.26 | 0.35 | 5.03 |

## DST-PAU Project: North Indian Centre for Water Technology Research in Agriculture

### Development of technology for judicious use of saline groundwater in Agra district of Uttar Pradesh

In the Agra region, farmers use saline ground waters for crop production. The crop productivity is low due to saline water irrigation. The dilution of saline groundwater is possible through artificial groundwater recharge and same diluted groundwater can be used for crop production through drip to improve crop and water productivity. Therefore, a study was undertaken at Research Farm of RBS College, Agra, Uttar Pradesh for Tomato-Okra crop rotation. A tube well having recharge structure was constructed at research farm to dilute saline groundwater in aquifer itself. The experiment was planned with three irrigation water quality levels (saline groundwater, diluted saline groundwater due to recharge and stored rainwater) as main irrigation water quality treatments while irrigation water application (drip irrigation at 80% ETC, drip irrigation at 100% ETC and flood irrigation) and mulch (no much and mulch at 6 t $ha^{-1}$) as sub treatments. The first crop of tomato (Variety NS 592) was transplanted on 7$^{th}$ Jan. 2020. The date of nursery preparation was 29$^{th}$ Nov. 2019. The doses of N: P: K (kg $ha^{-1}$) were 120:60:60. The irrigation was done at interval of 4 days and total numbers of irrigation were 12. Total rainfall during crop growing period of Tomato was 74.45 mm. The crop was harvested on 10$^{th}$ May 2020. The second crop in sequence was Okra (Variety: Mona Golden). The date of transplanting was 17$^{th}$ July 2020. The doses of N: P: K (kg $ha^{-1}$) were 120:60:60. The irrigation was done at interval of 5 days and total numbers of irrigation were 15. Total rainfall during crop growing period of Okra was 233.2 mm. The crop was harvested on 25$^{th}$ Nov. 2020. The yields of Tomato and Okra as influenced by different treatments are provided in Table 82.

Results revealed that there was significant reduction in tomato fruit yield in case of saline ground water ($EC_{iw}$ 6 dS $m^{-1}$) as compared to stored rainwater. However reduction in saline


Performance of DSR (CSR 60) in foliar application of 0.2% Fe-EDDHA

Table 82. The yields of Tomato and Okra as influenced by different treatments

| Treatments | Tomato Fruit yield (t $ha^{-1}$) | Okra Fruit yield (t $ha^{-1}$) |
|---|---|---|
| **Source of water:** | | |
| S (Saline ground water (ECiw 6 dS $m^{-1}$) without Recharge water) | 18.96 | 15.55 |
| SD (Saline ground water (Diluted) from tube well with recharge structure) | 20.60 | 18.86 |
| SR (Stored rain water) | 23.34 | 17.03 |
| CD at 5% | 3.74 | 2.82 |
| **Method of irrigation:** | | |
| D80 (Drip irrigation at 80% of ETc) | 21.88 | 17.73 |
| D100 (Drip irrigation at 100% of ETc) | 21.34 | 17.59 |
| F (Surface flood irrigation (Recommended) | 19.68 | 16.13 |
| CD at 5% | NS | 0.9 |
| **Mulch level:** | | |
| M0 (No mulch) | 19.33 | 16.62 |
| M6 (Crop residue mulch (6t $ha^{-1}$)22.60 | 17.67 | |
| CD at 5% | 1.21 | 0.60 |
| Interactions | | |
| SW x MI | NS | NS |
| SW X ML | NS | 0.81 |
| ML x MI | 2.16 | NS |
| SW x MI x ML | NS | NS |

ground water (diluted) was not significant compared to stored rain water (Table 82). The fruit yield of tomato was increased significantly with crop residue mulch as compared to no mulch treatment. The yield of Okra fruit decreased significantly with application of saline water ($EC_{iw}$ 6 dS $m^{-1}$) as compared to saline water (diluted) and stored rain water (Table 82). In case of irrigation schedule the 80% ETc and 100% ETc with drip irrigation the fruit yield gave at par while the surface flood irrigation fruit yield was reduced significantly. Further, fruit yield increased significantly with crop residue mulch as compared to no mulch treatment.

## Development of technology for judicious use of sodic groundwater in Patiala district of Punjab

This experiment on Direct Seeded Rice –Wheat rotation along with drip irrigation was initiated on farmer's field at village Budhmor in Patiala district of Punjab. Initially soil samples (0-15 cm depth) were collected at different points from selected field and processed for representative sample which was analyzed for different soil chemical properties and soil fertility parameters. The texture of experimental field is silt loam and having alkaline with pH (1:2) value as 8.33 and EC (1:2) 0.57 $dSm^{-1}$; alkaline permanganate oxidizable nitrogen as 154.8 kg $ha^{-1}$, available phosphorus as 8.2 kg $ha^{-1}$,1 N ammonium acetate exchangeable potassium as 200 kg $ha^{-1}$ and organic carbon as 0.56%. The groundwater was source of irrigation and it was of sodic in nature with pH as 8.02 indicating that the water was neutral to alkaline in nature. The EC of the soil sample was 0.71 dS $m^{-1}$. The concentration of $Na^{+}$, $Ca^{2+}$ + $Mg^{2+}$, $K^{+}$, $Cl^{-}$ and $CO_3^{-}$ + $HCO_3^{-}$ in groundwater

Table 83. Effect of irrigation and gypsum application on rice grain yield (t $ha^{-1}$)

| Levels of Irrigation | Levels of gypsum application | | | |
|---|---|---|---|---|
| | G1: No Gypsum | G2: 25% GR | G3: 50% GR | Mean |
| I1: 150 % of ETc (Drip) | 2.85 | 2.93 | 3.14 | 2.97 |
| I2: 175 % of ETc (Drip) | 2.84 | 2.97 | 2.99 | 2.93 |
| I3: Flood (Surface) | 2.78 | 2.82 | 2.97 | 2.86 |
| Mean | 2.82 | 2.91 | 3.03 | |
| CD(p=0.05) | I=NS | G=0.048 | I×G= 0.0478 | |

sample were 6.15, 1.40, 0.11, 0.30 and 5.29 me $L^{-1}$, respectively. The cationic concentration followed the order: $Na^{+} > Mg^{2+} + Ca^{2+} > K^{+}$. The Sodium adsorption ratio (SAR) and Residual sodium carbonate (RSC) were 5.21 (mmol $L^{-1})^{1/2}$ and 3.89 me$L^{-1}$. The RSC value exceeds 2.5 me $L^{-1}$, the water is considered harmful as soil texture is silt loam. Drip system was designed in view of experimental design and provision of gypsum bed was made for RSC neutralization. The first rice crop (CSR-30) was sown under DSR on 15 June 2020. The results of experiment are given in the Table 1. The total rainfall amount during crop growing period from 15 Jun to 31 Oct 2020 was 486.00 mm. The rainfall was well distributed within crop growing period and also rainfall amount sufficient. The experimental field is located low-lying area and surface runoff from surrounding area also reached the field. As result, drip system was operated on 2 occasions and it was followed by rains. Therefore, effect of irrigation treatment was not significant on grain yield. However, effect of gypsum was significant on the yield (Table 83).

## Projection of climate parameters in climate changing scenario, their impact on water balance in cropped soil and groundwater at spatial scale

Delineation of rice cropped area in Haryana was done using the remote sensing image of 2000. Arc GIS tool was used to classify the area under rice crop using Iso cluster unsupervised classification technique. The total area under rice crop was found to be 1049 thousand ha in the year 2000 by Agricultural Statistics at a Glance, 2001, Department of Agriculture, Haryana. However, the delineated area for the year 2000 using remote sensing was 1051 thousand hectares and it was close agreement with observed area (Fig. 69).

On basis of remote sensing data, Karnal, Kaithal, Kurukeshtra and Panipat districts growing rice crop on large scale were selected for modeling study. These districts are mainly groundwater irrigated and water table is declining at faster rate in these districts.

**Climate change impact on reference Evapo-transpiration ($ET_0$)**: The $ET_0$ is very important variable in irrigation planning and it is affected by climate change. Hence, effect of different weather parameters (minimum temperature, maximum temperature, relative humidity, sunshine hour, wind speed, etc.) on $ET_0$ was studied using CROPWAT (8.0) model and long-term weather data from ICAR-CSSRI Observatory. The temporal changes in annual $ET_0$ (in mm) and kharif $ET_0$ were studied. It was observed that annual and Kharif $ET_0$ values are decreasing with time. $ET_0$ was influenced by maximum and minimum temperature, relative humidity, sunshine hour, vapour pressure and wind speed. The average annual maximum and minimum temperature were increasing with time. These parameters could increase annual $ET_0$. Further, decreasing sunshine hour and increasing RH/vapour pressure could decrease annual $ET_0$. However, annual $ET_0$ was decreasing with time. It indicated that influence of sunshine hour, RH and vapour

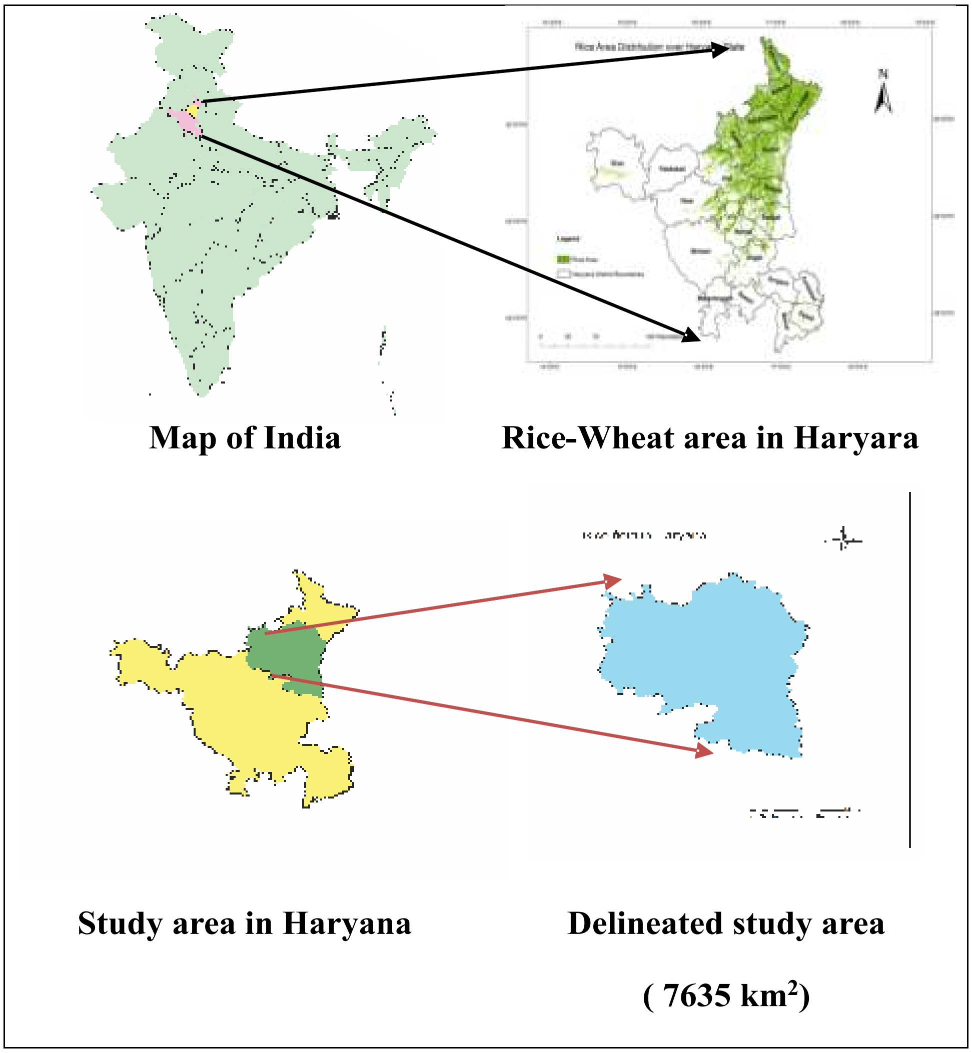



Fig 69. Delineation of rice cropped area in Haryana

pressure was more dominant on $ET_0$ compared effect due to increase in maximum and minimum temperature, particularly in this agro-climatic condition. Sensitivity analysis will be carried out to understand contribution of individual weather parameter towards $ET_0$. Further, it was observed that groundwater table was also declining despite of decrease in annual $ET_0$ with time. As groundwater withdrawal was influenced by effective rainfall towards $ET_c$ in groundwater irrigated areas of rice-wheat rotation, temporal changes in effective rainfall were studied. It was observed that rate of decline of effective rainfall was much higher than rate of decline of $ET_0$. Hence groundwater table was declining at faster rate in groundwater irrigated rice-wheat areas of Haryana (Fig. 70).

## Survey and characterization of ground water of Ramanathapuram district of Tamil Nadu for Irrigation (Tiruchirapalli)

Ramanathapuram is one of the coastal districts bounded on the north by Sivagangai and Pudukottai districts, on the east and south by the Bay of Bengal, and on the west by Thoothukudi and Virudhunagar districts. The district headquarters is located at Ramanathapuram. The district lies between 9°05' and 9°5' North Latitude and 78  1' and 79°27' East Longitude. The general geographical information of the district is simple and flat. Vaigairiver and Gundar river are flowing in the district and they will be dry during the

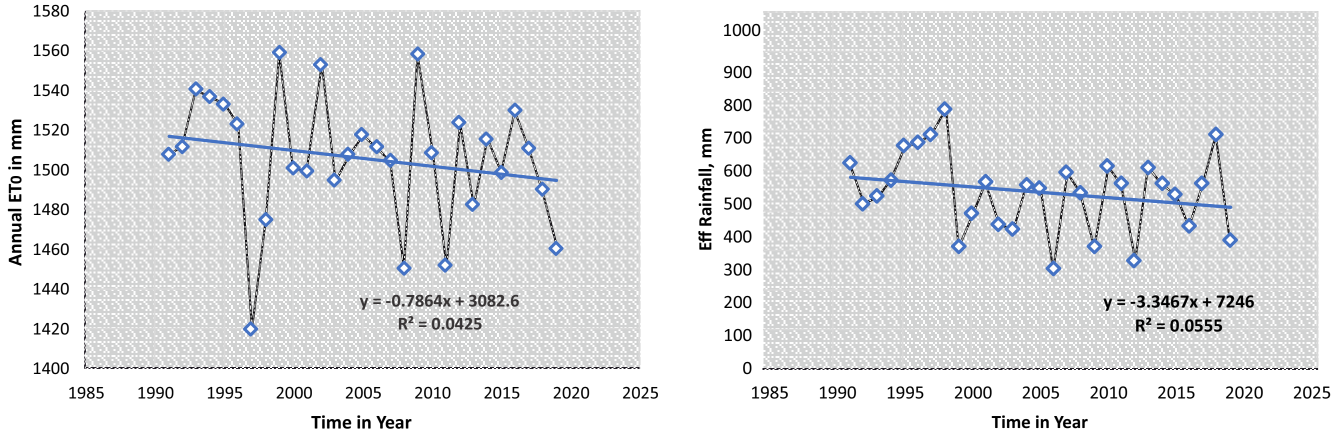



Fig 70. Temporal changes in ET0 and effective rainfall at Karnal

summer season. The total geographical area of the district is 4,175 sq.km. The district receives the rain under the influence of both southwest and northeast monsoons. The northeast monsoon chiefly contributes to the rainfall in the district. Most of the precipitation occurs in the form of cyclonic storms caused due to the depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible. Rainfall data from two stations over the period from 1901 to 2000 were utilized and a perusal of the data shows that the normal annual rainfall over the district is 827mm with the maximum around Pamban and all along the coast and it decreases towards inland. The district enjoys a Tropical climate. The period from May to June is generally hot and dry. The weather is pleasant during the period from December to January. Usually mornings are more humid than afternoons. The relative humidity is on an average between 79 and 84%. The mean minimum temperature is 25.7°C and mean maximum daily temperature is 30.6°C respectively. A study was undertaken to assess the groundwater quality in Ramanathapuram district by collecting 116 groundwater samples using GPS and analyzed for pH, EC, anions viz ., $HCO_3^-$, $CO_3^-$, $Cl^-$, $SO_4^{2-}$ and cations viz., $Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$ by adopting standard procedures and thematic maps were prepared using Arc GIS software 10.1. Average concentrations of cations and anions in different blocks of Ramanathapuram district are given in Table 84. In general, the distribution of cations

Table 84. Average cationic and anionic concentrations in different blocks of Ramanathapuram district

| S.NO | Block name | Cations (meq $l^{-1}$) | | | | Anions (meq $l^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | $CO_3^{2-}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ |
| 1. | Ramanathapuram | 10.36 | 28.57 | 89.39 | 1.01 | 3.53 | 9.95 | 118.17 | 0.94 |
| 2. | Paramakkudi | 3.42 | 8.82 | 49.71 | 0.12 | 2.6 | 10.72 | 51.80 | 0.70 |
| 3. | Kamuthi | 5.44 | 13.52 | 32.71 | 0.75 | 1.76 | 6.96 | 47.80 | 0.37 |
| 4. | Kadaladi | 13.71 | 38.60 | 129.73 | 2.35 | 2.8 | 7.21 | 174.00 | 1.15 |
| 5. | Tirupullani | 12.8 | 25.96 | 109.03 | 0.66 | 3.72 | 6.64 | 139.00 | 0.81 |
| 6. | Nainarkovil | 5.8 | 14.32 | 35.95 | 0.33 | 3 | 5.74 | 45.40 | 0.43 |
| 7. | Mandapam | 5.01 | 15.76 | 86.86 | 3.17 | 3.86 | 10.88 | 99.07 | 0.49 |
| 8. | Mudukalathur | 5.5 | 12.50 | 33.72 | 0.27 | 2.35 | 5.4 | 40.75 | 0.74 |
| 9. | Bogalur | 3.85 | 7.50 | 69.49 | 0.16 | 3.65 | 9.57 | 70.00 | 0.78 |
| 10 | Tiruvadanai | 10.55 | 38.09 | 110.91 | 3.25 | 2.73 | 8.04 | 155.69 | 0.63 |
| 11. | R.S Mangalam | 13.66 | 40.87 | 106.85 | 3.93 | 1.93 | 9 | 158.33 | 0.80 |

Table 85. Water quality distribution (%) in Ramanathapuram district

| S.No | Block | No.of samples | Good | MS | Saline | HSS | MA | Alkali | HA |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Ramanathapuram | 12 | | 16.6 | | 33.3 | | | 50 |
| 2. | Paramakkudi | 10 | | 10 | | 10 | | 10 | 70 |
| 3. | kamuthi | 10 | 20 | 30 | | 20 | | 20 | 10 |
| 4. | Kadaladi | 14 | 7.1 | | | 71.4 | 7.1 | | 14.2 |
| 5. | Tirupullani | 10 | 10 | 20 | | 70 | | | |
| 6. | Nainarkovil | 10 | 20 | 20 | 10 | 50 | | | |
| 7. | Mandapam | 15 | 20 | | | 33.3 | | 33.3 | 13.3 |
| 8. | Mudukalathur | 8 | 25 | 12.5 | 12.5 | 50 | | | |
| 9 | Bogalur | 8 | | | | 62.5 | | 12.5 | 25 |
| 10. | Tiruvadanai | 13 | 7.6 | 7.6 | 7.6 | 46.1 | | 15.3 | 15.3 |
| 11. | R.S Mangalam | 6 | | | 16.6 | 50 | | 16.6 | 16.6 |
| | Average | 116 | 10 | 10 | 4 | 46 | 1 | 10 | 19 |

followed the order of $Na^{+}$> $Mg^{2+}$> $Ca^{2+}$>$K^{+}$ in all the blocks. With respect to the distribution of anions followed the order of $Cl^{-}$> $HCO_3^{-}$> $CO_3^{2-}$> $SO_4^{2-}$ in all blocks. The ground water investigation revealed that groundwater samples with respect to pH and EC ranged from 7.17 to 8.57 and 0.47 to 80.86 dS $m^{-1}$ respectively. Residual Sodium Carbonate (RSC) varied from nil to18 $meL^{-1}$ and Sodium Adsorption Ratio (SAR) ranged from 0.52 to 144.34. Out of the total samples collected in Ramanthapuram district, 10% is characterized under good quality, 10% is marginally saline, 4% is saline, 1% is marginally alkaline, 10% is alkaline, 46% high SAR saline and 19% high alkaline The distribution of water samples in different water quality classes revealed that the samples of good quality groundwater were found in almost all the Mudukalathur blocks (25%), Mandapam (20%), Nainarkovil (20%), Kamuthi (20%), Tirupullani (10%), Tiruvadanai (7.6%), and Kadaladi (7.1%) as provided in Table 85. Among the different blocks investigated the highest percentage of samples with good quality found in Mudukalathur (25%), Kamuthi (20%), Mandapam (20%) and Nainorkovil (20%). Similarly, the poor-quality water viz., High SAR saline from Kadaladi block (71.4%), Saline from RS Mangalam (16.6), Marginal Saline from Kamuthi (30%), Marginal Alkali from Kadaladi (7.1%), Alkali from Mandapam (33.3%), High Alkali from Paramakudi (70%). Among the different blocks of Ramanathapuram district, Kadaladi (50%), Tirupullani (50%) and RS Mangalam (50%) recorded the high level of possible seawater intrusion. The spatial distribution of groundwater quality categories is provided in Fig. 71.

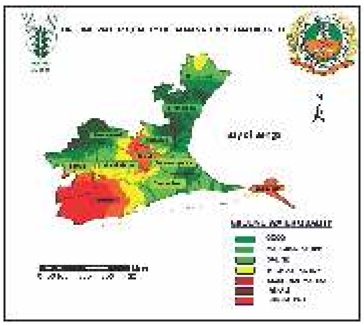


Fig 71. Spatial distribution of ground water quality in Ramanathapuram district

## Survey and characterization of groundwater for irrigation for Kanpur Dehat and Auriya district of Uttar Pradesh (Kanpur)

Two hundred four groundwater water samples were collected from different villages of Auraiya district. Out of total samples, 32, 29, 27, 34, 43 and 39 samples were collected from Ajitmal, Bidhuna, Erwakatra, Achalda, Sahar and Bhagyanagar blocks of the district respectively. Salient features of ground water samples of different blocks of Auraiya district are given in Table 86.

**Frequency distribution of water samples:** Two hundred four groundwater samples were collected from different villages of Auraiya district. Out of total samples, 32, 29, 27, 34, 43 and 39 samples, respectively, were collected from Ajitmal, Bidhuna, Erwakatra, Achalda, Sahar and Bhagyanagar blocks of the district respectively. Out of 204 samples, 139 (68.14 %) belonged to good category, 42 (20.59 %) belonged to marginally saline, 05 (2.45 %)

Table 86. Salient features of ground water samples of Auraiya district

| Blocks | pH | Mean | EC (dS $m^{-1}$) | Mean | SAR | Mean | RSC (meq $l^{-1}$) | Mean |
|---|---|---|---|---|---|---|---|---|
| Ajitmal | 7.2-8.4 | 7.85 | 0.38-3.28 | 0.97 | 0.7-10.2 | 2.84 | 0.0-7.2 | 0.48 |
| Bidhuna | 7.4-8.2 | 7.73 | 0.32-3.21 | 0.89 | 0.6-09.3 | 3.22 | 0.0-2.7 | 0.22 |
| Erwakatra | 7.3-8.6 | 7.72 | 0.35-3.25 | 0.94 | 0.4-09.5 | 3.34 | 0.0-2.5 | 0.18 |
| Achalda | 7.5-8.4 | 7.75 | 0.33-3.24 | 0.88 | 0.7-09.6 | 3.12 | 0.0-2.9 | 0.24 |
| Sahar | 7.3-8.3 | 7.43 | 0.32-3.45 | 1.10 | 0.4-10.2 | 4.21 | 0.0-7.6 | 0.59 |
| Bhagyanagar | 7.3-8.5 | 7.76 | 0.38-4.05 | 1.14 | 0.3-10.0 | 3.52 | 0.0-2.0 | 0.15 |

Table 87. Frequency distribution of groundwater samples of Auraiya district

| Category | Ajitmal | Bidhuna | Erwakatra | Achalda | Sahar | Bhagya-nagar | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| Good | 24 | 21 | 18 | 23 | 27 | 26 | 139 | 68.14 |
| M. Saline | 05 | 05 | 06 | 07 | 10 | 09 | 42 | 20.59 |
| Saline | -- | 01 |  | 01 | 2 | 01 | 05 | 2.45 |
| H. Saline | -- | -- | 02 | -- | -- | 01 | 03 | 1.47 |
| M. Alkali | 02 | -- | -- | 01 | 2 | -- | 05 | 2.45 |
| Alkali | 01 | 01 | 01 | -- | 1 | 02 | 06 | 2.94 |
| H. alkali | -- | 01 | -- | 02 | 01 | - | 04 | 1.96 |
| Samples | 32 | 29 | 27 | 34 | 43 | 39 | 204 | -- |

belonged to saline, 03 (1.47 %) belonged to highly saline, 05 (2.45%) belonged to marginally alkaline, 06 (2.94 %) belonged to alkali and 04 (1.96 %) belonged to highly alkaline category. The results are presented in Table 87.

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

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 from CGWB was collected 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 CSSRI. The ground water quality of all the districts was classified according to ICAR-CSSRI classification (Table 88).

**Groundwater quality of Kerala for irrigation:** 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.

Table 88. Classification of ground water samples in Kerala for irrigation

| Sl No | District | No. of samples | Good (%) | Marginally saline (%) | Saline(%) | High SAR Saline (%) | Marginally alkali (%) | High alkali (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Thiruvanathapuram | 38 | 89.47 | 2.63 | 7.89 | | | |
| 2. | Kollam | 21 | 95.23 | 4.76 | | | | |
| 3. | Pathanamthitta | 5 | 100.00 | | | | | |
| 4. | Kottayam | 17 | 82.35 | 11.76 | 5.88 | | | |
| 5. | Alappuzha | 56 | 87.50 | | | | 7.14 | 5.35 |
| 6. | Ernakulam | 28 | 75.86 | | | 20.68 | 3.40 | |
| 7. | Idukki | 28 | 100.00 | | | | | |
| 8. | Thrissur | 33 | 93.93 | | | 6.06 | | |
| 9. | Palakkad | 22 | 97.00 | | | | 3.00 | |
| 10. | Kozhikode | 19 | 73.68 | | | | 26.31 | |
| 11. | Kannur | 15 | 60.00 | | | | 26.66 | 13.33 |
| 12. | Wayanad | 23 | 100.00 | | | | | |
| 13. | Malappuram | 20 | 35.00 | | | | 65.00 | |
| 14. | Kasargod | 26 | 73.07 | 3.86% | | | 23.07 | |

### Drip Irrigation to Cotton in Alkali Soils using Ameliorated Alkali Water (Tiruchirapalli)

The experiment was initiated to study efficacy of application of ameliorated alkali water using gypsum and using distillery spent wash through drip irrigation to cotton along with soil application of gypsum and distillery spent wash (Table 89). The field layout was prepared in strip-plot design at A6b farm of ADAC&RI, Tiruchirapalli to study the efficacy of ameliorated alkali water using gypsum and distillery spent wash applied through drip irrigation on cotton BG II hybrid RCH - 20. The pH, EC, organic carbon content and ESP of the initial experimental field soil were 8.90, 0.44 $dSm^{-1}$, 0.50% and 23.4%, respectively. The available nitrogen, phosphorus and potassium content of the initial experimental field soil were 179, 15.7 and 162 kg $ha^{-1}$, respectively. The experimental soil was reclaimed through distillery spent wash and gypsum as per the treatment details. Then the experimental plot was thoroughly ploughed to bring optimum soil tilt and the layout was taken up forming ridges and furrows with a spacing of 90 cm.

**Amelioration of alkali water:** Among the different treatments tried to ameliorate the alkali water (pH 8.96 and RSC 7.6), injection of DSW to drip system at 1:250 ratio could reduce the pH of irrigation water from 8.96 to 6.95 with complete neutralization of RSC (Table 90). Gypsum bed treatment reduced the RSC to 3.4.

**Post Harvest Soil pH, EC & ESP:** Among the main plot treatment $M_2$ recorded with a lowest pH followed by $M_1$ and $M_3$. Among the sub plot treatment $S_2$ recorded with a least

Table 89. Treatment details

| Main plot: Water treatment (3) | | Sub-plot: Soil treatment (3) | | Other Details |
|---|---|---|---|---|
| M1 | Drip with gypsum bed treated water | S1 | Soil application of gypsum @ 50% GR | Design : Strip- plot design<br>Replications : Four |
| M2 | Drip with spent wash treated water | S2 | One time application of DSW @ 5 lakh liters ha-1 | Crop : Cotton<br>Hybrid : RCH 20 |
| M3 | Drip with untreated alkali water | S3 | No amendments | Spacing : 90 x 60 cm |

Table 90. Changes in quality of ameliorated alkali water

| Sr. No. | Treatment | pH | EC (dS $m^{-1}$) | RSC |
|---|---|---|---|---|
| 1 | Alkali water (untreated) | 8.96 | 1.62 | 7.6 |
| 2 | Gypsum bed treated water | 8.20 | 1.80 | 3.4 |
| 3 | Distillery spent wash treated water (1:250) | 6.95 | 1.92 | Nil |

Table 91. Effect of drip irrigation using ameliorated alkali water and soil amendments on ESP content of post harvest soil

| Treatments (M: Drip Irrigation / S: Soil amendment) | $S_1$: (Gypsum @ 50% GR) | $S_2$: ( DSW @ 5 lakh liters $ha^{-1}$) | $S_3$: (Control) | Mean |
|---|---|---|---|---|
| $M_1$: (Gypsum bed) | 14.13 | 12.48 | 22.43 | 16.34 |
| $M_2$: (DSW treated) | 13.98 | 11.28 | 21.68 | 15.64 |
| $M_3$: (Alkali water ) | 18.10 | 17.28 | 24.10 | 19.81 |
| Mean | 15.40 | 13.68 | 22.72 | |
| | | SED | CD(0.05) | |
| | M | 0.190 | 0.46 | |
| | S | 0.210 | 0.44 | |
| | M at S | 0.353 | 0.78 | |
| | S at M | 0.364 | 0.77 | |

pH value followed by $S_1$ and $S_3$. There is no significant interaction between main plot and sub plot treatment. Among the main plot treatment $M_3$ recorded the least value of soil EC followed by $M_1$ and $M_3$. Among the sub plot treatment $S_3$ recorded with a significant lowest value of soil EC followed by $S_1$ and $S_2$. There is a significant interaction between main plot and sub plot treatments. The treatment combination $M_3S_3$ and $M_1S_3$ recorded with a least post harvest soil EC which are on par with each other. The highest value soil EC is recorded for the treatment $M_2S_2$. The post harvest soil ESP value is presented in Table 91. Among the main plot treatment $M_2$ recorded with lowest ESP value followed by $M_1$ and $M_3$. Among the sub plot treatment $S_2$ recorded with a lowest ESP value followed by $S_1$ and $S_3$. There is a significant between main plot and sub plot. The treatment $M_2S_2$ recorded with a lowest soil ESP value followed by $M_1S_2$. The highest soil ESP value was recorded for the treatment $M_3S_3$.

### Effect of ameliorated alkali water on cotton yield

The results showed that among the main plot (drip irrigation) treatment, the treatment $M_1$ recorded with significantly seed cotton yield of 1.5 t $ha^{-1}$ followed by $M_2$ with a seed cotton yield of 1.31 t $ha^{-1}$. The treatment $M_3$ recorded with significantly lowest seed cotton yield of 0.93 t $ha^{-1}$. Among the sub plot (soil amendments) treatments $S_2$ (application of DSW @ 5 lakh litres $ha^{-1}$) recorded with statistically highest seed cotton yield of 1.48 t $ha^{-1}$ followed by $S_1$ (application of gypsum @ 50%GR). The treatment $S_3$(control-no soil amendments) recorded with a least seed cotton yield of 0.98 t $ha^{-1}$. There is a significant interaction between different methods of alkali water treated irrigation in the main plot and application of different soil amendment in the sub plot. The treatment combination $M_1S_2$ ( drip irrigation with gypsum bed treated alkali water + application of DSW @ 5 lakh litres $ha^{-1}$ a soil amendment) recorded with a significantly highest seed cotton yield of 1.6 t $ha^{-1}$ followed by $M_2S_2$ and $M_1S_1$ which are statistically on par with a corresponding value of 1.6 and 1.54 t $ha^{-1}$ respectively. The treatment $M_3S_3$ (drip irrigation with untreated alkali water + control-no soil amendments) recorded with a lowest seed cotton yield of 0.74 t $ha^{-1}$.

Table 92. Initial soil properties of experimental plot

| Sr. No. | Particulars | Values | Sr. No. | Particulars | Values |
|---|---|---|---|---|---|
| 1. | pH | 6.82 | 7. | $Ca^{+}2$(me $L^{-1}$) | 196.0 |
| 2. | EC (d $Sm^{-1}$) | 2.35 | 8. | $Mg^{+}$ (me $L^{-1}$) | 179.0 |
| 3. | $CO_3$- (me $L^{-1}$) | 0.00 | 9. | $Na^{+}$ (me $L^{-1}$) | 20.89 |
| 4. | $HCO_3$- (me $L^{-1}$) | 2.00 | 10. | $K^{+}$(kg $L^{-1}$) | 913.65 |
| 5. | Cl- (me $L^{-1}$) | 10.0 | 11. | RSC (me $L^{-1}$) | 0.0 |
| 6. | $SO_4$-(mg $kg^{-1}$) | 3.89 | 12. | SAR (me $L^{-1}$) | 4.314 |

### Effect of various salinity levels of irrigation water on growth of leafy vegetables in coastal saline soils of Konkan in *rabi* season (Panvel)

The experiment was laid out with five levels of irrigation water. The objective of the experiment was to study response of leafy vegetables to saline water irrigation and to study the changes in soil properties. The experiment was conducted during *rabi* 2018-19 for Radish, Dill and Spinach with five levels of saline water irrigation (by surface irrigation). The initial pH and EC of experimental soil were 6.82 and 2.35 dS $m^{-1}$, respectively. Other chemical properties are provided in Table 92. The experimental soil was clay loam in texture, neutral in reaction, medium in available nitrogen and phosphorus and very high in potassium. Details of treatments for saline water use irrigation are given in Table 93.

Table 93. Treatments Details

| A) Crop | B) Salinity of irrigation water |
|---|---|
| Spinach ($C_1$) | • Pond water ($T_1$) |
| Dill ($C_2$) | • 2 $dSm^{-1}$($T_2$) |
| Radish ($C_3$) | • 4 $dSm^{-1}$($T_3$) |
| | • 6 $dSm^{-1}$($T_4$) |
| | • 8 $dSm^{-1}$($T_5$) |

Data about influence of irrigation water salinity on crop yield are provided in Table 94. As far as effect of salinity of irrigation water is concerned, application of pond water $T_1$ (13.62 $tha^{-1}$) showed significantly higher vegetable yield over rest of all treatments. The crop $C_3$ i.e. radish (15.47 t $ha^{-1}$) produced significantly higher yield over $C_1$ (Spinach 9.49 t $ha^{-1}$) and $C_2$ (Dill 8.31 t $ha^{-1}$). In case of interaction effect, $T_1C_3$ i.e. irrigation of radish crop with pond water recorded significantly higher yield (18.78 t $ha^{-1}$) over rest of all the interactions. It will be interesting to understand economics of growing different vegetables with saline water considering their market prices.

### Integrated nutrient management in Pearl millet-wheat under saline water irrigation (Hisar)

The study was conducted at CCS HAU, Hisar to work out the performance of microbial culture on the pearl-millet (HHB 223) and wheat (WH 1105) crop when irrigated with saline water of EC 8 dS $m^{-1}$ along with different levels of recommended doses of fertilizer. Seed of both the crop were treated with the microbial cultures '*Azotobacter ST-3* and

Table 94. Influence of irrigation water salinity on crop yield (t $ha^{-1}$)

| Treatments | Spinach ( C1) | Dill ( C2) | Radish ( C3) | MEAN | |
|---|---|---|---|---|---|
| Pond water (T1) | 10.98 | 11.10 | 18.78 | 13.62 | |
| 2 d $Sm^{-1}$ (T2) | 10.49 | 7.49 | 16.46 | 11.48 | |
| 4 d $Sm^{-1}$ (T3) | 7.61 | 10.30 | 10.34 | 9.42 | |
| 6 d $Sm^{-1}$ (T4) | 8.91 | 8.06 | 16.11 | 11.02 | |
| 8 d $Sm^{-1}$ (T5) | 9.44 | 4.62 | 15.65 | 9.90 | |
| MEAN | 9.49 | 8.31 | 15.47 | | |
| SE± m for salinity levels | 0.41 | SE± m for crop | 0.31 | SE± m for interaction | 0.71 |
| CD @5% | 1.18 | CD @5% | 0.92 | CD @5% | 2.05 |

Table 95. Effect of various treatments on grain and stover yield (t ha-1) of pearl millet under saline water irrigation

| Treatment | Grain | Stover |
|---|---|---|
| 75% RDF | 2.42 | 6.82 |
| RDF | 2.65 | 7.55 |
| 75% RDF +ST-3 | 2.45 | 6.90 |
| RDF +ST-3 | 2.67 | 7.65 |
| 75% RDF +2.5t $ha^{-1}$ biogas slurry + ST-3 | 2.77 | 8.05 |
| RDF +2.5t $ha^{-1}$ biogas slurry + ST-3 | 2.80 | 8.07 |
| 75% RDF + 2.5t $ha^{-1}$ Vermicompost + ST-3 | 2.80 | 7.96 |
| RDF + 2.5t $ha^{-1}$ Vermicompost + ST-3 | 2.86 | 8.34 |
| 75% RDF + 10t $ha^{-1}$ FYM + Biomix | 2.94 | 8.45 |
| RDF + 10t $ha^{-1}$ FYM + Biomix | 2.95 | 8.55 |
| 75% RDF + 2.5t $ha^{-1}$ Vermicompost + Biomix | 2.82 | 8.10 |
| RDF + 2.5t $ha^{-1}$ Vermicompost + Biomix | 2.95 | 8.48 |
| CD (p=0.05) | 0.19 | 0.65 |

ST-3= Azotobacter chrococuum, Biomix = Azotobacter chrococuum (Mac27) + Azospirillum + PSB Composition of biogas slurry: N=1.72%, P=1.21%, K=1.67%, FYM: N=0.72%, P=0.48%, K=1.02%, Vermicompost: N=1.58%, P=0.80%, K=1.06%

*Biomix* at the time of sowing. Recommended cultural practices and fertilizer doses were applied for raising the crops. Treatment details are given in Table 95. The crops were harvested at maturity and yield data were recorded for each plot.

**Pearl millet:** The grain and stover yield (2.95 and 8.55 t $ha^{-1}$) of pearl millet was obtained with RDF + FYM 10 t $ha^{-1}$ + Biomix followed by RDF +2.5 t $ha^{-1}$ vermicompost + Biomix (2.95 and 8.48 t $ha^{-1}$) Table 3.33. The minimum grain and stover yield (2.42 and 6.82 t $ha^{-1}$) was recorded with 75% RDF alone (Table 95).

**Wheat:** The maximum grain and straw yield (5.31 and 8.34 t $ha^{-1}$) of wheat (WH 1105) was obtained with RDF + 10t $ha^{-1}$ FYM + Biomix followed by RDF +2.5 t $ha^{-1}$ vermicompost + Biomix (5.30 and 8.27 t $ha^{-1}$).The minimum grain and straw yield (4.48 and 6.97 t $ha^{-1}$) was recorded with 75% RDF alone (Table 96).

Table 96. Effect of various treatments on grain and straw yield (t $ha^{-1}$) of wheat under saline water irrigation

| Treatment | Grain | Straw |
|---|---|---|
| 75% RDF | 4.48 | 6.97 |
| RDF | 4.95 | 7.80 |
| 75% RDF +ST-3 | 4.55 | 7.05 |
| RDF +ST-3 | 5.00 | 7.88 |
| 75% RDF +2.5t $ha^{-1}$ biogas slurry + ST-3 | 5.08 | 7.96 |
| RDF +2.5t $ha^{-1}$ biogas slurry + ST-3 | 5.23 | 8.18 |
| 75% RDF + 2.5t $ha^{-1}$ Vermicompost + ST-3 | 5.19 | 8.25 |
| RDF + 2.5t $ha^{-1}$ Vermicompost + ST-3 | 5.30 | 8.27 |
| 75% RDF + 10t $ha^{-1}$ FYM + Biomix | 5.21 | 8.23 |
| RDF + 10t $ha^{-1}$ FYM + Biomix | 5.31 | 8.34 |
| 75% RDF + 2.5t $ha^{-1}$ Vermicompost + Biomix | 5.22 | 8.26 |
| RDF + 2.5t $ha^{-1}$ Vermicompost + Biomix | 5.30 | 8.27 |
| CD (p=0.05) | 0.54 | 0.89 |

# Technology Assessed and Transferred

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

The study was undertaken to assess the socio-economic impact and constraints across the lateral spacing of SSD in waterlogged and saline conditions in Maharashtra. The SSD projects in Maharashtra were planned with 15 m lateral spacing along with closed main drain and control valve in each farmer's field. Primary survey for data collection was done from selected SSD villages located in Kolhapur district of Maharashtra during 2019-20 by using random sampling technique. The beneficiary farmers, contractor engineers, sugar factory officials and government officials of state line departments were interviewed for data collection.

The farmers' perceptions were recorded separately for all the three systems of lateral spacing of SSD pipes (15 m, 20 m and 30 m) for 9 different factors and these factors were again categorized as 'low', 'medium' and 'high' across the spacing. The preferences given by the farmers for each factors were then converted into percentages. The study indicated that more than half of the farmers (82%) felt that the initial capital requirement is 'high' in 15 m spacingas compared to 20 m and 30 m spacing. Maintenance cost was'low' in 15 m spacing expressed by 76% farmers as compared to 'medium' and 'high' in 20 m and 30 m spacing, respectively. Social cooperation among the farmers was 'low' across the spacing, whereas the benefits accrued was'high' in 15 m spacing, perceived by 90% farmers as against 'medium' and 'low' in 20 m and 30 m spacing, respectively. The study revealed that the yield and income benefit was higher with closer (15 m) spacing of laterals as compared to higher spacing (20 m and 30m). Majority farmers (over 80%) adopting 15 m lateral spacing agreed that SSD had higher economic benefits, had scope for land improvement, increased yield and income and market value of land rendering and it was best practice available for managing waterlogging and salinity problem in the study area. Similar opinions were expressed by farmers with 20 m and 30 m lateral spacing but to the lesser extent of economic benefit in terms of yield and return from sugarcane crop.

### Socio-economic Constraints faced by potential adopters and adopters of SSD

The socio-economic constraints faced by farmers for SSD adoption was recorded separately for farmers who have already adopted SSD as well as farmers who may adopt such system in future (potential adopters). The analysis includes all the three systems of lateral spacing of SSD pipes (15 m, 20 m and 30 m) with respect to five major constraints *viz,* resources, technological, economic, extension and social constraints (Table 97). The study revealed that lack of institutional support in terms of providing credit as well as subsidy was the most 'severe' constraint as opined by the farmers across the spacing as far as potential adopter farmer's area concerned. Apart from this, the high cost of technology and lack of available capital with the farmers were also 'severe' concerns expressed by the farmers in the study region. The technological constraints were of 'least' concern for the farmers as there was no difficulty arised in the technology implementation. In case of farmers who have already adopted the SSD system, expressed that loss of irrigation water due to continuous flow of drain water, lack of space for disposal of drain water and high rate of interest on loan were the most 'severe' constraints. They clearly indicated that SSD system was providing them good economic return and there was no major constraint as far as technology was concern.

Table 97. Socio-economic constraints of potential adopters of SSD in the study area

| Constraints | Potential adopters category of SSD<br>Distance between Lateral spacing of SSD pipes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 15 m (N=21) | | | 20 m (N=3) | | | 30 m (N=1) | | |
| | Severe | Moderate | Least | Severe | Moderate | Least | Severe | Moderate | Least |
| ***Resource Constraints*** | | | | | | | | | |
| Lack of institutional support (Credit facility/ subsidy) | 80.95 | 19.05 | 0.00 | 66.67 | 33.33 | 0.00 | 100.00 | 0.00 | 0.00 |
| Unavailability of trencher (SSD) machine on time | 0.00 | 23.81 | 76.19 | 0.00 | 33.33 | 66.67 | 0.00 | 0.00 | 100.00 |
| ***Technological constraints*** | | | | | | | | | |
| Changes in layout design of SSD at the time of installation | 4.76 | 9.52 | 85.71 | 0.00 | 33.33 | 66.67 | 0.00 | 0.00 | 100.00 |
| Use of low quality materials in SSD | 0.00 | 4.76 | 95.24 | 0.00 | 33.33 | 66.67 | 0.00 | 0.00 | 100.00 |
| ***Economic constraints*** | | | | | | | | | |
| High cost of technology | 85.71 | 14.29 | 0.00 | 66.67 | 33.33 | 0.00 | 100.00 | 0.00 | 0.00 |
| Lack of adequate capital | 80.95 | 19.05 | 0.00 | 100.00 | 0.00 | 0.00 | 100.00 | 0.00 | 0.00 |
| ***Extension constraints*** | | | | | | | | | |
| Lack of knowledge about SSD | 47.62 | 33.33 | 19.05 | 33.33 | 66.67 | 0.00 | 0.00 | 100.00 | 0.00 |
| Lack of technical expertise Social constraints | 76.19 | 14.29 | 9.52 | 33.33 | 33.33 | 33.33 | 0.00 | 100.00 | 0.00 |
| Lack of cooperation among neighbouring farmers for installing collector pipes | 19.05 | 52.38 | 28.57 | 66.67 | 33.33 | 0.00 | 100.00 | 0.00 | 0.00 |
| No space for disposal of drain water | 66.67 | 23.81 | 9.52 | 0.00 | 33.33 | 66.67 | 0.00 | 100.00 | 0.00 |

## Salient observations

Viewing the effectiveness of such SSD system, during recent years, sugar factories were playing a pivotal role in funding and implementation of SSD in Maharashtra. Recent SSD projects in the state were planned with 15 m lateral spacing with closed main drain and control valve for each farmer's field with an estimated cost of ₹2.43 lakh $ha^{-1}$ with 15 m spacing. The yield of sugarcane and return increased with lesser lateral spacing and vice-versa. The market value of reclaimed saline land has increased by 163 per cent from ₹7.17 lakh to ₹18.86 lakh per hectare after SSD implementation.The farmers' perception on SSD installation reveals that the cost of SSD and economic benefits were inversely related to spacing of lateral SSD pipes. Majority farmers were adopting 15 m lateral spacing and agreed that SSD had higher economic efficiency with scope for land improvement, increasedthe crop yield, income and market value of land and it was the best practice for managing waterlogging and soil salinity. Farmers adopting 20 m and 30 m lateral spacing also had similar opinion but to the lesser extent in terms of benefit. Lack of institutional support in terms of providing credit as well as subsidy was the most severe constraint as opined by the farmers across the spacing. Apart from this, the high cost of technology and lack of available capital with the farmers were also severe concerns. The technological constraints were of least concern for the farmers as there was no difficulty arised in the technology implementation. Overall, the SSD system was the most suitable practice for managing waterlogged and saline soils in study area.

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

Key objectives of the project are to analyse extent and magnitude of technology adoption for management of salt-affected soils (SAS) in India, its implications on farm income, food security and suggesting suitable policy needs. Overall, it was estimated that SAS districts across states were accounting for 62% of the population and 61% of the NSA within the respective states. Overall, the SAS districts across the states were accounted for producing 55% of rice and 61% of wheat in their respective states. Average yield of rice and wheat in SAS districts were 2.61 t $ha^{-1}$ and 2.91 t $ha^{-1}$, respectively as compared to states' average yield of 2.73 t $ha^{-1}$ (rice) and 2.75 t $ha^{-1}$ (wheat), indicated that average yield of rice within SAS districts were marginally lower but wheat yield was marginally higher than the states' average yield. At aggregate level, in terms of production (1293 lakh t) and consumption demand (765 lakh t) of rice and wheat, the status of SAS districts were food surplus (529 lakh t).

The impact studies indicated that the incremental yield (due to technology) of rice, wheat, cotton and sugarcane were, 2.03 t $ha^{-1}$, 1.55t $ha^{-1}$, 0.87 t $ha^{-1}$ and 60 t $ha^{-1}$, respectively, under SSD installed area. Gypsum use provided incremental yield of 3.96 t $ha^{-1}$ for rice and 2.60 t $ha^{-1}$ for wheat. Land modification technology created the option for cultivation of more high-value crops such as fruits and vegetables instead of rice or wheat. The CSSRI technologies successfully provided incremental cropping intensities (121 to 175%), incremental net return (Rs. 26000 to Rs. 183929 per ha) and incremental output-input ratio (1.10 to 1.37) across the regions under the large scale-demonstration of the technologies. This indicated that the CSSRI technologies have desired potential to be implemented in larger areas for increasing farmers' income gainfully. In terms of financial viability of key CSSRI technologies, it showed that all the financial criteria (IRR, BCR, NPV and Payback period) were favourable for investment with positive return. (Table 98)

Table 98. Financial viability and impact of SAS technologies of ICAR-CSSRI on crops and net return under large scale demonstration

| **Criteria** | **ICAR-CSSRI Technology** | | | |
|---|---|---|---|---|
| | **Sub-surface drainage** | **Gypsum use** | **Land shaping (coastal)** | **Land modification (waterlogged sodic)** |
| ***Incremental yield (t/ha)*** | | | | |
| *-Rice* | 2.03 | 3.96 | - | 2.35 |
| *-Wheat* | 1.55 | 2.60 | - | 1.83 |
| *-Cotton* | 0.87 | | - | - |
| *-Sugarcane* | 60 | | - | - |
| Incremental Cropping Intensity (%) | 121 | 170 | 140 | 175 |
| Incremental Net Return (Rs $ha^{-1}$) | 79462 | 26000 | 137526 | 183929 |
| Incremental O/I ratio | 1.17 | 1.37 | 1.22 | 1.10 |
| Avg. Initial Inv. (Rs $ha^{-1}$) | 98719 | 57520 | 120539 | 465478 |
| Internal Rate of Return (%) | 36.38 | 35.47 | 48.60 | 44.00 |
| Benefit Cost Ratio | 2.39 | 1.78 | 1.54 | 1.28 |
| Net Present Value (Rs) | 113000 | 56000 | 232326 | 1.86 |
| Payback period (years) | 4.40 | 2.67 | 1.86 | 2.31 |

CSSRI technologies have large contribution towards profitable management of SAS in the country which are financially viable across problem areas. Public investments on SAS management are needed to increase with active guidance/collaboration of CSSRI. Different key issues for out-scaling of CSSRI technologies at large scalefor SAS management in relation to policy have been identified as; sometimes the management options are technically feasible but challenged by socio-economic factors such as high investment cost, land size, instability in return; crop losses due to salt-affected soils are often quite high at farm/plot-level but not recognised at macro level because normal and problem soils co-exist and part of the crop losses are compensated by the production from good land at aggregate level; cost of land degradation is high but replacement of input cost or amelioration is also high, therefore the trade-offs between action and no-action often remains unfavourable at private cost (i.e., without subsidy or public support); benefits of ecosystem services gained through good agricultural practices remains intangibles, that has high social but lesser private benefits - need social cost-benefits accounting instead of focusing only through private cost-benefits; and strategy/solution needed for diagnosing future problems areas well ahead of time so thatprecautions along with the reclamations programmes can be taken up and promotion of good agricultural practices with incentives and restriction of exploitative practices through regulatory measures.

## Screening and Evaluation of Wheat, Mustard and Rice genotypes for sodicity tolerance (Y.P. Singh and V.K. Mishra)

### Wheat

#### All India salinity/alkalinity tolerance screening nursery trial

All India salinity/alkalinity tolerant screening nursery trial on wheat consisted of 32 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 9.0 and $EC_2$ 0.43dS $m^{-1}$. Each entry was sown in a gross plot size of 3$m^2$ with three rows of 5 m length. The trial was sown on 20.11.2019 and harvested on 13.04.2020. Recommended dose of fertilizer (120:60:40 N: P: K) was applied. Among the genotypes evaluated, genotype SATSN02, SATSN 05, SATSN01 ranked 1$^{st}$, 2$^{nd}$ , and 3$^{rd}$ in terms of grain yield and produced 4.50, 4.47 4.42 t $ha^{-1}$ respectively.

### Mustard

#### All India coordinated trial on rapeseed mustard

An IVT Mustard saline/alkaline trial consisted of 8 lines was conducted under alkaline condition ($pH_2$ 9.05 and $EC_2$ 0.30dS$m^{-1}$) at CSSRI, Research farm Shivri, Lucknow. These lines were sown on 15.10.2019 and harvested on 05.03.2019. Three times replicated field experiment with 6 rows of each entry at a spacing of 45 x 15cm was conducted in Randomized Block design. Observations like days to 50% flowering, plant height, number of primary branches, number of secondary branches, main shoot length, number of siliqua on main shoot, days to maturity and grain yield were recorded. Significant differences were observed in seed yield amongst the genotypes evaluated. Highest grain yield was recorded in entry CSCN 19-5 (1.684 t $ha^{-1}$) followed by CSCN19-3 (1.214 t $ha^{-1}$) and CSCN19-4 (1.207 t $ha^{-1}$) (Fig. 72).

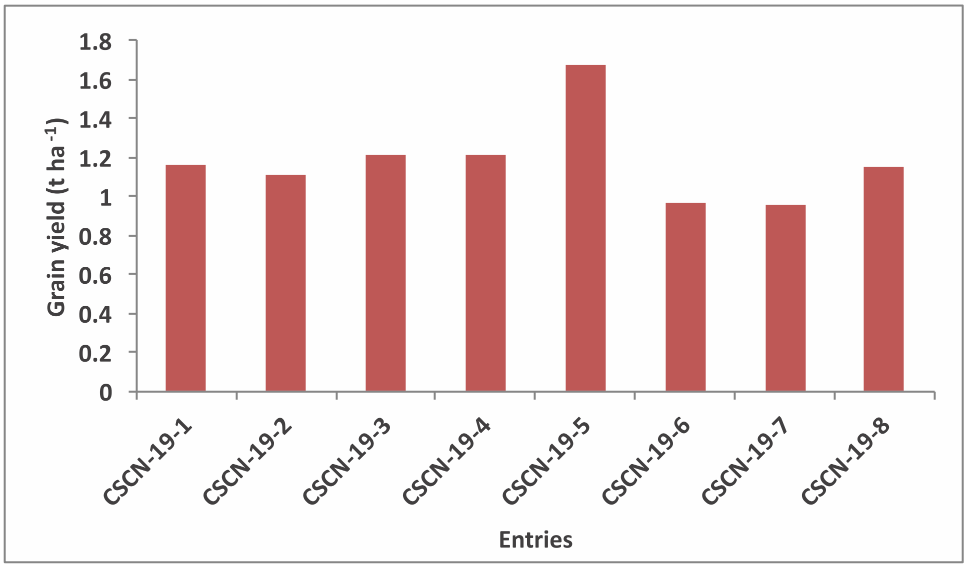



Fig 72. Grain yield of mustered strains in alkaline conditions

## Rice

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

Advance variety trial consisting of 16 rice entries (entry no.4501 to 45015) including one local check (Bioseed 501) was conducted during Kharif 2020 at CSSRI, Research farm, Shivri, Lucknow. The initial pH and EC of the experimental field was 9.7 and 1.1dSm$^{-1}$ respectively. The trial was conducted in RBD with four replications. Each line was planted at 20x15cm apart in 10 rows of 3m length having net plot size of 6.0 m$^2$. Thirty days old seedlings was planted on 07.08.2020. The recommended dose of fertilizer (150:60:40 N: P: K) and 25kg ha$^{-1}$ zinc sulphate was applied uniformly in all the entries. Among the entries evaluated, entry number 4511, 4510 and 4506 yielded 1.281,1.240 and 1.085 t ha$^{-1}$, respectively and ranked 1$^{st}$, 2$^{nd}$, and 3$^{rd}$ in terms of grain yield (Fig. 73).

### Initial varietal trial-Alkaline and Inland saline tolerant variety trial (IVT)

Advance variety trial consisting of 20 rice entries (entry no.4601- to 4620) including one local check (CSR36) was conducted during Kharif 2020 at CSSRI, Research farm, Shivri,

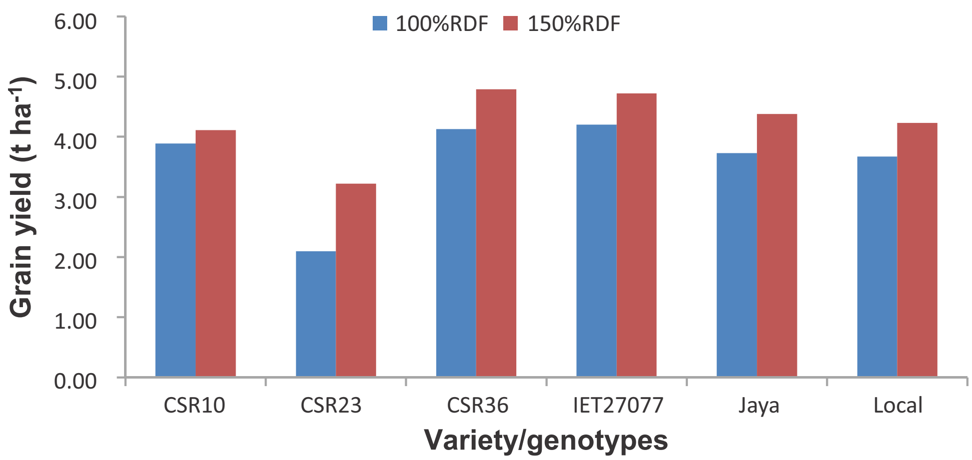



Fig 73. Grain yield of genotypes/ varieties under low and high N doses


Performance of rice genotypes under low and high nutrient doses

Lucknow. The initial pH and EC of the experimental field was 9.4 and 0.58dSm$^{-1}$ respectively. The trial was conducted in RBD with four replications. Each lines was planted at 20x15cm apart in 15 rows of 3m length having plot size of 9.0 m$^2$. Thirty days old seedlings was planted on 21.08.2020. The recommended dose of fertilizer (150:60:40 N: P: K) and 25kg ha$^{-1}$ zinc sulphate was applied uniformly in all the entries. Among the entries evaluated, entry number 4603 and 4613 were not germinated and 4617, 4602 and 4619 yielded 55.8, 45.8 and 32.5q ha$^{-1}$ respectively and ranked 1$^{st}$, 2$^{nd}$, and 3$^{rd}$ in terms of grain yield.

### All India Coordinated Agronomy Trial

Nitrogen response trials on selected AVT-2 rice cultures under high and low input management environments was conducted at Shivri farm, Lucknow during Kharif 2020 with the objectives to study the grain yield potential, nutrient response and nutrient use efficiency of promising AVT-2 cultures under high and low input management and to identify promising and stable genotypes based on the grain yield efficiency index. 30 days old seedlings of all the varieties were transplanted on 31.07.2020 at a spacing of 20cm x 15cm. The 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, Jaya and IET 27077 and one local check Bio-seed 501 in sub plots. Three times replicated experiment was laid in split plot design with a plot size of 15.4m$^2$. The initial soil pH and EC of the experimental field were 8.9 and 0.37dSm$^{-1}$ respectively. Maximum grain yield at 100% RDF was given by IET 27077 however, CSR 36 gave higher yield at 150% of recommended dose of fertilizer but there was no significant difference in grain yield between CSR 36 and IET 27077 (Fig. 73).

## 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 (T. Damodaran, V.K. Mishra and S.K. Jha)

### Survey sample collection and isolation of antagonistic rhizobacteria in Fusarium suppressive soils of hot spot regions

The survey area was restricted to the disease hot spot regions with a history of 30-40 % disease incidence continuously for five years. Banana rhizosphere soils, from approximately 10-20 cm layer was collected from the identified wilt suppressive sites located in the hot spot region of Mangalsi village (26˚46.30 N and 81˚59.748 E) of Ayodhya district, India that resulted in the isolation of 67 isolates from which 16 pure cultures were separated for antagonistic property evaluation.

Antagonism against FOC TR4

### In-vitro screening for antagonism against FOC TR4

A bioassay was conducted by dual culture technique. The antifungal activity of the 16 bacterial isolates against *F. oxysporum* f.sp. *cubense* Tropical race 4 was tested with dual plate culturing. Five isolates (CSR-D1, CSR-D2, CSR-D4, CSR-D5, and CSR-D16) inhibited the mycelial spread of *Fusarium* due to their antagonistic activities. We found that the isolate CSR-D4 significantly inhibited (77.59 %, ±14.61) the mycelial growth of the pathogen.


Evaluation of *B. licheniformis* banana plant for *Fusarium* disease control

### In-vivo evaluation of elite bacterial strain *B. licheniformis CSR-D4* on *Fusarium* disease control

Based on the results obtained from *in*-vitro dual plate assays and analysis of plant growth promotional activity, a systematic pot culture experiment on banana (cv. Grand Naine) was carried out from July- August 2019 and 2020 to assess the interaction between the bacterial isolates and the targeted wilt pathogen. After six weeks of inoculation, two plants in the infected treatment showed complete wilting and mortality, while the others were observed with severe leaf symptoms. In contrast, the plants treated with *B. licheniformis* CSR-D4 and challenge inoculated with *Fusarium oxysporum* f.sp. *cubense* Tropical race 4 showed mild leaf symptoms initially during the first week after inoculation but showed complete recovery after six weeks of planting. The healthy control plants (HC) without any microbial application remained healthy, without any sign of leaf chlorosis. Our study showed that the bacterial isolate *B. licheniformis* CSR-D4 (CSR-D4 + FOC TR4) was able to confer a high degree of tolerance to banana plants against the Fusarium infection.

### CSR-GROW-SURE – A bio-consortia for enhancing the productivity of agri-horticultural crops in salt affected soils.

CSR GROW-SURE is a unique bio-stimulant that has been developed using the highly efficient salt tolerant bacteria strains CSR-M-16 (*Bacillus licheniformis*), CSR-A-11 (*Lysnibacillus fusiformis*), CSR-A-16 (*Lysnibacillus sphaericus*) obtained from high stress rhizosphere cultured in a unique modified CSR medium which is under IPR protection. The four bacterial strains were made into consortia and cultured on a patent protected media. The formulation was assessed for growth and yield parameters in tomato var.NS585 grown in sodic soils of pH 9.14-9.30 in field experiment conducted at the sodic soil experimental research farm of CSSRI, Regional Research Station, Lucknow in field and pot experiment. The results clearly showed 10 percent more efficacy of the current consortia than the earlier CSRBIO. The consortia used in CSR-GROW-SURE gave the highest yield of 55.5 t $ha^{-1}$ with higher lycopene content (166.57 mg $kg^{-1}$) while the control exhibited the highest mortality index with an yield of 12.00 t $ha^{-1}$ and lycopene content of (44.22 mg $kg^{-1}$). The results were further evaluated in banana were CSR GROW-SURE comprising of the bacterial microbial consortia of CSR-M16, CSR-A11 and CSR-A16 resulted in successful cultivation of banana in partially reclaimed sodic soils of pH 9.2. The formulation was further validated in farmers field experiment at Samesi in UP in waterlogged sodic soils for two years. It was also evaluated at CSSRI, Karnal in DSR rice against the efficacy of 25% more Nitrogen dosage to increase the productivity of rice under DSR system.

Farmer field of waterlogged sodic soil at Samesi, Lucknow where tomato cultivation been successfully demonstrated with land modification model and application of CSR GROW-SURE

### Evaluation of CSR GROW-SURE in tomato at multilocations

A multilocation trial was conducted at three locations with different soil pH using CSR GROW-SURE at three different concentrations to assess its efficacy in increasing the growth, yield and quality parameters of the commercial salt susceptible high yielding variety NS 585. One set of untreated control was maintained for comparison. The trial was conducted at three locations situated at village Samesi, Lucknow District (land modification model in waterlogged sodic soil), Marx Nagar, Unnao, Uttar Pradesh and Dighri village, Kattihar district of Bihar (Normal soil). The desired concentration of the CSR GROW-SURE is mixed with water and incubated with 0.2 % of jaggery for 24 hours. The fermented formulation is through muslin cloth and drenched in the transplanted tomato crop at 10$^{th}$, 30$^{th}$ and 50$^{th}$ day after planting. Application of CSR GROW-SURE at 1 percent showed significant increase in yield, plant height and lycopene content of the crop under all types of soil. The yield decreased as the pH of the soil increased under all concentrations (Fig. 74). However, the treatment with 1 % CSR GROW-SURE acted as a bio-stimulant in inducing salt stress tolerance in the tomato plants at various pH range.

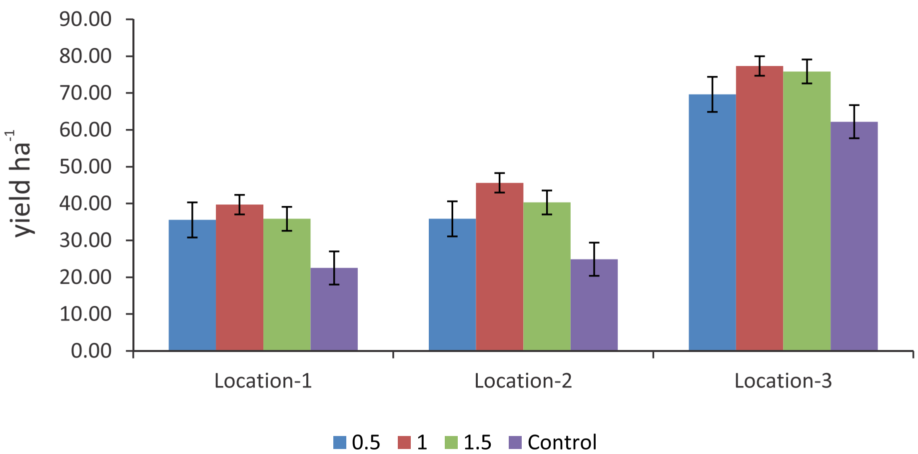



Fig 74. Efficacy of CSR GROW-SURE on the yield ha$^{-1}$ of tomato var. NS 585

## Generation of bio-efficacy and toxicological data for commercialization of the bio-formulation CSR-FUSICONT towards management of banana wilt caused by *Fusarium oxysporum* f. sp. cubense Tropical race 4 (ICAR EXTRAMURAL 2019-21) (T. Damodaran, S. Rajan and M. Muthukumar)

The biofungicide ICAR-FUSICONT developed by culturing the CSR-T-3 *Trichoderma reesei* on a patent protected media for the management of the fusarium wilt disease was studied for the mechanism of tolerance, shelf life studies, toxicological studies and multi-locational bio-efficacy studies for generating regulatory data and commercialization.

### Studies to assess the mechanism of tolerance induced by CSR-T-3 in the banana plants against FOC TR-4

LC-MS analysis was performed in the plant samples of treatments TC (treatment negative control), TF (treatment Foc-TR4), and TFTR (treatment Foc-TR4 and *Trichoderma reesei* isolate CSR-T-3) of the pot experiment to identify important organic compounds and their role in inducing host tolerance. The compounds identified from LC-MS analysis could be broadly categorized as phenolic esters, antioxidants, fatty acids, fungal toxins, and compounds with antifungal and antibacterial principles. The extracts from the treatment control (TC) showed distinct peaks for fatty acid compound 20-methyl spirolide G (MeG) and soyasapogenol e-3-o-rhamnosyl glucosyl glucuronide. The compounds in the crude extract of TFTR treatment with relative abundance was identified as ß-caryophyllene (1,429.9), catechin-o-gallate, soyasapogenol rhamnosyl glucoronide (729), peptaibols (1,788.2), fenigycin (1,462.2), iturin C19 (1,134.9), anthocyanin (1,191.7), and gallocatechin-o-gallate (913.5) (Fig. 75 E,F). Fungal toxins and metabolites produced by Fusarium spp. like enniatin A, fusarin C, chlamydosporal, etc. were also identified in TFTR treatment with low peak intensity (Fig. 75 C,D). The extracts of treatment Foc TR4 showed distinct compounds like fusaristatin A, fusarin C, chlamydosporal, and beauveric acid with high peak intensity (Fig. 75 A,B).

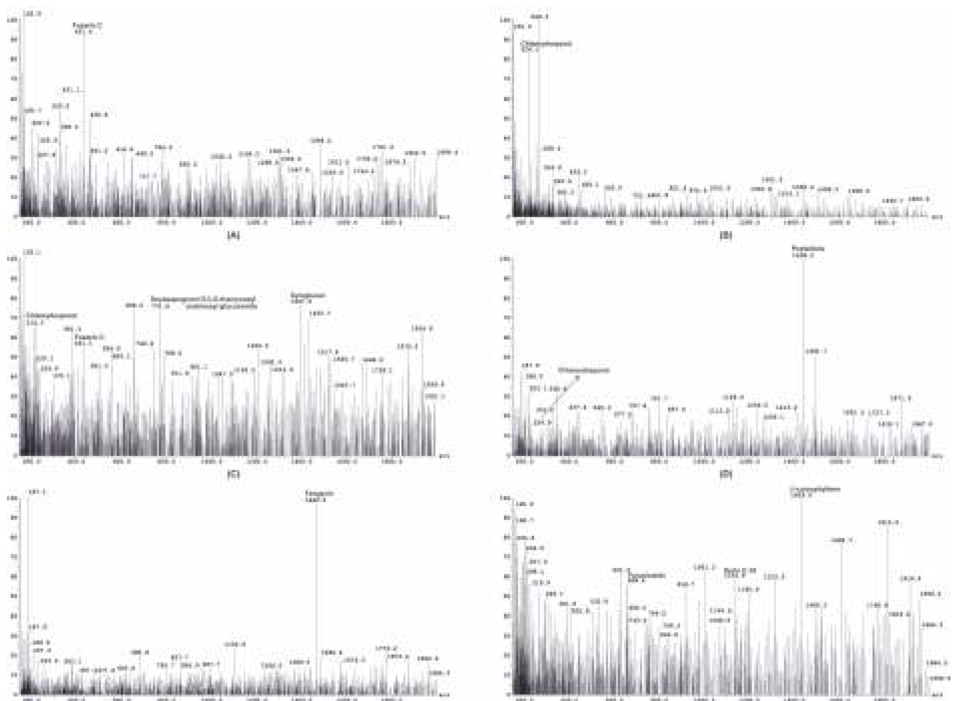


Fig 75. Gene Expression Profiling of Banana Plants With CSR-T-3 Treatment

### Gene Expression Profiling of Banana Plants With CSR-T-3 Treatment

Gene expression studies were conducted in Biotechnology lab of ICAR- Central Institute of Subtropical Horticulture, Lucknow by the team members of collaborative institute. Gene expression profiling revealed that the expression levels of Fusarium-related genes indicated a clear pattern of up regulation of the Fusaric acid biosynthesis genes in only Fusarium treatments (TF and TFTR) evident from the heat map presented in Fig. 75. In the case of Trichoderma mycoparasitism genes (TrCBH1, TrCBH2, TrEGL1, TrXYN1) and signal transduction pathway genes for secondary metabolite production (TrTGA1, TrTMK1, and TrVEL1) a distinct pattern of up regulation was recorded in only the Trichoderma treatments (TFTR and TTR). The significant up regulation of the Fusaric acid biosynthetic genes in TF and their corresponding down regulation in TFTR confirmed the suppression of Fusarium toxin production by T. reesei. An exception was recorded in the expression levels of the FUB3 gene which showed a trend toward no change in TFTR (Z score-0). Contrarily, the significant down regulation in TTR (i.e., almost no expression) also strongly affirms the absence of the pathogen Foc TR4 and thereby toxin pathway gene expressions are being curtailed. On the other hand, the mycoparasitism-related genes, such as TrCBH1, TrCBH2, TrEGL1, TrXYN1 were found to be significantly up regulated in TFTR and these genes were involved in the breakdown of the Foc cell wall and their components and are being produced by CSR-T-3.

**Mass multiplication of the bio-formulation commercialized by CSSRI for sustainable crop productivity in U.P. (RKVY – 2019-21)** (T. Damodaran, V.K. Mishra, P.C. Sharma and S.K. Jha)

Bio-fertilizer laboratory was established for the mass multiplicaiton of ICAR FUSICONT, CSR BIO, CSR GROW-SURE, HALO AZO, and HALO PSB on a large scale for the sustainable production of agri-horti crops in the normal and salt affected soils. The building is being successfully in construction and the equipments required for the laboratory has been purchased and production has been initiated on a pilot scale in the existing laboratory. A production of about 3.40q of CSR BIO and 4.00q of ICAR-FUSICONT in the current season and sold to the stakeholders.

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

At farm level, we require user-friendly soil moisture sensors, which require less technicality and should be cost effective to facilitate application of adequate amount and timely application of irrigation water. Sensors also facilitate automation of irrigation systems when sensor output is integrated with pump operation. This may facilitate in applying water judiciously but also results in saving of labour and energy cost. Considering above the project attempts to develop a soil moisture sensor which further can be employed for automation purposes. A prototype has been developed based on resistive concept and is under calibration and validation process.

The electronic circuit initially developed was modified including an electronic component named TL431 in the circuit which is known for adjustable voltage and current referencing, secondary side regulation in fly back SMPSs, zener replacement, voltage monitoring and comparator with integrated reference. The modified circuit was connected with probes. Two types of probes were designed a). Double leg and b). Single leg. The material used for

Table 99. Relationship between sensor output and gravimetric soil moisture content

| Sensor Code | Correlation | $R^2$ |
|---|---|---|
| **Prototypes** | | |
| S2 | $Y=-0.0003 X^2 -0.5844 X + 38.904$ | 0.62 |
| SAl4 | $Y=-0.002 X^2 -0.2883 X + 27.778$ | 0.57 |
| SAl5 | $Y= 0.0041 X^2 -0.8661 X + 37.157$ | 0.57 |
| SAl6 | $Y= 0.0071 X^2 -0.949 X + 35.775$ | 0.63 |
| **Commercial** | | |
| PMS-714 | $Y= -0.0213 X^2 + 1.6306 X - 6.0775$ | 0.77 |
| TSS | $Y=0.007 X^2 -0.5658 X + 12.844$ | 0.77 |

these were copper and aluminium pipes. Nine combinations were developed (3 for double leg and 6 for single leg probes). All the nine developed probes were initially screened for their performances. Based on the screening results one double leg probe comprising of one copper leg and one aluminium leg and three single leg probes fabricated from aluninium pipe was selected for field testing by attaching them with the developed electronic circuit. Besides this two commercial soil moisture sensor were also field tested for their performances. Based on the field performances the output of prototypes and commercial sensors were corelated with the observed gravimetric soil moisture content. The observed relationship is depicted in Table 99.

Overall, the results reflects that developed prototypes are working technically well but the correlation of prototypes output with observed gravimetric soil moisture contents is not satisfactory. As the $R^2$values observed for prototypes ranged between 0.57 to 0.62. Wide variation was also observed in the output of prototypes when observations were taken at same soil moisture content. This suggests that the prototypes require further improvement in the electronic circuit as well as in the design of probes. The two commercial soil moisture sensors i.e. TSS and PMS-714 were also evaluated for their performances and it was observed that output of both the sensors is in better correlation with observed gravimetric soil moisture values. The $R^2$ values observed in case of commercial sensors was around 0.77. The correlation between prototypes output and observed gravimetric soil moisture content was not satisfactory, hence the developed prototype needs further improvement.

## 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)

### Comparative performance of decomposer with Halo-CRD for in-situ paddy residue decomposition

In order to compare the efficacy of Halo-CRD for in-situ paddy residue decomposition, field experiments were continued. The consortia of two efficient and compatible halophilic bacterial lingo-cellulolytic strains having plant growth promotion traits were developed as liquid bio-formulation 'Halo-CRD'-a crop residue decomposer. The bioformulation Halo-CRD and Waste Decomposer was evaluated for use of in-situ residue degradation on the retained paddy residues in comparison to burning residues and use of urea. It was observed that application of liquid bio-formulation Halo-CRD resulted in maximum decrease in dry weight of the stubbles at 28 days after application during both the years which was followed by application of Waste decomposer. Stubble weight at 28 days decreased by more than 20% and 63% with Halo-CRD and Waste Decomposer compared to 14 days and date of application, respectively, indicating sufficient degradation for next crop sowing (Fig. 76). Similarly, the decline in C:N ratio with all the imposed residue management treatments showed the significant effect of use of Halo-CRD and Waste Decomposer in 28 days on paddy residue during both years (Fig. 77).

### Multilocation trials for use of Halo-CRD to avoid paddy residue burning

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 Unnao on moderately sodic soil showed that the use of Halo-CRD on paddy resulted in 12.6% higher average wheat yield compared to burning (Table 100). Also soil organic C content was upto 0.34% with use of Halo-CRD sprayed on residues compared to 0.31% in where the residues were burnt (Table 100).

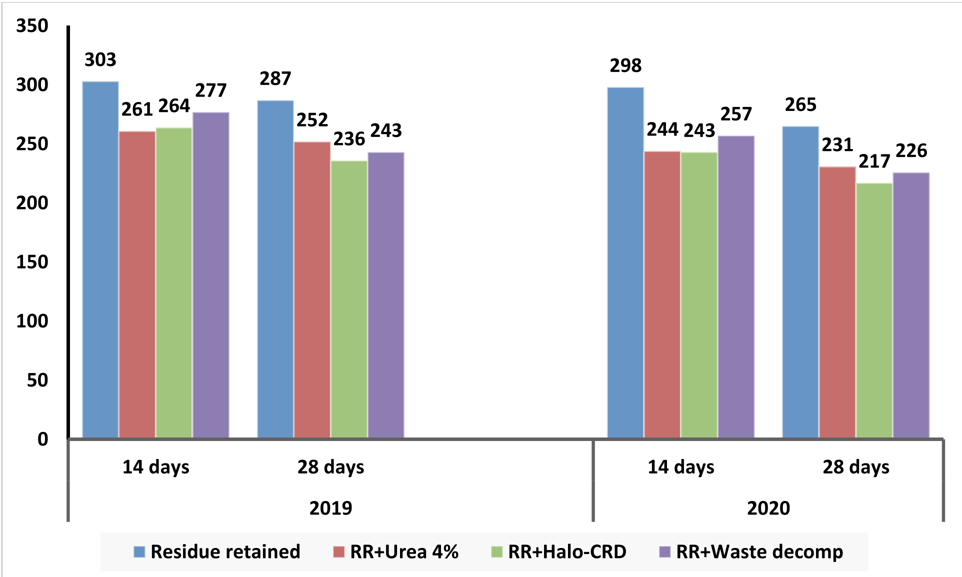



Fig 76. Effect of in-situ paddy residue decomposition on dry weight of paddy stubbles (g $m^{-2}$)

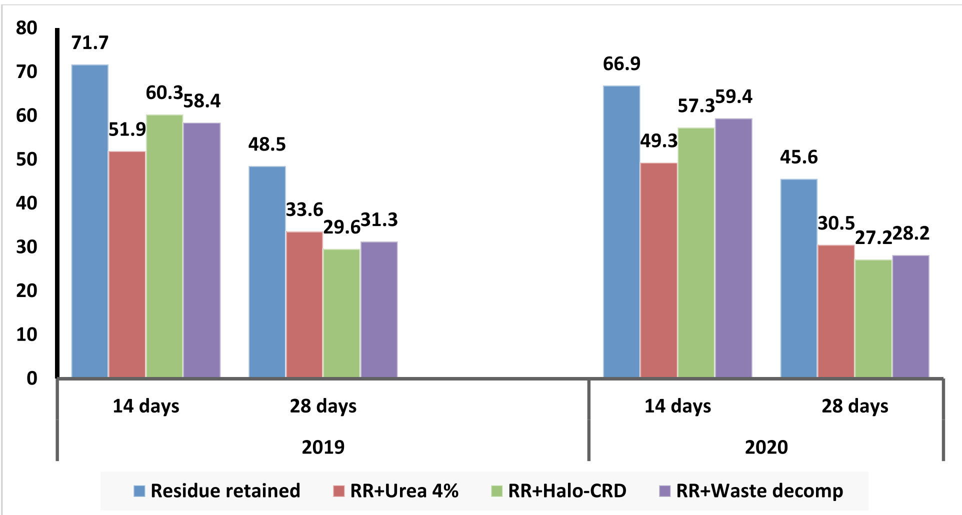



Fig 77. Effect of in-situ paddy residue decomposition on C:N ratio of residues

Table 100. Effect of Halo-CRD bioformulation on wheat yield at farmer's field in Unnao (2019-20)

| Treatments | No of farmers | Soil pH | Org. C (%) | Avg. grain yield (t $ha^{-1}$) |
|---|---|---|---|---|
| Residue burnt | 3 | 8.6-9.2 | 0.24-0.31 | 3.68 |
| Residue removed | 4 | 8.5-9.0 | 0.28-0.30 | 3.81 |
| Residue as such | 7 | 8.8-9.1 | 0.22-0.36 | 4.02 |
| Residue+CRD | 4 | 8.5-8.9 | 0.24-0.34 | 4.15 |
| CD(5%) | - | - | - | 0.21 |

The multilocation trials on use of Halo-CRD on paddy residues were continued in 6 districts on sodic and normal soils of Indo-Gangetic plains and monitored its effect on succeeding wheat crop as well as effect on changes in soil C status. It was observed that with incorporation of paddy residue along with inoculation of Halo-CRD, the subsequent wheat was on an average 9.8 to 11.22% higher compared to uninoculation (Table 101). On these locations, there was build up organic C in soils to the magnitude of 0.7 to 1.2 g $kg^{-1}$ and total C was enhanced to the tune of 33.3% with inoculation of paddy residue with Halo-CRD over un-inoculation (Table 102).

### GypKIT: A Field Testing Kit for Rapid Sodic Soil Assessment

The GypKIT was developed for estimation of gypsum requirement of sodic soils by team of scientist at ICAR-CSSRI, Regional Research Station, Lucknow. The Institute has licensed this technology after approval from Indian Council of Agricultural research, New Delhi

Table 101. Effect of CRD bioformulation on wheat yield (t $ha^{-1}$) at farmers field in different districts (2019-20)

| Locations | Soil pH | 2018-19 | | 2019-20 | |
|---|---|---|---|---|---|
| | | Without Halo-CRD | With Halo-CRD | Without Halo-CRD | With Halo-CRD |
| Raebareli (n=4) | 8.9-9.2 | 3.05 | 3.52 (25) | 2.85 | 3.27 (26)* |
| Hardoi (n=5) | 8.4-9.0 | 2.84 | 3.37 (30) | 3.24 | 3.57 (27) |
| Kanpur dehat (11) | 8.7-9.4 | 2.75 | 2.95 (26) | 2.56 | 2.85 (29) |
| Kausambi (n=5) | 8.5-9.1 | 3.15 | 3.34 (22) | 3.37 | 3.67 (28) |
| Lucknow (n=3) | 8.3-9.2 | 3.37 | 3.68 (23) | 3.41 | 3.52 (25) |
| Lakhimpur kheri (n=3) | 8.2-8.8 | - | - | 3.75 | 4.16 (26) |

* () average no. of days for wheat sowing after Halo-CRD use on paddy residue

Table 102. Changes in soil after paddy residue decomposition through Halo-CRD and incorporation

| Location | pH | SOC (%) | | Total C (g $kg^{-1}$) | | Total N (g $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After |
| Raebareli (n=4) | 8.9-9.2 | 0.17±0.08 | 0.29±0.11 | 3.57±0.54 | 4.18±0.71 | 0.21±0.02 | 0.26±0.05 |
| Hardoi (n=5) | 8.4-9.0 | 0.24±0.11 | 0.31±0.12 | 4.04±0.63 | 4.33±0.65 | 0.27±0.04 | 0.32±0.03 |
| Kanpur dehat (11) | 8.7-9.4 | 0.18±0.06 | 0.25±0.09 | 2.86±0.34 | 3.74±0.63 | 0.22±0.06 | 0.24±0.07 |
| Kausambi (n=5) | 8.5-9.1 | 0.24±0.07 | 0.30±0.14 | 3.21±0.74 | 4.28±0.71 | 0.27±0.04 | 0.34±0.04 |
| Lucknow (n=3) | 8.3-9.2 | 0.28±0.12 | 0.32±0.12 | 3.84±0.45 | 4.46±0.83 | 0.23±0.02 | 0.27±0.03 |
| Lakhimpur kheri (n=3) | 8.2-8.8 | 0.32±0.11 | 0.36±0.07 | 4.28±0.82 | 5.39±1.04 | 0.25±0.03 | 0.36±0.06 |


GypKIT Technology Transfer Event

through Agrinnovate India, New Delhi to M/s Parashar Agrotech Bio. Pvt. Ltd, Varanasi, Uttar Pradesh for commercial scale production and supply to farmers and other stakeholders. The technology was transferred after training by innovators Dr. Sanjay Arora, Dr. Atul K. Singh, Dr. Y.P. Singh, Dr. V.K. Mishra and Dr. D.K. Sharma in presence of Dr. P.C. Sharma, Director of the institute in a programme on December 30, 2020.

### Impact of Salt Tolerant Varieties in terms of additional food grain production and revenue generation

During the year 2020-21, about 0.97 t basmati rice, 1.4 t nonbasmati rice, 4.67 t wheat and 0.38 t of 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 (12.7 t of Basmati CSR 30, 3.87 t non-basmati and 28.52 t wheat) were

Table 103. Estimated impact of the salt tolerant varieties of rice, wheat and mustard during the year 2020-21

| Crop/variety | Multiplication ratio | Production year | 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]@ | MSPs (Rs./q)** | Estimated value of produce (Crore Rs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| A | B | C | D | E | F | G | H | I | J | K |
| **Rice** | | | | | | | | | | |
| Basmati CSR 30 | 1:80 | 2020 | 9.68 | 61952 | 127 | 62079 | 204861 | 409721 | 1888 | 774 |
| CSR 60 | | | 3.55 | 22720 | 11.6 | 22732 | 75014 | 150029 | 1868 | 280 |
| Others | | | 10.5 | 67200 | 27.1 | 67227 | 221849 | 443699 | 1868 | 829 |
| **Wheat** | | | | | | | | | | |
| KRL 210 | 1:25 | 2019-20 | 25.5 | 15938 | 170.4 | 16108 | 16108 | 72486 | 1925 | 140 |
| KRL 283 | | | 18.7 | 11688 | 99.6 | 11787 | 11787 | 53042 | 1925 | 102 |
| KRL 213 | | | 2.5 | 1563 | 15.2 | 1578 | 1578 | 7100 | 1925 | 14 |
| **Mustard** | | | | | | | | | | |
| (CS60, CS 58) | 1:100 | 2019-20 | 3.82 | 38200 | 11.49 | 38211 | 638132 | 638132 | 4650 | 2967 |
| Total | | | 74.3 | 219260 | 462.4 | 219722 | 1169329 | 1774208 | | 5105 |

**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= 4.5t/ ha, Mustard= 1t/ ha

produced and distributed to farmers of different states. The total estimated area coverage by these salt tolerant varieties of rice, wheat and mustard was 1.16 Million ha. The value of additional production obtained due to adoption of ICAR-CSSRI salt tolerant varieties of rice, wheat and mustard during 2020-21 would be 1.77 million tonnes giving estimated revenue of Rs. 5105 crores at the national level (Table 103).

**Empowering farmers through selective interventions in salt affected agroecosystems of Ghaghar Plains (Farmer FIRST)** (Parvender, R.K. Singh, Satyendra Kumar, Arvind Kumar, R. Raju, Arijit Burman, Kailash Prajapat, Dar Jaffer Yusuf and K. Punnusamy)

### Management strategies for reclamation of sodic soils: effect of gypsum+pressmud mediated approach

A total of 10 on–farm trials were carried out to assess the reclamation potential of gypsum (chemical) and/or pressmud (organic) amendment applied together in checking the sodicity build–up and improving rice productivity. The treatments include (i) unamended control (C) (ii) 50% of gypsum requirement on soil test basis ($GR_{50}$), and (iii) 25% of gypsum requirement on soil and irrigation water basis + sugarcane pressmud at 5 t $ha^{-1}$ ($GR_{25}PM_5$).

Soil sodification invariably increased in plough layer (0–15 cm) when no amendment (C) was used; increasing soil $pH_2$ by 0.19 units and ESP by 6% in comparison to the initial values. Among amendments, magnitude of reduction in soil $pH_2$ (0.38 units) and ESP (27%) was more pronounced when gypsum ($GR_{50}$) was applied alone. Application of $GR_{50}$ and $GR_{25}PM_5$improved leaf RWC (4 and 6%), Pn (29 and 39%) and gS (33 and 42%); reduced

Table 104. Changes in soil properties, crop growth parameters, rice yield and economics in relation to reclamation amendments used for sodic soils at farmers' fields.

| Parameters | Unamended control (C) | Gypsum ($GR^{50}$) | Gypsum Pressmud ($GR_{25}PM_5$) | + p-value |
|---|---|---|---|---|
| ***Soil properties**** | | | | |
| Soil pH2 | $9.13^a$±0.24 | $8.56^c$±0.21 | $8.70^b$±0.23 | <0.0001 |
| Exchangeable soil percentage, ESP (%) | $33.7^a$±7.18 | $23.2^c$±5.82 | $24.9^b$±5.71 | <0.0001 |
| ***Physiological traits*** | | | | |
| Relative water content, RWC (%) | $83.5^b$±2.8 | $87.0^a$±2.3 | $88.7^a$±1.9 | 0.0019 |
| Membrane injury index, MII (%) | $39.9^a$±3.4 | $33.4^b$±3.6 | $31.7^c$±3.6 | <0.0001 |
| Photosynthetic rate, Pn (μ mol CO2 $m^{-2}s^{-1}$) | $17.7^c$±1.6 | $22.9^b$±1.3 | $24.6^a$±1.6 | 0.0031 |
| Stomatal conductance, gS (m mol H2O $m^{-2}s^{-1}$) | $1.69^c$±0.12 | $2.26^b$±0.12 | $2.40^a$±0.11 | 0.0003 |
| Shoot $Na^+/K^+$ ratio | $0.83^a$±0.09 | $0.52^b$±0.10 | $0.46^c$±0.08 | <0.0001 |
| Root $Na^+/K^+$ ratio | $1.78^a$±0.22 | $1.05^b$±0.15 | $0.97^c$±0.12 | <0.0001 |
| ***Growth and yield parameters*** | | | | |
| Effective tillers $hill^{-1}$ | $14.8^b$±1.4 | $16.9^a$±1.3 | $17.2^a$±1.6 | 0.0026 |
| Tillers sterility (%) | $11.8^a$±0.4 | $6.4^b$±0.4 | $5.9^c$±0.3 | <0.0001 |
| Grains $panicle^{-1}$ | $55.8^c$±2.9 | $64.9^b$±2.6 | $69.7^a$±1.8 | <0.0001 |
| 1000–grain weight (g) | $23.9^b$±0.8 | $24.6^a$±1.1 | $24.7^a$±0.9 | 0.0305 |
| Grain yield (t $ha^{-1}$) | $2.19^c$±0.5 | $2.81^b$±0.5 | $2.96^a$±0.4 | <0.0001 |
| Straw yield (t $ha^{-1}$) | $5.56^c$±0.9 | $6.73^b$±0.7 | $7.03^a$±0.7 | <0.0001 |

**Initial soil pH2: 8.94±0.25; ESP: 31.7±6.92*

Table 105. Effect of seedling density on crop growth parameters, yield traits and economics of rice (cv. CSR 30 Basmati) at farmers' fields during *kharif* 2018 (FPT–III).

| Parameters | Number of seedlings hill$^{-1}$ | | | p-value |
|---|---|---|---|---|
| | 1$^{¥}$ | 2 | 3 | |
| ***Growth and yield parameters*** | | | | |
| Plant height (cm) | 130.0±3.4 | 132.2±4.8 | 132.5±4.6 | 0.0697 |
| Effective tillers hill$^{-1}$ | 13.5$^{b}$±1.7 | 16.1$^{a}$±1.9 | 16.8$^{a}$±2.0 | <0.0001 |
| Tillers sterility (%) | 6.9$^{b}$±1.1 | 7.6$^{ab}$±0.9 | 8.4$^{a}$±1.3 | 0.0118 |
| Grains panicle$^{-1}$ | 66.1±4.3 | 65.3±4.0 | 64.9±3.4 | 0.3547 |
| Unfilled grains panicle$^{-1}$ | 6.1$^{c}$±1.6 | 6.7$^{b}$±1.8 | 7.5$^{a}$±2.1 | <0.0001 |
| 1000–grain weight (g) | 26.7±1.3 | 26.5±1.2 | 26.2±1.2 | 0.1412 |
| Grain yield (t ha$^{-1}$) | 2.82$^{b}$±0.5 | 3.12$^{a}$±0.5 | 3.15$^{a}$±0.4 | 0.0025 |
| Straw yield (t ha$^{-1}$) | 7.43$^{c}$±0.7 | 7.92$^{b}$±0.3 | 8.11$^{a}$±0.6 | 0.0008 |

¥*Farmers' Practice*

MII (16 and 21%); and lowered $Na^+/K^+$ concentration in shoot (37 and 45%) and root (41 and 46%) portion, respectively in comparison to the unamended control. Further, their complementary effects were realized through significant improvement in yield traits; effective tillers hill$^{-1}$ (14–16%), grains panicle$^{-1}$ (16–25%), 1000–grain weight (2.9–3.3%) with concomitant reduction in tillers sterility (46–50%). Ameliorants applied either individually ($GR_{50}$) or in combination ($GR_{25}PM_5$) led to 28 and 35% yield gain, respectively in comparison to the situations where no amendment was applied (2.19 t ha$^{-1}$). Within amendments, when gypsum and pressmud were used together ($GR_{25}PM_5$), yield improvement to the tune of 5% was observed compared to alone application of gypsum ($GR_{50}$) (Table 104).

### Standardizing seedlings density and hill spacing for sustainable rice production in sodic soils

On-farm experiments were conducted at 5 locations in randomized block design with 3 replications to standardize the management practices (number of seedlings hill$^{-1}$ and spacing requirement) for sustainable rice production in sodic soils. Rice (CSR 30 Basmati) crop was manually transplanted in puddled and levelled fields during the first fortnight of July. The crop was established by transplanting one, two and three seedlings hill$^{-1}$. In another trials to optimize hill spacing, variable plant population was maintained by transplanting rice seedlings at different spacings; random planting/farmers' practice, 15 cm × 15 cm, 20 cm × 15 cm, 20 cm × 20 cm.

#### Optimizing seedling density

Compared to farmers' practice of rice transplanted with 1 seedling hill$^{-1}$, significant improvement (21%) in productive tillers led to 11% yield advantage when 2 seedlings were transplanted per hill (Table 105). Plant height, unfilled grains and tillers sterility increased with increasing planting density; being highest when 3 seedlings hill$^{-1}$ were transplanted (132 cm, 7.5 and 8.4%, respectively).

#### Optimizing hill spacing

Rice transplanted at 20 cm × 15 cm spacing resulted in 15.4% higher grain yield and 7.7% higher straw yield over the farmers' practice of random planting (≈18–25 plants m$^{-2}$) (Table 106). Further increase in spacing (20 cm × 20 cm) accommodated lesser plant

Table 106. Growth, yield and economics of rice (cv. CSR 30 Basmati) as influenced by hill spacing at farmers' fields during *kharif* 2018 (FPT–IV).

| Parameters | Hill spacing (cm) | | | | p-value |
|---|---|---|---|---|---|
| | Random planting[¥] | 15 × 15 | 20 × 15 | 20 × 20 | |
| ***Growth and yield parameters*** | | | | | |
| Plant height (cm) | 130.7 $^{b}$±4.4 | 133.9$^{a}$±5.1 | 131.6 $^{ab}$±4.5 | 130.3$^{b}$±4.7 | 0.0299 |
| Effective tillers hill$^{-1}$ | 15.5$^{a}$±1.8 | 13.3$^{b}$±1.7 | 15.1$^{a}$±1.9 | 15.8$^{a}$±2.1 | 0.0008 |
| Tillers sterility (%) | 7.4$^{b}$±0.6 | 9.6$^{a}$±1.1 | 7.7$^{b}$±0.7 | 6.9$^{c}$±0.4 | 0.0021 |
| Grains panicle$^{-1}$ | 66.8$^{a}$±3.5 | 63.6$^{b}$±3.6 | 66.9$^{a}$±3.9 | 68.2$^{a}$±3.8 | 0.0001 |
| Unfilled grains panicle$^{-1}$ | 6.3$^{b}$±1.5 | 7.5$^{a}$±1.8 | 6.5$^{b}$±1.3 | 6.2$^{b}$±1.2 | <0.0001 |
| 1000–grain weight (g) | 27.1$^{a}$±1.1 | 26.4$^{b}$±1.2 | 26.9$^{ab}$±1.1 | 27.3$^{a}$±1.0 | 0.0354 |
| Grain yield (t ha$^{-1}$) | 2.86$^{c}$±0.4 | 3.24$^{a}$ ±0.3 | 3.30$^{a}$ ±0.4 | 2.96$^{b}$±0.5 | <0.0001 |
| Straw yield (t ha$^{-1}$) | 7.27$^{b}$±0.9 | 7.81$^{a}$±0.7 | 7.83a±0.8 | 7.26$^{b}$±1.0 | 0.0005 |

[¥]*Farmers' Practice*

population, thus, recorded 10.3% (0.34 t ha$^{-1}$) lower grain yield compared to 20 cm × 15 cm spacing. Lowest tillers hill$^{-1}$ (13.3), grains panicle$^{-1}$ (63.6) and grain weight (26.4 g); and maximum unfilled grains panicle$^{-1}$ (7.5) and tillers sterility (9.6%) were noticed with closer spacing (15 cm × 15 cm).

# MISCELLANEOUS


# Training and Capacity Building

| Sr. | Name and Designation | Subject | Duration | Organiser |
|---|---|---|---|---|
| 1 | Dr. Lokesh Kumar BM, Scientist | To participate in CAFT training programme on "Advanced Bioinformatics Techniques for Mapping and GWAS using NGS data" | 06-26 February, 2020 | ICAR-IASRI, New Delhi |
| 2 | Dr. Madhu Choudhary, Scientist | Attended DST sponsored training programme on 'Climate Change: Challenges and Response' | 10-14 February, 2020 | CDM, LBSNAA, Mussoorie |
| 3 | Ms. Bhagya Vijayan, Scientist | National Training programme on Enterpreneurship Development and Management for Women Scientists and Technologies working in Governement Sector | 10-21 February, 2020 | EDII, Ahmedabad |
| 4 | Dr. Nirmalendu Basak, Scientist | Attended training programme on "Statistical designs and experimental data analysis" | 18 February-02 March, 2020 | ICAR-IASRI, New Delhi |
| 5 | Dr. Dar Jaffer Yousuf, Scientist | Attended the Short Course Training Programme on "antimicrobial resistance with special reference to aquaculture | 02-12 March, 2020 | ICAR-CIFE, Mumbai |
| 6 | Dr. Ashwani Kumar, Scientist | Participated in International Webinar on "Achieving Land Degradation Neutrality" | 22-24 July, 2020 | IIASC, Dehradun |
| 7 | Dr. A.K.Mandal, Pr. Scientist | Participated in International Webinar on "Achieving Land Degradation Neutrality" | 22-24 July, 2020 | IIASC, Dehradun |
| 8 | Pr. P.R.Bhatnagar, Pr. Scientist | Participated in International Webinar on "Achieving Land Degradation Neutrality" | 22-24 July, 2020 | IIASC, Dehradun |
| 9 | Dr. D.S.Bundela, Head DIDE | Participated in International Webinar on "Achieving Land Degradation Neutrality" | 22-24 July, 2020 | IIASC, Dehradun |
| 10 | Dr. Arijit Barman, Scientist | Participated in International Webinar on "Achieving Land Degradation Neutrality" | 22-24 July, 2020 | IIASC, Dehradun |
| 11 | Dr. H.S.Jat, Pr. Scientist | Attended Online Webinar on "Vulnerability Assessment in Haryana State | 20 July, 2020 | Environmental & Climate Change Department, Govt. of Haryana |
| 12 | Dr. Jogendra Singh, Scientist | Attended Online Webinar on "Vulnerability Assessment in Haryana State | 20 July, 2020 | Environmental & Climate Change Department, Govt. of Haryana |
| 13 | Dr. Ram Kishor Fagodiya, Scientist | Attended Online Webinar on "Vulnerability Assessment in Haryana State | 20 July, 2020 | Environmental & Climate Change Department, Govt. of Haryana |
| 14 | Dr. Anita mann, Sr. Scientist | Attended Online training programme on "Analysis of Experimental Data using R" conducted by NAARM | 05-11 August, 2020 | NAARM, Hyderabad |
| 15 | Dr. Sagar Dattatraya Vibhute, Scientist | Participated in Online Training Programme on "Analysis of Experimental Data using R "Organized by ICAR-NAARM | 05-11 August, 2020 | ICAR-NAARM, Hydrabad |
| 16 | Dr. A.K.Mandal, Pr. Scientist | Participated in the Online MDP on "Intellectual Property Valuation and Technology Management" Organized by ICAR-NAARM Hyderabad | 17-21 August, 2020 | ICAR-NAARM, Hyderabad |
| 17 | Dr. Bhaskar Narjary, Scientist | Participated in Online Webinar on "Drone Remote Sensing in Agriculture" | 09 September, 2020 | ICAR-IARI, New Delhi |
| 18 | Dr. Priyanka Chandra, Scientist | Online Training Programme on "Climate Change: Challenges and Response" sponsored by the Department of Science & Technology, New Delhi | 05-9 October, 2020 | LBSNAA, Mussoorie |

| | | | | |
|---|---|---|---|---|
| 19 | Dr. P.C.Sharma, Director | DST sponsored training programme on managing Technology Value Chains for Directors and Division Heads | 02-06 November, 2020 | Hyderabad |
| 20 | Dr. D.S.Bundela, Head DIDE | DST sponsored training programme on managing Technology Value Chains for Directors and Division Heads | 02-06 November, 2020 | Hyderabad |
| 21 | Dr. M.J.Kaledhonkar, PC | DST sponsored training programme on managing Technology Value Chains for Directors and Division Heads | 02-06 November, 2020 | Hyderabad |
| 22 | Dr. R.K.Yadav, Head SCM | DST sponsored training programme on managing Technology Value Chains for Directors and Division Heads | 02-06 November, 2020 | Hyderabad |
| 23 | Dr. Neeraj Kulshreshtha, Head CI | DST sponsored training programme on managing Technology Value Chains for Directors and Division Heads | 02-06 November, 2020 | Hyderabad |
| 24 | Dr. Anil Kumar, Head SSR | DST sponsored training programme on managing Technology Value Chains for Directors and Division Heads | 02-06 November, 2020 | Hyderabad |
| 25 | Sh. Ravi Kran K.T., Scientist | Online training programme on "Analysis of Experimental Data using SAS" | 09-14 November, 2020 | NAARM, Hyderabad |
| 26 | Dr. Anita Mann, Sr. Scientist | DST sponsored two weeks training on "General Management for women Scientist | 23 November- 04 December, 2020 | Hyderabad |
| 27 | Dr. Arjun Singh, Scientist | DST sponsored 5 days online training programme on " Ethics & Values" | 23-27 November, 2020 | Hyderabad |
| 28 | Dr. Sagar D. Vibhte, Scientist | DST sponsored 5 days online training programme on " Ethics & Values" | 23-27 November, 2020 | Hyderabad |
| 29 | Dr. T.Damodaran, Pr. Scientist | Dst sponsored online training programme on "Science Administration and Research Management" | 07-18 December, 2020 | Hyderabad |
| 30 | Dr. D.S.Bundela, Head DIDE | DST sponsored online training program on "Scientist Administration and Research Management" | 07-18 December, 2020 | Hyderabad |
| 31 | Ms. Ramya H.R., Scientist | DST sponsored 5 days online training program on "INTERNET of THINGS" under women component DISHA | 14-18 December, 2020 | Hyderabad |
| 32 | Sh. Nitish Ranjan Prakash, Scientist | Online training "Advance Bioinformatics tools and its application in Agriculture | 07-11 December, 2020 | NAARM, Hyderabad |
| 33 | Dr. Satyendra Kumar, Pr. Scientist | Online training programmeon "Climate Change: Challenges and Response (CCCR) for Scientists & Technologysts | 14-18 December, 2020 | Lal Bhadur Shastri National Academy of Administration, Musoorie |
| 34 | Dr.A.K.Bhardwaj, Pr. Scientist | Online training programmeon "Climate Change: Challenges and Response (CCCR) for Scientists & Technologysts | 14-18 December, 2020 | Lal Bhadur Shastri National Academy of Administration, Musoorie |
| 35 | Dr. U.K.Mandal, Pr. Scientist | Online training programmeon "Climate Change: Challenges and Response (CCCR) for Scientists & Technologysts | 14-18 December, 2020 | Lal Bhadur Shastri National Academy of Administration, Musoorie |
| 36 | Dr. D.S. Bundela, Head DIDE | Participate Online 5 days Cloud Computing Bootcamp with a Top Morden Skill for Big Data, Software Development and IT Management | 26-30 December, 2020 | |

# Awards and Recognitions

- Dr. S.L. Krishnamurthy was awarded Japan International Award for Young Agricultural Researchers (Japan Award) by the Ministry of Agriculture, Forestry and Fisheries of Japan and Japan International Research Center for Agricultural Sciences for the year 2020.
- Dr. S.L. Krishnamurthy was awarded Associate fellow of National Academy of Agricultural Sciences, New Delhi for the year 2020.
- Dr. S.L. Krishnamurthy was awarded Fellow of Indian Society of Genetic and Plant Breeding in 2020.
- Dr. Jogendra Singh received Young Scientist Award-2019 for overall achievements and accomplishment in the field of Agriculture & Allied Science by Dr. Ram Avatar Shiksha Samiti (Reg. No. 265, 2007-08 under Society Registration act XXI of 1860), Pilibhit, Uttar Pradesh.
- Netaji Subhas-ICAR International Fellowships (NS-ICAR IFs) conferred to Mr. Dar Jaffer Yousuf for pursuing Doctoral degree.
- Dr. Y.P. Singh, Awarded Fellow of National Academy of Agricultural Sciences (NAAS) – 2020.
- Dr. Y.P. Singh, Awarded ICAR-CSSRI-Excellence award for the year 2018.
- Dr. Sanjay Arora awarded as Chief Editor, Journal of Soil and Water Conservation, India.
- Dr. Sanjay Arora awarded as Associate Editor, International Journal of Microbiology Research.
- Dr. Sanjay Arora awarded as Editor, Journal of the Indian Society of Soil Science, New Delhi.
- Dr. Sanjay Arora awarded as Chief Editor, Journal of Natural Resource Conservation and Management, Lucknow.
- Dr. Sanjay Arora elected as Councilor, World Association of Soil and Water Conservation (WASWAC), Beijing.
- Dr. A.K. Bhardwaj elected as Editor of Journal 'Ecological Processes (Springer Nature).
- Dr. Subhasis Mondal received Special Recognition as Member of District Monitoring Committee under ARYA Project, Hooghly district of West Bengal, nominated by DDG (Agril. Extension) on 19 December 2020.
- Dr. Anita Mann received Excellence Award as a Reviewer of Legume Research on 27th November 2020.
- Dr. H.S. Jat, Dr. Ashim Datta, Dr. Madhu Choudhary, Dr. S.K. Kakraliya, Dr. M.K. Gora, Dr. M.L. Jat and Dr. P.C Sharma were awarded first prize for "जलवायु स्मार्ट खेती/क्लाईमेट स्मार्ट एग्रीकल्चर– खाद्य एवं पौषण सुरक्षा को बनाये रखनें के लिए कृषि की एक उन्नत तकनीक" in Hindi Folder category by *Nagar Rajbhasha Kaariyenavyan Samiti, Karnal.*
- Dr. Madhu Choudhary, Dr. Kailash Prajapat, Dr. Manisha Kaushik and Dr. H.S. Jat were awarded first prize for "लवणग्रस्त मृदाओं हेतु उन्नत कृषि क्रियाएँ" in Hindi Bulletin category by *Nagar Rajbhasha Kaariyenavyan Samiti, Karnal.*
- Dr. P.C. Sharma, Dr. Anshuman Singh and Sh. Madan Singh were awarded second prize for "लवणता समाचार, जनवरी – जून, 2019" in News Letter category by *Nagar Rajbhasha Kaariyenavyan Samiti, Karnal.*
- Dr. P.C. Sharma, Dr. R.L. Meena, Dr. Kailash Prajapat and Sh. Madan Singh were awarded consolation prize for ''कृषि किरण'' in *Hindi Grah Patrika* category by *Nagar Rajbhasha Kaariyenavyan Samiti, Karnal.*

# Linkages and Collaborations

### International Collaboration

- Advanced Cultures on Rice for Shallow and Deep Water Situations with IRRI, Philippines
- Cereal Systems Initiative for South Asia (CSISA) (sponsored by IRRI, Philippines and CIMMYT, Mexico)
- Cropping System Intensification in the Salt Affected Coastal Zones of Bangladesh and West Bengal, India with CSIRO and Murdoch University, Australia
- CV Raman Fellow visiting scientist from Soil and Water Department, Faculty of Agriculture, Cairo University, Egypt
- Development of Crop and Nutrient Management Practices in Rice with IRRI, Philippines
- Future Rainfed Lowland Rice Systems in Eastern India 15 (T3) (Development of Crop and Nutrient Management Practices in Rice) (ICAR –W3) (IRRI).
- ICAR-CSSRI–JIRCAS Japan for "Development of Sustainable Resources Management Systems in the water-vulnerable areas of India"
- International Collaborative Programme on Testing Rice Germplasm for Coastal Salinity (IRSSTN) with IRRI, Philippines
- Marker Assisted Breeding of Abiotic Stress Tolerant Rice Varieties with Major QTL for Drought, Submergence and Salt Tolerance (DBT, India and IRRI, Philippines)
- Piloting and up-scaling an innovative underground approach for mitigating urban floods and improving rural water security in South Asia–IWMI
- Research Institute of Theoretical & Applied Physical Chemistry (INIFTA), La Plata, Argentina (funded by UNESCO-TWAS-CONICETS).
- Strategic Research Platform on Climate Smart Agriculture "Developing and defining climate smart agricultural practices portfolios in South Asia". ICAR-CCAFS
- Stress Tolerant Rice for Poor Farmers in Africa and South Asia under IRRI-BMGF Project.

### National Collaborations

- Academic linkages with Institute of Environmental Studies, Kurukshetra University, Kurukshetra, Haryana; Department of Biotechnology, Maharishi Markandeshwer University, Mullana, Haryana; Deenbandhu Chhotu Ram University of Science & Technology, Murthal, Haryana and ICAR-NDRI, Karnal, Haryana for Post Graduate teaching and research
- All India Coordinated Cotton Improvement Project, Coimbatore
- AMAAS-Application of Micro-organism in Agriculture and Allied Sectors (Funded by ICAR, New Delhi)
- Anand Agricultural University, Anand
- ATAPI Seva Foundation, NGO Jambusar
- Banasthali Vidyapeeth, Banasthali, Rajasthan
- BBAU, Lucknow

- Bidhan Chandra KrishiVisvaVidyalaya, Kalyani (West Bengal)
- CCSHAU, Hisar, Haryana for collaborative research
- Coastal Salinity Tolerant Varietal Trial (CSTVT) and National Salinity and Alkalinity Screening Nursery (NSASN) with IIRR, Hyderabad
- College of Agriculture, Bharuch
- Cotton Research Station, Bharuch
- Cotton Research Station, Surat.
- Department of Agriculture Govt. of Haryana
- Department of Agriculture, Government of West Bengal
- Department of Agriculure, Uttar Pradesh
- Department of Science and Technology, Govt. of India for developing gypsum enriched municipal solid waste compost and its use in sodic soil conditioning.
- Department of Soil Conservation, Government of West Bengal
- 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,
- FodazioneL'Alberodella Vita (FADV), Kolkata, West Bengal
- GB Pant Polytechnic College, Lucknow
- Gujarat Narmada Valley Fertilizer Company Ltd., Bharuch
- Haryana State Forest Department for performance evaluation of *Eucalyptus* and other forestry species plantations on water logged saline ecologies.
- ICAR Indian Institute of Wheat and Barley Research, Karnal
- ICAR-Central Institute of Cotton Research, Nagpur
- ICAR-Central Institute of Fisheries Education, Mumbai on technical guidance and training support for NAHEP Project on Development of Energy Efficient and Environment Protective Aquaculture Technologies for Degraded Soils under CAAST Sub-component.
- ICAR-Central Institute of Freshwater Aquaculture, Rahara, Kolkata
- ICAR-Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore
- ICAR-CIFE, Mumbai on inland saline water/ waterlogged saline soils mapping and integration of SSD technology with saline aquaculture under NAHEP Project
- ICAR-CISH, Lucknow
- ICAR-IISR, Lucknow
- ICAR-Indian Institute of Water Management, Bhubaneshwar
- ICAR-National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Kolkata Centre
- ICAR-National Bureau of Soil Survey and Land Use Planning Nagpur
- ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan
- ICAR-NBFGR, Lucknow

- ICAR-NCIPM, New Delhi
- Improvement of Salt Tolerance in Wheat (ICAR-IIWBR, Karnal)
- Indian National Academy of Engineering (INAE), Gurugram for joint Research proposal on Climate Change Impact on Water Resources and Agriculture: Mitigation and Adaptations for National Water and Food Security
- Inter-institutional collaboration with IISS Bhopal for standradising the conservation agriculture practices in rice-wheat cropping system on salt affected soils.
- Jaipur National University, Jaipur, Rajasthan
- Junagadh Agricultural University, Junagadh
- Kerala Agricultural University, Trivendrum
- KrishiVikas Kendra, Chaswad, Bharuch
- KrishiVikas Kendra, Dediapada, Narmada
- KrishiVikas Kendra, Surat, Dist. Surat
- KVK Dhoura, Unnao, Kaushambi, Pratapgarh, Sitapur, Auraiya and Bhadohi
- Linkage developed with Reliance Industries Ltd. for collaborative research on developing the alternate strategies for reclamation of sodic soils.
- Maharashtra Hybrid Seeds Co Pvt Ltd. (MAHYCO)
- Monsanto India Limited
- Multi-locational Evaluation of Bread Wheat Germplasm (NBPGR, New Delhi)
- NABARD, Mumbai & Chandigarh for Reclamation of Saline and Alkaline Soils in Haryana and Punjab
- Navsari Agricultural University, Navsari
- NCP, IGBP, IIRS, NRSA, Department of Space, Dehradun, Uttrakhand
- PRASARI, West Bengal
- Punjabi University, Patiala, Punjab
- Recent Space Technologies and Image Interpretations for Mapping and Characterizing Salinity Affected Areas with Higher Accuracies with National Remote Sensing Centre (NRSC), Hyderabad, State Remote Sensing Application Centres (RSAC) and ICAR-NBSS&LUP, Nagpur
- Regional Remote Sensing Centre (East), ISRO, Kolkata
- Remote Sensing Application Centre, Lucknow Uttar Pradesh
- Rex Polyextrusion Pvt Ltd, Sangli, Maharashtra for outscaling of SSD technology in heavy soils
- ROCL Jaipur Rajsthan and Horticulture Department, Govt. of J&K for salt tolerance evaluation of vaialble olive germplasm.
- SardarVallahbhai Patel University of Agriculture & Technology, Meerut (UP)
- SHIATS, Allahabad (U.P.)
- Strategies for Sustainable Management of Degraded Coastal Land and Water for Enhancing Livelihood Security of Farming Communities with RAKVK, West Bengal,

CIBA, Chennai, CARI, Port Blair and BCKV, West Bengal

- Subham Seeds, Hyderabad (Maize)
- Tagore Society for Rural Development (TSRD), West Bengal
- Technical Guidance and Monitoring and Evaluation of Large-Scale Subsurface Drainage Projects in Haryana (Funded by Haryana Operational Pilot Project, Department of Agriculture, Haryana)
- Transgenics in Crops-Salinity Tolerance in Rice: Functional Genomics Component (Funded by ICAR, New Delhi)
- U.P. Council of Agricultural Research (UPCAR), Lucknow
- U.P. Council of Science and Technology, Lucknow
- Utilization of Fly Ash for Increasing Crop Productivity by Improving Hydro-Physical Behavior of Sodic Soils of Uttar Pradesh (DST)
- Uttar Pradesh Bhumi Sudhar Nigam, Lucknow
- VIKAS-NGO, Ahmedabad.
- Water Conservation Department, Directorate of Irrigation Research & Development (DIRD) and Department of Agriculture, Pune for promotion of SSD technology for reclamation of waterlogged and saline soils in Maharashtra.
- Water Technology Centre, TNAU, Coimbatore
- World Wide Fund (WWF)
- YSR Horticultural University

# Publications


Anantha, K.C., Majumder, S.P., Badole, S., Padhan, D., Datta, A., Mandal, B. & Sreenivas, C.H. 2020. Pools of organic carbon in soils under a long-term rice–rice system with different organic amendments in hot, subhumid India, Carbon Management. (DOI: 10.1080/17583004.2020.1783624)

Arora, Sanjay and Singh, B.P. 2020. Status of soil degradation in state of Uttar Pradesh. *Journal of Soil and Water Conservation*, 19(2): 119-125.

Aryal, J.P., Jat, M.L., Sapkota, T.B., Rahut, D.B., Rai, M., Jat, H.S., Sharma, P.C. and Stirling, C., 2020. Learning adaptation to climate change from past climate extremes: Evidence from recent climate extremes in Haryana, India. *International Journal of Climate Change Strategies and Management* 12(1):128-146. (doi.org/10.1108/IJCCSM-09-2018-0065)

Bali, A. Awtar Singh, Minhas, P.S. and Yadav, R.K. 2020. Response of paddy (*Oryza sativa* L.) to exogenous application of bio-regulators in soils irrigated with alkali groundwater. *Indian Journal of Agricultural Sciences* 90 (9): 1670–2, 2020/Article.

Bali, A., Singh Awtar, Minhas, P.S., and Yadav R.K. 2020. Effect of plant bioregulators and their combinations on growth and yield of wheat under sodicity stress induced by alkali water irrigation. *Journal of Soil Salinity and Water Quality* 12(1), 45-49.

Baljeet, Kumar, S., M, Meena, BL, Meena,VK, Onte, S and Bhattchargee S 2020. Yield and Qualitative Evaluation of Fodder Maize (*Zea mays* L.) under Potassium and Zinc based Integrated Nutrient Management. *Indian J. Anim. Nutr.,* 37 (3): 235-241.

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# Participation in Conference/Seminar/Symposia/Workshop

**ICAR-CSSRI Scientists participated/attended large number of webinars during the COVID-19 pandemic situation as directed by the competent authority. Few important webinars and workshops are listed below:**

| Name | Title | Place | Period |
|---|---|---|---|
| Dr. Sanjay Arora | Delivered lead talk in International Conference on Environmental Sustainability: Innovations, Translational Dimensions and way forward | BBAU, Lucknow | 12.02.2020, 04.03.2020 |
| Dr. Y.P. Singh | International Conference on Environmental Sustainability : Innovations, Translational Dimensions and Way Forward | BBAU, Lucknow, U.P. | 12.02.2020 |
| Dr. Y.P. Singh<br>Dr. Sanjay Arora | Training workshop cum Faculty Development Programme on Environment, Biodiversity and Disaster Risk Management | NIDM, New Delhi & BBAU, Lucknow | 02.03.2020 – 06.03.2020 |
| Dr. Sanjay Arora | National webinar on Zero budget natural farming - Delivered lead talk on “Soil microbial formulations: important component of natural farming” on second day. | APSRPF, Dehradun | 06.06.2020 – 07.06.2020 |
| Dr. T.D. Lama | National Webinar on 'Biochar: Potential availability, Usefulness and Limitation for use in Indian Agriculture' on June 19, 2020 | ICAR-Indian Institute of Soil Science, Bhopal | 19.06.2020 |
| Dr. Subhasis Mondal | Invited lecture on Agricultural Marketing Management with special Reference to Small-holder Farmers in India - Opportunities and Way Forwards during National Webinar on "Strategic Agriculture for Rural Employment and Sustainable Development" | State Agricultural Management & Extension Training Institute-West Bengal, IR DM Faculty Centre- RKMVU and Sassya Shyamala Krishi Vigyan Kendra of Ramakrishna Mission Ashrama, Narendrapur. | 30.06.2020 |
| Mr. Dar Jaffer Yousuf | One Day International Virtual Conference on Microplastics 2020. | VIT, Vellore | 30.06.2020 |
| Dr. T. Damodaran | Delivered keynote lecture on “Field Management of Banana Fusarium Wilt” in the National Webinar on Advances in Disease and Pest Management for Sustainable Banana Industry | Assam Agricultural University, Jorhat in collaboration with ICAR-AICRP Fruits, IIHR, Bangalore. | 04.07.2020 |
| Dr. H.S. Jat | Awareness cum Sensitization Workshop (Online mode) on “Implementation of Access and Benefit Sharing Regulations in Agriculture Research” | ICAR-National Academy of Agricultural Research Management, Rajendranagar, Hyderabad. | 07.07.2020-10.07.2020 |
| Dr. Subhasis Mondal | Keynote lecture on Self-reliance and profitability challenges of agriculture in India – The Small-holder Perspectives during National Conference on “Agricultural Resource Management for Atmanirbhar Bharat” | Central Agricultural University, Imphal, Manipur | 17.07.2020 - 19.07.2020 |
| Dr. Raj Kumar (Fruit Science) | Delivered a lecture on the *'Cultivation of Mango fruit in salt affected soils- a profitable option'* in the webinar on 'आम की खेती की आधुनिक तकनीक' | HTI, Uchani, Karnal | 21.07.2020 |
| Dr. Arvind Kumar | International virtual webinar on achieving land degradation neutrality | ICAR-IISWC, Dehradun | 22.07.2020 - 24.07.2020 |
| Dr. Sagar Vibhute | Online Training Programme on “Analysis of Experimental Data using R” | ICAR-NAARM, Hyderabad | 05.08.2020 – 11.08.2020 |
| Dr. U.K. Mandal | NICRA Thematic review workshop 2020. | Natural Resource Management (NRM) & Agril. Engineering | 17.08.2020 |
| Dr. P.R. Bhatnagar | National Web-Conference on Technological Approaches for Resource Conservation and Management for Environmental Sustainability" | I.I.T., Kharagpur | 24.08.2020 |
| Dr. Arvind Kumar,<br>Dr. Neeraj Kulshreshtha | 59th All India Wheat and Barley Research Workers' | ICAR-IIWBR, Karnal | 24.08.2020 - 25.08.2020 |

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| Dr. B L Meena | National Webinar on "Recent Advances in Soil Microbiological Research with a Special Thrust to Biofertilizer Technology" | BAU, Sabour | 25.08.2020 |
| Dr. P.R. Bhatnagar | National Webinar on "Abiotic Stress in Agriculture: Geospatial Characterization and Management" | ICAR-NIASM, Baramati | 27.08.2020 |
| Dr. H.S. Jat | Workshop on *"Intellectual Property Valuation and Technology Management"* | ICAR- Intellectual Technology Management Unit, New Delhi | 01.09.2020 – 05.09.2020 |
| Dr. B.L. Meena | International Web Conference on "Soil Health Management for Sustainable Crop Productivity" | Madan Bharati Agriculture College, Bihar | 07.09.2020 – 08.09.2020 |
| Dr. Sanjay Arora | CSE Webinar on Organic and Natural Farming in India | CSE India, New Delhi | 08.09.2020 |
| Dr. H.S. Jat | Virtual workshop-cum-training on *"Intellectual Property Rights in Agricultural Research & Education in India"* | NAHEP and IP&TM Unit, ICAR HQ, New Delhi | 12.09.2020 – 28.09.2020 |
| Mr. Dar Jaffer Yousuf | International Webinar on Advances in Aquaculture Nutrition-2020. | TNJFU, Chennai | 24.09.2020 - 25.09.2020 |
| Dr. B L Meena | National Web Conference "Utilization of Organic Waste for Soil Health Management and Energy Production Under Changing Climate Scenario" | SKN Agriculture University, Jobner | 06.10.2020 |
| Dr. Arvind Kumar<br>Dr. Neeraj Kulshreshtha | BGRI virtual global wheat conference | BGRI | 07.10.2020 - 09.10.2020 |
| Dr. T.D. Lama | Webinar on 'Advanced Strategies for the Management of Coastal Agriculture' | School of Agricuture & Allied Science, The Neotia University, West Bengal and ICAR-CSSRI, Karnal | 15.10.2020 |
| Dr. Atul K. Singh | National Webinar on Hydroinformatics for Smart Water Management in Agriculture | RPCAU Pusa, NIH Roorkee and IIT Roorkee | 20.10.2020 |
| Dr. P.R. Bhatnagar | National Webinar on "Micro Irrigation System for Hill Agriculture: Challenges and Design Solution" | PFDC Pantnagar and NCPAH. | 31.10.2020 |
| All ICAR-CSSRI Scientists | International Salinity Webinar on 'Resilient Agriculture in Saline Environments under Changing Climate' | ICAR-CSSRI, Karnal & ICBA, Dubai | 03.11.2020 |
| Dr. H.S. Jat | Virtual workshop and annual review meeting of ZTMCs/ ITMUs/ ABIs under ICAR institutes of NRM, education and engineering division | Under the NAIF project at ICAR RC NEH, Umiam, Barapani | 23.11.2020 - 24.11.2020 |
| Dr. M.J. Kaledhonkar | Delivered a lecture on "Regional Scale Distributed Modeling for Sustainable Conjunctive Water Use Planning in Kheri Irrigation Command" in National Webinar on Nature, Extent and Management of Problematic Soils for Sustainable Agriculture. | Online Organised By Directorate Of Research Services, RVSKVV, Gwalior (M.P.) | 22.12.2020 |

# List of On-going Research 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. Fagodiya, Raj Mukhopadhyay, 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. NRMACSSRISIL201600400902. Farmer participatory enterprise mix diversification on reclaimed sodic land (Parveen Kumar, R. Raju, Awtar Singh, Raj Kumar (Hort.), Dar Jaffer Yusuf and K.S. Kadian)
4. 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)
5. 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)
6. NRMACSSRISIL201700300927.Sustainable nutrient management strategies for partially reclaimed salt affected soils. (Ajay Kumar Bhardwaj, Priyanka Chandra and Bhaskar Narjary)
7. NRMACSSRISIL201700600930. Development of endo-rhizospheric fungal consortia to increase salt tolerance in crops. (Priyanka Chandra, Awtar Singh and Kailash Prajapat)
8. NRMACSSRISIL201800200955. Amelioration of iron deficiency in direct seeded/aerobic rice in reclaimed sodic soils. (Babu Lal Meena, Ram Kishor Fagodiya, R.L. Meena, M.J. Kaledhonkar and P.C. Sharma)
9. 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)
10. 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)
11. NRMACSSRISIL201900100977. Impact assessment of salt tolerant wheat variety KRL 210 in salt affected regions. (Anil Kumar, Raju R., Kailash Prajapat, Bhagya Vijayan and Arvind Kumar)

12. NRMACSSRISIL202001301004. Low budget natural farming for sustainable crop production. (P.C. Sharma (PI);CSSRI-Raj Mukhopadhyay (CC-PI), RK Fagodiya, Awtar Singh, H.S.Jat ;RRS, Lucknow: Arjun Singh (CC-PI) , V.K. Mishra, Y.P. Singh, S.K. Jha; RRS Bharuch: Anil R. Chinchmalatpure (CC-PI), Bisweswar Gorain, Monika Shulkla, Vineeth T.V., Sagar D Vibhute; RRS Canning Town: D. Burman (CC-PI), U.K. Mandal, S.K. Sarangi and T.D. Lama)

### Priority Area - Drainage Investigations and Performance Studies

13. NRMACSSRISIL201701100935. Studies on salt load dynamics of drainage water and improvement in soil salinity in sub surface sites in Haryana, (Satyendra Kumar, Bhaskar Narjary, Kailash Prajapat and D.S. Bundela)

14. NRMACSSRISIL201900200980. Performance assessment of sub surface drainage technology in saline vertisols of Maharashtra (Raju R., Anil Kumar, Sagar D Vibhute and D.S. Bundela)

15. NRMACSSRISIL202000100992. Long-term impact of sub surface drainage on clay mineralogical transformation, physio-chemical properties and hyper spectral signatures if saline soils under Inceptisol and Vertisol. (Raj Mukhopadhyay, Bhaskar Narjary and Arijit Barman)

### Priority Area - Management of Marginal Quality Waters

16. 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)

17. NRMACSSRISIL201802100973. Salinity management and modeling under drip Irrigation, raised bed and mulch for optimum yield. (Bhaskar Narjary, Satyendra Kumar R.K Fagodiya and Raj Mukhopadhayay)

18. NRMACSSRISIL201900300981.Conjunctive water use strategies with conservation tillage and mulching for improving productivity of saline soils under high SAR saline water irrigation-(Arvind Kumar Rai, Nirmalendu Basak, Bhaskar Narjary and Gajender )

19. NRMACSSRISIL202000200993. Effect of saline environment and plastic mulch on vegetable crops under naturally ventilated polyhouse conditions. (RL Meena and Bhaskar Narjary,)

### Priority Area - Crop Improvement for Salinity, Alkalinity and Waterlogging Stresses

20. 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)

21. NRMACSSRISIL201800300956. Identification of salt tolerant genotypes in jamun (Syzygium cumini L. Skeels) (Anshuman Singh and Ashwani Kumar)

22. NRMACSSRISIL201801400966. Development of salt tolerant rice (oriza sativa L.) genotypes for coastal salinity (Jogendra Singh, Krishnamurthy S.L. and S.K. Sarangi )

23. NRMACSSRISIL201801800970. Genetic improvement of chickpea for salt tolerance through conventional and molecular breeding approaches. (S.K. Sanwal,

Vijayata Singh and Anita Maan)

24. NRMACSSRISIL201802300975. Screening of potato genotypes for higher tuber yield under salinity stress- (Parveen Kumar, B.L. Meena, V.K. Gupta, PS (VB), CPRS, Modipuram)

25. NRMACSSRICIL202000300994. Response of onion and garlic Varieties to salt stress. (Dr. S.K. Sanwal and Dr. B.K. Dubey (NHRDF, Karnal))

26. NRMACSSRISIL202001501006. Exploring the conventional and molecular breeding approaches to develop salt tolerant high yielding Indian Mustard (Brassica juncea L.) genotypes. (Jogendra Singh, P.C. Sharma and Vijayata Singh)

27. NRMACSSRISIL202001701008. Genetic approaches to improve wheat (Triticum aestivum L.) germplasm for salt tolerance. (Neeraj Kulshershtha, Arvind Kumar, PC Sharma, Ashwani Kumar, Y.P Singh and Vineeth TV)

28. NRMACSSRISIL202001801009. Genetic improvement of rice genotypes for salt tolerance using conventional and molecular breeding methods. (Krishnamurthy SL, Lokeshkumar BM, P.C. Sharma, Y.P. Singh, H.S. Jat and Vineeth TV)

29. NRMACSSRISIL202002101012. Genetic improvement of Lentil (Lens culinaris Medikus) for salt tolerance using conventional and molecular breeding approaches. (Vijayata Singh)

### Priority Area - Agroforestry in Salt Affected Soils

30. NRMACSSRISIL201701200936. Evaluation of potential Olive germplasm for salt affected soils. (Rakesh Banyal, Ashwani Kumar and Arijit Barman)

31. NRMACSSRISIL201701300938 Enhancing productivity potential of saline soils through agroforestry interventions. (R. Banyal, A.K. Bhardwaj, Parveen Kumar and Raj Kumar)

32. NRMACSSRISIL201800400957. Improvement of Melia dubia for salt tolerance through selection approach. (Raj Kumar, Rakesh Banyal and Awtar Singh)

33. NRMACSSRISIL202001101002 NRMACSSRISIL202001101002. Improving the productivity of senile ber orchards through top working. (Raj Kumar and Anshuman Singh).

34. NRMACSSRISIL202001201003. Exploration and characterization of spota cultivars for salt tolerance.(Raj Kumar, Anshuman Singh, Ashwani Kumar and Raj Kumar (Agroforestry))

### Priority Area - Reclamation and Management of Coastal Saline Soils

35. 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)

36. NRMACSSRISIL201801100964. Evaluation of pressurized irrigation system for rabi rice in coastal salt affected soils. (K.K. Mahanta, S.K. Sarangi, U.K. Mandal, D. Burman and S. Mandal)

37. NRMACSSRISIL201801500967. Economics of land modification models under

waterlogged sodic soils of Uttar Pradesh.(Subhasis Mandal, V.K. Mishra and C.L. Verma)

38. NRMACSSRICIL201900600984. Mapping and characterization of salt affected soils in coastal West Bengal- (T.D. Lama, D. Burman, U.K. Mandal, A.K. Mandal, S.K. Sarangi, S. Raut, K.K. Mahanta, K.D. Sah and S. Mukhopadhyay, (NBSS&LUP regional centre Kolkata)

39. NRMACSSRISIL201900700985. Assessment of spatio-temporal variation of surface water quality in the salt affected Ganges delta of coastal West Bengal for agricultural uses (D. Burman, T.D. Lama, U.K. Mandal, K.K. Mahanta and S. Mandal)

40. NRMACSSRISIL201900800986. Technology for management of salt-affected soils in India-Implication on farm income and food security (Subhasis Mandal)

41. NRMACSSRISIL202001401005. Coastal salinity management and cropping system intensification through conservation agriculture. (SK Sarangi, S. Raut, UK Mandal and KK Mahanta)

42. NRMACSSRISIL202001901010. Effect of ameliorants on soil water functional relationships and salinity in an inceptisol of Coastal West Bengal. (S Raut, D. Burman, S.K. Sarangi and T.D. Lama)

**Priority Area - Reclamation and Management of Salt Affected Vertisols**

43. NRMACSSRISIL201601000908. Cost effective drainage in waterlogged saline Vertisols for improving crop productivity in Gujarat. (Sagar Vibhute D., Anil R. Chinchmalatpure, Vineet TV and M.J. Kaledhonkar)

44. 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)

45. 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)

46. NRMACSSRISIL201800600959. Pulpwood-based silvipastoral systems for saline Vertisols. (Monika Shukla, Shrvan Kumar, Bisweswar Gorain and Vineet TV)

47. 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)

48. NRMACSSRISIL201800800961. Development of Desi cotton genotypes (G. herbaceum and G. arboreum) for salt affected Vertisols. (Vineet TV, Lokeshkumar B.M., Shrvan Kumar, Anil R. Chinchmalatpure and P.C. Sharma)

**Priority Area - Reclamation and Management of Alkali Soils of Central and Eastern Gangetic Plains**

49. 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)}

50. 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))

51. 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)

52. NRMACSSRISIL201802400976. Rain water harvesting, storage and use in Fluoride affected area of Unnao (U.P.)-(C.L. Verma, S.K. Jha and A.K. Singh)

### Foreign Funded Projects

1. NRMACSSRISOL201601500913. Strategic Research Platform on Climate Smart Agriculture "Developing and defining climate smart agricultural practices portfolios in South Asia". (P.C. Sharma, Ashim Datta and Madhu Choudhary) ICAR-CCAFS

2. 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.

3. NRMACSSRISOL201801300965. Development of sustainable resource management systems in water vulnerable regions of India. (Team Leader; P.C. Sharma, Dr. R.K. Yadav (PI), D.S. Bundela, Satyendra Kumar, Bhaskar Narjary, Gajender and A.K. Rai) Funded by ICAR-JIRCAS, Japan

4. NRMACSSRICOL201702500949. Development of High Zinc rice varieties. (Krishnamurthy S.L. and P.C. Sharma)-IRRI

5. NRMACSSRICOL202000400995. Trait discovery-Rainfed Ecosystem. (Team Leader: Dr. P.C. Sharma) Krishnamurthy S.L., Lokeshkumar B.M.) Funded by IRRI, Philippines

6. NRMACSSRICOL202000500996. Rice grain quality and nutritional quality: Low arsenic rice, Bioactives in rice and Low GI rice. (Team Leader: Dr. P.C. Sharma) ( Krishnamurthy S.L., S.K. Sarangi, Lokeshkumar B.M.) Funded by IRRI, Philippines

7. NRMACSSRICOL202000600997. Climate Smart Management Practices. Sub Project 2.1 and 2.4 (Team Leader: Dr. P.C. Sharma) (H.S. Jat, Krishnamurthy S.L., Y.P. Singh, S.K. Sarangi, Lokeshkumar B.M.) Funded by IRRI, Philippines

8. NRMACSSRICOL202000700998. Climate Smart Management Practices. Sub Project 2.4 (Team Leader: Dr. P.C. Sharma) (H.S. Jat, Krishnamurthy S.L., S.K. Sarangi, Lokeshkumar B.M.) Funded by IRRI, Philippines

### Externally Funded Projects

1. Intellectual property management transfer/commercialization of agricultural technologies renamed as NAIF. (H.S. Jat, Krishnamurthy SL and Ajay Kumar Bhardwaj)-ICAR

2. 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

3. NRMACSSRISOL201501600892. Molecular genetic analysis of resistance/tolerance in rice, wheat, chickpea and mustard including sheath blight complex genomics. [(Rice: component 1): Krishnamurthy, S.L. and P.C. Sharma, (Chickpea: component 3): S.K. Sanwal, P.C. Sharma, (Mustard: component 4): Jogendra Singh, P.C. Sharma and Vijayata Singh)] – ICAR, New Delhi

4. NRMACSSRISOL201502200898. CRP on Conservation Agriculture 'Productive utilization of salt affected soils through conservation agriculture". (Ranbir Singh, Arvind Kumar Rai, Parvender and Priyanka Chandra)-ICAR

5. 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)-ICAR

6. 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

7. 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

8. 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

9. 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

10. NRMACSSRICOL201702000944. Phyto-remediation potential of selected halophytes for salt affected lands of Haryana. (Ashwani Kumar, Arvind Kumar, B.L. Meena and Anita Mann) –RKVY

11. NRMACSSRICOL201702100945. 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)- RKVY

12. 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

13. NRMACSSRICOL201702400948. CRP on Agro-Biodiversity—Component 2 - Evaluation of rice germplasm accessions against biotic/abiotic stresses. (Krishnamurthy S.L. and P.C. Sharma)-ICAR

14. NRMACSSRICOL201702600950. HOPP Project "Technical guidance on monitoring & evaluation of large scale SSD projects in Haryana"{Team Leader: PC Sharma, D.S. Bundela (PI) Team A: Satyendra Kumar, Arijit Barman and Kailash Prajapat and Team B: R.L. Meena, Bhaskar Narjary, R. Raju, R.K. Fagodiya, Raj Mukhopadhyay,Dar Jaffer Yusuf, PR Bhatnagar)

15. 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

16. 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)

17. 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.

18. NRMACSSRISOL201900400982. Methodology for real-time assessment of salt affected soil Ghaghar Plain of Haryana using hyperspectral remote sensing. (Arijit Barman, A.K. Mandal, Bhaskar Narjary and Parvender) (SERB –DST)

19. NRMACSSRICOL201900500983. North Indian Centre for Water Technology Research in Agriculture (Team leader: P.C. Sharma, M.J. Kaledhonkar (PI), B.L. Meena, Satyendra Kumar, Parvender Sheoran, Bhaskar Narjary, R.K Fagodiya, Awtar Singh, R.B. Singh and S.K. Chauhan (AICRP Agra Centre)

20. NRMACSSRICOP201901200990. Development of high density linkage map and tagging salinity tolerance in lentil using genotyping-by-sequencing approach for improving salt tolerance. (Vijayata Singh (CC-PI) and S.K. Sanwal (Co-PI), DBT funded

21. NRMACSSRISOL201901300991. Methodology for rapid detection, characterization and 3-D representation and risk zone identification of hot spots soil salinity in Rohtak district, Haryana using electromagnetic induction and remote sensing techniques.(Bhaskar Narjary, Arijit Barman, Raj Mukhopadhyay and D S Bundela) SERB-DST funded

22. NRMACSSRICOL202000901000. Assignment for study and development of practices for application of FGD Gypsum for sodic soil reclamation and it's effect on environment. (Parul Sundha, Nirmalendu Basak, A.K. Rai, Raj Mukhopadhyay R.K. Yadav, and P.C. Sharma) NTPC

23. NRMACSSRICOL202001001001.Pilot Project on Reclamation of Saline and Alkaline soils in Haryana and Punjab.(Team Leader P.C. Sharma) (NABARD) Saline Soil Reclamation: DS Bundela (PI), Raj Mukhopadhyay, Jaffer Yousaf Dar, Khuswant Alkaline Soil Reclamation: R.K. Yadav (PI), A.K. Mondal, Ashim Datta, Naresh Arora. Training: Anil Kumar, Bhagya Vijayan/Kailash Prajapat)

24. NRMACSSRICOL202002001011. Germplasm characterization and trait discovery in wheat using genomics approaches and its integration for improving climate

resilience, productivity and nutritional quality. Sub Project 3: Evaluation of wheat germplasm for abiotic stresses (Component -6 ) (Arvind Kumar and Neeraj Kulsherstha) DBT Funded

25. NRMACSSRICOL202002101012. Leveraging genetic resources for accelerated genetic improvement of linseed using comprehensive genomics and phenotyping approaches. Sub project: Evaluation of linseed germplasm for major abiotic stresses (Drought and salt stress) (Component -4) (S.K. Sanwal and Jogindra Singh) DBT Funded

### Collaborative Projects

1. QTL mapping and identification of markers linked to salinity tolerance in chickpea (Cicer arietinum L.). (Vijayata Singh (Co-PI) and S.K. Sanwal (Co-PI) (Collaboration with JAU, Junagarh)

2. Physiological and biochemical mechanism of salt tolerance in Guinea grass. (Raj Kumar (Agroforestry) Co-PI) (Collaboration with IGFRI, Jhansi)

### Consultancy

1. Effect of treated effluent from Aniline-ETP Plant of GNFC Unit II on growth and yield of Isabgol (Plantago ovata Forsk.) and properties of Vertisols. (Anil R Chinchmalatpure, Shrvan Kumar, Sagar Vibhute D., Bisweswar Gorain and PC Sharma)

2. Improving the nutritional status of mothers and children through improved WASH, nutrition and health care practices in flood prone Canning-II block, West Bengal (D. Burman, U.K. Mandal, T.D. Lama, S. Mandal, K.K. Mahanta )

### Contract Research

1. Enhancing nutrient use efficiency using nano-fertilizer in rice-wheat cropping system under salt stress. (Ashwani Kumar, Parvender Sheoran, Anita Mann and Ajay Bhardwaj) funded by IFFCO

# INSTITUTE ACTIVITIES

### Institute Management Committee Meeting

The 44th Institute Management Committee meeting was held on 21st March, 2020 at ICAR-CSSRI, Karnal and was attended by the following IMC Members.

| | | |
|---|---|---|
| 1. | Dr. P. C. Sharma, Director, ICAR-CSSRI, Karnal. | Chairman |
| 2. | Dr. Padamni Swain Head, Principal Scientist,ICAR-NRRI, Cuttack | Member |
| 3. | Dr. J Ranem, Head, SDSM, ICAR-NIASM, Baramati | Member |
| 4. | Dr. Neeraj Kulshrestha, Head, S.B.I., R.R.S, Karnal | Member |
| 5. | Dr. M.J. Kaledhonkar, P.C, SAS & PQW, CSSRI, Karnal | Member |
| 6. | Sh. Hemchand Kaushik, Nominee of the President, ICAR | Member |
| 7. | Sh. Mehar Chand Gahlot, Nominee of the President, ICAR | Member |
| 8. | Sh. N.K. Arora, Sr. FAO, ICAR, New Delhi | Member |
| 9. | Sh. Alok Kumar, SAO, ICAR-CSSRI, Karnal. | Member Sec. |

IMC meeting in progress

The Meeting started with the confirmation of the proceedings of the last meeting held on 23rd March, 2019. Subsequently, the research achievements of different Divisions, Regional Research Stations and Project Coordinating Unit were discussed. This was followed by discussion on other activities carried out during by the Institute. These included activities by the Institute Rajbhasha Committee, different trainings and programs organized during the period, the issues related to staff position, Institute budget and expenditure, sale of farm produce, publications, linkages, collaborations and the activities related to '*Swachh Bharat Abhiyaan*' and '*Mera Gaon Mera Gaurav*' programme.

### Institute Joint Staff Council Meeting

The Institute Joint Staff Council Meeting was held at ICAR-CSSRI Karnal on 31st August 2020 under the Chairmanship of Dr. P.C. Sharma, Director. It was attended by Dr. H.S. Jat, OIC, PME, Dr. Neeraj Kulshrestha, Head, CI Div., Sh. Alok Kumar, SAO and IJSC members - Sh. Devender Kumar, Sh. Tarun Kumar, Sh. Dharambir Narwal, Sh. Sukhbir and Sh. Ramesh Kumar. The

IJSC meeting in progress

members discussed various agenda items and other related issues for the welfare of the Institute staff at length and settled various issues systematically and amicably.

### Research Advisory Committee (RAC) Meeting

The 23rd meeting of the Research Advisory Committee (RAC), constituted vide Council letter No. NRM/9-2/2019-IA-II dated 8th March 2019, was held online, using the Zoom meeting platform, on 17th September 2020 under the Chairmanship of Dr. A.K. Sikka, Ex-Deputy Director General (NRM), ICAR, and currently IWMI Representative-India. Other members present online were: Dr. R.K. Jhorar, Dr. N.S. Bains, Director Research, PAU, Ludhiana, Punjab, Dr. A.K. Mehta, Ex-ADG (Agricultural Extension), ICAR, currently located at Ludhiana, Punjab, Dr. Adlul Islam, Additional Director General (SWM), ICAR, New Delhi, Dr. P.C. Sharma, Director, ICAR-CSSRI, Karnal, Haryana, and Dr. Ajay Kumar Bhardwaj, Principal Scientist and Member Secretary, RAC, ICAR-CSSRI, Karnal, Haryana. Two farmer representative members of the RAC, Sh. Meharchand Gehlot and Sh. Hemchand Kaushik were also connected online. Dr. P.C. Sharma, Director, CSSRI, presented a brief account of the institute's achievements and new initiatives undertaken in the field of salinity management by CSSRI. Dr. A.K. Bhardwaj, Member Secretary, RAC presented the action taken report on the recommendations of the last (22nd) RAC meeting. The committee reviewed the last year research activities and advised for future research work. All Heads of Divisions/Stations, Project Coordinator and Scientists of the Institute were also present in this meeting.

Glimpse of RAC meeting

# Workshop, Seminar, Training, Foundation Day and Kisan Mela organised

## Workshop, Seminar, Training, Foundation Day and Kisan Mela organised

### Model Training Course

Trainees with the chief guest

The Institute organized 08 days' Model Training Course sponsored by Directorate of Extension, Ministry of Agriculture & Farmers' Welfare, Govt. of India, New Delhi on “Livelihood Security of Farmers through Technological Interventions in Salt Affected Soils” during 31 January to 07 February, 2020. This training course was attended by 21 officers of state developmental departments and 1 from KVK from six different salt affected states of Punjab, Haryana, Rajasthan, Maharashtra, Karnataka and Odhisha. The training programme was inaugurated by Dr. G.P. Singh, Director, ICAR-Indian Institute of Wheat and Barley Research, Karnal.

During the training course, the participating officers were trained on various aspects of salt affected soils and poor quality irrigation water, and also the social aspects like entrepreneurship development through value addition and organic farming, economic analysis of reclamation of sodic/saline soils and motivational skills for effective dissemination of land reclamation technologies to farmers. The trainees were also given hands on soil and water sampling, methodology for assessment of Gypsum requirement for sodic soil reclamation, determination of EC, pH and ESP of soil, estimation of water quality of irrigation water, etc. They were exposed to the Institute's experimental farms, salinity museum and experimental sites at farmer's fields.

### ATMA Maharashtra Sponsored Training

A 4-days training programme on “Management of Salt affected Soils and Poor Quality Irrigation Water of Maharashtra” was organized during 24-27 February, 2020 at ICAR-CSSRI, Karnal. In this training programme, 14 farmers and one agriculture officer from salt affected areas of Ahmadnagar district of Maharashtra state participated. The participating farmers were acquainted on the location specific solutions for management of saline soils, waterlogged saline soils and saline irrigation water, crop


Dr. P.C. Sharma, Director interacting with the trainees

production technologies in saline soils, etc. through expert lectures by the Institute's scientists. Exposure visits of participating farmers were also made to ICAR-NDRI, Karnal, ICAR-SBI-RRS Karnal, and the Zero Budget Natural Farming practices at Gurukul, Kurukshetra.

### Skill India Development Training Programme

The Institute organized Skill Development Training on 'Soil and Water Testing Lab Assistant' during 24 February to 19 March, 2020 which was sponsored by Ministry of Skill Development and Entrepreneurship, Govt. of India, and coordinated by Agriculture Skill Council of India (ASCI), New Delhi. In this training programme 20 unemployed youth, majority of whom were having Science background, participated with a goal of entrepreneurship. During the 25 days' training programme, the participants we re trained on different aspects of soil and water testing *viz*. Laboratory testing procedures, Adherence to sanitation & safety guidelines in the lab, Registering and preparing soil & water samples for analysis,


Dr. P.C. Sharma, Director addressing the trainees

Calibration of equipments & preparation of solutions required for analysis, *etc*. through a mix of lectures and practical/ hands-on experience. The trainees were also subjected to online assessment by Agriculture Skill Council of India and all of them got qualified in the evaluation test with an average of 70 per cent score.

### DUAL EM Survey conducted under ACIAR, Australia funded project

Farmers awareness programme under ACIAR

GIS assisted DualEm soil survey was conducted in the zero tillage potato experiments at Sonagaon village, Gosaba on 26 February 2020. Unlike previous years, this time the walking survey was conducted in marked lines. First the survey was done in the experiment located (N22$^{0}$08'00.87″ E88$^{0}$47'42.87″) in Mrs. Sumitra Giri's plot. The field layout of the experiment was made with measurements of plot length, width and dimensions of bunds. Then same type of survey was conducted in the ZT potato experiment located (N22$^{0}$08'00.75″ E88$^{0}$47'53.66″) in the Mr. Srihari Mandal's plot. After the survey, soil samples were collected for calibration purpose. Trainings/meetings/field visits and other events were conducted under the ACIAR project on CSI4CZ during 2016-2020 by ICAR-CSSRI, RRS, Canning Town. While introducing improved cultivation methods like direct seeded rice, lime and rock phosphate application, new varieties of crops, drum seeding machine, zero tillage potato cultivation, mulching, drip irrigation etc. there were many queries from farmers, those were answered with demonstration. Similarly, during rabi season, for the first-time improved maize cultivation methods, broccoli cultivation, zero tillage mustard cultivation has been introduced in the project site. About 700 farmers directly acquired knowledge on improved practices like use of *Rhizobium* culture in mungbean cultivation, improved potato variety, cultivation practices and use of scientific instruments like chameleon soil moisture sensors, piezometers etc through various meetings, trainings, awareness programmes (photo 2 &3).

### 52nd Foundation day

ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal celebrated its 52$^{nd}$ Foundation Day on 1$^{st}$ March, 2020. On this occasion, Chief Guest Dr. S. K. Chaudhari, DDG (NRM), ICAR, New Delhi delivered the foundation day lecture. He said that special focus needs to be placed on managing salinity and water quality problems in climate vulnerable districts of India. He observed that remunerative non-food crops

Dr. S K Chaudhari, DDG (NRM) delivering the foundation day lecture should be identified for the productive utilization of huge amounts of municipal and industrial waste waters. He said that a lot needs to be done to manage salinity on landscape and regional levels. He observed that farmers in salt-affected areas need to be provided viable high value land use options with focus on horticultural crops. Dr. Gurbachan Singh, Ex-Chairman ASRB presided over the function. Earlier, Dr. P. C. Sharma, Director ICAR-CSSRI, Karnal welcomed all the dignitaries and highlighted salient achievements of Institute.

### Parthenium Week

Glimpse of the programmes during the Parthenium Week

ICAR-CSSRI organized 'Parthenium week' from 16th to 22nd August 2020 in which awareness programmes and cleanliness drives were organized within the Institute premises to sensitize the people about the ill-effects of parthenium weed and the programme was coordinated by Dr. Ashwani Kumar, Dr. Priyanka Chandra and Dr. Kailash Prajapat. In the awareness programme, control measure for parthenium were also discussed such as spray of glyphosate, 1%-1.5% of metribuzin or 10% of salt. During this week, a total of 100 people were participated in weeding out the parthenium from residential area of CSSRI campus and the farm and field area on 19th August 2020. Dr. Kailash also told the people about the various ways of composting of parthenium and to use it as fertilizer.

### Hindi Pakhwada

Hindi Pakhwada was organized at ICAR-CSSRI Karnal from 14th to 28th September 2020. It was inaugurated by Dr. Rajan Lamba, Principal, Tagore Bal Niketan Sr. Sec. School. During this Pakhwada various events and competitions including Speech, Essay Writing, Debate etc were organized to promote the use of Hindi language. Dr. Chander Shekhar Bhardawaj, Principal, Dayal Singh College was the chief guest during the closing ceremony of the programme, in his address he talked about the role of Hindi language in Independence Movement and in forming the link between all other regional languages of the nation. He appreciated the institute's dedication and efforts towards promoting the use of Hindi language. Report was presented by Dr. Madhu Choudhary, Chair person of Hindi.


Chief guest addressing the gathering during Hindi Pakhwada

## Mahila Kisan Divas

Glimpse of
Mahila Kisaan Diwas

The Institute organised Mahila Kisan Diwas on 15th October 2020 in Budhanpur village of Karnal district. On this occasion around 60 farmwomen were present and participated in the deliberation. Addressing the gathering, the Director of the Institute Dr. PC Sharma told that the Institute is consistently working for the welfare of the farmers and has programs for farmwomen also in order to enable them for self employment and self reliance. On this occasion Dr. Vijay Kumar Arora, former Director Extension of Maharana Pratap Horticulture University Karnal also addressed the gathering and motivated the farmwomen to start their own enterprise for having their own source of income.

In this program Dr. Geetanjali Kaushal, social worker from one of the reputed Institute of New Delhi expressed concern over the increasing air pollution due to stubble burning. In this regard she expressed hope that the farmwoman could play a major role in checking the pollution arising out of agriculture. On this occasion Shri Tulsidas Mishra member of Kisan Morcha, Smt. Indira Devi, Sarpanch of Budhanpur village and Shri Surendra Singh, ex sarpanch of Budhanpur village also expressed their viewpoints and encouraged the farmwomen of the village to start their own enterprise in order to have self-sufficiency. Besides, some master trainers also addressed the gathering and explained the farmwomen about the procedure to start a new enterprise.

## Formation of Self help Group

The institute was instrumental in formation of "CSSRI *Navya Mahila* Self Help Group" consisting of 16 member farmwomen from Bhudanpur village of Karnal District. A resolution was passed in this regard in village meeting on 15th October 2020 which was handed over to the president of the SHG Smt. Kavita by the Director CSSRI, Dr. PC Sharma. The Bhudanpur village has about 235 farm families belonging to SC community majority of these farm families are landless and the male members are engaged in labour employment in the surrounding areas or in Karnal city. This SHG has been formed in order to enable the members to earn for themselves through different agri-enterprises at the household level. The Institute will provide technical guidance and logistic support in caring out the employment generation activities by the SHG.


Self help group formation in presence of Dr. PC Sharma, Director

Glimpse of webinar

### International Salinity Webinar

ICAR- CSSRI in collaboration with International Centre for Biosaline Agriculture (ICBA) organized an international salinity webinar "Resilient Agriculture in Saline Environments under Changing Climate" on November 3, 2020. The webinar was inaugurated by Dr. Trilochan Mohapatra, Director General, ICAR & Secretary DARE, Govt. of India, New Delhi after which Dr. Ismahane Elouafi, DG, ICBA, Dubai gave her inaugural remarks. All the eminent speakers from FAO, Rome (Dr. Ronald Vargas), Australia (Dr. M Mainuddin), USA (Dr. Elia Scudiero and Dr. Devinder Sandhu), Dubai (Dr. R. K. Singh) and India (Dr. P. C. Sharma) have covered global status of salt affected soils (SAS) and their mapping and monitoring, genetic characterization for salt tolerance mechanism, crop diversification and sustainable crop management in face of multiple stressors. Dr. S.K. Chaudhari, DDG (NRM), ICAR, New Delhi summarized the deliberations of presenters and highlighted the major issues needed for SAS. Webinar received 967 registrations, out of which 554 joined as attendees including 17 panelists. About 200 people took advantages of this seminar on live streaming on YouTube. The event was summed up with the vote of thanks by Dr. HS Jat, organizing secretary of seminar.

### Swachta Pakhwada

Mrs. Renu Bala Gupta talking about the importance of cleanliness

Institute organized 'Swachhta Abhiyan' from 16th December to 31st December 2020 in which awareness programmes and cleanliness drives were organized within and outside the Institute premises to sensitize the people about clean India Mission and the programmes were coordinated by Dr. Ashwani Kumar, Dr. Rajkumar and Dr. Kailash Prajapat. The 'Swachhta Abhiyan' began with the Swachhta Pledge by all the Staff of the institute on 16th December 2020. Different teams of Scientists, Administrative and Technical Staff were constituted for implementing the *Swachhta* activities as per guidelines received from the council. These teams organized mass awareness programmes in 6 villages involving about 370 households on waste segregation, composting of organic waste, hazards of plastic and role of cleanness in human health etc. A workshop on "Complete sanitation: a step forwards towards Developed Nation" was organized on 30.12.2020 in which Prof. Radhey Shyam Sharma, Ex-Vice Chancellor, GJU, Hisar delivered a talk on the workshop subject. On 31st December 2020, closing ceremony, Mrs. Renu Bala Gupta, Mayor, Karnal was the Chief Guest. She applauded the role of CSSRI in *Swachh Bharat* Mission and emphasized on need of sensitizing people for complete sanitation which would lead to a clean and healthy Nation.

Table 107. Performance of KRL-210 in 23 locations of soils affected by sodicity and salinity (2019-2020)

| | | | | | |
|---|---|---|---|---|---|
| *Sodic soil* | | | | | |
| Soil pH range (n=6) 8.34-8.85 | Soil pH mean 8.54 | Soil EC range 0.30-0.71 | Soil EC mean 0.45 | Yield range (q/ha) 51.5-57.5 | Mean yield* 52.5 |
| *Sodic soil with saline water* | | | | | |
| Soil pH range (n=6) 8.65-9.2 | Soil pH mean 8.94 | Water EC range (n=5) 3.0-4.5 | Water EC mean 3.74 | Yield range (q/ha) 36.25-56.0 | Mean yield* 48.63 |
| *Sodic soil with high RSC water* | | | | | |
| Soil EC range (n=6) 2.0-4.5 | Soil EC mean 3.04 | Water RSC range 2.5-4.5 | Water RSC mean 3.33 | Yield range (q/ha) 38.53-44.63 | Mean yield* 41.76 |
| *Waterlogged saline soils* | | | | | |
| Soil EC range (n=5) 2.0-4.5 | Soil EC mean 3.04 | Water EC range 2.5-4.5 | Water EC mean 3.3 | Yield range (n=6) q/ha 45.0-50.0 | Mean yield* 50.4 |

* All mean yield in q/ha

Performance of KRL-210 in sodic soil of Budhmour (Patiala)

### Mera Gaon Mera Gaurav: Interventions of salt tolerant wheat variety KRL-210

Mera Gaon Mera Gaurav has been an important programme in making aware the farmers and transferring institute's technologies in different adopted villages across two states (Haryana and Punjab). Under this programme 20.0 quintal seed of salt tolerant wheat KRL-210 was provided to a set of 50 farmers of saline and sodic environments during 2019-2020. Similarly, 5.0 quintal seed of salt tolerant rice Basmati CSR 30 was also provided to these farmers during this period. The trend of distribution of wheat KRL-210 and Basmati rice CSR-30 riceseeds remained same during 2020-2021 period also. In order to see the impact of interventions of salt tolerant crop varieties, the grain yield of salt tolerant KRL-210 was recorded from 23 farmers who adopted this variety in managing different levels of salinity stress. It is to worth mentioning that farmers were also exposed to variable climates during the crop season (2020), and simultaneously of COVID-19 pandemic. Farmers were provided regular agroadvisories while cultivating KRL-210.

It was observed that in sodic soil where mean soil pH was 8.54, this variety yielded 52.5 q grain ha$^{1}$ (Table 107). The soil having sodicity was a stress (pH 8.94) and irrigation water was saline (EC 3.74), crop yield was recorded to be 48.63 q ha$^{1}$. The soil that was affected by sodicity (pH 8.9) and irrigation water was of high RSC (5.55), grain yield of KRL-210 was recorded to be 41.76 q ha$^{1}$. In case of water logged saline soils (soil EC 3.04 and water EC 3.33), the grain yield of this variety was found to be 50.4 q ha$^{1}$. The trend of grain yield of KRL-210 indicated that it varied from 41.76 to 52.4 q ha$^{1}$ in different levels of salinity stress, and demonstrated a viable option to reduce crop yield risks to the farmers.

### SC-SP Programme: Activities and interventions

The socio-economically and ecologically marginalized communities have been deprived of accessing planned knowledge and technologies to enhance their livelihoods. In order to address these issues, central government has initiated a programme called Schedules Caste Sub-Plan (SCSP) for the scheduled caste community. Under SC-SP programme, different central government research organizations were directed to transfer the scientifically evolved knowledge and technology to empower SC community. Through this drive, ICAR-Central Soil Salinity Research Institute, Karnal has implemented various capacity development and technological interventions among SC community during 2020-21. Under SC-SP programme, a total of 13 training trainings were conducted on agricultural aspects covering soil, water, crop and allied enterprises benefitting a total of 620 farmers. A total of 453 demonstrations of salt tolerant rice and wheat, and other

Table 108. Progress of activities and interventions under SC-SP programme

| Sr. No. | Indicators/activities pursued | Achievements during 2020-2021 | |
|---|---|---|---|
| | | Numbers/ Quantity | No. of beneficiaries |
| 1. | No. of Trainings | 13 | 620 |
| 2. | No. of Demonstrations of salt tolerant wheat and rice | 453 | 453 |
| 3. | No. of Field visits/Exposure visits | 85 | 780 |
| 4. | No. of Saplings | 1200 | 182 |
| 5. | No. of Animal mat | 44 | 44 |
| 6. | No. of Sewing machine | 50 | 50 |
| 7. | No. of Equipment created for farmers: Drip irrigation system (3.5 acre) | 1 | 150 |
| 8. | No. of Equipment created for farmers: Power tiller | 1 | 200 |
| 9. | No. of Equipment created for farmers: Plot planter | 1 | 150 |
| 10. | No. of Water harvesting structures for farmers | 30 | 30 |
| 11. | Amount of Biofertilizers | 15.32 q | 231 |
| 12. | Amount of Urea/DAP/Zinc | 5.812 q | 99 |
| 13. | Amount of Salt tolerant rice varieties seed | 15.6 q | 360 |
| 14. | Amount of Salt tolerant & normal wheat seed | 105.5 q | 391 |
| 15. | Amount of Salt tolerant mustard varieties seed | 15 Kg | 30 |
| 16. | Amount of Vegetable seed | 25.68 Kg | 168 |
| 17. | Amount of Animal feed mixture | 41 q | 5 |

Distribution of saplings and sewing machines to SC farmers

Capacity development of SC farmers at ICAR-CSSRI, Karnal

normal varieties were conducted to benefit SC farmers. Field and exposure visits could benefit 780 farmers by enriching their knowledge about various technologies, policies and schemes those can empower these communities. Various other inputs including biofertilizers, urea, DAP, fruit saplings, vegetable seeds, animal mattress and animal feed mixture those could benefit a total of 729 SC farmers in enhancing their livelihood portfolios (Table 108).

A total of 30 water harvesting structures were created in order to harvest rainwater and improve water quality for animal and human, while sewing machine was provided to 50 women so that they can enhance livelihood diversification and monthly income. Through SC-SP various infrastructures like power tiller, plot planter and drip irrigation system were created to provide them trainings and exposure visits so as to improve their agricultural management practices.

# List of Scientific, Technical and Administrative Personnel

**Parbodh Chander Sharma, Ph.D., Director**

## Division of Soil and Crop Management

R.K. Yadav, Ph.D., Head (A)

A.K. Mandal, Ph.D.

Ranbir Singh, Ph.D.

Parveen Kumar, Ph.D. (31.10.2020)[a]

A.K. Rai, Ph.D.

H.S. Jat, Ph.D.

A.K. Bhardwaj, Ph.D.

Rakesh Banyal, Ph.D.

Gajender Yadav, Ph.D.

Madhu Choudhary, Ph. D.

Anshuman Singh, Ph.D. (03.10.2020)[a]

Nirmalendu Basak, Ph.D.

Ashim Dutta, Ph.D.

Parul Sundha, Ph.D.

Raj Kumar, (Agroforestry) Ph.D.

Rajkumar, (Horticulture) Ph.D.

R.L. Meena, Ph.D.

Arijit Burman, Ph.D.

Awtar Singh, Ph.D

Priyanka Chandra, Ph.D.

Manish Kumar, M.Sc (study leave)

Raj Mukhopadhyay, Ph.D.

### Technical Officers

Naresh Kumar, Ph. D.

Dilbag Singh

## Division of Crop Improvement

Neeraj Kulshereshtha, Ph.D., Head (A) (12.03.2020)[b]

S.K. Sanwal, Ph.D.

Anita Mann, Ph.D.

S.L. Krishna Murthy, Ph.D

Joginder Singh, Ph.D.

Ashwani Kumar, Ph.D

Arvind Kumar, Ph.D.

Vijayata Singh, Ph.D.

Lokesh Kumar B.M.

## Division of Irrigation and Drainage Engineering

D.S. Bundela, Ph.D., Head

P.R.Bhatnagar (29.06.2020)[b]

Satyender Kumar, Ph.D.

Bhaskar Nurjury, Ph.D.

R.K. Fagodiya, Ph.D.

Pathan Aslam Latif, M.Tech. (study leave)

Jaffer Yousuf Dar, M.Sc.

### Technical Officers

Rajiv Kumar, M.Sc.

Dharam Pal Kansia, M.Lib.

## Division of Social Science Research

Anil Kumar, Ph.D. Head (A)

Subhasis Mandal, Ph.D. (14.12.2020)[b]

R.K. Singh, Ph.D.

Parvender Sheoran, Ph. D.

R. Raju, Ph.D (31.08.2020)[a]

Dr. Kad Sanjay Vasant (07.08.2020)[a]

Kailash Prajapat, Ph.D.

Bhagya Vijayan (study leave)

Ramya H.R. (04.04.2020)[b]

## AICRP (Saline Water)

M.J. Kaledhonkar, Ph.D., P.C.

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.

U.K. Mandal, Ph.D.

Shishir Raut, Ph. D.

K.K. Mahanta, Ph. D.

T.D. Lama, Ph.D.

Nitish Ranjan Prakash (04.04.2020)[b]

Rinchen Nopu Bhutia (04.04.2020)[b]

### Technical officers

D. Pal, Ph. D. (30.06.2020)[c]

N.B. Mondal, Diploma (31.10.2020)[c]

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

Monika Shukla, Ph.D.

David Cames D., M.Sc. (study leave)

Vibuti Sagar, M.Tech.

Bisweshwar Gorain, M.Sc.

Vineeth TV, M.Sc.

### Technical Officer

Akshay Kumar

## Regional Research Station, Lucknow

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.

Ravi Kiran, Ph.D.

### Technical Officer

C.S. Singh, Ph.D.

Hari Mohan Verma, M.Tech.

### Administrative and Supporting Section

### Administration

Alok Kumar, SAO

Sunil Kumar, FAO

Ishwar Dayal, AO (31.05.2020)[c]

Tarun Kumar, Asstt. Admn. Officer

Ranjeet Singh, Asstt. Admn. Officer

Sultan 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.

### Publications and Supporting Services Unit

H.S. Jat, Ph.D

### Technical Officer

Madan Singh, M.A. (31.12.2020)[c]

Dilawar Singh

### Hindi Cell

Alok Kumar, SAO,OIC

### Technical Officer

S.K. Tyagi, Ph.D (30.04.2020)[c]

### Director Cell

Sunita Malhotra, PS

### Public Relation Officer

Anil Kumar Sharma, M.A.

### Farm Section

Jai Parkash, M.Sc., Farm Manager (31.11.2020)[c]

Jaswant Singh

### Library

Meena Luthra, M. Lib.

### Medical Unit

Sunita Dhingra (30.04.2020)[c]

Chanchal Rani

Geeta Rani

### Estate Section

N.K. Vaid, M.Tech. OIC (Estate Civil)

S.K. Dahiya, OIC, Security

Ashwani Kumar, Diploma (30.04.2020)[c]

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 31.12.2020.

| 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 | | 78 | 78 | 6 | 7.69 | 3 | 3.84 |
| Lowest rung of Class-1 | | 3 | 3 | 1 | 33.33 | - | - |
| Class-II | | 56 | 56 | 11 | 19.64 | 6 | 10.71 |
| Class-III | | 80 | 80 | 6 | 7.5 | 3 | 3.75 |
| Class-IV (excluding sweepers) | | - | - | - | - | - | - |
| Class-IV (only sweepers) | | 1 | 1 | 1 | 100 | - | - |
| Total | | 218 | 218 | 25 | 11.46 | 12 | 5.50 |

## Statement of Scheduled Castes (SC) and Scheduled Tribes (ST)

Statement showing the number of reserved vacancies filled by Scheduled Castes (SC)/ Scheduled Tribes (ST) as on 31.12.2020.

| Classified posts | Total vacancies | | Scheduled Castes | | Scheduled Tribes | |
|---|---|---|---|---|---|---|
| | Notified | Filled | Notified | Filled | Notified | Filled |
| Direct Recruitment | | | | | | |
| Class-I | | | | | | |
| Class-II | | | | | | |
| Class-III | | | Nil | | | |
| Class-IV | | | | | | |
| Promotions | | | | | | |
| Class-I | | | | | | |
| Class-II | | | Nil | | | |
| Class-III | | | | | | |
| Class-IV | | | | | | |

# Weather Report 2020

### Main Institute, Karnal

During the year 2020, a total rainfall of 1324.8 mm was recorded at Agro-met Observatory, Karnal as compared to the mean annual rainfall of 746.8 mm (for the last 49 years). The year was an excessive rainfall year (177% of the long-term mean annual rainfall) whereas the year 2019 was a deficient rainfall year (67% of the long-term mean annual rainfall). The maximum monthly rainfall of 440.6 mm was recorded during July. During the monsoon season, the highest rainstorm 121.0 mm was recorded on 5$^{th}$ July and the second highest of 116.4 mm on 28$^{th}$Aug. During January and February, there was a good amount of rainfall of 74.4 and 21.4 mm which substantially reduced the irrigation demand of wheat and other *Rabi* crops either met from canal water or groundwater or both. There was 167.7 mm winter rainfall (March) as compared to the last year 7.4 mm winter rainfall. Heavy winter rainfall resulted in almost zero irrigation demands and temporary water stagnation for different *Rabi* crops during March leading to bumper *Rabi* crop production. There were 63 rainy days as compared to 46 days during the last year.

The minimum and maximum air temperatures, 0.6°C and 44.0 °C were recorded on 1$^{st}$ January and 27$^{th}$ May, respectively. The air relative humidity was the lowest (18%) on 19$^{th}$ May while the highest (100%) was recorded on several occasions during the year. The highest soil temperatures at 5 and 10 cm depth were 54.0 and 45.5.0 °C on 27$^{th}$ May. The lowest values at same depths were recorded as 2.4 and 3.2 °C on 5$^{th}$ January (5 and 10 cm). The total open pan evaporation during the year was 1325.7 mm, which was equal to the annual rainfall. The lowest evaporation of 0.2 mm was recorded on 8$^{th}$ January and the highest of 12.8 mm was on 27$^{th}$ May. The average sunshine hours per day were 7.2. The highest and lowest vapour pressure values were 29.9 and 5.1 mm on 12$^{th}$ & 16$^{th}$ August and 1$^{st}$ January, respectively. The average wind speed was 3.5 km per hour. The monthly weather parameters recorded at Agro-meteorological Observatory, ICAR-CSSRI, Karnal (Haryana) for the year 2020 are presented in Table 109.

### Weather Report 2020 Bharuch

Agro-meteorological observations (Table 110) recorded at Regional Cotton Research Station, NAU, Bharuch during the year 2020 revealed that this region received normal rainfall of 908 mm spread over 60 days. Season's highest rainfall 376.1 mm was received during August followed by 286.2 mm, 167.0 mm and 51.5 mm in the month of September, July and June 2020, respectively. Maximum air temperature ranged from 27.1°C (January) to 39.7°C (May) and minimum air temperature varied from 13.2°C (January) to 27.5°C (Jun). Pan evaporation varied from 2.3 mm day$^{-1}$ to 9.0 mm day$^{-1}$ during the year. The average bright sunshine hours varied from 2.6 to 10.0 hr/day. Mean relative humidity ranged from 43 to 85 per cent the year. The average wind speed varied from 3.8 kmph to 9.7 kmph during the year.

### Weather Report 2020 Canning Town

The onset of southwest monsoon was on 12$^{th}$ June,2020. Total annual rainfall of 1684.7 mm recorded by the meteorological unit of this institute during 2020, the maximum of 515.1 mm rainfall and 19 rainy days was recorded in the month of August. Rainfall received in the month of august was significantly 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 94 rainy days in this year, which was helps the farming system and timely arrival of monsoon of this year, the production improved significantly. The average daily sunshine hours were moderate. The minimum temperature reaches its lowest (total mean monthly average

**Table 109: Mean monthly weather parameters for the year 2020 recorded at the Agro-meteorological Observatory, ICAR-CSSRI, Karnal**

**Latitude: 29° 43' N**
**Longitude: 76° 58' E**

**Altitude : 245 m above the Mean Sea Level**

**I Time : 0722/0830 hours IST**
**II Time : 1422 hours IST**

| Month | Temperature, °C | | | | | | | Vapour pressure (mm of Hg) | | Relative Humidity (%) | | Max. Temp, °C | | Min. Temp, °C | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Grass Min. | Dry bulb | | Wet bulb | | | | | | High/ date | Low/ date | High/ date | Low/ date |
| | | | | I | II | I | II | I | II | I | II | | | | |
| Jan. | 16.2 | 6.6 | - | 7.9 | 15.8 | 7.7 | 13.3 | 8.2 | 10.1 | 99 | 74 | 21.0/03 | 12.2/09 | 11.4/08 | 0.6/01 |
| Feb. | 21.0 | 7.9 | - | 9.1 | 20.7 | 8.8 | 16.2 | 8.6 | 11.4 | 97 | 62 | 25.0/21 | 13.6/01 | 14.8/29 | 4.0/01 |
| Mar. | 25.3 | 12.4 | - | 14.0 | 24.7 | 13.7 | 19.6 | 11.8 | 14.2 | 95 | 62 | 29.6/26 | 19.0/08 | 17.8/27 | 8.4/15 |
| Apr. | 33.3 | 17.0 | - | 20.8 | 32.7 | 18.3 | 21.7 | 14.3 | 12.9 | 77 | 37 | 37.9/17 | 26.4/27 | 24.4/15 | 11.4/03 |
| May | 36.8 | 22.0 | - | 25.5 | 35.3 | 21.5 | 24.6 | 16.8 | 16.1 | 69 | 39 | 44.0/27 | 29.8/30 | 27.8/28 | 18.2/04 |
| Jun. | 35.9 | 25.7 | - | 28.0 | 34.8 | 25.9 | 28.4 | 24.0 | 24.5 | 84.6 | 59.4 | 39.5/19 | 31.0/01 | 29.2/13 | 19.8/01 |
| Jul. | 33.5 | 26.3 | - | 27.4 | 42.3 | 26.6 | 28.8 | 25.8 | 27.5 | 93.7 | 76 | 38.5/04 | 27.6/22 | 29.0/10 | 23.0/21 |
| Aug. | 32.9 | 26.5 | - | 27.6 | 31.4 | 33.4 | 28.7 | 26.4 | 27.9 | 95.0 | 81.3 | 35.0/07 | 30.0/18 | 28.6/06 | 24.0/22 |
| Sept. | 34.3 | 25.1 | - | 26.2 | 33.6 | 25.8 | 29.0 | 24.8 | 27.2 | 95 | 70.6 | 35.5/22 | 32.0/01 | 27.0/03 | 20.8/03 |
| Oct. | 33.3 | 16.4 | - | 17.9 | 32.5 | 17.4 | 24.0 | 14.8 | 17.3 | 94.7 | 47.1 | 35.0/07 | 31.0/31 | 20.8/01 | 12.4/31 |
| Nov. | 26.2 | 10.6 | - | 11.6 | 25.2 | 11.3 | 19.4 | 9.9 | 13.3 | 95.6 | 56.7 | 30.6/01 | 18.5/26 | 14.4/16 | 8.0/30 |
| Dec. | 20.1 | 7.0 | - | 8.0 | 19.3 | 7.9 | 15.9 | 8.2 | 11.8 | 97.9 | 71.5 | 25/03 | 11.6/31 | 9.3/02 | 2.6/29 |
| **Total** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Average** | **29.1** | **17.0** | - | **18.7** | **29.0** | **18.7** | **22.5** | **16.1** | **17.9** | **91** | **63** | - | - | - | - |

| Month | Soil Temperature, °C (Depth-wise) | | | | | | Rainfall* | | | Evaporation | | Sunshine (hr/day) | Wind Speed (km/hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 cm | | 10 cm | | 20 cm | | | | | | | | |
| | I | II | I | II | I | II | Monthly (mm) | No of rainy days | Heavy/ date | mm/ day | mm/ month | | |
| Jan. | 7.8 | 17.3 | 8.3 | 15.5 | 10.8 | 12.9 | 74.4 | 08 | 22.6/09 | 1.5 | 45.7 | 4.2 | 3.0 |
| Feb. | 8.7 | 2.4.2 | 9.3 | 21.7 | 12.9 | 16.8 | 21.4 | 02 | 14.6/21 | 2.0 | 57.2 | 7.1 | 3.4 |
| Mar. | 13.5 | 27.0 | 14.2 | 24.2 | 17.1 | 20.6 | 161.7 | 08 | 39.0/08 | 3.0 | 88.7 | 6.9 | 3.9 |
| Apr. | 19.7 | 38.9 | 20.6 | 34.9 | 23.9 | 29.6 | 25.6 | 3 | 10.0/19 | 5.1 | 152.8 | 8.5 | 4.0 |
| May | 24.6 | 42.2 | 25.5 | 38.5 | 28.4 | 33.5 | 66.8 | 8 | 16.6/28 | 7.7 | 239.0 | 9.3 | 5.8 |
| Jun. | 28.3 | 44.1 | 28.8 | 40.9 | 31.1 | 35.7 | 103.9 | 6 | 47.8/22 | 6.3 | 182.9 | 9.1 | 5.5 |
| Jul. | 27.6 | 38.6 | 28.5 | 36.0 | 30.6 | 32.8 | 440.6 | 13 | 121.0/05 | 4.5 | 116.1 | 7.2 | 5.2 |
| Aug. | 27.5 | 34.5 | 27.8 | 32.6 | 29.2 | 30.8 | 384.0 | 12 | 116.4/28 | 3.5 | 102.1 | 6.3 | 3.9 |
| Sept. | 26.4 | 39.7 | 27.0 | 36.1 | 29.9 | 33.6 | 0.0 | 0 | - | 4.0 | 121.00 | 8.0 | 2.1 |
| Oct. | 18.6 | 37.2 | 19.8 | 34.0 | 25.1 | 29.8 | 0.0 | 0 | - | 3.6 | 119.9 | 7.5 | 1.3 |
| Nov. | 11.9 | 26.7 | 12.7 | 22.9 | 17.0 | 20.3 | 43.6 | 2 | 39.0/16 | 2.2 | 62.5 | 6.3 | 1.7 |
| Dec. | 8.7 | 21.6 | 9.5 | 17.4 | 13.1 | 19.7 | 2.4 | 1 | 2.4/12 | 1.2 | 37.8 | 5.5 | 1.9 |
| **Total** | - | - | - | - | - | - | **1324.8** | **63** | - | - | **1325.7** | - | - |
| **Average** | **18.6** | **32.7** | **19.3** | **29.6** | **22.4** | **26.3** | - | - | - | **3.7** | - | **7.2** | **3.5** |

*Note:* Rainfall < 2 mm is drizzle or trace.*

**Table 110. Monthly average agro-meteorological parameters at Bharuch during 2020**

| Month | Air Temperature ($^{0}C$) | | Rainfall (mm) | Total rainy days | Avg. Relative humidity (M+E) (%) | Vapour pressure(mm) | | Wind speed (km/hr) | Sunshine (hr/day) | EPan (mmpd) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | | | | M | E | | | |
| January | 27.1 | 13.2 | 0.0 | 0 | 58 | 9.7 | 12.6 | 4.4 | 8.2 | 3.8 |
| February | 32.1 | 18.8 | 0.0 | 0 | 46 | 12.1 | 9.9 | 5.9 | 9.0 | 6.7 |
| March | 36.2 | 22.0 | 0.0 | 0 | 52 | 15.0 | 12.7 | 7.3 | 8.6 | 7.7 |
| April | 38.7 | 22.6 | 0.0 | 0 | 44 | 15.7 | 10.5 | 8.2 | 9.9 | 8.8 |
| May | 39.7 | 27.1 | 0.0 | 0 | 47 | 19.4 | 15.0 | 6.8 | 10.0 | 9.0 |
| June | 35.7 | 27.5 | 51.5 | 7 | 68 | 24.2 | 22.5 | 9.7 | 6.5 | 6.2 |
| July | 33.7 | 26.4 | 167.0 | 19 | 79 | 25.1 | 25.8 | 8.6 | 4.2 | 3.8 |
| August | 30.8 | 25.8 | 376.1 | 20 | 85 | 25.1 | 24.9 | 8.1 | 2.6 | 2.3 |
| September | 32.9 | 25.8 | 286.2 | 11 | 79 | 25.0 | 24.7 | 4.7 | 4.0 | 4.1 |
| October | 35.6 | 24.3 | 9.2 | 1 | 62 | 21.7 | 20.0 | 3.8 | 7.5 | 7.1 |
| November | 33.1 | 18.0 | 0.0 | 0 | 43 | 12.4 | 9.7 | 4.5 | 8.3 | 5.6 |
| December | 29.7 | 15.2 | 17.6 | 2 | 57 | 12.3 | 11.6 | 4.9 | 7.5 | 5.4 |
| **Total** | | | **908** | **60** | | | | | | |
| **Average** | **33.8** | **22.2** | | | **60.0** | **18.1** | **16.7** | **6.4** | **7.2** | **5.9** |

13.4$^{0}$C in the month of January) in the month of December. The average means monthly temperature of 18.7$^{0}$C in January rises very rapidly to 29.6$^{0}$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. Rainfall recorded 41.4 mm on 20.5.20,48.0mm on 21.5.20 and average wind velocity 28.8 km/h recorded due to very severe Cyclonic Storm "Amphan" occurred on 20.5.20 in this region. The mean monthly weather parameters recorded at RRS, Canning, are presented in Table 111.

**Table 111. Mean monthly weather parameters at Canning Town (Latitude 22$^{0}$15' N, longitude 88$^{0}$40' E, altitude (amsl) 3.0 m) during the year-2020**

| Month | TEMPERATURE($^{0}C$) | | | RH (I) (%) | RH (II)(%) | Rainfall (mm) | Rainy Days (no.) | Evaporation (mm) | Av. WIND (km $h^{-1}$) | BSSH ($day^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | MAX. | MIN. | MEAN | | | | | | | |
| Jan | 24.0 | 13.4 | 18.7 | 87.9 | 76.9 | 41.6 | 1.0 | 5.0 | 1.7 | 04 |
| Feb | 27.1 | 15.3 | 21.2 | 80.0 | 50.1 | 7.6 | 2.3 | 6.6 | 1.9 | 01 |
| Mar | 32.3 | 21.7 | 27.0 | 82.9 | 62.0 | 30.0 | 4.9 | 6.7 | 3.1 | 04 |
| Apr | 35.3 | 24.0 | 29.6 | 85.9 | 66.4 | 58.8 | 6.2 | 6.7 | 5.3 | 05 |
| May | 34.7 | 25.2 | 30.0 | 85.8 | 72.9 | 224.2 | 5.3 | 7.0 | 7.9 | 09 |
| Jun | 33.8 | 26.8 | 30.3 | 90.8 | 82.5 | 274.6 | 3.6 | 4.5 | 6.0 | 15 |
| Jul | 33.1 | 27.2 | 30.1 | 93.4 | 86.6 | 257.3 | 3.5 | 5.1 | 5.9 | 16 |
| Aug | 42.3 | 26.9 | 34.6 | 94.8 | 87.8 | 515.1 | 3.0 | 3.7 | 5.7 | 19 |
| Sep | 33.0 | 28.4 | 30.7 | 88.3 | 84.4 | 186.7 | 3.8 | 4.7 | 3.2 | 12 |
| Oct | 32.9 | 26.1 | 29.5 | 82.2 | 78.3 | 88.0 | 3.8 | 6.2 | 2.5 | 09 |
| Nov | 30.5 | 19.7 | 25.1 | 73.0 | 64.4 | 0.8 | 2.9 | 7.3 | 2.1 | 00 |
| Dec | 26.3 | 14.1 | 20.2 | 72.3 | 57.8 | 0.0 | 1.4 | 6.1 | 1.5 | 00 |
| **Total** | | | | | | **1684.7** | **41.7** | **69.5** | **46.9** | **94** |
| **Average** | **32.1** | **22.4** | **27.3** | **84.8** | **72.5** | | | **5.8** | **3.9** | |

Max temperature= 37.6 $^{0}$C on 16.5.2020
Minimum temp= 10.0 $^{0}$C on 21.12.20 and 28.12.20
Maximum Rainfall= 77.2 mm on 21.8.20
Rainfall recorded on 20.5.20 (41.4 mm) and 21.5.20 (48.0 mm) due to very severe Cyclonic Storm Amphan on 20.5.20 in evening.

2020

बेटी बचाओ बेटी पढ़ाओ

स्वच्छ भारत
एक कदम स्वच्छता की ओर

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