भाकृअनुप-अखिल भारतीय समन्वित अनुसंधान परियोजना

लवणग्रस्त मृदाओं का प्रबंधन एवं खारे जल का कृषि में उपयोग

ICAR-All India Coordinated Research Project

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

द्विवार्षिक प्रतिवेदन

Biennial Report

(2019-20)

Project Coordinating Unit

ICAR-Central Soil Salinity Research Institute

Karnal - 132 001, Haryana (India)

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Telephone: +91-184-2290501; Gram: Salinity
Fax: +91-184-2290480; Email: director.cssri@icar.gov.in

Contact details **:** Dr MJ Kaledhonkar
Project Coordinator (A)
ICAR-Central Soil Salinity Research Institute, Karnal
Tel: +91-184-2292730 (O); +91-184-2294730 (R)
Fax: +91-184-2290480
Email: mj.kaledhonkar@icar.gov.in; pcunitkarnal@gmail.com

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Cooperating Centres

1. Raja Balwant Singh College, Bichpuri, Agra (Uttar Pradesh)
2. Regional Research Station, ANG Ranga Agricultural University Bapatla (Andhra Pradesh)
3. SK Rajasthan Agricultural University, Bikaner (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences, Gangawati (Karnataka)
5. Department of Soils, CCS Haryana Agricultural University, Hisar (Haryana)
6. Agriculture College, RVS Krishi Vishwa Vidyalaya, Indore (Madhya Pradesh)
7. Agriculture College, CS Azad University of Agriculture & Technology, Kanpur (Uttar Pradesh)
8. AD Agricultural College and Research Institute, TN Agril University Tiruchirappalli (Tamil Nadu)

Volunteer Centres

1. Regional Research Station, Punjab Agril University, Bathinda (Punjab)
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3. ICAR-Central Island Agril Research Institute, Port Blair (A&N Islands)
4. Rice Research Station, Kerala Agril University, Vyttila, Kochi (Kerala)

भाकृअनुप
ICAR

परियोजना समन्वयन इकाई

भाकृअनुप –केन्द्रीय मृदा लवणता अनुसंधान संस्थान

करनाल – 132 001 (भारत)

Project Coordinating Unit

ICAR-Central Soil Salinity Research Institute

Karnal - 132 001 (India)

FOREWORD

The world population has reached to 7.9 billon. However, natural resources like land and water, to feed such huge population, are limited and continuously threatened due to industrialization, urbanization, infrastructure development and disposal of waste material. All the countries in the world are trying to increase cropping and irrigation intensity with all means. In this endeavour, all types of soils and all types of available waters, irrespective of their suitability classes, are being used to grow crops. Due to frequent agricultural operations, over use of fertilizers, herbicides, insecticides and pesticides, natural flora and fauna of soil system are being adversely affected. Some of the soils, where irrigation and drainage requirements are not properly addressed, are going out of cultivation due to soil sodicity and soil salinity problems. This is the global phenomenon and most of the countries in world suffer from these problems. As per FAO, over 1100 Mha of soils are affected by salinity and sodicity, of which about 60 percent are saline, 26 percent sodic and the remaining 14 percent saline-sodic. Salt-affected soils are found on all continents. The most affected regions are the Middle East, Australia, North Africa, and Eurasia. Out of total degraded land of 120.70 Mha in India, salt affected land is 6.74 M ha. Of Course, these problems were noticed in the India before the independence. However, systematic scientific understanding based basic and applied research was developed after establishment of Central Soil Salinity Research Institute (CSSRI) during 1969 as per recommendations of Indo-American team for assisting the Indian Council of Agricultural Research (ICAR) to develop a comprehensive water management programme for the country. The AICRP on Salt Affected Soils and Use Saline Water in Agriculture (AICRP on SAS&USW) got associated with ICAR-CSSRI's vision and efforts in 1972. Since from its existence, the ICAR-CSSRI contributed to characterization, mapping, reclamation and management of salt affected soils, comprising alkali, waterlogged saline and coastal saline soils, bio-saline agriculture, development of salt tolerant varieties, use of consortia of microbes for plant growth promotion and plant protection and management techniques of alkali and saline groundwater. The ICAR-CSSRI has been recognized nationally and globally for its untiring services and now it is also focusing on issues of climate change by developing climate resilient technologies. The institute has greater role to play at national level to address `Land Degradation Neutrality (LDN)' in order to restore productivity of vast degraded lands so as to improve livelihoods of billions as well as to ensure different sustainability development of United Nations. The ICAR-CSSRI has acted as centre of excellence at national level and playing important role of helping other developing countries for managing salt affected soils and poor quality saline and alkali waters.

The centres of AICRP on SAS&USW are located in different salt affected eco systems under different agro-ecological regions of the country and are involved in developing location specific technologies. Important technologies of AICRP can be listed as conjunctive use of saline/sodic water and good quality water, use of drip for saline/sodic waters, amelioration of alkali waters, subsurface drainage and controlled drainage, skimming of fresh water layer from coastal aquifers, low cost recharge structure for poor quality semi-arid regions, use of distillery spent wash for reclamation of alkali soil and water, drip with mulching on waterlogged saline soils, reclamation of abandoned aqua ponds, integrated farming system (IFS) models, screening and identification of crop genotypes/ varieties for salt tolerance, etc. The contributions made by the centres have been well appreciated by planners and farmers as these technologies are helping the farmers who are in distress.

At the end, efforts of Dr MJ Kaledhonkar, Project Coordinator (A) and other staff members of the unit in smooth running of the scheme are appreciated. Also efforts in compilation and editing of Biennial Report of the scheme deserve appreciation. It would be my pleasure to extend all support to the project for addressing future challenges and achieve desirable output.

23/10/2021

(PC Sharma)
Director, ICAR-CSSRI

PREFACE

The availability water per capita in India has declined with time; from 2009 m^3 during 1991 to 1902 m^3 during 2001. It will be 1191 m^3 in 2050 indicting that the country will face acute water shortage. Though agriculture is major user of surface and groundwater resources, its share is declining. Thus, there is clear indication that good quality available water would go to industry and domestic sector and agriculture has to depend on low quality waters. With advancement in groundwater extraction technologies, more and more groundwater is being pumped out from aquifers for irrigation. The average stage of ground water development of the country was 58% in 2004 and at present, it is 63.33%. As a result, top fresh water layers in aquifers have been already exploited and lower layers are of either saline or alkali groundwater. In coastal regions, groundwater quality deterioration is observed due to sea water intrusion. Total irrigated area of the country is around 68.1 million ha. Out of it, 43.5 million ha is groundwater irrigated. It clearly indicates our over dependence on groundwater. As per preliminarily estimate, around 175 districts of the country face groundwater quality problems. It is interesting that these districts are found in arid, semi-arid and coastal regions. Thus saline and alkali groundwater are found almost in all states of the country except hilly states. Farmers are compelled to use poor quality groundwater (saline or alkali) for irrigation in problem areas. However, use of such waters not only reduces the crop yields but also degrades the soil by irrigation induced soil salinization and alkalization. Thus, land and water productivities are adversely affected. The main mandate of the AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture is to use these marginal waters by combining synergetic effect of natural resource management (NRM) and biological strategies. In case of NRM technologies, emphasis is given on reducing salt and water stresses in active root zone either by removing salts from root zone or displacing the salts within root zone. This AICRP is actively involved with ICAR-CSSRI, Karnal and gives more emphasis on management on poor quality saline and alkali groundwater and irrigation induced salinization and alkalization. The scheme has made significant contributions towards characterization, mapping and judicious utilization of saline and alkali groundwater in different situations such as arid, semi-arid and coastal. Different centres of scheme have provided many cost effective and environment friendly technologies which have been well accepted by farmers. Efforts are going on to revise groundwater quality of the country. The scheme is moving ahead with concept of converge of ideas from different disciplines with assumption that synergetic effects of different approaches may reduce yield losses of farmers by upholding national goals of more crop per drop and more crop per unit land.

I take this opportunity to express my sincere thanks and gratitude to Dr T Mohapatra, Secretary, DARE and DG, ICAR for providing financial support and taking keen interest in AICRP activities. I also express my deep sense of gratitude to Dr SK Chaudhari, DDG (NRM) ICAR for guiding the technical programme and providing unstinted support to the scheme. Heartfelt thanks are due to Dr PC Sharma, Director, ICAR-CSSRI for their excellent support to the scheme and cooperation in all spheres. Special thanks are due to Dr Adlul Islam, ADG (SWM)-Acting for kind support for smooth running of the AICRP.

I wish to extend my sincere thanks to Chief Scientists/ OICs at cooperating centers; Dr RB Singh, Dr Radha Krishna (Retd.), Dr A Mrudhula, Dr AK Singh (Retd.), Dr Ranjeet Singh, Dr Vishwanath Jowkin, Dr Satyvan (Retd.), Dr Ram Prakash, Dr UR Khandkar (Retd.), Dr KS Bangar, Dr Ravindra Kumar and Dr P Balasubramaniam and Nodal Officers at Volunteer Centres; Dr SB Dodake, Dr KV Vaidya Dr BK Yadav, Dr AK Sreelatha, Dr A Velmurgan and all scientific, technical and supporting staff at respective centres for undertaking successful research programmes and reporting the achievements to Project Coordinating Unit timely. I also thank staff at Project Coordinating Unit staff such as Dr BL Meena, Shri AK Sharma, Smt Dinesh Gugnani, Shri Shashi Pal, Shri Pradeep and Shri Ram Sevak as well as administration and finance sections of the institute for providing all necessary help.

23/10/2021

(M J Kaledhonkar)
Project Coordinator (A)

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AICRP ON MANAGEMENT SALT AFFECTED SOILS & USE OF SALINE WATER IN AGRICULTURE, ICAR-CSSRI, KARNAL

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1. RESOURCE INVENTORIES OF POOR QUALITY GROUNDWATERS & SALT AFFECTED SOILS

1.1 Resource Inventories of Poor Quality Groundwater for Irrigation Purpose

- **Survey and characterization of ground water of Mathura district (Agra)**

The distribution of 463 water samples in different water quality classes revealed that 17.9, 6.5, 22.2, 18.1,7.0 per cent samples were of good quality in Farah, Goverdhan, Mathura, Baldev and Nauhjheel blocks and none of the samples were found of good quality in Chaumuha and Raya blocks. The 52.3, 88.7, 69.4, 68.7, 78.0, 73.0 and 80.7 per cent samples of Farah, Goverdhan, Mathura, Baldev, Chaumuha, Raya and Nauhjheel blocks came under different saline classes (Marginally saline, saline and High SAR saline) while, rest 29.8, 4.8, 8.4, 13.2, 22.0,27.0 , 12.3 per cent samples came in alkali classes (Marginally Alkali and High Alkali only) respectively. Comparing the water quality of latest collected samples with 40 years ago collected samples of Mathura district, it can be explained that the area under good quality increased in Farah block and reduced in Goverdhan, Mathura and Nauhjheel block while in Baldev it was found at par. No samples of good quality water were found in Chaumuha and Raya block. The major number of samples falls in Saline water quality in the surveyed periods. High SAR Saline water area increased in Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks. The saline water quality (marginally saline and saline) decreased in Farah block and Alkali water area found decreasing in Goverdhan, Mathura and Baldev blocks, whereas, minute change was recorded in Farah block in respect of Alkali classes.

- **Survey and characterization of ground water of Nellore district (Bapatla)**

Revisiting of sampling sites during 2018-19 in Nellore district indicted that quality of irrigation water has deteriorated as compared to earlier study during 1993-94. Per cent good quality water came down to 38% as compared to 39%. There was significant increase in marginal saline water area to 22.4% as compared to earlier 6.2%. Saline water area exhibited an increase to 6.9% from 0.4% and high SAR saline water enhanced to 4.9% as compared to 2.6% based on earlier study.

- **Survey and characterization of underground irrigation water of Chittoor district (Bapatla)**

Groundwater survey was conducted in Chittoor district again during 2019-20 to determine the ground water quality changes in Chittoor district with time. Earlier survey was conducted during 2003-04. Total 359 ground water samples were collected from 66 mandals. The pH of samples varied from 5.5 to 8.8 while EC (Electrical Conductivity) ranged from 0.2 to 13.5 dSm^{-1} with a mean value of 1.73 dSm^{-1}. The order of dominance of ions was Na^{+}>HCO_3^{-}>Cl^{-}>Ca^{+2}>Mg^{+2}>SO_4^{-2}> CO_3^{-2}>K^{+}. As per the classification given by CSSRI, Karnal 65.64 per cent samples were in good quality and can be used for all types of soils and crops, 25.69 samples are marginally saline and can be used with slight salt tolerant crops. High SAR samples were 0.27 per cent and were unsuitable for irrigation, 6.7 per cent samples with marginally alkaline quality could be used along with use of gypsum. The 1.11 per cent samples with alkali quality and 0.55 per cent samples with highly alkaline quality were unsuitable for irrigation. There was deterioration in groundwater quality with time. Per cent good quality water has reduced from 71.3% (2003-04) to 65.64% (2019-20). However, marginally saline water showed an increase from 9.3% to 25.69% during the same period.

- **Survey and characterization of groundwater for irrigation for Jodhpur district (Bikaner)**

Total 170 water samples from 121 villages i.e. 19 villages of Balesar,13 villages of Bap, 23 villages of Denchu, 23 villages of Lohawat, 22 villages of Phalodi and 21 villages Shergarh tehsils of Jodhpur district were collected and analyzed. About 38.71, 58.06 and 3.23 per cent water samples in Balesar tehsil are under good, marginally saline and saline; 6.25, 6.25, 62.50 and 25.00 per cent water samples in Bap tehsil lies under good, marginally saline, High SAR saline and highly alkali; 12.90, 58.06, 3.23 and 25.81 per cent water samples in Denchu tehsil lies under good, marginally saline, saline, High SAR saline; 71.87, 18.75 and 9.38 per cent water samples in Lohawat tehsil lies under good, marginally saline, High SAR saline; 10.34, 41.38, 20.69, 27.59 per cent water samples in Phalodi tehsil lies under good, marginally saline, High SAR saline and highly alkali and 3.33, 33.33, 3.33, 56.68 and 3.33 per cent water samples in Shergarh tehsil lies under good, marginally saline, saline, High SAR saline and marginally alkali. The concentration of Fluoride in water samples ranged from 0.02 to 1.34 (mean 0.46), 0.02 to 1.85 (mean 0.75), 0.04 to 0.85 (mean 0.47), 0.30 to 0.90 (mean 0.56), 0.03 to 1.50 (mean 0.63) and 0.02 to 2.52 (mean 0.71) mg/L, whereas, Nitrate content of water samples ranged from 1.10 to 114.40 (mean 52.67), 5.30 to 53.10 (mean 33.92), 1.50 to 128.20 (mean 31.79), 2.10 to 130.50 (mean 42.56), 2.70 to 120.60 (mean 32.93), and1.40 to123.00 (mean 46.65) mg/L, respectively for Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils of Jodhpur district.

- **Survey and characterization of ground water of Pali district (Bikaner)**

Water samples from 166 tube wells in 121 villages in six tehsils (16 Jaitaran, 20 Pali, 20 Raipur, 20 Rohat, 21 Sojat and 24 Sumerpur) of Pali district were collected and analyzed for various chemical characteristics. About 16, 16, 8, 48, 8 and 4 per cent water samples in Jaitaran tehsil were under good, marginally saline, saline, high SAR saline, marginally alkali and alkali. Similarly 14.81, 11.11, 7.41, 48.15, 7.41 and 11.11 per cent water samples in Pali tehsil were under good, marginally saline, saline, high SAR saline, marginally alkali and highly alkali. In case of Raipur tehsil, 27.59, 24.14, 3.45, 13.79 and 31.03 per cent water samples in Raipur tehsil were under good, marginally saline, saline, high SAR saline, marginally alkali. In case of Rohat Tehsil, 13.04, 8.70, 69.56 and 8.70 per cent water samples were under good, marginally saline, high SAR saline, marginally alkali. Also 29.41, 11.76, 26.48, 5.88, 11.76 and 14.71 per cent water samples in Sojat tehsil lies under good, marginally saline, high SAR saline, marginally alkali, alkali and highly alkali and 21.43, 14.29, 10.71, 42.86, 7.14 and 3.57 per cent water samples in Sumerpur tehsil were under good, marginally saline, saline, high SAR saline, marginally alkali and alkali categories.

The range of chemical characteristics of soil samples in these tehsils indicated that pH_2 of soil samples in Jaitaran tehsil varied from 7.75 to 9.56, Pali tehsil from 8.04 to 9.62, Raipur tehsil varied from 7.73 to 9.69, Rohat tehsil from 8.43 to 9.80, Sojat tehsil varied from 8.20 to 9.70 and Sumerpur tehsil from 8.40 to 9.66, whereas, the corresponding EC_2 ranged from 0.08 to 1.33, 0.10 to 3.60, 0.07 to 1.57, 0.10 to 1.87, 0.10 to 6.23, 0.09 to 4.49 dS/m, respectively in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils.

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

The survey, characterization and mapping of underground irrigation water of namely Ballabgarh and Faridabad blocks of Faridabad district was undertaken during 2018-19. In Ballabgarh block of Faridabad district 29.0, 30.8, 2.6, 13.7, 13.7, 3.4 and 6.8 per cent samples were found in good, marginally saline, saline, high SAR saline, marginally alkali, alkali and highly alkali categories, respectively. In Faridabad block it was found that 33 percent samples were of good quality, 50 percent saline and 17 percent alkali in nature. Out of the saline water, 39 and 11 percent were in marginally saline and high SAR saline, respectively. In alkali group, 11, 4 and 2 percent samples were observed as marginally alkali, alkali and highly alkali categories, respectively. Overall in Faridabad district it was found that 30.9 percent samples were of good quality, 48.4 percent saline and 20.7 percent alkali in nature. Out of the saline water, 34.6, 1.4 and 12.4 percent were in marginally saline, saline and high SAR saline, respectively. In alkali group 12.4, 3.7 and 4.6 percent were in marginally alkali, alkali and high alkali, respectively.

- **Survey and characterization of ground water of Gurugram district (Hisar)**

The survey and characterization of underground irrigation water were undertaken in Gurugram and Sohana blocks of Gurugram district. In Gurugram block , 28.0, 37.0, 3.0, 26.0, 3.0 and 3.0 per cent samples were found in good, marginally saline, saline, high SAR saline, marginally alkali and highly alkali categories, respectively. In Sohana block, 37.0, 31, 4, 19, 4 and 5 per cent samples were found in good, marginally saline, saline, high SAR saline, marginally alkali and highly alkali categories, respectively. Overall in Gurugram district it was found that 39.69 percent samples were of good quality, 37.78 percent saline and 22.53 percent alkali in nature. Out of the saline water, 18.37, 5.89 and 13.52 percent were in marginally saline, saline and high SAR saline, respectively. In alkali group 11.09, 4.51 and 6.93 percent were in marginally alkali, alkali and high alkali, respectively. Out of seven categories of water, maximum 39.69 percent of samples were found in good quality followed by marginally saline (18.37 percent) and minimum 4.51 percent were found in alkali category.

- **Survey and characterization of groundwater for irrigation and salinity associated problems in Dewas district of Madhya Pradesh (Indore)**

A ground water survey of the Dewas district was conducted by collecting and analysing 235 ground water samples from different villages from different tehsils of the district. Out of these 235 samples, 208 (88.5%) belongs to category “Good”, 23 (9.8%) belong to category “Marginally Saline” and 4 (1.7 %) belong to category “Saline”. The ground water quality map of the district was also generated with the help of software ERDAS IMAGINE 8.7.

- **Groundwater quality of Madhya Pradesh for irrigation purpose (Indore)**

Ground water quality maps of Madhya Pradesh with respect to EC, pH, SAR and saline / alkali water categories were generated with the data available with the AICRP on Management of Salt Affected Soils and Use of saline water in agriculture and data procured from Ground Water Board of Madhya Pradesh with the help of GIS & RS soft ware (ArcMap GIS software 9.3.1). In whole state, 6482 ground water samples were used to generate maps og ground water quality. Out of fifty one districts of the state, the AICRP centre of Indore has covered 17 districts so far and remaining districts data procured from the Ground Water Board of Madhya Pradesh. In whole Madhya Pradesh, 87.3% samples were good (A), 7.7 % saline (B) and 5 % alkali (C) water. Out of eleven agro climatic zone of Madhya Pradesh, seven have the good quality water in more than 90% water samples. The Chhatisgarh Plains, Northern Hills Zone of Chhatisgarh, Central Narmada Valley, Satpura Plateau and Jhabua Hills agro-climatic zones have good quality water in more than 95% samples. The ground waters of Gird zone and Bundelkhand Zone have poor quality water in respect of alkali water category and represented 20.5% and 12.5% samples. On the other hand the water of Malwa Plateau has 12% saline and 2.5% alkali in nature. Similarly Nimar Valley area of the agro-climatic zone depicted 14.2% saline and 0.4% alkali water.

- **Survey and characterization of groundwater for irrigation for Kanpur Dehat and Auriya district of Uttar Pradesh (Kanpur)**

Two hundred four underground irrigation 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. Out of 204 samples, 139 (68.14 %) belongs to category good, 42 (20.59%) belongs to category marginally saline, 05 (2.45 %) belongs to category saline, 03 (1.47%) belongs to category highly saline, 05 (2.45%) belong to category marginally alkaline, 06 (2.94%) belongs to category alkali and 04 (1.96%) belongs to category highly alkaline water.

- **Survey and characterization of ground water of Ramanathapuram district of Tamil Nadu for Irrigation (Tiruchirapalli)**

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^+ andK^+ by adopting standard procedures and thematic maps were prepared using Arc GIS software 10.1. The 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}. Residual Sodium Carbonate (RSC) varied from nil to18 meL^{-1} and Sodium Adsorption Ratio (SAR) ranged from 0.52 to 144.34.According to CSSRI, Karnal water quality classification, only 10 per cent of groundwater found under good quality, (10%) marginally saline, (4%) saline, (1%) marginally alkaline, (10%) alkaline, (46%) high SAR saline and (19%) high alkaline. The cationic and anionic order of different blocks in Ramanathapuram are followed as the $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ and $Cl^- > HCO_3^- > CO_3^{2-} > SO_4^{2-}$, respectively. Among the different blocks investigated, the highest percentage of a 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%), High 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.

- **Survey and characterization of ground water of Thoothukudi district of Tamil Nadu for Irrigation (Tiruchirapalli)**

A study was undertaken to assess the groundwater quality in Thoothukudi district by collecting 151 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^+ andK^+ by adopting standard proceduresand thematic maps were prepared using Arc GIS software 10.1. The investigation revealed that groundwater samples with respect to pH and EC ranged from 6.84 to 8.87 and 0.13 to 11.90 dS m^{-1}. Residual Sodium Carbonate (RSC) varied from Nil to 18.00 meq L^{-1} and Sodium Adsorption Ratio (SAR) ranged from 0 to 37.02. According to CSSRI, Karnal water quality classification, only 51 per cent of groundwater found under good quality, (21%) marginally saline, (13%) saline, (3%) marginally alkaline, (2%) alkaline, (7%) high SAR saline and (3%) high alkaline. The cationic and anionic order of different blocks in Thoothukudi are followed as the $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ and $Cl^- > HCO_3^- > CO_3^{2-} > SO_4^{2-}$, respectively. Among the different blocks investigated, the highest percentage of a samples with good quality found in Ottapidaram (92%),Karunkulam (82%), Srivaikundam (75%), Alwarthirunagari (72%), Tiruchendur (59%), Vilathikulam (57%),Kayathar (50%), and Similarly, the poor-quality water viz., High SAR saline from Vilathikulam block (43%), Saline from Sathankulkam (44%), Marginal Saline from Kovilpatti (44%), High Alkali from Thoothukudi (10%), Alkali from Thoothukudi (20%). Among the different blocks of Thoothukudi district, Udangudi (46.15%), Kovilpatti (40%), Srivaikuntam (37.5%) and Sathankulam (37.5%) recorded the possibility of seawater intrusion.

- **Survey and characterization of ground water of Tirunelveli district of Tamil Nadu for Irrigation (Tiruchirapalli)**

In general, the distribution of cations followed the order of Na^{+}> Mg^{2+}> Ca^{2+}>K^{+} in all blocks while anions followed the order of Cl^{-}> HCO_3^{-}> CO_3^{2-}> SO_4^{2-} in majority of blocks except Nanguneri, Ambasamudram, Keezhapavur and Kadayam where order of anions was HCO_3^{-}>Cl^{-}> CO_3^{2-}> SO_4^{2-}. Out of the 130 total samples collected in Tirunelveli district, 57% were characterized under good quality, (18%) Marginally saline, (4%) Saline, (1%) High-SAR saline, (11%) Marginally alkali, (8%) Alkali and (1%) high alkali.

- **Survey and characterization of groundwater for irrigation for Mansa, district, Punjab (Bathinda)**

The 94, 259 and 58 groundwater samples were collected from Budhlada, Mansa and Sardulgarh block of Mansa district. The EC of majority of the cases i.e. 47% in Budhlada, 37% in Mansa and 22% in Sardulgarh was less than 2 dSm^{-1}. Whereas, 43% in Budhlada, 52% in Mansa and 32% in Sardulgarh were observed between 2 to 4 dSm^{-1} and rests was more than 4 dSm^{-1}. On basis of electrical conductivity only 36% water could be used without any possible risk of soil salinization. Further, 42% water was rated as marginal (EC, 2 to 4 dSm^{-1}) for irrigation and 22% water was under saline category. Also it was observed that 65, 77 and 86% water samples have RSC < 2.5 me L^{-1}, while 10, 16 and 7% of water samples showed RSC between 2.5-5.0 me L^{-1} in Budhlada, Mansa and Sardulgarh, respectively. On the basis of RSC, 76% water is safe (RSC <2.5 meq^{-1}), 11% water is marginal (RSC, 2.5 to 5.0 meL^{-1}) and 13% water is unsuitable for irrigation (RSC, > 5.0 meL^{-1}). Fluoride content in Budhlada, Mansa and Sardulgarh blocks of Mansa district ranged from 0.55 – 4.54 mg L^{-1} with mean value 1.99 mg L^{-1}, from 0.20 – 7.75 mg L^{-1} with mean value 2.24 mg L^{-1} and from 0.57 – 5.54 mg L^{-1} with mean value 2.06 mg L^{-1}, respectively. It is also reported that the maximum fluoride varied in Mansa followed by Sardulgarh and Budhalada**.** About 10% samples were found within safe limit (<1.5 mgL^{-1}), in which 7 % samples having fluoride (<1.0 mgL^{-1}), whereas 3% samples having fluoride between 1.0-1.5 mgL^{-1}. Remaining 90% samples were beyond permissible limits (>1.5 mgL^{-1}) as per WHO (1994).

- **Survey and characterization of ground irrigation water of Shri Muktsar Sahib, district, Punjab (Bathinda)**

The EC of majority of the cases i.e. 28 % in Muktsar, 44 % in Malout, 31 % in Gidderbaha and 44 % in Lambi block was less than 2 dS m^{-1}. Whereas, 52 % in Muktsar, 34 % in Malout, 54 % in Gidderbaha and 33 % in Lambi blocks were observed between 2 to 4 dSm^{-1} and rests was more than 4 dSm^{-1}. It is reported that based on electrical conductivity only 40 % water could be used without any possible risk of soil salinization. Further, 40% water was rated as marginal (EC, 2 to 4 dSm^{-1}) for irrigation and 20% water was not suitable for irrigation due to their higher electrical conductivity. It is observed that 60, 71, 77 and 77% water samples have RSC < 2.5 me $L^{-1,}$ while 8, 2, 8 and 9 % of water samples showed RSC between 2.5-5.0 me L^{-1} in the blocks Muktsar, Malout, Gidderbaha and Lambi, respectively. Further, it is reported that on the basis of RSC, 76% water is safe (RSC, <2.5 meL^{-1}), 7% water is marginal (RSC, 2.5 to 5.0 meL^{-1}) and 17% water is unsuitable for irrigation (RSC, > 5.0 meL^{-1}) in Muktsar district. The 26% samples had SAR less than 10 while 74% samples had SAR more than 74%. The most of water samples collected from the Muktsar district have higher amount of fluoride, which makes it unsuitable for use. About 17 % samples were found within safe limit (<1.5 mgL^{-1}), in which 6 % samples having fluoride (<1.0 mgL^{-1}), whereas 11% samples had fluoride between 1.0-1.5

mgL^{-1}.While, 83% samples were beyond permissible limits (>1.5 mgL^{-1}) (WHO, 1994) in the district. It was also reported water in Malout and Gidderbaha blocks contain more fluoride as compared to Muktsar and Lambi blocks of Shri Muktsar Sahib District.

- **Survey and characterization of ground water of Fazilka district (Bathinda)**

The ground water quality classes for irrigation purpose for Fazilka districts were studied. As per electrical conductivity 50, 45 and 5% samples were of good, marginal and saline category. As per RSC, 78, 14 and 8% samples were good, marginal alkali and alkali category. On basis of SAR, 73% samples were good while 27% samples were having SAR above 10. Intersection of all these categories indicated that only 50% samples were suitable for irrigation without any limitations and 23% samples were under marginal saline category. Around 27% samples together were of alkali and high category. Fluoride in groundwater was also an important issue and Fluoride content ranged from 1.62-5.33 mg L^{-1} with mean 2.40 mg L^{-1}, from 1.05-4.91 mg L^{-1} with mean 2.36 mg L^{-1}, from 0.96 – 5.35 mg L^{-1} with mean 2.19 mg L^{-1} in Abohar, Fazilka and Jalalabad tehsils, respectively. The 100% samples of Abohar block were unsafe while 97 and 93% samples of Fazilka and Jalalabad, respectively. On an average 96% samples were unsafe for drinking purpose.

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

The ground water samples collected from fourteen districts of Kerala were analyzed. 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 respectively. The ground water data of Idukki, Palakkad and Wayanad districts obtained from Central Ground Water Board revealed that all the water samples of the three districts were grouped under good quality for irrigation. It might be due to absence of sea shore and back water in those districts. From the survey and analysis of data, it was noticed that the salinity observed was seasonal and during summer months mainly from January to May. The salinity also fluctuates along with rainfall received.

1.2 Resource Inventories of Salt Affected Soils

- **Assessment and mapping of salt affected soils of TBP command area of Karnataka (Gangavathi)**

Soil salinity and water logging are the twin problems of TBP command Karnataka. With the aid of GPS and toposheet, soil samples were collected on a grid basis (5’ x 5’) from Hospet, Bellary and Siruguppa taluks in Bellary district under TBP Command. A total of 420 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 60 grid points were collected. The analysis of the results revealed that Na^+ and Cl^- ions are the dominant cation and anion respectively. Out of 420 samples in Bellary district nearly 28.8 and 33 (0-15 cm), 20.8 and 30.1 (15-30 cm), 25.8 and 39 (30-60 cm) and 31 and 43 (60+ cm) per cent of samples respectively were found to be having ECe > 4 dS/m and SAR > 13 at the time of sampling. The average $(CO_3+HCO_3)/(Cl+SO_4)$ and $Na/(Cl+SO_4)$ were <1 and >1 at all the depths respectively. The per cent of samples with $(CO_3+HCO_3)/(Cl+SO_4)$ >1 were 13.6, 13.1, 7.22 and 4.92 at 0-15, 15-30, 30-60 and 60+ cm respectively. Similarly, The per cent of samples with $Na/(Cl+SO_4)$ >1 were 52.3, 53.9, 68.0 and 72.1 at 0-15, 15-30, 30-60 and 60+ cm respectively. The analysis indicated the saline vertisols have tendency towards sodification.

- **Delineation and Mapping of Salt Affected Soils of Kadapa District in Andhra Pradesh (Bapatla)**

Soil survey was carried out in 79 locations covering 57 villages in 18 mandals of YSR Kadapa district of Andhra Pradesh. From each location, soil samples were collected from two depths (0-25 cm and 25-50 cm) and recorded their GPS locations. Survey revealed that majority of the locations, affected by salts, were connected to local drains having sparse vegetation and in barren condition. In the surface (0-25cm) five types of soil textures were identified viz., sandy loam (58.22%), loamy sand (10.12%), sandy clay loam (19.0%), loam (10.0%) and clay loam (2.53%). The soil pH_2 ranged from 7.2 to 10.6, ECe ranged from 0.4 dSm^{-1} to 46.0 dSm^{-1}, CEC ranged from 12.09 cmol (p+) kg^{-1} to 77.76 cmol (p+) kg^{-1} and ESP ranged from 1.65 to 81.19. On basis of laboratory analysis, dominant soil types observed were alkali soil and saline alkali soil. In subsurface the textural classes were mainly Sandy loam, Sandy clay loam, loamy sand, Loam, sand and Clay loam. pH_2 ranged from 6.9 to 10.6, ECe from 0.4 to 33 dSm^{-1} CEC from 6.9 c mol (p+) kg^{-1} to 59.8 c mol(p+) kg^{-1} and ESP from 2.73 to 89.53. On basis laboratory analysis, the dominant soil types were alkali and saline alkali soil.

- **Characterization and delineation of salt affected soils using remotely sensed data and ground truth of Dewas district of Madhya Pradesh (Indore)**

Soil salinity survey of the Dewas district was conducted by collecting and analyzing 235 soil samples from different villages of the district. The soil samples were classified according to soil salinity as EC (dSm^{-1}) of saturation extract and ESP of soil on the basis of slight to high. The 208 (88.5%) soil samples belonged to very slight salinity category (ECe< 4 dS/m) and 22 (9.4%) samples belonged to slight salinity category (ECe 4-8 dS/m). Only 5 samples i.e. 2.1% belonged to moderate salinity category (ECe 8-15). On the other hand, 204 (86.8%) soil samples come under the category of very slight sodicity (ESP < 15). Slight (ESP 15-25), moderate (ESP 25-40) and high sodicity (ESP >40) samples were 5.2%, 3.8% and 4.2% respectively. Total 2702 ha area in district was delineated as salt affected. Out of total salt affected area, slightly saline (ECe 4-8 dS/m) was 361 ha followed by Moderate alkali (ESP 25-40) area was 354 ha in Tonkkhurd tehsil. Small patch of 28 ha of high sodicity of 28 ha was found in Sonkatch tehsil of Dewas district. On the basis of chemical analysis of soil samples, the salt affected area was generated in the form of map.

- **Delineation and mapping of salt affected soils in the coastal areas of Kerala (Vyttila)**

The study showed that the soil samples from eight districts *viz.* Thiruvananthapuram, Kottayam, Kollam, Pathanamthitta, Kannur, Kozhikode, Malappuram and Kasargod were acidic and non saline.The data also revealed that in both Ernakulam and Thrissur districts, more than 50 per cent belonged to neutral category and rest was classified into different acidic classification. Whereas in Alappuzha, only 21 per cent of the samples belonged to the neutral category. The soils are good as per soil salinity but acidic in nature. Concentrations of different metals change with acidity. Acidity and these metals affect plant growth. Liming can be done to reduce acidity.

2 MANAGEMENT OF POOR QUALITY WATERS

2.1 Management of Alkali Water

- **Conjunctive use of alkali groundwater and canal water for toria-chikori crop rotation (Agra)**

Toria – chikori crop rotation was irrigated under different conjunctive modes of canal and alkali (RSC 10 meq/l) waters, to find out the most suitable cyclic and mixing mode of the toria-chikori crop rotation. In toria crop, canal water mode gave 39.8% higher yield than alkali modes while it gave 66.5% higher for chikori crop. Toria crop required two to three irrigations while Chikori required 5 to 7 irrigations. Field remained fallow during monsoon season under this crop rotation. It gave enough opportunity for leaching of salts. Therefore, salt leaching took place naturally under Toria-Chikori crop rotation. In all modes of the conjunctive water use, B:C ratios for both crops were above 1 during five years field experiment. Thus both crops had enough tolerance to alkali water and the crop rotation was sustainable under long-term use of alkali water.

- **Conjunctive use of high RSC water in different cropping systems under sodic soil (Kanpur)**

The average grain yield of rice varied from 23.13-40.07 q/ha in rice- wheat cropping system. The highest yield was obtained from best available water (BAW) 40.07 q/ha followed by residual sodium carbonate water (RSCW) - (Rest irrigation with BAW) (35.97 q/ha) and BAW + RSCW (35.43 q/ha) while lowest yield was received from RSCW treatment. The average grain yield of wheat varied from 17.03-35.34 q/ha in rice- wheat cropping system. The maximum yield was obtained from best available water (BAW) 35.34 q/ha followed by RSCW - (Rest irrigation with BAW) (30.21 q/ha) and BAW + RSCW (29.65 q/ha) while minimum yield was received from RSCW treatment. The average grain yield of pearl-millet varied from 08.26-15.73 q/ha in pearl millet - wheat cropping system. The highest yield was obtained from best available water (BAW) 15.73 q/ha followed by RSCW - (Rest irrigation with BAW) (13.28 q/ha) and BAW + RSCW (12.64 q/ha) while lowest yield was received from RSCW treatment. The average grain yield of wheat varied from 17.36-35.49 q/ha in pearl millet-wheat cropping system. The maximum yield was obtained from best available water (BAW) 35.49 q/ha followed by RSCW - (Rest irrigation with BAW) (30.94 q/ha) and BAW + RSCW (28.35 q/ha) while minimum yield was received from RSCW treatment. Changes in pH, electrical conductivity, exchangeable sodium percentage (ESP) and organic carbon (OC) indicated that although there has been overall improvement in soil properties in every treated plots excluding residual sodium carbonate water (RSCW). The soil pH, EC and ESP is decreased in BAW irrigated plot and increased with RSCW. There was noted improvement in organic carbon in all the treatments excluding RSC.

- **Drip irrigation to cotton in alkali soils using ameliorated alkali water (Tiruchirapalli)**

Field experiment was conducted to compare the efficacy of ameliorated alkali water using gypsum and distillery spent wash applied through drip irrigation to cotton with soil application of gypsum and distillery spent wash. The irrigation treatments in the main plot were; M_1: Drip irrigation with gypsum bed treated water, M_2: Drip irrigation with spent wash treated water and M_3: Drip irrigation with untreated alkali water. In the sub plots, S_1: One time Soil application of gypsum @ 50% GR, S_2: One time application of DSW @ 5 lakh liters ha^{-1} and S_3: No amendments. The cotton crop was sown on 01.03.2018. The results shows that among the main plot (drip irrigation) treatment, the treatment M_1 (drip irrigation with gypsum bed treated with alkali water recorded with significantly seed cotton yield of 1499 kg /ha followed by M_2 (drip irrigation with DSW treated alkali water) with a seed cotton yield of 1305 kg/ha. The treatment M_3 (drip irrigation with untreated alkali water) recorded with significantly lowest seed cotton yield of 927 kg /ha. Among the sub plot (soil amendments) treatments S_2 (application of DSW @ 5 lakh litres/ha) recorded with statistically highest seed cotton yield of 1479 kg/ha 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 977 kg /ha. 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 litre /ha a soil amendment) recorded with a significantly highest seed cotton yield of 1601 kg/ha followed by M_2S_2 and M_1S_1 which are statistically on par with a corresponding value of 1601 and 1541 kg/ha respectively. The treatment M_3S_3 (drip irrigation with untreated alkali water + control-no soil amendments) recorded with a lowest seed cotton yield of 735 kg/ha.

2.2 Management of Saline Water

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

The flower crops like Chrysanthemum and Marygold and also medicinal crop Tulasi were grown on coastal sandy soil at Bapatla with saline water irrigation through drip. Initially soil was non-saline with pH 7.1 and ECe as 0.5 dS/m. The crops were irrigated with waters with different salinity such as 0.6, 2, 4, 6, 8 dS/m. The results (Table 11) indicated that chrysanthemum recorded 96.8 flowers per plant at 0.6 dS/m and reduced to 30.9 flowers per plant, thus reduction of 68.1%. Marygold registered 158.6 flowers/ plant at 0.6 and reduced to 44.7 flowers per plant with reduction of 71.8%. For both, chrysanthemum and marygold 50% yields were obtained at water salinity level of 5.8 and 5.5 dS/m, respectively. However, Tulasi recorded 8.6 t ha^{-1} of biomass at 0.6 dS/m and reduced to 5.6 t ha^{-1} at 8.0 dS/m and there was a reduction of 35.2%. It clearly showed that Tulasi was more tolerant to salinity as compared to chrysanthemum and marigold. The salinity build up in soil at different salinity levels after harvest of the crop was ranged between 0.8 to 3.2 dSm^{-1}.

- **Performance of vegetable crops (chilli) with saline irrigation water through drip system (Bapatla)**

The growth and yield of chilli crop were significantly influenced by water salinity level. The use of best available water (0.6 $dSm\text{-}^{1}$) recorded the highest plant height (86.7cm), No. of branches per plant (5.6), no. green pods per plant (79.6) and yield of green pods (28.6 t ha^{-1}). These parameters were significantly reduced with increase in water salinity and the lowest plant height (55.7cm), no. of main branches per plant (4.3), no. of green pods per plant (50.7) and yield of green pods (12.3 tha^{-1}) at water salinity of 8.0 ECiw. The yield reduction varied from 7.3 to 57% with increasing water salinity from 0.6 dSm^{-1} to 8.0 dSm^{-1}.

- **A case study on the functioning of doruvu technology in farmers' fields and its impact on coastal saline agricultural production systems**

The salinity of irrigation water in *doruvu* wells was ranged from 0.7 to 4.0 dS/m. Recently majority of the farmers adopted shallow bore wells (20 ft. depth) and irrigate the crops with electrical motor. Simultaneously, water samples from these bore were also collected and tested for water salinity. The salinity of water was ranged from 1.0 to 3.6 dS/m except in one bore well where the salinity was higher such as 6.2 dS/m. In general, the quality of irrigation water in shallow bore wells installed in sandy soils was within permissible limit.

- **Effect of saline irrigation water on growth, yield attributes and yield of Cumin through drip (Bikaner)**

This experiment was initiated during Rabi 2018-19 to study the effect of saline irrigation water on growth, yield attributes and yield of cumin through drip. The treatments comprised of four levels of ECiw (BAW, 2.4 dS/m, 6 dS/m and 8 dS/m). Results indicated that irrigation water salinity had significant effect on growth, yield attributes and yields of cumin. Increase in ECiw beyond 6 dS/m caused significantly drastic reduction in seed yield. As compared to ECiw of 0.25 (BAW) with ECiw 2.40, 6.0 and 8.0 dS/m caused reduction of 7.24, 9.82 and 34.37 per cent, respectively. Similar trends were noticed in all the parameters studied.

- **Influence of saline water and different micro-irrigation techniques on soil properties, yield and water use efficiency of tomato *(Solanum lycopersicum)* & simulation modeling (HYDRUS) in Tungabhadra Command Area (Gangavathi)**

The experiment was laid out in three replications with main treatments (Irrigation methods) such as furrow irrigation as control (M_0), surface drip (M_1), subsurface drip (M_2) and five sub treatments viz. normal water (control with EC as 0.65 dS/m), ECiw-2 dS/m, 3 dS/m, 4 dS/m and 5 dS/m, respectively. From the two years data, it was found that highest water requirement (563.4 mm) was in furrow irrigation followed by surface (538.6 mm) and subsurface drip (247.6 mm) irrigation. The water saved in surface drip and subsurface drip over furrow irrigation varied from 41.0 to 45.7% and 46.3 to 54.7%, respectively. At a depth of 0–15 and 15–30 cm, more salts were accumulated near the plant and horizontal distances in furrow irrigation; in case of surface drip more salt was present at 20 cm distance away from the dripper. In subsurface drip irrigation salt accumulation was more at the soil surface (0-15 cm) but it was lesser near and below the buried dripper, and increased away from the dripper. The pooled data of two years results revealed that the maximum total yield (27.3 t ha^{-1}) yield was recorded in M_2 followed by M_1 (26.67 t ha^{-1}) and M_0 (20.38 t ha^{-1}). Similarly, under saline water treatments the maximum total tomato yield was significantly higher under control- S_0 (29.59 tha^{-1}) compared to other treatments but at par with S_1 (28.42 tha^{-1}) (ECiw =2 dS/m).The yield decreased with increase in salinity levels of irrigation water. The two year pooled data showed higher (98.65 kg ha^{-1} mm^{-1}) water use efficiency (WUE) under M_2 followed by M_1 (84.2 kg ha^{-1} mm^{-1}) and least in case of M_0 (37.55 kg ha^{-1} mm^{-1}). Decreased WUE with increased in salinity levels of irrigation was observed. The results of simulation through HYDRUS-1D model revealed that model is able to predict the soil water and soil salinity. Calibration and validation results showed better R^2 and RMSE values. The highest benefit cost ratio of 1.84 was obtained under M_2S_0 followed by M_1S_0 (1.8) and M_2S_1 (1.78). The minimum (0.524 year) payback period was obtained under M_1S_0 followed by M_2S_0 (0.544 year), M_1S_1 (0.548 year) and M_2S_1 (0.567 year). In northern dry semi arid zone no III, saline water with salinity 2 dS m^{-1} can be used through either surface or sub-surface drip as a safe alternative water source for tomato cultivation without any harmful effect to the soil and crop yield.

- **Integrated nutrient management in Pearl millet -wheat under saline water irrigation (Hisar)**

During 2018-2019, the grain and stover yield (29.54 and 85.52 q/ha) of pearl millet was obtained with RDF + FYM 10 t/ha + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (29.52 and 84.75 q/ha). The minimum grain and stover yield (24.22 and 68.15 q/ha) was recorded with 75% RDF alone. The maximum plant height (203.90 cm), yield attributes viz., effective tillers/plant (3.03), earhead length (22.73cm).The maximum grain and straw yield (53.13 and 83.38 q/ha) of wheat (WH 1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (53.02 and 82.72 q /ha).The minimum grain and straw yield (44.77and 69.67 q/ha) was recorded with 75% RDF alone**.** During 2019-2020, the highest grain and stover yield (29.76 and 86.16 q/ha) of pearl millet was obtained with RDF + FYM 10 t/ha + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (29.70 and 85.26 q/ha). The lowest grain and stover yield (24.68 and 69.48 q/ha) was recorded with 75% RDF alone. The highest grain and straw yield (53.99 and 89.09 q/ha) of wheat (WH 1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (53.24 and 86.24 q /ha).The lowest grain and straw yield (46.47and 68.97 q/ha) was recorded with 75% RDF alone.

- **Evaluation of sewage sludge as a source of NPK for pearl millet wheat rotation irrigated with saline water (Hisar)**

The grain yield of pearl millet (HHB 226) decreased by 27.25 and 35.54 % in all saline irrigation of 8 and 10 dS/m as compared to canal irrigation. A reduction of 19.36, 9.8 and 4.37% in mean grain yield of pearl millet was observed in treatment sewage sludge 5 t/ha (alone), sewage sludge 5t/ha + 50% RDF and sewage sludge 5t/ha + 75% RDF as compared with RDF. The grain yield of wheat (WH 1105) decreased by 26.83 and 36.23% in all saline irrigation 8 and 10 dS/m as compared to canal irrigation. Reduction of 32.60, 15.49 and 5.75 % in grain yield of wheat was observed in treatments sewage sludge 5t/ha (alone), sewage sludge 5t/ha + 50% RDF and sewage sludge 5t/ha + 75% RDF as compared with RDF.The application of sewage sludge @5t/ha along with 75% RDF was found as good as application of RDF both pearl millet and wheat under saline water irrigation. In case pearl millet irrigated with ECiw (10 dS/m) treatment RDF and SS (5 t/ha) + 75 % RDF were found to be profitable with net returns and B: C of Rs. 7, 656 and 1.15; and 3, 003/ha and 1.06, respectively., whereas in case of wheat irrigated with ECiw (10 dS/m) treatment RDF and SS (5 t/ha) + 75 % RDF were found to be profitable with net returns and B: C of Rs. 8400/ha and 1.13; and 4061 and 1.06, respectively.

- **Effect of nitrogen fertigation utilizing good and saline water under drip irrigation system in vegetable crops (Hisar)**

Onion: During 2018-19, under drip irrigation with 75% recommended dose of nitrogen (RDN) application, the reduction in yield of onion were 8.8 and 32.5 % when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in RDN application, the reduction in yields of onion were 6.8 and 31.0% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in 125% recommended dose of nitrogen application, the reduction in yield of onion obtained 5.0 and 29.33% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Significant reduction in onion yield was recorded at ECiw 5.0 dS/m as compared to canal water irrigation. Significantly highest yield of onion was recorded with the application of 125% RDN.
Brinjal: During 2019-2020, brinjal crops under drip irrigation with 75% RDN of nitrogen application; the reduction in fruit yield of brinjal was 11.97 and 28.08 % when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the fruit yield recorded with canal water irrigation. Under drip irrigation in RDN application, the reduction in fruit yields of brinjal was 9.53 and 24.50% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded with canal water irrigation. Under drip irrigation in 125% recommended dose of nitrogen application, the reduction in fruit yield of brinjal obtained 8.04 and 21.69% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded with canal water irrigation. Significant reduction in brinjal fruit yield was recorded at EC_{iw} 5.0 dS/m as compared to canal water irrigation. Significantly highest fruit yield of brinjal was recorded with the application of 125%RDN.

- **Effect of various salinity levels of irrigation water on growth of leafy vegetables in coastal saline soils of Konkan in *rabi* season (Panvel)**

The salinity tolerant crops like Spinach, Radish and Dill were irrigated by the pond water, 2, 4, 6, 8 dS/m. There was yield reduction with increase in irrigation water salinity. The pond water was of good quality. It resulted in highest yield for like Spinach, Radish and Dill as 10.98, 18.78 and 11.10 t/ha, respectively. The yield reduction at irrigation water salinity of 8 dS/m for Spinach, Radish and Dill was 14.03, 16.66 and 58.38%. The results showed that Spinach is the tolerant among three crops followed by radish and dill. However, crop productivity (yield/ha) was higher in case of radish crop.

At irrigation water salinity of 8 dS/m, yield per ha was 15.65 t/ha for Radish, 9.44 t/ha for spinach and 4.62 t/ha for dill. Thus, Spinach and Radish can be good choices for coastal salinity. Selection of particular crop can be done considering market prices and overall economics.

- **Study the effect of saline water on vegetable cowpea with liquid bio-fertilizer (Bathinda)**

The effect of saline water (EC 4.42 dS/m and SAR 19.24 and RSC Nil) on different yield parameters was studied. It was observed that the use of poor quality water decreased seed germination, plant height as well as vegetable cowpea yield. However, use of liquid bio-fertilizer increased the seed germination and plant height, irrespective of fertilizer quantity. The treatment comprising 100%RDF+ *Burk*. sp.+*Brady*. sp. increased yield substantially under saline water use. The vegetable cowpea yield was decreased up to 65% due to poor quality water either alone or with liquid bio-fertilizer; therefore, saline water irrigation is not suitable for vegetable cowpea production. However, it is used for fodder cowpea production**.**

2.3 Management of Waste Water

- **Management of sewage water as a source of irrigation and nutrients (Agra)**

A field experiment was conducted on cluster bean- cauliflower – okra crop rotation in sandy loam soil with a treatment combination having three irrigation water i.e. sewage water, tube well water & 1 sewage water: 1 tube well water and three levels of fertilizer i.e. 50, 75 and 100 % recommended dose of fertilizer. The cluster bean crop sown as a first crop in kharif season, the second crop cauliflower was sown in winter season and third okra crop was sown in summer season. The application of sewage water irrigation for cluster bean, cauliflower and Okra resulted in significantly higher yield and minimum was recorded in tube well water irrigation. In case of application of recommended dose of fertilizer, significantly higher pod yield was recorded for 100% RDF and lowest for 50% RDF. The interaction effect of irrigation water and recommended dose of fertilizer on yield was found significant for all three crops. The two years average system productivity details of different crops in case of cluster bean-cauliflower-okra cropping sequence indicated that among the irrigation waters, the maximum system yield was observed in treated sewage water irrigation treatment (539.3 q/ha) and minimum in tube well irrigated treatment (366.2 q/ha). Under treatments related to recommended dose of fertilizers, maximum system productivity was for 100% RDF (512.1 q/ha) and lowest for 50% RDF (422.0 q/ha). The use of treated sewage water helped in improving organic carbon soil and in long-term it may help in saving of 25% of fertilizers. It was observed that conjunctive use of treated sewage and tubewell water is better than sewage water alone in long-term.

3 MANAGEMENT OF IRRIGATION INDUCED ALKALIZATION AND SALINIZATION

3.1 Management of Irrigation Induced Alkali Soils

- **Management of sodic Vertisols through resources conservation technologies (Indore)**

An experiment was conducted out by taking paddy as test crop (CSR-10) during 2019-20 with and without mulch and three tillage practices i.e. conventional, reduced and zero tillage. The paddy was transplanted on 2.8.2019 and harvested on 7.11.2019. Paddy and straw yield were significantly influenced by various tillage systems and mulch during the experimentation. Among different tillage practices, highest paddy yield (3680 kg/ha) was recorded in conventional tillage which was significantly superior to reduced tillage and zero tillage. On the other hand, grain yield did not influence significantly by the application ofmulch. Similarly, straw yield followed the same trend as found in paddy yield. Maximum ESP (33.07) was recorded in fallow treatment and was significantly higher over other treatments under study. All the tillage treatments are significantly differ in eachother in respect of ESP. The lowest mean value of ESP (25.60) was recorded under conventional tillage. Similarly, the lower ESP (28.20) was also noticed with mulch treatment as compared to no mulch (30.12) treatment. The result showed that the mulch has the capacity to reduce ESP to some extent in sodic vertisols of Nimar Valley. Further experiment continued in sodic vertisols on wheat (HI 1544) during 2019-20 with and without mulch and three tillage practices i.e. conventional, reduced and zero tillage. The sowing of wheat was done on 15.11.2019 and harvested on 19.3.2020. Wheat and straw yield were significantly influenced by various tillage systems and mulch. Among the tillage systems highest wheat (3490 kg/ha) and straw yield (4732 kg/ha) was recorded in conventional tillage which was significantly superior to reduced tillage and zero tillage. Application of rice crop residue as mulch @ 5 t/ha produced significantly higher straw yield (4658 kg/ha) in comparison to no mulch (4440 kg/ha). ESP was also influenced significantly by various tillage and mulch practices. The lowest mean value of ESP was recorded under conventional tillage (25.60) and then with mulch (28.20) treatment.

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

The average grain and straw yield of rice varied from 24.48-42.37 and 29.48-50.89 q/ha respectively. The maximum yield of grain (42.37 q/ha) and straw (50.89 q/ha) was obtained from 25%GR + Poultry manure @ 3t/ha treatment followed by 25%GR + GM @5 t/ha + Microbial culture and 25%GR + City Waste Manure @5 t/ha while minimum yield was received from control plot. The average grain and straw yield of wheat varied from 19.59-36.78 and 24.13-44.73 q/ha respectively. The maximum yield of grain (36.78 q/ha) and straw (44.73 q/ha) was obtained from 25%GR + Poultry manure @3t/ha treatment followed by 25%GR + GM @5 t/ha + Microbial culture and 25%GR + City Waste Manure @5 t/ha while minimum yield was received from control plot. The improvement of soil properties was observed with the application of different treatments over control plot. The maximum changes in pH, electrical conductivity, exchangeable sodium percentage (ESP) and organic carbon (OC) were observed in 50%GR treated plot followed by 25%GR + Poultry manure @3t/ha and 25%GR + GM @5 t/ha + Microbial culture than other treatments.

- **Evaluating the reclamation efficiency of different sources of Gypsum for Sodic Soil Management (Tiruchirapalli)**

Field experiments were conducted during kharif 2020 and Rabi 2021. Among the different treatments the highest grain yield was obtained for the treatment T_4 (Marine Gypsum, 50% GR) followed by T_2 (Mineral Gypsum, 50% GR), T_3 (Phospho Gypsum, 50% GR) and T_1 (Control) during both kharif and rabi seasons. All the treatments were significantly different. The data also indicated that highest pH was recorded in T_1 followed by T_3 and T_2. The lowest pH was recorded in T_4. However, T_2 and T_4 are on par with each other. The highest Exchangeable Sodium Percentage (ESP) was recorded in T_1 followed by T_3 and T_2. The lowest Exchangeable Sodium Percentage (ESP) was recorded in T_4. Field results showed that marine gypsum was the most effective amendment among all.

3.2 Management of Irrigation Induced Waterlogged Saline Soils and Coastal Saline Soils

- **Evaluation of spacing and controlled subsurface drainage system on soil properties, water table, crop yield and nutrient losses in rice fields of TBP Command (Gangavathi)**

To find out a workable solution to the problem of soil salinity and irrigation water shortage, a comparative field study on conventional (CNV) and controlled SSD (CTD) at 40, 50 and 60 m, lateral spacing was undertaken in waterlogged saline Vertisols of Tungabhadra irrigation project (TBP) at Agriculture Research Station, Gangavathi, Karnataka, India. The conventional and controlled drainage treatments were applied since the installation of the system. Since, SSD with 40 m spacing area had inadequate water supply in the previous years, a comparative study was made between 50 and 60 m spacing only. The data over seven seasons (from rabi/summer 2013-14 to *kharif* 2019) revealed that rate of reclamation of waterlogged saline soil was faster in the case of conventional SSD compared to controlled SSD. However, controlled SSD saved irrigation water by 28 to 35% and reduced drainage water volume by 39 to 70%. Apart from this, controlled SSD also reduced the movement of nitrate by 42 to 70% by maintaining shallow water depth as compared to conventional SSD. Comparison of conventional and controlled drainage showed that the B:C ratio under conventional SSD for 60 and 50 m was 1.66 and 1.73,respectively while controlled drainage, though slightly less effective in reclamation leaching, gave reasonably good values of B:C ratio of 1.55 and 1.56 for 60 and 50m, respectively. It indicated that 60 m drain spacing with controlled SSD could be a reasonably good strategy for addressing soil salinity and water shortage in tail-end areas of TBP command of Karnataka.

- **Evaluation of different depth (head) of controlled drainage system in saline vertisols of TBP command (Gangavathi)**

The experiment was conducted on farmer's field. There were many limitations with respect to irrigation water availability, large variations in initial soil salinity and data collection. Despite of the difficulties, few things have been understood that risers of different heights can be adopted in controlled drainage system. As height of riser is increased, there would be lesser leaching. The lesser leaching results in lesser nitrogen loss and more saving of irrigation water. Important output of the project is that once reclamation leaching is completed, controlled drainage riser height can be selected depending on the irrigation water availability and this can be good management strategy.

- **Assessing pre and post canal irrigation effect on soil, water and crops in Vertisols of Narmada Sagar Command (Indore)**

Water tables were recorded in 13 Nos. wells situated in head reach of Indira Sagar Command (ISC) of Narmada Sagar command during the pre canal irrigation period (2005 and 2012) and post canal irrigation period (2015 and 2019). In 2005, depth to water table was around 9.00 m, slowly it reduced. In post monsoon of 2015, it was 3.00 m. However, it became 2.30 m in post monsoon of 2019. It was less 3.00 (i.e. depth of capillary rise) and it might affect agricultural production adversely. Out of 13 locations, depth to water table was less than 1.5 m at 4 locations; between 1.5 to 3.0 at 5 locations and above 3.0 m at 4 locations. Thus water logging is serious problem in the command and subsurface drainage is urgently required to control water table. If possible, irrigation water allocation to the command may be reduced to avoid water logging. Surface and subsurface soil samples were collected during post irrigation period (2018-19) around main canal with the distance of 1, 2, 3, and 5 km. The samples were analyzed for EC, pH and organic carbon content. Soil pH, EC and OC ranged from 7.40 - 7.79, 0.18-0.36 dSm^{-1} and 0.28-0.65%, respectively, in surface and subsurface samples. The surface soil samples depicted higher pH, EC and OC content. It was observed that there was severe waterlogging in the command. However, soil salinity was not major issue as values of soil salinity are relatively low.

- **Effect of different levels of organic manures and mulching on yields of vegetables (Chilli, Brinjal and Tomato) under drip irrigation on coastal saline soils (Panvel)**

In general mulching treatment slowed down soil salinity development by restricting soil capillary rise and drip helped in leaching of salts from root zone at low leaching fraction. The combined effect of drip, mulch and organic manures was very much positive. Data on yield of tomato, Brinjal and Chilli crop indicated that the among various treatments of mulching, the treatment of paddy straw mulch (M_2) gave statistically significant higher yield over rest of all treatments containing plastic mulch (M_1) and no mulch (M_3). Critical look on the data further revealed that the F_3 (Paddy straw mulching with FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}) produced statistically higher yield over the organic treatments of manure FYM @ 15 t ha^{-1} (F_1) (151.58 q ha^{-1}), Vermicompost @ 5 t ha^{-1} (F_2) and without application of organic manure (F_4). Interaction effect of M_2F_3 (Paddy straw mulching with FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}) produced statistically significant and higher yield for all crops over remaining treatments of interactions.

- **Effect planting windows and irrigation on dibbling of wal (Field bean) grown under zero tillage in coastal saline soils of Konkan (Panvel)**

It was evident that the significant decrease in EC and pH was observed as a result of two irrigations (at flowering and pod formation). The effect of 2 irrigations at flowering and pod formation was significant on yield of Wal crop, sown after harvest of rice. Similarly, sowing of crop immediately after rice crop showed significant improvement in yield. It might be mainly because crop was able to utilize residual moisture. However significant increase in moisture content was found due to two irrigations (I_2). Similarly two irrigations caused a significant increase in yield of wal. Interactions of two irrigations (I_2) with sowing of wal immediately after harvest of rice (I_2P_1) also caused a significant improvement in yield of wal.

- **Effect of organics and raised bed on Okra in coastal saline soils of A&N Islands (Port Blair)**

An experiment, to assess the effects of saline tolerant PGPR, prepared as Biogel (bioconsortia + seaweed extract) and other organics on Okra on a raised bed system was conducted during monsoon season (July- October) of 2019. Raised bed system (alternate land management) has been found useful for vegetable cultivation under lowland condition and hence the same was selected under this experiment. The results showed that organic treatments significantly increased number of fruits, fruit weight and per plant fruit yield ($p > 0.05$). Treatment of Biogel + panchagavya was found to be superior over all other organic treatments. It increased fruit yield by 31% than control. Although biogel formulation, bioconsortia and panchagavya were at par for all other yield parameters, saline tolerant PGPR in biogel formulation significantly increased fruit weight by 27% and fruit yield by 18.7% over control. The results demonstrated the potential of saline tolerant PGPR in biogel formulation either alone or in combination with panchagavya for improving crop performance under island condition.

- **Evaluation of saline tolerant bio-consortia on brinjal and tomato in coastal saline soils of A&N Islands (Port Blair)**

A pot culture experiment was conducted to study the effect of saline tolerant bioconsortia (seed treatment and soil application) on brinjal and tomato under varying salinity level (2, 4, 6 dSm^{-1}). The result indicated that bioconsortia treatment significantly increased the plant height and biomass at all levels of salinity however, the effect was more pronounced in brinjal. However the effect was highly pronounced in brinjal than tomato. Thus, the bioconsortia can be a potential organic material to enhance the performance of brinjal and tomato under moderate saline condition. Further field evaluation and analysis of biochemical properties are in progress.

3.3 Management of Saline-Acidic Soils in Kerala

- **Integrated farming system: Rice-vegetable-fish-duck for sustainability in Pokkali lands at RRS, Vyttila (Vytilla)**

On the basis of study, it was observed that mulching with polythene sheet was having a significant effect on crop growth and yield of vegetables. The data showed that treatments with mulch were found to have significantly higher yield than treatments without mulch. Hence for vegetable cultivation on *Pokkali* bunds mulch and drip fertigation attained a great scope. Integrated farming may enhance the soil qualities as well as the growth and yield of following rice crop. Duck droppings acted as feed for fish, where we did not require additional cost for feeding fish. The farming system obtained a BC ratio of 2.35, which showed that the rice-vegetables-duck-fish integration was found to very beneficial and successful in *Pokkali* lands.

- **Rice – prawn integration in Pokkali lands (Kumbalangi, Ernakulam)**

The traditional rice-prawn integration was one of the best sustainable and eco-friendly means of integrated farming in *Pokkali* lands. In this system the growth of both the components are interrelated, where the rice residues acts as feed for prawn and the leftovers of prawn cultivation become manure for rice cultivation, thereby reducing the additional requirements of any external means of fertilizers. During this year, grain yield recorded was 1.0 t/ha and total of 400 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 1.98. Integrating aquaculture with agriculture was found suitable for ideal utilization of farm resources.

4. ALTERNATE LAND USE

- **Studies on performance of fodder crops in salt affected soils (Bapatla)**

Six fodder crops were tested on large plots in farmer's fields at Nidubrolu, Guntur district. The groundwater having salinity of 7.1 is used for irrigation. The initial soil salinity is recorded as 1.1

dS/m and the soil salinity increased to 5.6 dS/m after irrigation with saline water. Out of six crops tested, sweet sudan grass recorded the maximum biomass yield of 42.8 t/ha followed by CoFS-29 (39.7 t/ha) and Panthchari-6 (36.5 t/ha.). Hedge lucerne yielded the biomass of 31.4 t/ha. Stylo and Lucerne recorded the biomass yield of 7.2 and 8.7 t/ha respectively.

- **Survey of existing plantations and characterization in coastal area (Bapatla)**

Existing plantations in coastal areas were surveyed in Guntur and Prakasam districts. The major plantations were, in coastal area, of cashew, casuarina, eucalyptus, subabul and mango. Some plantations of citrus, amla, guava and ber were also observed. Prosopis was observed in abandoned lands. The soil samples were collected from fields of these plantations and analysed for ECe and pH. The pH varied from 5.8 – 10.5. The highest pH was noticed in abandoned land. The soil salinity ranged between 0.1 – 15.0 dSm^{-1}. The casuarina was growing at highest soil salinity of 15.0 dSm^{-1}. Subabul was growing at highest soil pH of 9.0.

- **Development of horticulture based agri-horti system under saline water condition (Bikaner)**

An experiment was started during Rabi 2018-19 to develop agri-horti system under saline water. The treatments comprised of three levels of EC_{iw} (0.25 (BAW), 2.40 and 6.0 dS/m) with four intercrops (mustard, taramira, oat and barley) between alleys of bael trees. Data (Rabi 2019-20) indicated that seed and straw yields of mustard, taramira, oat and barley decreased with increase of ECiw from 0.25 dS/m, but the difference in yield was statistically at par over BAW except in oat. In case of oat as compared to 0.25 (BAW), ECiw of 2.4 dS/m, ECiw of 6.0 dS/m showed significant reduction of 1.63 and 3.16 per cent, respectively.

5. SCREENING FOR SALINITY/ SODICITY TOLERANCE (During 2019 and 2020)

- **Screening of mustard cultivars for saline irrigation (Agra)**

2018-19 and 2019-20:

In 2018-19 the yield of genotype (AVT) was significantly affected in saline water irrigation. The significantly higher yield was produced in genotype CSCN 18-7 (1975.50 kg/ha) and lowest was recorded for genotype CSCN 18-4 (1646.60 kg/ha). During 2019-20 also, the yield of genotype (AVT) was significantly affected in saline water irrigation. The significantly higher yield was produced in genotype CSCN 19-8 (2472.22 kg/ha) and lowest was recorded in genotype CSCN 19-2 (1812.35 kg/ha).

- **Performance of promising mustard (Brassica juncea) entries under different fertility levels irrigated with saline irrigation (Agra)**

2018-19:

The grain yield of mustard increased with 125% and 150% dose of fertilizer over 100% dose of fertilizer. In case of 150% dose of fertilizer the grain yield of mustard was significantly higher compared to 125% RDF. The data of mustard grain yield (kg ha^{-1}) clearly indicated significant differences in yield with the entries. The highest grain yield was found in AG-2 (2141.9 kg/ha) and lowest AG-7 (1691.4 kg/ha) but AG-1 and AG-4 produced grain yield at par.

- **Screening trials of lentil germplasm in saline and alkali irrigation waters (Agra)**

2018-19:
Eight entries of lentil were tested in saline and alkali water having ECiw 6 (dS/m) and RSCiw 6 (meq/l). The yield of entries was significantly affected in saline and alkali water. The higher yield was recorded for lentil entries SL 18-3 (1417.84 kg/ha) and lowest was recorded in SL 18-4 (335.06 kg/ha) in saline water. In case of sodic water the entries SL 18.3 gave higher grain yield (1281.17 kg/ha) and lowest yield was reported in case of SL 18-8 (368.21 kg/ha).

- **Advanced varietal trial (AVT) of mustard under saline/ alkaline conditions (Bikaner)**

2018-19:

Under AVT mustard, twelve entries were evaluated in randomized block design with four replications under saline conditions (ECiw 10.0 dS/m). The differences among the genotypes for seed yield were found significant. Entry CSCN-18-2 was top yielder for seed yield (20.04 q/ha) closely followed by CSCN-18-3 and CSCN-18-11. It was significantly superior over rest of the entries.

- **Initial varietal trial (IVT) of mustard under saline/ alkaline conditions (Bikaner)**

2019-20:

In IVT of mustard, eight entries were evaluated in randomized block design with three replications under saline conditions (ECiw 10.0 dS/m).The differences among the genotypes for seed yield was found significant. Entry CSCN-19-07 was top yielder for seed yield (41.39 q/ha) closely followed by CSCN-19-08 and CSCN-19-03. It was significantly superior over rest of the entries.

- **Screening of elite varieties of crops irrigated with poor quality waters (Hisar)**

2018-19:

The tolerance of seven genotypes of cotton (H 1508, H 1519, H 1523, H 1525, H 1527, H 1530 and HF-2228X1117P), fourteen genotypes of wheat (WH 1237, WH 1239, WH 1255, WH 1256, WH 1257, WH 1258, WH 1259, WH 1260, WH 1261, WH 1262, WH 1263, WH 1264, Kh 65 and KRL 210), seven genotype of pearl millet (HHB 272, HHB 299, HHB 301, HHB 311, HHB 333, HHB 335 and HMS48A XSGP-10-107) and twelve genotypes of mustard (CSCN-18-1, CSCN-18-2, CSCN-18-3, CSCN-18-4, CSCN-18-5, CSCN-18-6, CSCN-18-7, CSCN-18-8, CSCN-18-9, CSCN-18-10, CSCN-18-11 and CSCN-18-12) were tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m.

The tolerance of cotton, wheat, pearl millet and mustard under saline water irrigation treatments was evaluated in lined micro-plots of 2 m x 2 m in size. Among the seven genotypes, H 1525 gave the highest (203.19 g/m2) seed cotton yield and H 1519 resulted in the lowest seed cotton yield (155.51 g/m^2) at ECiw 7.5 dS/m. The mean seed cotton yield reduced by 25.16 % at ECiw 7.5 dS/m as compared to canal irrigation. Overall mean yield (241.60 g/m2) of H 1525 was significantly higher than other genotypes followed by H 1530 (222.08 g/m2) and H 1523 was the lowest yielder (190.29 g/m2).

Wheat genotype WH 1256 performed the best at ECiw 7.5 dS/m and gave 17.34% higher grain yield compared with KRL 210 (check). It was followed by WH 1264 which gave 15.29 % higher grain yield than KRL 210 whereas the performance of Kh 65 (294.93 g/m^2) was the least. Among the pearl millet hybrids, HHB 335 performed best at ECiw (7.5 dS/m) followed by HHB 272 whereas the performance of HHB 301 was the poorest. The mean grain yield (258.97g/m2) of HHB 335 was higher than other genotypes followed by HHB 272 (252.22 g/m2) and HHB 299 (242.90 g/m2). Whereas the parent of pearl millet hybrids HMS48A XSGP-10-107 mean grain yield was 222.07 g/m^2. In AVT, the mustard genotypes CSCN-18-2 gave the highest seed yield (200.88 g/m^2) followed by CSCN-18-7 (200.48 g/m^2) at ECiw 7.5 dS/m and the lowest seed yield (161.27/m^2) was obtained in CSCN-18 -9.

2019-2020:

The tolerance of seven genotypes of cotton (H 1098i, H 1353, H 1465, H 1480, H 1518, H 1526 and H-1530), thirteen genotypes of wheat (WH 1271, WH 1272, WH 1274, WH 1276, WH 1277, WH 1278, WH 1279, WH 1280, WH 1281, WH 1283, WH 1284, , Kh 65 and KRL 210), six genotype of pearl millet (HHB 272, HHB 299, HHB 301, HHB 311, HMS48A XSGP-10-107and 9455 X ISK-51) and eight genotypes of mustard (CSCN-19-1, CSCN-19-2, CSCN-19-3, CSCN-19-4, CSCN-19-5, CSCN-19-6, CSCN-19-7 and CSCN-19-8) were tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m. Overall mean yield (229.72 g/m^2) of cotton genotype H 1526 was significantly higher than other genotypes followed by H 1480 (223.73 g/m^2) and H 1465 was the lowest yielder (166.11 g/m^2).

Wheat genotype WH 1283 performed the best at EC_{iw} 7.5 dS/m and gave 16.32% higher grain yield compared with KRL 210 (check). It was followed by WH 1278 which gave 11.90 % higher grain yield than KRL 210 whereas the performance of WH 1272 (309.10 g/m^2) was the least. Among the pearl millet hybrids, HHB 272(216.60 g/m^2) performed best at EC_{iw} 7.5 dS/m followed by HHB 299 (202.17 g/m^2). In IVT, the mustard genotype CSCN-19-6 gave the highest seed yield (203.92 g/m^2) followed by CSCN-19-8 (197.20 g/m^2) at ECiw 7.5 dS/m and the lowest seed yield (152.81/m^2) was obtained in CSCN-19-2.

- **Evaluation of different crops for their tolerance to sodicity level (Tiruchirapalli)**

2019:

The results revealed that the maximum mean grain yield of 885.8 kg per ha was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 728.4, 566.8, 460.7, 133 and 75.6 kg per ha respectively. Among the different varieties evaluated the Co 30 recorded the highest mean grain yield of 793.8 kg per ha followed by K12, Red local and Irungu local by recording 510.4, 365.4 and 230.5 kg per ha respectively. Among the interaction of ESP and Cultivars, the highest grain yield of 1433.7 kg per ha was recorded by Co 30 at 8 ESP level. The lowest grain yield of 26.3 kg per ha recorded by Irungu local at 48 ESP level. However, 50 per cent grain yield was recorded in the cultivars viz., Co 30, Red local and Irungu local at the ESP of 32 per cent whereas in the cultivar K12 recorded 50 per cent yield at 24 ESP level which is clearly indicated that the cultivars Co 30, Red local and Irungu local could be grown in the sodic soil having the ESP up to 32 per cent wheras the cultivar K12 can be recommended to the sodic soil having the ESP level up to 24 per cent.

Further, results revealed that the maximum mean haulm yield of 1331.6 kg per ha was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 1216.1, 1146.9, 951.5, 705.5 and 539.7 kg per ha respectively (Table 7). Among the different varieties evaluated the Irungu local recorded the highest mean haulm yield of 1381 kg per ha followed by K12, Red local and Co30 by recording 1066.9, 741.6 and 738 kg per ha respectively. Among the interaction of ESP and Cultivars, the highest haulm yield of 1749.7 kg per ha was recorded by Irungu local at 8 ESP level. The lowest haulm yield of 435 kg per ha recorded by Red local at 48 ESP level. However, 50 per cent haulm yield was recorded in the cultivars viz., Red local and K12 at the ESP of 32 per cent whereas, Co 30 and Irungu local recorded 50 per cent yield at 48 and 40 ESP level respectively. The haulm yield results clearly indicated that the cultivars Co 30, though it recorded the lowest haulm yield, it tolerance to 48 ESP while obtaining 50 per cent of maximum possible haulm yield. Although, the Irungu local recorded the lowest grain yield, it recorded the highest haulm yield among the cultivar which could suitably recommended for cultivation as fodder crop in the sodic soil up to 40 per cent ESP level.

2020:
Among the different varieties evaluated the Co 30 recorded the highest mean grain yield of 735 kg per ha followed by K12, Red local and Irungu local by recording 462, 324 and 219 kg per ha respectively. Among the interaction of ESP and Cultivars, the highest grain yield of 1340 kg per ha was recorded by Co 30 at 8 ESP level. The lowest grain yield of 22 kg per ha recorded by Irungu local at 48 ESP level. However, 50 per cent grain yield was recorded in the cultivars *viz.*, Co 30, Red local and Irungu local at the ESP of 32 per cent whereas in the cultivar K12 recorded 50 per cent yield at 24 ESP level which is clearly indicated that the cultivars Co 30, Red local and Irungu local could be grown in the sodic soil having the ESP up to 32 per cent whereas the cultivar K12 can be recommended to the sodic soil having the ESP level up to 24 per cent.

Among the different varieties evaluated the Irungu local recorded the highest mean haulm yield of 1293 kg per ha followed by K12, Red local and Co 30 by recording 977, 667 and 666 kg per ha respectively. However, the Red Local and Co 30 recoded significantly on par with each other with respect to haulm yield. Among the interaction of ESP and Cultivars, the highest haulm yield of 1640 kg per ha was recorded by Irungu local at 8 ESP level. Although, the Irungu local recorded the lowest grain yield, it recorded the highest haulm yield among the cultivar which could suitably recommended for cultivation as fodder crop in the sodic soil up to 40 per cent ESP level which was on par with 48 ESP.

- **Screening of salinity tolerance Clusterbean (*Cyamopsis tetragonoloba* L.) germplasm (Bathinda)**

2019:
Data revealed that pod length, number of grains/pod and seed index does not affect significantly by poor quality water, whereas, grain yield/plant was significantly influenced by poor quality water. It was also reported that maximum grain yield was observed in gremplasm IC 40235 followed by IC 40417 > IC 40752 and IC 44202.

6. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

- **Operational Research Program for the use of underground poor quality waters at farmers' fields (Agra)**

2018-19:
The low cost groundwater recharge structure for improving groundwater quality and salinity tolerant crop varieties were demonstrated on 26 farmers' fields under ORP. The conjunctive use of good quality canal water and saline groundwater was also promoted wherever possible. The different crops such as Pearl-millet variety Chetak (6 farmers); sorghum Purvi white (3 farmers); mustard variety Rohini (6 farmers); wheat variety KRL-210 (6 farmers); beet root Myhico hybrid (1 farmer); cauliflower MH-555 (1farmer); Onion variety Nasik red (1 farmer), Okra Myhico-747 (2 farmers) were demonstrated. The use of centre's technologies farmers got yield advantage of 10 -15 percent.

2019-20:

In 2019-20, fifteen farmers were selected using saline water (ECiw ranges 3.8 to 13.3 dS/m) of different villages i.e. Signa in district Agra and Jalal & Kurkunda in district Mathura (U.P.). The technologies were used according to the nature of the water problem viz. Conjunctive use of saline and low saline waters, sowing with rain conserved moisture and saline water recharge technique along with recommended agronomic practices. It was observed that with the use of improved technologies, the crop yield increased over the field what farmers were getting previously with traditional agricultural practices. The use of forate and zinc also gave fruitful results by controlling the effect of termite and zinc deficiencies.

- **Performance of different crops to reclaimed sodic water through gypsum tank (Bapatla)**

2018-19:

The bore well water having RSC of 9.3 passed through gypsum beds to the existing crops of paddy, fodder jowar, pillipesara and paragrass to evaluate their performance at Elurivaripalem village of Chimakurthy mandal. The grain yield of paddy increased by 8.4% when irrigation water passing through gypsum. Similarly, the biomass of fodder jowar, pillipesara and paragrass increased to 5.7, 7.8 and 3.8 percent, respectively.

- **Effect of CSR-Bio on tomato and cabbage in sodic soil at farmer's field (Kanpur)**

2018-19:

The maximum survival percentage, fruit/plant, diameter of fruit and yield of tomato was recorded as 62.6%, 26.75, 3.63 cm and 128.35 q/ha in CSR-Bio (soil application + foliar spray) and minimum in control plot. The 25.28% increase in yield of tomato was recorded in CSR-Bio (soil application + foliar spray) and 20.18% with CSR-Bio (soil application) over control. The maximum survival percentage, no of leaves, head weight and yield of cabbage was recorded as 70.5, 12.42, 0.99 kg and 145.37 q/ha in CSR-Bio (soil application + foliar spray) and minimum in control plot. The 27.03% increase in yield of cabbage was recorded in CSR-Bio (soil application + foliar spray) and 23.12% with CSR-Bio (soil application) over control. The data indicated that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in both the treatments including control, maximum decrease, however was observed in CSR-Bio (soil application + foliar spray) treated plot. The organic carbon improved with the application of CSR-Bio treated plots.

- **Demonstration of wheat varieties (KRL-210 and KRL-213) at farmer's field (*Rabi* -2018-19) (Bathinda)**

2018-19:

Data revealed that that variety KRL210 showed higher plant height, whereas HD 2967 perform higher number of tillers/m^2 and ear length among the varieties tested. The variety KRL-213 showed higher number of seed/ear followed by HD 2967, whereas, higher grain yield was observed in variety HD2976 followed by KRL 210 and KRL213. This is mainly because the soil salinity of demonstration field was below threshold salinity of wheat.

- **Implementation of Scheduled Caste Sub Plan (SCSP)**

Different centres of AICRP on SAS&USW are implementing SCSP activities and distributed agricultural inputs to SC farmers. . However, Tiruchirapalli centre has concentrated its activities in village of Manikandam Block of Tiruchirappalli District where SC population is sizable and sodic soils are affecting agricultural production. The centre has adopted 75 SC families and trying to address majority of issues related to sodic soils of SC population through SCSP.

The SCSP activities are planned at the centre with following objectives.

- ✓ Facilitating improved Farm productivity and Economic development of scheduled caste people engaged in Agriculture and allied sector through dissemination of improved farm technologies ; On and Off Farm Training, Front Line Demonstration, On Farm Trail, skill development, method demonstration, exposure visit, input distribution etc.,
- ✓ Use of Information and Communications Technology (ICT) for enhancement of Agricultural and allied sector productivity for the benefit of Scheduled caste people.
- ✓ Engaging qualified Technical Manpower belonging to Scheduled Caste community for effective implementation of SCSP programme as per the University norms.

- **Policy Support provided to the states:**

    - **सिंचाई के पानी गुणवत्ता मार्गनिर्देश (पहला पुनरीक्षण) Quality of Irrigation Water- Guidelines (First Revision) Indian Standard- IS 11624:2019** issued by Bureau of Indian Standards (BIS) on basis of inputs from AICRP on SAS&USW, ICAR-Central soil Salinity Research Institute, Karnal, ICAR- Indian Institute of Water Management, Bhubaneshwar & Water Technology Centre, IARI, New Delhi

INTRODUCTION

The All India Coordinated Project on Use of Saline Water in Agriculture was first sanctioned during the IVth Five Year Plan under the aegis of Indian Council of Agricultural Research, New Delhi at four research centres namely Agra, Bapatla, Dharwad and Nagpur to undertake researches on saline water use for semi–arid areas with light textured soils, arid areas of black soils region, coastal areas and on the utilization of sewage water respectively. During the Fifth Five Year plan, the work of the project continued at the above four centres. In the Sixth Five Year Plan, four centres namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water Management and Soil Salinity were transferred to this Project whereas the Nagpur Centre was dissociated. As the mandate of the Kanpur and Indore centres included reclamation and management of heavy textured alkali soils of alluvial and black soil regions, the Project was redesignated as All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture. Two of its Centres located at Dharwad and Jobner were shifted to Gangavathi (w.e.f. 01.04.1989) and Bikaner (w.e.f. 01.04.1990) respectively to work right at the locations having large chunks of land afflicted with salinity problems. During the Seventh Plan, Project continued at the above locations. During Eighth Five Year Plan, two new centres at Hisar and Tiruchirappalli were added. These Centres started functioning from 1 January 1995 and 1997 respectively. Further, during Twelfth Five Year Plan, four new Volunteer centres namely Bathinda, Port Blair, Panvel and Vyttila were added to this AICRP. These four centres started functioning from 2014.

As per recommendations of QRT (2011-2017) of ICAR-CSSRI, Karnal, Indore centre was converted from main cooperating centre to volunteer centre. The Kanpur and Port Blair centre were closed on 31 March 2020. During 2017-2020 Plan, Project continued with an outlay of Rs. 2522.18 lakh at these centres with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The ICAR share was of Rs. 1980.60 Lakh while state share was of Rs. 541.58 Lakh. The year wise actual allocation in terms of ICAR share for financial year 2017-18, 2018-19, 2019-20 and 2020-21 were Rs. 615.00 Lakhs, Rs. 649.67 Lakhs, Rs. 527.03 Lakhs and Rs. 560.70 Lakhs, respectively.

Cooperating centres with addresses:

1. Raja Balwant Singh College, Bichpuri, Agra (Uttar Pradesh)
2. Regional Research Station, ANG Ranga Agricultural University Bapatla (Andhra Pradesh)
3. SK Rajasthan Agricultural University, Bikaner (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences, Gangavati (Karnataka)
5. Department of Soils, CCS Haryana Agricultural University, Hisar (Haryana)
6. Agriculture College, RVS Krishi Vishwa Vidyalaya, Indore (Madhya Pradesh)
7. Agriculture College, CS Azad University of Agriculture & Technology, Kanpur (Uttar Pradesh)
8. AD Agricultural College and Research Institute, TN Agri. Univ. Tiruchirappalli (Tamil Nadu)

However, with the establishment of Agricultural Universities at Gwalior (Madhya Pradesh) and Raichur (Karnataka), the administrative control of the centres at Indore and Gangavathi were transferred to these respective universities.

- As per recommendations of QRT (2011-2017) of ICAR-CSSRI, Karnal, Indore centre became Volunteer centre from 1st April 2020 and Kanpur was closed on 31st March 2020.

Volunteer Centres:

1. Regional Research Station, Punjab Agril University, Bathinda (Punjab)
2. Khar Land Research Station, Dr. BS Konkan Krishi Vidyapeeth, Panvel (Maharashtra)
3. ICAR-Central Island Agril. Research Institute, Port Blair (A&N Islands)
4. Rice Research Station, Kerala Agril. University, Vyttila, Kochi (Kerala)

- As per recommendations of QRT (2011-2017) of ICAR-CSSRI, Karnal, Port Blair centre was closed on 31st March 2020.

Existing and proposed mandate for the AICRP

Name of the scheme (Present):

AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture,
ICAR-Central Soil Salinity Research Institute, Karnal, Haryana- 132001

Proposed:
In the NRM Division meeting dated 18 Nov. 2019, the issue of revision of the title of AICRP was discussed and the following title was finalized.

"AICRP on Management of Saline Water & Associated Salinization in Agriculture"

Objectives of the scheme (Present):

Survey and characterization of the salt affected soils and ground water quality in major irrigation commands.

- Evaluate the effects of poor quality waters on soils and crops and plants.
- Develop standards/guidelines for assessing the quality of irrigation waters.
- Develop management practices for utilization of waters having high salinity/alkalinity and toxic ions.
- Develop and test technologies for the conjunctive use of poor quality waters in different agro-ecological zones/major irrigation commands.
- Develop alternate land use strategies for salt-affected soils
- Screen crop cultivars and tree species appropriate to saline/alkali soil conditions.

Proposed:

- Survey, characterization and mapping of groundwater quality for irrigation purpose
- Evaluation of effects of poor quality groundwater irrigation on soils and crops under different agro-climate conditions
- Development of management practices for irrigation induced salinization / guidelines for saline water irrigation (including micro irrigation) under different agro-climatic regions
- Screen crop cultivars and tree species appropriate to soil salinity and alkalinity conditions

FINANCE:
The Three Year Plan (2017–2020) was sanctioned by the Council vide letter No. NRM-24--1/2017-IA-II dated 23-11-2017 with an outlay of Rs. 2522.18 lakh at these centres with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The ICAR share was of Rs. 1980.60 Lakh while state share was of Rs. 541.58 Lakh. The year wise actual allocation in terms of ICAR share for financial year 2017-18, 2018-19 and 2019-20 were Rs. 615.00 Lakhs, Rs. 649.67 Lakhs and Rs. 527.03 Lakhs, respectively. The centre wise ad head wise budget details are provided in the section 7.6.

1. RESOURCE INVENTORIES OF POOR QUALITY GROUNDWATERS & SALT AFFECTED SOILS

1.1 Resource Inventories for Poor Quality Groundwater

- **Survey and characterization of ground water of Mathura district of Uttar Pradesh(Agra)**

2019 and 2020

Ground water survey of Mathura district in Uttar Pradesh was initiated again since 2017. Total seven blocks viz. Farah, Goverdhan, Mathura, Baldev, Chaumuha, Raya and Nauhjheel were surveyed and total 463 samples were collected mostly from December to March as maximum number of tube wells were in use for irrigation purpose. The samples were analyzed for different water quality parameters such as pH, EC, cations (Ca, Mg, Na and K) and anions (CO_3, HCO_3, Cl and SO_4). Classification of water quality was done on the basis of EC, SAR and RSC values as suggested by CSSRI, Karnal (Table 1.1).

Table 1.1: Grouping of quality irrigation waters for irrigation in India

Quality of water	EC (dS/m)	SAR (mmol/l)$^{1/2}$:	RSC (meq/l)
A. Good	<2	<10	<2.5
B. Saline			
i. Marginally saline	2-4	<10	<2.5
ii. Saline	>4	<10	<2.5
iii. High –SAR saline	>4	>10	<2.5
C. Alkali water			
i. Marginally alkali	<4	<10	2.5-4
ii. Alkali	>4	<10	>4
iii. High alkali	<4>	>10	>4

The range of EC, pH, SAR and RSC characters are presented in Table 1.2. The maximum EC 20.4 dS/m was recorded in Chaumuha followed by 13.2 dS/m in Baldev and 12.9 dS/m in Raya block. The highest RSC value 16.0 meq/l was recorded in Mathura block followed by 15.6 & 15.0 meq/l in Raya and Baldev block, respectively. Whereas the highest SAR 45.7 (mmol/l)$^{1/2}$ was recorded in Chaumuha followed by 32.4 and 31.8 (mmol/l)$^{1/2}$ in Baldev and Mathura blocks , respectively.

The distribution of water samples in different EC, SAR and RSC classes are presented in Table 1.3. According to EC classes 40.3, 14.5, 34.7, 21.7, 45.8, 31.8 and 29.8 per cent samples of were found in 1.5-3.0 dS/m category, 23.9, 30.6, 23.6 ,31.3, 28.8 , 23.8 and 33.3 per cent in 3.0-5.0, while 25.4, 45.2, 20.8 , 28.9, 13.5, 38.1 and 33.3 per cent samples in 5.0-10.0 dS/m category in Farah, Goverdhan, Mathura, Baldev, Chaumuha , Raya and Nauhjheel blocks were found respectively. More than 75 per cent samples in surveyed blocks were having RSC <2.5 meq/l except Farah, Chaumuha and Raya block. In category >10.0 meq/l RSC only 1.5, 2.8, 1.2 and 1.6 per cent samples in Farah, Mathura, Baldev and Raya were recorded, respectively. In case of SAR classes, the major number of samples were found in 0-10 and 10-20 (mmol/l)$^{1/2}$ classes. In class 20-30 (mmol/l)$^{1/2}$ only 4.5, 3.2, 4.2 , 6.0, 7.9 & 4.8 per cent samples of Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya were recorded.

Table 1.2: Range and mean of different water quality parameters in Farah, Goverdhan, Mathura, Baldev, Chaumuha, Raya and Nauhjheel blocks of Mathura district

Blocks Name	EC (dS/m)		pH		RSC (meq/l)*		SAR $(mmol/l)^{1/2}$	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Farah	1.0-9.5	3.5	7.8-9.1	8.5	Nil-10.4	4.1	3.0-24.0	10.1
Goverdhan	1.2-12.4	5.6	7.7-9.0	8.3	Nil-3.4	0.9	Nil-27.1	9.6
Mathura	0.8-12.2	4.4	7.7-9.5	8.3	Nil-16.0	4.5	0.9-31.8	8.6
Baldev	1.0-13.2	4.1	8.2-9.5	8.8	Nil-15.0	4.1	0.4-32.4	12.0
Chaumuha	2.1-20.4	5.2	7.3-8.6	8.0	Nil- 9.6	3.3	7.6-45.7	15.7
Raya	2.0-12.9	5.0	7.6-8.7	8.1	Nil-15.6	4.8	5.1-25.5	13.6
Nauhjheel	1.1-12.5	4.5	8.0-8.9	8.4	Nil- 7.4	1.9	3.8-29.0	15.1

*Mean RSC of positive value.

Table 1.3: Frequency distribution of water samples in different EC, RSC and SAR classes of Farah, Goverdhan, Mathura, Baldev, Chaumuha, Raya and Nauhjheel blocks of Mathura district

Particulars/ Blocks	Farah (67)	Goverdhan (62)	Mathura (	Baldev (83)	Chaumuha (59)	Raya (63)	Nauhjheel (57)
EC Classes							
0- 1.5	10.4	1.6	11.2	14.5	-	-	1.8
1.5- 3.0	40.3	14.5	34.7	21.7	45.8	31.8	29.8
3.0- 5.0	23.9	30.6	23.6	31.3	28.8	23.8	33.3
5.0-10.0	25.4	45.2	20.8	28.9	13.5	38.1	33.3
>10.0	-	8.1	9.7	3.6	11.9	6.3	1.8
RSC Classes							
Absent	65.7	93.5	84.7	73.5	61.0	69.8	66.7
0-2.5	6.0	6.5	5.6	10.8	16.9	3.2	24.5
2.5- 5.0	17.9	-	6.9	7.2	11.9	17.5	5.3
5.0-10.0	8.9	-	-	7.2	10.2	7.9	3.5
>10.0	1.5	-	2.8	1.2	-	1.6	-
SAR Classes							
0-10	62.7	56.5	65.2	36.1	27.0	27.0	15.8
10-20	32.8	40.3	29.2	56.6	65.1	68.2	66.7
20-30	4.5	3.2	4.2	6.0	7.9	4.8	17.5
30-40	-	-	1.4	1.2	-	-	-
>40	-	-	-	-	-	-	-

Nitrate:

The samples were tested for nitrate and it was detected only in Mathura and Goverdhan blocks in 1.4 and 6.5 per cent samples, respectively. All samples in 0-2.5 meq/l category (Table 1.4).

Fluoride:

It is clear from Table 1.5 that the most of the samples (>65%) in all surveyed blocks came into class 0-1.5 ppm F category. In 1.5-3.0 ppm category, 22.4, 8.1, 15.3, 10.8, 30.5 and 12.7% samples were reported while 10.4, 3.2, 9.7, 7.3,13.6, 12.7 per cent samples found in 3.0-5.0 ppm category, respectively. In all blocks, order of cations was found as Na>Mg>Ca>K while order of anions was found as Cl>SO_4>HCO_3>CO_3.

Table 1.4: Nitrate in different blocks of Mathura district

Particulars	Mathura	Goverdhan
Nitrate (meq/l) :		
*Nitrate having samples (%)	1.4	6.5
** Per cent among Nitrate having samples		
0 - 2.5	100.0	100.0
2.5 - 5.0	-	-
5.0 – 7.5	-	-
7.5–10.0	-	-
>10.0	-	-

*Per cent of collected samples in respective blocks

** Per cent of nitrate having samples only.

Table 1.5. Fluoride in Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks of Mathura district

Blocks Name	Fluoride classes (ppm)				
	0-1.5	1.5-3.0	3.0-5.0	5.0-10.0	>10.0
Farah	67.2	22.4	10.4	-	-
Goverdhan	88.7	8.1	3.2	-	-
Mathura	75.0	15.3	9.7	-	-
Baldev	81.9	10.8	7.3	-	-
Chaumuha	55.9	30.5	13.6	-	-
Raya	74.6	12.7	12.7	-	-
Nauhjheel	91.2	5.3	3.5	-	-

The distribution of water samples in different water quality classes (Table 1.6) revealed that 17.9, 6.5, 22.2, 18.1,7.0 per cent samples were of good quality in Farah, Goverdhan, Mathura, Baldev and Nauhjheel blocks and none of the samples were found of good quality in Chaumuha and Raya blocks. The 52.3, 88.7, 69.4, 68.7, 78.0, 73.0 and 80.7 per cent samples of Farah, Goverdhan, Mathura, Baldev, Chaumuha, Raya and Nauhjheel blocks came under different saline classes (Marginally saline, saline and High SAR saline) while, rest 29.8, 4.8, 8.4, 13.2, 22.0,27.0 , 12.3 per cent samples came in alkali classes (Marginally Alkali and High Alkali only) respectively.

Table 1.6: Per cent distribution of water samples in different water quality ratings (2019-20).

S. No.	Blocks	No. of Samples	Good	Marginally Saline	Saline	High SAR Saline	Marginally Alkali	Alkali	High Alkali
1	Farah	67	17.9	19.4	6.0	26.9	16.4	-	13.4
2	Goverdhan	62	6.5	25.8	29.0	33.9	-	-	4.8
3	Mathura	72	22.2	29.1	11.1	29.2	4.2	-	4.2
4	Baldev	83	18.1	19.3	2.4	47.0	3.6	-	9.6
5	Chaumuha	59	-	35.6	1.7	40.7	6.8	-	15.2
6	Raya	63	-	23.8	6.3	42.9	14.3	-	12.7
7	Nauhjheel	57	7.0	29.8	-	50.9	7.0	-	5.3

Results of recent survey were compared with results survey conducted before 40 years. It was observed that good quality water area has increased in Farah block and reduced in Goverdhan, Mathura, Chaumuha, Raya and Nauhjheel and Baldev blocks. The major numbers of samples were in saline water quality in the surveyed periods. The samples under High SAR Saline water quality have increased in Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks (Table 1.7). The saline water quality areas (marginally saline, saline and high SAR saline) increased in blocks except Farah block and Alkali water areas decreased in Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks. Minute changes were recorded in Farah block in respect of Alkali classes. The spatial distribution of different ground water quality classes is shown in Fig. 1.1.

Table 1.7: Per cent distribution of water samples in different water quality ratings (1983-85)

S.No.	Blocks	No. of Samples	Good	Marginally Saline	Saline	High SAR Saline	Marginally Alkali	Alkali	High Alkali
1	Farah	97	9.3	10.3	15.5	35.0	11.3	5.1	13.5
2	Goverdhan	104	20.2	20.2	19.2	26.9	9.6	3.0	0.9
3	Mathura	94	28.7	20.2	17.0	14.9	6.4	5.4	7.4
4	Baldev	76	19.7	25.0	7.9	23.4	7.9	13.5	2.6
5	Chaumuha	85	15.3	15.3	11.8	16.3	29.4	-	11.9
6	Raya	97	17.5	13.4	11.3	24.7	16.5	7.3	9.3
7	Nauhjheel	125	14.8	19.5	16.4	20.6	7.8	8.0	12.5

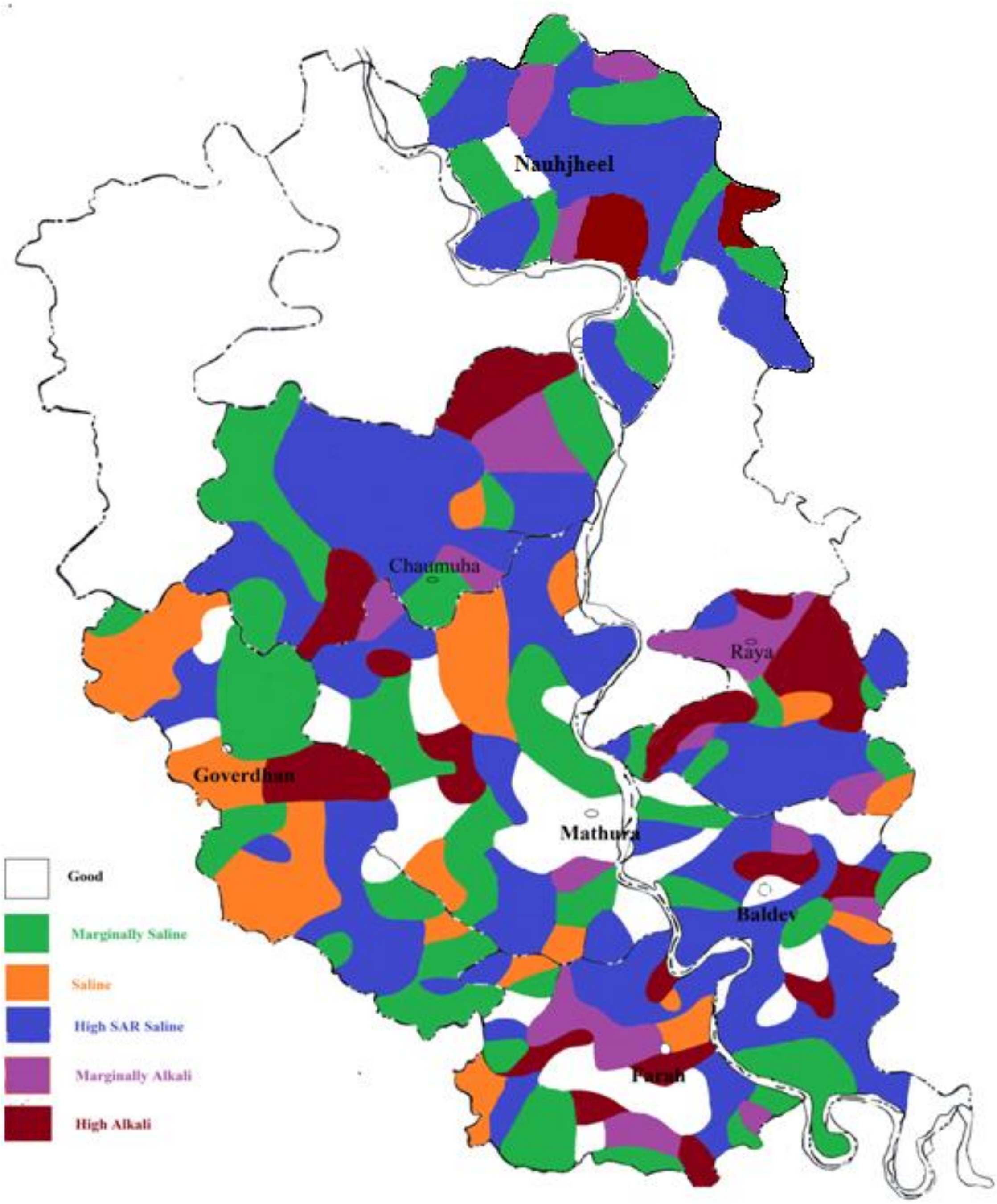


Fig. 1.1 Water quality map of Farah, Mathura, Goverdhan, Baldev, Chaumuha, Raya and Nauhjheel blocks of Mathura district

- **Survey and characterization of ground water of Nellore district of Andhra Pradesh (Bapatla)**

The groundwater quality of Nellore district was done during 1993-94. The groundwater system is coastal area is more sensitive to excessive groundwater pumping and hence groundwater quality survey was undertaken again during 2018-19. Total 245 groundwater samples from 46 mandals were collected from existing wells/tube wells. The samples were analysed for salinity, cations and anions. The mean and ranges for different quality parameters are given in Table 1.8

Table 1.8 Mean and ranges for different quality parameters

Particular	pH	EC (dS/m)	SO_4^{2-}	Cl^-	CO_3^{2-}	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
			meq/l							
Mean	7.55	2.31	2.36	10.89	0.00	8.39	4.81	3.77	9.50	0.35
Range	6.0-8.9	0.2-9.3	0.02-15.11	1.2-136.80	0.00	0-14.8	1.2-21.2	0.01-20.4	0.30-57.41	0.01-6.27

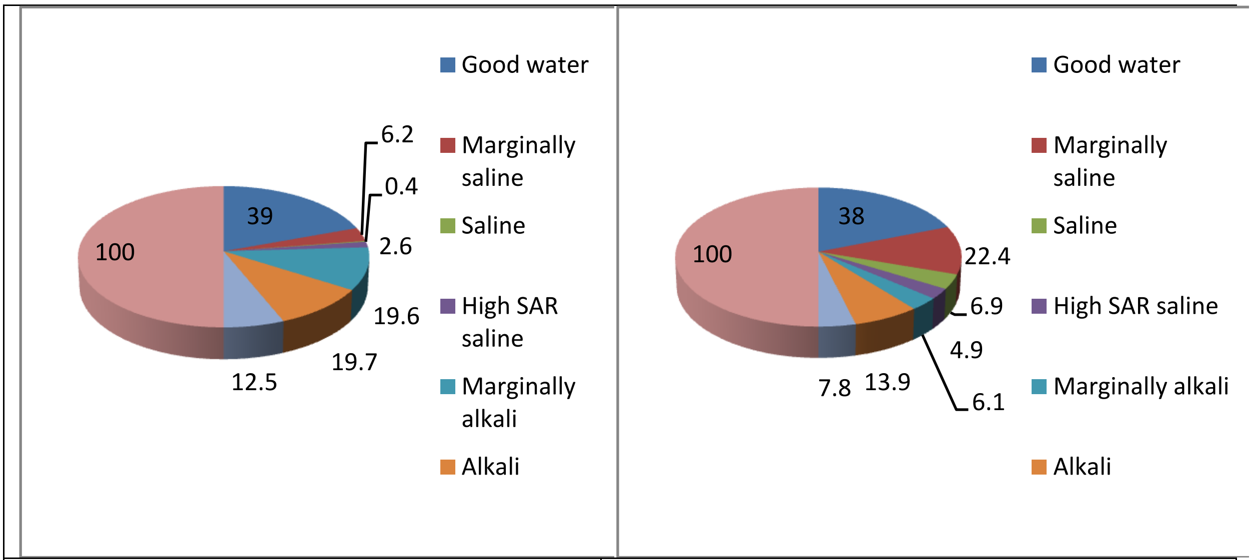
Particular	RSC	SAR	Total cations	Total anions
Unit	meq/l		meq/l	meq/l
Mean	-0.41	4.91	18.43	21.90
Range	(-)40-16.6	0.13-18.84	2.93-77.91	(-)35.37-150.25

On the basis of EC, SAR and RSC, samples were classified into different classes of irrigation water quality. The percent of samples under different categories during 1993-94 and 2018-19 were compared to understand changes in groundwater quality with time (Table 1.9). It is observed that samples under good quality groundwater were more or less same. The samples under marginally saline water increased to 22.4% from 6.2%, saline water exhibited an increase to 6.9 % from 0.4% and High SAR saline water enhanced to 4.9% from 2.6% during 1993-94. The samples under marginally alkali, alkali and highly alkali categories decreased compared to their status during 1993-94.

Table 1.9 Comparison of ground water quality of Nellore district with previous period

S.No.	Quality	Per cent samples		Number of samples	
		Previous (1993-94)	Present (2018-19)	Previous	Present
1	Good water	39	38	362	93
2	Marginally saline	6.2	22.4	58	55
3	Saline	0.4	6.9	4	17
4	High SAR saline	2.6	4.9	24	12
5	Marginally alkali	19.6	6.1	182	15
6	Alkali	19.7	13.9	183	34
7	Highly alkali	12.5	7.8	116	19
	Total	100	100	929	245

The changes in groundwater quality are shown graphically also in Fig. 1.2.



1993-94 (Previous)	2018-19 (Present)

Fig. 1.2. Changes in groundwater quality in Nellore district with time

- **Survey and characterization of underground irrigation water of Chittoor district of Andhra Pradesh (Bapatla)**

2020

Groundwater survey was conducted in Chittoor district again during 2019-20 to determine the ground water quality changes in Chittoor district with time. Earlier survey was conducted during 2003-04. Total 359 ground water samples were collected from 66 mandals. The pH of samples varied from 5.5 to 8.8 while EC (Electrical Conductivity) ranged from 0.2 to 13.5 dS/m with a mean value of 1.73 dS/m (Table 1.10). The order of dominance of ions was Na^{+}>HCO_3^{-}>Cl^{-}>Ca^{+2}>Mg^{+2}>SO_4^{-2}> CO_3^{-2}>K^{+}. The classification of groundwater based on pH, EC, RSC and Cl is provided in Table 1.11, Table 1.12, 1.13, 1.14 and 1.15, respectively. As per the classification given by Central Soil Salinity Research Institute, Karnal (Table 1.16) 65.64 per cent samples were in good quality and can be used for all types of soils and crops, 25.69 samples are marginally saline and can be used with slight salt tolerant crops. High SAR samples were 0.27 per cent and were unsuitable for irrigation, 6.7 per cent samples with marginally alkaline quality could be used along with use of gypsum. The 1.11 per cent samples with alkali quality and 0.55 per cent samples with highly alkaline quality were unsuitable for irrigation. There was deterioration in groundwater quality with time. Per cent good quality water has reduced from 71.3% (2003-04) to 65.64% (2019-20). However, marginally saline water showed an increase from 9.3% to 25.69% during the same period (Table 1.17 and Fig. 1.3).

Table 1.10 Physico-chemical and chemical properties of groundwater samples of Chittoor district

SN	Parameter	Range	Mean
1	pH	5.5-8.8	7.35
2	EC(dS/m)	0.2-13.5	1.73
3	CO_3^{2-}(meq/l)	0-5.6	0.84
4	HCO_3^-(meq/l)	0.2-14.6	6.46
5	Cl^-(meq/l)	0.8-85.2	5.84
6	SO_4^{2-}(meq/l)	0-45	2.03
7	Ca^{2+}(meq/l)	0.8-26.4	5.13
8	Mg^{2+}(meq/l)	0-15.6	3.64
9	Na^+(meq/l)	0.25-91.31	6.58
10	K^+(meq/l)	0.001-2.64	0.11
11	RSC(meq/l)	-37.6-9.4	-1.46
12	SAR	0.26-20.14	3.08

Table 1.11. Classification of ground water samples based on pH

S.No.	pH		No.of samples	Per cent of samples
	Class	Value		
1	Acidic	<7	20	5.58
2	Neutral	7	17	4.74
3	Alkali	>7	321	89.66

Table 1.12. Classification of ground water samples based on EC (dS/m)

S.No.	EC(dS/m)		No.of samples	Per cent of samples
	Class	Value		
1	Good	<2	253	70.6
2	Marginally saline	2-4	103	28.77
3	Saline	>4	2	0.55

Table 1.13. Classification of ground water samples based on RSC (meq/l)

S.No.	RSC (meq/l)		No.of samples	Per cent of samples
	Class	Value		
1	None	<2.5	328	91.6
2	Slight to moderate	2.5-4	22	6.14
3	Severe	>4	8	2.23

Table 1.14. Classification of ground water samples based on SAR

S.No.	SAR		No.of samples	Per cent of samples
	Class	Value		
1	Low Na	<10	353	98.6
2	High Na	>10	5	1.4

Table 1.15. Classification of ground water samples based on Cl^- (meq/l)

S.No.	Cl^- (meq/l)		No.of samples	Per cent of samples
	Class	Value		
1	Excellent water	<4	161	44.97
2	Moderately good water	4-7	86	24.02
3	Slightly unsuitable	7-12	86	24.02
4	Not suitable for irrigation	>12	25	6.98

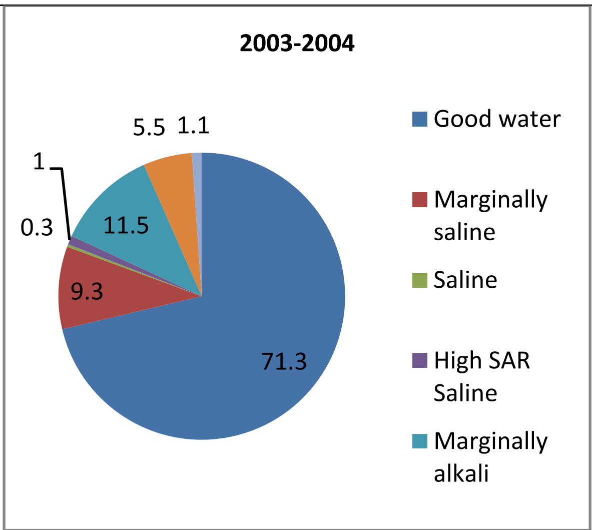
Table 1.16. Classification of Groundwater and their management (Minhas and Gupta,1992)

Rating	EC (dS/m)	SAR	RSC (meq/l)	Per cent Samples	Recommended management practices
A.Good	<2	<10	<2.5	65.64	Can be used for all types of soils and crops
B. Saline					
Marginally saline	2-4	<10	<2.5	25.69	Can be used with slight salt tolerant crops and periodic monitoring
Saline	>4	<10	<2.5	0.0	Unsuitable for irrigation can be used with slight salt tolerant crops and periodic monitoring salts
High SAR Saline	>4	>10	<2.5	0.27	Unsuitable for irrigation but good quality of irrigation is required
C. Alkali Water					
Marginally alkaline	<4	<10	2.5-4.0	6.7	Can be used periodic monitoring of gypsum
Alkali	<4	<10	>4.0	1.11	Can be used periodic monitoring of gypsum
Highly alkaline	variable	>10	>4.0	0.55	Unsuitable for irrigation

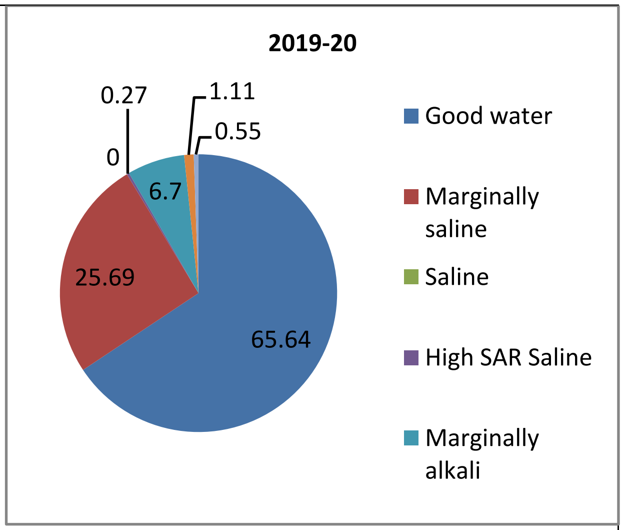
$Na^{+} > HCO_3^{-} > Cl^{-} > Ca^{+2} > Mg^{+2} > SO_4^{-2} > CO_3^{-2} > K^{+}$

Table 1.17. Comparison of recent ground water quality survey with previous survey of Chittoor district

S.No.	Quality	Number of samples		Per cent of samples	
		2003-2004	2019-20	2003-2004	2019-20
1	Good water	508	235	71.3	65.64
2	Marginally saline	66	92	9.3	25.69
3	Saline	2	0	0.3	0.0
4	High SAR Saline	7	1	1.0	0.27
5	Marginally alkali	82	24	11.5	6.7
6	Alkali	39	4	5.5	1.11
7	Highly alkali	8	2	1.1	0.55
	Total	712	358	100	100



2003-2004 (Previous)



2019-20 (Present)

Fig. 1.3 Changes in ground water quality of Chittore over a period from 2003-04 to 2019-20

- **Survey and characterization of groundwater for irrigation for Jodhpur district of Rajasthan (Bikaner)**

2019

Total 170 water samples from 121 villages i.e. 19 villages of Balesar, 13 villages of Bap, 23 villages of Denchu, 23 villages of Lohawat, 22 villages of Phalodi and 21 villages Shergarh tehsils of Jodhpur district were collected and analyzed for various chemical characteristics (EC, pH, cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}), anions (CO_3^-, HCO_3^-, Cl^- and SO_4^{2-}), Floride (F^-) and Nitrate (NO_3^-). Surface soil samples were also collected from the fields irrigated with corresponding water and analyzed for their characterization. The data on range of chemical characteristics of tube well waters collected from 121 villages of Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils of Jodhpur district are presented in Table 1.18.

Table 1.18. Characteristics of groundwater of different tehsils of Jodhpur district

Characteristics	Tehsils of Jodhpur district					
	Balesar Water (31)*	Bap Water (16)*	Denchu Water (32)*	Lohawat Water (32)*	Phalodi Water (29)*	Shergarh Water (30)*
pH	7.60-8.35 (7.97)	7.52-8.33 (7.84)	7.19-8.33 (7.96)	7.60-8.53 (8.16)	7.43-8.62 (8.03)	7.30-9.90 (8.01)
EC (dS/m)	0.97-4.31 (2.33)	0.56-9.77 (5.14)	1.26-7.35 (3.32)	0.67-5.03 (1.86)	0.99-9.47 (3.98)	1.99-12.40 (4.89)
Ca (meq/l)	0.60.6.40 (2.62)	0.70-20.80 (6.01)	0.60-14.60 (3.82)	0.10-7.20 (1.83)	0.30-6.60 (2.83)	1.00-25.80 (6.61)
Mg (meq/l)	1.70-9.20 (3.65)	0.90-24.80 (8.49)	1.40-16.60 (5.87)	0.60-11.00 (3.27)	1.40-9.0 (4.92)	2.40-30.40 (8.48)
Na (meq/l)	6.20-28.19 (16.54)	3.86-51.07 (36.39)	9.70-41.91 (23.09)	5.0-32.50 (13.25)	7.80-80.0 (31.63)	14.03-69.79 (33.27)
K (meq/l)	0.10-0.99 (0.28)	0.10-0.33 (0.22)	0.08-0.31 (0.20)	0.08-0.36 (0.15)	0.11-0.50 (0.21)	0.11-0.41 (0.22)
CO_3 (meq/l)	0.06-6.45 (2.38)	0.46-15.61 (5.79)	0.82-9.43 (3.35)	0.02-6.99 (1.81)	0.05-14.05 (4.23)	1.40-19.01 (5.81)
HCO_3 (meq/l)	1.53-6.30 (3.52)	0.91-15.23 (7.94)	1.92-8.80 (4.88)	1.13-8.14 (2.93)	1.32-12.30 (6.02)	3.05-19.82 (6.89)
Cl (meq/l)	6.16-25.86 (14.66)	3.36-58.62 (32.16)	7.50-47.77 (21.20)	4.15-33.19 (11.79)	6.50-57.76 (25.11)	12.13-78.12 (31.03)
SO_4 (meq/l)	1.16-4.61 (2.51)	0.82-7.82 (5.09)	1.09-6.89 (3.52)	0.74-6.08 (1.93)	1.41-10.42 (4.08)	1.99-11.26 (4.69)
RSC (meq/l)	Nil-2.33 (0.37)	Nil-6.01 (1.90)	Nil-2.10 (0.39)	Nil-2.15 (0.29)	Nil-11.90 (2.62)	Nil-3.07 (0.46)
SAR	4.76-14.29 (9.29)	4.32-22.03 (14.66)	6.77-14.66 (10.75)	3.89-15.28 (8.33)	8.0-29.81 (15.71)	7.29-19.52 (12.64)
Potential salinity (meq/l)	6.87-28.17 (15.91)	3.77-62.53 (34.70)	8.05-51.22 (22.96)	4.52-36.23 (12.76)	7.49-62.97 (27.15)	13.23-83.75 (33.38)
Adj. SAR	8.08-34.36 (21.76)	6.47-61.68 (40.92)	14.23-38.11 (27.25)	7.40-39.72 (17.57)	11.20-92.42 (40.48)	17.51-51.42 (35.05)
SSP	59.25-81.18 (71.15)	52.65-84.88 (72.74)	57.10-83.07 (71.12)	58.57 86.70 (72.65)	72.26-87.92 (79.39)	55.54-86.63 (70.99)
Water table (ft)	200-650 (371.7)	300-700 (510.6)	260-550 (421.56)	350-1000 (634.16)	475-900 (634.66)	200.800 (397.6)
Floride (mg/L)	0.02-1.34 (0.46)	0.02-1.85 (0.75)	0.04-0.85 (0.47)	0.30-0.90 (0.56)	0.03-1.50 (0.63)	0.02-2.52 (0.71)
Nitrate (mg/L)	1.10-114.4 (52.67)	5.30-53.10 (33.92)	1.50-128.20 (31.79)	2.10-130.50 (42.56)	2.70-120.60 (32.93)	1.40-123.00 (46.65)

* No. of samples tested ** Figure in parenthesis are the average value

About 100, 62.5, 100, 100, 72.42 and 93.33 per cent water samples in Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils had RSC in the range of < 2.5, meq/l, respectively. As regards salinity per cent water samples in Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils showed EC in the range of <2 dS/m 41.94,6.25,12.50,71.88,10.34 and 3.33, respectively. While, 29.03,0,31.25,3.13,24.14 and 30.00 per cent water samples lies in the range of EC 2 to 3 dS/m in these tehsils, respectively. 25.81, 12.50, 28.13, 15.63, 27.59, 10.00 and 3.23, 81.25, 28.13, 9.38, 37.33, 56.67 per cent water samples had EC 3 to 4 and >4 dS/m in Balesar, Bap, Denchu, Lohawat, Phalodi and Shergarh tehsils, respectively

Categorizations of water samples as per water quality are presented in Table 1.19. About 38.71, 58.06 and 3.23 per cent water samples in Balesar tehsil are under good, marginally saline and saline; 6.25, 6.25, 62.50 and 25.00 per cent water samples in Bap tehsil lies under good, marginally saline, High SAR saline and highly alkali; 12.90, 58.06, 3.23 and 25.81 per cent water samples in Denchu tehsil lies under good, marginally saline, saline ,High SAR saline; 71.87, 18.75 and 9.38 per cent water samples in Lohawat tehsil lies under good, marginally saline, High SAR saline; 10.34,41.38,20.69,27.59 per cent water samples in Phalodi tehsil lies under good, marginally saline, High SAR saline and highly alkali and 3.33, 33.33, 3.33, 56.68 and 3.33 per cent water samples in Shergarh tehsil lies under good, marginally saline, saline, High SAR saline and marginally alkali.

Table 1.19. Per cent water samples under different categories of water quality in different tehsils of Jodhpur district

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

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

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

- **Survey and characterization of ground water of Pali district of Rajasthan (Bikaner)**

2020

Groundwater samples from 166 tube wells distributed in 121 villages in six tehsils (16 Jaitaran, 20 Pali, 20 Raipur, 20 Rohat, 21 Sojat and 24 Sumerpur) of Pali district were collected and analyzed for various chemical characteristics (Table 1.20).

Table 1.20. Range of chemical characteristics of ground waters of different tehsils of Pali district

Characteristics	Tehsils					
	Jaitaran (25)*	Pali (27)*	Raipur (29)*	Rohat (23)*	Sojat (34)*	Sumerpur (28)*
pH	7.01-8.65 (7.57)**	7.09-8.99 (8.10)	7.06-8.53 (7.69)	7.05-9.12 (8.05)	7.00-8.43 (7.55)	7.52-9.00 (8.19)
EC (dS/m)	1.26-10.20 (4.56)	0.99-16.50 (5.94)	0.70-7.61 (2.50)	0.95-21.60 (9.51)	0.86-16.20 (4.05)	0.44-11.20 (4.36)
Ca (meq/l)	0.60-14.60 (5.60)	0.40-24.20 (7.38)	0.20-10.40 (2.19)	0.80-36.70 (13.18)	0.60-23.40 (4.33)	0.20-13.00 (5.09)
Mg (meq/l)	2.60-23.00 (9.57)	1.30-35-60 (12.16)	1.00-16.60 (4.05)	2.00-46.80 (20.83)	1.60-36.40 (7.69)	0.60-24.20 (8.31)
Na (meq/l)	8.29-63.37 (29.68)	7.60-103.47 (38.99)	4.27-48.29 (18.36)	6.04-126.72 (59.40)	5.68-103.87 (58.06)	3.05-77.56 (29.86)
K (meq/l)	0.10-0.99 (0.53)	0.03-0.97 (0.57)	0.06-0.78 (0.24)	0.11-5.36 (1.46)	0.03-3.29 (0.30)	0.04-1.16 (0.17)
CO3 (meq/l)	1.00-5.80 (3.18)	0.40-11 (4.09)	0.30-6.00 (1.70)	0.20-15.00 (4.07)	0.40-4.00 (1.46)	0.10-6.00 (2.12)
HCO3 (meq/l)	2.10-14.60 (6.10)	3.00-24.87 (10.18)	2.00-10.00 (5.08)	2.00-26.00 (14.04)	1.00-16.02 (6.69)	0.90-16.51 (6.89)
Cl (meq/l)	6.80-76.20 (30.02)	4.00-118.00 (36.29)	3.20-52.80 (14.67)	6.00-181.00 (68.27)	4.00-139.00 (27.870	3.00-81.00 (29.48)
SO4 (meq/l)	1.37-13.72 (6.08)	2.13-21.50 (8.58)	0.45-7.95 (3.31)	0.69-23.91 (8.55)	0.94-9.00 (4.17)	0.50-12.00 (4.94)
RSC (meq/l)	Nil-6.20 (2.40)	Nil-7.99 (3.38)	Nil-420 (1.94)	Nill-2.80 (1.62)	Nil-6.20 (2.04)	Nil-4.86 (1.80)
SAR	4.85-15.32 (11.13)	4.82-19.20 (12.58)	3.82-15.78 (10.63)	4.78-19.61 (14.06)	5.35-24.34 (12.18)	3.27-19.65 (11.72)
Potential salinity (meq/l)	7.49-82.10 (33.06)	5.10-124.13 (40.58)	3.66-56.78 (16.32)	6.35-185.65 (72.54)	4.53-142.00 (29.96)	3.30-87.00 (31.95)
SSP	55.31-82.24 (67.75)	49.43-81.84 (67.59)	61.04-87.53 (74.88)	52.57-78.19 (64.75)	54.31-89-99 (72.65)	48.68-90.67 (70.69)
Adj. SAR	10.67-48.38 (30.41)	12.06-70.01 (37.57)	7.26-42.06 (24.57)	9.07-68.86 (45.44)	9.75-65.47 (30.70)	4.91-68.77 (31.28)
Water table (ft)	30-550 (287.20)	40-250 (90.00)	40-700 (293.17)	20-105 (68.48)	70-600 (274.56)	50.355 (128.25)
Fluoride (mg/L)	0.09-1.05 (0.47)	0.20-2.50 (0.77)	0.10-1.50 (0.44)	0.25-1.50 (0.71)	0.10-1.58 (0.55)	0.30-1.00 (0.65)

* No. of samples tested ()**Figures in parenthesis are the average value

The data on range of EC and pH of water samples in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils showed that EC ranged from 1.26 to 10.20, 0.99 to 16.50, 0.70 to 7.61, 0.95 to 21.60, 0.86 to 16.20 and 0.44 to 11.20 dS/m, whereas, pH ranged from 7.01 to 8.65, 7.09 to 8.99, 7.06 to 8.53, 7.05 to 9.12,7.00 to 8.43 and 7.52 to 9.00, respectively. The concentration of calcium varied from 0.60 to

14.60, 0.40 to 24.20, 0.20 to 10.40, 0.80 to 36.70, 0.60 to 23.40 and 0.20 to 13.00 and magnesium varied from 2.60 to23.00, 1.30 to 35.60, 1.00 to 16.60, 2.00 to 46.80, 1.60 to 36.40 and 0.60 to 24.20 meq/l in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils of Pali district, respectively. Sodium concentration ranged from 8.29 to 63.37, 7.60 to 103.47, 4.27 to 48.29, 6.04 to 126.72, 5.68 to 103.87 and 3.05 to 77.56 meq/l in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils, whereas, concentration of potassium ion for Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils varied from 0.10 to 99, 0.03 to 0.97, 0.06 to 0.78, 0.11 to 5.36, 0.03 to 3.29 and 0.04 to 1.16 meq/l, respectively. Concentration of carbonates varied from 1.00 to 5.80, 0.40 to 11.00, 0.30 to 6.00, 0.20 to 15.00, 0.40 to 4.00 and 0.10.6.00 meq/l in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils while bicarbonates varied from 2.10 to 14.60, 3.00 to 24.87, 2.00 to 10.00, 2.00 to 26.00, 1.00 to 16.02 and 0.90 to 16.51 meq/l in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils of Pali district. The concentration of chloride varied from 6.80 to 76.20, 4.00 to 118.00, 3.20 to 52.80,6.00 to 181.00 ,4.00 to 139.00 and 3.00 to 81.00 meq/l while sulphate varied from 1.37 to 13.72, 2.13 to 21.50, 0.45 to 7.95, 0.69 to 23.91, 0.94 to 9.00 and 0.50 to 12.00 meq/l for Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils, respectively. Chloride and sodium was the dominant anion and cation, respectively. The SAR of water samples ranged from 4.85 to 15.32, 4.82 to 19.20, 3.82 to 15.78, 4.78 to 19.61, 5.35 to 24.34 and 3.27 to 19.65 whereas, soluble sodium percentage (SSP) of water samples ranged from 55.31 to 82.24, 49..43 to 81.84, 61.04 to 87.53, 52.57 to 78.19, 54.31 to 89.99 and 48.68 to 90.67, respectively for Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils of Pali district. The Potential salinity varied from 7.49 to 82.10, 5.10 to 124.13, 3.66 to 56.78, 6.35 to 185.65, 4.53 to 142.00 and 3.30 to 87.00 meq/l and Adj. SAR varied from 10.67 to 48.38, 12.06 to 70.01, 7.26 to 42.06, 9.07 to 68.86, 9.75 to 65.47 and 4.91 to 68.77 meq/l in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils of Pali district, respectively.The RSC of these water samples ranged from Nil to 6.20, Nil to 7.99 Nil to 4.20, Nil to 2.80, Nil to 6.20 and Nil to 4.86 meq/l in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils of Pali district, respectively. The concentration of Fluoride in water samples ranged from 0.09 to1.05, 0.20 to 2.50, 0.10 to 1.50, 0.25 to 1.50, 0.10 to 1.58 and 0.30 to 1.00 mg/L L in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils of Pali district, respectively.

About 88, 77.78, 79.31, 95.65, 79.41 and 92.86 per cent water samples in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils had RSC in the range of < 2.5, meq/l, respectively. As regards salinity per cent water samples in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils showed EC in the range of <2 dS/m 16, 14.81,31.03,17.39, 29.41 and 25, respectively. While, 12, 3.70, 20.69, 0, 5.88 and 10.71 per cent water samples lies in the range of EC 2 to 3 dS/m in these tehsils, respectively. 8, 7.41, 6.90, 8.70, 17.65, 0 and 52, 51.85, 20.69, 69.57, 26.47, 53.57 per cent water samples had EC 3 to 4 and >4 dS/m in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils, respectively (Table 1.21).

Among the tehsils, good quality groundwater samples ranged from 14.81 to 29.41%. Saline group (marginally saline, saline and high SAR saline) water samples ranged from 38.24 to 78.26% while alkali group (marginally alkali, alkali and high alkali) samples ranged from 8.7 to 32.35%. Thus, saline water group was the dominant. High SAR saline samples ranged from 13.79 to 69.56% and it was the dominant subclass within saline group. It is indication of arid climate of Pali district. Good quality water samples and alkali water samples were almost in equal proportions (Table 1.22).

The concentration of Fluoride in water samples ranged from 0.09 to1.05 with mean as 0.47 mg/l, 0.20 to 2.50 with mean as 0.77 mg/l, 0.10 to 1.50 with mean as 0.44 mg/l, 0.25 to 1.50 with mean as 0.71 mg/l, 0.10 to 1.58 with mean as 0.55 mg/l and 0.30 to 1.00 with mean as 0.65 mg/l in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils of Pali district, respectively.

The range of chemical characteristics of soil samples in these tehsils indicated that pH2 of soil samples in Jaitaran tehsil varied from 7.75 to 9.56, Pali tehsil from 8.04 to 9.62, Raipur tehsil varied from 7.73 to 9.69, Rohat tehsil from 8.43 to 9.80, Sojat tehsil varied from 8.20 to 9.70 and Sumerpur tehsils from 8.40 to 9.66, whereas, the corresponding EC2 ranged from 0.08 to 1.33, 0.10 to 3.60, 0.07 to 1.57, 0.10 to 1.87, 0.10 to 6.23, 0.09 to 4.49 dS/m, respectively in Jaitaran, Pali, Raipur, Rohat, Sojat and Sumerpur tehsils (Table 1.24).

Table 1.21. Distribution (per cent) of water samples in different ranges of EC and RSC in different tehsils of Pali district

ECiw (dS/m)	Tehsils	RSC(meq/l)			
		<2.5	2.5-5.0	5.0 – 7.5	> 7.5
< 1	Jaitaran	-	-	-	-
	Pali	3.70	-	-	-
	Raipur	10.34	-	-	-
	Rohat	4.35	-	-	-
	Sojat	8.82	-	-	-
	Sumerpur	10.71	-	-	-
1-2	Jaitaran	16.00	4.00	-	-
	Pali	11.11	-	-	-
	Raipur	20.69	10.34	-	-
	Rohat	13.04	-	-	-
	Sojat	20.59	-	-	-
	Sumerpur	14.29	3.57	-	-
2-3	Jaitaran	12.00	4.00	4.00	-
	Pali	3.70	-	-	-
	Raipur	20.69	10.34	-	-
	Rohat	-	4.34	-	-
	Sojat	5.88	8.82	5.88	-
	Sumerpur	10.71	3.57	-	-
3-4	Jaitaran	8.00	-	-	-
	Pali	7.41	7.41	-	-
	Raipur	6.90	-	-	-
	Rohat	8.70	-	-	-
	Sojat	17.65	2.94	-	-
	Sumerpur	-	3.57	-	-
>4	Jaitaran	52.00	-	-	-
	Pali	51.85	7.41	3.70	3.70
	Raipur	20.69	-	-	-
	Rohat	69.57	-	-	-
	Sojat	26.47	-	2.94	-
	Sumerpur	53.57	-	-	-

Table 1.22. Percent water samples under different water quality classes in different tehsils of Pali district

SN	Water quality categories	Name of tehsil					
		Jaitaran	Pali	Raipur	Rohat	Sojat	Sumerpur
1.	**Good** (EC<2 dS/m, SAR <10 and RSC <2.5 meq/l)	16.00	14.81	27.59	13.04	29.41	21.43
2.	**Marginally saline** (EC 2-4dS/m, SAR<10 and RSC <2.5 meq/l)	16.00	11.11	24.14	8.70	11.76	14.29
3.	**Saline** (EC >4dS/m, SAR<10 and RSC < 2.5 meq/l)	8.00	7.41	3.45	-	-	10.71
4.	**High- SAR saline** (EC > 4dS/m,SAR >10 and RSC <2.5 meq/l)	48.00	48.15	13.79	69.56	26.48	42.86
5.	**Marginally alkali** (EC < 4dS/m,SAR< 10 and RSC2.0- 4.0meq/l)	8.00	7.41	31.03	8.70	5.88	7.14
6.	**Alkali** (EC < 4dS/m,SAR< 10 and RSC >4.0 meq/l)	4.00	-	-	-	11.76	3.57
7.	**Highly alkali** (EC -Variable, SAR> 10 and RSC > 4.0 meq/l)	-	11.11	-	-	14.71	-

Percent distribution of water samples in relation to pH, EC, SAR and SSP is presented in Table 1.23.

Table 1.23. Distribution of water samples in relation to pH, EC, SAR and SSP in different tehsils

Characteristics	Jaitaran (%)	Pali (%)	Raipur (%)	Rohat (%)	Sojat (%)	Sumerpur (%)
pH						
7.0-7.5	48.00	11.11	24.14	8.70	47.06	0.00
7.5-8.0	40.00	29.63	58.62	47.83	41.18	28.57
8.0-8.5	4.00	48.15	10.34	26.09	11.76	42.86
> 8.5	8.00	11.11		17.39	0.00	28.57
EC(dS/m)						
<2	20.00	14.81	41.38	17.39	29.41	28.57
2-4	28.00	18.52	37.93	13.04	41.18	17.86
4-6	20.00	33.33	17.24	8.70	11.76	25.00
>6	32.00	33.33	3.45	60.87	17.65	28.57
SAR						
0-10	32.00	22.22	37.93	21.74	44.12	39.29
10-20	68..00	77.78	62.07	78.26	50.00	60.71
20-30	-	-	-	-	5.88	-
> 30	-	-	-	-	-	-
SSP						
< 50	-	3.70	-	-	-	3.57
50-60	16.00	11.11	-	30.43	8.82	7.14
60-70	48.00	40.74	17.24	39.13	29.41	32.14
70-80	32.00	37.04	65.52	30.43	38.24	39.29
> 80	4.00	7.41	17.24	-	23.53	17.86

Table 1.24. Range of chemical parameters of soils irrigated with tube well waters of different tehsils of Pali district

Characteristics	Tehsils					
	Jaitaran (24) *	Pali (23) *	Raipur (28) *	Rohat (16) *	Sojat (34) *	Sumerpur (28) *
pH	7.75-9.56 (8.04)**	8.04-9.62 (8.87)	7.73-9.69 (8.88)	8.43-9.80 (8.96)	8.20-9.70 (9.07)	8.40-9.66 (8.97)
EC (dS/m)	0.08-1.33 (0.44)	0.10-3.60 (1.22)	0.07-1.57 (0.26)	0.10-1.87 (0.53)	0.10-6.23 (0.78)	0.09-4.49 (0.85)
Ca (meq/l)	0.10-2.20 (0.65)	0.10-6.40 (1.27)	0.10-1.40 (0.35)	0.10-3.20 (0.81)	0.10-10.80 (1.17)	0.10-6.80 (1.19)
Mg (meq/l)	0.20-4.00 (1.11)	0.30-10.80 (2.34)	0.17-3.60 (0.69)	0.20-5.20 (1.38)	0.20-15.40 (1.85)	0.20-13.00 (2.31)
Na (meq/l)	0.46-7.65 (2.45)	0.55-29.12 (8.34)	0.30-10.39 (1.44)	0.50-10.50 (2.93)	0.51-35.80 (4.66)	0.50-24.80 (4.87)
K (meq/l)	0.05-0.52 (0.16)	0.07-1.00 (0.28)	0.03-0.37 (0.09)	0.05-0.41 (0.15)	0.05-0.95 (0.17)	0.05-0.40 (0.15)
CO3 (meq/l)	0.05-0.45 (0.13)	0.05-2.00 (0.42)	0.02-0.50 (0.08)	0.02-1.00 (0.21)	0.02-3.05 (0.35)	0.02-2.60 (0.32)
HCO3 (meq/l)	0.20-5.70 (1.70)	0.40-14.00 (4.93)	0.29-6.40 (1.06)	0.42-8.20 (2.21)	0.35-25.00 (3.22)	0.38-18.00 (3.51)
Cl (meq/l)	0.42-6.67 (2.27)	0.50-18.80 (5.93)	0.33-7.80 (1.29)	0.46-9.06 (2.46)	0.48-28.30 (3.68)	0.45-20.00 (3.92)
SO4 (meq/l)	0.08-0.85 (0.28)	0.06-3.60 (0.96)	0.04-1.01 (0.15)	0.05-1.65 (0.37)	0.05-6.00 (0.61)	0.04-4.32 (0.57)
SAR	1.03-8.12 (2.67)	1.23-16.81 (5.91)	0.77-6.57 (1.83)	1.00-5.87 (2.47)	1.01-12.52 (2.85)	1.29-9.41 (3.23)
SSP	39.00-83.09 (56.15)	41.18-82.14 (64.36)	40.15-68.57 (54.90)	46.36-62.50 (54.28)	44.47-69.45 (54.54)	44.29-71.29 (55.43)

* No. of samples tested ()**Figures in parenthesis are the average value

Recommendations for using poor quality groundwater for irrigation

Since >50 per cent of ground waters of the nine tehsils surveyed (Balesar, Bap, Denchu, Phalodi and Shergarh tehsils of Jodhpur district and Jaitaran, Pali, Rohat and Sumerpur tehsils of Pali district) have shown marginally saline, saline and high SAR saline characteristics and soils of corresponding fields have also shown dominance of sodium, therefore, these waters can be safely used by adopting following practices-

- Use of gypsum either for neutralization of RSC of waters or application in field is recommended
- Farmers are advised to mix ground water with good quality water for raising crops.
- Growing of salt resistant crops e.g. pearl millet, sorghum, cotton, chilli, brinjal in kharif and barley, wheat and mustard in rabi season.
- Giving alternate irrigation with good and poor quality water.
- Use of micro irrigation system for using poor quality water.
- Apply 25% more seed and fertilizers as per recommendations.

- **Survey and characterization of ground waters of Faridabad district of Haryana for irrigation (Hisar)**

2019

Faridabad district of Haryana located on south eastern part of Haryana state lies between 270 39', 280 31' north latitude and 760 40' and 77'32' east longitudes. In the north it is bordered by the Union Territory of Delhi in the east by Uttar Pradesh, in the North West by Mewat and Gurgram districts of Haryana and in the west. Total geographical area of the district is 2151 sq. km. Faridabad district is divided into two blocks, namely, Faridabad and Ballabgarh. Faridabad town is the headquarter of the district (Fig. 1.4).

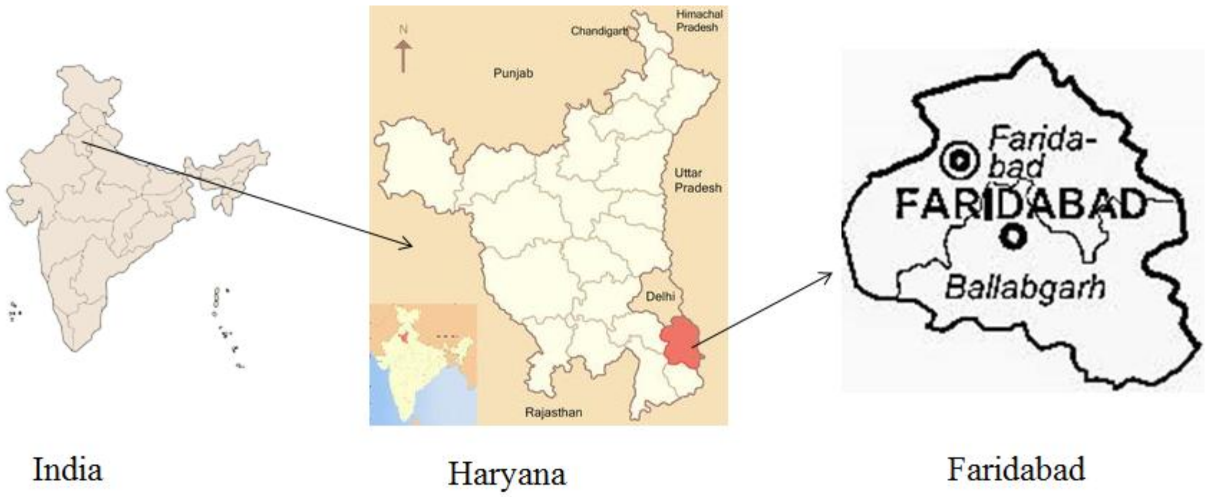


Fig.1.4 Location Map of Faridabad district representing its block

The district is mainly drained by the rivers Yamuna, which is a perennial besides this a number of small streams originates from the hill ranges of the central parts of the district, which do not meet any major stream or Rivers but disappears in the permeable deposits of alluvial plains after traversing some distance. The climate of Faridabad district can be classified as tropical steppe, semiarid and hot which is mainly characterized by the extreme dryness of the air except during monsoon months. Total 118 groundwater samples were collected randomly from Ballabgarh block while 100 groundwater samples were collected randomly from Faridabad block. In the Faridabad district, electrical conductivity (EC) ranged from 0.50 to 9.91 dS/m with a mean of 2.57dS/m. Ranges of pH, RSC and other parameters are also given in Table 1.25. It was observed that in Faridabad district, 188 samples had EC 0-4 dS/m. 77 samples had EC ranges from 4 to 10 dS/m, 29 samples had EC ranges from 8-10 dS/m (Table 1.26 and Fig. 1.5).

Table 1.25. Range and mean of different water quality parameters for Faridabad district

Sr. No.	Quality Parameter	Range	Mean	Sr. No.	Quality Parameter	Range	Mean
1	pH	6.81-9.88	7.82	7	Na^{+} (meq/l)	2.60-63.20	16.35
2	EC (dS/m)	0.50-9.91	2.57	8	K^{+} (meq/l)	0.06-3.14	0.27
3	RSC (meq/l)	0.00-5.60	0.95	9	CO_3^{2-} (meq/l)	0.00-6.40	1.47
4	SAR $(mmol\ l^{-1})^{1/2}$	2.54-20.05	7.76	10	HCO_3^{-} (meq/l)	0.20-15.20	5.03
5	Ca^{2+} (meq/l)	5.50-8.10	2.09	11	Cl^{-} (meq/l)	1.90-68.00	12.95
6	Mg^{2+} (meq/l)	1.50-26.10	6.16	12	SO_4^{2-} (meq/l)	0.20-31.40	4.47

Table 1.26. Chemical composition of groundwater samples of Faridabad district in different EC classes

EC Classes (dSm^{-1})	No. of samples	Na^+	Ca^{2+}	Mg^{2+}	K^+	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	RSC	SAR
		---(meq/l)---									$(mmol\ l^{-1})^{1/2}$
0-2	103	8.78	1.19	3.41	0.22	1.20	4.04	5.60	1.73	1.37	5.78
2-4	85	17.76	2.40	7.11	0.30	1.64	5.82	14.65	4.53	0.71	8.25
4-6	18	32.51	3.96	11.31	0.31	1.79	5.66	29.78	9.86	0.13	11.98
6-8	11	47.08	4.89	14.74	0.32	2.18	6.78	37.62	20.14	0.16	15.23
8-10	01	63.20	8.10	26.10	0.53	2.30	10.50	68.00	16.80	0.00	15.28

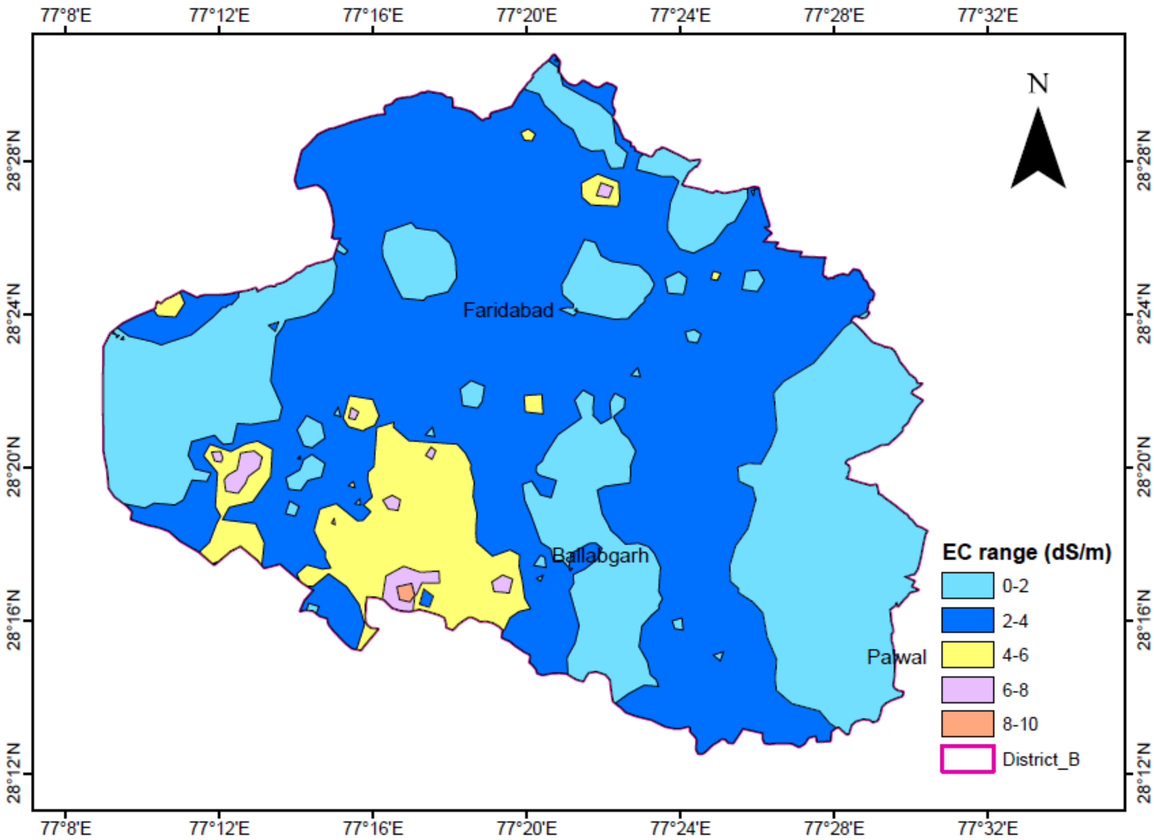


Fig.1.5 Spatial variability of EC of groundwater used for irrigation in Faridabad district

In case of anions, chloride was the dominant anion with maximum the concentration of chlorides in groundwater samples varied from 1.90 to 68.0 meq/l with the mean value of 12.95 meq/l. The concentration of bicarbonates in groundwater samples varied from 0.20 to 15.20 meq/l with a mean value of 5.03 meq/l. The mean values for CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} were found to be 1.47, 5.03, 12.95 and 4.47 meq/l, respectively (Table 1.25). Table 1.26 and Fig. 1.6 show distribution of samples within EC classes while Fig. 1.7 illustrates the mean of anions according to the EC classes in district, the Cl^- was the highest and its value increased with the increase in EC.

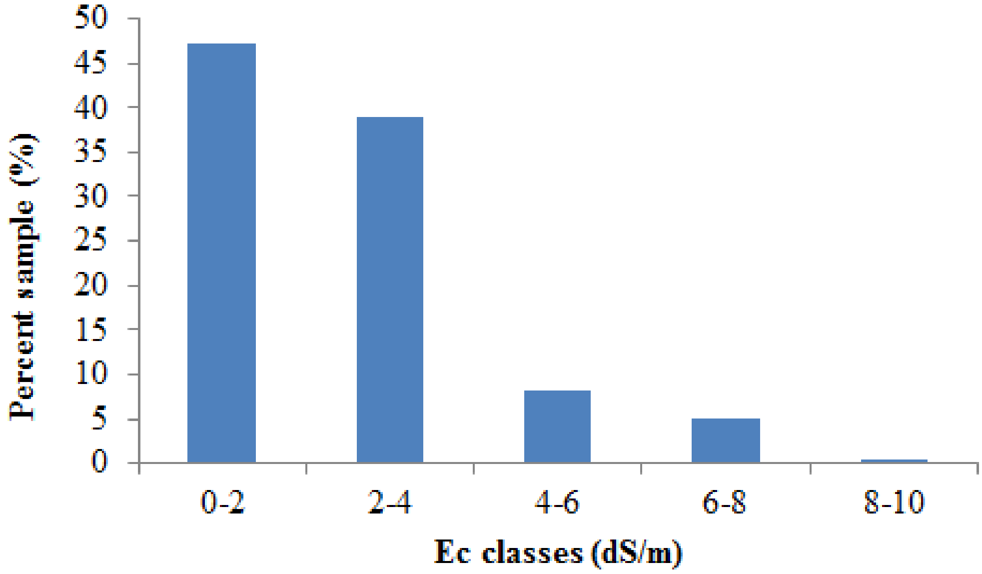


Fig.1.6 Percent samples in different EC (dS/m) classes in Faridabad district

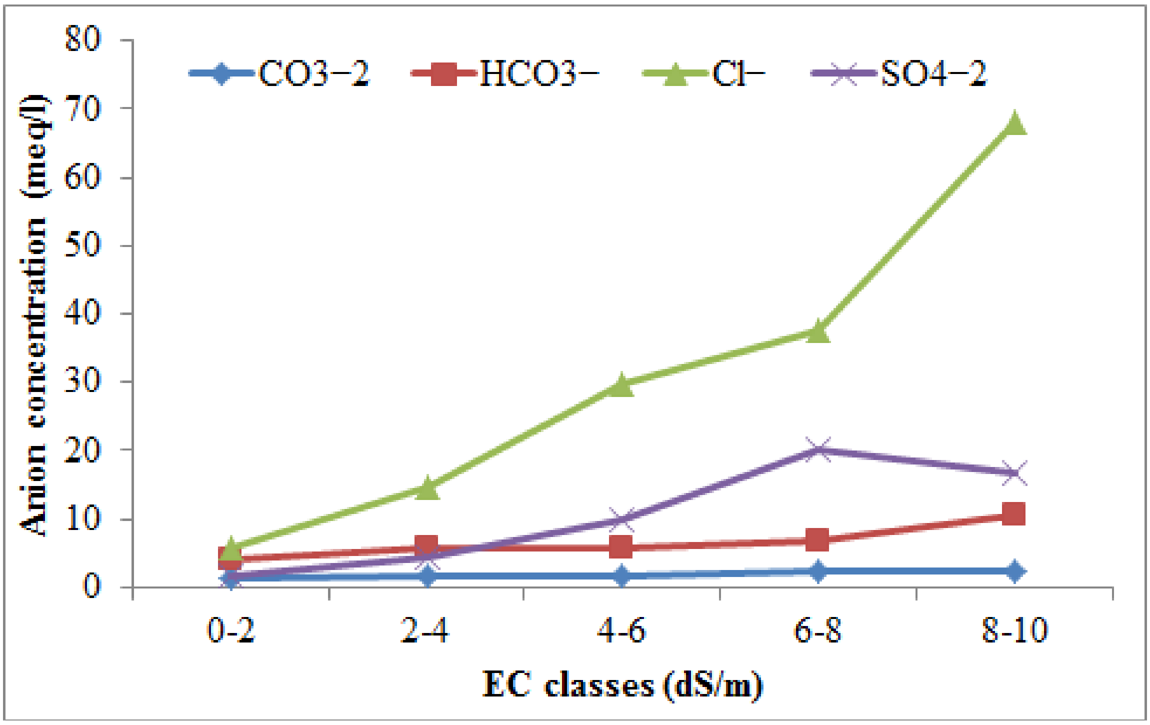


Fig.1.7 Anions (CO_3, HCO_3, Cl, SO_4) concentration (meq/l) in different EC classes of Faridabad district

The concentration of sodium in groundwater samples varied from 2.60 to 63.20 meq/l with an average value of 16.35 meq/l (Table 1.25), followed by magnesium (1.50 to 26.10 meq/l) and calcium (5.50to 8.10 meq/l). Mean values for Na^+, Mg^{2+}, Ca^{2+} and K^+ were 16.35, 6.16, 2.09 and 0.27 meq/l, respectively. Table 1.26 and Fig. 1.8 illustrate the mean of cation according to the different EC classes in Faridabad district, Na^+ was the highest and its value increased with the increase in EC. Its lowest mean value (8.78 meq/l) was found in the class 0-2, the highest mean value (63.20 meq/l) was laid in the EC class of 8-10 dS/m.

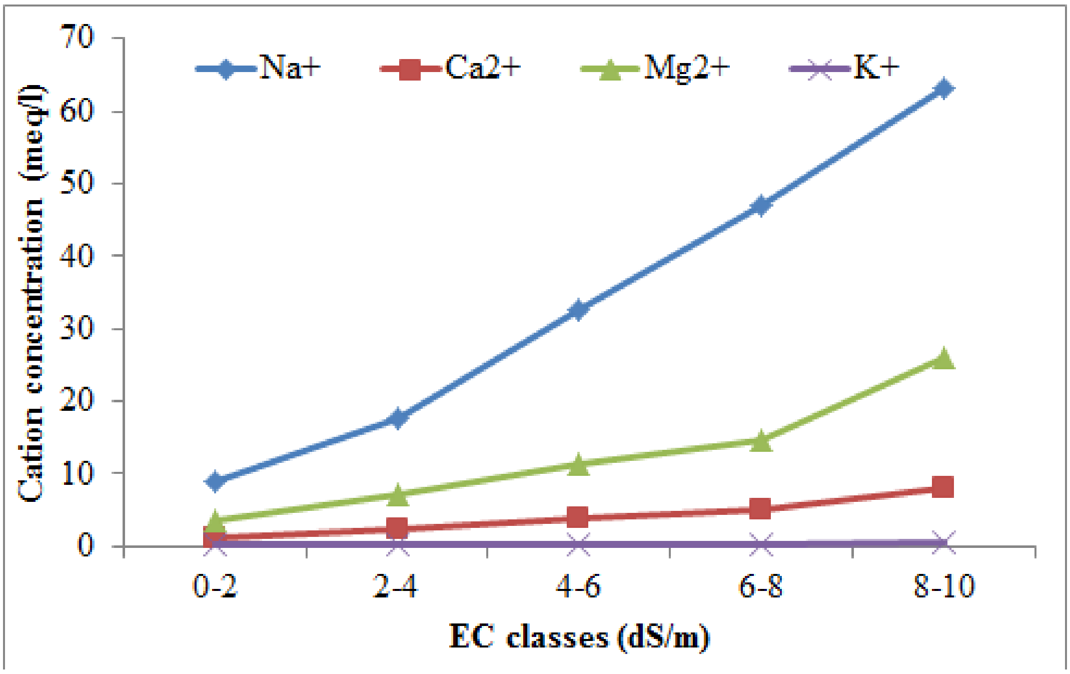


Fig. 1.8 Cations (Ca, Mg, Na, K) concentration (meq/l) in different EC classes of Faridabad district

The spatial variability of RSC and SAR id the district is shown in Fig. 1.9 and Fig. 1.10.

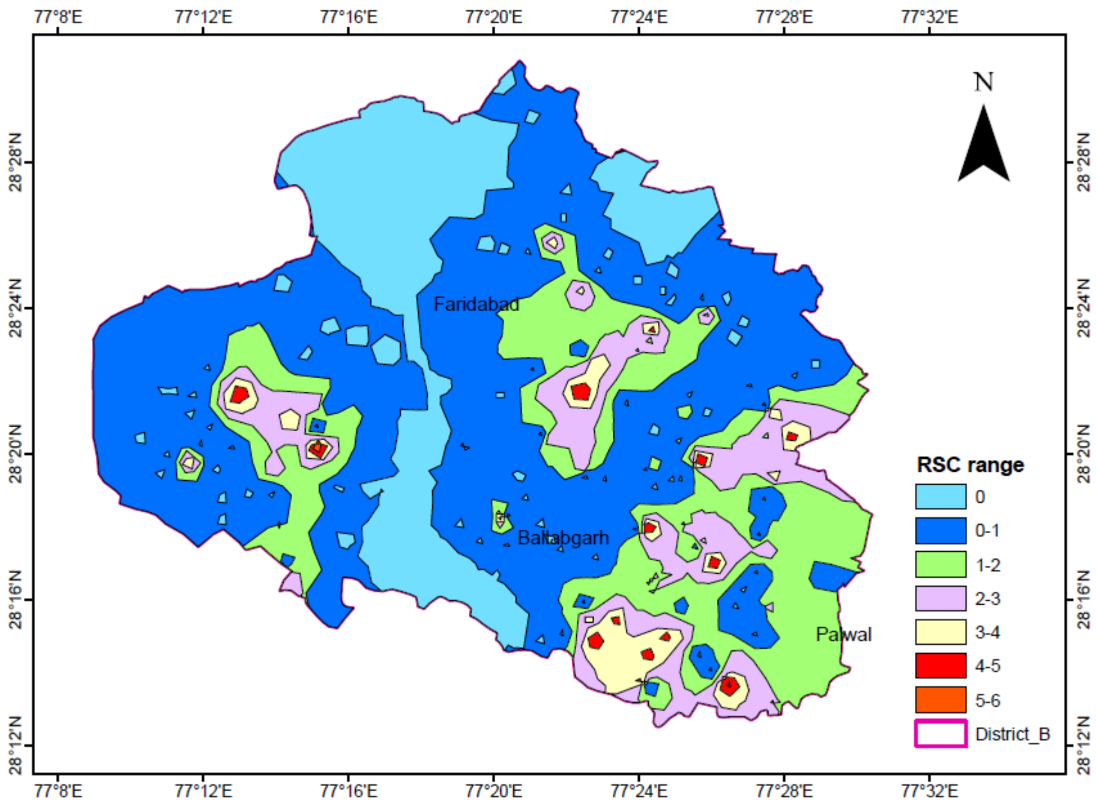


Fig. 1.9 Spatial variability of RSC of groundwater used for irrigation in Faridabad district

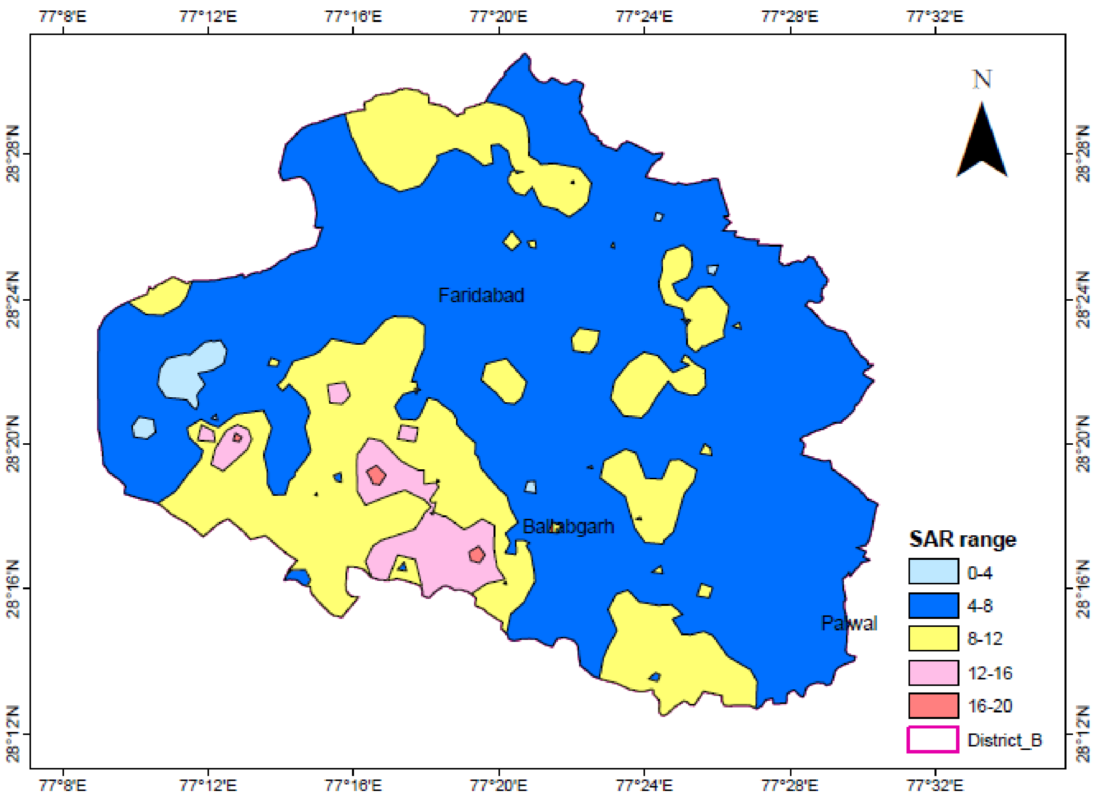


Fig. 1.10 Spatial variability of SAR of groundwater used for irrigation in Faridabad district

According to AICRP classification, it was found that 30.9 percent samples were of good quality, 48.4 percent saline and 20.7 percent alkali in nature (Fig. 1.11). Out of the saline water, 34.6, 1.4 and 12.4 percent were in marginally saline, saline and high SAR saline, respectively. In alkali group 12.4, 3.7 and 4.6 percent were in marginally alkali, alkali and high alkali, respectively. Out of seven categories of water, maximum 34.6percent of samples were found in marginally saline followed by good quality (30.6 percent) and minimum 1.4 percent were found in saline category.

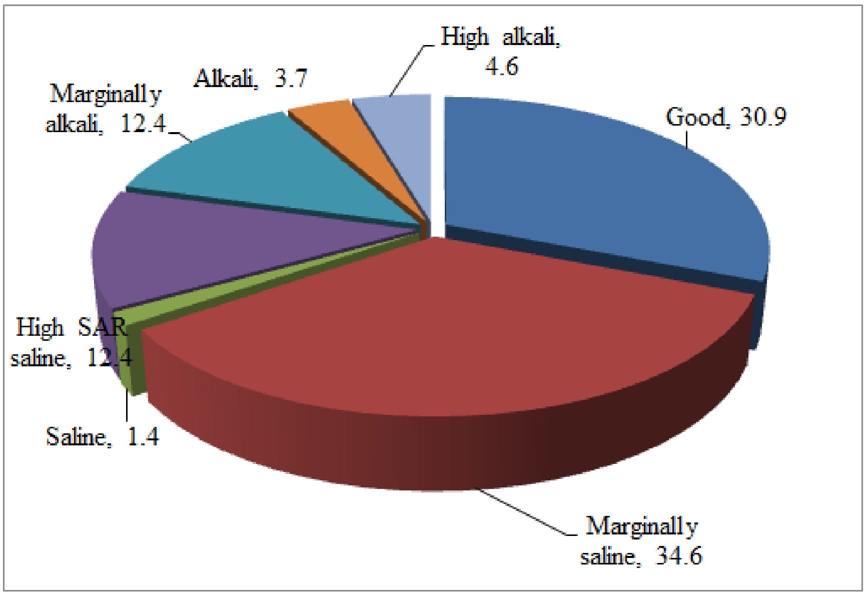


Fig.1.11 Quality of groundwater (percent) in Faridabad district

Groundwater quality map for Faridabad district according to AICRP criteria was prepared to study its spatial variability in the district (Fig. 1.12). In the district, 30.9 percent samples are under good category but spatial variable map of block indicates less area under good quality. This is due to higher concentration of tubewells in that area and accordingly more samples were collected from that area. Good category groundwater is 29% in Ballabgarh block and 33% in Faridabad block of the district and highly scattered in other blocks. Maximum saline water 50.0% was found in Faridabad block whereas maximum alkali 37.6% water was found in Ballabgarh block. Area of the district having EC < 2 can come under good quality category but among these area where SAR < 10 and RSC ≥ 2.5 will come under marginally alkali and alkali. Most of the area where EC is more than 4 dS/m went under high SAR saline in comparison to saline condition, whereas, in both condition EC is more than 4 dS/m. With this fact area under high SAR saline is increased and area under saline condition is reduced. There is a little problem of alkalinity in groundwater of the district because marginally alkali and alkali categories were observed very scattered with small polygons.

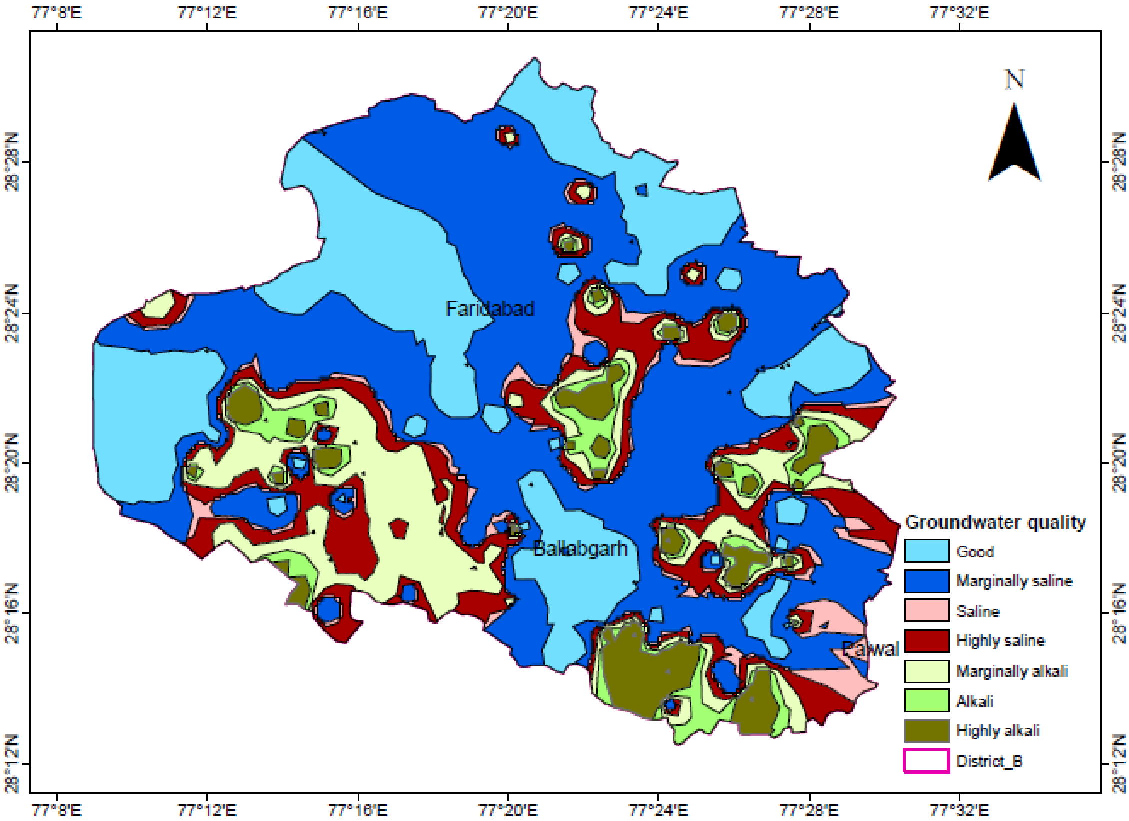


Fig. 1.12**.** Groundwater quality map for Faridabad district according to AICRP criteria

2020

- **Survey and characterization of ground waters of Gurugram district of Haryana for irrigation (Hisar)**

Gurugram district of Haryana adjoining to Delhi is bordered by Rewari, Jhajjar, Palwal, Faridabad and Mewat districts.It has oval to longated shape and located between 27° 39' 00" North and 28° 32' 25" North latitudes and between 76° 39' 30" East and 77° 20' 45" East longitudes. Out of total area of 1258.00 square kilometres, 976.65 square kilometres under rural area and 281.35 square kilometres under urban area. Gurugram is situated in south-eastern part of Haryana and Delhi is having common border with Gurugram in the north. Faridabad district is divided into four blocks, namely, Gurugram, Sohana, Pataudi and Farukanagar (Fig. 1.13). Gurugram town is theheadquarter of the district. A rolling plain along with scatterness of extensions of aravallis features Gurugram district. The aravalli rocks are among the oldest mountain systems of country spreads in western part of the district. Physiographically, Gurugram plain and Sohna undulating plain with aravalli hills are two main sub-parts of Gurugram district. The Gurugram district has sub-tropical continental monsoon climate which has features like temperature extremes, insufficient rainfall and cool winter. In Gurugram district, out of total irrigated area of 71,000 hectares, 69,000 hectare area was irrigated through groundwater and remaining 2000 hectare through canals. According to an estimate, 84.5% of net sown area of district was irrigated during 2009-10. The district has lowest irrigation intensity in Haryana. A total of 24576 tubewells running in the district out of which 23953 were electrified and 623 were diesel operated. The major *kharif* crops of the district include paddy, jowar, bajra while the minor ones include *kharif* oilseeds, *kharif* pulses like massar and *kharif* vegetables (kaddu, karela, bhindi, kakri, tinda, ghia, chillies, tomato, brinjal, onion). The major *rabi* crops are wheat, barley, rape seed & mustard oil seeds while the minor ones include *rabi* pulses, fodder crops and *rabi* vegetables (raddish, carrot, turnip, brinjal, cauliflower, potato, pea, tomato, band gobhi, palak, methi). Vegetables are main cash crops of the district

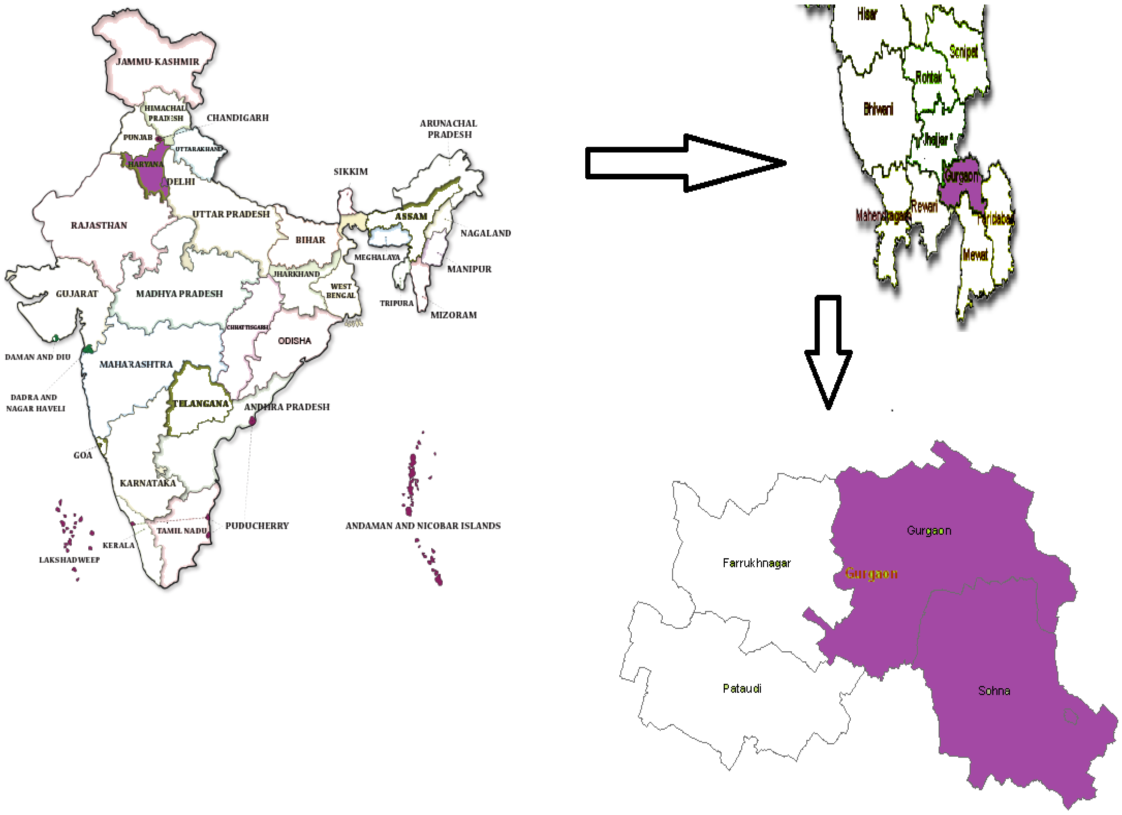


Fig.1.13 Location Map of Gurugram district representing its block

Water samples were collected at an interval of three to four kilometers on the kachcha, link and main roads. The elevation, longitude and latitude angles of the sampling points were recorded by GPS system at each location. All the 577ground water samples(72, from Gurugram,79from Sohana,269 from Pataudi and 157 from Faruknagar block) were colleced for various chemical parameters, viz. pH, EC, cations (Na^+, Ca^{+2}, Mg^{+2} and K^+) and anions (CO_3^{-2}, HCO_3^-,Cl^- and SO_4^{-2}). Subsequently, SAR and RSC were calculated for these samples. The range and mean of different water quality parameters of these blocks are presented in various tables. By using the latitude and longitude angles, a map is prepared for the sampling points for Gurugram district (Fig.1.14).

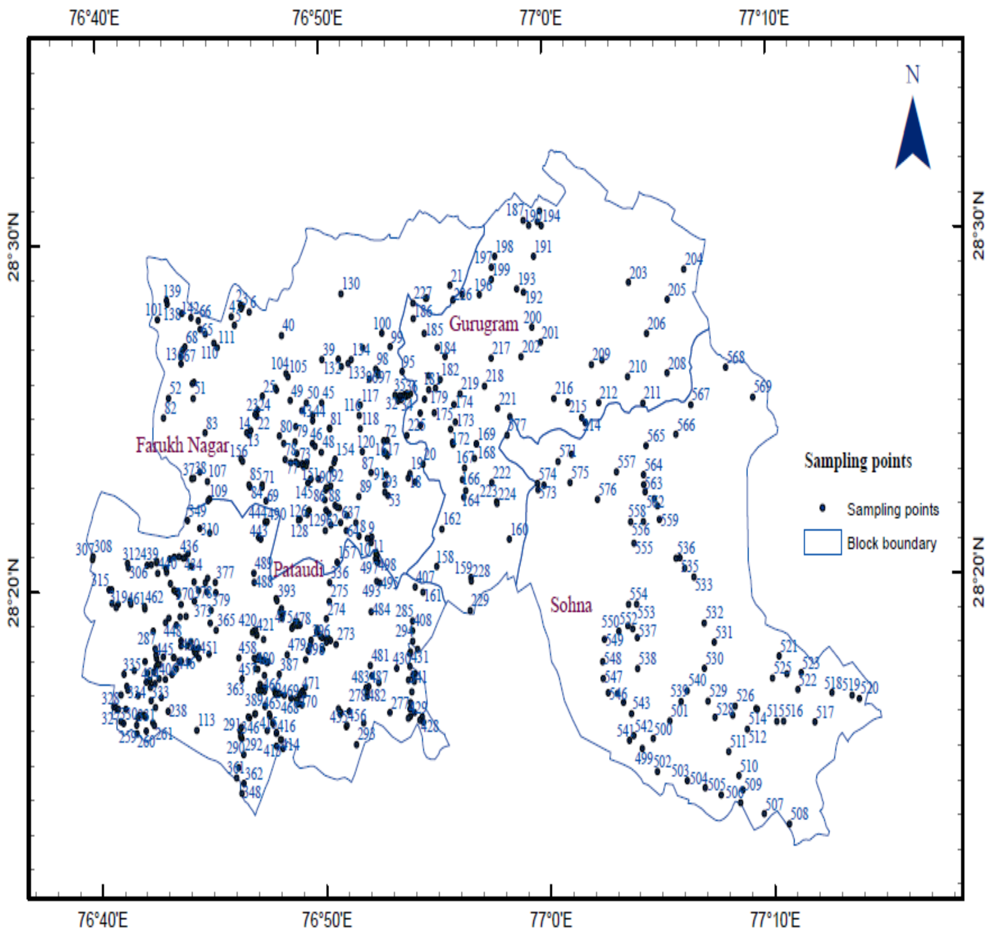


Fig.1.14 Location map of the sampling points in Gurugram district

In the Gurugram district, electrical conductivity (EC) ranged from 0.45 to 13.40 dS/m with a mean of 2.64dS/m. The pH ranged from 6.88 to 9.30 with a mean of 8.02. The range and mean for other parameters such RSC, SAR and concentrations of cations and anions are given in Table 1.27.

Table 1.27: Range and mean of different water quality parameters for Gurugram district

Sr. No.	Quality Parameter	Range	Mean	Sr. No.	Quality Parameter	Range	Mean
1	pH	6.88-9.30	8.02	8	K^+ (meq/l)	0.01-2.91	0.56
2	EC (dS/m)	0.45-13.40	2.64	9	CO_3^{2-} (meq/l)	0.00-4.00	0.79
3	RSC (meq/l)	0.00-13.50	1.36	10	HCO_3^- (meq/l)	0.25-39.75	5.85
4	SAR (mmol $l^{-1})^{1/2}$	0.30-28.55	7.57	11	Cl^- (meq/l)	0.9-88.0	14.97
5	Ca^{2+} (meq/l)	0.125-17.1	2.21	12	SO_4^{2-} (meq/l)	0.03-23.7	3.28
6	Mg^{2+} (meq/l)	0.6-60.95	6.68	13	NO_3^-(meq/l)	0.0-5.7	0.46
7	Na^+ (meq/l)	0.58-103.94	15.96				

It was observed that in Gurugram district, 461 samples had EC 0-4 dS/m, 108 samples had EC ranges from 4 to 10 dS/m, 6 samples had EC ranges from 10-12 dS/m and 2 samples had EC ranges from >12 dS/m (Table 1.28 and Fig. 1.15).

Table 1.28: Chemical composition of groundwater samples of Gurugram district in different EC classes

EC Classes (dSm^{-1})	No. of samples	Na^{+}	Ca^{2+}	Mg^{2+}	K^{+}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	NO_3^{-}	RSC	SAR
		--------(meq/l)--------										$(mmol\ l^{-1})^{1/2}$
0-1	125	4.25	0.94	2.86	0.25	0.59	4.40	2.49	0.54	0.21	1.53	3.35
1-2	204	7.97	1.20	3.60	0.41	0.74	5.05	5.54	1.34	0.38	1.75	5.60
2-3	84	15.73	2.02	6.05	0.66	0.80	4.70	14.31	3.81	0.50	0.94	8.54
3-4	48	22.73	2.67	8.01	0.85	1.23	6.73	20.49	4.82	0.59	2.18	11.02
4-5	30	29.27	3.45	10.45	0.87	0.78	7.40	28.50	6.40	0.52	0.77	12.09
5-6	28	34.68	4.32	12.81	0.74	1.03	7.52	35.49	8.12	0.72	0.69	12.85
6-7	23	43.08	4.61	14.12	1.06	1.03	8.28	44.41	8.27	0.96	0.43	15.41
7-8	13	47.12	6.06	18.09	1.08	0.92	8.22	53.92	9.93	0.81	0.00	14.41
8-9	11	50.13	7.63	22.24	1.25	0.64	10.99	58.74	11.79	0.73	0.03	13.60
9-10	3	40.68	12.33	37.33	0.18	0.67	14.17	67.08	8.36	1.27	0.00	8.84
10-11	4	53.33	10.65	36.28	1.37	0.38	19.06	72.33	8.92	1.22	0.00	12.43
11-12	2	55.80	13.23	40.03	1.57	0.00	24.38	79.00	10.98	0.43	0.00	10.81
>12	2	94.92	8.20	26.55	2.68	2.75	29.38	71.95	23.45	4.37	0.00	23.54

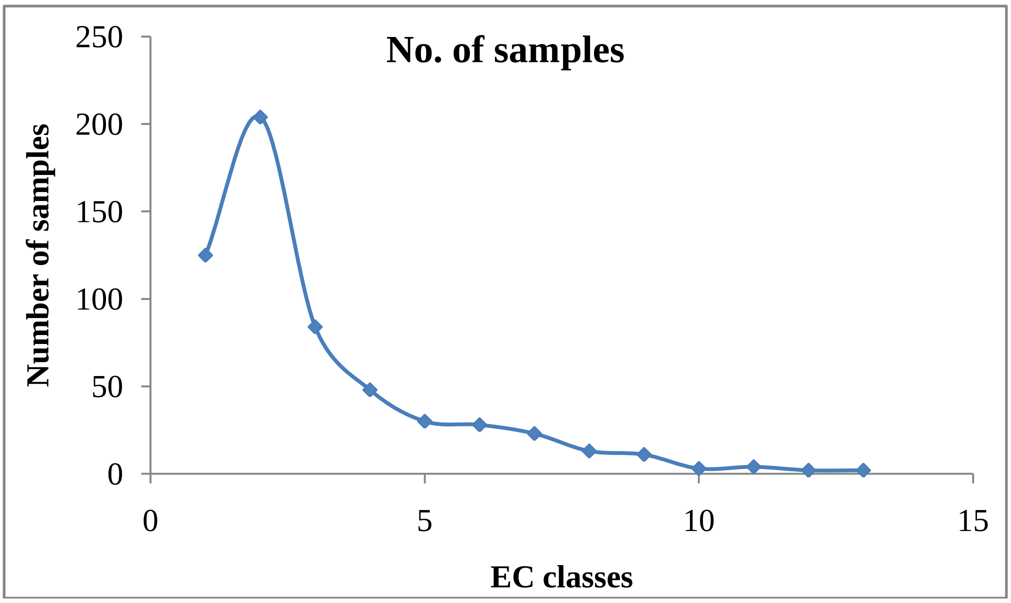


Fig. 1.15 Percent samples in different EC (dS/m) classes in Gurugram district

To study the spatial distribution of EC in the whole district, a spatial variable map was prepared by using ArcGIS through the interpolation of the available data at 577 sampling points (Fig. 1.16). The variation of EC in Gurugram district is grouped into 13 classes with a class interval of 1dS/m. The most dominating range of EC is 0-2 dS/m which occupied maximum area in the district and covering all the blocks of the district. The next dominating range was 2-4 dS/m which is covering a large portion. EC ranging from >12 dS/m is observed in small sport in the district.

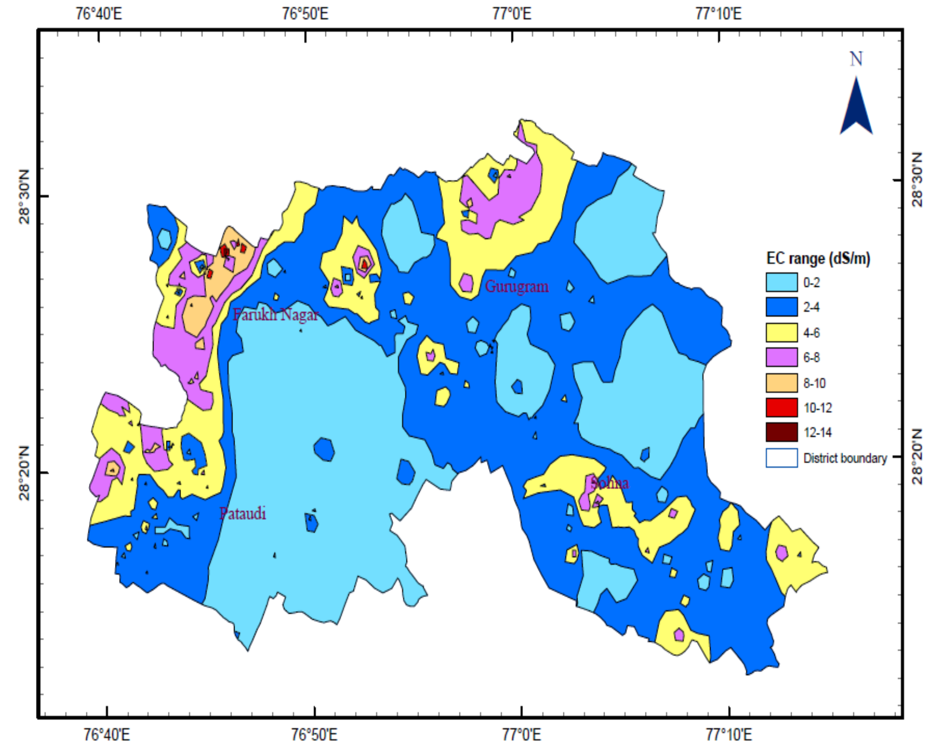


Fig.1.16 Spatial variability of EC of groundwater used for irrigation in Gurugram district

The residual sodium carbonate (RSC) was found to be ranged between from 0.00 to 13.50 meq/l with a mean value of 1.36 meq/l. Spatial variability of RSC of groundwater used for irrigation in Gurugram district presented in (Fig. 1.17).

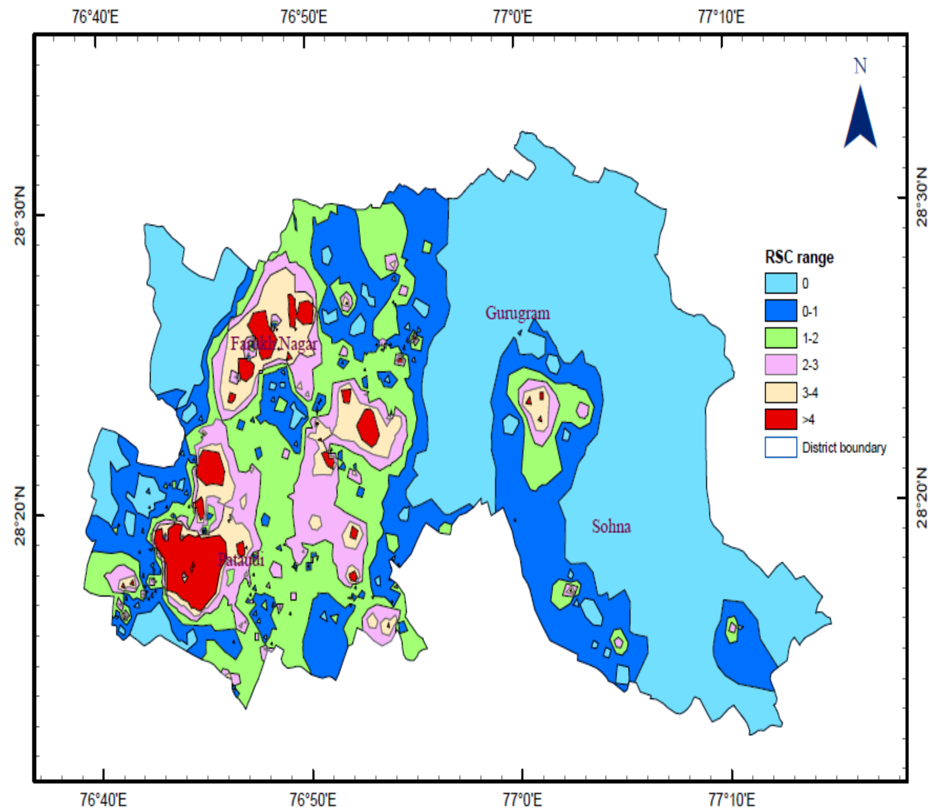


Fig. 1.17: Spatial variability of RSC of groundwater used for irrigation in Gurugram district

The sodium adsorption ratio (SAR) were found to be ranged between from 0.30 to 28.55 (mmol $l^{-1})^{1/2}$ with a mean value of 7.57 (mmol $l^{-1})^{1/2}$. Spatial variability of SAR of groundwater used for irrigation in Gurugram district district presented in (Fig. 1.18).

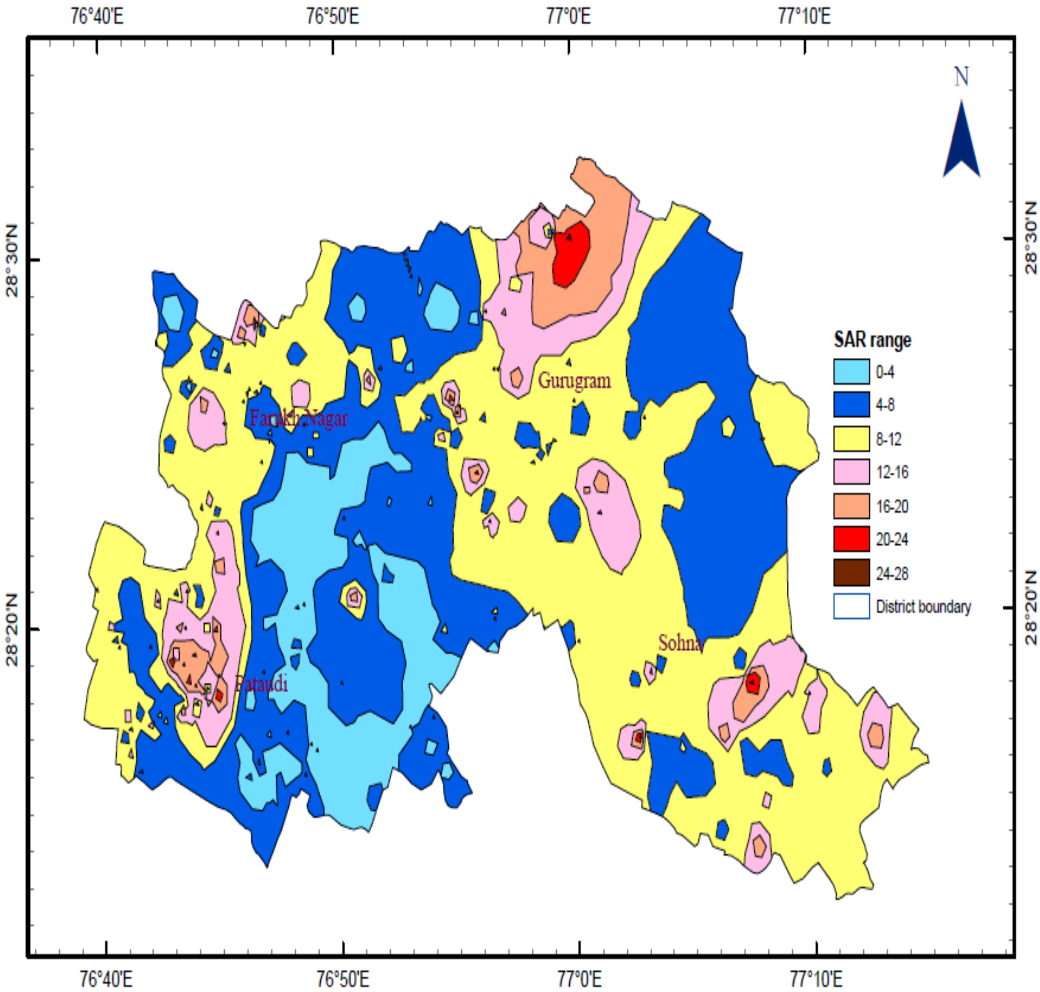


Fig. 1.18 Spatial variability of SAR of groundwater used for irrigation in Gurugram district

In case of anions, chloride was the dominant anion with maximum the concentration of chlorides in groundwater samples varied from 0.90 to 88.00 meq/l with the mean value of 14.97 meq/l. The concentration of bicarbonates in groundwater samples varied from 0.25 to 39.75 meq/l with a mean value of 5.85 meq/l. The mean values for CO_3^{2-}, HCO_3^-, Cl^- , SO_4^{2-} and NO_3^- were found to be 0.79, 5.85, 14.97,3.28 and 0.46 meq/l, respectively (Table 1.27). Table 1.28 and Fig. 1.19 illustrate the mean of anions according to the EC classes in district, the Cl^- was the highest and its value increased with the increase in EC.

The concentration of sodium in groundwater samples varied from 5.58 to 103.94 meq/l with an average value of 15.96 meq/l (Table 1.27), followed by magnesium (10.60 to 60.95 meq/l) and calcium (0.12 to 17.10 meq/l). Mean values for Na^+, Mg^{2+}, Ca^{2+} and K^+ were 15.96, 6.68, 2.21 and 0.56 meq/l, respectively. Table 1.28 and Fig. 1.20 illustrate the mean of cation according to the different EC classes in Gurugram district, Na^+ was the highest and its value increased with the increase in EC. Its lowest mean value (4.25 meq/l) was found in the class 0-1, the highest mean value (94.92 meq/l) was laid in the EC class of >12 dS/m.

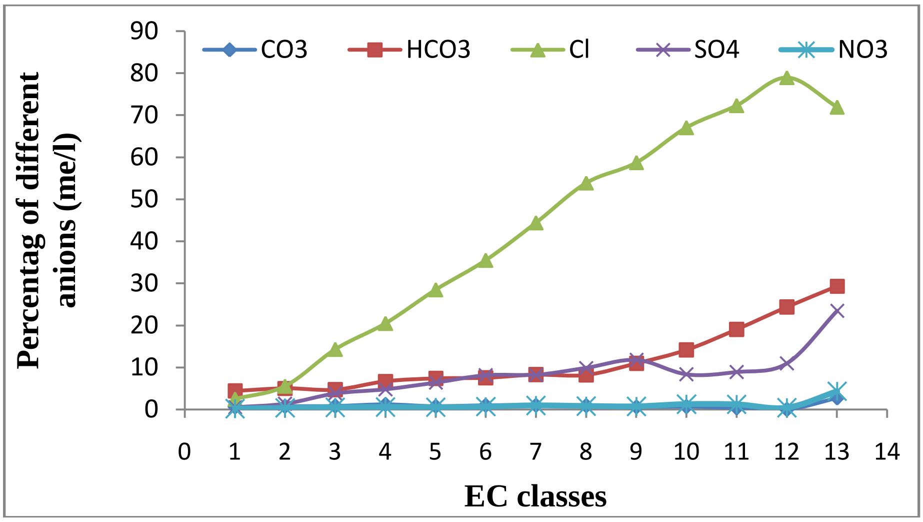


Fig. 1.19 Anions (CO_3, HCO_3, Cl, SO_4 and NO_3) concentration (meq/l) in different EC classes of Gurugram

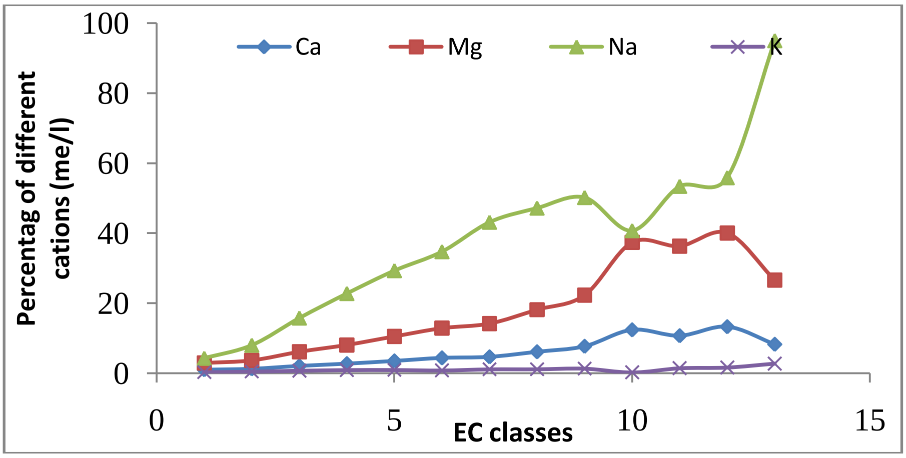


Fig.1.20 Cations (Ca, Mg, Na, K) concentration (meq/l) in different EC classes of Gurugram district

According to AICRP classification, it was found that 39.69 percent samples were of good quality, 37.78 percent saline and 22.53 percent alkali in nature (Fig. 1.21). Out of the saline water, 18.37, 5.89 and 13.52 percent were in marginally saline, saline and high SAR saline, respectively. In alkali group 11.09, 4.51 and 6.93 percent were in marginally alkali, alkali and high alkali, respectively. Out of seven categories of water, maximum 39.69 percent of samples were found in good quality followed by marginally saline (18.37 percent) and minimum 4.51 percent were found in alkali category.

Groundwater quality map for Gurugram district according to AICRP criteria was prepared to study its spatial variability in the district (Fig. 1.22). In the district, 39.69 percent samples are under good category but spatial variable map of block indicates less area under good quality. This is due to higher concentration of tubewells in that area and accordingly more samples were collected from that area. Good category groundwater is 29% in Gurugram, 36.71 in Sohana block 43.87 in Pataudi block and39.50% in Faruknagar block of the district and highly scattered in other blocks. Maximum saline water 66.67 % was found in Gurugram block whereas maximum alkali 28.25% water was found in Pataudi block. Area of the district having EC < 2 can come under good quality category but among these area where SAR < 10 and RSC ≥ 2.5 will come under marginally alkali and alkali. Most of the area where EC is more than 4 dS/m went under high SAR saline in comparison to saline condition, whereas, in both condition EC is more than 4 dS/m. With this fact area under high SAR saline is increased and area under saline condition is reduced. There is a little problem of alkalinity in groundwater of the district because marginally alkali and alkali categories were observed very scattered with small polygons.

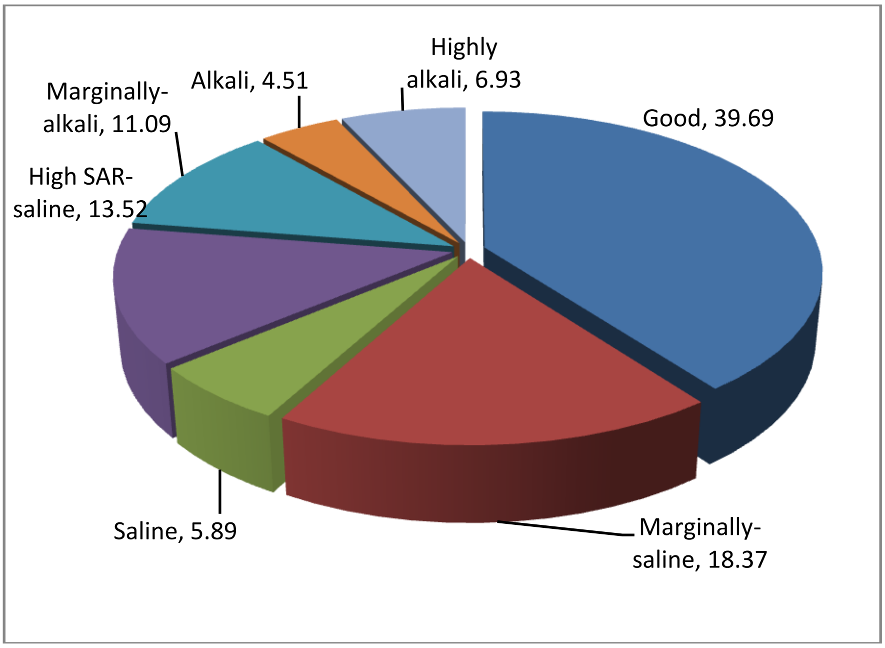


Fig.1.21 Quality of groundwater (percent) inGurugram district

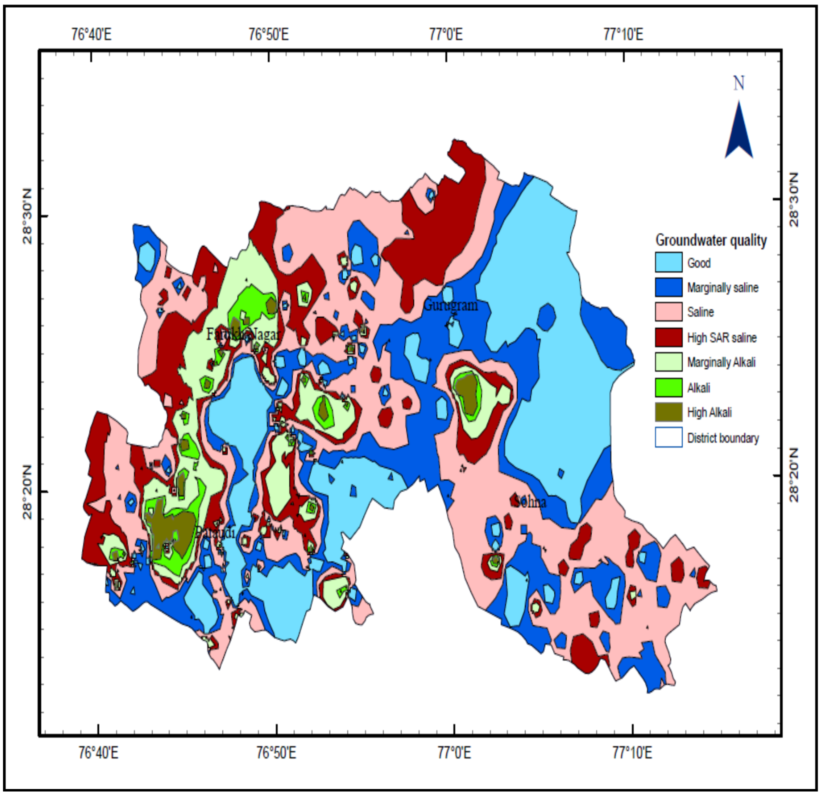


Fig.1.22 Groundwater quality map for Gurugram district according to AICRP criteria

- **Survey and characterization of groundwater for irrigation and salinity associated problems in Dewas district of Madhya Pradesh (Indore)**

The survey and characterization of underground irrigation water of Dewas district of Madhya Pradesh was undertaken during 2018-19. The district is situated in the southern part of the state. It lies in between 22^o 17' to 23^o 20' N & 75^o 50" to 77^o 10' E. A variety of crops like soybean, cotton, maize, sorghum wheat, gram and vegetables etc. are the main crops grown in the districts. Canal as well as open/tube wells usually irrigate these crops. The Districts has hot sub-humid climate characterized by hot summers and mild winters. The average annual rainfall is about 1067 mm. Maximum and minimum temperatures are 45 °C and 5.0 °C respectively. Two hundred thirty five water samples were collected from different tehsils of Dewas district for purpose of determination of quality parameters. The samples were from open wells and tube wells. The wells/ tube wells vary in depth from 8 to 255 m depth in Dewas district. Data based on survey work are provided in Table 1 and discussed below.

Dewas Tehsil: The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 7.1 to 8.25, 0.59 to 4.15 dS/m, 0.60 to 9.45 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 8.6, 2.0 to 22.4 and 0.6 to 52.0 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^+ and K^+ varied from 1.8 to 18.0, 0.0 to 12.8, 1.18 to 17.67 and 0.01 to 10.30, respectively (Table 1.29). Out of thirty two samples, 27 (84.4 %) water samples come under good water category "A". However, 4 (12.5 %) and 1 (3.1 %) samples fall under marginally saline water (B_1) and saline (B_2) categories respectively (Table 1.30).

Bagali Tehsil: The quality of groundwater of Bagali tehsil indicate that pH, EC, SAR and RSC ranged from 7.50 to 8.14, 0.62 to 1.40 dS/m, 0.63 to 2.28 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.00 to 3.00, 2.20 to 8.80 and 0.80 to 4.40 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^+ and K^+ varied from 2.00 to 7.80, 0.40 to 3.40, 1.01 to 4.45 and 0.00 to 0.30, respectively (Table 1.29). Out of 14 samples, 14 (100.0 %) water samples come under good water category "A" (Table1.30).

Kannod Tehsil: The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 7.3 to 8.70, 0.59 to 1.87 dS/m, 0.03 to 2.34 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 2.0 to 4.4, 1.98 to 10.0 and 0.6 to 1.68 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^+ and K^+ varied from 2.2 to 10.8, 1.20 to 6.40, 0.07 to 7.24 and 0.01 to 0.32, respectively (Table 1.29). Total 19 samples (100%) come under good water category "A" (Table 1.30).

Khategaon Tehsil: The quality of groundwater of Khategaon tehsil indicate that pH, EC, SAR and RSC ranged from 7.10 to 8.30, 0.65 to 2.24 dS/m, 0.12 to 2.96 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 2.0 to 4.80, 2.0 to 7.80 and 0.60 to 6.80 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^+ and K^+ varied from 2.80 to 7.20, 0.40 to 3.00, 0.6 to 14.96 and 0.12 to 0.36, respectively (Table 1.29). Out of 27 samples, 26 (96.0 %) come under good water category "A" (Table 1.30).

Hatpipaliya Tehsil: The quality of groundwater of Hatpuipliya tehsil indicate that pH, EC, SAR and RSC ranged from 7.40 to 8.3, 0.57 to 1.76 dS/m, 0.42 to 1.67 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 4.80, 2.0 to 7.0 and 1.0 to 9.6 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^+ and K^+ varied from 2.6 to 9.40, 1.20 to 6.20, 0.7 to 3.27 and 0.03 to 0.21, respectively (Table 1.29). All the 12 samples (100.0 %) come under good water category "A" (Table 1.30).

Sonkatch Tehsil: The quality of groundwater of Sonkatch tehsil indicate that pH, EC, SAR and RSC ranged from 7.20 to 9.3, 0.48 to 3.98 dS/m, 0.52 to 5.58 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 5.40, 2.0 to 21.4 and 0.2 to 14.4 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied from 1.60 to 17.0, 0.00 to 13.0, 0.82 to 8.85 and 0.00 to 1.08, respectively (Table 1.29). Out of thirty four samples, 33 (97.1 %) come under good water category "A". However, 1 (2.9 %) sample fall under marginally saline water (B_1) categories (Table 1.30).

Udainagar Tehsil: The quality of groundwater of Udainagar tehsil indicate that pH, EC, SAR and RSC ranged from 7.5 to 8.5, 0.35 to 1.27 dS/m, 0.29 to 3.50 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 3.0, 1.4 to 8.2 and 2.0 to 4.8 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied from 1.20 to 5.20, 0.00 to 5.20, 0.38 to 6.07 and 0.00 to 0.60, respectively (Table 1.29). All the 24 samples (100.0 %) come under good water category "A" (Table 1.30).

Tonkkhurd Tehsil: The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 7.0 to 9.3, 0.52 to 4.58 dS/m, 0.20 to 10.99 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 2.0 to 8.00, 1.20 to 31.0 and 0.6 to 28.60 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied from 2.0 to 26.0, 1.0 to 13.4, 0.42 to 17.37 and 0.01 to 1.18, respectively. Out of forty samples, 20 (50%) water samples come under good water category "A" (Table 1.29). However, 17 (42.5%) and 3 (7.5%) samples fall under marginally saline water (B_1) and saline (B_2) categories, respectively (Table 1.30).

Satwas Tehsil: The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 7.12 to 8.70, 0.24 to 1.98 dS/m, 0.07 to 1.44 and Nil meq/l respectively. Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 0.60 to 6.80, 0.4 to 7.20 and 0.6 to 5.80 meq/l, respectively. Similarly the cations like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} varied from 0.40 to 10.80, 0.20 to 6.40, 0.43 to 3.51 and 0.00 to 0.55, respectively (Table 1.29). All the 33 samples (100.0 %) come under good water category "A" (Table 1.30).

Table 1.29. Salient Features of ground water samples of Dewas district

Parameter	Dewas	Bagali	Kannod	Khategaon	Hatpipaliya	Sonkatch	Udalgarh	Tonkkhurd	Satwas
pH	7.10-8.25 (7.80)	7.50-8.14 (7.83)	7.3-8.7 (7.85)	7.1-8.3 (7.7)	7.40-8.30 (7.96)	7.20-9.30 (8.30)	7.50-8.50 (8.10)	7.00-9.30 (8.46)	7.1-8.7 (7.51)
EC (dS/m)	0.59-4.15 (1.30)	0.62-1.40 (0.87)	0.59-1.87 (0.92)	0.65-2.24 (0.65)	0.57-1.76 (0.93)	0.48-3.98 (1.12)	0.35-1.27 (0.75)	0.52-4.58 (2.15)	0.24-1.98 (0.88)
Ca^{2+}	1.80-18.00 (5.41)	2.00-7.80 (4.57)	2.20-10.00 (4.60)	2.80-7.20 (4.78)	2.60-9.40 (4.30)	1.60-17.00 (4.59)	1.20-5.20 (3.27)	2.00-26.00 (11.20)	0.4-10.8 (4.00)
Mg^{2+}	0.00-12.8 (3.21)	0.40-3.40 (1.94)	1.20-6.40 (2.40)	0.40-3.00 (2.09)	1.20-6.20 (3.20)	0.00-13.00 (3.04)	0.00-5.20 (2.50)	1.00-13.40 (3.40)	0.2-6.4 (2.20)
Na^{+}	1.18-17.67 (4.08)	1.01-4.45 (2.08)	0.07-7.24 (2.07)	0.60-14.96 (3.76)	0.70-3.27 (1.58)	0.82-8.85 (3.22)	0.38-6.07 (1.65)	0.42-17.37 (6.15)	0.43-3.51 (2.00)
K^{+}	0.01-10.30 (0.44)	0.00-0.30 (0.07)	0.01-0.32 (0.11)	0.12-0.36 (0.12)	0.03-0.21 (0.12)	0.00-1.08 (0.20)	0.00-0.60 (0.14)	0.01-1.18 (0.23)	0.0-0.55 (0.06)
CO_3^{2-}	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
HCO_3^{-}	1.00-8.60 (2.53)	1.00-3.00 (1.66)	2.00-4.40 (3.00)	2.00-4.80 (3.18)	1.00-4.80 (2.13)	1.00-5.40 (3.22)	1.00-3.00 (2.00)	2.00-8.00 (3.03)	0.6-6.8 (2.90)
Cl^{-}	2.00-22.40 (6.49)	2.20-8.80 (4.30)	1.98-10.00 (3.80)	2.00-7.80 (3.97)	2.00-7.00 (3.68)	2.00-21.40 (5.20)	1.40-8.20 (3.16)	1.20-31.00 (9.95)	0.4-7.2 (2.60)
SO_4^{2-}	0.60-52.00 (5.39)	0.80-4.40 (2.69)	0.6-6.80 (2.50)	1.20-9.80 (3.60)	1.00-9.60 (3.40)	0.20-14.40 (2.60)	0.20-4.80 (2.32)	0.60-28.60 (8.54)	0.6-5.8 (2.80)
SAR	0.60-9.45 (2.15)	0.63-2.28 (1.15)	0.03-2.34 (0.51)	0.12-2.96 (0.85)	0.42-1.67 (0.80)	0.52-5.58 (1.75)	0.29-3.50 (0.97)	0.20-10.99 (2.28)	0.07-1.44 (0.46)
RSC (meq/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Data in parenthesis are mean values of the parameters

Frequency distribution of water samples

A ground water survey of the Dewas district was conducted by Salt Affected Soils Project, College of Agriculture, Indore. 235 ground water samples were collected from different villages from different tehsils of the district. Out of these 235 samples, 208 (88.5%) belongs to category "A", 23 (9.8%) belong to category "B_1" and 4 (1.7 %) belong to category "B_2" (Table 1.30). The ground water quality map of the district was also generated with the help of software ERDAS IMAGINE 8.7 (Fig. 1.23).

Table 1.30 Frequency distribution of water samples into different categories of water quality in Dewas district

Tehsils	Category							
	A	B_1	B_2	B_3	C_1	C_2	C_3	Total
Dewas	27 (84.4)	4 (12.5)	1 (3.1)	0	0	0	0	32
Bagali	14 (100)	0	0					14
Kannod	19 (100)	0	0					19
Khategaon	26 (96)	1 (4)	0					27
Hatpipaliya	12 (100)	0	0					12
Sonkatch	33 (97.1)	1 (2.9)	0					34
Udalnagar	24 (100)	0	0					24
Tonkkhurd	20 (50)	17 (42.5)	3 (7.5)					40
Satwas	33 (100)	0	0					33
Total	208 (88.5)	23 (9.8)	4 (1.7)					235

Figures in parenthesis are percentage of the samples

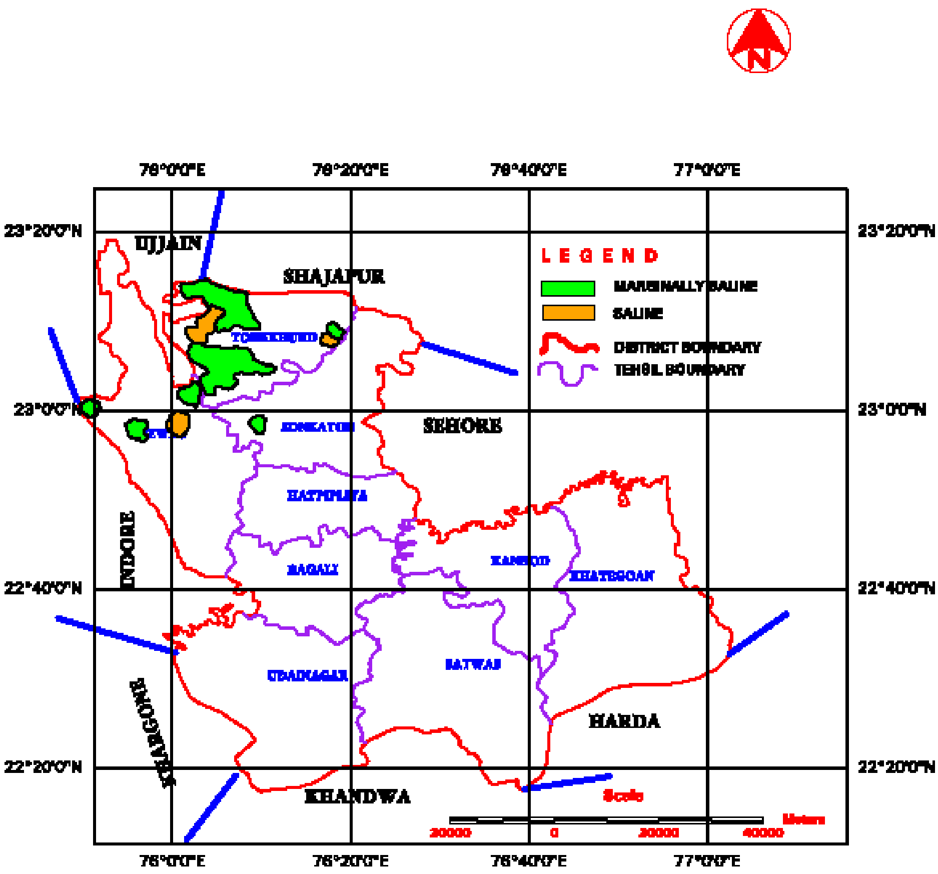


Fig. 1.23 Groundwater quality of Dewas district of Madhya Pradesh

- **Groundwater quality of Madhya Pradesh for irrigation purpose (Indore)**

New Ground water quality maps of Madhya Pradesh

2020

Brief description of the area

The Madhya Pradesh is a state situated in the heart of India. It has 11 agro-climatic zones and the having semi-arid to arid climate (Fig. 1.24 & Table 1.31).

Fig.1.24 Agro-climatic zones of Madhya Pradesh

Table 1.31. Districts covered in agroclimatic zones of Madhya Pradesh

Zone	Name of Zone	District covered
I	Chhatisgarh Plains	Balaghat
II	Northern Hills Zone of Chhatisgarh	Mandla, Dindori, Shahdol, Umaria, Anuppur
III	Kymore Plateau and Satpura Hills	Jabalpur, Katni, Seoni, Rewa, Panna, Satna, Sidhi, Singrauli
IV	Vindhyan Plateau	Sagar, Damoh, Bhopal, Raisen, Sehore, Vidisha
V	Central Narmada Valley	Narsingpur, Hoshangabad, Harda
VI	Gird Zone	Gwalior, Guna, Ashok Nagar, Morena, Bhind, Shivepuri, Sheopur
VII	Bundelkhand Zone	Datia, Chhattterpur, Tikamgarh
VIII	Satpura Plateau	Betul, Chhindwara
IX	Malwa Plaeau	Indore, Ujjain, Neemach, Dhar, Mandsaur, Dewas, Ratlam, Rajgarh, Shajapur, Agar Malwa
X	Nimar Valley	Khandwa, Khargone, Barwani, Burhanpur
XI	Jhabua Hills	Jhabua, Alirajpur

It lies in between latitude of 21° 30′ to 26° 15′ N & longitude of 74° 09′ to 82° 48′ E. The state constituted of 51 different districts. A variety of crops like soybean, cotton, maize, sorghum, wheat, gram, Mustard and vegetables etc. are the main crops grown in the state. River, Canal as well as open/tube wells usually irrigate these crops in the state. The state has semi arid and arid climate characterized by hot summers and mild winters. The average annual rainfall of the state ranges between 800- 1500 mm. Maximum and minimum temperatures are 45 °C and 5.0 °C respectively. The northern part of the state shows highest temperature in summer i.e. Bhind, Datia, Morena, Gwalior etc. The maximum rainfall in the state is found in the districts of Jabalpur, Narsingpur, Hoshangabad etc.

The AICRP on Management of Salt Affected soils and Use of Saline Water in Agriculture has done ground water survey of 17 districts of the state and collected 4218 ground water samples. The data related to ground water quality of 17 districts has already been given in the previous annual reports (2000-2018). Total ground water samples (6482) of whole Madhya Pradesh used for categorization of water quality and preparation of map. About 4378 (68 %) ground water samples were collected from the Indore centre and other 2104 (32 %) ground water samples data of depicted / marked wells and tube wells were procured from the Ground Water Board of Madhya Pradesh state during last year. These data were maintained and produced in the form of report and followed the criteria given by the CSSRI, Karnal for classification of ground water quality in different categories.

The location of wells / tube wells and chemical composition in respect of cations and anions are given in different tables according to various districts. After compilation of ground water quality data of Indore centre and ground water board. The maps were generated with the help of GIS software (ArcMap GIS software 9.3.1) in association with Department of Soil Science and Agricultural Chemistry, J. N. Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh.

RESULTS: The ground water quality details of different districts of Madhya Pradesh in respect of soluble cation and anions are presented in EC, SAR and RSC and different categories of saline and alkali water.

1. Agar Malwa District: Out of 25 samples, 20 (80.0%) belongs to category "A", 3 (12.0 %) belong to category "B_1". Only two samples belonged to C_2 (8%) alkali water category. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.46 to 8.71, 0.21 to 2.86 dS/m, 0.12 to 3.50 and 0.05 to 5.75 meq/l respectively. Among anions Cl was the dominant one and ranged from 0.31-12.2 meq/l followed by bicarbonates (0.6-10 meq/l) and carbonates (0.0-2.6 meq/l). Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.42-15.33 meq/l) followed by Na (0.3-11.17 meq/l) and Ca (0.6-8.4 meq/l), respectively.

2. Anuppur District: Out of 34 samples, 33 (97.0%) belongs to category "A", and only one sample belonged to C_2 (3%) alkali water category. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.03-8.04, 0.17-1.13, 0.09-3.23 and 0-6.91, respectively. Among anions HCO3 was the dominant one and ranged from 0.51-8.51 meq/l followed by chloride (0.39-3.80 meq/l) and sulphate (0.10-2.29 meq/l). Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.26-8.17 meq/l) followed by Mg (0.33-5.75 meq/l) and Ca (0.60-3.60 meq/l), respectively. The village Amarkanta of Pushprajgarh block showed highest RSC value (6.91 meq/l) of ground water sample and belonged to alkali water category.

3. Ashok Nagar District: Out of 22 samples, 20 (90.0 %) belongs to category "A" and only one sample each belonged to B_1 (5 %) and C_2 (5 %) alkali water category. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.44-8.30, 0.18-3.31, 0.01-9.89 and 0-4.60, respectively. Among anions Cl was the dominant one and ranged from 0.20-14.68 meq/l followed by HCO3 (1.26-7.82 meq/l), sulphate (0.04-2.19 meq/l) and carbonates (0.6-2.0 meq/l). Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.42-25.42 meq/l) followed by Ca (0.90-7.5 meq/l), Na (0.13-3.78 meq/l) and K (0.01-2.38 meq/l), respectively. The village Saraskheri of Isagarh block showed highest RSC value (4.60 meq/l) of ground water sample and belonged to alkali water category (C_2).

4. Balaghat District: Out of 110 samples, 106 (96.0 %) belongs to category "A" and only four samples belonged to B_1 (4 %) category. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 6.85-8.25, 0.18-3.74, 0.06-1.89 and 0-2.48, respectively. Among anions SO_4 was the dominant one and ranged from 0.04-15.63 meq/lfollowed by Cl (0.14-15.58 meq/l), HCO_3 (0.39-8.10 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.26-16.74 meq/l) followed by Mg (0.17-15.00 meq/l), Ca (0.6-14.55 meq/l) and K (0.00-0.42 meq/l), respectively. The two villages each of Katangi and Khairlanji block showed EC value grater than 2.0 dS/m of ground water sample and belonged to marginally saline category (B_1).

5. Barwani District: Out of 25 samples, 24 (96.0 %) belongs to category "A" and only one sample belonged to B_1 (4 %) category. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.06-8.11, 0.45-2.11, 0.12-1.50 and 0-1.68 respectively. Among anions HCO3 was the dominant one and ranged from 0.61-9.30 meq/lfollowed by Cl (0.31-8.9 meq/l), SO_4 (0.06-2.77 meq/l) respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from (0.8-10.3 meq/l) followed by Mg (0.42-7.58 meq/l), Na (0.65-5.22 meq/l) and K (0.01-2.38 meq/l), respectively. Borlai village of Barwani block showed EC value grater than 2.0 dS/m of ground water sample and belonged to marginally saline category (B_1).

6. Betul District: Out of 82 samples, 79 (96.0 %) belongs to category "A" and three samples belonged to C_1 (4%) category. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.14-9.01, 0.21-1.68, 0.06-2.56 and 0.0-3.96 respectively. Among anions HCO3 was the dominant one and ranged from 0.7-8.39 meq/lfollowed by Cl (0.2-6.48 meq/l), SO_4 (0.06-2.77 meq/l) respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.17-10.83 meq/l) followed by Ca (0.3-8.0 meq/l), Na (0.22-6.26 meq/l) and K (0.00-0.92 meq/l), respectively. Three villages of district showed RSC value grater than 2.5 meq/l of ground water sample and belonged to marginally alkali category (C_1).

7. Bhopal District: All the 39 (100 %) ground water samples belong to category "A" according to criteria of CSSRI, Karnal. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.22-8.74, 0.24-1.93, 0.02-1.18 and 0-1.25 respectively. Among anions Cl was the dominant one and ranged from 0.68-11.49 meq/lfollowed by HCO_3 (0.61-7.90 meq/l), SO_4 (0.13-6.56 meq/l) and CO_3 (0-2.8 meq/l) respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.33-11.83 meq/l) followed by Ca (1.50-9.60 meq/l), Na (0.13-4.96 meq/l) and K (0.00-02.79 meq/l) respectively. Dig Bangla village of Phanda block showed highest RSC value of 1.25 meq/l.

8. Burhanpur District: Out of 30 samples, 27 (91.0 %) belongs to category "A" and one sample each belonged to B_1, C_1 and C_2 category and represent total 9%. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.33-8.93, 0.46-2.66, 0.13-2.86 and 0-7.68 respectively. Among anions Cl was the dominant one and ranged from 0.31-12.59 meq/lfollowed by HCO_3 (1.61-9.0 meq/l), SO_4 (0.04-2.60 meq/l) respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.08-11.17 meq/l) followed by Ca (0.3-11.10 meq/l), Na (0.7-9.74 meq/l) and K (0.0-0.56 meq/l) respectively. Two villages

(Ichchapur and Burhanpur 1) of Burhanpur block showed RSC value grater than 2.5 meq/l of ground water sample and belonged to marginally alkali (C_1) and alkali (C_2) water category.

9. Chattarpur District: Out of 70 samples, 69 (98.5 %) belongs to category "A" and one sample belonged to B_1 category and represent 1.5 %. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.02-8.82, 0.28-2.33, 0.07-1.28 and 0-1.83 respectively. Among anions Cl was the dominant one and ranged from 0.28-12.39 meq/lfollowed by HCO_3 (0.8-10.31 meq/l), SO_4 (0.04-7.83 meq/l) respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from (0.9-10.5 meq/l) followed by Na (0.22-8.57meq/l), Mg (0.33-7.33 meq/l) and K (0.0-0.87 meq/l), respectively. Only one sample of Laundi block showed EC greater than 2.0 dS/m of ground water sample and belonged to marginally saline (B_1) water category.

10. Chindwara District: A ground water data of Chindwara district were procured by the centre and categorized in to different categories. All the 115 ground water samples belonged to category "A" and represent 100 %.water samples are good quality water. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.06-8.76, 0.26-1.79, 0.07-0.94 and 0-1.59 respectively. Among anions HCO_3 was the dominant one and ranged from 0.2-11.9 meq/lfollowed by Cl (0.37-8.59 meq/l), SO_4 (0.02-4.42 meq/l) respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from (0.7-11.10 meq/l) followed by Mg (0.17-9.25 meq/l), Na (0.30-5.13 meq/l) and K (0.0-1.44 meq/l) respectively.

11. Damoh District: A ground water data of Damoh district were procured by the centre and categorized in to different categories. Out of 50 samples, 43 (86.0 %) belongs to category "A", four samples belonged to B_1 marginally saline (8 %), one sample of saline in nature B_2 (2 %) and two samples belonged to C_2 category and represent 4.0 % ground water as alkali in nature. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.06-8.76, 0.20-4.24, 0.04-17.28 and 0.00-5.22, respectively. Among anions Cl was the dominant one and ranged from 0.20-14.0 meq/lfollowed by SO4 0.06-10.0 meq/l, and HCO_3 (0.61-9.30 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.17-29.26 meq/l) followed by Mg (0.17-10.33 meq/l), Ca (0.3-8.90 meq/l) and K (0.0-4.41 meq/l), respectively.

12. Dindori District: A ground water data of Dindori district were procured by the centre and categorized in to different categories. All the 40 (100 %) ground water samples belonged to category "A", i.e. good quality water. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.0-8.25, 0.25-1.47, 0.02-3.18 and0.00-0.65 respectively. Among anions Cl was the dominant one and ranged from 0.20-8.70 meq/lfollowed by HCO3 (1.10-5.51 meq/l) and SO4 (0.04-4.27 meq/l), respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from 0.3-6.70 meq/l followed by Mg (0.17-5.92 meq/l), Na (0.13-4.78 meq/l) and K (0.0-0.14 meq/l), respectively. Over the entire district Dindori has good quality water and can be used safely for irrigation.

13. Guna District: A ground water data of Guna district were procured by the centre and categorized in to different categories. Out of 75 samples, 72 (96.0%) belongs to category "A", two samples belonged to C_1 marginally alkali (3%), one sample of alkali in nature C_2 (1%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.14-8.28, 0.12-1.67, 0.04-2.19 and 0.00-6.30, respectively. Among anions Cl was the dominant one and ranged from 0.34-10.59 meq/lfollowed by HCO_3 0.9-10.41 meq/l, and SO_4 (0.06-5.00 meq/l) respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.92-

10.5 meq/l) followed by Na (0.22-8.61 meq/l), Ca (0.4-5.70 meq/l) and K (0.0-0.62 meq/l), respectively.

14. Harda District: A ground water data of Harda district were procured by the centre and categorized in to different categories. Out of 32 samples, 27 (84.4%) belongs to category "A", three samples belonged to C_1 marginally alkali (9.3%), two sample of belonged to C_2 category and represent 6.3% ground water as alkali in nature (Table 22). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.09-9.09, 0.39-2.08, 0.13-3.90 and 0-8.37, respectively. Among anions HCO3 was the dominant one and ranged from 3.1-9.10 meq/lfollowed by SO_4 0.06-6.25 meq/l and Cl (0.39-5.83 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.70-13.39 meq/l) followed by Mg (01.33-7.75 meq/l), Ca (0.7-6.50 meq/l) and K (0.0-1.62 meq/l), respectively. Two villages of Harda and Timarani block showed alkali water (C_2) and denote the RSC > 4.0 meq/l.

15. Jabalpur: A ground water data of Jabalpur district were procured by the centre and categorized in to different categories. Out of 73 samples, 70 (96.0%) belongs to category "A" and three samples belonged to C_1 marginally alkali (4%) category, The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 6.98-8.56, 0.22-1.95, 0.06-3.10 and 0.0-2.91, respectively. Among anions HCO_3 was the dominant one and ranged from 1.39-9.0 meq/lfollowed by Cl 0.11-5.89 meq/l, and SO_4 (0.02-3.85 meq/l), respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from 0.90-20.75 meq/l followed by Mg (0.42-9.42 meq/l), Na (0.26-7.39 meq/l) and K (0.0-2.51 meq/l), respectively.

16. Katni: A ground water data of Katni district were procured by the centre and categorized in to different categories. Out of 49 samples, 44 (90.0%) belongs to category "A", two samples each belonged to B1 Marginally saline (4%) and C_1 marginally alkali (4%) and one sample of alkali in nature C_2 (2%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.11-8.82, 0.08-2.20, 0.02-1.91 and 0.00-5.27, respectively. Among anions Cl was the dominant one and ranged from 0.06-14.48 meq/lfollowed by HCO_3 0.51-10.70 meq/l and SO_4 (0.04-4.69 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.09-10.22 meq/l) followed by Mg (0.42-10.0 meq/l), Ca (0.2-7.10 meq/l) and K (0.01-1.26 meq/l), respectively. Ubra village of Vijay Raghavgarh block showed RSC value of 5.27 meq/l and belonged to category of alkali water.

17. Mandla: A ground water data of Mandla district were procured by the centre and categorized in to different categories. Out of 88 samples, 86 (98.0%) belongs to category "A", one sample each belonged to B_1 Marginally saline (1%) and C_1 marginally alkali (1%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.06-8.42, 0.29-3.35, 0.02-3.02 and 0.0-3.78, respectively. Among anions Cl was the dominant one and ranged from 0.14-20.68 meq/lfollowed by HCO_3 0.90-11.0 meq/l, and SO_4 (0.04-6.15 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.09-17.39 meq/l) followed by Mg (0.17-15.17 meq/l), Ca (0.1-12.2 meq/l) and K (0.01-0.23 meq/l), respectively.

18. Narsingpur: A ground water data of Narsingpur district were procured by the centre and categorized in to different categories. Out of 50 samples, 49 (98.0%) belongs to category "A", and only one sample belonged C_2 category of alkali water (2%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.01-8.31, 0.46-1.55, 0.06-1.34 and 0.0-4.25, respectively. Among anions HCO_3 was the dominant one and ranged from 1.10-10.95 meq/lfollowed by SO_4 (0.04-5.83 meq/l) and Cl (0.28-4.08 meq/l) respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (1.92-7.50 meq/l) followed by

Na (0.35-6.96 meq/l), Ca (0.80-5.90 meq/l) and K (0.01-1.15 meq/l), respectively. One sample of village Deoribadwani of Sainkheda block showed higher value of RSC (4.25 meq/l) and come in the category of alkali water as per the criteria of CSSRI, Karnal.

19. Panna: A ground water data of Panna district were procured by the centre and categorized in to different categories. Out of 73 samples, 65 (89.1%) belongs to category "A", two samples belonged to B_1 marginally saline category (2.7%), five samples belonged to C_1 marginally alkali (6.8%), one sample of alkali in nature C2 (1.4%). The quality of groundwater samples are indicates that pH, EC, SAR and RSC ranged from 7.08-9.98, 0.13-2.96, 0.03-1.75 and 0.00-4.73, respectively. Among anions SO4 was the dominant one and ranged from 0.02-16.15 meq/lfollowed by Cl (0.03-13.66 meq/l) and HCO_3 (0.2-8.75 meq/l), respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from (0.3-22.0 meq/l) followed by Na (0.13-9.78 meq/l), Mg (0.17-8.92 meq/l) and K (0.0-0.64 meq/l) respectively. A Village Powai Salleha of Shahnagar block showed alkali water (C_2) and denote the RSC of 4.73 meq/l.

20. Raisen: A ground water data of Raisen district were procured by the centre and categorized in to different categories. Out of 77 samples, 66 (85.7%) belongs to category "A", six samples belonged to B1 marginally saline category (7.8%), one sample belonged to C_1 marginally alkali (1.3%), four samples of alkali in nature C_2 (5.2%). The quality of groundwater samples are indicates that pH, EC, SAR and RSC ranged from 7.01-8.61, 0.36-2.35, 0.06-4.23 and 0.00-10.26, respectively. Among anions HCO_3 was the dominant one and ranged from 0.90-12.0 meq/lfollowed by Cl (0.28-11.38 meq/l), CO_3 (0-4.8 meq/l) and SO4 (0.06-4.65 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.35-14.78 meq/l) followed by Ca (0.5-10.7 meq/l), Mg (0.17-8.33 meq/l) and K (0.01-5.33 meq/l), respectively.

21. Rajgarh: A ground water data of Rajgarh district were procured by the centre and categorized in to different categories. Out of 57 samples, 54 (95.0%) belongs to category "A" , two samples belonged to B_1 marginally saline (3.5%) category and one sample belonged to C_1 marginally alkali (1.5%) category, The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.17-9.15, 0.41-2.21, 0.04-2.87 and 0.0-3.95 respectively. Among anions Cl was the dominant one and ranged from 0.34-10.59 meq/lfollowed by HCO3 (0.70-10.41 meq/l) and SO4 (0.08-8.85 meq/l) respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from 0.42-14.25 meq/l followed by Ca (0.5-9.60 meq/l), Na (0.22-9.00 meq/l) and K (0.0-0.62 meq/l) respectively. Sandawata village of Saranpur block showed RSC of 3.95 meq/l and belonged to C_1 category.

22. Rewa: A ground water data of Rewa district were procured by the centre and categorized in to different categories. Out of 79 samples, 73 (92.4%) belongs to category "A", five samples belonged to B_1 marginally saline (6.3%) and one sample of alkali in nature C_2 (1.3%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 6.9-8.81, 0.22-2.60, 0.04-2.28 and 0.00-4.02, respectively. Among anions SO4 was the dominant one and ranged from 0.06-21.02 meq/lfollowed by Cl (0.2-9.49 meq/l) and HCO_3 (1.0-6.70 meq/l), respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from (0.4-23.6meq/l) followed by Mg (0.42-9.5 meq/l), Na (0.22-7.48 meq/l) and K (0.00-1.00 meq/l) respectively. Barduhawan village of Jawa block showed RSC value of 4.02 meq/l and belonged to category of alkali water (C_2).

23. Sagar: A ground water data of Sagar district were procured by the centre and categorized in to different categories. Out of 81 samples, 78 (96.3%) belongs to category "A", two samples belonged to B1 marginally saline (2.5%) and one sample of C_1 marginally alkali (1.2%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.11-9.05, 0.3-3.63, 0.02-

4.32 and 0.0-3.55 respectively. Among anions Cl was the dominant one and ranged from 0.2-22.28 meq/lfollowed by HCO_3 0.8-8.70 meq/l and SO_4 (0.04-7.40 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.09-14.96 meq/l) followed by Ca (0.6-13.35 meq/l), Mg (0.58-13.17 meq/l) and K (0.00-0.49 meq/l), respectively.

24. Satna: A ground water data of Satna district were procured by the centre and categorized in to different categories. Out of 67 samples, 58 (86.5%) belongs to category "A", six samples belonged to B_1 Marginally saline (9%), two samples belonged to C_1 marginally alkali (3%) and one sample of alkali in nature C_2 (1.5%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 6.98-9.90, 0.25-3.36, 0.04-2.85 and 0.00-5.75 respectively. Among anions Cl was the dominant one and ranged from 0.2-12.48 meq/l followed by SO4 (0.06-10.31 meq/l) and HCO_3 (0.39-9.30 meq/l), respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from (0.6-20.10 meq/l) followed by Na (0.17-11.30 meq/l), Mg (0.42-9.0 meq/l) and K (0.01-0.56 meq/l), respectively.

25. Sehore: A ground water data of Sehore district were procured by the centre and categorized in to different categories. Out of 50 samples, 44 (88%) belongs to category "A", four samples belonged to B_1 Marginally saline (8%), two samples belonged to C_1 marginally alkali (4%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.14-8.57, 0.35-3.06, 0.11-1.97and 0.0-3.67, respectively. Among anions Cl was the dominant one and ranged from 0.39-13.89 meq/l followed by HCO_3 (1.2-9.2 meq/l) and SO4 (0.08-6.43 meq/l), respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.17-14.83 meq/l) followed by Na (0.43-10.91 meq/l), Ca (0.6-10.6 meq/l) and K (0.0-0.41 meq/l), respectively.

26. Seoni: A ground water data of Seoni district were procured by the centre and categorized in to different categories. Out of 127 samples, 125 (98%) belongs to category "A", one sample each belonged to B_1 Marginally saline (1%) and C_1 marginally alkali (1%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.06-8.18, 0.28-2.16, 0.03-2.99 and 0.0-3.13, respectively. Among anions Cl was the dominant one and ranged from 0.2-14.42 meq/l followed by HCO_3 (0.39-8.39 meq/l) and SO_4 (0.04-3.85 meq/l), respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.08-11.58 meq/l) followed by Ca (0.7-11.1 meq/l), Na (0.17-8.09 meq/l), and K (0.0-0.26 meq/l), respectively

27. Shahdol : A ground water data of Shahdol district were procured by the centre and categorized in to different categories. All the 75 ground water samples (100%) belonged to category "A" i.e. good water quality. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.11-8.04, 0.09-1.86, 0.0-1.65 and 0.0-2.30, respectively. Among anions Cl was the dominant one and ranged from 0.06-12.0 meq/l followed by HCO_3 (0.39-6.80 meq/l) and SO4 (0.04-3.56 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.0-9.78 meq/l) followed by Mg (0.17-8.08 meq/l), Ca (0.2-5.60 meq/l) and K (0.0-1.65 meq/l), respectively.

28. Shajapur: A ground water data of Shajapur district were procured by the centre and categorized in to different categories. Out of 51 samples, 42 (82.3%) belongs to category "A", nine samples belonged to B_1 Marginally saline (17.7%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.15-9.51, 0.33-3.05, 0.05-4.78 and 0.0-1.6, respectively. Among anions Cl was the dominant one and ranged from 0.48-24.28 meq/l followed by HCO_3 (0.39-15.3 meq/l) and SO_4 (0.13-6.35 meq/l) respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.22-21.17 meq/l) followed by Mg (0.5-19.67 meq/l), Ca (0.5-9.80 meq/l) and K (0.0-0.8 meq/l), respectively.

29. Shivpuri: A ground water data of Shivpuri district were procured by the centre and categorized in to different categories. Out of 77 samples, 72 (93.5%) belongs to category "A", four samples belonged to B_1 Marginally saline (5.2%), one sample belonged to C_2 alkali (3%) water category. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.09-8.08, 0.35-3.26, 0.02-3.10 and 0.0-7.77, respectively. Among anions C_l was the dominant one and ranged from 0.51-17.77 meq/l followed by HCO3 (1.70-9.90 meq/l) and SO4 (0.04-6.29 meq/l), respectively. Calcium showed its dominance in respect of cations present in ground water samples and ranged from (1.20-17.10 meq/l) followed by Na (0.09-13.13 meq/l), Mg (0.58-9.42 meq/l) and K (0.0-0.86 meq/l), respectively.

30. Sidhi: A ground water data of Sidhi district were procured by the centre and categorized in to different categories. All the 80 ground water samples (100%) belonged to category "A" i.e. good water quality. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.12-8.47, 0.17-1.61, 0.05-1.43 and 0.0-1.10, respectively. Among anions Cl was the dominant one and ranged from 0.14-8.99 meq/l followed by HCO_3 (0.89-5.30 meq/l) and SO_4 (0.04-5.31 meq/l) respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.50-7.92 meq/l) followed by Na (0.22-7.70 meq/l), Ca (0.4-6.20 meq/l) and K (0.01-0.51 meq/l), respectively.

31. Singrauli: A ground water data of Singrauli district were procured by the centre and categorized in to different categories. Out of 38 samples, 36 (94.7%) belongs to category "A", two samples belonged to C1 marginally alkali (5.3%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.16-8.68, 0.11-1.46, 0.05-1.43 and 0.0-3.16, respectively. Among anions Cl was the dominant one and ranged from 0.06-10.0 meq/l followed by HCO_3 (0.64-7.62 meq/l) and SO_4 (0.04-2.50 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.22-6.43 meq/l) followed by Ca (0.2-5.15 meq/l), Mg (0.42-4.00 meq/l) and K (0.0-0.56 meq/l), respectively.

32. Tikamgarh: A ground water data of Tikamgarh district was procured by the centre and categorized in to different categories. Out of 49 samples, 44 (89.8%) belongs to category "A", five samples belonged to B_1 marginally saline (10.2%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.02-9.50, 0.25-2.35, 0.06-2.26 and 0.0-2.55, respectively. Among anions Cl was the dominant one and ranged from 0.48-19.35 meq/lfollowed by SO_4 (0.02-8.63 meq/l), HCO_3 (0.51-8.0 meq/l) and CO_3 (0.0-2.60 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.30-13.04 meq/l) followed by Ca (0.8-12.10 meq/l), Mg (0.17-8.42 meq/l) and K (0.01-1.12 meq/l), respectively.

33. Umaria: A ground water data of Umaria district were procured by the centre and categorized in to different categories. All the 41 ground water samples (100%) belonged to category "A" i.e. good water quality. The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.11-8.11, 0.17-1.89, 0.05-1.29 and 0.0-2.0, respectively. Among anions Cl was the dominant one and ranged from 0.14-14.42 meq/l followed by HCO_3 (0.64-8.7 meq/l) and SO_4 (0.04-3.08 meq/l), respectively. Sodium showed its dominance in respect of cations present in ground water samples and ranged from (0.22-7.83 meq/l) followed by Ca (0.3-7.60 meq/l), Mg (0.50-7.58 meq/l) and K (0.0-0.97 meq/l), respectively

34. Vidisha: A ground water data of Vidisha district were procured by the centre and categorized in to different categories. Out of 73 samples, 70 (96%) belongs to category "A" and three samples belonged to C_1 Marginally alkali (4%). The quality of groundwater samples are indicates that pH, EC SAR and RSC ranged from 7.0-8.59, 0.01-1.83, 0.07-2.93 and 0.0-3.61, respectively. Among anions HCO_3 was the dominant one and ranged from 0.51-9.20 meq/l followed by Cl (0.28-8.0 meq/l) and

SO_4 (0.04-3.85 meq/l), respectively. Magnesium showed its dominance in respect of cations present in ground water samples and ranged from (0.08-11.08 meq/l) followed by Na (0.43-9.48 meq/l), Ca (0.3-7.35 meq/l) and K (0.0-3.0 meq/l), respectively.

Distribution of ground waters under different catagories in different districts:

District wise distribution of groundwater samples under different categories is given in Table 1.32. In whole state, 6482 ground water samples were collected and procured from Ground Water Board of Madhya Pradesh. Out of fifty one districts of the state, the AICRP centre of Indore has covered 17 districts so far and remaining districts data procured from the Ground Water Board of Madya Pradesh. Out of 6482 ground water samples, the AICRP centre of Indore had collected 4378 (68%) samples and analysed in the laboratory of SAS Project, Indore and other 2104 (32%) samples data were procured from Ground Water Board of Madya Pradesh. The maximum ground water samples were collected from Ujjain, Hoshangabad and Neemuch districts i.e. 712, 444 and 405 respectively and analysed at salinity lab of AICRP centre, Indore. In general saline water is prevailed in the districts of Ujjain, Dhar, Neemuch, Mandsaur, Khargonr , Khandwa, and Dewas. Whereas, alkali water was found in the districts of Bhind, Morena, Gwalior and Datia. In whole Madhya Pradesh, 87.3% good, 7.7 % saline and 5 % alkali water categories (Fig. 1.25).

Table 1.32. Category of Ground water quality in different districts of Madhya Pradesh

S.No.	District	Category of Ground water quality							
		A	B_1	B_2	B_3	C_1	C_2	C_3	Total
1	Agar Malwa	20	3	-	-	-	2	-	25
2	Alirajpur	104	6	-	-	-	-		110
3	Annupur	33	-	-	-	-	-	1	34
4	Ashoknagar	20	1	-	-	-	1	-	22
5	Balaghat	106	4	-	-	-	-	-	110
6	Bawarni	24	1	-	-	-	-	-	25
7	Betul	79	-	-	-	3	-	-	82
8	Bhind	158	20	7	5	47	47	18	302
9	Bhopal	39	-	-		-	-	-	39
10	Burhanpur	27	1	-	-	1	1	-	30
11	Chhindwara	115	-	-	-	-	-	-	115
12	Chattarpur	69	1	-	-	-	-	-	70
13	Damoh	43	4	1	-	-	2	-	50
14	Datia	80	2		-	16	12	-	110
15	Dewas	208	23	4	-	-	-	-	235
16	Dhar	216	14	1	-	-	1	1	233
17	Dindori	40	-	-	-	-	-	-	40
18	Guna	72	-	-	-	2	1	-	75
19	Gwalior	126	6	0	-	20	6	3	161
20	Harda	27	-	-	-	3	2	-	32
21	Hoshangaad	425	16	1	1	1	-	-	444
22	Indore	308	5	1	-	-	2	1	317
23	Jabalpur	70	-	-	-	3	-	-	73
24	Jhabua	119	4	-	-	-	-	-	123
25	Katni	44	2	-	-	2	1	-	49
26	Khandwa	158	22	-	-	-	-	-	180
27	Khargone	208	44	1	-	-	-	-	253
28	Mandla	86	1	-	-	1	-	-	88
29	Mandsour	314	36	-	1	1	1	1	354
30	Morena	60	6	-	-	20	2	2	90

31	Narsinghpur	49	-	-	-	-	1	-	50
32	Neemuch	294	98	2	3	2	-	6	405
33	Panna	65	2	-	-	5	1	-	73
34	Raisen	66	6	-	-	1	4	-	77
35	Rajgarh	54	2	-	-	1	-	-	57
36	Ratlam	143	5	-	-	-	-	-	148
37	Rewa	73	5	-	-	1	-	-	79
38	Sagar	78	2	-	-	1	-	-	81
39	Satna	58	6	-	-	2	1	-	67
40	Sehore	44	4	-	-	2	-	-	50
41	Seoni	125	1	-	-	1	-	-	127
42	Shajapur	42	9	-	-	-	-	-	51
43	Shahdol	75	-	-	-	-	-	-	75
44	Sheopur	174	3	4	-	9	9	2	201
45	Shivpuri	72	4	-	-	-	1	-	77
46	Sidhi	80	-	-	-	-	-	-	80
47	Singrauli	36	-	-	-	2	-	-	38
48	Ujjain	572	63	30	4	33	10	-	712
49	Tikamgarh	44	5	-	-	-	-	-	49
50	Umaria	41	-	-	-	-	-	-	41
51	Vidisha	70	-	-	-	3	-	-	73
	Total	**5653**	**437**	**52**	**14**	**183**	**108**	**35**	**6482**
	Per Cent	**87.3**	**6.7**	**0.8**	**0.2**	**2.8**	**1.7**	**0.5**	**-**

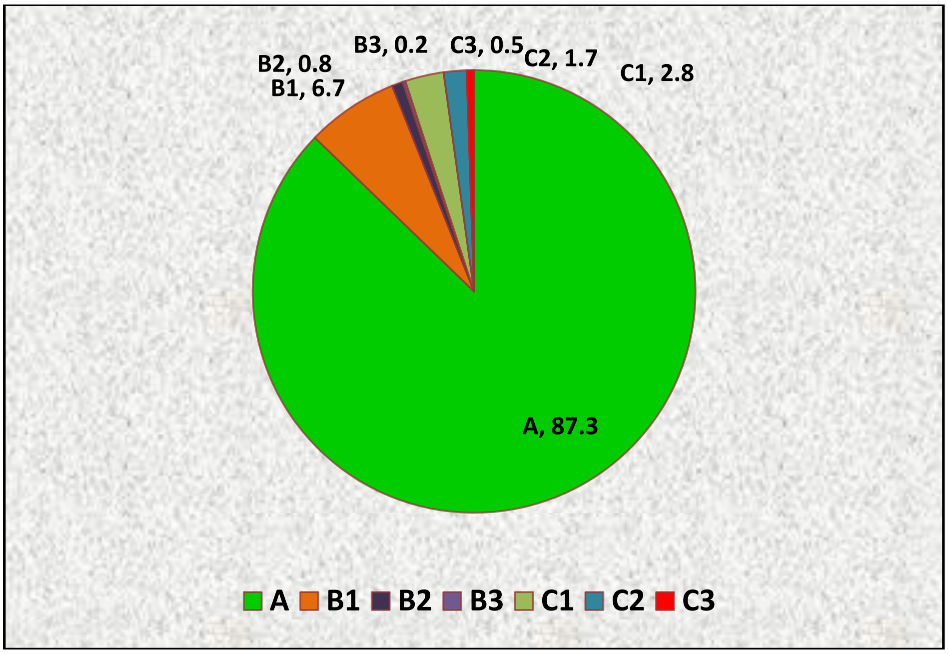


Fig. 1.25 Per cent distribution of ground water quality in to different categories in M.P.

Ground water quality in different agro climatic zones :

Out of eleven agro climatic zone of Madhya Pradesh, seven shows the good quality water more than 90% (Table 1.33). On the other hand, Chhatisgarh Plains, Northern Hills Zone of Chhatisgarh, Central Narmada Valley, Satpura Plateau and Jhabua Hills shows good quality water in more than 95% samples. The ground waters of Gird zone and Bundelkhand Zone shows poor quality water in respect of alkali water category and represented 20.5% and 12.5%. On the other hand the water of Malwa Plateau has 12% saline and 2.5% alkali in nature. Similarly Nimar Valley area of the agroclimatic zone depicted 14.2% saline and 0.4% alkali water. The over all picture of Madhya Pradesh represented as 87% good quality, 7.7% saline and 5.0% alkali in nature. The ground water quality maps in respect of EC, pH, SAR and categories (Good, saline and alkali) were prepared with the help of RS and GIS soft ware (ArcMap GIS software 9.3.1).

Table 1.33. Quality of ground water in different agro-climatic zones of Madhya Pradesh

S. No.	Agroclimatic Zone	Category of ground water							
		A	B_1	B_2	B_3	C_1	C_2	C_3	Total
I	Chhatisgarh Plains	106 (96.4)*	4 (3.6)	0	0	0	0	0	110
II	Northern Hills Zone of Chhatisgarh	275 (98.8)	1 (0.4)	0	0	1 (0.4)	0	1 (0.4)	278
III	Kymore Plateau and Satpura Hills	551 (94.0)	16 (2.7)	0	0	16 (2.7)	3 (0.6)	0	586
IV	Vindhyan Plateau	340 (91.9)	16 (4.3)	1 (0.3)	0	7 (1.9)	6 (1.6)	0	370
V	Central Narmada Valley	501 (95.2)	16 (3.0)	1 (0.2)	1 (0.2)	4 (0.8)	3 (0.6)	0	526
VI	Gird Zone	682 (73.5)	40 (4.3)	11 (1.2)	5 (0.5)	98 (10.5)	67 (7.2)	25 (2.8)	928
VII	Bundelkhand Zone	193 (84.3)	8 (3.5)	0	0	16 (7.0)	12 (5.2)	0	229
VIII	Satpura Plateau	194 (98.5)	0	0	0	3 (1.5)	0	0	197
IX	Malwa Plaeau	2171 (85.5)	258 (10.2)	38 (1.5)	8 (0.3)	37 (1.5)	16 (0.6)	9 (0.4)	2537
X	Nimar Valley	417 (85.4)	68 (14.0)	1 (0.2)	0	1 (0.2)	1 (0.2)	0	488
XI	Jhabua Hills	223 (95.7)	10 (4.3)	0	0	0	0	0	233
	Total	**5653**	**437**	**52**	**14**	**183**	**108**	**35**	**6482**
	Per cent	**87.3**	**6.7**	**0.8**	**0.2**	**2.8**	**1.7**	**0.5**	-

* Figure given in parenthesis are per cent of ground water covered in the category

The maps in respect of EC, pH, SAR and different categories were generated and presented in Fig. 1.26 to 1.29.

EC (dS/m) of Ground Water (Fig. 1.26): Most of the area of M.P. shows lower EC (<1.0 dS/m). Some of the patces in district northern district and westen parts depicted EC in between 1-2 dS/m. Very few patches of Bhind , Ashok nagar and Damoh shows higher EC.

pH of Ground Water (Fig. 1.27)**:** The pH of the ground water samples in the state ranges in between 7.0 to 9.1. These values are denoted tha the water of the state is alkaline in nature. The eastern parts of the state shows pH in between 7.4-7.6. The Gird region of the M.P. shows pH 7.0-7.4, whereas south-west part of state having the pH 7.0-9.1.

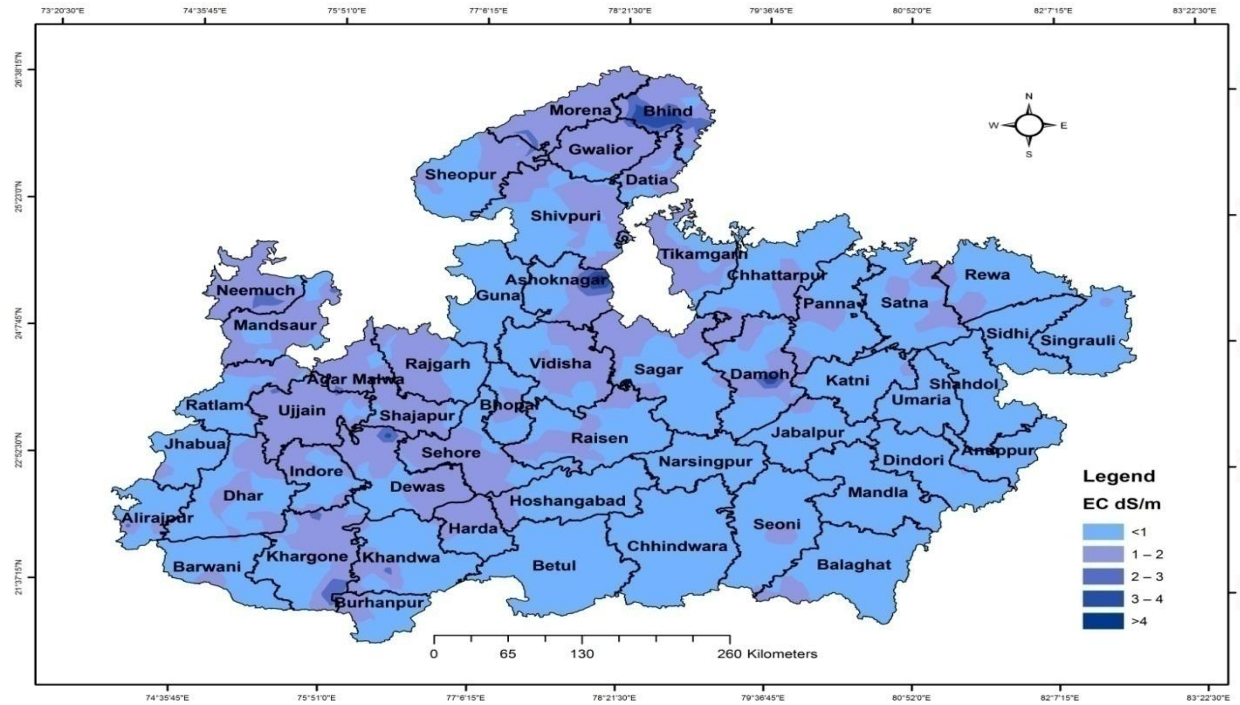


Fig. 1.26 EC (dS/m) map of ground water of Madhya Pradesh

SAR of Ground Water (Fig 1.28)**:** The SAR of the ground water samples in the state ranged in between 0.0 to 8.2. The northern part and south western part of state are showing the SAR values greater than >3.00. Eastern and south east part of the state has SAR values in between 0.00-1.13. On an average theSAR of ground water samples are in satisfactory range.

Ground Water quality map as per CSSRI, Karnal (Fig 1.29**):** The ground water map of the state also prepared with the help of RS and GIS soft ware. Most of the area of Madhya Pradesh having good quality water category and depicted as (A). Some of the patches in Gird region of the state show alkali water categories (C_1, C_2 and C_3). Some patches in east part and western part also show alkali waters. Most of the area of the western M.P. i.e. Ujjain, Neemuch, Harda and Betul also shows saline water (B_1, B_2 and B_3) categories.

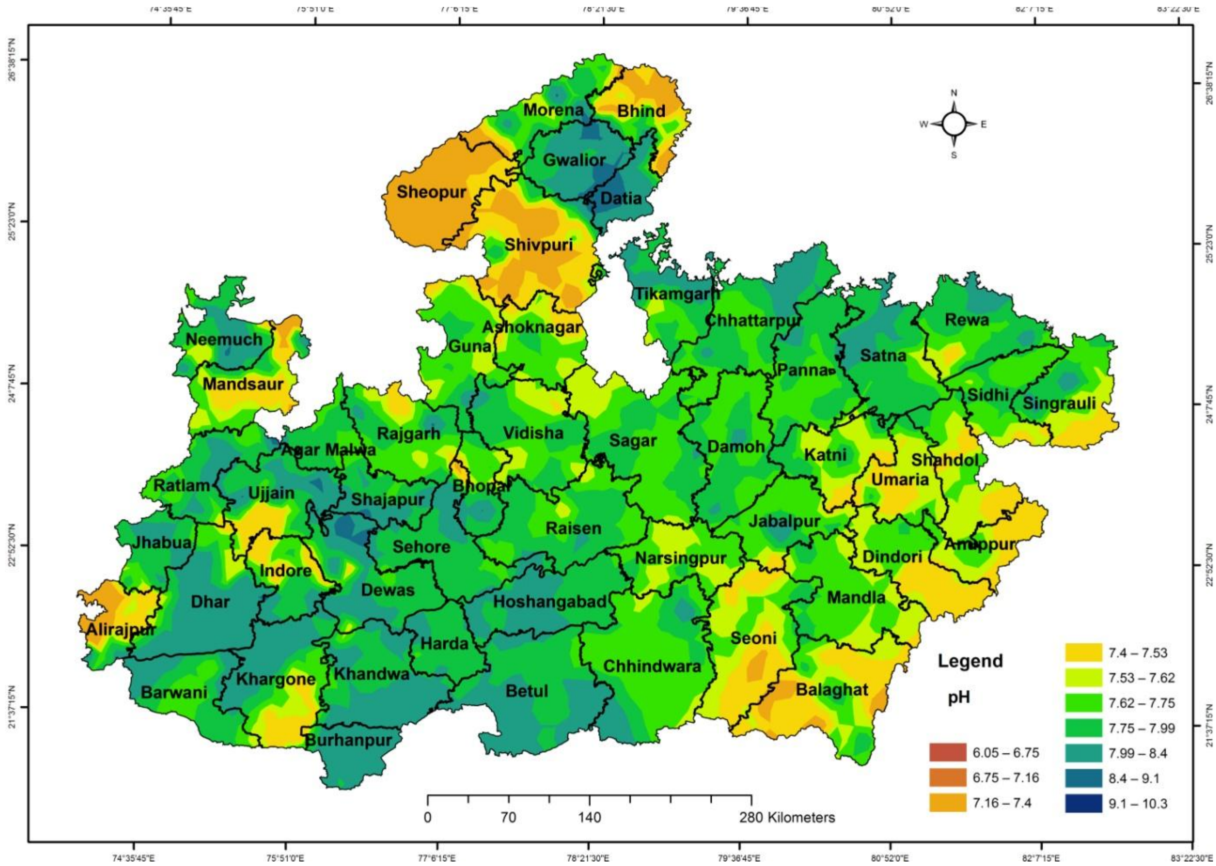


Fig. 1.27 pH map of ground water of Madhya Pradesh

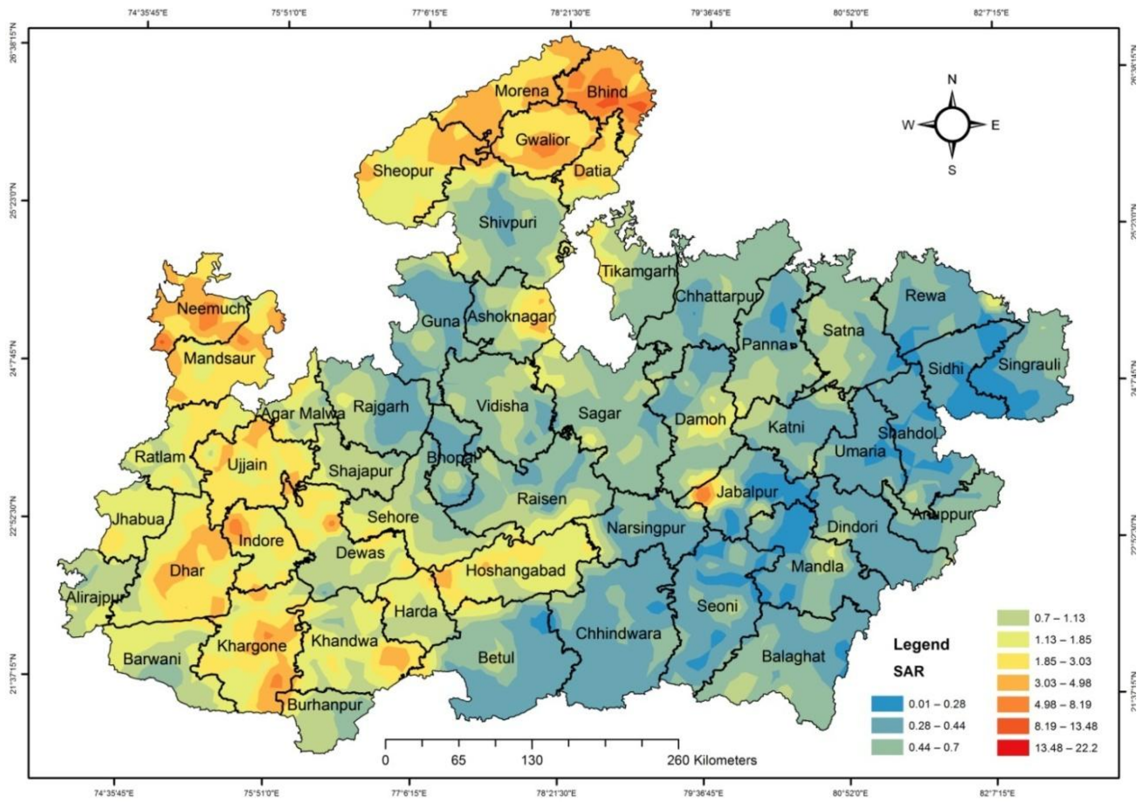


Fig.1.28 SAR map of ground water of Madhya Pradesh

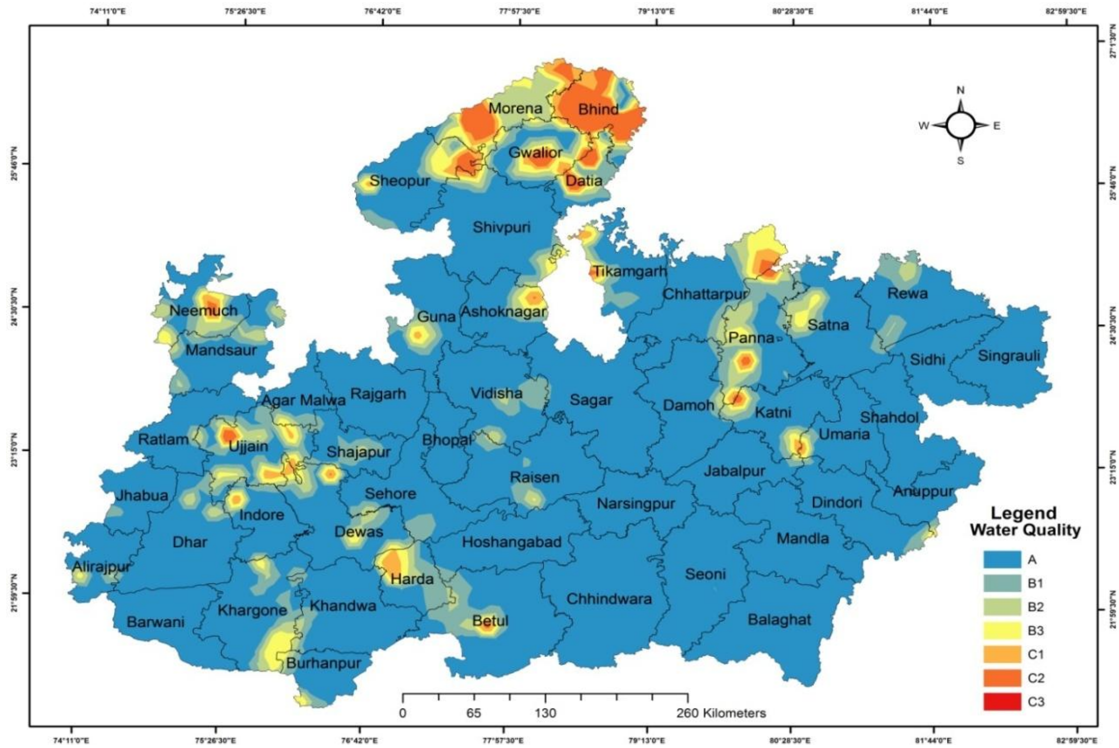


Fig. 1.29 Ground water quality map of Madhya Pradesh for irrigation purpose

Acknowledgements: Project Coordinator of AICRP on Salt Affected Soils & Use of Saline Water in Agriculture, CSSRI, Karnal, Director Research Services, RVSKVV, Gwalior for providing necessary facilities, M.P. GROUND WATER BOARD, BHOPAL for ground water data procurement, Dr. G.S. Tagore, Assistant Professor, Dept. Soil Science & Agricultural Chemistry, JNKVV, Jabalpur for preparing water quality map of M.P. Dr. S. C. Tiwari, Senior Technical Officer, Soil Testing Service Scheme, College of Agriculture, Indore

- **Survey and characterization of groundwater for irrigation for Kanpur Dehat and Auriya district of Uttar Pradesh (Kanpur)**

2019

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 1.34.

Block Ajitmal: The analysis of groundwater samples from Ajitmal block indicated that pH, EC, SAR and RSC ranged from 7.2 to 8.4, 0.38 to 3.28 dS/m, 0.7 to 10.2 and 0.0 to 7.2 meq/l with the mean value of 7.84, 0.97 dS/m, 2.84 and 0.48 meq/l , respectively. Most of the water samples belonged to good category (24 samples). Out of 32 samples, only seven (7) samples were of marginally saline and one (01) was of alkali water. The chloride was the dominant anion and calcium was the dominant cation followed by sodium.

Block Bidhuna: The analysis of groundwater samples from Bidhun block indicated that pH, EC, SAR and RSC ranged from 7.4 to 8.2, 0.32 to 3.21 dS/m, 0.6 to 9.3 and 0.0 to 2.7 meq/l with the mean value of 7.73, 0.89 dS/m, 3.22 and 0.22 meq/l, respectively. Most of samples belonged to good category (21 samples). Out of 29 samples, only 05 water samples were of marginally saline category, 01 sample was saline, 1 sample was alkaline and 01 sample highly alkaline. The chloride was the dominant anion followed by bicarbonate and calcium was the dominant cation followed by sodium and magnesium.

Block Erwakatra: The analysis of groundwater samples from Erwakatra block indicated that pH, EC, SAR and RSC varied from 7.3 to 8.6, 0.35 to 3.25 dS/m, 0.4 to 9.5 and 0.0 to 2.5 meq/l with the mean value of 7.72, 0.94 dS/m, 3.34 and 0.18 meq/l, respectively. Out of 27 groundwater samples, 20 samples were of good category, 05 water samples were marginally saline, 01 was saline and 1 highly saline. The chloride was the dominant anion followed by bicarbonate and sodium was the dominant cation followed by calcium.

Block Achalda: The analysis of groundwater samples from Achalda block indicated that pH, EC, SAR and RSC ranged from 7.5 to 8.4, 0.33 to 3.24 dS/m, 0.7 to 9.6 and 0.0 to 2.9 meq/l with the mean value of 7.75, 0.88 dS/m, 3.12 and 0.24 meq/l, respectively. Most of the water belonged to good category (22 samples). Out of 34 samples, only 08 water samples were of marginally saline water, 01 was of saline, 01 was of marginally alkaline,02 was of alkaline and 01 was of highly alkaline category. The chloride was the dominant anion and calcium was the dominant cation followed by sodium.

Block Sahar: The analysis of groundwater samples from Sahar block indicated that pH, EC, SAR and RSC ranged from 7.3 to 8.3, 0.32 to 3.25 dS/m, 0.4 to 10.2 and 0.0 to 7.6 meq/l with the mean value of 7.43, 1.10 dS/m, 4.21 and 0.59 meq/l, respectively. Most of the samples belonged to good category (27 samples). Out of 43 samples, only 10 water samples belonged marginally saline water, 02 samples were saline, 2 samples were marginally alkaline, 01 was alkaline and 01 was highly alkaline. The chloride was the dominant anion and calcium was the dominant cation followed by sodium.

Block Bhagyanagar: The analysis of groundwater samples from Bhagyanagar block indicated that pH, EC, SAR and RSC ranged from 7.3 to 8.5, 0.38 to 4.05 dS/m, 0.3 to 10.0 and 0.0 to 2.0 meq/l with the mean value of 7.76, 1.14 dS/m, 3.52 and 0.15 meq/l, respectively. Most of the water belonged to good category (26 samples). Out of 39 samples, only 09 water samples were marginally saline water, 01 sample was saline, 1 sample was highly saline and 2 samples were alkaline. The chloride was the dominant anion and calcium was the dominant cation followed by sodium.

Table 1.34 Salient features of ground water samples of Auraiya district

Blocks	pH	Mean	EC (dS/m)	Mean	SAR	Mean	RSC (meq/l)	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

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 %) 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 1.35.

Table: 1.35. 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	--

- **Survey and characterization of ground water of Ramanathapuram district of Tamil Nadu for Irrigation (Tiruchirapalli)**

2019

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 summer season. The total geographical area of the district is 4,175 sqkm. 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^+ andK^+ 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 1.36. The concentration Ca^{2+} with the district varied from 3.42 to 13.71 meq/l; Mg^{2+} varied from 7.50 to 40.87 meq/l; Na^+ varied from 32.71 to 129.73 meq/l; K^+ varied from 0.12 to 3.93 meq/l. In case of anions, CO_3^{2-} varied from 1.76 to 3.86; HCO_3^- varied from 5.4 to 10.88; Cl^- varied from 47.80 to 174.00 and SO_4^{2-} varied from 0.43 to 1.15 meq/l. In general, the distribution of cations 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.

Table 1.36. Average cationic and anionic concentrations in different blocks of Ramanathapuram district

S.NO	Block name	Cations(m.eq/l)				Anions(m.eq/l)			
		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

The ranges for groundwater pH, EC, Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR) for different blocks are given in Table 1.37. The 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. Residual Sodium Carbonate (RSC) varied from nil to18 meq/l and Sodium Adsorption Ratio (SAR) ranged from 0.52 to 144.34.

Table 1.37. Quality of ground waters in different blocks of Ramanathapuram District

Name of the Block	pH			EC (dS/m)			SAR			RSC (meq/l)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Ramanathapuram	7.22	8.24	7.82	1.85	32	13.19	9.31	45.55	20.20	Nil	21.2	Nil
Paramakkudi	7.77	8.49	8.12	2.56	21.96	6.40	8.5	37.09	21.7	Nil	15.2	1.05
Kamuthi	7.46	8.31	7.97	0.51	30.28	5.4	1.15	25.12	8.92	Nil	10.6	Nil
Kadaladi	7.85	8.3	7.76	1.62	51.9	18.63	1.76	126.5	29.84	Nil	5.6	Nil
Tirupullani	7.18	8.01	7.64	1.01	47.2	14.96	1.39	49.1	21.24	Nil	0.6	Nil
Nainarkovil	7.32	8.22	7.73	0.87	9.89	5.35	2.28	25.52	11.15	Nil	0.6	Nil
Mandapam	7.27	8.57	7.92	0.72	80.1	11.13	0.89	144.4	18.61	Nil	22.8	Nil
Mudukalathur	7.36	8.3	7.86	0.17	10.82	4.95	0.54	24.05	11.46	Nil	Nil	Nil
Bogalur	7.63	8.34	7.94	1.22	18.27	8.22	6.23	62.66	27.82	Nil	11	2.15
Tiruvadanai	7.17	8.17	7.71	0.29	80	16.53	0.51	44.51	19.79	Nil	10.2	Nil
R.S Mangalam	7.3	8.08	7.61	1.91	49.4	16.79	6.76	40.44	18.16	Nil	9.2	Nil

Water quality distribution in Ramanathapuram district

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 1.38 and Fig. 1.30. 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. 1.31.

Table: 1.38. 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

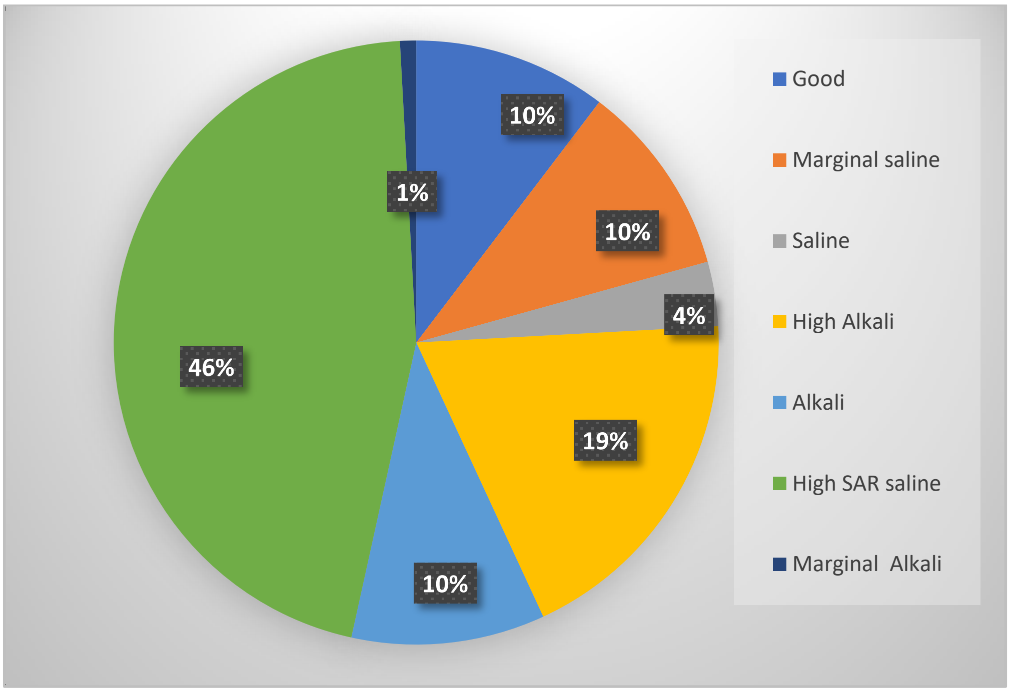


Fig. 1.30 Percentage distribution of ground water quality in Ramanathapuram district

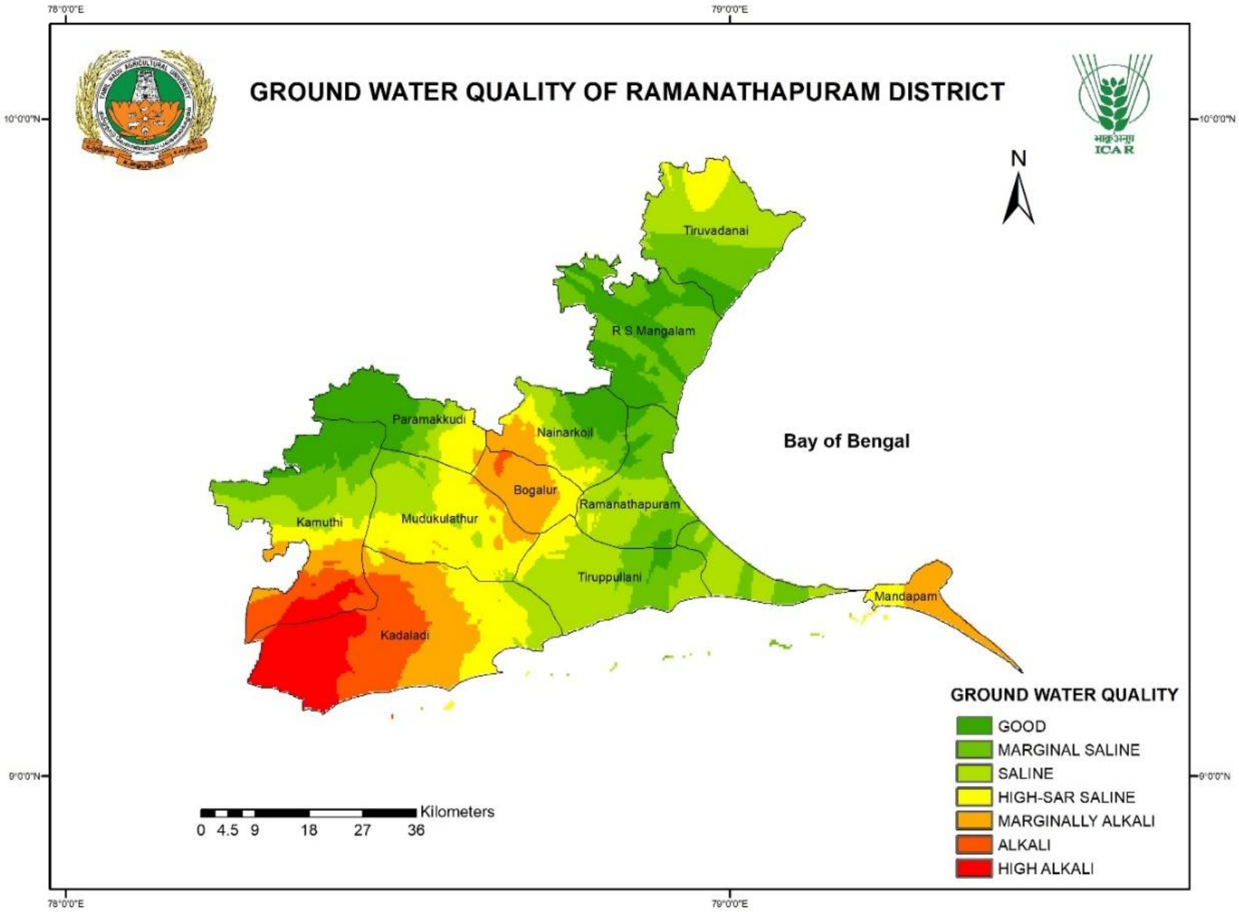


Fig. 1.31 Spatial distribution of ground water quality in Ramanathapuram district

- **Survey and characterization of ground water of Thoothukudi district of Tamil Nadu for Irrigation (Tiruchirapalli)**

Thoothukudi is one of the coastal districts bounded on the north by Virudhunagar and Ramanathapuram districts, on the east by the Bay of Bengal, and on the west and south west by Tirunelveli district. The district headquarters is located at Ramanathapuram. The district lies between 8^{0}19'00" N Latitude and 78^{0}40'00" E Longitude. The general geographical information of the district is simple and flat. Vaippar and Karamaniyar river are flowing in the district and they will be dry during the summer season. The total geographical area of the district is 4621 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 coastal line of Thoothukudi district runs for about 163.5 km. Generally, groundwater quality depends on the quality of recharged water, atmospheric precipitation, inland surface water and on subsurface geochemical processes.

A study was undertaken to assess the groundwater quality in Thoothukudi district by collecting 151 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^+ andK^+ 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 Thoothukudi district are given in Table 1.39. The concentration Ca^{2+} with the district varied from 2.92 to 12.60 meq/l; Mg^{2+} varied from 2.94 to 12.14 meq/l; Na^+ varied from 2.81 to 37.36

meq/l; K^+ varied from 0.19 to 2.30 meq/l. In case of anions, CO_3^{2-} varied from 0.25 to 3.60; HCO_3^- varied from 2.80 to 10.90; Cl^- varied from 8.00 to 42.00 and SO_4^{2-} varied from 0.11 to 0.80 meq/l. In general, the distribution of cations 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.

Table : 1.39 Average cationic and anionic concentrations in different blocks of Thoothukudi district

S.NO	Block name	Cations(meq/l)				Anions(meq/l)			
		Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
1.	V.Pudur	3.12	5.24	12.16	0.19	0.80	3.80	17.80	0.80
2.	Vilathikulam	7.29	5.20	37.36	0.35	0.86	5.71	42.00	0.75
3.	Kovilpatti	5.35	7.05	11.99	0.54	1.58	5.19	19.75	0.61
4.	Kayathar	5.72	8.48	10.08	0.32	0.80	4.70	19.40	0.40
5.	Karunkulam	3.93	3.15	4.57	0.25	0.67	2.80	9.41	0.30
6.	Ottapidaram	2.92	2.94	2.81	0.60	0.46	2.83	8.00	0.36
7.	Thoothukudi	7.10	8.04	17.03	0.31	3.60	10.90	15.50	0.57
8.	Srivaikuntam	3.65	5.28	3.95	1.53	0.25	3.38	11.13	0.11
9.	Alwarthirunagari	3.13	3.63	8.64	0.42	0.29	4.14	12.79	0.19
10	Thiruchendur	6.00	6.35	14.84	0.61	0.82	3.39	26.41	0.40
11.	Udangudi	7.02	7.85	16.88	2.30	0.31	4.54	26.69	0.24
12	Sathankulam	12.60	12.14	14.59	0.95	0.25	4.94	36.19	0.14

The investigation revealed that groundwater samples with respect to pH and EC ranged from 6.84 to 8.87 and 0.13 to 11.90 dS/m. Residual Sodium Carbonate (RSC) varied from Nil to 18.00 meq/l and Sodium Adsorption Ratio (SAR) ranged from 0 to 37.02 (Table 1.40).

According to CSSRI, Karnal water quality classification, only 51 per cent of groundwater found under good quality, (21%) marginally saline, (13%) saline, (3%) marginally alkaline, (2%) alkaline, (7%) high SAR saline and (3%) high alkaline. The cationic and anionic order of different blocks in Thoothukudi are followed as the Na^+> Mg^{2+}> Ca^{2+}>K^+ and Cl^-> HCO_3^-> CO_3^{2-}> SO_4^{2-}, respectively. Among the different blocks investigated, the highest percentage of a samples with good quality found in Ottapidaram (92%),Karunkulam (82%), Srivaikundam (75%), Alwarthirunagari (72%), Tiruchendur (59%), Vilathikulam (57%),Kayathar (50%), and Similarly, the poor-quality water viz., High SAR saline from Vilathikulam block (43%), Saline from Sathankulkam (44%), Marginal Saline from Kovilpatti (44%), High Alkali from Thoothukudi (10%), Alkali from Thoothukudi (20%). Among the different blocks of Thoothukudi district, Udangudi (46.15%), Kovilpatti (40%), Srivaikuntam (37.5 %) and Sathankulam (37.5%) recorded the possibility of seawater intrusion (Table 1.41 and Fig. 1.32). The spatial distribution of groundwater quality categories is provided in Fig. 1.33.

Table: 1. 40. Quality of ground waters in different blocks of Ramanathapuram District

Name of the Block	pH			EC (dS/m)			SAR			RSC (meq/l)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
V.Pudur	7.53-8.84	8.00	0.54	0.73-3.92	2.10	1.31	-21.20-4.20	-3.76	10.33	4.62-12.32	8.50	3.44
Vilathikulam	7.72-8.87	7.88	0.52	0.6-11.9	4.72	4.58	-24.00-2.40	-5.91	8.66	0.77-37.02	13.69	12.57
Kovilpatti	7.08-8.30	7.68	0.35	1.12-5.37	2.74	1.17	-24.80-14.20	-4.09	10.35	0.44-11.48	5.14	2.98
Kayathar	7.5-8.19	7.78	0.33	0.43-6.13	2.39	1.72	-22.20-2.20	-8.70	8.25	0.27-7.88	3.43	2.33
Karunkulam	7.34-8.07	7.69	0.22	0.32-2.53	1.20	0.64	-15.60-5.60	-3.45	4.38	0.00-7.98	2.62	2.48
Ottapidaram	7.19-7.95	7.59	0.28	0.13-2.35	1.03	0.67	-10.60-2.60	-2.55	3.69	0.01-5.26	1.48	1.46
Thoothukudi	7.11-8.01	7.51	0.32	0.4-6.42	3.00	1.95	-6.40-18.00	-0.64	7.92	0.61-15.69	5.88	4.57
Srivaikuntam	7.12-8.01	7.45	0.30	0.33-4.03	1.42	1.26	NIL	-5.30	4.64	0.41-7.76	1.78	2.51
Alwarthiru-nagari	7.11-7.93	7.57	0.23	0.43-3.41	1.63	0.92	-10.60-4.40	-2.33	4.50	0.54-16.82	5.03	4.22
Thiruchendur	6.98-8.18	7.60	0.32	0.16-10.08	2.93	2.84	-85.20-2.60	-8.12	21.00	0.01-31.71	8.11	9.29
Udangudi	6.9-8.04	7.61	0.35	0.42-8.59	3.12	2.63	NIL	-10.02	8.77	0.18-24.23	6.06	6.86
Sathankulam	6.84-8.18	7.48	0.35	0.55-8.58	4.08	2.61	NIL	-19.55	18.51	0.40-14.11	4.27	3.90

Table: 1.41. Water quality distribution (%) in Thoothukudi district

S.No	Block	No.of samples	Good	MS	Saline	HSS	MA	Alkali	HA
1	V.Pudur	5	-	60	-	-	20	-	20
2	Vilathikulam	7	57.1	-	-	42.9	-	-	-
3	Kovilpatti	16	37.5	43.7	18.8	-	-	-	-
4	Kayathar	10	50	40	10	-	-	-	-
5	Karunkulam	22	81.8	18.2	-	-	-	-	-
6	Ottapidaram	13	92.3	7.7	-	-	-	-	-
7	Thoothukudi	10	30	10	30	-	-	20	10
8	Srivaikuntam	8	75	12.5	12.5	-	-	-	-
9	Alwarthirunagari	14	71.4	14.2	-	-	7.2	-	7.2
10	Thiruchendur	17	58.9	11.7	5.9	17.6	5.9	-	-
11	Udangudi	13	46.1	7.7	30.8	15.4	-	-	-
12	Sathankulam	16	18.8	31.2	43.8	6.2	-	-	-
	Average	151	51	21	13	7	3	2	3

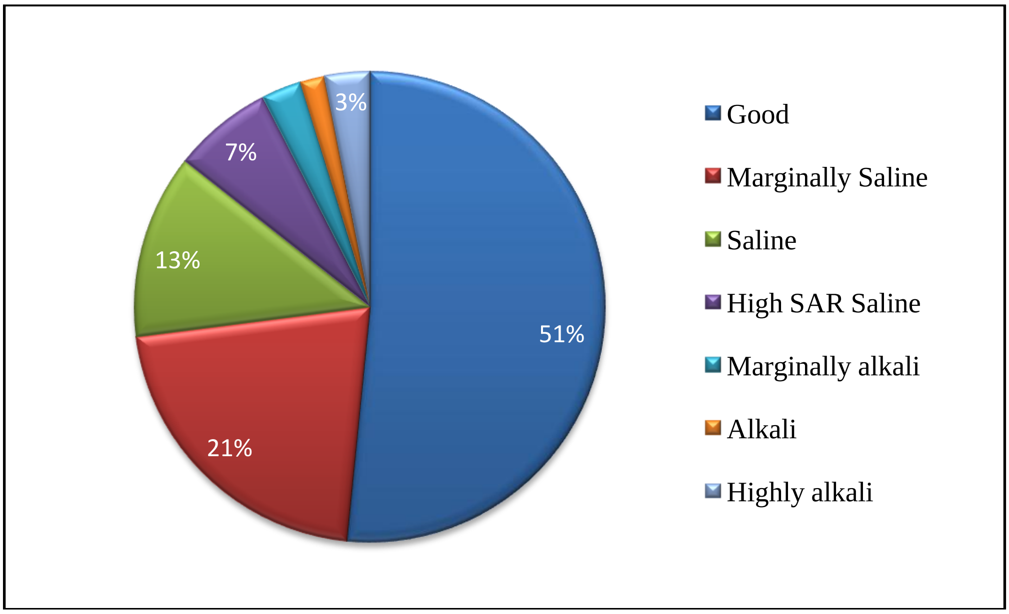


Fig. 1.32 Percentage distribution of ground water quality in Thoothukudi district

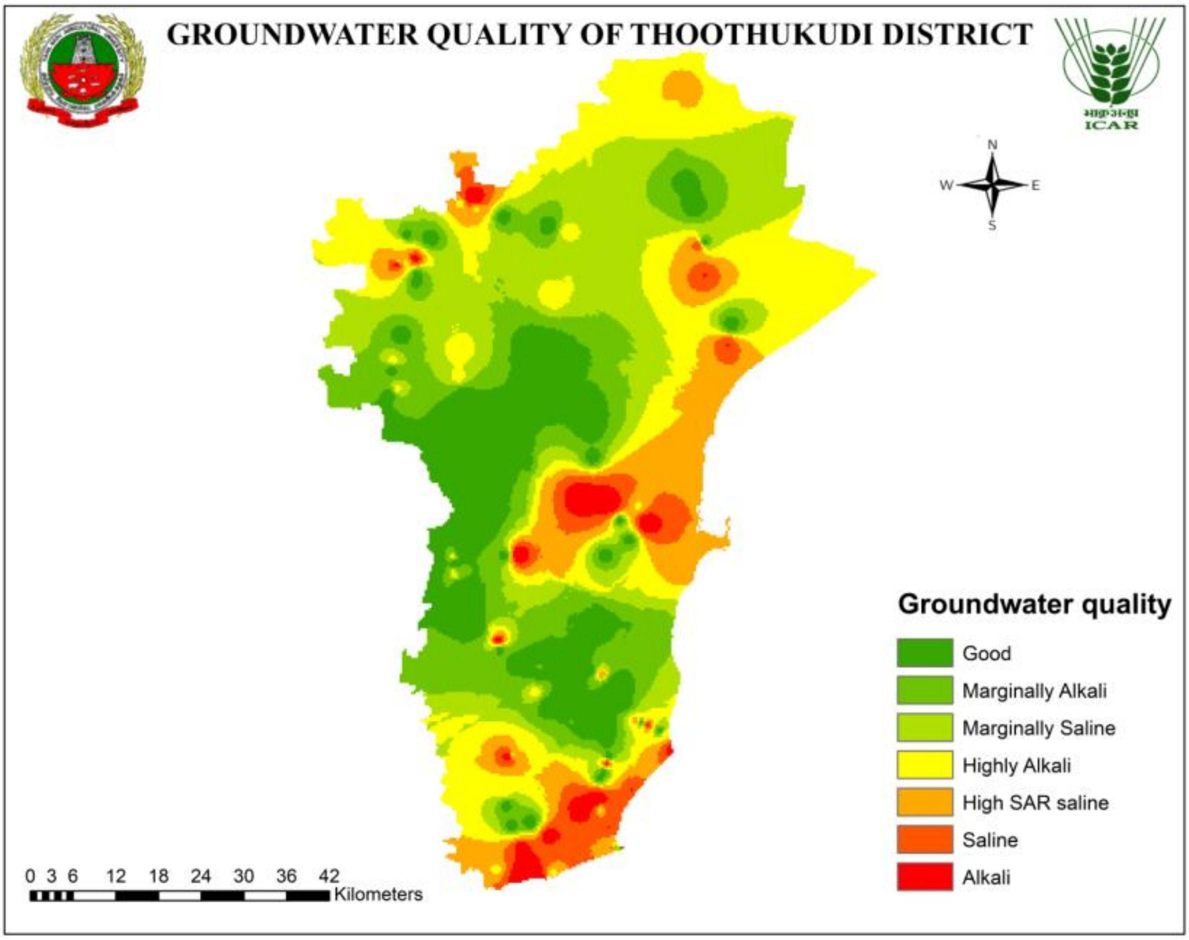


Fig. 1.33 Spatial distribution of groundwater quality categories for Thoothukudi district

- **Survey and characterization of ground water of Tirunelveli district of Tamil Nadu for Irrigation (Tiruchirapalli)**

2020

Tirunelveli is one of the coastal districts bounded on the north by Virudhunagar district, on the southwest by the Kanniyakumari district, on the west by Western Ghats in Kerala state and on the east by Thoothukudi district. The district headquarters is located at Tirunelveli. The district lies between 08°08'09'' and 09°24'30'' North Latitude and 77°08'30'' and 77°58'30''East Longitude. The general geographical information of the district is plain terrain. Thamiraparani river, and Nambiar river are flowing in the district and they will be dry during the summer season. The total geographical area of the district is 6,810 sqkm. 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 of 2019 were utilized and a perusal of the data shows that the normal annual rainfall over the district is 844.4 mm. 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 74 and 79%. The mean minimum temperature is 28°C and means maximum daily temperature is 36°C respectively.

Around 130 groundwater samples were collected based on grid survey with GPS during October 2019 which cover the 19 blocks of Tirunelveli district. Samples are stored in airtight bottles. The samples were analyzed for pH, EC, cations *viz.,*Ca^{2+}, Mg^{2+},K^{+} and Na^{+} and anions *viz.,* CO_3^{2-}, HCO_3^{-}, $Cl^{-}$and SO_4^{2-} by adopting standard procedure. Quality parameters like SAR and RSC were calculated. Screening of groundwater samples for their suitability to irrigation is done on the basis of EC, SAR and RSC values as suggested by Central Soil Salinity Research Institute, Karnal and Thematic maps pertaining to groundwater quality were prepared using Arc GIS software 10.1.

Tirunelveli District has 19 Blocks *viz.*, Palayamkottai, Cheranmahadevi, Nanguneri, Radhapuram, Valliyur, Kalakkadu, Ambasamudram, Tenkasi, Shencottai, Kadayanallur, Vasudevanallur, Sankarankoil, Keezhapavur, Kadayam, Pappakudi, Alangulam, Melaneelithanallur, Kuruvikulam and Manur. The ranges for groundwater pH, EC, Residual Sodium Carbonate (RSC) and Sodium Adsorption Ratio (SAR) for different blocks are given in Table 1.42.

Water quality distribution (%) in Tirunelveli district

In general, the distribution of cations followed the order of $Na^{+}> Mg^{2+}> Ca^{2+}>K^{+}$ in all blocks while anions followed the order of $Cl^{-}> HCO_3^{-}> CO_3^{2-}> SO_4^{2-}$ in majority of blocks except Nanguneri, Ambasamudram, Keezhapavur and Kadayam where order of anions was $HCO_3^{-}>Cl^{-}> CO_3^{2-}> SO_4^{2-}$. Out of the total samples collected in Tirunelveli district, 57 per cent is characterized under good quality, (18%) Marginally saline, (4%) Saline, (1%) High-SAR saline, (11%) Marginally alkali, (8%) Alkali and (1%) High alkali (Table 1.43). The distribution of water samples in different water quality classes revealed that the samples of good quality underground irrigation water was found in almost all the Kalakkadu and Pappakudi (100%), Ambasamudram (87.5%), Cheranmahadevi and Alangulam (80%) and Nanguneri (70%) as shown in Fig. 1.34. The spatial distribution is shown in Fig. 1.35.

Table 1.42. Quality of ground waters in different blocks of Tirunelveli District

Name of the Block	pH			EC (dS/m)			SAR			RSC (meq/l)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Palayamkottai	6.8	7.8	7.18	1.07	6.91	2.64	1.75	9.46	4.63	Nil	6.40	Nil
Cheranmahadevi	6.60	7.60	7.32	1.42	2.79	1.87	1.82	5.99	3.02	Nil	2.10	0.12
Nanguneri	6.8	7.5	7.13	1.01	2.89	1.53	0.82	9.22	3.54	Nil	7.20	2.80
Radhapuram	6.90	8.50	7.65	0.54	44.5	3.99	0.37	55.58	4.64	Nil	4.00	Nil
Valliyur	6.60	8.30	7.36	0.89	3.69	1.93	0.81	69.12	10.2	Nil	19.6	Nil
Kalakkadu	6.70	7.70	7.25	0.77	1.99	1.38	0.34	5.78	2.33	Nil	1.00	Nil
Ambasamudram	7.00	7.70	7.32	0.85	1.64	1.24	0.70	4.83	1.86	Nil	4.80	1.23
Tenkasi	6.80	7.70	7.36	1.52	2.25	1.86	1.94	5.80	3.34	Nil	7.20	0.48
Shencottai	7.30	7.70	7.46	1.38	3.27	2.04	2.57	7.35	4.51	Nil	2.20	Nil
Kadayanallur	7.20	7.90	7.46	1.00	2.38	1.72	1.15	5.58	3.25	Nil	3.60	Nil
Vasudevanallur	6.90	7.70	7.17	1.32	4.18	2.32	1.16	9.03	4.93	Nil	2.20	Nil
Sankarankoil	6.80	8.00	7.27	1.04	2.48	1.95	1.25	6.62	3.82	Nil	9.40	Nil
Keezhapavur	6.60	7.30	6.98	1.42	2.11	1.61	1.58	3.84	2.74	Nil	6.20	1.72
Kadayam	6.50	7.70	7.13	0.88	1.92	1.25	0.60	1.96	1.39	1.40	4.80	2.90
Pappakudi	7.30	8.10	7.75	1.06	1.72	1.39	0.77	5.11	1.98	Nil	1.60	Nil
Alangulam	7.50	8.00	7.72	1.07	2.34	1.49	0.94	4.64	2.23	Nil	2.00	Nil
Melaneelithanallur	7.40	8.00	7.76	1.43	2.51	1.82	2.01	2.47	2.24	Nil	3.80	Nil
Kuruvikulam	7.20	7.70	7.47	1.16	4.27	2.22	0.60	5.77	3.11	Nil	4.60	Nil
Manur	7.30	7.90	7.67	1.12	2.60	1.74	1.35	4.10	2.40	Nil	8.80	0.30

Table 1.43. Water quality distribution (%) in Tirunelveli district

S. No	Block	No. of samples	Good	MS	Saline	HSS	MA	Alkali	HA
1.	Palayamkottai	5	20		20		20	40	
2.	Cheranmahadevi	5	80	20					
3.	Nanguneri	10	70				20	10	
4.	Radhapuram	24	49.9	16.6	8.3	4.1	20.8		
5.	Valliyur	9	55.5	22.2			11.1		11.1
6.	Kalakkadu	6	100						
7.	Ambasamudram	8	87.5					12.5	
8.	Tenkasi	5	60	20				20	
9	Shencottai	5	60	40					
10.	Kadayanallur	5		60			40		
11.	Vasudevanallur	7	42.84	42.84	14.28				
12.	Sankarankoil	6	66.64	16.66				16.66	
13.	Keezhapavur	5	20	20			20	40	
14.	Kadayam	4	50				25	25	
15.	Pappakudi	4	100						
16.	Alangulam	5	80	20					
17.	Melaneelithanallur	5	60	20			20		
18.	Kuruvikulam	6	33.32	16.66	16.66		16.66	16.66	
19.	Manur	6	49.98	33.32				16.66	
	Average	130	57	18	4	1	11	8	1

Marginal Saline (MS), High-SAR Saline (HSS), Marginally Alkali (MA), High Alkali (HA)

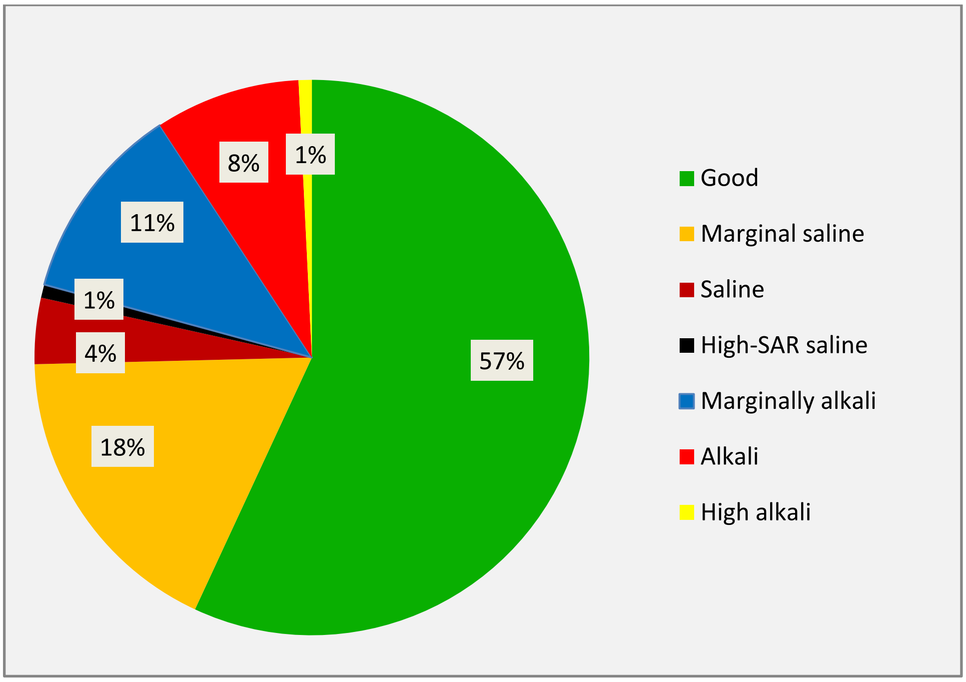


Fig. 1.34 **Percentage distribution of ground water quality in Tirunelveli district**

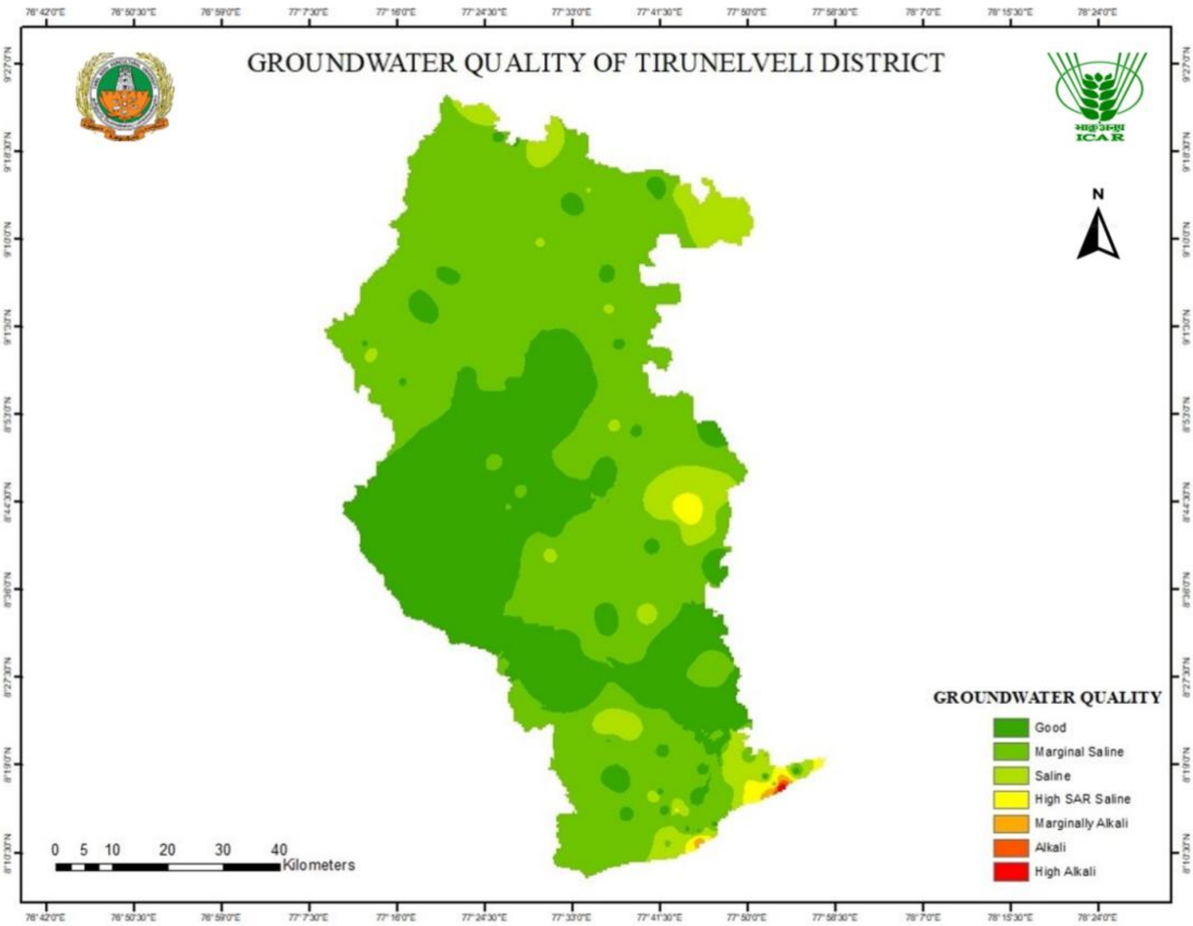


Fig. 1.35 **Spatial distribution of groundwater quality categories for Tirunelveli district**

- **Survey and characterization of groundwater for irrigation for Mansa, district, Punjab (Bathinda)**

2019

Mansa district is located at 29.9871°N and 75.4345° E, shared border with Fatehabad District of Haryana to the South , Bathinda District to the west , Sangrur District to the East. The district has divided in to three tehsils viz. Mansa, Budhlada and Sardulgarh (Fig. 1.36)

Fig. 1.36 Location map of Mansa district of the Punjab

GPS based water samples were collected from running tube wells from different villages of all three tehsils and analysed for know the suitability of ground water for irrigation.

Number of samples collected from different tehsils of Mansa district

Name of tehsils →	Budhlada	Mansa	Sardulgarh
Number of Samples	94	259	58

The ranges of chemical constituents of groundwater are presented in Table 1.44. The electrical conductivity (EC) ranged between 0.60-4.50 dS/m with mean value 2.17 dS/m, 0.34-5.50 dS/m with mean value 2.33 dS/m, and 1.20-12.60 dS/m with mean value 4.10 dS/m in blocks Budahlada, Mansa and Sardulgarh, respectively. Higher RSC (2.19 meq/l) was reported in Budahlada as compared to Mansa (1.31 meq/l) and Sardulgarh (1.25 meq/l). Whereas, maximum Ca^{+2} +Mg^{+2} was reported in Sardulgarh and minimum average value was recorded in Budahlada. Among the anions, chloride was dominant ion with values ranging from 0.40 to 66.0 meq/l followed by bicarbonate (0.80 to15.80 meq/l) and carbonate (nil to 1.20 meq/l) in the district.

Table 1.44**.** Range and average value for different chemical constituents of ground water in different tehsils of Mansa district surveyed in 2018-19

Name of Blocks	Budahlada (94)		Mansa (259)		Sardulgarh (58)	
Parameters	Range	Average	Range	Average	Range	Average
pH	7.12-9.15	8.23	7.42-9.44	8.41	7.71-9.31	8.25
EC (dS/m)	0.60-4.50	2.17	0.34-5.50	2.33	1.20-12.60	4.10
Ca^{+2} +Mg^{+2} (meq/l)	1.50-15.70	5.84	1.90-26.50	7.44	2.80-35.00	9.26
Cl^{-1} (meq/l)	0.80-17.00	5.69	0.40-32.00	8.50	2.40-66.00	20.80
CO_3^{-2} (meq/l)	0.00-0.60	0.14	0.00-1.20	0.13	0.00-1.20	0.19
HCO_3^- (meq/l)	0.80-15.40	6.65	1.20-15.80	6.34	1.80-11.20	9.26
RSC (meq/l)	0.00-10.20	2.19	0.00-12.00	1.31	0.00-7.60	1.25

*Values in parenthesis are number of water samples

The distribution of water samples in different ranges of electrical conductivity (EC) are given in Table 1.45. The EC of majority of the cases i.e. 47% in Budhlada, 37% in Mansa and 22% in Sardulgarh was less than 2 dS/m. Whereas, 43% in Budhlada, 52% in Mansa and 32% in Sardulgarh were observed between 2 to 4 dS/m and rests was more than 4 dS/m. It is reported that based on electrical conductivity only 36% water could be used without any possible risk of soil salinization. Further, 42% water was rated as marginal (EC, 2 to 4 dS/m) for irrigation and 22% water was not suitable for irrigation due to their higher electrical conductivity.

Table 1.45. Distribution of water samples in different water quality ratingstion (%) of Mansa district.

Blocks	EC (dS/m)				RSC (meq/l)			SAR	
	<2.0	2.0-4.0	>4.0	<4.0	<2.5	2.5-5.0	>5.0	<10	>10
Budhlada	47.37	43.16	9.47	90.53	65.26	9.48	25.26	24.21	75.79
Mansa	37.31	51.52	11.17	81.91	76.54	16.54	6.92	55.38	44.62
Sardulgarh	22.04	32.20	45.76	54.24	86.44	6.78	6.78	43.77	56.23
Avg.	35.57	42.29	22.13	75.56	76.08	10.93	12.99	41.12	58.88

The distribution of water samples in different ranges of residual sodium carbonate (RSC) are presented in Table 1.45. It is observed that 65%, 77% and 86% water samples have RSC < 2.5 meq/l' while 10%, 16% and 7 % of water samples showed RSC between 2.5-5.0 meq/l in Budhlada, Mansa and Sardulgarh, respectively. Further, it is reported that on the basis of RSC 76% water is safe (RSC, <2.5 meq/l), 11% water is marginal (RSC, 2.5 to 5.0 meq/l) and 13% water is unsuitable for irrigation (RSC, > 5.0 meq/l).

Fluoride in ground water: The distribution of fluoride in ground water of Mansa district is presented in Table 1.46. Fluoride content ranged from 0.55 – 4.54 mg L^{-1} with mean value 1.99 mg L^{-1} , from 0.20 – 7.75 mg L^{-1} with mean value 2.24 mg L^{-1} and from 0.57 – 5.54 mg L^{-1} with mean value 2.06 mg in Budhlada, Mansa and Sardulgarh, respectively. It is also reported that the maximum fluoride varied in Mansa followed by Sardulgarh and Budhalada**.** About 10 % samples were found within safe limit (<1.5 mgL^{-1}), in which 7 % samples having fluoride (<1.0 mgL^{-1}), whereas 3 % samples having fluoride between 1.0-1.5 mgL^{-1}. While, 90% samples were beyond permissible limits (>1.5 mgL^{-1}) (WHO, 1994).

Table 1.46. Percentage distribution of fluoride (mg/L) in Mansa district

Name of Tehsils	No. of Samples	Min.	Max.	Avg.	Distribution		
					Safe (<1.0 mg/L)	Margin (1.0-1.5 mg/L)	Unsafe (>1.5 mg/L)
Budhalada	94	0.55	4.54	1.99	12.63	4.21	83.16
Mansa	259	0.20	7.75	2.24	11.16	5.38	83.46
Sardulgarh	58	0.57	5.54	2.06	6.78	3.39	89.83

- **Survey and characterization of ground irrigation water of Shri Muktsar Sahib, district, Punjab (Bathinda)**

2020

Location of the surveyed area of Shri Muktsar Sahib was presented in Fig.1.37. The district was divided into four blocks *viz.* Muktsar, Malout, Gidderbaha and Lambi. The ranges of chemical constituents of groundwater under different blocks of Shri Muktsar Sahib district are presented in Table 1.47.

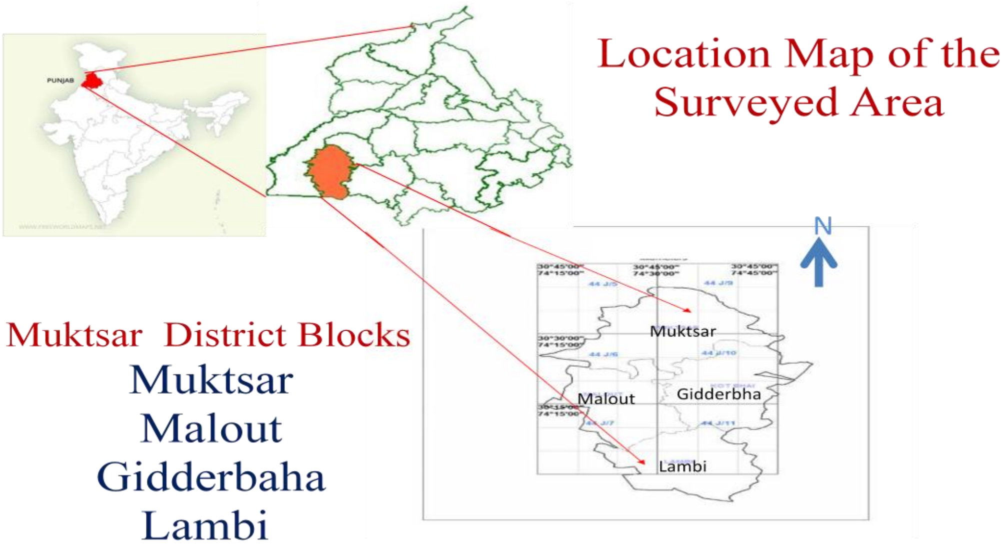


Fig. 1.37 **Location of the surveyed area**

Table 1.47. Range and Average for different parameters of ground water in Shri Muktsar Sahib District

Name of Blocks	Muktsar		Malout		Gidderbaha		Lambi	
Parameters	Range	Average	Range	Average	Range	Average	Range	Average
pH	8.1-8.8	8.3	7.1-8.6	7.8	8.0-9.5	8.4	7.3-9.5	8.1
EC (dS/m)	1.0-6.7	3.1	0.35-7.5	2.8	0.3-6.9	2.7	0.2-18.0	2.8
Ca^{+2} +Mg^{+2} (meq/l)	3.5-20.0	8.8	1.0-29.0	8.5	1.4-20.0	8.5	0.7-52.2	9.3
Cl^{-1} (meq/l)	0.6-17.6	6.9	0.8-20.0	6.9	1.0-35.6	8.0	0.4-54.0	13.7
CO_3^{-2} (meq/l)	0.0-2.4	0.4	0.0-1.6	0.3	0.0-1.2	0.1	0.0-2.3	0.2
HCO_3^- (meq/l)	4.0-15.0	8.9	2.0-12.0	7.1	1.0-15.4	6.7	1.0-18.0	6.3
RSC (meq/l)	0.0-11.0	3.8	0.0-11.0	3.5	0.0-9.6	2.85	0.0-32.5	3.4

The high pH of water was reported in Gidderbaha block followed by Muktsar block. The electrical conductivity (EC) ranged between 1.0-6.7 dS/m with mean value 3.1 dS/m, 0.35-7.5 dS/m with mean value 2.8 dS/m, 0.3-6.9 dS/m with mean value 2.7 dS/m and 0.2-18.0 dS/m with mean value 2.8 dS/m in blocks Muktsar, Malout, Gidderbaha and Lambi, respectively. Muktsar block contain higher RSC (3.8 meq/l) followed by Malout (3.5 meq/l) as compared to Lambi (3.4 meq/l) and Gidderbaha (2.9) block. Whereas, maximum Ca^{+2} +Mg^{+2} was reported in Lambi block and minimum average value was recorded in Malout. Among the anions, chloride was dominant ion with values ranging from 0.4 to 52.2 meq/l followed by bicarbonate (1.0-18.0 meq/l) and carbonate (0.0 to 2.4 meq/l).

The distribution of water samples in different ranges of electrical conductivity (EC) are given in Table 1.48. The EC of majority of the cases i.e. 28 % in Muktsar, 44 % in Malout, 31 % in Gidderbaha and 44 % in Lambi block was less than 2 dS m^{-1}. Whereas, 52 % in Muktsar, 34 % in Malout, 54 % in Gidderbaha and 33 % in Lambi blocks were observed between 2 to 4 dS/m and rests was more than 4 dS/m. It is reported that based on electrical conductivity only 40 % water could be used without any possible risk of soil salinization. Further, 40% water was rated as marginal (EC, 2 to 4 dS/m) for irrigation and 20% water was not suitable for irrigation due to their higher electrical conductivity.

The distribution of water samples in different ranges of Residual Sodium Carbonate (RSC) are given in Table 1.48. It is observed that 60, 71, 77 and 77% water samples have RSC < 2.5 meq/l' while 8, 2, 8 and 9 % of water samples showed RSC between 2.5-5.0 meq/l in the blocks Muktsar, Malout, Gidderbaha and Lambi, respectively. Further, it is reported that on the basis of RSC, 76% water is safe (RSC, <2.5 meq/l), 7% water is marginal (RSC, 2.5 to 5.0 meq/l) and 17% water is unsuitable for irrigation (RSC, > 5.0 meq/l) in Muktsar district.

Table 1.48. Percent (%) distribution of water samples in different water quality

	EC (dS/m)			RSC (meq/L)			SAR(m mol/L)	
Block	<2.0	2.0-4.0	>4.0	<2.5	2.5-4.0	>4.0	<10	>10
Muktsar	28	52	20	60	8	32	12	88
Malout	44	34	22	71	2	27	16	84
Gidderbaha	31	54	15	77	8	15	23	77
Lambi	44	33	23	77	9	14	31	69
Average	40	40	20	76	7	17	26	74

Fluoride (mg/L) in groundwater: The distribution of fluoride in ground water of Muktsar district is presented in Table 1.49. Fluoride content ranged from 0.5 – 4.4 mg L^{-1} with mean 2.8 mg L^{-1} , from 0.7 – 5.5 mg L^{-1} with mean 3.1 mg L^{-1} , from 0.9 – 6.3 mg L^{-1} with mean 3.9 mg L^{-1}, from 0.4 -3.9 mg L^{-1} with mean 2.2 mg L^{-1} in Muktsar, Malout, Gidderbaha and Lambi blocks, respectively. The maximum range of fluoride variation was reported in Gidderbaha block with average value of 3.9 mg L^{-1} followed by Malout block with average value of 3.1 mg L^{-1}. The ground water in Lambi block contain low amount of fluoride as compared to other blocks of the district. The most of water samples collected from the Muktsar district have higher amount of fluoride, which makes it unsuitable for use. About 17 % samples were found within safe limit (<1.5 mgL^{-1}), in which 6 % samples having fluoride (<1.0 mgL^{-1}), whereas 11% samples had fluoride between 1.0-1.5 mgL^{-1}.While, 83% samples were beyond permissible limits (>1.5 mgL^{-1}) (WHO, 1994) in the district (Table 1.50). It was also reported water in Malout and Gidderbaha blocks contain more fluoride as compared to Muktsar and Lambi blocks of Shri Muktsar Sahib District.

Table 1.49. Range of fluoride (mg/L) in Shri Muktsar Sahib district

Name of Blocks	Muktsar	Malout	Gidderbaha	Lambi
Minimum	0.5	0.7	0.9	0.4
Maximum	4.4	5.5	6.3	3.9
Average	2.8	3.1	3.9	2.2

Table 1.50. Percentage distribution of fluoride (mg/L) in Muktsar district

Name of Blocks	Muktsar	Malout	Gidderbaha	Lambi	Average
Safe (<1.0 mg/L)	4	2	2	8	6
Margin (1.0-1.5 mg/L)	20	7	4	14	11
Unsafe (>1.5 mg/L)	76	91	94	78	83

- **Survey and characterization of ground water of Fazilka district, Punjab (Bathinda)**

Location of the surveyed area of Fazilka district is presented in Fig. 1.38. The district has three tehsils namely Abohar, Fazilka and Jalalabad. The ranges of chemical constituents of groundwater under different blocks of Fazilka district are presented in Table 1.51.The high pH of water was reported in Jalalabad followed by Fazilka tehsil. The electrical conductivity (EC) ranged between 0.22-9.50 dS/m with mean value 2.58 dS/m, 0.10-6.90 dS/m with mean value 2.06 dS/m, 0.10-5.20 dS/m with mean value 2.17 dS/m in tehsil Abohar, Fazilka and Jalalabad, respectively.

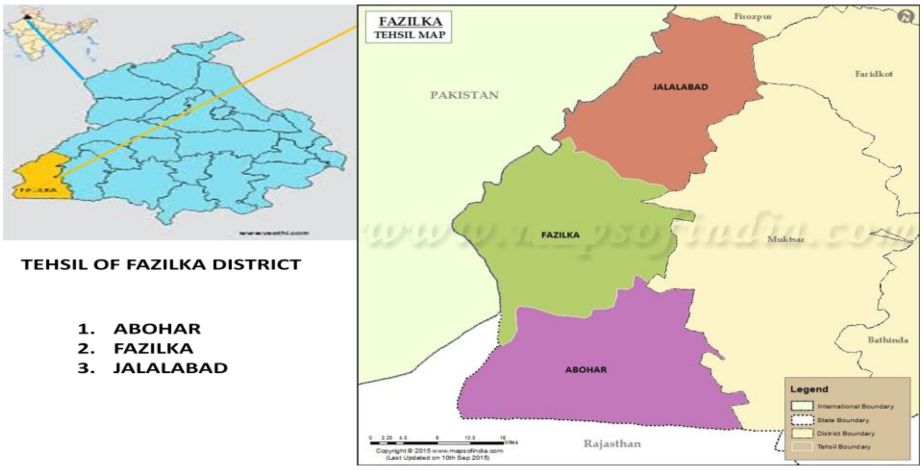


Fig. 1.38 Location of the surveyed area

Table 1.51: Range and Average of different chemical constituents of ground water in Fazilka District

Name of Tehsil	Abohar		Fazilka		Jalalabad	
Parameters	Range	Average	Range	Average	Range	Average
pH	6.37-9.88	7.38	6.81-10.08	7.81	6.71-9.67	7.88
EC (dS/m)	0.22-9.50	2.58	0.10-6.90	2.06	0.10-5.20	2.17
Ca^{+2} $+Mg^{+2}$ (meq/l)	1.70-60.60	14.35	1.40-42.00	7.63	1.80-31.00	8.82
Cl^{-1} (meq/l)	0.60-54.00	7.95	0.60-78.00	6.78	0.40-25.10	8.17
CO_3^{-2} (meq/l)	0.00-0.40	0.23	0.00-1.40	0.32	0.00-0.50	0.24
HCO3- (meq/l)	1.00-7.60	4.82	1.20-15.00	6.76	1.60-15.20	6.30
RSC (meq/l)	0.00-2.20	1.10	0.00-10.70	3.80	0.00-7.00	1.97
SAR	0.08-4.55	1.32	0.05-35.33	6.94	0.06-50.56	12.98

The Fazilka tehsil contain higher RSC (3.80 meq/l) followed by Jalalabad (1.97 meq/l) and Abohar tehsil (1.10 meq/l). Whereas, maximum Ca^{+2} $+Mg^{+2}$ was reported in Abohar tehsil and minimum average value was recorded in Fazilka tehsil. Among the anions, chloride was dominant ion with values ranging from 0.40 to 78.0 meq/l followed by bicarbonate (1.0-15.20 meq/l) and carbonate (0.0 to 1.40 meq/l).

Distribution of water samples in different ranges of electrical conductivity (EC) are given in Table 1.52. The EC of majority of the cases i.e. 48% in Abohar, 49% in Fazilka and 51% in Jalalabad tehsil was less than 2 dS m^{-1}. Whereas, 40% in Abohar, 46% in Fazilka and 45% in Jalalabad tehsil were observed between 2 to 4 dS/m and rests was more than 4 dS/m. It was reported that based on electrical conductivity only 50 % water could be used without any possible risk of soil salinization. Further, 45% water was rated as marginal (EC, 2 to 4 dS/m) for irrigation and 5% water was not suitable for irrigation due to their higher electrical conductivity.

The distribution of water samples in different ranges of Residual Sodium Carbonate (RSC) are given in Table 1.52 showed that 100%, 70% and 87 % water samples have RSC < 2.5 meq/l' while 0%, 18% and 12% of water samples showed RSC between 2.5-5.0 meq/l in Abohar, Fazilka and Jalalabad tehsils, respectively. Further, it was reported that on the basis of RSC 78% water is safe (RSC, <2.5

meq/l), 14% water is marginal (RSC, 2.5 to 5.0 meq/l) and 8% water is unsuitable for irrigation (RSC, > 5.0 meq/l) in Fazilka district.

Table 1.52: Percent (%) distribution of water samples of Fazilka district in different water quality

	EC (dS/m)			RSC (meq/L)			SAR(m mol/L)	
	<2.0	2.0-4.0	>4.0	<2.5	2.5-5.0	>5.0	<10	>10
Abohar	48	40	12	100	0	0	100	0
Fazilka	49	46	5	70	18	12	76	24
Jalalabad	51	45	4	87	12	1	51	49
Average	50	45	5	78	14	8	73	27

Fluoride (mg/L) in groundwater: The fluoride distribution in ground water of Fazilka district is presented in Table 1.53. Fluoride content ranged from 1.62-5.33 mg L^{-1} with mean 2.40 mg L^{-1}, from 1.05-4.91 mg L^{-1} with mean 2.36 mg L^{-1}, from 0.96 – 5.35 mg L^{-1} with mean 2.19 mg L^{-1} in Abohar, Fazilka and Jalalabad tehsils, respectively. The maximum range of fluoride variation was reported in Abohar tehsils with average value of 2.40 mg L^{-1} followed by Fazilka tehsils with average value of 2.36 mg L^{-1}. The ground water in Jalalabad tehsil contain low amount of fluoride (2.19 mg L^{-1}) as compared to other tehsils of Fazilka district. The most of water samples collected from the Fazilka district have higher amount of fluoride, which makes it unsuitable for use. only 4% samples were found within safe limit (<1.5 mgL^{-1}), in which only 1% samples having fluoride (<1.0 mgL^{-1}), whereas 3 % samples having fluoride between 1.0-1.5 mgL^{-1}.However, Maximum samples (96%) were beyond permissible limits (>1.5 mgL^{-1}) (WHO, 1994) in the district (Table 1.54).

Table 1.53 . Range of fluoride (mg/L) in Fazilka district

Name of Blocks	Abohar	Fazilka	Jalalabad
Minimum	1.62	1.05	0.96
Maximum	5.33	4.91	5.35
Average	2.40	2.36	2.19

Table 1.54. Percentage distribution of fluoride (mg/L) in Fazilka district

Name of Blocks	Abohar	Fazilka	Jalalabad	Average
Safe (<1.0 mg/L)	0	0	1	1
Margin (1.0-1.5 mg/L)	0	3	7	3
Unsafe(>1.5 mg/L)	100	97	93	96

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

2019

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 1.55).

Table: 1.55. Classification of ground water samples in Kerala for irrigation

Sl No	District	Good (%)	Marginally saline (%)	Saline (%)	High SAR Saline (%)	Marginally alkali (%)	High alkali (%)
1	Thiruvanathapuram	89.47	2.63	7.89			
2.	Kollam	95.23	4.76				
3.	Pathanamthitta	100.00					
4.	Kottayam	82.35	11.76	5.88			
5.	Alappuzha	87.50				7.14	5.35
6.	Ernakulam	75.86			20.68	3.40	
7.	Idukki	100.00					
8.	Thrissur	93.93			6.06		
9.	Palakkad	97.00				3.00	
10.	Kozhikode	73.68				26.31	
11.	Kannur	60.00				26.66	13.33
12.	Wayanad	100.00					
13.	Malappuram	35.00				65.00	
14.	Kasargod	73.07	3.86%			23.07	

A total of thirty eight ground water samples were collected from Thiruvananthapuram district. Out of this 89.47, 2.63 and 7.89% belonged to good, marginally saline and saline categories of irrigation water quality. A total of twenty one ground water samples were collected from Kollam district. Out of this, 95.23 % and 4.76 % fall under good and marginally saline categories of irrigation water quality. A total of five water samples were collected from Pathanamthitta district. All the samples fall under good category of irrigation water quality. A total of seventeen ground water samples were collected from Kottayam district. Out of this, 82.35, 11.76 and 5.88% belonged to good, marginally saline and saline categories of irrigation water quality. A total of fifty six ground water samples were collected from Alappuzha district. Out of this, 87.50, 7.14 and 5.35% belonged to good, marginally alkali and high alkali categories of irrigation water quality. A total of twenty-eight ground water samples were collected from Ernakulam district. Out of this, 75.86, 20.68 and 3.40% fall under good, high SAR saline and marginally alkali categories of irrigation water quality. A total of thirty three ground water samples were collected from Thrissur district. Out of this, 93.93 and 6.06 % fall under good and high SAR categories of irrigation water quality. A total of twenty ground water samples were collected from Malappuram district. Out of the total ground water samples collected, 35 and 65 % fall under good, marginally alkaline categories of irrigation water quality. A total of nineteen ground water samples were collected from Kozhikode district. Out of the total ground water samples collected, 73.68 and 26.31% fall under good, marginally alkaline categories of irrigation water quality. A total of fifteen ground water samples were collected from Kannur district. Out of the total ground water samples collected, 60.00, 26.66 and 13.33% fall under good, marginally alkaline and high alkali categories of irrigation water quality. A total of twenty six ground water samples were collected from Kasargod district. Out of the total ground water samples collected, 76.92 and 23.07% fall under good and marginally alkaline categories of irrigation water quality. The ground water data were collected for the districts such as Palakkad, Wayanad and Idukki from Central ground water board (CGWB) and were classified according to CSSRI classification. All samples from Wayanad and Idukki districts and 97% samples from Palakkad fall under good quality for irrigation and 3% samples from Palakkad district fall under marginally alkali quality for irrigation. Preparation of ground water quality maps of Thiruvanathapuram and Ernakulam districts were completed. In other districts, the preparation of maps is under progress (Fig. 1.39).

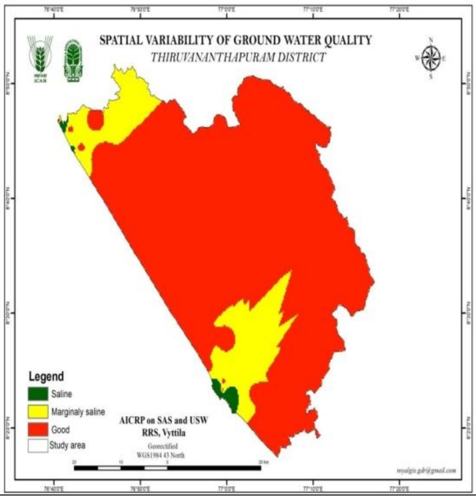
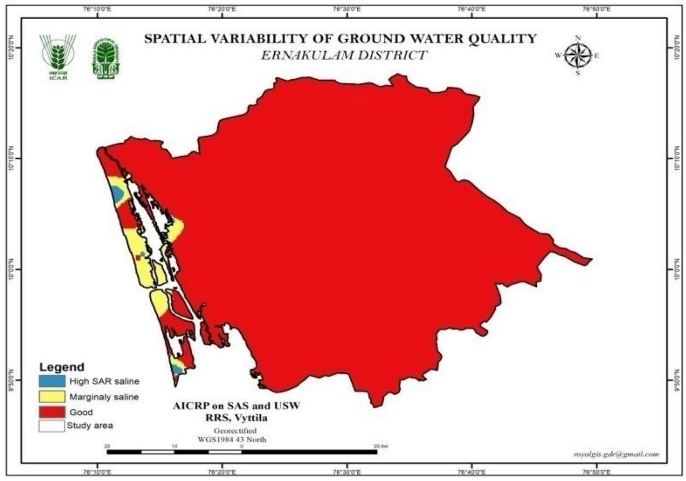
	
Thiruvananthapuram	Ernakulam

Fig. 1.39 Spatial variability of ground water quality of Thiruvananthapuram and Ernakulam district

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 (Fig. 1.40).

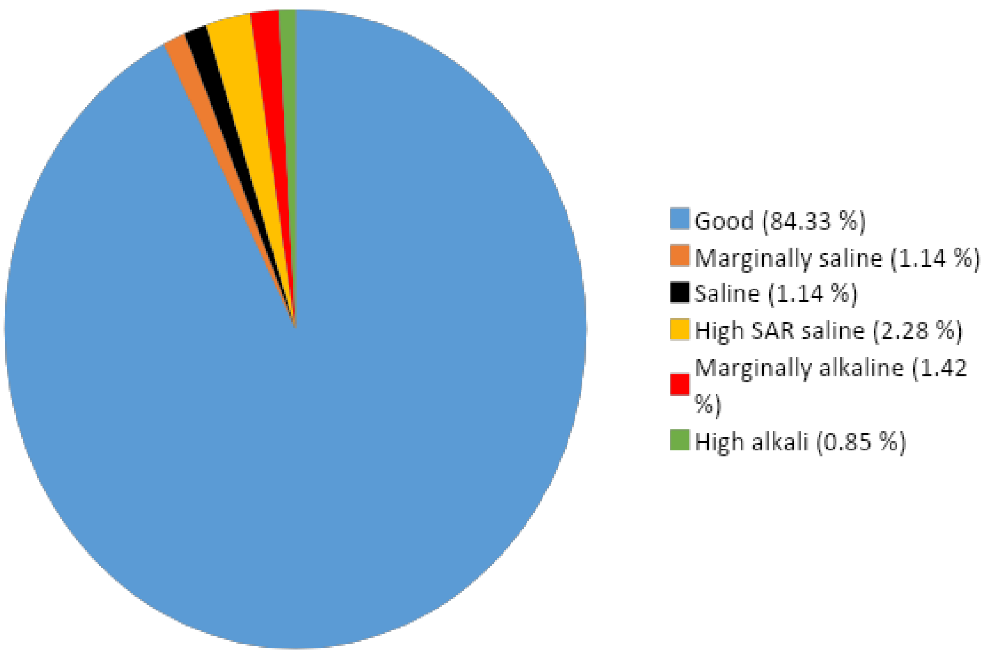


Fig. 1.40. Classification of ground water samples in Kerala for irrigation

1.2 Resource Inventories of Salt Affected Soils

- **Assessment and mapping of salt affected soils of TBP command area of Karnataka (Gangavathi)**

Soil salinity and water logging are the twin problems of TBP command due to unscientific land and water management and violation of cropping pattern over the years. A proper delineation of the salt affected area through ground truth is imperative in arriving at a close approximate of salt affected area. No such delineation of salt affected soils in TBP command is available. Therefore, a clear assessment and mapping of salinity in the command may thus help policy makers and researcher to take up appropriate measures to arrest further increase in salt affected area and also to make salt affected soils productive again. Soil salinity and water logging are the twin problems of TBP command due to unscientific land and water management and violation of cropping pattern over the years. Majority of the reports vary in their estimates on the extent of soil salinity. A proper delineation of the area through intensive ground truth is thus look imperative in arriving at a close approximate of salt affected area. No such delineation of salt affected soils in TBP command is available. With the aid of GPS and toposheet, soil samples were collected on a grid basis (5' x 5') from Hospet, Bellary and Siruguppa taluks in Bellary district. A total of 420 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 60 grid points were collected.

2019

A total of 126 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 27 grid (52 sampling) points were collected from Siruguppa taluk in Bellary district on grid basis (5' x 5') i.e. 9 x 9 km. The results of chemical analysis of samples are given in Table 1.56 and 1.57.

Table 1.56 Characterization of soil samples collected from Sirguppa taluk, Bellary district, Karnataka for soil salinity appraisal

Properties	**Depth (cm)**											
	0-15 cm			**15-30 cm**			**30-60 cm**			**60+ cm**		
	Max	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**
pH (1:2.5)	8.96	7.48	8.0	9.45	7.60	8.15	9.12	7.68	8.20	8.63	7.70	8.18
EC (1:2.5)	6.30	0.33	1.68	7.60	0.25	1.21	6.60	0.32	1.47	3.80	0.30	1.21
pHs	8.10	6.98	7.50	8.92	7.05	7.71	8.48	6.96	7.58	8.26	7.13	7.58
ECe (dS/m)	14.50	0.69	3.76	11.90	0.46	2.42	11.9	0.62	2.61	8.90	0.55	2.54
Cation/Anion												
Ca+Mg	58.3	4.50	16.36	35.40	2.70	7.87	33.8	2.60	6.87	29.3	3.00	6.14
Na+	125.0	2.22	33.38	155.8	3.84	27.24	100	4.82	23.7	62.9	3.47	21.2
K+	0.72	0.07	0.28	0.36	0.036	0.16	0.50	0.02	0.13	0.16	0.03	0.07
HCO_3^-	13.50	5.50	8.95	13.60	5.00	7.69	35.4	3.21	8.19	19.6	3.50	8.91
Cl^-	124.5	10.5	25.44	27.5	3.50	13.0	96.8	4.20	18.8	55.2	7.50	15.7
SO_4^{2-}	1.76	0.09	0.85	2.35	0.11	0.59	2.50	0.20	0.72	2.02	0.10	0.62
SAR	37.50	1.18	11.30	37.04	2.99	13.48	27.6	4.07	11.7	29.40	2.31	11.9
$(CO_3+HCO_3)/(Cl+SO_4)$	0.93	0.09	0.44	2.42	0.28	0.65	0.86	0.10	0.55	0.65	0.03	0.19
$Na/(Cl+SO_4)$	2.89	0.21	1.18	7.47	0.40	1.83	1.77	0.87	1.21	3.18	0.45	1.26

Table 1.57. Percent distribution of soil properties of samples collected from Sirguppa taluk, Bellary district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pHs			ECe (dS/m)			$(CO_3+HCO_3)/(Cl+SO_4)$		$Na/(Cl+SO_4)$		SAR	
	<7.5	**7.5-8.5**	**>8.5**	**<2.0**	**2-4**	**>4**	**<1**	**>1**	**<1**	**>1**	**<13**	**>13**
0-15	46.2 (18)	53.8 (21)	0	23.0 (9)	48.7 (19)	28.3 (11)	100 (39)	0	35.9 (14)	64.1 (25)	69.2 (27)	30.8 (12)
15-30	25.7 (10)	69.2 (27)	5.10 (2)	43.6 (17)	48.7 (19)	7.70 (3)	94.9 (37)	5.10 (2)	15.4 (6)	84.6 (33)	66.7 (26)	33.3 (13)
30-60	50.0 (14)	50.0 (14)		60.7 (17)	28.6 (8)	10.7 (3)	100 (28)	0	21.4 (6)	78.6 (22)	67.9 (19)	32.1 (9)
60+	35.0 (7)	65.0 (13)	0	65.0 (13)	15.0 (3)	20.0 (4)	100 (20)	0	35.0 (7)	65.0 (13)	70.0 (14)	30.0 (6)

Note: No. of samples: 0-15 cm (39), 15-30 cm (37), 30-60 cm (28) and 60+ cm (20). Values in parentheses are number of samples.

It was revealed that at surface soil (0-15 cm) $pH_{(1:2.5)}$, pHe, $EC_{(1:2.5)}$ and ECe varied from 8.96 to 7.48, 8.10 to 6.98, 6.30 to 0.33 (dS/m) and 14.5 to 0.69 (dS/m) respectively with an average of 8.0, 7.50, 1.68 dS/m and 3.76dS/m respectively. Among cations, average Na content was more than Ca+Mg followed by K. In case of anions, average Cl^- content was more than HCO_3^- followed SO_4^{2-}. Nearly 11 per cent of surface samples had ECe > 4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 $(Na/(Cl+SO_4)$ ratios was to the extent of nearly 64 indicating that the soils could be sodic or developing into sodic. Accordingly, nearly 31 per cent of surface samples had SAR >13.

Sub-surface (15-30 cm) soils had pH_{sw}, pH_e, ECsw and ECe varied from 9.45 to 7.60, 8.92 to 7.05, 7.60 to 0.25 (dS/m), and 11.9 to 2.42 (dS/m) respectively with an average of 8.15, 7.71, 1.21 and 2.42 respectively. Nearly 7.70 per cent of samples were considered to be saline as the ECe of these samples was >4.0 dS/m. The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas $Na/(Cl+SO_4)$ was >1. However, about 5 and 85 percent of these samples had derived parameters (1 and 2) values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodicity. Accordingly, nearly 33.3 per cent of samples had SAR values >13.

At lower depths, the mean ECe was slightly lower than the surface value. The per cent of samples having >4 dS/m were 11 and 20 at 30-60 and 60+cm respectively. Similar to surface soil, Na^+ and Cl^- were dominant among cations and anions, respectively at lower depths. The per cent of samples with >1 of $(Na/(Cl+SO_4)$ ratios were 79 and 65, respectively. The per cent of sample with SAR >13 was 32 and 30 at 30-60 and 60+ cm, respectively, which were similar to the upper layers i.e., 0-15 and 15-30 cm.

2020

The Bellary district as a whole (Table 1.58), surface soil (0-15 cm) $pH_{(1:2.5)}$, pHs, $EC_{(1:2.5)}$ and ECe varied from 10.76 to 5.72, 10.2 to 5.88, 31.0 to 0.12 (dS/m) and 75.0 to 0.39 (dS/m), respectively with an average of 8.07, 7.66, 3.02 dS/m, and 7.23 dS/m, respectively. Among cations, average Na content was more than Ca+Mg followed by K. In case of anions, average Cl^- content was more than HCO_3^- followed by SO_4^{2-}. Nearly 29 per cent of surface samples had ECe > 4.0 dS/m reflecting that these soils are saline (Table 1.59). The per cent of samples with >1 $(CO_3+HCO_3)/(Cl+SO_4)$ and $(Na/(Cl+SO_4)$ ratios were to the extent of nearly 13.6 and 52.3 respectively indicating that the soils could be Alkali/sodic or developing into Alkali/sodic. Accordingly, nearly 33 per cent of surface samples had SAR >13.

Sub-surface (15-30 cm) soils had $pH_{(1:2.5)}$, pHs, $EC_{(1:2.5)}$ and ECe varied from 10.55 to 4.76, 10.33 to 6.49, 19.9 to 0.12 (dS/m), and 35 to 0.23 (dS/m) with an average of 8.04, 7.82, 1.80 dS/m and 3.98 dS/m respectively (Table 1.58). Nearly 21 per cent of samples were considered to be saline as the ECe of these samples was >4.0 dS/m. The per cent of samples with >1 $(CO_3+HCO_3)/(Cl+SO_4)$ and $(Na/(Cl+SO_4)$ ratios were to the extent of nearly 13.1 and 53.9 respectively. Nearly 31 per cent of the sub-surface samples had SAR >13.

At 30-60 cm, the $pH_{(1:2.5)}$, pHs, $EC_{(1:2.5)}$' and ECe varied from 10.2 to 6.72, 10.1 to 6.53,9.4 to 0.16 dS/m and 24.0 to 0.30 dS/m with an average of 8.28, 7.90, 1.97 dS/m and 3.64 dS/m respectively. Similar to above depths, Na^+ and Cl- were the dominant cation and anion respectively (Table 1.58). As given in Table 1.59, nearly 25.8 per cent of samples were found to be saline as their ECe was >4.0 dS/m. The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas $Na/(Cl+SO_4)$ ratio was >1. However, about 7.2 and 68 percent of these samples had values more than 1. Nearly 39 per cent of the samples had SAR >13.

At 60+ cm, the $pH_{(1:2.5)}$, pHs, $EC_{(1:2.5)}$' and ECe varied from 10.3 to 7.06, 9.65 to 6.48, 8.40 to 0.19 dS/m and 19.3 to 0.36 dS/m with an average of 8.37, 7.90, 1.85 dS/m and 3.76 dS/m respectively. Similar to above depths, Na^+ and Cl^- were the dominant cation and anion respectively (Table 1.58). As given in Table 1.59, nearly 31 per cent of samples were found to be saline as their ECe was >4.0 dS/m.-The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas $Na/(Cl+SO_4)$ ratio was >1. However, about 72.1 and 42.6 percent of these samples had values more than 1. Nearly 43 per cent of the samples had SAR >13.

Table 1.58. Characterization of soil samples collected from Bellary district, Karnataka for soil salinity appraisal.

Properties	**Depth (cm)**											
	0-15 cm			**15-30 cm**			**30-60 cm**			**60+ cm**		
	Max	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**
pH (1:2.5)	10.76	5.72	8.07	10.55	4.76	8.04	10.22	6.72	8.28	10.30	7.06	8.37
EC (1:2.5)	31.0	0.12	3.02	19.90	0.12	1.80	9.40	0.16	1.97	8.40	0.19	1.85
pHs	10.23	5.88	7.66	10.33	6.49	7.82	10.08	6.53	7.90	9.65	6.48	7.90
ECe (dS/m)	75.0	0.39	7.23	35.0	0.23	3.98	24.0	0.30	3.64	19.30	0.36	3.76
Ca+Mg	126.0	3.20	16.13	64.8	2.40	10.2	38.0	2.30	9.46	37.10	2.40	9.87
Na+	634.5	1.59	62.84	262.8	1.16	36.9	196.5	1.88	33.9	145.6	2.60	33.6
K+	1.56	0.04	0.31	0.60	0.02	0.21	0.50	0.02	0.12	1.05	0.03	0.12
HCO_3^-	259.5	5.25	15.5	54.6	2.50	10.0	41.5	2.50	11.7	35.40	2.10	11.9
Cl^-	554.5	5.50	57.12	254.6	3.50	28.4	120.4	4.20	24.7	145.1	4.21	24.4
SO_4^{2-}	4.87	Tr	0.90	3.68	Tr	0.81	3.20	Tr	0.90	2.82	0.04	0.94
SAR	290.7	0.94	21.1	122.9	0.68	14.63	83.1	1.29	14.9	54.3	1.22	14.6
$(CO_3+HCO_3)/(Cl+SO_4)$	3.21	0.04	0.62	2.42	0.07	0.67	2.24	0.10	0.61	1.59	0.03	0.47
$Na/(Cl+SO_4)$	3.41	0.14	1.08	7.47	0.14	1.27	6.30	0.26	1.29	11.1	0.14	1.50

Table 1.59. Percent distribution of soil properties of samples collected from Bellary district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pHs			ECe (dS/m)			$(CO_3+HCO_3)/(Cl+SO_4)$		$Na/(Cl+SO_4)$		SAR	
	<7.5	**7.5-8.5**	**>8.5**	**<2.0**	**2-4**	**>4**	**<1**	**>1**	**<1**	**>1**	**<13**	**>13**
0-15	37.12(49)	57.58 (76)	5.30 (7)	38.6 (51)	32.6 (43)	28.8 (38)	86.4 (114)	13.6 (18)	47.7 (63)	52.3 (69)	66.7 (88)	33.3 (44)
15-30	23.85 (31)	66.9 (87)	9.23 (12)	53.1 (69)	26.2 (34)	20.8 (27)	86.9 (113)	13.1 (17)	46.2 (60)	53.9 (70)	69.2 (90)	30.8 (40)
30-60	27.84 (27)	59.8 (58)	12.4 (12)	54.6 (53)	19.6 (19)	25.8 (25)	92.8 (90)	7.22 (7)	32.0 (31)	68.0 (66)	60.8 (59)	39.2 (38)
60 +	21.31 (13)	68.9 (42)	9.84 (6)	50.8 (31)	18.0 (11)	31.2 (19)	95.1 (58)	4.92 (3)	27.9 (17)	72.1 (44)	57.4 (35)	42.6 (26)

No. of samples: 132 (0-15 cm), 130 (15-30 cm), 97 (30-60 cm); 61 (60 + cm). Values in parentheses are number of samples.

- **Delineation and Mapping of Salt Affected Soils of Kadapa District in Andhra Pradesh (Bapatla)**

Soil survey was carried out in 79 locations covering 57 villages in 18 mandals of YSR Kadapa district of Andhra Pradesh. From each location, soil samples were collected from two depths (0-25 cm and 25-50 cm) and recorded their GPS locations (Fig. 1.41). Survey revealed that majority of the locations, affected by salts, were connected to local drains having sparse vegetation and in barren condition. In the surface (0-25cm) five types of soil textures were identified viz., sandy loam (58.22%), loamy sand (10.12%), sandy clay loam (19.0%), loam (10.0%) and clay loam (2.53%). The soil pH2 ranged from 7.2 to 10.6, ECe ranged from 0.4 dSm^{-1} to 46.0 dSm^{-1}, CEC ranged from 12.09 c mol (p+) kg^{-1} to 77.76 c mol (p+) kg^{-1} and ESP ranged from 1.65 to 81.19. On basis of laboratory analysis, dominant soil types observed were alkali soil and saline alkali soil. In subsurface the textural classes were mainly Sandy loam, Sandy clay loam, loamy sand, Loam, sand and Clay loam. pH2 ranged from 6.9 to 10.6, ECe from 0.4 to 33 dSm^{-1} CEC from 6.9 c mol (p+) kg^{-1} to 59.8 c mol(p+) kg^{-1} and ESP from 2.73 to 89.53. On basis laboratory analysis, the dominant soil types were alkali and saline alkali soil.

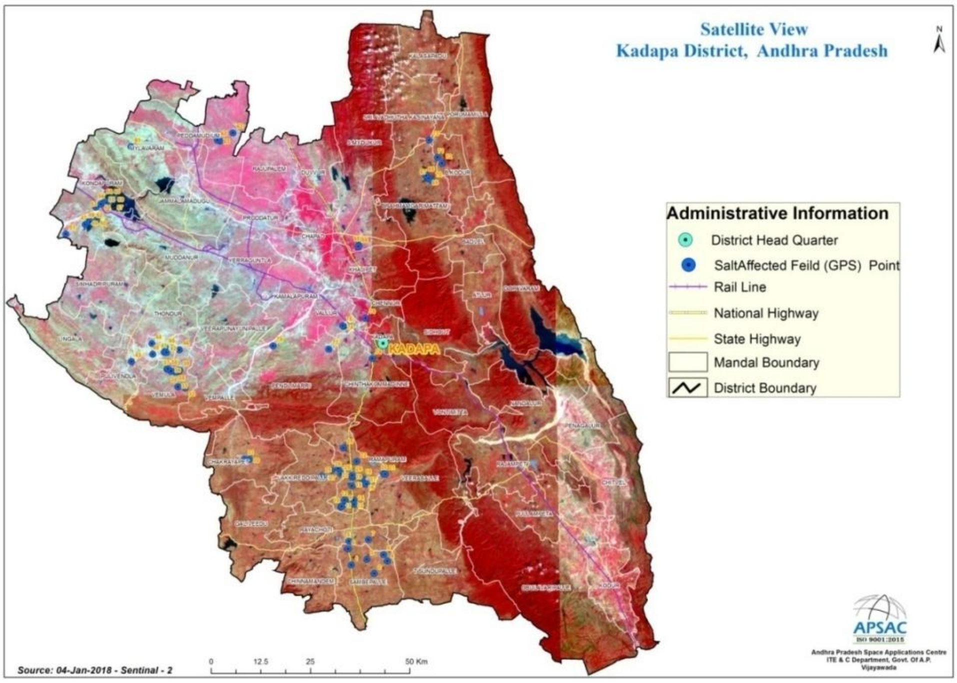


Fig. 1.41. Satellite imagery and locations of salt affected soils in Kadapa district obtained from APSAC, Vijayawada

- **Characterization and delineation of salt affected soils using remotely sensed data and ground truth of Dewas district of Madhya Pradesh (Indore)**

2019

Detailed reconnaissance soil survey was carried in different tehsils of Dewas district of Madhya Pradesh to find out locations, extent and nature of salt affected soil. The district is situated in the southern part of Madhya Pradesh. On the basis of physiography and geographical regional characteristics, Dewas district is It lies in between 22° 17' to 23° 20' N & 75° 50" to 77° 10' E. Crops like soybean, cotton, maize, sorghum wheat gram and vegetables etc. are the main crops grown in the districts. Canal as well as open/tube wells usually irrigate these crops. The district has hot sub-humid climate characterized by hot summers and mild winters. The average annual rainfall is about 1067 mm. Maximum and minimum temperatures are 45 °C and 5.0 °C, respectively.

Geographical position of the identified points was recorded using RS software and soil samples were also collected from identified points with the help of GPS for ground truthing. During the traversing of the area, soil samples were also collected from locations other than identified one, showing salinity/ alkalinity problem and there GPS points were recorded. Two hundred thirty five surface soil samples were collected from different villages of Dewas district. The reaction of soil (pHs) in the surface layer was alkaline. pHs of the saturation paste ranged from 7.0 to 8.90. The ECe of saturation extract was an important property to judge the behaviour of soil in respect of salinity/ alkalinity. ECe values ranged from 0.30 to 14.7 dSm^{-1}. Among different cations, Na ranged from 0.10 to 18.10 me L^{-1}. The SAR values ranged between 0.10 and 3.20. The data pertaining to exchangeable cations, CEC and ESP revealed that exchangeable Ca, Mg and Na ranged from 10.0 to 28.60, 5.80 to 21.40 and 0.50 to 22.40 cmol (p^+) kg^{-1}, respectively. Cation exchange capacity (CEC) ranged from 34.30 to 48.90 cmol (p^+) kg^{-1}, whereas, exchangeable sodium percentage (ESP) varied from 1.08 to 54.82, respectively. According to salinity and alkalinity hazards, the soil was classified in to three different categories of salinity (slight - ECe 4 to 8 dSm^{-1}, moderate - EC_e 8 to 15 dSm^{-1} and high - EC_e >15 dSm^{-1}) and alkalinity (slight - ESP 15 to 25), moderate - ESP 25 to 40) and high - ESP > 40). The soil samples were classified according to soil salinity as EC (dSm^{-1}) of saturation extract and ESP of soil on the basis of slight to high (Table 1.60).

Table 1.60. Frequency of soil samples with respect to EC and ESP of Dewas district

Category		**No. of samples**
Soil Salinity (dSm^{-1})		
Very slight	< 4	208 (88.5%)
Slight	4-8	22 (9.4 %)
Moderate	8-15	5 (2.1 %)
High	>15	0
Soil Alkalinity (ESP)		
Very slight	< 15	204 (86.8%)
Slight	15-25	12 (5.2%)
Moderate	25-40	9 (3.8%)
High	>40	10 (4.2%)

The data in Table 1.60 clearly shows that 208 (88.5%) soil samples were very slight salinity category and 22 (9.4%) samples belong to slight salinity category. Only 5 samples i.e. 2.1% belong to moderate salinity category. On the other hand, 204 (86.8%) soil samples come under the category of very slight sodicity in respect of ESP. Slight, moderate and high sodicity samples were 5.2, 3.8 and 4.2%, respectively. Total 2702 ha area in district was delineated as salt affected. Out of total salt affected area, slightly saline (361 ha) was higher in Dewas tehsil followed by Moderate alkali (354 ha) present in Tonkkhurd tehsil of the district. Very less area of slight saline strong alkali (28 ha) was obtained in Sonkatch tehsil of Dewas district (Table 1.61).

Table 1.61. Area and distribution of salt affected soils in Dewas district

Category	Tehsil	Area (in ha)	Category	Tehsil	Area (in ha)
Slight Saline	Dewas	361	Moderate Alkali	Tonkkhurd	354
	Hatpipliya	175		Sonkatchh	60
	Bagli	192	Strong Alkali	Tonkkhurd	249
	Udaynagar	140		Sonkatchh	83
	Khategaon	140	Slight Saline Moderate Alkali	Tonkkhurd	89
Moderate Saline	Dewas	231	Slight Saline Strong Alkali	Sonkatchh	28
	Kannod	70	Moderate Saline Strong Alkali	Sonkatchh	49
Slight Alkali	Tonkkhurd	194			
	Sonkatchh	287		**Total**	**2702**

A salt affected soils map was generated using data of soil analysis, features identified showing salinity/ sodicity problem on digital satellite data of Resourcesat-1 LISS-III through visual interpretation of the digital image using Remote Sensing Software (ERDAS IMAGINE 8.7) and ground truth (Fig. 1.42).

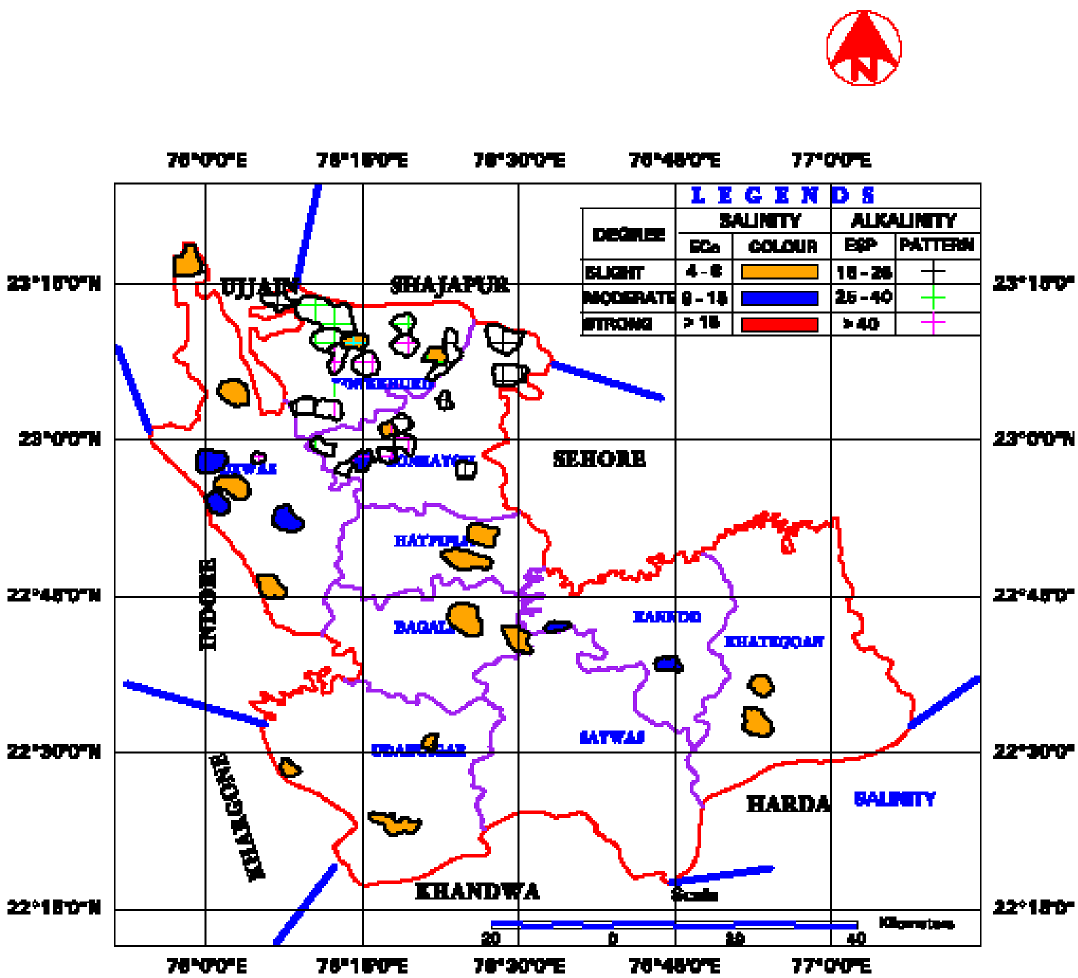
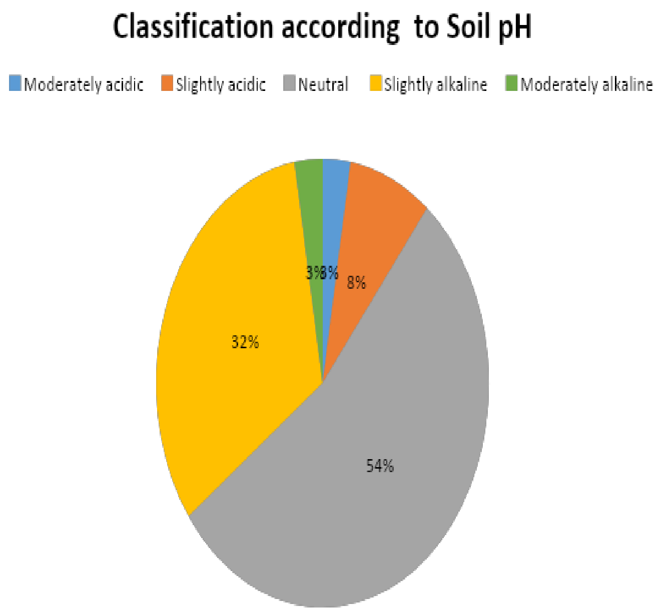


Fig. 1.42 Salt affected soils of Dewas district of MP

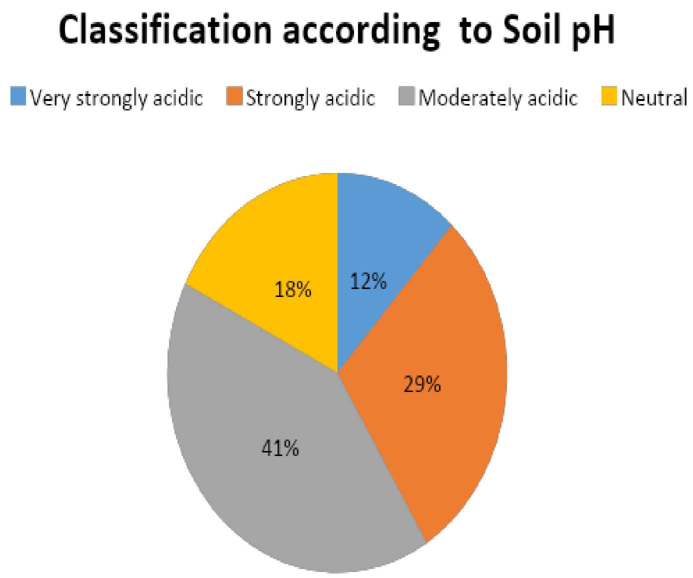
- **Delineation and mapping of salt affected soils in the coastal areas of Kerala (Vyttila)**

2019

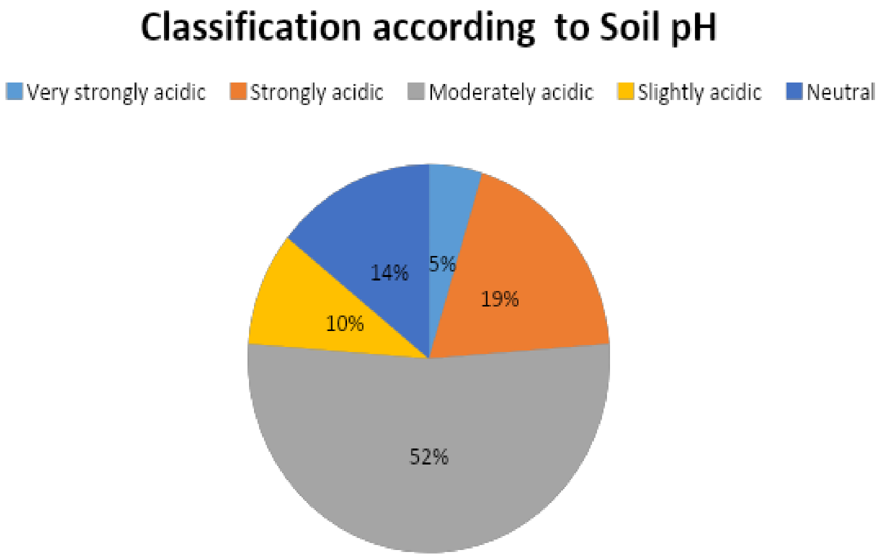
Georefernced soil samples from the coastal area of eleven districts of Kerala viz. Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod were collected and analyzed for pH, electrical conductivity, sodium, potassium, calcium, magnesium, sulphur, boron, iron, copper, manganese and zinc. On the basis of pH, soils samples belonged to slightly acidic, moderately acidic, strongly acidic, very strongly acidic, neutral, slightly alkaline and moderately alkaline category. Distribution of soils under different categories in Thiruvanathapuram, Kottayam, Kollam and Pathanamthitta district is shown in Fig. 1.43.



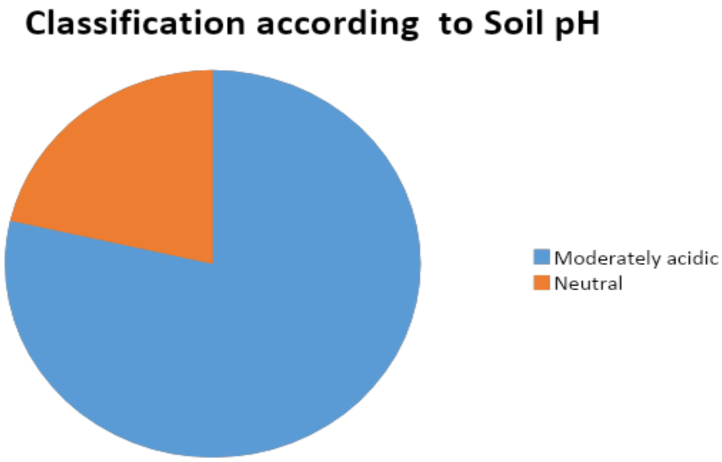
Thiruvanathapuram



Kottayam



Kollam



Pathanamthitta

Fig. 1.43 Classification according to soil pH –Thiruvanathapuram, Kottayam, Kollam and Pathanamthitta district

In general the soil samples collected from eight districts *viz.* Thiruvananthapuram, Kottayam, Kollam, Pathanamthitta, Kannur, Kozhikode, Malappuram and Kasargod were acidic and EC values were in the good category and most of the soil samples collected from different districts were non saline. Saline soils were observed mostly in the places which are near to sea which are subject to tidal influence. Organic carbon per cent of the samples were found to be medium to higher. The available phosphorus content was also sufficient in almost all the samples. Among the secondary nutrients, available magnesium content was found to be deficient in most of the cases but deficiency of calcium was prominent in Thiruvananthapuram, Kottayam, Kollam and Pathanamthitta. On studying the micronutrient status of the soils, widespread deficiency of zinc, copper and boron was recorded throughout the districts and the concentration of iron and manganese in the soil samples were found to be sufficient.

2. MANAGEMENT OF POOR QUALITY WATERS

2.1 Management of Alkali Water

- **Conjunctive use of alkali groundwater and canal water for toria-chikori crop rotation (Agra)**

An experiment on conjunctive use of alkali and good quality canal water was initiated in 2015-16 for toria-chikori crop rotation to assess effects of its different modes (cyclic and mixing) on soil properties and crop yields. The alkali irrigation water had RSC as 10 meq/l. Toria grain yield as well as stove, biological yield and harvest index under different conjunctive use modes are given in Table 2.1 and Table 2.2, respectively. The grain yield differed significantly amongst the different modes of canal and alkali irrigations. The average higher grain yield was recorded in canal irrigated treatments (12.9 q/ha) while lowest grain yield was recorded in all alkali irrigated treatment (10.4 q/ha). The Stover, biological yield and harvest index of toria were recorded (Table 2.2). The maximum net profit and B:C ratio was observed in canal irrigated plots (Rs. 31,225 and 2.37) and lowest in all alkali irrigated treatments (Rs. 22,228 and 2.02)

Table 2.1. Toria grain yield (q/ha) in different treatments

Treatments	Year					Mean
	2015	2016	2017	2018	2019	
CW	8.5	14.5	13.9	14.0	13.4	12.9
1CW:1AW	8.1	14.9	12.7	13.0	13.4	12.4
2CW:2AW	8.3	14.9	12.6	12.9	13.2	12.4
2AW:2CW	8.1	13.1	11.3	12.2	12.8	11.5
Mix.(1:2)	8.0	14.2	12.2	12.9	13.1	12.1
Mix.(2:1)	8.1	14.9	12.1	12.9	13.3	12.3
AW	7.9	12.1	9.3	10.0	12.8	10.4
CD at 5%	NS	2.6	2.4	1.2	NS	2.1

Table 2.2 Effect conjunctive use on Stover yield, biological yield, harvest index, net profit and benefit cost ratio of Toria (Av.2018-19 and 2019-20)

Treatments	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	Net profit (Rs/ha)	B:C
1CW:1AW	24.2	37.4	34.7	29,235	2.78
2CW:2AW	23.9	37.0	35.3	28,581	2.75
2AW:2CW	23.7	36.2	34.3	26,288	2.15
Mix.(1:2)	24.2	37.2	35.0	28,380	2.24
Mix. (2:1)	24.7	37.8	34.5	28,648	2.24
AW	20.5	31.9	35.9	22,288	2.02
CD at 5%	1.6	3.9	2.4	-	-

After harvest of toria crop, the chikori crop was grown during rabi season with different conjunctive use modes of alkali and canal irrigation. Data on chikori root yield are presented in Table 2.3.

Table 2.3: Chikori root yield (q/ha) in different treatments

Treatments	Year					Mean
	2015	2016	2017	2018	2019	
CW	171.9	253.7	263.2	302.9	316.5	261.6
1CW:1AW	167.3	246.4	251.0	292.0	308.0	252.9
2CW:2AW	166.6	246.0	248.9	287.7	306.3	251.1
2AW:2CW	162.3	229.0	225.5	253.1	287.4	231.5
Mix.(1:2)	161.1	235.6	240.8	277.0	291.7	241.2
Mix.(2:1)	167.3	246.0	249.3	285.5	299.9	249.6
AW	159.0	178.4	167.4	181.9	244.0	186.1
CD at 5%	5.3	18.6	21.9	16.1	17.7	15.9

The chikori root yield differed significantly amongst the different modes of canal and alkali irrigations. On the basis of 5 years' data, average maximum chikori root yield was reported from canal irrigation treatment (261.6 q/ha) and lowest was reported from alkali water irrigated treatment (186.1 q/ha) and all other treatments were in between. The maximum net profit and B: C ratio was found in canal irrigated treatment (Rs. 92,305 and 3.34) and lowest in all alkali treatments (Rs. 51,336 and 2.31). Details are provided in Table 2.4.

Table 2.4: Effect of conjunctive water use on net profit and benefit cost ratio of chikori (Av. 2 years)

Treatments	Diameter of chikori root(cm)	Length of chikori root (cm)	Net profit (Rs/ha)	B:C ratio
1CW:1AW	12.9	23.6	88,183	3.24
2CW:2AW	12.7	23.2	86,908	3.22
2AW:2CW	11.8	21.2	75,539	2.92
Mix.(1:2)	12.2	22.4	81,531	3.07
Mix. (2:1)	12.1	23.4	85,080	3.17
AW	10.2	19.6	51,336	2.31
CD at 5%	1.05	2.28	-	-

Cropping System productivity:

The average two years system productivity details of Toria –Chikori cropping sequence are given in Table 2.5. The maximum system yield was observed in all canal (CW) treatment 323.4 q/ha and minimum in all alkali treatment (AW) 224.3 q/ha. The other best system treatments for system productivity were 1CW:1AW, 2CW:2AW and cyclic 2CW:1AW. The other treatments gave system productivity yield in between these two treatments.

Table 2.5: Effect of modes of irrigation on system productivity (Av.2018-19 and 2019-20)

Treatments	Toria yield (q/ha)	Chikori yield (q/ha)	System yield (q/ha)
CW	13.7	309.7	323.4
1CW:1AW	13.2	300.0	313.2
2CW:2AW	13.1	297.0	310.1
2AW:2CW	12.5	270.3	282.8
Mix.(1:2)	13.0	284.4	297.4
Mix. (2:1)	13.1	292.7	305.8
AW	11.4	212.9	224.3

Soil properties:

The ECe, SAR, pH and ESP of soil profile were determined at sowing of toria crop, harvest of toria crop and harvest of chikori crop depth wise under different treatments and reported in Table 2.6. In general the ECe, pH, SAR and ESP values at sowing and harvest of toria crop were relatively lower as total number of irrigations were less as well as there was rainfall during the season. During chikori crop, the value of ECe, SAR, pH and ESP increased slightly.

Table 2.6: Soil analysis for conjunctive water use treatments (Av.2018-19 to 2019-20)

Treat-ments	Soil Depth (cm)	Toria at sowing				Toria at harvest				Chikori at harvest			
		EC_e	pH	SAR	ESP	EC_e	pH	SAR	ESP	EC_e	pH	SAR	ESP
T_1	0-15	2.3	7.6	2.7	7.8	2.5	7.7	2.8	7.8	2.5	7.7	2.7	7.8
	15-30	2.3	7.5	2.7	8.1	2.5	7.6	2.7	8.3	2.5	7.6	2.6	8.1
	30-60	2.2	7.5	2.6	-	2.4	7.6	2.9	-	2.5	7.6	2.7	-
	60-90	2.1	7.5	2.8	-	2.4	7.6	3.2	-	2.4	7.6	2.8	-
T_2	0-15	2.4	7.6	3.2	7.8	2.6	7.7	3.6	8.6	2.5	7.6	3.2	8.5
	15-30	2.3	7.6	3.2	8.2	2.5	7.6	3.7	8.8	2.5	7.6	3.1	8.8
	30-60	2.2	7.6	3.3	-	2.9	7.6	3.4	-	2.4	7.6	3.2	-
	60-90	2.2	7.6	3.2	-	2.4	7.6	3.5	-	2.4	7.6	3.4	-
T_3	0-15	2.4	7.6	3.2	7.8	2.5	7.7	4.0	8.5	2.5	7.7	3.4	8.4
	15-30	2.4	7.6	3.2	8.3	2.5	7.6	3.9	9.1	2.5	7.6	3.5	9.1
	30-60	2.3	7.5	3.2	-	2.4	7.6	3.7	-	2.5	7.6	3.4	-
	60-90	2.2	7.5	3.1	-	2.6	7.6	3.5	-	2.4	7.6	3.3	-
T_4	0-15	2.5	7.7	6.0	8.7	2.6	7.7	6.8	9.8	2.5	7.6	6.2	9.5
	15-30	2.4	7.7	5.7	9.2	2.5	7.7	6.6	10.7	2.5	7.6	5.9	10.5
	30-60	2.3	7.7	5.5	-	2.5	7.6	5.8	-	2.5	7.6	5.5	-
	60-90	2.3	7.6	5.3	-	2.6	7.6	5.3	-	2.4	7.6	5.4	-
T_5	0-15	2.4	7.6	5.8	8.3	2.6	7.8	6.5	8.6	2.5	7.6	5.8	9.5
	15-30	2.3	7.6	5.1	8.8	2.5	7.6	6.4	8.5	2.5	7.6	5.4	10.0
	30-60	2.2	7.6	4.9	-	2.5	7.7	5.2	-	2.5	7.6	4.5	-
	60-90	2.3	7.6	4.3	-	2.6	7.6	4.8	-	2.5	7.6	4.4	-
T_6	0-15	2.4	7.6	3.6	8.2	2.5	7.7	4.5	8.4	2.5	7.6	4.8	9.5
	15-30	2.3	7.5	3.5	8.6	2.5	7.6	4.4	8.7	2.5	7.7	4.7	9.9
	30-60	2.3	7.5	3.6	-	2.3	7.7	3.9	-	2.5	7.6	3.8	-
	60-90	2.2	7.5	3.5	-	2.7	7.6	3.6	-	2.5	7.6	3.2	-
T_7	0-15	2.5	7.8	7.8	9.3	2.6	8.1	9.7	10.1	2.8	7.9	10.3	12.4
	15-30	2.4	7.8	7.5	9.8	2.5	8.0	9.0	11.4	2.7	8.1	10.2	14.0
	30-60	2.4	7.6	7.5	-	2.5	7.8	8.2	-	2.6	8.0	8.5	-
	60-90	2.3	7.6	6.8	-	2.5	7.8	7.4	-	2.6	7.8	8.4	-

- **Conjunctive use of high RSC water in different cropping systems under sodic soil (Kanpur)**

The purpose of the experiment was to find out the suitable cyclic mode of irrigation water particularly under sodic groundwater areas and study crop response to such modes in terms of crop yield. The rice-wheat rotation and pearl millet –wheat, prevalent in the area, were considered during the experiment. Details of experiment are given below (Table 2.7). Initially pH, ECe, ESP and Organic Carbon of soil were 9.10, 093 dS/m, 42.2 and 0.28%, respectively.

Table 2.7 Details of conjunctive water use experiments

Mode Irrigation water application	
✓ T1: Best Available Water (BAW)	
✓ T2: RSC groundwater	
✓ T3: BAW followed by all irrigations by RSC water	
✓ T4: RSC water followed by all irrigations by BAW	
✓ T5: 1 BAW and 1RSCW (Alternately)	
✓ T6: BAW + RSC water after mixing	
Other details	
Crop rotation:	Rice, wheat and pearl millet
Varieties:	CSR-36 (rice), KRL-211 (wheat)and ICTP-8203 (pearl millet)
No. :	6
No of replications:	3
Design:	Split plot
Plot size:	20 m^2
Year of start:	2014
Location:	Crop Research Farm, Dalipnagar, Kanpur

Quality parameters of two irrigation waters, namely Best Available Water (BAW) and RSC water are provided in Table 2.8.

Table 2.8 Chemical composition of irrigation waters

Composition	BAW	RSCW
pH	7.55	8.81
EC(dSm^{-1})	0.72	1.10
Anions (meq/l)		
CO_3	Nil	NIL
HCO_3	4.23	8.44
Cl	3.30	1.88
SO_4	0.11	0.73
Cations (meq/l)		
Ca+Mg	6.40	2.63
Na+K	1	8.47
RSC (meq/l)	Nil	5.82

The average grain yield of rice varied from 23.13-40.07 q/ha in rice- wheat cropping system, (Table 2.9). The highest yield was obtained from best available water (BAW) 40.07 q/ha followed by RSCW - (Rest irrigation with BAW) (35.97 q/ha) and BAW + RSCW (35.43 q/ha) while lowest yield (29.65 q/ha) was received from residual sodium carbonate water (RSCW) treatment. The average straw yield of rice varied from 28.35-48.56 q/ha in rice- wheat cropping system. The highest yield was obtained from best available water (BAW) 48.56 q/ha followed by RSCW - (Rest irrigation with BAW) (44.03 q/ha) and BAW + RSCW (43.23 q/ha) while lowest yield (28.35 q/ha) was received from residual sodium carbonate water (RSCW) treatment.

Table 2.9 Effect of treatments on yield of rice in rice-wheat cropping system

Treatments	Grain yield (q/ha)						Straw yield (q/ha)					
	2014	2015	2016	2017	2018	Mean	2014	2015	2016	2017	2018	Mean
T_1: BAW	37.18	39.25	40.12	41.25	42.55	40.07	44.98	45.68	49.34	50.70	52.12	48.56
T_2: RSCW	24.25	23.77	22.50	22.12	23.00	23.13	29.58	28.99	27.67	27.20	28.30	28.35
T_3: BAW - (Rest irrigation with RSCW)	28.77	28.46	27.88	27.25	28.24	28.12	35.09	34.72	34.29	33.52	35.00	34.52
T_4: RSCW - (Rest irrigation with BAW)	33.26	34.43	36.75	37.17	38.46	35.97	40.57	42.07	45.20	45.71	46.52	44.03
T_5: 1 BAW-1 RSCW (Alternate)	31.65	32.36	32.47	33.05	34.15	32.74	38.61	39.47	39.97	40.65	42.23	40.19
T_6: BAW + RSCW	34.61	36.11	33.52	35.15	36.18	35.43	42.42	44.05	41.22	43.22	45.15	43.23
CD (0.05)	1.57	1.64	1.67	1.62	1.33	--	1.52	1.56	1.58	1.68	1.66	-

The average grain yield of wheat varied from 17.03-35.34 q/ha in rice- wheat cropping system, (Table 2.10). The maximum yield was obtained from best available water (BAW) 35.34 q/ha followed by RSCW - (Rest irrigation with BAW) (30.21 q/ha) and BAW + RSCW (29.65 q/ha) while minimum yield (17.03 q/ha) was received from residual sodium carbonate water (RSCW) treatment. The average straw yield of wheat varied from 20.61-42.72 q/ha in rice- wheat cropping system. The maximum yield was obtained from best available water (BAW) 42.72 q/ha followed by RSCW - (Rest irrigation with BAW) (36.60 q/ha) and BAW + RSCW (35.73 q/ha) while minimum yield (20.61 q/ha) was received from residual sodium carbonate water (RSCW) treatment.

Table 2.10 Effect of treatments on grain yield of wheat in rice-wheat cropping system

Treatments	Grain yield of wheat (q/ha)						Straw yield of wheat (q/ha)					
	2014-15	2015-16	2016-17	2017-18	2018-19	Mean	2014-15	2015-16	2016-17	2017-18	2018-19	Mean
T_1: BAW	32.73	34.95	35.78	36.04	37.22	35.34	39.60	42.28	43.29	43.60	44.85	42.72
T_2: RSCW	17.45	17.12	16.72	16.40	17.45	17.03	21.11	20.71	20.23	19.89	21.10	20.61
T_3: BAW - (Rest irrigation with RSCW)	22.04	23.10	21.94	22.25	23.32	22.53	26.66	27.95	26.54	27.85	28.76	27.55
T_4: RSCW - (Rest irrigation with BAW)	27.14	28.88	30.22	31.82	32.98	30.12	32.83	34.94	36.56	38.55	40.12	36.60
T_5: 1 BAW-1 RSCW (Alternate)	26.00	27.65	27.42	29.07	30.55	28.14	31.46	33.45	33.17	35.17	36.35	33.92
T_6: BAW + RSCW	28.11	29.46	28.71	30.14	31.85	29.65	34.05	35.64	34.75	36.47	37.72	35.73
CD *(p=0.05)*	1.23	1.46	1.49	1.52	1.28	--	1.46	1.42	1.52	1.49	1.66	--

The average grain yield of pearl-millet varied from 08.26-15.73 q/ha in pearl millet - wheat cropping system, (Table 2.11). The highest yield was obtained from waste available water (BAW) 15.73 q/ha followed by RSCW - (Rest irrigation with BAW) (13.28 q/ha) and BAW + RSCW (12.64 q/ha) while lowest yield (8.26 q/ha) was received from residual sodium carbonate water (RSCW) treatment. The average stover yield of pearl millet varied from 22.26-42.39 q/ha in pearl millet- wheat cropping system, (Table 2.11). The highest yield was obtained from waste available water (BAW) 42.39 q/ha followed by RSCW - (Rest irrigation with BAW) (35.98 q/ha) and BAW + RSCW (33.16 q/ha) while lowest yield (22.26 q/ha) was received from residual sodium carbonate water (RSCW) treatment.

Table 2.11 Effect of treatments on grain yield of pearl millet in pearl millet-wheat cropping system

Treatments	Grain yield of pearl millet (q/ha)						Stover yield of pearl millet (q/ha)					
	2014	2015	2016	2017	2018	Mean	2014	2015	2016	2017	2018	Mean
T_1: BAW	14.52	15.55	15.97	16.05	16.58	15.73	39.20	41.98	43.17	43.34	44.26	42.39
T_2: RSCW	08.41	08.12	08.78	07.98	08.00	08.26	22.07	21.92	23.72	21.57	22.03	22.26
T_3: BAW - (Rest irrigation with RSCW)	10.58	10.05	09.62	09.42	10.15	10.37	28.56	27.14	25.97	25.45	26.53	26.73
T_4: RSCW - (Rest irrigation with BAW)	12.24	12.83	13.36	13.88	14.10	13.28	33.12	34.67	36.15	37.49	38.46	35.98
T_5: 1 BAW-1 RSCW (Alternate)	10.98	11.27	10.64	11.52	12.00	11.28	29.64	30.45	28.75	32.10	32.00	30.58
T_6: BAW + RSCW	12.75	12.35	11.42	12.05	12.65	12.64	34.45	34.12	30.83	32.64	33.75	33.16
CD *(p=0.05)*	1.17	1.29	1.27	1.31	1.37	--	1.47	1.52	1.57	1.55	1.68	--

The average grain yield of wheat varied from 17.36-35.49 q/ha in pearl millet- wheat cropping system, (Table 2.12). The maximum yield was obtained from waste available water (BAW) 35.49 q/ha followed by RSCW - (Rest irrigation with BAW) (30.94 q/ha) and BAW + RSCW (28.35 q/ha) while minimum yield (17.36 q/ha) was received from residual sodium carbonate water (RSCW) treatment. The average straw yield of wheat varied from 21.16-43.70 q/ha in pearl millet - wheat cropping system (Table 2.12). The maximum yield was obtained from waste available water (BAW) 43.70 q/ha followed by RSCW - (Rest irrigation with BAW) (37.58 q/ha) and BAW + RSCW (34.78 q/ha) while minimum yield (21.16 q/ha) was received from residual sodium carbonate water (RSCW) treatment.

Table 2.12 Effect of treatments on grain yield of wheat in pearl millet-wheat cropping system

Treatments	Grain yield of wheat (q/ha)						Straw yield of wheat (q/ha)					
	2014-15	2015-16	2016-17	2017-18	2018-19	Mean	2014-15	2015-16	2016-17	2017-18	2018-19	Mean
T_1: BAW	33.27	35.37	36.28	35.52	37.00	35.49	40.58	43.15	44.32	43.33	45.10	43.70
T_2: RSCW	18.08	17.85	16.74	16.47	17.65	17.36	22.05	21.77	20.42	20.12	21.45	21.16
T_3: BAW - (Rest irrigation with RSCW)	20.55	20.82	19.96	20.14	21.75	20.64	25.07	26.25	24.35	24.72	25.98	25.27
T_4: RSCW - (Rest irrigation with BAW)	27.95	29.05	31.15	32.78	33.75	30.94	34.09	35.44	38.10	39.99	40.25	37.58
T_5: 1 BAW-1 RSCW (Alternate)	26.78	28.00	28.25	28.75	29.65	28.29	32.67	34.16	34.57	35.07	36.34	34.56
T_6: BAW + RSCW	28.35	28.16	27.62	28.10	29.55	28.35	34.58	35.22	33.72	34.58	35.83	34.78
CD *(p=0.05)*	1.21	1.37	1.35	1.41	1.27	--	1.49	1.53	1.57	1.62	1.66	--

Changes in pH, electrical conductivity, exchangeable sodium percentage (ESP) and organic carbon (OC) indicated that although there has been overall improvement in soil properties in every treated plots excluding residual sodium carbonate water (RSCW). The values of soil pH, EC and ESP decreased in BAW irrigated plot and increased with RSCW. There was noted improvement in organic carbon in all the treatments excluding RSCW. Related data are given in Table 2.13.

Table 2.13 Effect of treatments on physico-chemical properties of soil after two years

Treatments	Rice-wheat				Pearl millet-wheat			
	pH	EC (dS/m)	ESP	OC (%)	pH	EC (dS/m)	ESP	OC (%)
BAW	8.6	0.88	34.7	0.35	8.7	0.89	33.2	0.36
RSCW	9.2	0.94	40.5	0.26	9.3	0.93	40.9	0.27
BAW - (Rest irrigation with RSCW)	9.0	0.93	39.1	0.28	9.1	0.93	39.6	0.28
RSCW - (Rest irrigation with BAW)	8.7	0.91	36.0	0.33	8.7	0.92	36.1	0.32
1 BAW-1 RSCW (Alternate)	8.8	0.92	38.2	0.29	8.9	0.91	39.2	0.30
BAW + RSCW	8.8	0.89	37.2	0.32	8.8	0.90	38.7	0.31
Initial values	pH-9.10		EC-0.93		ESP-42.2		OC-0.28	

- **Drip Irrigation to cotton in alkali soils using ameliorated alkali water (Tiruchirapalli)**

2019

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 2.14). 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, 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.

Table 2.14 Treatment details

Main plot: Water treatment (3)		Sub-plot: Soil treatment (3)		Other Details
M_1	Drip with gypsum bed treated water	S_1	Soil application of gypsum @ 50% GR	Design : Strip- plot design Replications : Four Crop : Cotton Hybrid : RCH 20 Spacing : 90 x 60 cm
M_2	Drip with spent wash treated water	S_2	One time application of DSW @ 5 lakh liters ha^{-1}	
M_3	Drip with untreated alkali water	S_3	No amendments	

Drip irrigation system was installed and the laterals were laid in centre of each ridge. In line drippers of 4 l/h were used at a spacing of 60 cm. After that Cotton BG II hybrid RCH 20 seeds were sown along the ridges with a spacing of 90 cm between rows and 60 cm between plants. Other management practices like gap filling and weeding were carried out according to the recommended package of practices. The gypsum bed treatment structure was fabricated to a capacity of 1000 litre with RCC rings and a mild steel rod stand. The inlet of the alkali irrigation water is provided below the stand and the irrigation water was treated during its upward movement through the gypsum bed kept within a gunny bag over the stand. This treated water is being collected in a storage tank from which the water is pumped into drip system through fertigation unit (ventury). Similarly, the distillery spent wash was mixed with irrigation water in a ratio of 1:250 through the fertigation unit to treat the alkali water. The drip irrigation is being operated and the duration of drip irrigation system is based on the daily rainfall, evaporation rate, stage of the crop.

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 2.15). Gypsum bed treatment reduced the RSC to 3.4.

Table 2.15 Changes in quality of ameliorated alkali water

Sr. No.	Treatment	pH	EC (dS/m)	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

Post Harvest Soil pH: The post harvest soil samples were analyzed in the laboratory and the value of pH is presented in the Table 2.16. 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 pH value followed by S_1 and S_3. There is no significant interaction between main plot and sub plot treatment.

Table 2.16 Effect of drip irrigation using ameliorated alkali water and soil amendments on pH 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)	7.75	7.51	8.76	8.00
M_2: (DSW treated)	7.62	7.28	8.68	7.86
M_3: (Alkali water)	7.82	7.63	8.84	8.10
Mean	7.73	7.47	8.76	
		SED	CD(0.05)	
	M	0.030	0.07	
	S	0.031	0.06	
	M at S	0.053	NS	
	S at M	0.053	NS	

Post Harvest soil EC: The EC was observed in the post harvested soil sample and presented in Table 2.17. 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.

Post Harvest Soil ESP: The post harvest soil ESP value is presented in Table 2.18. 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.

Table 2.17. Effect of drip irrigation using ameliorated alkali water and soil amendments on EC 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)	0.62	1.08	0.52	0.74
M_2: (DSW treated)	0.79	1.15	0.59	0.84
M_3: (Alkali water)	0.53	0.94	0.47	0.65
Mean	0.65	1.06	0.53	
		SED	CD(0.05)	
	M	0.011	0.03	
	S	0.012	0.03	
	M at S	0.021	0.05	
	S at M	0.022	0.05	

Table 2.18 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 litre 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	

Post Harvest soil available N, P and K: The results showed that among the main plot treatment M_2 recorded with a highest soil available nitrogen content (275 kg/ha) followed by M_1 (268 kg/ha) and M_3(255 kg/ha). Among the sub plot treatment S_2 recorded a highest soil available nitrogen content (354 kg/ha) followed by S_1 (258 kg/ha) and S_3 (186 kg/ha). There is no significant interaction between main plot and sub plot treatment.

Among the main plot treatment M_2 recorded with a highest soil available P (19.3 kg/ha) followed by M_1 (18.7) and M_3 (18.5 kg/ha) which are statistically on par. Among the sub plot S_2 recorded with highest available P (21.8) followed by S_1 (18.0) and S_3 (16.6 kg/ha). There is no significant interaction between main plot and sub plot treatment.

Among the main plot treatment M_2 (435 kg/ha) recorded with a highest soil available potassium content followed by M_1 (419) and M_3 (413 kg/ha), which are statistically on par. Among the sub plot S_2 (916 kg/ha) recorded with highest available potassium content followed by S_1 (185) and S_3 (177 kg/ha). There is no significant interaction between main plot and sub plot treatment.

Post Harvest Soil organic carbon: The post harvest soil organic carbon is presented in Table 2.19. It was observed that among the main plot treatment M_2 recorded with a highest soil organic carbon content followed by M_1 and M_3. Among the sub plot S_2 recorded with highest organic carbon content followed by S_1 and S_3. There is significant interaction between main plot and sub plot treatment. The treatment M_2 S_2 recorded with a highest value soil organic carbon content followed by M_1S_2 and M_3S_2. The least soil organic carbon content was recorded for the treatment M_3S_3.

Table 2.19 Effect of drip irrigation using ameliorated alkali water and soil amendments on available organic carbon 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)	0.60	0.89	0.45	0.65
M_2: (DSW treated)	0.77	0.94	0.45	0.72
M_3: (Alkali water)	0.55	0.88	0.42	0.61
Mean	0.64	0.90	0.44	
		SED	CD*(p=0.05)*	
	M	0.014	0.04	
	S	0.007	0.01	
	M at S	0.017	0.04	
	S at M	0.012	0.02	

Effect of ameliorated alkali water on cotton yield

The cotton crop was on 1st March 2018. The observation on seed cotton yield was recorded and presented in Table 2.20.

Table 2.20. Effect of drip irrigation using ameliorated alkali water on seed cotton yield and yield attributes

Treat-Ments	No. of sympodia / plant				No. of bolls /plant				Seed cotton yield (kg/ha)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_1	12.2	14.5	8.2	11.6	33.2	37.2	28.3	30.2	1541	1718	1237	1499
M_2	11.8	12.2	7.9	10.6	29.0	31.2	15.1	25.1	1357	1601	958	1305
M_3	9.4	8.4	7.0	8.3	15.2	17.2	11.3	14.6	930	1117	735	927
Mean	11.1	11.7	7.7		25.8	28.5	15.6		1276	1479	977	
		SED	CD(0.05)			SED	CD(0.05)			SED	CD(0.05)	
	M	0.16	0.4		M	0.76	1.9		M	12.77	47	
	S	0.11	0.2		S	0.74	1.6		S	25.21	73	
	M at S	0.23	0.5		M at S	1.29	2.9		M at S	37.88	113	
	S at M	0.20	0.4		S at M	1.28	2.7		S at M	43.68	126	

The results showed that among the main plot (drip irrigation) treatment, the treatment M_1 (drip irrigation with gypsum bed treated with alkali water recorded with significantly seed cotton yield of 1499 kg /ha followed by M_2 (drip irrigation with DSW treated alkali water) with a seed cotton yield of 1305 kg/ha. The treatment M_3 (drip irrigation with untreated alkali water) recorded with significantly lowest seed cotton yield of 927 kg /ha. Among the sub plot (soil amendments) treatments S_2 (application of DSW @ 5 lakh litre/ha) recorded with statistically highest seed cotton yield of 1479 kg/ha 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 977 kg /ha. 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 litre /ha a soil amendment) recorded with a significantly highest seed cotton yield of 1601 kg/ha followed by M_2S_2 and M_1S_1 which are statistically on par with a corresponding value of 1601 and 1541 kg/ha respectively. The treatment M_3S_3 (drip irrigation with untreated alkali water + control-no soil amendments) recorded with a lowest seed cotton yield of 735 kg/ha.

2.2 Management of Saline Water

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

2019

The flower crops like Chrysanthemum and Marygold and also medicinal crop Tulasi were grown on coastal sandy soil at Bapatla with saline water irrigation through drip. Initially soil was non-saline with pH 7.1 and ECe as 0.5 dS/m. The crops were irrigated with waters with different salinity such as 0.6, 2, 4, 6, 8 dS/m. The results (Table 2.21) indicated that chrysanthemum recorded 96.8 flowers per plant at 0.6 dS/m and reduced to 68.1 flowers per plant at 8.0 dS/m by recording 30.9 flowers per plant. Marygold registered 158.6 flowers/ plant at 0.6 and reduced to 71.8 at ECiw of 8.0 dS/m with 44.7 flowers per plant. For both, chrysanthemum and marygold 50% yields were obtained at water salinity level of 5.8 and 5.5 dS/m, respectively. However, Tulasi recorded 8.6 t ha^{-1} of biomass at 0.6 dS/m and reduced to 5.6 t ha^{-1} at 8.0 dS/m and there was a reduction of 35.2%. It clearly showed that Tulasi was more tolerant to salinity as compared to chrysanthemum and marigold. The salinity build up in soil at different salinity levels after harvest of the crop was ranged between 0.8 to 3.2 dSm^{-1} depending on quality of irrigation water. The initial soil pH and soil salinity (ECe) were 7.1 and 0.5 dS/m.

Table 2.21. Performance of flower / medicinal plants at different salinity levels of water

ECiw levels	Plant height (cm)	No. of main branches/ plant	No. of flowers/plant	Percent reduction
Chrysanthemum				
BAW	50.6	7.4	96.8	-
2EC	44.6	7.4	83.9	13.3
EC	42.8	7.2	62.2	35.7
6EC	37.5	7.0	44.4	54.1
8EC	35.8	6.4	30.9	68.1
Marygold				
BAW	57.0	9.2	158.6	-
2EC	54.2	8.6	133.7	15.7
4EC	53.6	8.0	97.5	38.5
6EC	51.6	8.0	69.8	56.0
8EC	45.8	7.4	44.7	71.8
Tulasi Biomass (t/ha)				
BAW	67.2	8.6		-
2EC	65.1	8.3		3.5
4EC	60.3	7.4		14.0
6EC	57.2	6.3		26.5
8EC	53.8	5.6		35.2

Irrigation water salinity with respect to different yield levels starting from 100 to 0% based on irrigation water salinity yield relation in case of Chrysanthemum, Marygold and Tulasi are given in Table 2.22. The 50% yield compared to yield at good quality irrigation water can be obtained at 5.8, 5.5 and 11.0 dS/m for Chrysanthemum, Marygold and Tulasi, respectively. It suggested that Tulasi is most tolerant among three crops (Plate 2.1).

Table 2.22. Irrigation water salinity with respect to different yield levels of crops

Yield Level	Chrysanthemum		Marygold		Tulasi	
	No. of flowers/plant	EC_{iw} dS/m	No. of flowers/plant	EC_{iw} dS/m	Biomass (t/ha)	EC_{iw} dS/m
100	96.8	0.5	158.6	0.4	8.6	0.9
90	**87.12**	**1.5**	**142.7**	**1.4**	**7.74**	**3.0**
80	77.44	2.6	126.9	2.4	6.88	5.0
75	**72.6**	**3.1**	**119.0**	**2.9**	**6.45**	**6.0**
70	67.76	3.7	111.0	3.5	6.02	7.0
60	58.08	4.7	95.2	4.5	5.16	9.0
50	**48.4**	**5.8**	**79.3**	**5.5**	**4.3**	**11.0**
40	38.72	6.9	63.4	6.5	3.44	13.0
30	29.04	7.9	47.6	7.6	2.58	15.0
20	19.36	9.0	31.7	8.6	1.72	17.1
10	9.68	10.1	15.9	9.6	0.86	19.1
0	0	11.1	0.0	10.6	0	21.1




Plate 2.1 Field view of flower/medicinal plants with saline irrigation water through drip system

- **Performance of vegetable crops (chilli) with saline irrigation water through drip system**

2020

A response of green chilli to different irrigation water salinity levels such as 0.6, 2, 4, 6 and 8 dS/m was studied. Irrigation water was applied through drip. The experiment was laid out in Randomized Block Design with four replications. The seedlings of variety VNR 314 were planted on 03-12-2019 under drip irrigation. The pH of the soil was 7.4 and soil salinity was 0.3 dSm^{-1}. The tube well water salinity was 0.6 dSm^{-1}. The data presented in Table 2.23 indicated that growth and yield of chilli crop were significantly influenced by water salinity level. The use of best available water (0.6 dSm^{-1}) recorded the highest plant height (86.7cm), number of branches per plant (5.6), no. green pods per plant (79.6) and yield of green pods (28.6 t ha^{-1}). These parameters were significantly reduced with increase in irrigation water salinity. The lowest plant height (55.7cm), number of main branches per plant (4.3), number of green pods per plant (50.7) and yield of green pods (12.3 tha^{-1}) were recorded at irrigation water salinity of 8.0 dSm^{-1}. The Table 2.24 revealed yield reduction from 7.3 to 57% with increasing water salinity from 0.6 dSm^{-1} to 8.0 dSm^{-1}.

Table 2.23. Effect of water salinity on growth and yield of chilli crop

Treatment	Plant height (cm)	No. of branches per plant	No. of green pods per plant	Yield of green pods (t/ha)	Yield reduction (%)
BAW (1.0)	86.7	5.6	79.6	28.6	-
2ECiw	78.5	5.2	73.5	26.5	7.3
4ECiw	73.2	4.7	65.7	22.6	21.0
6ECiw	65.5	4.5	57.3	18.7	34.6
8ECiw	55.7	4.3	50.7	12.3	57.0
SEm±	1.9	0.2	2.0	0.6	
CD (5.0%)	5.9	0.5	6.0	1.9	
CV (%)	5.4	7.3	6.0	5.6	

Table 2.24. Yield levels of chilli at different irrigation water salinities

Yield level	Yield t/ha	EC_{iw} (dSm^{-1})	Yield level	Yield t/ha	EC_{iw} (dSm^{-1})
100	28.6	0.6	50	14.3	7.6
90	25.7	2.3	40	11.4	8.9
80	22.9	3.6	30	8.6	10.2
75	21.5	4.3	20	5.7	11.5
70	20.0	4.9	10	2.9	12.9
60	17.2	6.2	0	0	14.2

The soil salinity after harvest of the crop varied from 1.5 to 2.5 dSm^{-1} and pH varied from 7.1 to 7.6 (Table 2.25).

Table 2.25. Soil salinity and pH after harvest of the crop

Treatment	pH	EC_e (dSm^{-1})
BAW (0.6) dSm^{-1}	7.1	1.5
2 dSm^{-1}	7.3	1.7
4 dSm^{-1}	7.6	2.3
6 dSm^{-1}	7.5	2.5
8 dSm^{-1}	7.5	2.5

- **A case study on the functioning of doruvu technology in farmers' fields and its impact on coastal saline agricultural production system (Bapatla)**

2019

The centre monitored improved doruvu technology wells regularly every month for water salinity. The salinity of irrigation water in doruvu wells was ranged from 0.7 to 4.0 dS/m. Recently majority of the farmers adopted shallow bore wells (20 ft. depth) and irrigating the crops with electrical motor. Simultaneously, water from these bore wells was also collected and tested for water salinity (Table 2.26 and Table 2.27). The salinity of water from these borewells was ranged from 1.0 to 3.6 dS/m except in one bore well where the salinity was 6. 2 in March, 2019. In majority of the bore wells, the water quality is in permissible limit.

Table 2.26. Water salinity of improved doruvu wells

S.No.	Particulars	EC_{iw} (dS/m)						Cropping pattern
		Oct, 2018	Nov, 2018	Dec, 2018	Jan, 2019	Feb, 2019	Mar, 2019	
1.	Satyavathipeta	1.0	0.9	0.8	0.9	1.0	1.5	Paddy, Vegetables
2.	Timmareddipalem	2.0	1.8	1.7	1.6	1.7	2.2	Chillies
3.	Rambotlavaripalem	0.7	0.6	0.8	1.1	1.3	2.1	Paddy, Groundnut
4.	P.V. Palem	1.9	1.9	2.3	2.5	2.5	4.0	Folder crops
5.	D.V. Palem	1.3	1.6	1.3	1.1	1.2	1.8	Fruit trees
6.	Forest Office	2.5	2.6	2.2	2.4	2.5	2.4	Nursery
7.	Agril. College Farm, Bapatla	2.2	1.9	1.9	1.7	1.8	2.5	Paddy, jowar

Table 2.27. Water salinity of shallow bore wells

S.No.	Particulars	EC_{iw} (dS/m)			Cropping pattern
		Jan, 2019	Feb, 2019	Mar,2019	
1.	Satyavathipeta	1.0	1.1	2.1	Chillies
2.	New Nandaipalem	4.0	4.2	6.2	Marigold, chillies
3.	Yazali	1.1	1.1	-	Chillies
4.	Timmareddy palem	2.2	2.6	3.6	Chillies
5.	Chandolu	1.9	2.1	2.8	Paddy, groundnut

The cropping pattern followed under improved doruvu wells / bore wells in low land fields is paddy-vegetables and paddy-groundnut. In upland sandy soils the cropping pattern under improved doruvu wells was Chillies, flower plants, nurseries and vegetable crops. The method of irrigation was flash watering / sprinkler irrigation.

2020

Nowadays, shallow tubewells are installed by the farmers instead of traditional doruvu or improved doruvu technology. Therefore, changes in pumped water quality with time are monitored for 7 improved doruvu and 10 bore wells. The cropping pattern, crop yield and net returns were monitored with these groundwater structures. The changes in pH and EC of pumped water for improved doruvu wells are given Table 2.28 and Table 2.29, respectively. The changes in pH and EC of pumped water for bore wells are given Table 2.30 and Table 2.31, respectively.

Table 2.28. pH of water in *doruvu* wells

S.No.	Jan, 20	Feb,20	June,20	July,20	Aug,20	Sept,20	Oct,20	Nov,20	Dec,20	Mean
1.	7.3	7.5	7.4	7.5	7.6	7.4	7.5	7.4	7.5	7.5
2.	7.6	7.6	7.4	7.5	7.5	7.6	7.4	7.5	7.6	7.5
3.	7.3	7.4	7.5	7.4	7.3	7.2	7.3	7.4	7.4	7.4
4.	7.5	7.5	7.5	7.6	7.2	7.5	7.6	7.2	7.5	7.4
5.	7.4	7.5	7.8	7.5	7.7	7.8	7.6	7.4	7.5	7.6
6.	7.6	7.6	7.8	7.6	7.8	7.8	7.5	7.4	7.6	7.6
7.	7.6	7.5	7.5	7.4	7.6	7.5	7.4	7.5	7.6	7.5
Mean	7.5	7.5	7.6	7.5	7.5	7.5	7.5	7.4	7.5	

Table 2.29. Water salinity (EC_{iw}) dS m^{-1} for *doruvu* wells

S.No.	Jan, 20	Feb,20	June,20	July,20	Aug,20	Sept,20	Oct,20	Nov,20	Dec,20	Mean
1.	1.4	1.9	1.4	2.0	2.0	2.1	2.0	1.9	1.8	1.9
2.	1.5	1.5	1.3	1.7	1.4	1.3	1.5	1.4	1.5	1.5
3.	2.3	1.8	2.0	2.1	1.9	1.6	1.5	1.3	1.7	1.8
4.	1.3	1.3	1.4	1.6	1.0	1.4	1.0	0.8	0.7	1.2
5.	4.0	3.7	2.8	2.1	2.0	2.3	2.5	2.7	3.1	2.8
6.	1.6	1.2	1.2	1.0	1.0	1.0	1.1	1.1	1.2	1.2
7.	1.5	1.6	1.5	1.7	1.5	1.8	1.6	1.5	1.5	1.6
Mean	1.9	1.9	1.7	1.7	1.5	1.6	1.6	1.5	1.6	

Table 2.30. pH of bore well waters

S.No.	Jan, 20	Feb,20	June,20	July,20	Aug,20	Sept,20	Oct,20	Nov,20	Dec,20	Mean
1.	7.8	7.5	-	7.6	7.4	7.6	7.7	7.6	7.2	7.6
2.	7.6	7.6	-	7.5	7.3	7.5	7.5	7.4	7.9	7.5
3.	8.1	8.0	-	7.8	-	-	7.8	7.6	7.5	7.8
4.	8.6	7.9	8.0	8.2	8.6	7.3	7.4	7.5	7.5	7.9
5.	7.7	8.4	8.2	7.8	7.7	7.0	7.3	7.5	7.6	7.7
6.	7.0	7.4	-	7.5	7.8	7.4	7.5	7.6	7.5	7.5
7.	7.1	7.5	-	-	-	-	7.2	7.2	7.4	7.3
8.	7.9	8.1	-	7.8	7.9	7.6	7.5	7.6	7.7	7.8
9.	8.0	-	-	7.7	7.8	7.7	7.7	7.8	7.7	7.8
10	8.0	7.9	8.2	7.5	7.5	7.6	7.9	7.7	7.5	7.8
Mean	7.8	7.8	8.1	7.7	7.8	7.5	7.6	7.6	7.6	

Table 2.31. Water salinity (EC_{iw}) dS m^{-1} of bore wells

S.No.	Jan, 20	Feb,20	June,20	July,20	Aug,20	Sept,20	Oct,20	Nov,20	Dec,20	Mean
1.	1.9	1.5	-	1.6	2.1	2.0	1.8	1.6	1.5	1.8
2.	1.9	1.6	-	1.5	2.0	1.6	1.4	1.5	2.0	1.7
3.	1.7	1.3	-	1.4	-	-	1.0	1.2	1.3	1.3
4.	5.8	4.9	5.8	5.0	6.1	5.9	4.5	4.7	4.7	5.3
5.	2.0	1.4	1.8	1.5	1.8	2.0	1.8	1.7	1.5	1.7
6.	2.3	1.9	-	2.0	2.0	2.2	2.1	1.8	1.6	2.0
7.	3.9	2.5	-	-	-	-	3.0	3.0	2.5	3.0
8.	4.1	4.0	-	4.2	4.1	4.3	4.5	4.4	4.5	4.3
9.	3.0	-	-	2.4	2.4	2.5	2.3	2.5	2.4	2.5
10	3.5	2.9	3.4	2.9	2.9	2.8	2.6	2.4	2.9	2.9
Mean	3.0	2.4	3.7	2.5	2.9	2.9	2.5	2.5	2.5	

The pumped water pH and EC for before and after pumping situations for few tube wells are given in Table 2.32.

Table 2.32. Output and water quality of bore wells before and after pumping

Bore well No.	Output (l/sec)	Before pumping		After pumping	
		pH	EC_{iw} (dSm^{-1})	pH	EC_{iw} (dSm^{-1})
4	3.0	7.5	4.7	7.7	4.8
9	2.8	7.7	2.4	7.8	2.4
10	3.0	7.5	2.9	7.8	2.9

The water quality in *doruvu* wells and shallow bore wells is monitored every month. In coastal sands, farmers used to grow paddy nursery groundnut, green chillies, leafy vegetables, vegetables and flower plants. Each farmer used to cultivate less than one acre by installing a shallow bore well at a depth of 20 ft. Two bore wells are installed at 3m distance from each other and connected to each other for harvesting more water. The water is pumped out by using 2HP motor. It takes 3-4 hours for giving irrigation to one acre area. Many of the farmers give irrigation through flash watering and some farmers are using sprinklers. The water quality in *doruvu* wells and bore wells was regularly monitored every month. Farmers used to give irrigation daily and operate the motor for 2.0 hours for giving irrigation to half acre land. The pH of *doruvu* well waters varied from 7.4 to 7.6 and salinity varied from 1.5 dSm^{-1} to 1.9 dSm^{-1} in different months starting from January to December, 2020. The pH and salinity of different *doruvu* wells varied from 7.4 to 7.6 and salinity varied from 1.2 to 1.9 dSm^{-1}. The pH and water salinity of 10 shallow bore wells during January, 2020 - December, 2020 varied from 7.5 to 8.1 and 2.4 dSm^{-1} to 3.7 dSm^{-1}, respectively. It is slightly higher than doruvu wells. These parameters are varied from 7.3 to 7.8 (pH) and 1.3 dSm^{-1} to 5.3 dSm^{-1} (water salinity) in different bore wells. The data indicated that improved doruvu is better technique for skimming of fresh water than shallow tubewells. Therefore, there is need to convince farmers and planners about improved doruvu technology.

The output and water quality before and after pumping was also monitored in shallow bore wells. The output was 3 l/sec. There was no much variation in water salinity before and after pumping. The net returns received with paddy nursery, chilli and groundnut were Rs. 35,000/-, Rs.20,000 and Rs. 30,000/- per acre, respectively.

- **Effect of saline irrigation water on growth, yield attributes and yield of Cumin through drip (Bikaner)**

This experiment was initiated during Rabi 2018-19 to study the effect of saline irrigation water on growth, yield attributes and yield of cumin through drip. The treatments comprised of four levels of ECiw (BAW, 2.4 dS/m, 6 dS/m and 8 dS/m). Results (Table 2.33) indicated that irrigation water salinity had significant effect on growth, yield attributes and yields of cumin. Increase in ECiw beyond 6 dS/m caused significantly drastic reduction in seed yield. As compared to ECiw of 0.25 (BAW) with ECiw 2.40, 6.0 and 8.0 dS/m caused reduction of 7.24, 9.82 and 34.37 per cent, respectively. Similar trends were noticed in all the parameters studied.

Table 2.33. Effect of water salinity on growth, yield attributes and yield of cumin

Treatments	Plant Height (cm)			Number of branches per plant			Test weight (g)			Seed yield (q/ha)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
BAW (EC 0.25 dS/m)	32.60	21.20	26.90	13.00	7.48	10.24	4.19	4.11	4.15	5.13	2.64	3.89
Tube-well water (EC 2.40 dS/m)	31.40	20.24	25.82	12.50	7.24	9.87	4.02	3.89	3.96	4.88	2.31	3.59
Saline water (EC 6.0 dS/m)	31.17	20.00	25.58	12.05	6.56	9.31	3.79	3.82	3.80	4.79	2.20	3.49
Saline water (EC 8.0 dS/m)	24.50	16.12	20.31	9.28	4.88	7.08	2.93	2.78	2.86	3.40	1.68	2.54
SEm±	0.58	0.52	0.39	0.32	0.33	0.23	0.16	0.17	0.12	0.12	0.15	0.10
CD (P=0.05%)	1.78	1.59	1.13	0.99	1.01	0.67	0.51	0.52	0.35	0.37	0.47	0.283

- **Influence of saline water and different micro-irrigation techniques on soil properties, yield and water use efficiency of tomato *(Solanum lycopersicum)* & simulation modeling (HYDRUS) in Tungabhadra Command Area (Gangavathi)**

2019

One of the major problems confronting irrigated agriculture nowadays throughout the world is the decreasing availability of fresh water. In many countries and regions, fresh water is relatively scarce, but there are considerable resources of saline water, which could be utilized for irrigation if proper crops, soil and water management practices were established. The use of poor quality water in crop production not only adversely affects crop yields in these areas but also leads to land degradation. Therefore, safe and efficient use of saline water for irrigation is to undertake appropriate practices to prevent the development of excessive soil salinization for crop production.

Drip irrigation has been shown to be the most useful irrigation technique when irrigating with saline water as it avoids the leaf injury to plants and improves the yield, water use efficiency and quality of vegetables. If irrigation can be managed in a way such that it provides high soil moisture content and consequently high soil water potential within the whole root zone then the osmotic effects could be masked. Moreover, when saline water is skillfully used for irrigation, it can be beneficial for agricultural production, particularly in fruits and vegetables.

Tomato (Solanum Lycopersicum), native of Peru-Ecuador-Bolivian area of South-America, is the most widely grown vegetable crop in the world as well as in India. It is one of the most popular and widely grown vegetable in the world ranking second in importance. During the last few years, irrigated tomato has been expanding rapidly in the semi-arid part of Karnataka around shallow to deep wells having a salinity of more than 2 dS/m with normal irrigation methods.

A field experiment was initiated to study the influence of saline water and different micro-irrigation techniques on soil properties, yield and water use efficiency of tomato *(Solanum lycopersicum)* &

simulation modeling (HYDRUS) in Tungabhadra Command area during late Rabi -2017-18 and continued during Rabi-2018-19 at Agricultural Research Station, Gangavathi (Table 2.34). The soil textural analysis through international pipette method revealed that the sand, silt and clay percentages were 33.6, 21.4 and 43.8 at 0-30 cm, 25.1, 26.7 and 47.3 at 30-60 cm and 17.5, 26.4 and 55.3 at 60-90 cm depths respectively and the texture of the soil is clay and textural class is fine clay. Initial soil salinity and pH of the soils were 0.92, 1.19 and 1.65 and 7.72, 7.78 and 7.88 at depths of 0-30 and 30-60 and 60-90 cm depths respectively. The bulk density of the plot was 1.26 gm/cc and field capacity was ranging from 29 to 33 %. The average infiltration rate of the soil was 2.18 mm/hr. The saturated hydraulic conductivity (ks) of the soil was 0.4, 0.9 and 1.4 cm/hr at 0-30, 30-60 and 60-90 cm depths.

Table 2.34. Details of the experiment

Crop	Tomato (Solanum Lycopersicum *L.*)	Nursery	December 2017
Variety/Hybrid	Lakshmi F_1 Hybrid	Date of Nursery	12-12-2017
Location	A.R.S Gangavathi	Date of Transplanting	17-01-2018
Soil	Clay	Sowing method	Single row
Number of treatments	16	Row spacing	120 cm
Number of replications	3	Plant spacing	40 cm
Design	Split plot	Dripper discharge	2.0 lph
Treatment size	3.6 m (w) x 15.2 m (L)	Dripper spacing	40 cm
Fertilizer & water soluble	60:46:60 kg NPK/ac-19:19:19 twice a week	Drip line –PC-Anti siphon	DNPC 2016 x 0.4x 2 lph
		Duration	120-140 days

The experiment was laid out in three replications with main treatments (Irrigation methods) such as furrow irrigation as control (M_0), surface drip (M_1), subsurface drip (M_2) and sub treatments (Irrigation water quality) such as normal water/BAW i.e. canal water (S_0), ECiw (Electric conductivity of irrigation water)-2 dS m^{-1} (S_1), ECiw-3 dS m^{-1}(S_2), ECiw-4 dS m^{-1}(S_3) and ECiw-5 dS m^{-1}(S_4) of saline water treatments. The tomato variety viz, Lakshmi F1 Hybrid (Nunhems Bayer Seeds Pvt.Ltd) transplanted during January-2018 in single row system (1.2 x 0.4 m). The 16 mm inline pressure compensated (PC) anti siphon drippers (dripnet) with emitter spacing of 0.4 m and discharge 2.0 LPH were selected and installed. For subsurface drip treatment, the inline lateral was buried in soil at a depth of 0.20 m facing emitters upward and collecting sub mains for flushing of laterals were given with vacuum breakers. Soil samples were collected randomly from the experimental plot before sowing for basic properties and distribution at 'Z' vertical direction to lateral i.e at emitter location (20 and 40 cm depth), 'Y' along the lateral direction (20 cm apart at 20 and 40 cm depth) and 'X' perpendicular to lateral direction (20 cm apart at 20 and 40 cm depth). According to the fertigation schedule, the soluble fertilizers were given through venturi as per the RDF (recommended dose of fertilizer) given by IHR, Bangalore. Soil moisture analysis was carried out at regular interval through Time-domine reflectometer (TDR). The experimental setup, irrigation and water quality analysis were as below:

Experimental setup consists of all accessories of drip irrigation *viz.*, pump, filters (primary and secondary), fertigation unit (venturi), mainline, sub main, lateral, inline dripper for surface and subsurface drip (emitter to emitter-0.4m and discharge-2 lph with pressure compensated drippers).
Water tanks of 2000 lit capacity were installed for preparation of five different EC levels of irrigation i.e. Normal, 2, 3, 4 and 5 dS/m respectively. Irrigation was applied only when soil metric potential at 0.2 m depth (measure with vacuum tensiometer, Irrometers) up to close -30 kPa soil moisture

tension (SMT), except at seedling and establishment stage. Quantity of irrigation will be applied at 100% ET level. EC, pH, SAR and RSC of irrigation water, after every filling up of the five tanks, were collected. The average water salinity of irrigation water after mixing sodium chloride (NaCl) in normal, 2, 3, 4 and 5 dS/m tanks were 0.65, 2.09, 3.24, 4.04 and 5.12 dS/m and average water pH of irrigation water tanks were 7.10, 7.15, 7.40, 7.43 and 7.50 respectively.

For plotting moisture distribution pattern, SURFER version 11.0 software was used. Different moisture distribution patterns for the main and sub treatments during 30, 60 and 90 DAT with average interval were drawn using co-ordinate techniques. This study was done to know the wetting pattern, moisture behavior and how the intervals are changing during crop growth period under different treatments. The moisture distribution diagrams depict the moisture movement along the lateral at different distances (0, 10 and 20 cm) with spatial and temporal under different treatments.

During first year, the highest water applied was at M_0S_0 (546.4 mm) followed by M_0S_1 (538.6 mm) and least at M_2S_4 (247.6 mm). As compared to control (M_0S_0) there was 41.0–45.7% and 46.3–54.7% saving of water in surface and subsurface drip from 0.65 dS m^{-1} to 5 dSm^{-1} saline water treatments respectively. In second year, the highest water applied was also at M_0S_0 (563.4 mm) followed by M_0S_1 (559.1 mm) and least at M_2S_4 (261.1 mm). There was 41.2 to 43.9% and 46.0 to 53.7% saving of water in surface and subsurface drip from 0.65 dS m^{-1} to 5 dS m^{-1} saline water treatments, respectively, as compared to control (M_0S_0). Thus the decreasing trend in the total water applied was observed as irrigation saline water level increases because of higher tension required by the plant to withdraw water from the soil due to high osmotic potential (Table 2.35).

Table 2.35. Total irrigation water applied under different treatments during first and second year

Sl. No	Treat-ments	Tensio-meters	First year (2018)				Second year (2019)			
			Effective Rainfall (mm)	Water applied during (mm)	Total water applied (mm)	Percent decrease over control (%)	Effective Rainfall (mm)	Water applied (mm)	Total water applied (mm)	Percent decrease over control (%)
1	M_0 S_0	T_{11}	0	546.4	546.4	-	5.76	557.6	563.4	-
2	M_0 S_1	T_7	0	538.6	538.6	1.4	5.76	553.3	559.1	0.8
3	M_0 S_2	T_3	0	531.1	531.1	2.8	5.76	544.5	550.3	2.3
4	M_0 S_3	T_{14}	0	529.1	529.1	3.2	5.76	538.6	544.4	3.4
5	M_0 S_4	T_5	0	519.4	519.4	4.9	5.76	527.7	533.5	5.3
6	M_1 S_0	T_6	0	322.4	322.4	41.0	5.76	325.4	331.2	41.2
7	M_1 S_1	T_2	0	315.8	315.8	42.2	5.76	321.7	327.5	41.9
8	M_1 S_2	T_{13}	0	307.6	307.6	43.7	5.76	315.8	321.6	42.9
9	M_1 S_3	T_9	0	302.4	302.4	44.7	5.76	312.2	318.0	43.6
10	M_1 S_4	T_{15}	0	296.8	296.8	45.7	5.76	310.1	315.9	43.9
11	M_2 S_0	T_1	0	293.6	293.6	46.3	5.76	298.5	304.3	46.0
12	M_2 S_1	T_{12}	0	280.6	280.6	48.6	5.76	284.8	290.6	48.4
13	M_2 S_2	T_8	0	270.1	270.1	50.6	5.76	278.6	284.4	49.5
14	M_2 S_3	T_4	0	253.9	253.9	53.5	5.76	262.5	268.3	52.4
15	M_2 S_4	T_{10}	0	247.6	247.6	54.7	5.76	255.3	261.1	53.7

Soil moisture distribution: Soil moisture at different depths was higher than field capacity after first day of irrigation (surface) at near, 10 and 20 cm distances away from the plant and decreased as days progressed under furrow irrigation technique. The soil moisture decreased to field capacity at

15 to 30 cm after eleven, ten and eight days after the irrigation during 30 DAT respectively. During this period, not much soil moisture difference was observed at near, 10 and 20 cm distances away from the plant.
In case of surface drip, soil moisture at different depths was higher than the field capacity after first day of irrigation near, 10 and 20 cm distances away from the dripper and slightly less in case of 60 cm depth. The soil moisture decreased below field capacity at 15 to 30 cm depth after two days during 30 DAT. During this period the soil moisture decreased both vertically downward and horizontally away from the dripper.

In case of subsurface drip irrigation technique, soil moisture at different depths was higher than field capacity after first day of irrigation near, 10 and 20 cm distances away from the buried dripper except at 5 cm depth where moisture was less because of drier surface. The soil moisture decreased below field capacity at 15 to 30 cm depth after three days during 30 DAT. Upward capillary movement of water was slightly low because of buried drip laterals at 20 cm depth. Soil moisture distribution uniformity in the root zone was better in this technique compared to surface and furrow irrigation. Water lost through evaporation from the soil surface would be less in case of subsurface drip irrigation.

Soil salinity (EC): Prior to imposition of treatments (Table 2.36), at plant/dripper point soil salinity varied from 0.58 (M_0S_1) to 1.02 (M_2S_1) and 0.72 (M_0S_2 and M_2S_3) to 1.41 (M_0S_3) at 0–15 and 15–30 cm depths respectively. At 10 cm away, soil salinity varied from 0.56 (M_2S_3) to 1.20 (M_0S_3) and 0.76 (M_0S_1) to 2.02 (M_0S_3) at 0–15 and 15–30 cm depth respectively. At 20 cm away, soil salinity varied from 0.54 (M_1S_0) to 1.27 (M_0S_3) and 0.64 (M_0S_0) to 1.36 (M_0S_3) at 0–15 and 15–30 cm depth respectively. Soil EC was slightly more at 15–30 cm compared to surface soil (0–15 cm) across the sampling position and depths.

Table 2.36. Soil salinity at different vertical depths (cm) in different irrigation techniques and irrigation salinity water treatments during before transplanting of first season crop

Sl. No.	Treatments	Soil salinity (dS m^{-1})at plant/ dripper location		Soil salinity (dS m^{-1}) at 10 cm away from plant/dripper location (horizontal)		Soil salinity (dS m^{-1}) at 20 cm away from plant/dripper location (horizontal)	
		0-15	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
1	M_0 S_0	0.77	0.96	0.82	0.85	0.72	0.64
2	M_0 S_1	0.58	1.26	0.64	0.76	0.58	1.10
3	M_0 S_2	0.67	0.72	0.69	0.84	0.75	0.98
4	M_0 S_3	0.95	1.41	1.20	2.02	1.27	1.36
5	M_0 S_4	0.85	1.17	0.72	0.82	0.98	0.87
6	M_1 S_0	0.64	1.04	0.69	0.90	0.54	0.84
7	M_1 S_1	0.74	0.93	0.72	0.88	0.87	1.07
8	M_1 S_2	0.59	0.82	0.63	0.93	0.98	1.14
9	M_1 S_3	0.82	1.19	0.85	1.17	1.01	1.21
10	M_1 S_4	0.85	1.14	0.77	1.22	0.86	0.97
11	M_2 S_0	0.77	0.88	0.74	0.88	0.64	0.87
12	M_2 S_1	1.02	1.11	0.99	1.08	1.05	1.12
13	M_2 S_2	0.69	0.82	0.85	0.94	1.07	1.15
14	M_2 S_3	0.61	0.72	0.56	0.90	0.83	1.18
15	M_2 S_4	0.99	1.08	1.01	1.20	1.09	1.15

After harvest of the first crop (Rabi 2017-18), at plant/dripper point, soil EC (**Table 2.37**) varied from 1.05 dS m^{-1} (M2S0) to 3.30 dS m^{-1} (M2S4), 1.04 dS m^{-1} (M1S0) to 2.44 dS m^{-1} (M1S4) and 1.98 dS m^{-1} (M0S0) to 5.15 dS m^{-1} (M_0S_4) at 0–15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. At 15–30 cm depth, soil EC varied from 0.87 dS m^{-1} (M_2S_0) to 2.0 dS m^{-1} (M_2S_4), 1.30 dS m^{-1} (M_1S_0) to 3.01 (M_1S_4) dS m^{-1} and 1.70 (M_0S_0) dS m^{-1} to 4.12 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. At 10 cm away, the soil EC varied from 1.14 dS m^{-1} (M_2S_0) to 3.98 dS m^{-1} (M_2S_4), 1.19 dS m^{-1} (M_1S_0) to 2.93 dS m^{-1} (M_1S_4) and 1.86 dS m^{-1} (M_0S_0) to 4.86 dS m^{-1} (M_0S_4) at 0–15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. At 15–30 cm depth, soil EC varied from 0.92 dS m^{-1} (M_2S_0) to 2.90 dS m^{-1} (M_2S_4), 1.38 (M_1S_0) dS m^{-1} to 3.34 dS m^{-1} (M_1S_4) and 1.65 dS m^{-1} (M_0S_0) to 4.42 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. At 20 cm away, the soil EC varied from 1.30 dS m^{-1} (M_2S_0) to 5.15 dS m^{-1} (M_2S_4), 1.28 dS m^{-1} (M_1S_0) to 4.30 dS m^{-1} (M_1S_4) and 1.75 dS m^{-1} (M_0S_0) to 4.54 dS m^{-1} (M_0S_4) at 0–15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. Soil EC varied from 1.10 dS m^{-1} (M_2S_0) to 3.34 dS m^{-1} (M_2S_4), 1.75 dS m^{-1} (M_1S_0) to 4.48 dS m^{-1} (M_1S_4) and 1.68 dS m^{-1} (M_0S_0) to 3.85 dS m^{-1} (M_0S_4) at 15–30 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. Among different treatment combination, M_0S_4 had (5.15 and 4.86 dS m^{-1}) higher soil EC at both depths compared to other treatment combinations. In comparison of EC near plant/dripper, 10 and 20 cm away at 0–15 cm depth, higher EC was observed near plant and lower at 20 cm away from the plant in furrow method. In surface drip, higher EC was observed at 20 cm away from the dripper and lower at dripper location. In subsurface drip, higher EC was observed at 20 cm away from the dripper and lower at buried dripper point. At 15–30 cm depth, higher EC was observed near the plant and lower at 20 cm away from the plant, higher at 20 cm away from the dripper and lower at the dripper location and higher at 20 cm away from the buried dripper and lower at the buried dripper under furrow, surface drip and subsurface drip irrigation methods respectively.

Table 2.37 Soil salinity in different irrigation techniques and irrigation salinity water treatments during after harvest of first season crop (Rabi 2017-18)

Sl. No.	Treatments	Soil salinity (dS m^{-1}) at plant/ dripper location		Soil salinity (dS m^{-1}) at 10 cm away from plant/dripper location (horizontal)		Soil salinity (dS m^{-1}) at 20 cm away from plant/dripper location (horizontal)	
		0-15	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
1	M_0 S_0	1.98	1.70	1.86	1.65	1.75	1.68
2	M_0 S_1	1.50	1.62	1.90	1.92	2.06	2.10
3	M_0 S_2	2.44	2.28	2.60	2.33	2.31	2.19
4	M_0 S_3	3.81	3.50	3.62	3.55	3.60	3.44
5	M_0 S_4	5.15	4.12	4.86	4.42	4.54	3.85
6	M_1 S_0	1.04	1.30	1.19	1.38	1.28	1.75
7	M_1 S_1	1.08	1.62	1.75	1.84	2.12	2.32
8	M_1 S_2	1.47	1.98	1.68	2.25	3.01	3.31
9	M_1 S_3	1.90	2.50	2.31	2.58	3.62	4.10
10	M_1 S_4	2.44	3.01	2.93	3.34	4.30	4.82
11	M_2 S_0	1.05	0.87	1.14	0.92	1.30	1.10
12	M_2 S_1	1.83	1.50	2.07	1.68	2.26	1.84
13	M_2 S_2	2.22	1.72	3.02	2.00	3.30	2.45
14	M_2 S_3	2.68	1.70	3.42	2.86	5.01	3.15
15	M_2 S_4	3.30	2.00	3.98	2.90	5.15	3.34

After harvest of the second crop (*Rabi* 2018-19), at plant/dripper point, soil EC (Table 2.38) varied from 1.31 dS m^{-1} (M_2S_0) to 3.49 dS m^{-1} (M_2S_4), 1.48 dS m^{-1} (M_1S_0) to 3.25 dS m^{-1} (M_1S_4) and 1.70 dS m^{-1} (M_0S_0) to 4.41 dS m^{-1} (M_0S_4) at 0–15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. At 15–30 cm depth, soil EC varied from 1.72 dS m^{-1} (M_2S_0) to 3.10 dS m^{-1} (M_2S_4), 1.56 dS m^{-1} (M_1S_0) to 3.85 (M_1S_4) dS m^{-1} and 1.96 (M_0S_0) dS m^{-1} to 5.27 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. At 10 cm away, the soil EC varied from 1.86 dS m^{-1} (M_2S_0) to 3.86 dS m^{-1} (M_2S_4), 0.66 dS m^{-1} (M_1S_0) to 3.98 dS m^{-1} (M_1S_4) and 1.86 dS m^{-1} (M_0S_0) to 5.01 dS m^{-1} (M_0S_4) at 0–15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. At 15–30 cm depth, soil EC varied from 1.32 dS m^{-1} (M_2S_0) to 2.20 dS m^{-1} (M_2S_4), 1.65 (M_1S_0) dS m^{-1} to 3.51 dS m^{-1} (M_1S_4) and 1.33 dS m^{-1} (M_0S_0) to 2.94 dS m^{-1} (M_0S_4) in subsurface drip, surface drip and furrow methods of irrigation respectively. At 20 cm away, the soil EC varied from 2.07 dS m^{-1} (M_2S_0) to 4.55 dS m^{-1} (M_2S_4), 0.80 dS m^{-1} (M_1S_0) to 4.13 dS m^{-1} (M_1S_4) and 2.23 dS m^{-1} (M_0S_0) to 4.95 dS m^{-1} (M_0S_4) at 0–15 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. Soil EC varied from 0.71 dS m^{-1} (M_2S_0) to 2.98 dS m^{-1} (M_2S_4), 2.18 dS m^{-1} (M_1S_0) to 3.96 dS m^{-1} (M_1S_4) and 1.10 dS m^{-1} (M_0S_0) to 4.55 dS m^{-1} (M_0S_3) at 15–30 cm depth in subsurface drip, surface drip and furrow methods of irrigation respectively. Among different treatment combination, M_0S_4 had (5.27 and 5.01 dS m^{-1}) higher soil EC at both depths compared to other treatment combinations.

Table 2.38: Soil salinity in different irrigation techniques and irrigation salinity water treatments during after harvest of second season crop (Rabi 2018-19)

Sl. No.	Treatments	Soil salinity (dS m^{-1}) at plant /dripper location		Soil salinity (dS m^{-1}) at 10 cm away from plant /dripper location (horizontal)		Soil salinity (dS m^{-1}) at 20 cm away from plant/dripper location (horizontal)	
		0-15	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
1	M_0 S_0	1.70	1.96	1.86	1.33	2.23	1.10
2	M_0 S_1	2.05	2.18	2.84	3.75	2.94	4.52
3	M_0 S_2	2.39	3.00	3.58	3.21	4.02	3.72
4	M_0 S_3	3.18	3.6	4.51	3.80	4.89	4.55
5	M_0 S_4	4.41	5.27	5.01	2.94	4.95	3.48
6	M_1 S_0	1.48	1.56	0.66	1.65	0.80	2.18
7	M_1 S_1	1.56	1.92	2.10	2.71	2.93	4.09
8	M_1 S_2	2.08	2.95	2.98	2.56	3.19	3.56
9	M_1 S_3	2.50	3.10	3.14	3.24	3.58	3.55
10	M_1 S_4	3.25	3.85	3.98	3.51	4.13	3.96
11	M_2 S_0	1.31	1.72	1.86	1.30	2.07	0.71
12	M_2 S_1	2.40	2.35	2.21	1.28	2.33	1.33
13	M_2 S_2	2.74	2.61	2.31	2.69	5.05	3.11
14	M_2 S_3	3.20	3.10	3.37	0.56	4.22	0.77
15	M_2 S_4	3.49	3.10	3.86	2.20	4.55	2.98

More salts were accumulated in furrow irrigation near the plant and horizontal distances at a depth of 0–15 and 15–30 cm. Because of this, the growth of the plant was hindered due to higher osmotic potential and its effects were seen in the yield. In case of surface drip, more salt were present at 20 cm distance away from the dripper at a depth of 0–15 and 15–30 cm. This was mainly due to application of water on to the surface thus more salt were accumulated on the periphery of the water front outside the dripper. Measurement of soil salinity showed that less salt accumulation near the plant as compared to furrow irrigation. In case of subsurface drip irrigation, accumulation of salts was more at the soil surface but it was lesser near and below the buried dripper. Due to upward capillary action, more salts were accumulated on the top surfaces and at periphery of the water front outside the root zone of the crop. As the salinity was low below the root zone the growth and yields observed were good at subsurface drip irrigation. Subsurface drip irrigation probably helped in leaching out of the salts below 20 cm depth. Measurement of soil salinity showed that less salt accumulation at root zone as compared to surface drip irrigation. According to the moisture profile for each case examined, it can be concluded that subsurface drip maintains continuous soil leaching not only downwards, but also upward and radially.

Tomato Yield: There were not much difference either in the marketable yield or total yield of tomato between the years of respective different irrigation methods and different levels of saline water irrigation (Table 2.39).

Table 2.39: Yield parameters of tomato as influenced by irrigation techniques and saline water

Treatment details	Marketable yield (t ha^{-1})			Total yield (t ha^{-1})			Percent changes over control
	2018	2019	Pooled	2018	2019	Pooled	
Irrigation techniques (M)							
M_0	17.16	17.00	17.08	20.43	20.33	20.38	-
M_1	23.63	24.01	23.82	26.57	26.77	26.67	+30.9
M_2	24.10	24.43	24.27	26.99	27.61	27.30	+34.0
SE m $\pm$	0.24	0.27	0.25	0.25	0.31	0.26	
C.D (p=0.05)	0.69	0.78	0.73	0.73	0.89	0.76	
Irrigation saline water levels (S)							
S_0	25.97	27.02	26.49	28.91	30.26	29.59	-
S_1	24.80	26.08	25.44	27.84	29.00	28.42	-3.96
S_2	21.58	21.13	21.35	24.57	24.24	24.40	-17.53
S_3	19.35	18.86	19.11	22.37	21.94	22.15	-25.13
S_4	16.47	15.96	16.22	19.62	19.07	19.34	-34.63
SE m $\pm$	0.44	0.57	0.49	0.48	0.57	0.50	
C.D (p=0.05)	1.28	1.63	1.41	1.37	1.63	1.44	
Interaction (MxS)							
$M_0 S_0$	20.83	21.25	21.04	23.90	24.58	24.24	-
$M_0 S_1$	19.93	20.34	20.14	23.37	23.67	23.52	-2.97
$M_0 S_2$	16.92	16.44	16.68	20.09	19.77	19.93	-17.78
$M_0 S_3$	15.93	15.13	15.53	19.13	18.46	18.79	-22.47
$M_0 S_4$	12.18	11.83	12.01	15.65	15.16	15.40	-36.45
$M_1 S_0$	28.37	29.72	29.04	31.33	32.98	32.16	+32.67
$M_1 S_1$	27.11	28.75	27.93	29.97	31.10	30.54	+25.98
$M_1 S_2$	23.58	23.25	23.42	26.50	26.25	26.38	+8.81
$M_1 S_3$	20.87	20.47	20.67	23.80	23.24	23.52	-2.98
$M_1 S_4$	18.25	17.84	18.05	21.23	20.27	20.75	-14.40
$M_2 S_0$	28.70	30.09	29.39	31.50	33.21	32.36	+33.48
$M_2 S_1$	27.35	29.15	28.25	30.18	32.21	31.20	+28.70
$M_2 S_2$	24.24	23.69	23.97	27.11	26.69	26.90	+10.99
$M_2 S_3$	21.26	21.00	21.13	24.17	24.13	24.15	-0.36
$M_2 S_4$	18.97	18.22	18.60	21.97	21.78	21.88	-9.74
SE m $\pm$	1.33	1.70	1.47	1.43	1.70	1.50	
C.D (p=0.05)	NS	NS	NS	NS	NS	NS	

Among different irrigation techniques, the total yield was significantly higher under subsurface drip (M_2-27.00 & 27.61 t ha^{-1}) compared to furrow irrigation (M_0-20.43 & 20.33 t ha^{-1}), but on par with surface drip irrigation (M_1-26.57 & 26.67 t ha^{-1}) in 2018 and 2019 seasons, respectively. The pooled data shows that the highest total yield of 27.30 t ha^{-1} was obtained in subsurface drip followed by surface drip irrigation (26.67 t ha^{-1}) and lowest under furrow irrigation (20.38 t ha^{-1}) technique. Among the different saline water irrigation, the maximum total yield was significantly higher (28.91 & 30.26 t ha^{-1}) under S_0 (0.65 dS m^{-1}) compared S_2, S_3 and S_4 but on par with S_1 (2 dS m^{-1}) (27.84 & 29.0 t ha^{-1}) during 2018 and 2019 seasons respectively. The pooled data shows highest total yield of 29.59 followed by 28.42 t ha^{-1} in 0.65 dS m^{-1} and 2 dS m^{-1} salinity irrigation water which are on par with each other. Interaction effects were non-significant for both marketable and total yield of tomato in both the years.

From the study it was seen that, in case of surface drip and subsurface drip irrigation techniques there was 30.9 and 34.0 per cent increase in the total (pooled of two season) yield as compared to furrow technique (control). There was 3.96, 17.53, 25.13 and 34.63 per cent reduction in the total pooled yield in case of 2, 3, 4 and 5 dS m^{-1} respectively as compared to 0.65 dS m^{-1} (Control) treatment. In case of interaction, the subsurface drip and (M_2S_0) and surface drip with 0.65 dS m^{-1} (M_1S_0) recorded 33.48 and 32.67 per cent higher yield followed by subsurface drip with 2 dS m^{-1} (M_2S_1) and surface drip (M_1S_1) with 2 dS m^{-1} (28.70 and 25.98 per cent) as compared to control method (M_0S_0). In case of ECiw -2 dS m^{-1}, the surface and subsurface drip gave the best result. The maximum yield under this treatment was reduced only by 5.03 and 3.58% as compared to normal water under surface and subsurface drip irrigation respectvely. It was found that every 1 dS m^{-1} increase in salinity yield was reduced to the extent of 9–10% in all types of irrigation methodology.

Water use efficiency:

The pooled data of water use efficiency (WUE) of two seasons showed that (Table 2.40), among irrigation techniques, significantly higher WUE of 98.65 kg ha^{-1}mm^{-1} was recorded in subsurface drip irrigation compared to surface drip (84.20 kg ha^{-1}mm^{-1}) and furrow irrigation (37.55 kg ha^{-1}mm^{-1}) techniques. Among irrigation saline water levels, significantly higher WUE (83.43 kg ha^{-1}mm^{-1}) was recorded at 0.65 dSm^{-1} followed by 2 dSm^{-1} (82.34 kg ha^{-1}mm^{-1}), 3 dS m^{-1} (72.63 dS m^{-1}), 4 dS m^{-1} (67.83 kg ha^{-1}mm^{-1}) and least in case of 5 dS m^{-1} (61.07 kg ha^{-1}mm^{-1}). On par result was obtained between 0.65 and 2 dS m^{-1} treatment.

Decreased WUE with the increased irrigation saline water level was noted. The interaction effect between irrigation methods and levels was found non-significant. The maximum WUE was under subsurface drip irrigation because of the lesser water requirement during growing season and higher yield. The water use efficiency decreased with increase in salinity level of irrigation water as it recorded lower yield. This may be due to less evaporation of water under this technique.

Economic analysis:

The minimum payback period (0.524) was obtained under surface drip irrigation (Table 2.41) with 0.65 dS m^{-1} followed by subsurface drip irrigation (0.544) with 0.65 dS m^{-1}, surface drip irrigation with 2 dSm^{-1} and subsurface drip irrigation with 2 dSm^{-1} treatment and maximum under subsurface drip with 5 dSm^{-1} treatment (0.779). The highest benefit cost ratio of 1.84 was obtained under subsurface drip irrigation in normal irrigation (0.65 dSm^{-1}) water followed by surface drip irrigation (1.80), subsurface drip in 2 dSm^{-1} irrigation saline water level (1.78), surface drip irrigation in 2 dSm^{-1} irrigation saline water level (1.69) and lowest (1.06) in furrow irrigation technique in 5 dSm^{-1} treatment.

Table 2.40: Water use efficiency of tomato as influenced by different irrigation techniques and saline water

Treatment details	Water use efficiency (kg ha^{-1}mm^{-1})		
	2018	2019	Pooled
Irrigation techniques (M)			
M_0	38.24	36.85	37.55
M_1	85.70	82.69	84.20
M_2	99.84	97.46	98.65
SE m +	0.79	1.02	0.86
C.D (p=0.05)	2.29	2.93	2.48
Irrigation saline water levels (S)			
S_0	82.74	84.13	83.43
S_1	81.95	82.73	82.34
S_2	74.78	70.48	72.63
S_3	70.02	65.65	67.83
S_4	63.47	58.67	61.07
SE m +	1.47	1.72	1.53
C.D (*p=0.05*)	4.23	4.96	4.41
Interaction (MxS)			
M_0 S_0	43.74	43.64	43.69
M_0 S_1	43.38	42.34	42.86
M_0 S_2	37.82	35.93	36.88
M_0 S_3	36.15	33.91	35.03
M_0 S_4	30.12	28.42	29.27
M_1 S_0	97.19	99.60	98.39
M_1 S_1	94.91	94.98	94.95
M_1 S_2	86.15	81.64	83.89
M_1 S_3	78.70	73.08	75.89
M_1 S_4	71.54	64.16	67.85
M_2 S_0	107.29	109.15	108.22
M_2 S_1	107.56	110.87	109.21
M_2 S_2	100.38	93.87	97.13
M_2 S_3	95.21	89.95	92.58
M_2 S_4	88.75	83.44	86.10
SE m +	4.40	5.17	4.59
C.D *(p=0.05)*	NS	NS	NS

The maximum net present worth of Rs₹. 995344 was obtained under subsurface drip irrigation in normal irrigation (0.65 dSm^{-1}) water followed by surface drip irrigation in normal irrigation (0.65 dSm^{-1}) water (₹. 957831), subsurface drip in 2 dSm^{-1} irrigation saline water level (₹. 920650), surface drip irrigation in 2 dSm^{-1} irrigation saline water level (₹. 832542) and lowest (₹. 52618) in furrow irrigation technique in

5 dSm^{-1} treatment. The highest internal rate of return of 350 percentages was obtained under furrow irrigation in normal irrigation (0.65 dSm^{-1}) water followed by furrow irrigation in 2 dSm^{-1} and lowest in case of subsurface drip irrigation in 5 dSm^{-1} treatment. Among surface drip irrigation under different salinity levels, highest IRR was found in normal irrigation (0.65 dSm^{-1}) water followed by 2 dSm^{-1} treatment and lowest in 5 dSm^{-1}. Among subsurface drip irrigation under different salinity levels, highest IRR was found in normal irrigation water followed by 2 dSm^{-1} treatment and lowest in 5 dSm^{-1}. This was mainly because of high investment cost incurred for establishing the drip irrigation system during initial period.

In northern dry semi arid zone no III, when there is not enough fresh or normal water available for irrigation, irrigation water with salinity of 2 dSm^{-1} can be used as a safe alternative water source to irrigate tomato field without any harmful effect to the soil with surface and/or subsurface drip irrigation technique.

Table 2.41 Economic feasibility of tomato under different irrigation techniques and saline water

Sl.No.	Treatments	B/C ratio	NPW (Rs.)	IRR (%)	Payback period
1	$M_0 S_0$	1.70	664051	350.0	-
2	$M_0 S_1$	1.64	607368	330.0	-
3	$M_0 S_2$	1.37	355438	199.5	-
4	$M_0 S_3$	1.29	272081	156.0	-
5	$M_0 S_4$	1.06	52618	40.0	-
6	$M_1 S_0$	1.80	957831	104.9	0.524
7	$M_1 S_1$	1.69	832542	94.6	0.548
8	$M_1 S_2$	1.43	524681	67.6	0.620
9	$M_1 S_3$	1.27	328738	47.9	0.690
10	$M_1 S_4$	1.11	136239	28.9	0.774
11	$M_2 S_0$	1.84	995344	104.5	0.544
12	$M_2 S_1$	1.78	920650	99.2	0.567
13	$M_2 S_2$	1.49	578112	69.7	0.632
14	$M_2 S_3$	1.34	405719	54.3	0.709
15	$M_2 S_4$	1.21	251915	39.3	0.779

- **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 and wheat crop when irrigated with saline water of EC 8 dS/m along with different levels of recommended doses of fertilizer. Seed of both the crop were treated with the microbial cultures '*Azotobacter ST-3* and *Biomix* at the time of sowing. Recommended cultural practices and fertilizer doses were applied for raising the crops. Treatment details are giving below. Treatments were 75% RDF; RDF; 75% RDF + *Azotobacter* ST-3; RDF + *Azotobacter* ST-3; 75% RDF + 2.5 t/ha biogas slurry + *Azotobacter* ST-3; RDF + 2.5 t/ha biogas slurry + *Azotobacter* ST-3; 75% RDF + 2.5 t/ha Vermicompost + *Azotobacter* ST-3; RDF + 2.5 t/ha Vermicompost + *Azotobacter* ST-3; 75% RDF + 10 t/ha FYM + Biomix ; RDF + 10 t/ha FYM + Biomix ; 75% RDF + 2.5 t/ha Vermicompost + Biomix and RDF + 2.5 t/ha Vermicompost + Biomix.

2018-19

The details of the experiment are given in Table 2.42. The crops were harvested at maturity and yield data were recorded for each plot.

Table 2.42: Experiments details for Pearl millet and wheat crop

Operation	Pearl millet	Wheat crop
Date of sowing	24.06.2017	20.11.2017
Variety	HHB 223	WH 1105
Fertilizers dose (kg/ha)		
Nitrogen	156.2	150
Phosphorus	62.5	60
Zinc sulphate	25	25
No. of irrigations including pre-sowing	1	5
Date of harvesting	12.10.2018	18.04.2018

Pearl millet: The grain and stover yield (29.54 and 85.52 q/ha) of pearl millet was obtained with RDF + FYM 10 t/ha + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (29.52 and 84.75 q/ha) Table 2.43. The minimum grain and stover yield (24.22 and 68.15 q/ha) was recorded with 75% RDF alone. The maximum plant height (203.90 cm), yield attributes viz., effective tillers/plant (3.03), earhead length (22.73cm) Table 2.44

Wheat : The maximum grain and straw yield (53.13 and 83.38 q/ha) of wheat (WH 1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (53.02 and 82.72 q /ha).The minimum grain and straw yield (44.77and 69.67 q/ha) was recorded with 75% RDF alone (Table 2.45).

Table 2.43 Effect of various treatments on grain and stover yield (q/ha) of pearl millet under saline water irrigation

Treatment	**Grain**	**Stover**
75% RDF	24.22	68.15
RDF	26.46	75.48
75% RDF +ST-3	24.52	69.01
RDF +ST-3	26.70	76.48
75% RDF +2.5t/ha biogas slurry + ST-3	27.74	80.54
RDF +2.5t/ha biogas slurry + ST-3	27.97	80.73
75% RDF + 2.5t/ha Vermicompost + ST-3	28.04	79.63
RDF + 2.5t/ha Vermicompost + ST-3	28.59	83.35
75% RDF + 10t/ha FYM + Biomix	29.44	84.53
RDF + 10t/ha FYM + Biomix	29.54	85.52
75% RDF + 2.5t/ha Vermicompost + Biomix	28.15	81.00
RDF + 2.5t/ha Vermicompost + Biomix	29.52	84.75
CD (p=0.05)	**1.90**	**6.47**

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%

Table 2.44 Effect of various treatments on yield attributes of pearl millet under saline water irrigation

Treatments (Pearl millet)	Plant height at maturity (cm)	No. of effective tillers/plant	Earhead length (cm)
75% RDF	182.29	1.98	20.31
RDF	196.63	2.58	21.36
75% RDF +ST-3	188.33	2.14	20.32
RDF +ST-3	197.23	2.68	21.37
75% RDF +2.5t/ha biogas slurry + ST-3	192.77	2.43	21.87
RDF +2.5t/ha biogas slurry + ST-3	198.20	2.93	21.58
75% RDF + 2.5t/ha Vermicompost + ST-3	190.17	2.33	21.57
RDF + 2.5t/ha Vermicompost + ST-3	198.70	2.86	21.97
75% RDF + 10t/ha FYM + Biomix	191.93	2.62	21.68
RDF + 10t/ha FYM + Biomix	203.90	3.03	22.73
75% RDF + 2.5t/ha Vermicompost + Biomix	191.03	2.48	21.53
RDF + 2.5t/ha Vermicompost + Biomix	199.67	2.88	22.63
CD (p=0.05)	7.39	0.36	NS

Table 2.45. Effect of various treatments on grain and straw yield (q/ha) of wheat under saline water irrigation

Treatment	Grain	Straw
75% RDF	44.77	69.67
RDF	49.46	77.97
75% RDF +ST-3	45.52	70.47
RDF +ST-3	49.95	78.78
75% RDF +2.5t/ha biogas slurry + ST-3	50.81	79.58
RDF +2.5t/ha biogas slurry + ST-3	52.29	81.81
75% RDF + 2.5t/ha Vermicompost + ST-3	51.92	82.52
RDF + 2.5t/ha Vermicompost + ST-3	52.97	82.67
75% RDF + 10t/ha FYM + Biomix	52.05	82.27
RDF + 10t/ha FYM + Biomix	53.13	83.38
75% RDF + 2.5t/ha Vermicompost + Biomix	52.17	82.59
RDF + 2.5t/ha Vermicompost + Biomix	53.02	82.72
CD (p=0.05)	5.35	8.85

2019-20

The details of the experiment are given in Table 2.46. The crops were harvested at maturity and yield data were recorded for each plot.

Table 2.46: Experiments details for Pearl millet and wheat crop

Operation	Pearl millet	Wheat crop
Date of sowing	22.06.2019	26.11.2019
Variety	HHB 223	WH 1105
Fertilizers dose (Kg/ha)		
Nitrogen	156.2	150
Phosphorus	62.5	60
Zinc sulphate	25	25
No. of irrigations including pre-sowing	1	5
Date of harvesting	08.10.2019	15.04.2020

Pearl millet: The highest grain and stover yield (29.76 and 86.16 q/ha) of pearl millet was obtained with RDF + FYM 10 t/ha + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (29.70 and 85.26 q/ha). The lowest grain and stover yield (24.68 and 69.48 q/ha) was recorded with 75% RDF alone. The maximum plant height (209.78 cm), yield attributes viz., effective tillers/plant (2.89), earhead length (23.132cm) was observed in treatment RDF + FYM 10 t/ha + Biomix (Table 2.47 and 2.48).

Table 2.47: Effect of various treatments on grain and stover yield (q/ha) of pearl millet under saline water irrigation

Treatment	Grain	Stover
75% RDF	24.68	69.48
RDF	26.90	76.73
75% RDF +ST-3	24.97	70.26
RDF +ST-3	27.06	77.41
75% RDF +2.5t/ha biogas slurry + ST-3	28.07	81.48
RDF +2.5t/ha biogas slurry + ST-3	28.27	81.59
75% RDF + 2.5t/ha Vermicompost + ST-3	28.32	80.42
RDF + 2.5t/ha Vermicompost + ST-3	28.82	84.04
75% RDF + 10t/ha FYM + Biomix	29.65	85.14
RDF + 10t/ha FYM + Biomix	29.76	86.16
75% RDF + 2.5t/ha Vermicompost + Biomix	28.40	81.70
RDF + 2.5t/ha Vermicompost + Biomix	29.70	85.26
CD (p=0.05)	**2.50**	**7.32**

ST-3= *Azotobacter chrococuum,* Biomix = *Azotobacter chrococuum* (Mac27) + *Azospirillum* + PSB

Composition of biogas slurry: N=1.70%, P=1.18%, K=1.62%, FYM: N=0.70%, P=0.49%, K=1.05%, Vermicompost: N=1.62%, P=0.83%, K=1.09%

Table 2.48: Effect of various treatments on yield attributes of pearl millet under saline water irrigation

Treatments (Pearl millet)	Plant height at maturity (cm)	No. of effective tillers/plant	Earhead length (cm)
75% RDF	187.37	1.65	20.84
RDF	198.59	1.81	21.93
75% RDF +ST-3	192.16	1.76	20.82
RDF +ST-3	201.53	2.01	21.87
75% RDF +2.5t/ha biogas slurry + ST-3	196.89	2.09	21.70
RDF +2.5t/ha biogas slurry + ST-3	203.08	2.19	22.08
75% RDF + 2.5t/ha Vermicompost + ST-3	193.64	2.28	22.07
RDF + 2.5t/ha Vermicompost + ST-3	203.57	2.56	22.47
75% RDF + 10t/ha FYM + Biomix	196.74	2.76	22.18
RDF + 10t/ha FYM + Biomix	209.78	2.89	23.13
75% RDF + 2.5t/ha Vermicompost + Biomix	195.85	2.43	22.03
RDF + 2.5t/ha Vermicompost + Biomix	205.66	2.79	23.23
CD (p=0.05)	8.80	0.45	NS

Wheat: The highest grain and straw yield (53.99 and 89.09 q/ha) of wheat (WH 1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (53.24 and 86.24 q /ha).The lowest grain and straw yield (46.47and 68.97 q/ha) was recorded with 75% RDF alone (Table 2.49).

Table 2.49: Effect of various treatments on grain and straw yield (q/ha) of wheat under saline water irrigation

Treatment	Grain	Straw
75% RDF	46.47	68.97
RDF	50.20	75.31
75% RDF +ST-3	47.05	70.11
RDF +ST-3	50.60	76.41
75% RDF +2.5t/ha biogas slurry + ST-3	51.14	77.73
RDF +2.5t/ha biogas slurry + ST-3	52.51	83.49
75% RDF + 2.5t/ha Vermicompost + ST-3	52.11	80.77
RDF + 2.5t/ha Vermicompost + ST-3	53.14	85.03
75% RDF + 10t/ha FYM + Biomix	52.26	82.05
RDF + 10t/ha FYM + Biomix	53.99	89.08
75% RDF + 2.5t/ha Vermicompost + Biomix	52.40	82.78
RDF + 2.5t/ha Vermicompost + Biomix	53.24	86.24
CD (p=0.05)	4.54	7.32

- **Evaluation of sewage sludge as a source of NPK for pearl millet wheat rotation irrigated with saline water (Hisar)**

2019

Investigations on possible use of sewage sludge and canal/saline water on growth and yield of wheat crop at Soil Science Department farm, CCSHAU, Hisar. Wheat in *rabi* season was grown in plots of size 4.5 m x 4.5 m. Treatments were replicated thrice in the split plot design. Each micro-plot was separated by buffer of 1 m width from all sides to arrest the horizontal movement of water and salts from the adjoining plot. Treatment details are as below (Table 2.50).

Table 2.50: Details of experiments

a. Quality of irrigation water: 3
- Canal water
- Saline water (8 dS/m)
- Saline water (10 dS/m)

b. Sewage sludge application levels: 4
- Sewage sludge 5 t ha^{-1}
- Sewage sludge, 5 t ha^{-1} + 50% RDF
- Sewage sludge, 5 t ha^{-1} + 75% RDF
- RDF

- **Crop:** Pearl millet-Wheat
- **Design** : RBD
- **Replications** : Three

Pearl millet: The grain yield of pearl millet (HHB 226) decreased by 27.25 and 35.54 % in all saline irrigation of 8 and 10 dS/m as compared to canal irrigation. A reduction of 19.36, 9.8 and 4.37% in mean grain yield of pearl millet was observed in treatment sewage sludge 5 t/ha (alone), sewage sludge 5t/ha + 50% RDF and sewage sludge 5t/ha + 75% RDF as compared with RDF (Table 2.51).

***Wheat**:* The mean grain yield of wheat (WH 1105) decreased by 26.83 and 36.23% in all saline irrigation 8 and 10 dS/m as compared to canal irrigation. Reduction of 32.60, 15.49 and 5.75 % in grain yield of wheat was observed in treatments sewage sludge 5t/ha (alone), sewage sludge 5t/ha + 50% RDF and sewage sludge 5t/ha + 75% RDF as compared with RDF (Table 2.52). The mean salinity in the soil profile at the time of harvest of wheat varied between 2.95 (0-15 cm) to 13.01(0-15 cm) dS/m in canal water to the highest EC irrigating water plot (Table 2.53).

Table 2.51. Effect of sewage sludge on grain yield (q/ha) of pearl millet irrigated with saline water of different salinity

Treatment	**Canal (0.3 dS/m)**	**EC 8.0 (dS/m)**	**EC 10.0 (dS/m)**	**Mean**
Sewage sludge 5t/ha	27.20	19.89	17.62	21.57
Sewage sludge 5t/ha+50% RDF	30.80	21.94	19.61	24.12
Sewage sludge 5t/ha+75% RDF	32.60	23.74	20.39	25.58
RDF	33.57	24.76	21.92	26.75
Mean	31.04	22.58	19.88	
CD (p=0.05) Treatment (T) = 3.09, Salinity (S)= 2.70, T x S = NS				

Composition of sewage sludge: N=1.36 %, P = 0.62 %, K = 0.60 %, Pb = 28.41 ppm, Cd = 1.4 ppm, Cr = 9.9 ppm

Table 2.52. Effect of sewage sludge on grain yield (q/ha) of wheat irrigated with saline water of different salinity

Treatment	**Canal (0.3 dS/m)**	**EC 8.0 (dS/m)**	**EC 10.0 (dS/m)**	**Mean**
Sewage sludge 5t/ha	34.16	23.87	20.65	26.23
Sewage sludge 5t/ha+50% RDF	41.99	30.44	26.24	32.89
Sewage sludge 5t/ha+75% RDF	46.18	34.05	29.81	36.68
RDF	48.25	36.45	32.06	38.92
Mean	42.64	31.20	27.19	
CD (p=0.05): Treatment (T) = 3.56, Salinity (S)= 3.08 T x S = NS				

Table 2.53. ECe (dS/m) of the soil at different depths (0-15cm) after harvest of wheat in different treatment plots

Treatment	**Canal (0.3 dS/m)**	**EC 8.0 (dS/m)**	**EC 10.0 (dS/m)**
Sewage sludge 5t/ha	3.30	12.08	13.61
Sewage sludge 5t/ha+50% RDF	3.10	11.18	13.34
Sewage sludge 5t/ha+75% RDF	2.92	10.95	12.92
RDF	2.46	10.30	12.16
Mean	2.95	11.13	13.01

Organic carbon (%): The data (Table 2.54) indicated that soil organic carbon has been significantly affected by the application of sewage sludge and saline water irrigation. Soil organic carbon was significantly reduced with saline water irrigation and significantly higher mean soil organic carbon content was obtained with canal water irrigation *i.e.* 0.41 % being at par with 8 dS/m of saline water irrigation (0.40 %) and lowest was obtained with EC_{iw} 10 dS/m (0.39 %). Among treatments, the significantly higher mean soil carbon content was obtained with SS (5 t/ha) + 75% RDF and SS (5 t/ha) + 50% and SS (5 t/ha). The interaction effect of sewage sludge and saline water irrigation was however non significant.

Table 2.54. Effect of various treatments on soil organic carbon (%) different quality of irrigation water

Treatment	**0.3 dS/m (Canal)**	**EC 8.0 (dS/m)**	**EC 10.0 (dS/m)**
Sewage sludge 5t/ha	0.42	0.41	0.40
Sewage sludge 5t/ha+50% RDF	0.44	0.42	0.42
Sewage sludge 5t/ha+75% RDF	0.45	0.43	0.42
RDF	0.34	0.32	0.31
Mean	0.41	0.40	0.39
CD (*p= 0.05*): Irrigation- 0.018; Treatment- 0.021; Irrigation x Treatment- NS			

Available nitrogen (kg/ha): The perusal of data revealed that available nitrogen in soil was significantly affected by the application saline water irrigation (Table 2.55) and significantly higher mean available nitrogen was obtained with canal water irrigation *i.e.* 123.16 kg/ha and lowest mean available nitrogen (105.10 kg/ha) was recorded with 10 dS/m EC of saline water irrigation. Among treatments, the mean soil available nitrogen differs non-significantly with sewage sludge application the maximum available nitrogen (133.4 kg/ha) was observed in treatment SS (5 t/ha) +75% RDF followed by RDF (123.6 kg/ha) and lowest (116.5 kg/ha) was observed in treatment SS (5 t/ha). The interaction effect of sewage sludge and saline water irrigation was non- significant.

Table 2.55. Effect of various treatments on available N, P, K and S in soil under different quality of irrigation water

Available nitrogen (kg/ha)				
Treatment	Irrigation water quality			Mean
	Canal	8 dS/m	10 dS/m	
SS (5 t/ha)	116.5	101.4	100.0	105.97
SS (5 t/ha)+50% RDF	119.2	104.6	102.0	108.60
SS (5 t/ha)+75% RDF	133.4	114.5	111.4	119.75
RDF	123.6	109.3	107.0	113.30
Mean	123.16	107.45	105.10	
CD (p= 0.05): Irrigation- 9.41; Treatment- NS; Irrigation x Treatment- NS				
Available phosphorus (kg/ha)				
SS (5 t/ha)	18.2	15.5	14.9	16.17
SS (5 t/ha)+50% RDF	22.7	19.2	18.0	19.93
SS (5 t/ha)+75% RDF	24.4	20.8	19.3	21.53
RDF	20.1	17.3	16.4	17.93
Mean	21.34	18.19	17.15	
CD (p= 0.05): Irrigation- 2.07; Treatment- 2.39; Irrigation x Treatment- NS				
Available potassium (kg/ha)				
SS (5 t/ha)	290.1	328.7	353.1	323.96
SS (5 t/ha)+50% RDF	306.6	343.7	362.1	337.48
SS (5 t/ha)+75% RDF	314.2	359.2	374.0	349.12
RDF	295.9	334.4	350.2	326.83
Mean	301.70	341.52	359.83	
CD (p= 0.05): Irrigation- 24.35; Treatment- NS; Irrigation x Treatment- NS				
Available sulphur (ppm)				
SS (5 t/ha)	94.8	133.7	148.2	125.55
SS (5 t/ha)+50% RDF	99.5	142.7	154.0	132.07
SS (5 t/ha)+75% RDF	104.0	147.0	161.8	137.60
RDF	85.9	116.1	130.4	110.80
Mean	96.04	134.88	148.60	
CD (p= 0.05): Irrigation- 12.00; Treatment- 13.86; Irrigation x Treatment- NS				

Available phosphorus (kg/ha): A critical perusal of data (Table 2.56) indicated that available phosphorus in soil was significantly affected by the application of sewage sludge and saline water irrigation. The mean available phosphorus in soil was significantly reduced with application of saline water irrigation and higher mean available phosphorus was obtained with canal water irrigation *i.e.*21.34 kg/ha. Significantly lowest mean available phosphorus (17.15 kg/ha) was recorded with 10 dS/m EC of saline water irrigation. The mean available phosphorus was significantly increased with sewage sludge application and it was observed that significantly higher mean available phosphorus was obtained with SS (5 t/ha) + 75% RDF *i.e.* 21.53 kg/ha; being at par with SS (5 t/ha) + 50% RDF *i.e.* 19.93 kg/ha followed by RDF (17.93 kg/ha). Sole application of sewage sludge increased mean available phosphorus significantly over control. The interaction effect of sewage sludge and saline water irrigation was found however non-significant.

Available potassium (kg/ha): The perusal of data regarding available potassium contained in (Table 2.57) revealed that potassium in soil was significantly increased with saline water irrigation but it was remained non significant with sewage sludge application. It was observed that significantly higher mean available potassium was obtained with saline water irrigation (EC_{iw}10 dS/m) *i.e.*359.83 kg/ha being at par with 8 dS/m EC of saline water irrigation (341.52 kg/ha). The maximum available potassium (314.2 kg/ha) was observed in treatment SS (5 t/ha) +75% RDF followed by treatment SS (5 t/ha) +50% RDF (306.60 kg/ha) and minimum (290.1 kg/ha) was observed in SS (5 t/ha). The interaction effect of sewage sludge and saline water irrigation was non significant.

Available sulphur (ppm): The perusal of data (Table 2.58) showed that available sulphur in soil has been significantly affected by the application of sewage sludge and saline water irrigation. The significantly higher mean available sulphur was obtained with saline water irrigation (EC_{iw}10 dS/m) *i.e.* 148.60 ppm followed by 8 dS/m EC of saline water irrigation (134.88 ppm). Among treatments, the mean available sulphur in soil was significantly increased with sewage sludge application and significantly higher mean available sulphur was obtained with SS (5 t/ha) + 75% RDF *i.e.* 137.60 ppm being at par with SS (5 t/ha) + 50% RDF *i.e.* 132.07 ppm and SS (5 t/ha) *i.e.* 125.55 ppm. Sole application of sewage sludge significantly increased soil mean available sulphur over RDF and control during both years and interaction effect was non-significant.

DTPA-extractable micronutrients (mg/kg): The perusal of data regarding DTPA-extractable micronutrient (Fe, Mn, Zn and Cu) in soil as influenced by sewage sludge and saline water irrigation is expressed in Table 2.59. The soil micronutrients availability was remained unaffected by the saline irrigation water except Zn, which was decreased significantly with increasing salinity levels of irrigation water. The maximum mean concentration of Zn (2.19 mg/kg) was achieved with canal water irrigation being at par with 8 dS/m *i.e.* 1.84 mg/kg in comparison of EC_{iw}10 dS/m. It was observed that application of sewage sludge significantly increased micronutrient availability in soil. The maximum mean concentration of Fe, Mn, Zn and Cu *i.e.*4.43, 6.77, 2.24 and 1.40 mg/kg were obtained with the application of sewage sludge(5t/ha) being at par with SS (5 t/ha) + 50% RDF and SS (5 t/ha) + 75% RDF and lowest was observed in RDF where no sewage sludge was applied. The interaction effect of sewage sludge and saline water irrigation was however non significant.

DTPA-extractable heavy metals (mg/kg): The perusal of data regarding DTPA-extractable heavy metals (Pb, Cd, Cr, Ni and Co) in soil is expressed in Table 2.60. Application of sewage sludge and saline water irrigation significantly influenced the availability of heavy metals in soil. The mean heavy metal contents (Pb, Cd, Cr, Ni and Co) in soil were increased from 1.85 to 2.33 mg/kg, 0.07 to 0.13 mg/kg, 0.17 to 0.24 mg/kg, 0.30 to 0.44 mg/kg and 0.07 to 0.14 mg/kg, respectively. Significantly higher mean concentration of heavy metals was recorded with 10 dS/m EC of saline water irrigation being at par with 8 dS/m saline water as compared to canal water irrigation. The cobalt content in soils with 8 and 10 dS/m EC of saline water irrigation differs statistically with each other. Sewage sludge treatments significantly enhanced availability of heavy metals in soil and the mean heavy metals (Pb, Cd, Cr, Ni and Co) in soil ranged between 1.26 to 2.47 mg/kg, 0.03 to 0.14 mg/kg, 0.11 to 0.27 mg/kg, 0.18 to 0.48 mg/kg and 0.02 to 0.15 mg/kg, respectively but significantly higher availability of mean heavy metals (Pb 2.47 mg/kg; Cd 0.14 mg/kg; Cr 0.27 mg/kg; Ni 0.48 mg/kg and Co 0.15 mg/kg) was obtained with SS (5 t/ha) being at par with SS (5 t/ha) + 50 % RDF and SS (5 t/ha) + 75 % RDF except Cr and Co content where it was statistically at par with SS (5 t/ha) + 50 % RDF only. Sole application of sewage sludge significantly increased heavy metal contents in soil over RDF. The interaction effect of sewage sludge and saline water irrigation was non significant.

Table 2.56. Effect of various treatments on DTPA-extractable micronutrients in soil (mg/kg) under different quality of irrigation water

Fe				
Treatment	Irrigation water quality			Mean
	Canal	8 dS/m	10 dS/m	
SS (5 t/ha)	4.90	4.28	4.10	4.43
SS (5 t/ha)+50% RDF	4.72	4.05	3.93	4.23
SS (5 t/ha)+75% RDF	4.45	3.90	3.57	3.97
RDF	2.18	1.99	1.87	2.01
Mean	4.06	3.56	3.37	
CD (p= 0.05) Irrigation- NS; Treatment- 0.78; Irrigation x Treatment- NS				
Mn				
SS (5 t/ha)	7.50	6.56	6.26	6.77
SS (5 t/ha)+50% RDF	7.15	6.50	6.13	6.59
SS (5 t/ha)+75% RDF	6.80	6.60	6.10	6.50
RDF	4.12	3.90	3.73	3.92
Mean	6.39	5.89	5.56	
CD (p= 0.05) Irrigation- NS; Treatment- 1.12; Irrigation x Treatment- NS				
Zn				
SS (5 t/ha)	2.49	2.17	2.06	2.24
SS (5 t/ha)+50% RDF	2.38	2.06	1.91	2.12
SS (5 t/ha)+75% RDF	2.17	1.88	1.70	1.92
RDF	1.72	1.25	0.91	1.29
Mean	2.19	1.84	1.65	
CD (p= 0.05) Irrigation- 0.37; Treatment- 0.43; Irrigation x Treatment- NS				
Cu				
SS (5 t/ha)	1.51	1.40	1.30	1.40
SS (5 t/ha)+50% RDF	1.39	1.32	1.21	1.31
SS (5 t/ha)+75% RDF	1.31	1.26	1.14	1.24
RDF	0.61	0.58	0.51	0.57
Mean	1.20	1.14	1.04	
CD (p= 0.05) Irrigation- NS; Treatment- 0.23; Irrigation x Treatment- NS				

Table 2.57. Effect of various treatments on DTPA-extractable heavy metals in soil (mg/kg) under different quality of irrigation water

Pb				
Treatment	Irrigation water quality			Mean
	Canal	8 dS/m	10 dS/m	
SS (5 t/ha)	2.16	2.55	2.70	2.47
SS (5 t/ha)+50% RDF	2.10	2.48	2.65	2.41
SS (5 t/ha)+75% RDF	2.04	2.43	2.59	2.35
RDF	1.11	1.29	1.38	1.26
Mean	1.85	2.19	2.33	
CD (p= 0.05)	Irrigation- 0.32; Treatment- 0.37; Irrigation x Treatment- NS			
Cd				
SS (5 t/ha)	0.10	0.14	0.17	0.14
SS (5 t/ha)+50% RDF	0.08	0.14	0.15	0.13
SS (5 t/ha)+75% RDF	0.08	0.13	0.15	0.12
RDF	0.03	0.04	0.04	0.03
Mean	0.07	0.11	0.13	
CD (p= 0.05)	Irrigation- 0.027; Treatment- 0.031; Irrigation x Treatment- NS			
Cr				
SS (5 t/ha)	0.21	0.28	0.31	0.27
SS (5 t/ha)+50% RDF	0.20	0.26	0.29	0.25
SS (5 t/ha)+75% RDF	0.17	0.24	0.26	0.22
RDF	0.10	0.12	0.12	0.11
Mean	0.17	0.23	0.24	
CD (p= 0.05)	Irrigation- 0.034; Treatment- 0.039; Irrigation x Treatment- NS			
Ni				
SS (5 t/ha)	0.37	0.54	0.52	0.48
SS (5 t/ha)+50% RDF	0.34	0.49	0.51	0.45
SS (5 t/ha)+75% RDF	0.35	0.46	0.51	0.44
RDF	0.15	0.19	0.21	0.18
Mean	0.30	0.42	0.44	
CD (p= 0.05)	Irrigation- 0.05; Treatment- 0.06; Irrigation x Treatment- NS			
Co				
SS (5 t/ha)	0.10	0.16	0.19	0.15
SS (5 t/ha)+50% RDF	0.08	0.14	0.17	0.13
SS (5 t/ha)+75% RDF	0.07	0.12	0.16	0.12
RDF	0.02	0.03	0.02	0.02
Mean	0.07	0.11	0.14	
CD (p= 0.05)	Irrigation- 0.024; Treatment- 0.028; Irrigation x Treatment- NS			

Dehydrogenase activity: A critical perusal of data depicted in (Fig. 2.2) revealed that soil dehydrogenase activity at pearl millet and wheat crop harvest was significantly affected by the application of sewage sludge and saline water irrigation. The data indicated that dehydrogenase activity significantly decreased with gradually increase in levels of saline water irrigation. The maximum mean dehydrogenase activity in soil 35.90 and 40.07 µg TPF/g /24 hr at pearl millet and wheat crop harvest was recorded with canal water irrigation whereas minimum (18.65 and 19.82 µg TPF/g /24 hr) was observed in plot receiving saline irrigation of 10 dS/m, respectively. The dehydrogenase activity ranged from 14.90 to 44.83 µg TPF/g /24 hrat pearl millet harvest and 16.70 to 50.04 µg TPF/g /24 hr at wheat harvest. The dehydrogenase activity was significantly higher in sewage sludge treated plots. However, higher activity was recorded with the application of SS at the rate of 5 t/ha used in an integration with 75% RDF in comparison of RDF treatment. No significant interaction effect of sewage sludge and saline irrigation was found.

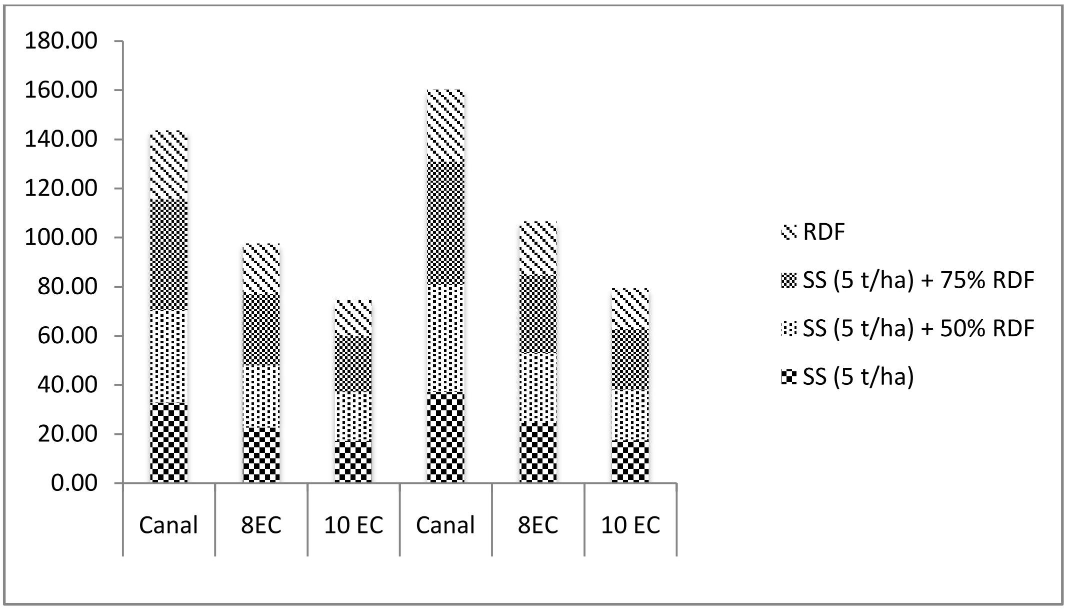


Fig. 2.2 Effect of sewage sludge application on soil dehydrogenase activity (μg TPF/g /24 hr) at pearl millet and wheat crop harvest under saline water irrigation

Microbial biomass carbon: A critical perusal of data depicted in (Fig. 2.3) revealed that soil microbial biomass carbon significantly affected by the application of sewage sludge and saline irrigation. It was observed that microbial biomass carbon was significantly reduced with increasing salinity levels of irrigation water at pearl millet and wheat harvest. Soil microbial biomass carbon was ranged from 143.00 to 410.00 μg/g at pearl millet harvest and 142.50 to 477.03 μg/g at wheat harvest. It was noticed that application of 8 and 10 dS/m EC of saline water irrigation significantly reduced soil microbial biomass carbon. Sewage sludge application significantly increased microbial biomass carbon as compared to RDF. However, significantly higher microbial biomass carbon was recorded with SS (5 t/ha) + 75% RDF at pearl millet and wheat harvest. The interactive effect was found non-significant.

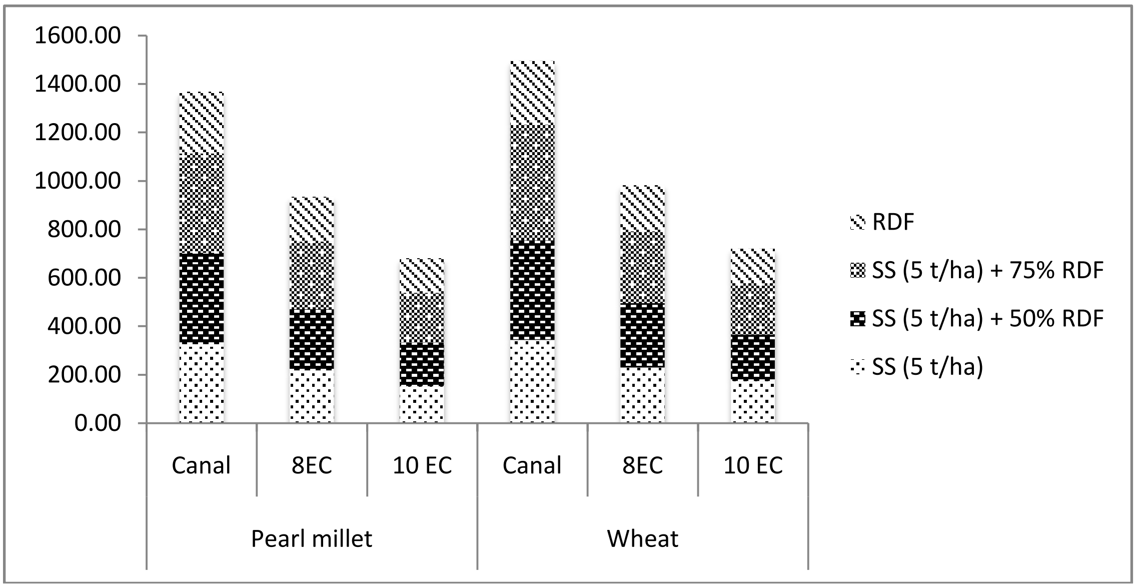


Fig. 2.3 Effect of sewage sludge application on soil microbial biomass carbon (μg/g) at pearl millet and wheat crop harvest under saline water irrigation

Economic analysis: Data (Table 2.58) on economics of pearl millet in canal water irrigation, RDF was proved to be economically beneficial with highest net returns of Rs. 37,446/ha and B: C (1.73) followed by SS (5t/ha) + 75% RDF (Rs. 35,887/ha and 1.71), SS (5t/ha) + 50% RDF (31,750/ha and 1.65) and SS (5 t/ha) (Rs. 24, 169/ha and 1.51). In case of irrigation with ECiw (8 dS/m) treatment RDF was found to be economically beneficial with highest net returns of Rs. 13,667/ha and B: C (1.26) followed by SS (5 t/ha) + 75% RDF (Rs. 12,367/ha and 1.24), SS (5t/ha) + 50% RDF (Rs. 7,912/ha and 1.24) and SS (5 t/ha) (Rs. 4,130/ha and 1.09). In case of irrigated with ECiw (10 dS/m) treatment RDF and SS (5 t/ha) + 75% RDF were found to be profitable with net returns and B: C of Rs. 5,564/ha and 1.11 and 3, 003 and 1.06, respectively. Whereas treatment receiving SS (5 t/ha) and SS (5 t/ha) + 50% RDF were found to be uneconomical due to negative net returns.

Data (Table 2.59) on economics of wheat under saline water irrigation revealed that in canal water irrigation, RDF was proved to be economically beneficial with highest net returns of Rs. 47042/ha and B: C (1.74) followed by SS (5 t/ha) + 75% RDF (Rs. 42,373/ha and 1.67), SS (5 t/ha) + 50% RDF (Rs. 35,001/ha and 1.57) and SS (5 t/ha) (Rs. 20,698/ha and 1.36).In case of irrigation with ECiw (8 dS/m) treatment RDF, SS (5 t/ha) + 75% RDF and SS (5 t/ha) + 50% RDF were found to be profitable with net returns and B: C of Rs. 18312 /ha and 1.28; 14068 and 1.22 and Rs. 7806/ha and 1.13, respectively. While the treatment receiving SS (5 t/ha) was found to be uneconomical due to negative net returns.

Table 2.58. Treatment wise economic analysis of pearl millet crop (Rs./ha) irrigated with saline water of different salinity

Treatment combinations	Cost of cultivation	Gross returns	Return over variable cost	Net returns	B:C
Canal					
SS (5 t/ha)	47106	71,275	49169	24169	1.51
SS (5 t/ha) + 50% RDF	49198	80,948	56750	31750	1.65
SS (5 t/ha) + 75% RDF	50244	86,131	60887	35887	1.71
RDF	51290	88,737	62446	37446	1.73
EC_{iw} 8 dS/m					
SS (5 t/ha)	47504	51,634	29130	4130	1.09
SS (5 t/ha) + 50% RDF	49596	57,508	32912	7912	1.16
SS (5 t/ha) + 75% RDF	50642	63,009	37367	12367	1.24
RDF	51688	65,355	38667	13667	1.26
EC_{iw}10 dS/m					
SS (5 t/ha)	47504	45,923	23419	-1581	0.97
SS (5 t/ha) + 50% RDF	49596	51,253	26657	1657	1.03
SS (5 t/ha) + 75% RDF	50642	53,645	28003	3003	1.06
RDF	51688	57,252	30564	5564	1.11

Table 2.59. Treatment wise economic analysis of wheat crop (Rs./ha) irrigated with saline water of different salinity

Treatment combinations	Cost of cultivation	Gross return	Return over variable cost	Net return	B:C
Canal					
SS (5 t/ha)	57,807	78,505	45,698	20,698	1.36
SS (5 t/ha) + 50% RDF	61,509	96,509	60,001	35,001	1.57
SS (5 t/ha)+ 75% RDF	63,360	1,05,732	67,373	42,373	1.67
RDF	63,885	1,10,927	72,042	47,042	1.74
EC_{iw}8 dS/m					
SS (5 t/ha)	58,337	55,695	22,358	-2,642	0.95
SS (5 t/ha)+ 50% RDF	62,039	69,845	32,806	7,806	1.13
SS (5 t/ha)+ 75% RDF	63,890	77,958	39,068	14,068	1.22
RDF	64,415	82,727	43,312	18,312	1.28
EC_{iw}10 dS/m					
SS (5 t/ha)	58,337	48,496	15,159	-9,841	0.83
SS (5 t/ha)+ 50% RDF	62,039	60,931	23,892	-1,108	0.98
SS (5 t/ha)+ 75% RDF	63,890	67,951	29,061	4,061	1.06
RDF	64,415	72,815	33,400	8,400	1.13

The experiment is concluded during 2019-20 with the finding that the application of sewage sludge @5t/ha along with 75% RDF was proved as good as application of RDF both pearl millet and wheat under saline water irrigation. In case pearl millet irrigated with ECiw (10 dS/m) treatment RDF and SS (5 t/ha) + 75 % RDF were found to be profitable with net returns and B: C of Rs. 7, 656 and 1.15; and 3, 003/ha and 1.06, respectively., whereas in case of wheat irrigated with ECiw (10 dS/m) treatment RDF and SS (5 t/ha) + 75 % RDF were found to be profitable with net returns and B: C of Rs. 8400/ha and 1.13; and 4061 and 1.06, respectively.

- **Effect of nitrogen fertigation utilizing good and saline water under drip irrigation system in vegetable crops (Hisar)**

The study was planned to study the effect of nitrogen fertigation on onion crop and to study the salt and water dynamics in drip irrigated soil. Treatment details are given below.

a) Quality of irrigation water:

- S_1: Canal water EC_{iw} = 0.3 dS/m
- S_2: Saline water EC_{iw} = 2.5 dS/m
- S_3: Saline water EC_{iw} = 5.0 dS/m

b) Nitrogen fertigation levels: three

- F_1: 75% of RDN
- F_2: RDN
- F_3: 125% of RDN

2018-19

The experiment was laid out in 2.0 x 2.0 m plot as per the following plan. The spacing between plant to plant and row to row was kept as 45 cm. Moisture content was taken at regular interval of 30 days, spatial and temporal contour maps were plotted for 30, 60 and 90 days after transplanting (DAT). Radial distance from the dripper and depth from the soil surface were taken on horizontal and vertical axis (downward), respectively. The study of wetting patterns was the function of radial distance from the plant or dripper and the depth from the soil surface. Wetting pattern at 30, 60 and 90 DAT under different water quality and nitrogen fertigation level i.e. S_1F_1, S_1F_2, S_1F_3, S_2F_1, S_2F_2, S_2F_3, S_3F_1, S_3F_2 and S_3F_3 were prepared. In case of S_1F_1, spatial and temporal movements of moisture are shown in Fig. 2.4. For different water quality and nitrogen fertigation level treatments, moisture content at dripper was more as compared to that of at a radial distance of 11 and 22.5 cm away from the dripper and as we move away from the dripper in vertical direction from the surface i.e. from 0 to 60 cm from the surface, moisture content showed decreasing trend in all treatments. In S_1F_1 treatment, contour of 9.6% moisture content was at 20 cm radial distance from dripper on the surface at 30 DAT and it moved to 10 and 6.5 cm radial distance at 60 and 90 DAT, respectively. Same contour of 9.6% moisture content was at 30 cm depth from the surface at 30 DAT. It rose up to the depth of 24.7 and 21.1 cm from the surface at 60 and 90 DAT, respectively. This depicts the depletion of moisture in soil profile with the passage of time, may be because of the development of roots and increasing water uptake capability of plant and an increase in climatic temperature as days passes by under each treatment.

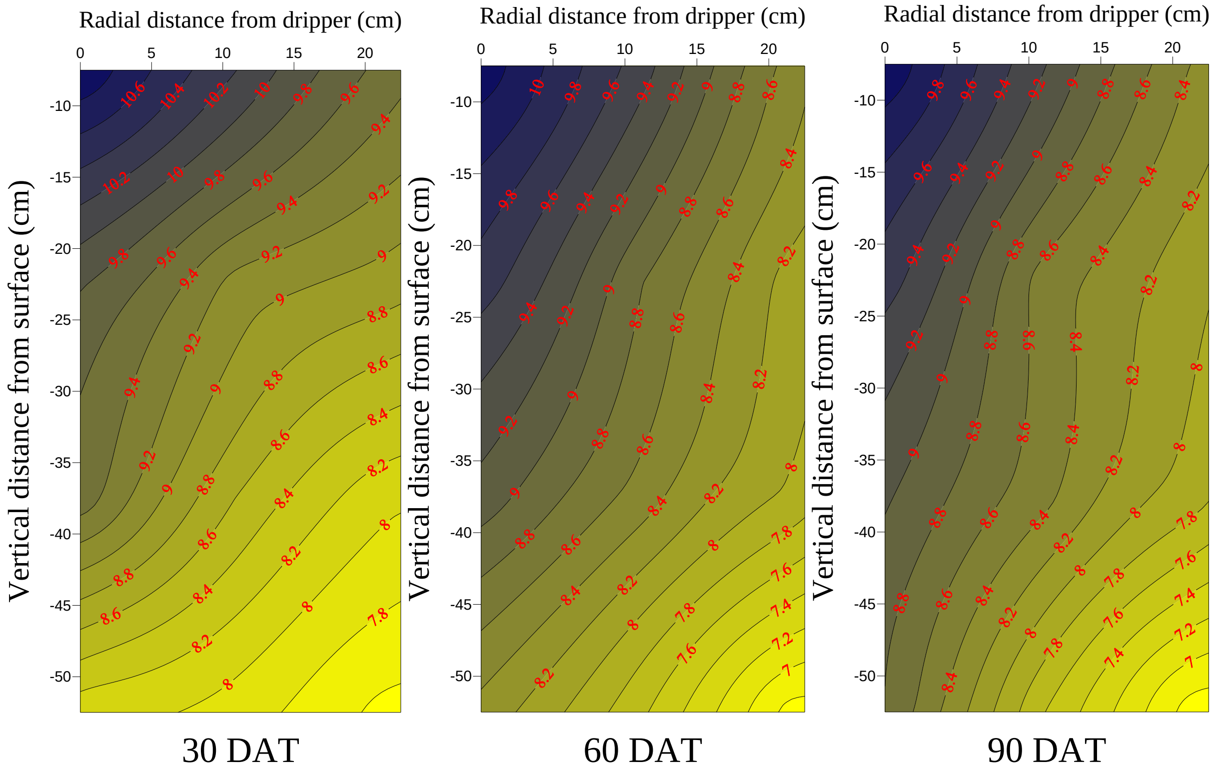


Fig. 2.4. Spatial and temporal movement of moisture content in S_1F_1

Salt distribution in soil profile under different treatments

Spatial and temporal contour maps for salt distribution were plotted for 30, 60 and 90 DAT. Radial distance from the dripper and depth from the soil surface were taken on horizontal axis and vertical axis (downward), respectively. The study of salt dynamic was the function of radial distance from the plant or dripper and the depth from the soil surface. Salt distribution pattern at 30, 60 and 90 DAT under different water quality and nitrogen fertigation level i.e. S_1F_3, S_2F_3 and S_3F_3 were prepared. In case of S_1F_3, the details are shown in Fig. 2.5. An increase in concentration of salt in soil profile was observed with the advancement in time in S_2 and S_3 unlike treatment S_1 in which no particular trend of salt variation in soil profile was observed with the advancement in time.

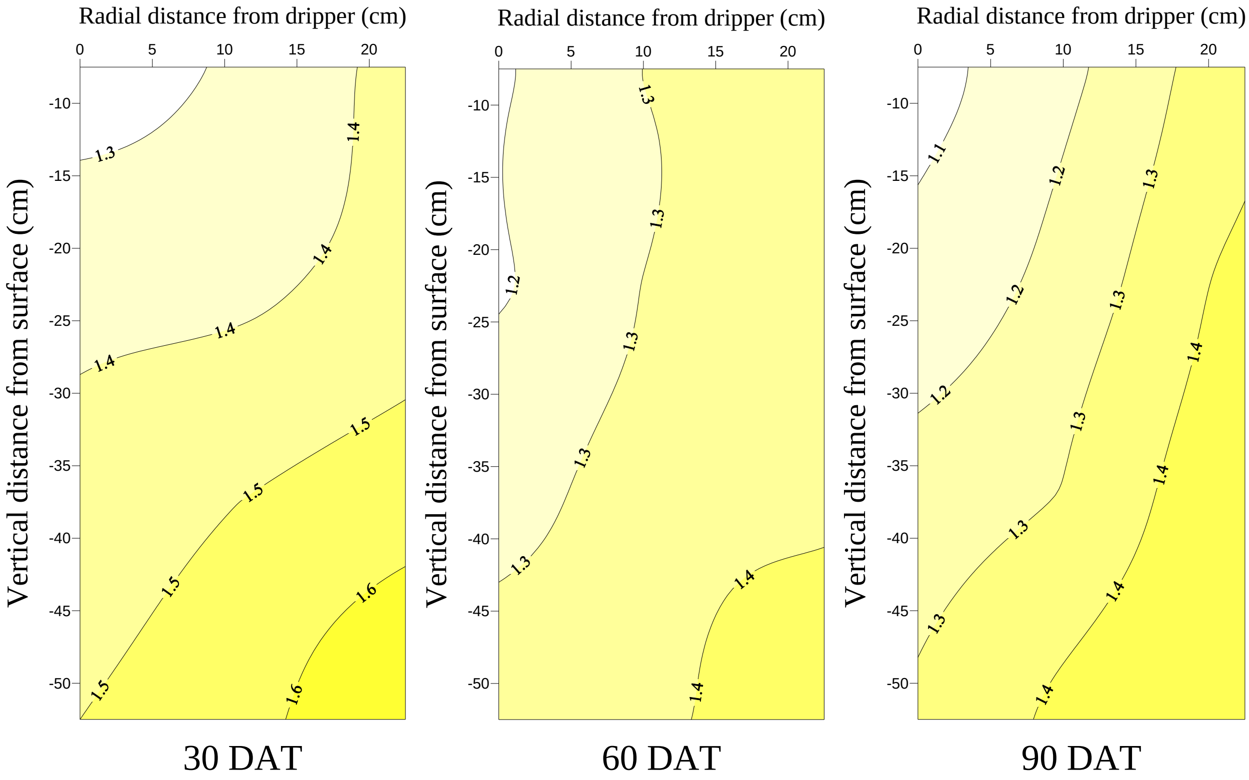


Fig. 2.5. Spatial and temporal movement of salt in S_1F_3

Plant height: Maximum plant height growth was found between 30 to 90 DAT and after that (at the harvest), the height increased gradually. The influence of the irrigation water quality and fertigation level on plant height at 30, 60, 90 DAT and at harvest were found significant and their interaction between them was non-significant except at harvesting stage where their interaction was found significant. An increasing trend was observed in height of plant with an increase in the application of N dose from 75 to 125% RDN under good quality water as well as saline water treatment (2.5 and 5 dSm^{-1}). Whereas a decreasing trend was observed as the irrigation water changes from good quality to poor quality water (2.5 dSm^{-1} and 5 dSm^{-1}) as shown in Fig 39. Use of saline water for irrigation makes the soil around the emitter saline and form a region of high salt concentration in root zone. Saline soil affects the available nitrogen in soil and leads to volatilization of NH_3 due to high pH and uptake of nitrogen due to presence of Cl^- ion which restricts NO_3 uptake. Therefore, a decreasing trend in plant height can be observed with an increase in salt concentration in irrigation water. Also, from the graph obtained in Fig. 2.6, it was indicated that highest plant height (64.5 cm) was observed under treatment of good quality water (S_1) with 125% RDN whereas, minimum plant height (49.9 cm) was registered under irrigation with saline water of EC 5 dS m^{-1} and 75% RDN.

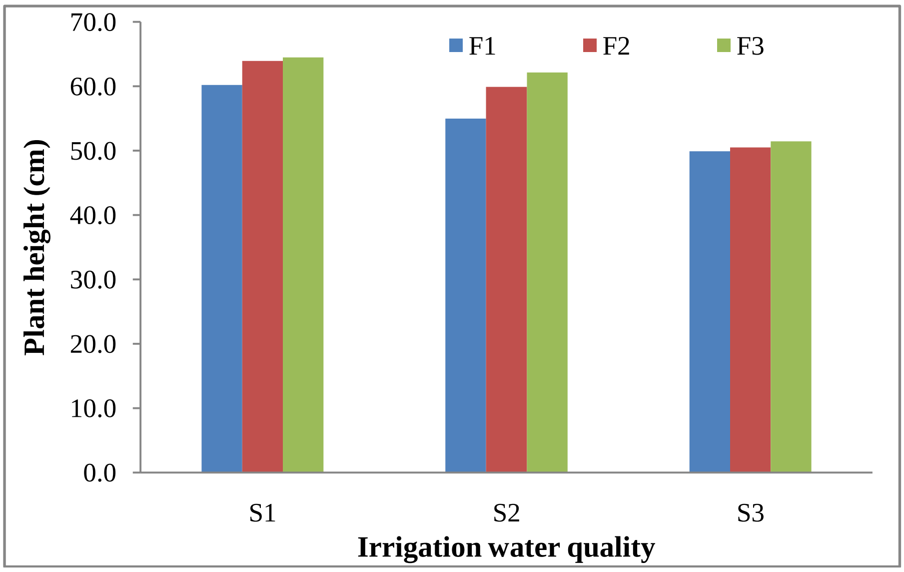


Fig. 2.6: Plant height of onion of different treatments at harvest

Average weight of bulb: The influence of irrigation water quality and fertigation level on weight of bulb was found significant and the interaction between them was non-significant. From Fig. 2.7, a positive correlation was observed between nitrogen dose and average weight of onion. Increase in weight of onion was observed with the increase in fertigation level. Its negative correlation was observed with salinity in respective fertigation treatment, maximum average weight of bulb (71.92 g) was observed under irrigation with good quality water with 125% RDN which may be due increase in synthesis of carbohydrate and increasing rate of its accumulation in bulb. Whereas, minimum average weight of bulb (44.23 g) was obtained under irrigation with saline water of 5 dS/m at 75% RDN.

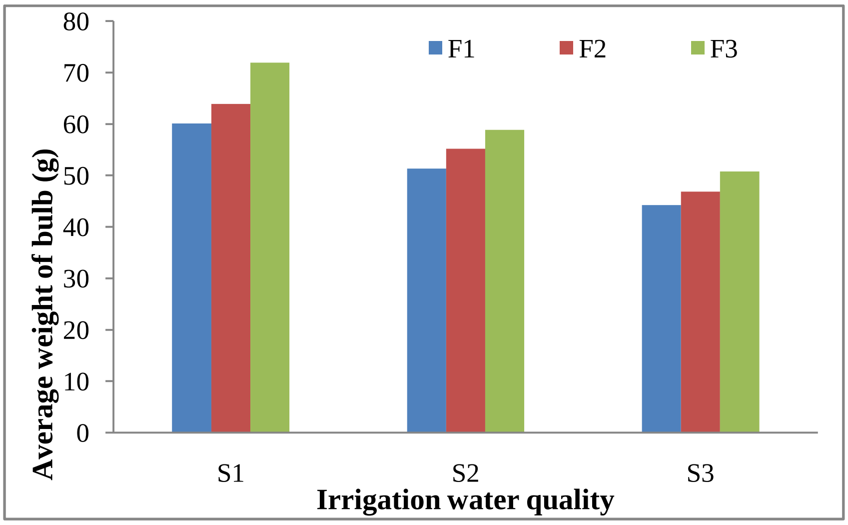


Fig. 2.7: Average weight of bulb under different treatments

Yield of Onion: The data on yield of onion under different N and salinity levels with drip irrigation (Table 2.60 revealed that under drip irrigation with 75% RDN of nitrogen application, the reduction in yield of onion were 8.8 and 32.5% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in RDN application, the reduction in yields of onion were 6.8 and 31.0% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation.

Under drip irrigation in 125% recommended dose of nitrogen application, the reduction in yield of onion obtained 5.0 and 29.33% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Significant reduction in onion yield was recorded at EC_{iw} 5.0 dS/m as compared to canal water irrigation. Significantly highest yield of onion was recorded with the application of 125%RDN.

Table 2.60: Effect of nitrogen fertigation under different saline water in drip irrigation system onion yield (q/ha)

N Level	0.3 dS/m (Canal)	2.5 dS/m	5.0 dS/m	Mean
75% RDN	254.07	231.60	171.63	219.10
RDN	292.30	272.40	201.60	255.43
125% RDN	331.77	315.00	234.43	293.73
Mean	292.71	266.16	202.56	
CD (p=0.05)	Nitrogen (N) = 8.07, Salinity level (S) =12.81, N x S = NS			

Nitrogen use efficiency: The influence of the irrigation water quality, fertigation level and interaction between them on NUE was found non-significant. From the Fig. 2.8, a drastic change in NUE can be observed with N fertigation level and salinity treatments. It was observed that for a given N-fertigation level, NUE was greater when irrigated with good quality water than that of the poor quality water. Decreasing trend in NUE was observed at a given irrigation water quality as nitrogen dose increases from 75-125% RDN. From the result obtained we can conclude that for a given irrigation water, a recommendable dose of nitrogen should be preferred as nitrogen use efficiency decreases with an increasing dose of nitrogen.

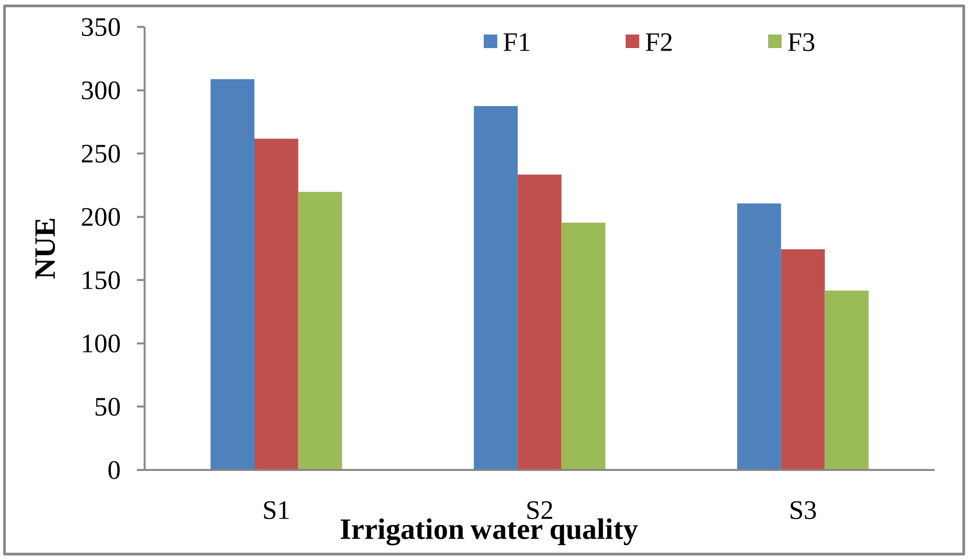


Fig. 2.8: NUE under different treatment

2019-20

Yield of brinjal fruit: The data on fruit yield of brinjal under different N and salinity levels with drip irrigation (Table 2.61) revealed that under drip irrigation with 75% RDN of nitrogen application, the reduction in fruit yield of brinjal was 11.97 and 28.08 % when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the fruit yield recorded with canal water irrigation. Under drip irrigation in RDN application, the reduction in fruit yields of brinjal was 9.53 and 24.50% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded with canal water irrigation. Under drip irrigation in 125% recommended dose of nitrogen application, the reduction in fruit yield of brinjal obtained 8.04 and 21.69% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded with canal water irrigation. Significant reduction in brinjal fruit yield was recorded at EC_{iw} 5.0 dS/m as compared to canal water irrigation. Significantly highest fruit yield of brinjal was recorded with the application of 125%RDN.

Table 2.61: Effect of nitrogen fertigation under different saline water in drip irrigation system brinjal fruit yield (q/ha)

N Level	0.3 dS/m (Canal)	2.5 dS/m	5.0 dS/m	Mean
75% RDN	228.29	200.95	164.17	197.80
RDN	248.27	224.61	187.42	220.10
125% RDN	256.38	235.77	200.76	184.12
Mean	244.31	220.44	184.19	
CD (p=0.05)	Nitrogen (N) = 9.20, Salinity level (S) =9.20, N x S = NS			

The data on plant height of brinjal under N and salinity levels with drip irrigation (Table 2.62) revealed that under drip irrigation with 75% of RDN of nitrogen application, the reduction in plant height of brinjal were 11.2 and 23.1% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the average plant height recorded with canal water irrigation. Under drip irrigation in RDN application, the reduction in height of the plants were 9.4 and 21.5% when irrigated with 2.5 and 5.0%, respectively, as compared to canal water irrigation. Under drip irrigation in 125% recommended dose of nitrogen application, the reduction in height of the plants was obtained 8.7 and 20.2% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively as compared to the plant height under canal water irrigation. Significant reduction in average plant height was recorded at ECiw 5.0 dS/m as compared to the canal water irrigation.

Table 2.62: Effect of nitrogen fertigation under different saline water in drip irrigation system on plant height (cm) of brinjal crop

N Level	0.3 dS/m (Canal)	2.5 dS/m	5.0 dS/m	Mean
75% RDN	150.53	133.66	115.73	133.31
RDN	156.80	142	123.06	140.62
125% RDN	163	148.8	130.06	147.28
Mean	156.77	141.48	122.95	
CD (p=0.05)	Nitrogen (N) = 4.72, Salinity level (S) = 4.72, N x S = NS			

Table 2.63: Effect of nitrogen fertigation under different saline water in drip irrigation system on fruit size (diameter, cm) of brinjal

N Level	0.3 dS/m (Canal)	2.5 dS/m	5.0 dS/m	Mean
75% RDN	30.8	26.66	22.9	26.78
RDN	33.5	30.36	26.43	30.1
125% RDN	36.56	33.86	29.96	33.46
Mean	33.62	30.3	26.43	
CD (p=0.05)	Nitrogen (N) = 3.29, Salinity level (S) =3.29, N x S = NS			

The data on fruit size of brinjal crop under N and salinity levels with drip irrigation (Table 2.63) revealed that under drip irrigation maximum reduction in fruit diameter was observed with 75% RDN of nitrogen application, the reduction were 13.4 and 25.6 % when irrigated with saline water 2.5 and 5.0 dS/m as compared to the canal water irrigation. Minimum reduction of fruit diameter was under 125% RDN, the reduction in size of the fruits were obtained 7.3 and 18.0 % with application of saline water of 2.5 and 5.0 dS/m, respectively as compared to the canal water irrigation. Significant reduction in the average size of the fruits was recorded at ECiw 5.0 dS/m as compared to the canal water irrigation.

- **Effect of various salinity levels of irrigation water on growth of leafy vegetables in coastal saline soils of Konkan in *rabi* season (Panvel)**

2019

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. The initial pH and EC of experimental soil were 6.82 and 2.35 dS/m, respectively. Other chemical properties are provided in Table 2.64. 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 2.65.

Table 2.64. Initial soil properties of experimental plot

Sr. No.	Particulars	Values	Sr. No.	Particulars	Values
1.	pH	6.82	7.	Ca^{+2}(meq/l)	196.0
2.	EC (d Sm^{-1})	2.35	8.	Mg^{+} (meq/l)	179.0
3.	CO_3^{-} (meq/ l)	0.00	9.	Na^{+} (meq/l)	20.89
4.	HCO_3^{-} (meq/l)	2.00	10.	K^{+}(kg L^{-1})	913.65
5.	Cl^{-} (meq/l)	10.0	11.	RSC (meq/l)	0.0
6.	SO_4^{-}(mg kg^{-1})	3.89	12.	SAR (meq/l)	4.314

Table 2.65: 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)

The soil salinity values (EC 1:2) at 15 days after sowing and harvest (90 days) of vegetable crops are provided in Table 2.66 and 2.67. One irrigation was already given by saline water before 15 days. The soil salinity was slightly less in case of pond water irrigation compared saline water irrigation and it increased with irrigation water salinity (Table 2.66). It was also observed that that the irrigation water salinity level 8 d Sm^{-1}*i.e.*T_5 recorded significantly higher EC 6.29 dSm^{-1}over rest of treatments. Radish exhibited (4.19 dSm^{-1}) numerically higher EC, however remained at par with Dill (4.18dSm^{-1}) and spinach (4.02dSm^{-1}) crop. In case of interaction, T_5C_3 showed significantly higher EC value 6.42 dSm^{-1}over rest of interactions except T_5C_2 (6.32 dSm^{-1}) and T_5C_1 (6.13 dSm^{-1}). Thus, there was increase in soil salinity values with increase in irrigation water salinity.

Table 2.66: Soil Electrical Conductivity ($_{1:2.5}$) at 15 days after sowing:

Treatments	Spinach (C_1)	Dill (C_2)	Radish (C_3)	MEAN	
Pond water (T_1)	2.91	2.98	2.83	2.91	
2 d Sm^{-1} (T_2)	2.94	3.00	3.07	3.00	
4 d Sm^{-1} (T_3)	3.71	3.80	3.81	3.78	
6 d Sm^{-1} (T_4)	4.42	4.81	4.86	4.70	
8 d Sm^{-1} (T_5)	6.13	6.32	6.42	6.29	
MEAN	4.02	4.18	4.19		
SE± m for salinity levels	0.16	SE± m for crop	0.13	SE± m for interaction	0.28
CD @5%	0.47	CD @5%	NS	CD @5%	0.82

Soil salinity values at harvest of crops are provided in Table 2.67. The treatment T_5 showed significantly higher EC 10.28 d Sm^{-1} over the rest of treatments. In case of the crops, Radish (C_3) showed numerically higher EC 8.04 d Sm^{-1}. In case of interaction effect, T_5C_3 showed significantly higher EC values over rest of interactions except T_5C_1 andT_5C_2. It was observed that soil salinity in pond water irrigated plot increased despite of good quality irrigation water. It is mainly because of capillary rise from shallow saline ground water. Therefore, mulching can be effective under this situation.

Table 2.67. Soil Electrical Conductivity (EC $_{1:2.5}$) at 90 days after sowing

Treatments	Spinach (C_1)	Dill (C_2)	Radish (C_3)	MEAN	
Pond water (T_1)	5.18	5.14	6.24	5.52	
2 d Sm^{-1} (T_2)	5.84	6.55	6.54	6.31	
4 d Sm^{-1} (T_3)	8.84	8.42	8.47	8.57	
6 d Sm^{-1} (T_4)	8.08	8.48	8.64	8.40	
8 d Sm^{-1} (T_5)	10.22	10.30	10.31	10.28	
MEAN	7.63	7.78	8.04		
SE± m for salinity levels	0.24	SE± m for crop	0.18	SE± m for interaction	0.43
CD @5%	0.69	CD @5%	NS	CD @5%	1.19

Soil pH after sowing (First irrigation):

In case of salinity levels, treatment T_3 showed significantly higher pH 6.88 over rest of treatments. As regard to crops, C_1 *i.e.* Spinach showed numerically higher pH (6.73). As far as interaction effect is concerned, T_3C_1 exhibited significantly higher pH value 7.10 over the rest of interactions (Table 2.68).

Soil pH at 90 days after sowing:

In case of salinity levels the treatment T_5 recorded higher pH value 8.11 over rest of treatment except treatment T_2 (7.89). The crop C_3 (Radish) showed numerically higher pH value 7.85 over rest of crops (Table 2.69). In interaction effect, it was seen that the treatment T_5C_3 recorded significantly higher pH 8.15 over T_1C_1, T_1C_2, T_3C_1, T_3C_2, T_3C_3 and T_4C_2 and remained at par with rest of interactions. The data further suggested that soil salinization due to saline water irrigation is leading to soil sodification.

Table 2.68: Soil pH $_{(1.2.5)}$ after sowing (First irrigation):

Treatments	Spinach (C_1)	Dill (C_2)	Radish (C_3)	MEAN	
Pond water (T_1)	6.58	6.60	6.68	6.62	
2 d Sm^{-1} (T_2)	6.67	6.66	6.72	6.68	
4 d Sm^{-1} (T_3)	7.10	6.76	6.78	6.88	
6 d Sm^{-1} (T_4)	6.61	6.64	6.64	6.63	
8 d Sm^{-1} (T_5)	6.69	6.70	6.72	6.70	
MEAN	6.73	6.67	6.71		
SE± m for salinity levels	0.05	SE± m for crop	0.03	SE± m for interaction	0.08
CD @5%	0.14	CD @5%	NS	CD @5%	0.25

Table 2.69: Soil pH at 90 days after sowing

Treatments	Spinach (C_1)	Dill (C_2)	Radish (C_3)	MEAN	
Pond water (T_1)	7.62	7.49	7.82	7.65	
2 dSm^{-1} (T_2)	7.82	7.95	7.89	7.89	
4 dSm^{-1} (T_3)	7.71	7.68	7.57	7.65	
6 dSm^{-1} (T_4)	7.81	7.72	7.79	7.78	
8 dSm^{-1} (T_5)	8.10	8.10	8.15	8.11	
MEAN	7.81	7.79	7.85		
SE± m for salinity levels	0.085	SE± m for crop	0.065	SE± m for interaction	0.14
CD @5%	0.24	CD @5%	NS	CD @5%	0.42

Data about influence of irrigation water salinity on crop yield are provided in Table 2.70. As far as effect of salinity of irrigation water is concerned, application of pond water T_1 (13.62 t ha^{-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.

Table 2.70. Influence of irrigation water salinity on crop yield (t/ha)

Treatments	Spinach (C_1)	Dill (C_2)	Radish (C_3)	MEAN	
Pond water (T_1)	10.98	11.10	18.78	13.62	
2 dSm^{-1} (T_2)	10.49	7.49	16.46	11.48	
4 dSm^{-1} (T_3)	7.61	10.30	10.34	9.42	
6 dSm^{-1} (T_4)	8.91	8.06	16.11	11.02	
8 dSm^{-1} (T_5)	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

The irrigation water salinity-yield relations are provided in Table 2.71.

Table 2.71: Mathematical models for yield under irrigation with saline water

Sr. No.	Crop	Equation	R^2 Value
1.	Spinach	Y (t ha^{-1})= -0.663*EC (dSm^{-1}) +17.45	R^2 = 0.113
2.	Dill	Y (t ha^{-1}) = -1.240*EC (dSm^{-1}) + 12.03	R^2 = 0.588
3.	Radish	Y (t ha^{-1}) = -0.331*EC (dSm^{-1}) + 16.79	R^2 = 0.113

- **Study the effect of saline water on vegetable cowpea with liquid bio-fertilizer (Bathinda)**

2019:
The effect of poor quality groundwater irrigation was studied on vegetable cowpea with liquid bio-fertilizer at Bathinda centre. The irrigation water quality parameters and initial soil properties of soils irrigated by different quality irrigation waters are provided in Table 2.72. It was observed that soils are loamy sand in texture, alkaline in reaction, having low organic carbon, available N and P. However, availability of micronutrients (Fe,Cu, Zn and Mn) are sufficient in soil.

Table 2.72: Initial characteristics of soils under different water quality

Irrigation water quality			**Soil properties**		
Particulars	Canal water	Tube well water	Parameter	Canal Water Irrigated	Tube well Water Irrigated
EC (dSm^{-1})	0.32	4.40	Soil Texture Sand (%) Silt (%) Clay (%)	Loamy sand 80.1 12.2 7.7	
Na^+ (meq/l)	1.42	36.6	pH $_{(1:2)}$	8.42	8.87
Ca^{+2}+ Mg^{+2} (meq/l)	1.78	7.4	EC $_{1:2}$ (dS m^{-1})	0.18	0.61
Cl^{-1} (meq/l)	0.8	11.8	OC (%)	0.33	0.32
CO_3^{-2} (meq/l)	nil	nil	Available N (kg ha^{-1})	235	210
HCO_3^-(meq/l)	1.6	6.8	Available P (kg ha^{-1})	10.6	8.86
RSC (meq/l)	0	0	Available K (kg ha^{-1})	207	186
SAR	1.5	19.0	Iron (mg kg^{-1})	5.80	5.30
			Copper (mg kg^{-1})	1.68	1.33
			Zinc (mg kg^{-1})	2.32	2.05
			Manganese (mg kg^{-1})	6.77	6.12

It was observed that tubewell had EC more 4 dS/m and SAR as 19 but there was no RSC. The cowpea-263 cultivar is used as a test crop with two microbial inoculants, namely, *Burkholderia* sp. (PSB) and *Bradyrhizobium* sp. (Nitrogen fixer) as liquid inoculums under the study. The field experiment was laid out in RCBD design and replicated thrice. The treatment details are given below:

T_1: Recommended dose of fertilizer (RDF-100%)- ($N:P_2O_5:K_2O$;50:40:25 kg ha^{-1})
T_2: RDF + liquid microbial inoculant of *Burkholderia* sp.
T_3: RDF + Liquid microbial inoculant of *Bradyrhizobium* sp.

T_4: RDF + Liquid microbialinoculant of *Burkholderia* sp. and *Bradyrhizobium* sp.
T_5: 75% Recommended dose of fertilizer (75%RDF-)-(N: P_2O_5:K_2O; 37.5:30:18.75 kg ha^{-1})
T_6: 75% of RDF + liquid microbial inoculant of *Burkholderia* sp.
T_7: 75% of RDF + Liquid microbial inoculant of *Bradyrhizobium* sp.,
T_8: 75% of RDF + Liquid microbial inoculant of *Burkholderia* sp. and *Bradyrhizobium* sp.

The effect of poor quality of water on different yield parameters was presented in Table 2.73. It was observed that use of poor quality water decreased seed germination, plant height as well as vegetable cowpea yield. However, use of liquid bio-fertilizer increased the seed germination and plant height, irrespective of quantity of fertilizer. The vegetable cowpea yield was decreased up to 65% due to poor quality water either alone or with liquid bio-fertilizer; therefore, poor quality water is not suitable for vegetable cowpea production. However, it can be used as for fodder.

Table 2.73. Effect of poor quality water and liquid bio-fertilizer on vegetable cowpea

	Number of plants			Plant height (cm)			Green vegetable yield (kg/ha)		
Treatments	TW	CW	% reduced by TW	TW	CW	% reduced by TW	TW	CW	% reduced by TW
T_1-100%RDF	68.3	78.0	12.4	17.3	21.1	17.7	1210.7	2045.3	40.8
T_2-100%RDF+*Burkholderia* sp.	73.7	82.7	10.9	18.8	21.2	11.3	1270.7	2294.7	44.6
T_3-100%RDF+*Bradyrhizobium* sp.	85.3	91.3	6.6	17.7	20.7	14.5	1949.3	3118.7	37.5
T_4-100%RDF+ *Burk*. sp.+*Brady*. sp.	81.7	82.3	0.7	17.1	20.2	15.5	2009.3	3749.3	46.4
T_5-75%RDF	66.7	73.7	9.5	17.1	20.0	14.7	1408.0	3980.0	64.6
T_6-75%RDF+*Burkholderia* sp.	71.3	74.0	3.6	17.7	19.1	7.3	1536.0	3954.7	61.2
T_7-75%RDF+*Bradyrhizobium* sp.	71.3	73.3	2.7	19.1	20.9	8.9	1213.3	3254.7	62.7
T_8-75%RDF+ *Burk.* sp.+*Brady.* sp.	69.3	74.7	7.1	17.8	19.1	6.6	1605.3	3400.0	52.8

2020:
The irrigation water quality parameters and initial soil properties of soils irrigated by different quality irrigation waters at start experiment during 2020 are provided in Table 2.74. The Initial characteristics of the soil are similar to prior year (2019) with very minor changes in their value.

The effect of poor quality of water on different yield parameters was presented in Table 2.75. It was observed that the use of poor quality water decreased seed germination, plant height as well as vegetable cowpea yield. However, use of liquid bio-fertilizer increased the seed germination and plant height, irrespective of fertilizer quantity. The vegetable cowpea yield was decreased up to 65% due to poor quality water either alone or with liquid bio-fertilizer; therefore, poor quality water is not suitable for vegetable cowpea production. However, it is used for fodder cowpea production**.**

Table 2.74. Initial characteristics of soils under different water quality

Irrigation water quality			Soil properties		
Particulars	Canal water	Tube well water	Parameter	Canal Water Irrigated	Tube well Water Irrigated
EC (dSm^{-1})	0.33	4.42	Soil Texture Sand (%) Silt (%) Clay (%)	Loamy sand 80.1 12.2 7.7	
Na^+ (meq/l)	1.41	36.5	pH (1:2)	8.44	8.88
Ca^{+2}+ Mg^{+2} (meq/l)	1.71	7.2	EC $_{1:2}$ (dS m^{-1})	0.19	0.63
Cl^{-1} (meq/l)	0.8	11.8	OC (%)	0.33	0.32
CO_3^{-2} (meq/l)	nil	nil	Available N (kg ha^{-1})	233	209
HCO_3^-(meq/l)	1.6	6.8	Available P (kg ha^{-1})	10.6	8.83
RSC (meq/l)	0	0	Available K (kg ha^{-1})	210	182
SAR	1.5 2	19.24	Iron (mg kg^{-1})	5.65	5.12
			Copper (mg kg^{-1})	1.45	1.21
			Zinc (mg kg^{-1})	2.12	1.95
			Manganese (mg kg^{-1})	6.11	5.92

Table 2.75 : Effect of poor quality water and liquid bio-fertilizer on vegetable cowpea

	Number of plants			Plant height (cm)			Green vegetable yield (kg/ha)		
Treatments	TW	CW	% reduced by TW	TW	CW	% reduced by TW	TW	CW	% reduced by TW
T_1-100%RDF	75.3	84.4	10.7	19.4	21.7	10.5	1311.9	2368.1	44.6
T_2-100%RDF+*Burkholderia* sp.	87.1	93.1	6.5	18.3	21.2	13.8	2011.6	3218.5	37.5
T_3-100%RDF+*Bradyrhizobium* sp.	83.4	83.9	0.6	17.7	20.7	14.7	2073.9	3869.3	46.4
T_4-100%RDF+ *Burk*. sp.+*Brady*. sp.	68.1	75.2	9.4	17.8	20.5	13.2	1454.0	4107.4	64.6
T_5-75%RDF	72.8	75.5	3.5	18.3	19.6	6.3	1583.5	4081.3	61.2
T_6-75%RDF+*Burkholderia* sp.	72.8	74.8	2.6	19.8	21.4	7.6	1252.9	3358.9	62.7
T_7-75%RDF+*Bradyrhizobium* sp.	70.8	76.2	7.1	18.5	19.6	5.7	1656.2	3508.8	52.8
T_8-75%RDF+ *Burk.* sp.+*Brady.* sp.	75.3	84.4	10.7	19.4	21.7	10.5	1311.9	2368.1	44.6

The two years' yield data suggested that microbial inoculants, namely, *Burkholderia* sp. (PSB) and *Bradyrhizobium* sp. (Nitrogen fixer) as liquid bio-fertilizer were effective in reducing adverse effect of salinity on germination, plant height and yield of cow pea.

2.3 Management of Waste Water

- **Management of sewage water as a source of irrigation and nutrients (Agra)**

A field experiment was started during 2015-16 to evaluate the effects of sewage water, tube well water and sewage + tube well water irrigation in cluster bean -cauliflower-okra crop rotation. The treatment comprised of three irrigation waters namely, i) SW (Sewage Water, ii) TW (Tube Well Water) and iii) 1SW: 1TW with three recommended doses of fertilizer i.e. 50%, 75% and 100% RDF.

Cluster bean: Table 2.76 clearly indicated that the application of sewage water irrigation significantly increased crop yields. Average five years maximum pods yield (122.3 q/ha) was reported in sewage water treatment while minimum yield was reported in case of tube well water irrigation (94.9 q/ha). There was no significant difference in pod yield (q/ha) in case of 75% RDF and 100% RDF. The application of 50% RDF produced significantly lowest pod yield compared with 75% and 100% RDF. The interaction was significant.

Table 2.76: Pod yield of cluster bean in different treatments

Treatments	Cluster bean yield (q/ha)					Mean
	2015	2016	2017	2018	2019	(q/ha)
Irrigation water						
SW	113.3	117.7	121.9	130.8	127.6	122.3
TW	106.6	109.2	87.9	86.5	84.3	94.9
1SW:1TW	108.8	112.4	117.3	125.6	121.6	117.1
	4.9	3.3	11.1	3.6	6.5	5.9
Recommended dose of fertilizer						
50%	99.6	102.5	99.6	109.5	106.2	103.5
75%	112.3	115.5	110.6	115.2	111.1	112.9
100%	116.9	121.3	117.6	118.2	116.2	118.0
CD at 5%	4.9	3.3	11.1	3.6	6.5	5.9

The data (Table 2.77) revealed that the effect of application of irrigation water on the cluster bean crop pod length (cm), pod yield per plant (g) and pod yield q/ha was statistically significant. The application of sewage water irrigation for cluster bean crop resulted in the highest pod length (11.3cm) and lowest for tube well water irrigation (9.8 cm) but tube well water and 1SW:1TW water irrigation gave at par pod length. The pod yield per plant was produced significantly higher in sewage water irrigation treatment (346.86 g) and lowest tube well water irrigation treatment (312.06 g) but tube well water and 1SW:1TW water irrigation gave at par per plant pod yield.

Table 2.77: Effect of different treatments on attributes and yield of cluster bean (Av.2018-19 and 2019-20)

Treatments	Pod length (cm)	Pod yield / plant (g)	Net profit (Rs.)	B: C ratio
Irrigation water				
SW	11.29	346.86	81,316	2.33
TW	9.81	312.06	32,852	1.51
1 SW:1TW	10.85	338.61	75,052	2.24
CD at 5%	0.87	3.77	-	-
Recommended dose of fertilizer				
50%	9.84	327.25	59,755	2.03
75%	10.51	332.29	64,232	2.04
100%	11.27	337.96	65,249	2.05
CD at 5%	0.87	3.77	-	-
IW X F	NS	NS	-	-

The Table 2.76 further clearly indicated that there was no significant difference in case of application of 100% and 75% RDF for pod length and pod yield per plant of cluster bean. The application of 50% RDF gave significantly lowest pod length and pod yield per plant. The net profits for different treatments are given in Table 2.77. The maximum net profit (Rs/ha) and B:C ratio for cluster bean crop were recorded in sewage water irrigation treatment (81,316 and 2.33) and minimum were in case of tube water irrigation treatments (32,852 & 1.51). The use of recommended dose of fertilizer 100% RDF gave maximum net profit (Rs/ha) and B: C ratio (65,249 and 2.03) and minimum was 50% RDF treatments (59,755 and 2.03).

Interaction:

The interaction effect of irrigation water and recommended dose of fertilizer on head yield of cluster bean was found to be significant. A critical examination of the data displayed in Table 2.78 revealed that irrigation water exhibited differential response to RDF. The irrigation water use in cauliflower crop the head yield was increased with every increase in the rate of RDF up to 100%. Where the rate of RDF was increased from 75% to 100% RDF the head yield per hectare marginally increased. The maximum head yield was obtained with the use of sewage water and 100% RDF which was significantly higher than that of rest combinations. After harvest of cluster bean crop, the cauliflower crop was grown during rabi season with different irrigation water and recommended dose of fertilizer.

Table 2.78 Interaction effect of irrigation water x fertilizer dose in cluster bean crop (Av. 2018-19 and 2019-20)

Irrigation water/ fertilizer	50%	75%	100%	Total	Av.
SW	124.4	129.9	133.5	387.7	129.2
TW	80.4	85.7	90.3	256.3	85.4
1SW:1TW	118.9	124.0	128.0	370.9	123.6
Total	323.6	339.5	351.8	-	-
Av	107.9	113.2	117.3	-	-
CD at 5% =		7.8			

Cauliflower crop: The yield data of cauliflower crop are given in Table 2.79. The application of sewage water irrigation to cauliflower crop produced significant increase in yield of cauliflower (250.2 q/ha). The minimum (194.2 q/ha) yield was recorded in tube well water irrigation. The application of 100% RDF gave significantly higher flower yield (251.5 q/ha) and lowest in 192.5 q/ha in 50% RDF.

Table 2.79: Flower yield of cauliflower (q/ha) in different treatments

Treatments	Years					Mean
	2015-16	2016-17	2017-18	2018-19	2019-20	
Irrigation water						
SW	210.4	230.2	234.5	282.1	293.9	250.2
TW	176.3	187.2	177.4	209.4	220.9	194.2
1SW:1TW	203.8	214.8	217.7	265.6	276.3	235.6
	8.8	7.9	7.5	12.9	13.7	10.2
Recommended dose of fertilizer						
50%	164.3	176.9	175.8	217.5	228.1	192.5
75%	210.4	223.8	223.1	255.9	267.3	236.1
100%	215.4	231.6	230.7	284.3	295.7	251.5
CD at 5%	8.8	7.9	7.5	12.9	13.7	10.2

The Table 2.80 clearly indicated that the application of irrigation water and dose of fertilizer gave the significant results in circumference of flower (cm) and weight of head (g). All attributes showed highest performance in sewage irrigated treatments and minimum in tube well irrigated treatments. In case of application of fertilizer, the highest no. of leaves per plant, circumference (cm) and weight of head (g) were recorded in 100% RDF and lowest in 50% RDF.

Table 2.80: Effect of different treatments on yield attributes and yields of cauliflower

Treatments	Flower circumference(cm)	Flower head Weight (gm)	Net profit (Rs.)	B: C ratio
Irrigation water				
SW	60.79	648.64	1,45,005	3.06
TW	42.84	465.25	91,838	2.28
1 SW:1TW	52.44	583.73	1,33,505	2.86
CD at 5%	3.65	11.4	-	-
Recommended dose of fertilizer				
50%	48.30	554.30	1,00,343	2.47
75%	52.55	572.93	1,24,955	2.75
100%	55.23	582.67	1,45,050	2.98
CD at 5%	3.65	11.4	-	-
IW X F	NS	NS	-	-

The net profits of different treatments are also given in Table 2.80. The maximum net profit (Rs/ha) and B:C ratio were recorded for sewage water irrigation treatment (1,45,005 and 3.06) and minimum was tube well water irrigation treatments (91,8838 and 2.28). The use of recommended dose of fertilizer 100% RDF gave maximum net profit (Rs/ha) and B:C ratio (1,45,050 and 2.98) and minimum was 50% recommended dose of fertilizer treatments (1,00,343 and 2.47).

Interaction:

The interaction effect of irrigation water and recommended dose of fertilizer on head yield of cauliflower (q/ha) was found to be significant. A critical examination of the data in Table 2.81 revealed that irrigation water exhibited differential response to RDF. In case of all types of irrigation water, there was increase in cauliflower head yield with every increase in the rate of RDF up to 100%. However, rate of increase with increase in RDF from 75% to 100% RDF was marginal. The maximum head yield was obtained with the use of sewage water and 100% RDF which was significantly higher than that of rest combinations.

Table 2.81. Interaction effect of irrigation water x fertilizer dose on cauliflower yield (q/ha) (Av.2018-19and 2019-20)

Irrigation water	fertilizer				
	50%	75%	100%	Total	Av.
SW	248.8	290.3	325.9	865.0	288.3
TW	193.0	220.2	232.4	645.6	215.2
1SW:1TW	226.8	274.4	311.5	812.6	270.9
Total	668.5	784.9	869.7	-	
Av	222.8	261.6	289.9	-	
CD at 5% =	19.2				

Okra: After harvest of cauliflower crop, okra crop was sown during summer season. The yield data of okra crop are given in Table 2.82. Significantly higher yield (113.9 q/ha) was recorded in case of sewage water irrigation and minimum (60.5 q/ha) was recorded in tube well water irrigation. In case of application of recommended dose of fertilizer, significantly higher pod yield (100.9 q/ha) was recorded for 100% RDF and lowest for (75.7 q/ha) in 50% RDF.

Table 2.82: Pod yield of Okra (q/ha) in different treatments

Treatments	Years					Mean
	2016	2017	2018	2019	2020	
Irrigation water						
SW	62.3	199.4	64.6	123.8	119.7	113.9
TW	39.8	102.6	28.7	68.0	63.2	60.5
1SW:1TW	53.0	158.7	44.2	108.7	103.6	93.6
	4.7	7.6	8.1	5.2	6.6	6.4
Recommended dose of fertilizer						
50%	35.1	127.4	33.6	93.9	88.6	75.7
75%	53.3	162.4	46.0	99.5	95.3	91.3
100%	65.9	170.9	57.9	107.1	102.6	100.9
CD at 5%	4.7	7.6	8.1	5.2	6.6	6.4

Table 2.83 clearly indicated that the application of irrigation water and dose of fertilizer gave the significant results for length of pod (cm) and pod yield per plant (g). The all attributes were the maximum for sewage water irrigated treatments and minimum for tube well water irrigated treatments. In case of application of fertilizer, the highest length of pod and pod yield per plant was recorded in case of 100% RDF and lowest in 50% RDF.

Table 2.83: Effect of different treatments on yield and economics of okra crop (Av.2018-19 and 2019-20)

Treatments	Length of pod (cm)	Pod yield per plant (g)	Net profit (Rs.)	B: C ratio
Irrigation water				
SW	9.41	326.41	94,618	2.06
TW	8.21	270.33	10,509	1.11
1 SW:1TW	9.22	301.61	70,851	1.80
CD at 5%	0.35	6.04	-	-
Recommended dose of fertilizer				
50%	7.61	288.33	52,420	1.62
75%	9.62	299.39	57,447	1.65
100%	10.34	304.17	65,878	1.72
CD at 5%	0.35	6.04	-	-
IW X F	NS	NS	-	-

The net profit for different treatments was calculated (Table 2.83). The maximum net profit (Rs/ha) and B:C ratio were reported for sewage water irrigation treatment (94,618 and 2.06) and minimum for tube well water irrigation (10,509 & 1.11). The 100% RDF gave maximum net profit (Rs/ha) and B:C ratio (65,878 and 1.72) and minimum was for 50% RDF treatment (52,420 and 1.62).

Interaction:

The interaction effect of irrigation water and recommended dose of fertilizer on pod yield of okra crop was found to be significant. A critical examination of the data (Table 2.84) revealed that irrigation water exhibited differential response to RDF. The okra crop the pod yield increased with every increase in the rate of RDF up to 100% in case of irrigation waters. However rate of increase was marginal from 75% to 100% RDF. The maximum pod yield was obtained with the use of sewage water and 100% RDF which was significantly higher than rest treatment combinations.

Table 2.84. Interaction effect of irrigation water x fertilizer dose in okra crop (Av. 2018-19 and 2019-20)

Irrigation water/ fertilizer	50%	75%	100%	Total	Mean
SW	115.4	122.3	127.7	365.4	121.8
TW	60.8	65.5	70.5	196.8	65.6
1SW:1TW	97.7	104.4	116.3	318.4	106.1
Total	273.8	292.2	314.5	-	-
Mean	90.7	97.4	104.8	-	-
CD at 5% =	9.2				

Cropping System Productivity:

The two years average system productivity details of different crops in case of cluster bean-cauliflower-okra cropping sequence are given in Table 2.85. Among the irrigation waters, the maximum system yield was observed in treated sewage water irrigation treatment (539.3 q/ha) and minimum in tube well irrigated treatment (366.2 q/ha). Under treatments related to recommended dose of fertilizers, maximum system productivity was for 100% RDF (512.1 q/ha) and lowest for 50% RDF (422.0 q/ha).

Table 2.85. Effect of different treatments on system productivity (Av. 2018-19 and 2019-20)

Treatments	Cluster bean yield (q/ha)	Cauliflower yield (q/ha)	Okra yield (q/ha)	Cropping system yield (q/ha)
Irrigation water				
SW	129.2	288.3	121.8	539.3
TW	85.4	215.2	65.6	366.2
1SW:1TW	123.6	270.9	106.2	500.7
Recommended dose of fertilizer				
50%	107.9	222.8	91.3	422.0
75%	113.2	261.6	97.4	472.2
100%	117.2	290.0	104.9	512.1

The soil samples were collected from different soil depths (0-15, 15-30, 30-60 and 60-90cm) at sowing and harvesting of cluster bean as well as harvesting of cauliflower and okra. Samples were analyzed for different cations and anions. Data at sowing of cluster bean and harvesting of Okra are given in Table 2.86.

Soil analysis at sowing of cluster bean:

The pH recorded in all the treatments at sowing time was normal range. The sodium range was recorded (19.6-24.7) in all the treatments of the experiment. The Ca+Mg present in all the soil samples collected at sowing time. The all collected soil samples CO_3 was not found but HCO_3 presence in all the samples. The chloride and sulphate present in all the samples collected at sowing of cluster bean crop. The SAR presents in all the collected soil samples but RSC not found any samples of at sowing time soil samples (Table 2.86).

Table 2.86: Soil analysis at sowing of cluster bean crop (Av. 2018-19 and 2019-20)

Treat.	Soil Depth (cm)	ECe	pH	Na	Ca+Mg	CO_3	HCO_3	Cl	SO_4	SAR	RSC
SW 50%RDF	0-15	3.4	7.6	22.1	11.4	-	8.5	11.9	13.1	9.3	-
	15-30	3.3	7.7	21.6	10.9	-	6.5	10.9	14.7	9.2	-
	30-60	3.2	7.6	20.8	11.2	-	7.0	12.2	12.8	9.0	-
	60-90	3.2	7.6	19.9	12.2	-	6.5	12.1	13.5	8.1	-
SW 75%RDF	0-15	3.3	7.7	21.9	11.1	-	7.5	12.5	13.1	9.4	-
	15-30	3.3	7.7	21.9	10.6	-	6.0	12.4	14.2	9.6	-
	30-60	3.2	7.6	21.1	10.9	-	7.5	11.7	12.8	9.1	-
	60-90	3.2	7.6	19.6	11.9	-	6.5	11.9	13.1	8.6	-
SW 100%RDF	0-15	3.3	7.7	21.7	10.8	-	7.0	12.2	13.3	9.4	-
	15-30	3.3	7.7	22.0	10.5	-	6.5	11.8	14.3	9.7	-
	30-60	3.2	7.6	20.5	11.0	-	6.5	11.8	13.2	8.8	-
	60-90	3.2	7.6	20.4	11.1	-	6.0	12.3	13.2	8.7	-
TW 50%RDF	0-15	3.7	7.6	24.7	11.9	-	7.5	11.5	17.5	10.2	-
	15-30	3.5	7.6	23.9	11.1	-	7.5	11.9	15.6	10.3	-
	30-60	3.4	7.5	22.1	11.4	-	6.5	11.9	15.2	9.5	-
	60-90	3.4	7.7	21.7	11.8	-	7.0	12.0	14.5	9.4	-
TW 75%RDF	0-15	3.9	7.8	24.2	9.4	-	7.0	13.1	18.4	13.5	-
	15-30	3.6	7.7	24.5	11.5	-	7.5	11.7	16.8	10.3	-
	30-60	3.5	7.6	22.0	13.0	-	7.0	11.7	16.4	8.7	-
	60-90	3.4	7.7	22.1	11.9	-	6.5	11.7	15.9	9.1	-
TW 100%RDF	0-15	3.8	7.7	26.0	9.3	-	7.5	11.4	19.2	12.9	-
	15-30	3.6	7.6	23.4	11.9	-	8.0	11.9	15.6	9.7	-
	30-60	3.5	7.6	23.1	11.8	-	7.0	12.5	15.1	9.4	-
	60-90	3.4	7.7	22.9	11.4	-	6.5	11.7	15.9	9.6	-
1SW:1TW 50%RDF	0-15	3.6	7.7	24.0	10.9	-	7.5	11.8	16.2	10.7	-
	15-30	3.4	7.6	22.1	11.7	-	7.0	11.5	15.0	9.1	-
	30-60	3.4	7.6	21.3	11.9	-	7.0	12.3	14.3	8.9	-
	60-90	3.3	7.6	21.6	10.9	-	6.0	11.4	15.2	9.3	-
1SW:1TW 75%RDF	0-15	3.5	7.6	22.9	12.1	-	7.0	11.9	16.1	9.4	-
	15-30	3.4	7.6	21.7	11.8	-	7.5	11.7	14.8	9.2	-
	30-60	3.3	7.6	21.1	12.3	-	6.0	11.7	15.4	8.4	-
	60-90	3.3	7.6	21.9	11.7	-	6.5	11.7	14.9	8.9	-
1SW:1TW 100%RDF	0-15	3.5	7.6	22.3	12.1	-	7.5	12.1	15.5	9.4	-
	15-30	3.4	7.7	22.3	11.9	-	6.5	11.8	15.7	9.1	-
	30-60	3.4	7.6	21.4	12.2	-	6.0	11.4	16.7	7.4	-
	60-90	3.3	7.6	21.9	11.4	-	6.5	11.1	15.4	9.1	-

Soil analysis at harvest of okra crop:

The pH recorded in all the treatments at harvesting time was normal range. The sodium range was recorded (21.2-32.5) in all the treatments of the experiment these were slightly higher that compare at harvest of cauliflower crop. The Ca+Mg present in all the soil samples but this value was higher compared with at sowing time values of Ca+Mg. The all collected soil samples CO_3 was not found but HCO_3 presence in all the samples. The chloride and sulphate present in all the samples collected at harvest of okra crop. The SAR presents in all the collected soil samples but RSC not found any samples of at harvest time soil samples (Table 2.87).

Table 2.87: Soil analysis at harvest of Okra crop (Av. 2018-19 and 2019-20)

Treat.	Soil Depth (cm)	ECe	pH	Na	Ca+Mg	CO_3	HCO_3	Cl	SO_4	SAR	RSC
SW 50%RDF	0-15	3.5	7.7	23.5	11.5	-	7.5	13.7	13.9	9.9	-
	15-30	3.5	7.6	23.6	10.9	-	7.5	13.5	13.6	10.1	-
	30-60	3.4	7.6	23.5	10.5	-	7.0	12.7	14.3	10.5	-
	60-90	3.4	7.6	23.4	10.2	-	7.0	13.2	13.8	10.4	-
SW 75%RDF	0-15	3.5	7.7	23.1	11.9	-	8.0	14.3	12.7	9.5	-
	15-30	3.5	7.7	24.0	10.5	-	7.0	12.8	14.2	10.6	-
	30-60	3.4	7.7	21.9	12.2	-	7.5	14.0	12.5	8.9	-
	60-90	3.4	7.7	23.8	10.2	-	7.0	13.2	14.4	10.6	-
SW 100%RDF	0-15	3.5	7.6	23.4	11.1	-	7.5	14.2	12.3	9.9	-
	15-30	3.5	7.6	22.8	11.7	-	7.0	13.8	13.7	9.5	-
	30-60	3.4	7.7	23.3	10.7	-	7.5	13.3	13.7	10.2	-
	60-90	3.4	7.7	21.5	12.6	-	7.0	12.1	14.9	8.6	-
TW 50%RDF	0-15	4.5	7.6	32.5	12.5	-	8.0	16.2	22.8	13.1	-
	15-30	4.3	7.7	30.5	12.5	-	7.0	14.2	21.8	12.4	-
	30-60	4.0	7.6	28.7	10.8	-	7.0	13.7	19.4	12.4	-
	60-90	3.8	7.6	28.2	14.3	-	7.5	13.8	16.7	13.9	-
TW 75%RDF	0-15	4.6	7.7	30.6	14.9	-	7.0	15.2	22.8	11.5	-
	15-30	4.4	7.7	29.5	14.1	-	6.5	14.5	22.5	11.5	-
	30-60	4.1	7.7	27.5	13.0	-	6.5	12.4	20.7	11.4	-
	60-90	3.9	7.7	26.9	11.6	-	7.5	13.2	18.4	11.0	-
TW 100%RDF	0-15	4.5	7.7	30.9	14.1	-	7.0	14.5	23.0	12.4	-
	15-30	4.3	7.7	30.9	12.1	-	7.0	15.3	20.7	12.3	-
	30-60	4.2	7.6	30.0	11.5	-	7.0	14.6	20.5	13.1	-
	60-90	4.1	7.6	30.2	10.4	-	7.0	13.9	19.2	12.7	-
1SW:1TW 50%RDF	0-15	3.7	7.6	26.2	10.9	-	8.0	13.6	15.9	11.8	-
	15-30	3.6	7.6	26.0	9.5	-	7.5	13.0	14.5	11.7	-
	30-60	3.5	7.6	23.7	11.4	-	7.0	13.6	14.5	10.0	-
	60-90	3.5	7.6	23.4	11.2	-	7.0	13.7	14.3	10.0	-
1SW:1TW 75%RDF	0-15	3.7	7.7	24.9	12.1	-	7.0	14.4	15.1	10.6	-
	15-30	3.6	7.6	25.0	10.5	-	6.5	13.4	15.7	10.3	-
	30-60	3.5	7.6	23.3	11.2	-	7.0	13.3	14.7	9.6	-
	60-90	3.5	7.6	23.3	11.2	-	7.5	13.4	13.7	12.3	-
1SW:1TW 100%RDF	0-15	3.7	7.6	24.3	12.7	-	7.5	13.3	15.7	10.5	-
	15-30	3.5	7.6	24.2	10.8	-	7.0	13.5	14.5	10.1	-
	30-60	3.5	7.6	24.0	11.0	-	7.0	13.5	15.0	8.9	-
	60-90	3.4	7.6	21.2	12.0	-	7.0	13.5	13.5	8.8	-

3. MANAGEMENT OF IRRIGATION INDUCED ALKALIZATION AND SALINIZATION

3.1 Management of Irrigation Induced Alkali Soils

- **Management of sodic Vertisols through resources conservation technologies (Indore)**

2019

This experiment was initiated to study effect different tillage practices and mulch on crop performance, soil properties and economics in case of rice-wheat crop rotation grown on sodic Vertisols. The initial ESP of the experiment plot was 45 and it was brought to 36 after gypsum treatment. Treatments details of the experiment are as below. Main plot (Tillage): T_1: Conventional Tillage-Conventional Tillage (CT-CT); T_2: Reduced tillage-Zero tillage (RT-ZT); T_3: Zero tillage (Self tilled)-zero tillage (ZT-ZT) and T_4: Fallow. Sub plot (Mulching): M_0: No mulch and M_1: Organic mulch. Experimental design was Split plot and replication : 3. The Rice straw was applied @ 5 t/ha was used as mulch in *rabi* season (wheat crop) and wheat straw @ 5 t/ha was used as mulch in *kharif* season (rice crop).

Results showed that grain and straw yield were significantly influenced by various tillage systems (Table 3.1). Among the tillage systems highest grain yield (3285 kg/ha) was recorded in conventional tillage which was significantly superior to reduced tillage and zero tillage. The grain yield was not influenced significantly by the application of mulch. Similarly, the highest straw yield (4827 kg/ha) was obtained under conventional tillage which was statistically comparable with reduced tillage (4671 kg/ha) and significantly superior to zero tillage (4397 kg/ha). Application of rice crop residue as mulch @ 5 t/ha produced significantly higher straw yield (4761 kg/ha) in comparison to no mulch (4502 kg/ha).

Table3.1 Effect of resources conservation technologies on grain and straw yield of wheat

Grain yield (kg/ha)				
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Mean
Without mulch	3273	3181	2879	3111
With mulch	3297	3116	3082	3165
Mean	3285	3148	2981	
	Tillage	Mulch	Tillage x mulch	
CD 5%	96	NS	NS	
Straw yield (kg/ha)				
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Mean
Without mulch	4740	4505	4262	4502
With mulch	4913	4837	4532	4761
Mean	4827	4671	4397	
	Tillage	Mulch	Tillage x mulch	
CD 5%	290	101	NS	

Effect of tillage and mulch on soil properties

The data indicated that tillage and mulch had no significant on pHs (Table 3.2), available N, P and K. However, significantly lowest value of ECe (1.39 dS/m) was recorded under conventional tillage followed by reduced tillage (1.47 dS/m) and zero tillage (1.73 dS/m). However, ECe was not influenced significantly by mulch. Similarly, significantly higher organic carbon content was recorded with conventional tillage (0.39%) which was at par with reduced and zero tillage. Application of mulch recorded higher organic carbon content (0.39%) as compared to without mulch treatment. ESP was influenced significantly by various tillage and mulch practices. The lowest mean value of ESP (27.37) was recorded under conventional tillage followed by reduced tillage (29.95). The lowest ESP (30.08) was noticed with mulch as compared to no mulch (32.03) as shown in Fig.3.1.

Table 3.2 Effect of resources conservation technologies on pHs, ECe, ESP and organic carbon

pHs					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	8.41	8.54	8.60	8.66	8.55
With mulch	8.40	8.47	8.49	8.63	8.49
Mean	8.40	8.51	8.54	8.64	
	Tillage	Mulch	Tillage x mulch		
CD 5%	NS	NS	NS		
ECe (dS/m)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	1.41	1.52	1.77	2.01	1.68
With mulch	1.37	1.41	1.69	1.95	1.61
Mean	1.39	1.47	1.73	1.98	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.10	NS	NS		
ESP					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	28.80	31.13	32.53	35.67	32.03
With mulch	25.93	28.77	30.77	34.87	30.08
Mean	27.37	29.95	31.65	35.27	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.79	0.72	NS		
Organic carbon (%)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	0.37	0.32	0.34	0.32	0.34
With mulch	0.41	0.40	0.36	0.39	0.39
Mean	0.39	0.36	0.35	0.35	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.04	0.05	NS		

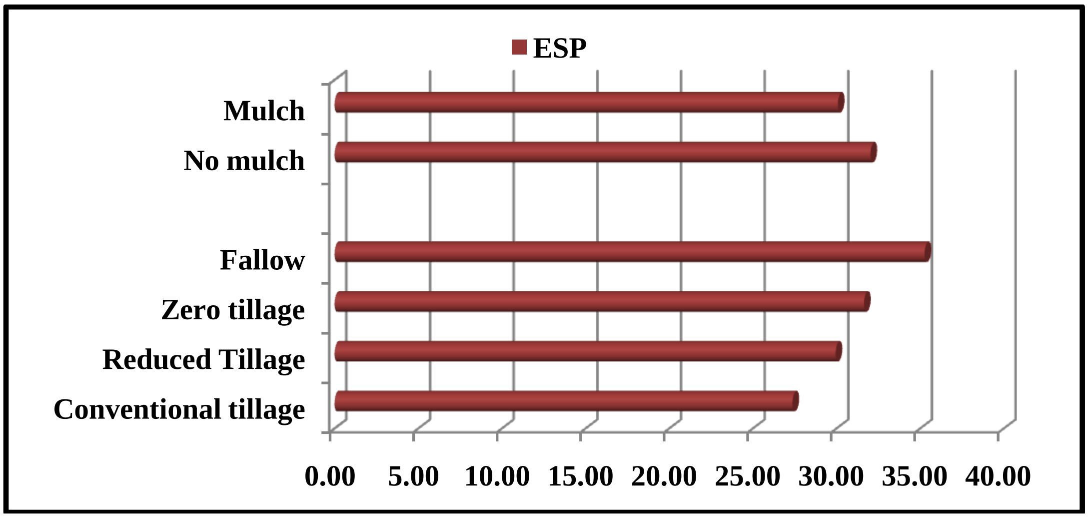


Fig. 3.1 Effect of resources conservation technologies on ESP

2020

The initial ESP of the experiment plot before the experimentation was 45. The gypsum was applied and its ESP was reduced up to 36. The paddy – wheat cropping sequence was taken. Only wheat crop was taken during 2018-19. The experiment was laid out by taking paddy as test crop paddy (CSR-10) and wheat (HI 1544) during 2019-20 with and without mulch and three tillage practices i.e. conventional, reduced and zero tillage. Growth and yield parameters of paddy and wheat were recorded and soil samples were also taken to know the soil properties before and after paddy and wheat. The paddy was transplanted on dated 2.8.2019 and harvested on 7.11.2019. The sowing of wheat was done on dated 15.11.2019 and harvested on 19.03.2020. Treatment details are given in earlier section.

Effect of tillage and mulch on paddy crop

Data presented in Table 3.3 revealed that plant height, number of tillers /plant, penicle length and grain and straw yield of paddy were significantly affected by various tillage practices during the experimentation. The highest values of plant height (68.97 cm), number of tillers/plant (9.60), penicle length (11.22 cm), grain yield (3680 kg ha^{-1}) and straw yield (4711 kg ha^{-1}) were recorded in conventional tillage followed by in reduced tillage and lowest was in zero tillage. However, the lowest values of all the parameters under study were noticed under zero tillage. Mulch failed to cause any significant effect on plant height, number of tillers /plant and penicle length of paddy length of panicle.

Data presented in Table 3.4 revealed that plant height (cm) of wheat did not influenced by various tillage practices during the experimentation. However, the maximum value (76.65 cm) of plant height was recorded in conventional tillage followed by in reduced tillage and lowest was in zero tillage. The number of tillers /m row length, length of ear head and grain and straw yield of wheat were significantly affected by various tillage practices during the experimentation. The highest values of number of tillers/m row length (82.5), length of earhead (6.75 cm), grain yield (3490 kg ha^{-1}) and straw yield (4732 kg ha^{-1}) were recorded in conventional tillage followed by reduced tillage and lowest was in zero tillage. Mulch were failed to cause any significant effect on plant height, number of tillers /plant, length of ear head and grain yield of wheat. However, application of rice crop residue as mulch @ 5 t/ha produced significantly higher straw yield (4658 kg/ha) in comparison to no mulch (4440 kg/ha). The photographs showing the effect of different treatments are given in Plate 3.1.

Effect of tillage and mulch on soil properties after paddy harvest

The data presented in Table 3.5 and 3.6 indicated that tillage and mulch had no significant on pHs, available N, P and K. However, significantly lowest value of ECe (1.37 dS/m) was recorded under conventional tillage. Non- significant difference in ECe was obtained between conventional and reduced tillage values. Fallow field shows maximum ECe (1.96 dS/m) followed by zero tillage and reduced tillage and they are significantly differed with each other. While, soil ECe did not affect by mulch application. Similarly, significantly higher organic carbon content was recorded with conventional tillage (0.42 %) which was at par with reduced and zero tillage. Application of mulch recorded higher organic carbon content (0.42%) as compared to without mulch treatment. ESP is an important soil property as influenced significantly by various tillage and mulch practices. Maximum ESP (33.07) was recorded in fallow treatment and was significantly higher over other treatments under study. All the tillage treatments are significantly differ in each other in respect of ESP. The lowest mean value of ESP (25.60) was recorded under conventional tillage. Similarly, the lowest ESP (28.20) was also noticed with mulch treatment as compared to no mulch (30.12) treatment. The result shows that the mulch has the capacity to reduce ESP to some extent in sodic vertisols of Nimar Valley.

Effect of tillage and mulch on soil properties after harvest of wheat

The pH values of soil paste were affected significantly by tillage practices (Table 3.7). Fallow field showed maximum soil pH (8.60) followed by zero tillage (8.52). Mulch did not affect soil pH. Significantly lowest value of ECe (1.37 dS/m) was recorded under conventional tillage followed by reduced tillage (1.45 dS/m) and zero tillage (1.70 dS/m). However, ECe did not influenced significantly by mulch. . ESP as influenced significantly by various tillage and mulch practices. The lowest mean value of ESP (25.60) was recorded under conventional tillage followed by reduced tillage (28.23). The lowest ESP (28.20) was noticed with mulch as compared to no mulch (30.12). Similarly, significantly higher organic carbon content was recorded with conventional tillage (0.43%). Application of mulch recorded significantly higher organic carbon content (0.42%) as compared to without mulch treatment. The data presented in Table 3.8 indicated that tillage practices and mulch had no significant effect on available N, P and K.

Table 3.3: Effect of RCT on paddy growth, yield attributes and yield of paddy

Mulches	**Tillage practices**			
	Conventional tillage	Reduced tillage	Zero tillage	Mean
Plant height (cm)				
Without mulch	66.27	62.67	60.03	62.99
With mulch	71.67	64.30	61.83	65.93
Mean	68.97	63.48	60.93	
	Tillage	Mulch	Tillage x mulch	
CD 5%	5.8	NS	NS	
Number of tillers/plant				
Without mulch	9.33	9.25	8.33	8.97
With mulch	9.87	9.55	8.67	9.36
Mean	9.60	9.40	8.50	
	Tillage	Mulch	Tillage x mulch	
CD 5%	1.0	NS	NS	
Panicle length (cm)				
Without mulch	16.14	15.90	15.05	15.69
With mulch	16.30	16.10	15.13	15.84
Mean	16.22	16.00	15.09	
CD 5%	Tillage	Mulch	Tillage x mulch	
	0.9	NS	NS	
Grain yield (kg/ha)				
Without mulch	3610	3308	3078	3332
With mulch	3750	3380	3285	3472
Mean	3680	3344	3182	
	Tillage	Mulch	Tillage x mulch	
CD 5%	155	NS	NS	
Straw yield (kg/ha)				
Without mulch	4693	4333	4032	4353
With mulch	4729	4394	4271	4465
Mean	4711	4364	4152	
	Tillage	Mulch	Tillage x mulch	
CD 5%	180	110	NS	

Table 3.4. Effect of resources conservation technologies on growth and yield attributes of wheat

Mulches	**Tillage practices**			
	Conventional tillage	Reduced tillage	Zero tillage	Mean
Plant height (cm)				
Without mulch	75.87	71.77	70.72	72.78
With mulch	77.43	72.73	71.53	74.90
Mean	76.65	72.25	71.12	
	Tillage	Mulch	Tillage x mulch	
CD 5%	NS	NS	NS	
Number of tillers/m row length				
Without mulch	80.68	68.62	64.30	71.20
With mulch	84.35	76.00	72.80	77.71
Mean	82.50	72.31	68.55	
	Tillage	Mulch	Tillage x mulch	
CD 5%	7.3	NS	NS	
Length of Ear head (cm)				
Without mulch	6.60	6.32	6.27	6.39
With mulch	6.90	6.87	6.60	6.79
Mean	6.75	6.59	6.43	
CD 5%	Tillage	Mulch	Tillage x mulch	
	0.31	NS	NS	
Grain yield (kg/ha)				
Without mulch	3445	3255	3178	3293
With mulch	3535	3305	3211	3350
Mean	3490	3280	3195	
	Tillage	Mulch	Tillage x mulch	
CD 5%	124	NS	NS	
Straw yield (kg/ha)				
Without mulch	4658	4428	4235	4440
With mulch	4805	4782	4388	4658
Mean	4732	4605	4312	
	Tillage	Mulch	Tillage x mulch	
CD 5%	370	110	NS	

Table 3.5. Effect of RCT on soil pHs, ECe, ESP and organic carbon after paddy harvest

pHs					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	8.40	8.50	8.58	8.62	8.53
With mulch	8.38	8.44	8.46	8.57	8.46
Mean	8.39	8.47	8.52	8.60	
	Tillage	Mulch	Tillage x mulch		
CD 5%	NS	NS	NS		
ECe (dS/m)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	1.40	1.49	1.74	2.00	1.66
With mulch	1.34	1.40	1.67	1.92	1.58
Mean	1.37	1.45	1.70	1.96	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.10	NS	NS		

ESP					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	27.03	29.23	30.50	33.70	30.12
With mulch	24.17	27.23	28.97	32.43	28.20
Mean	25.60	28.23	29.73	33.07	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.79	0.72	NS		
Organic carbon (%)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	0.40	0.35	0.38	0.36	0.37
With mulch	0.44	0.43	0.40	0.39	0.42
Mean	0.42	0.39	0.39	0.37	
CD 5%	Tillage	Mulch	Tillage x mulch		
	0.04	0.05	NS		

Table 3.6. Effect of resources conservation technologies on available N, P and K after paddy harvest

Available N (kg/ha)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	164.6	148.0	157.6	148.3	154.6
With mulch	179.3	176.6	157.3	173.0	171.5
Mean	172.0	162.3	157.5	160.6	
	Tillage	Mulch	Tillage x mulch		
CD 5%	NS	NS	NS		
Available P (kg/ha)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	9.45	8.77	8.20	9.67	9.02
With mulch	9.20	8.37	8.90	10.50	9.24
Mean	9.33	8.57	8.55	10.08	
	Tillage	Mulch	Tillage x mulch		
CD 5%	NS	NS	NS		
Available K (kg/ha)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	461.3	460.6	461.3	470.6	463.5
With mulch	464.0	461.3	443.0	501.3	467.4
Mean	462.6	461.0	452.1	486.00	
CD 5%	Tillage	Mulch	Tillage x mulch		
	NS	NS	NS		

Table 3.7. Effect of RCT on soil pHs, ECe, ESP and organic carbon after wheat harvest

pHs					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	8.38	8.50	8.58	8.62	8.52
With mulch	8.38	8.44	8.46	8.57	8.46
Mean	8.38	8.47	8.52	8.60	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.14	NS	NS		

ECe (dS/m)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	1.40	1.49	1.74	2.00	1.66
With mulch	1.34	1.40	1.67	1.92	1.58
Mean	1.37	1.45	1.70	1.96	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.10	NS	NS		
ESP					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	27.03	29.23	30.50	33.70	30.12
With mulch	24.17	27.23	28.97	32.43	28.20
Mean	25.60	28.23	29.73	33.07	
	Tillage	Mulch	Tillage x mulch		
CD 5%	1.26	0.43	NS		
Organic carbon (%)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	0.42	0.35	0.38	0.36	0.38
With mulch	0.44	0.43	0.40	0.39	0.42
Mean	0.43	0.39	0.39	0.37	
	Tillage	Mulch	Tillage x mulch		
CD 5%	0.03	0.03	NS		

Table 3.8. Effect of resources conservation technologies on available N, P and K after wheat harvest

Available N (kg/ha)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	168.62	164.00	157.60	148.16	159.59
With mulch	179.30	176.24	168.61	170.00	173.53
Mean	173.96	170.12	163.10	159.08	
	Tillage	Mulch	Tillage x mulch		
CD 5%	NS	NS	NS		
Available P (kg/ha)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	9.20	8.37	8.20	9.67	8.86
With mulch	9.45	8.77	8.90	10.50	9.40
Mean	9.33	8.57	8.55	10.08	
	Tillage	Mulch	Tillage x mulch		
CD 5%	NS	NS	NS		
Available K (kg/ha)					
Mulch	Conventional tillage	Reduced tillage	Zero tillage	Fallow	Mean
Without mulch	461.35	460.70	461.54	470.60	463.54
With mulch	467.00	466.22	463.71	501.35	474.57
Mean	462.17	463.46	462.62	485.97	
CD 5%	Tillage	Mulch	Tillage x mulch		
	NS	NS	NS		

T1 – Conventional Tillage + No Mulch

T1 – Zero Tillage + No Mulch

T1 – Reduced Tillage + No Mulch

T1 – Conventional Tillage + With Mulch

Plate 3.1 Performance of rice crop under conservation experiment

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

This experiment was conducted at Research farm, Dalipnagar, Kanpur with the objectives to find out the suitable combination of organic and inorganic inputs for sustainable crop production in sodic conditions during 2016 to 2019. The treatments comprised of T_1- 50%GR; T_2- 25%GR + rice straw @5 t/ha; T_3- 25%GR + GM @5 t/ha; T_4- 25%GR + GM @5 t/ha + Microbial culture; T_5- 25%GR + Poultry manure @3t/ha; T_6- 25%GR + City Waste Manure @5 t/ha and T_7 - Control. Rice variety CSR 36 and wheat variety KRL 210 were sown during kharif and rabi season. The initial soil status was pH 9.50, EC (0.94 dS/m), ESP 48.20 and OC 0.21%.

The average grain and straw yield of rice varied from 24.48-42.37 and 29.48-50.89 q/ha respectively, (Table 3.9). The maximum yield of grain (42.37 q/ha) and straw (50.89 q/ha) was obtained from 25%GR + Poultry manure @3t/ha treatment followed by 25%GR + GM @5 t/ha + Microbial culture and 25%GR + City Waste Manure @5 t/ha while minimum yield was received from control plot.

Table 3.9 Effect of different treatments on grain and straw yield of rice (q/ha)

Treatments	Grain				Straw			
	2016	2017	2018	Mean	2016	2017	2018	Mean
T_1- 50%GR	35.38	36.82	37.12	36.44	41.57	43.55	44.10	43.74
T_2- 25%GR + rice straw @5 t/ha	33.45	34.55	35.75	34.58	39.94	41.46	42.04	41.15
T_3- 25%GR + GM @5 t/ha	37.72	38.98	40.10	25.57	45.48	47.00	48.68	47.25
T_4- 25%GR + GM @5 t/ha + M C	39.27	40.86	42.00	40.71	47.53	49.44	51.20	49.39
T_5- 25%GR + Poultry manure @3t/ha	40.68	42.18	44.24	42.37	49.65	51.03	52.00	50.89
T_6- 25%GR + C W M @5 t/ha	38.15	39.65	40.68	39.49	45.95	47.97	49.10	47.67
T_7 – Control	23.82	24.58	25.04	24.48	28.44	29.74	30.25	29.48
CD = 0.05	1.87	1.93	1.86	--	2.01	2.27	2.31	--

The average grain and straw yield of wheat varied from 19.59-36.78 and 24.13-44.73 q/ha respectively (Table 3.10). The maximum yield of grain (36.78 q/ha) and straw (44.73 q/ha) was obtained from 25%GR + Poultry manure @3t/ha treatment followed by 25%GR + GM @5 t/ha + Microbial culture and 25%GR + City Waste Manure @5 t/ha while minimum yield was received from control plot.

Table 3.10 Effect of treatments on grain and straw yield of wheat (q/ha)

Treatments	Grain				Straw			
	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean
T1- 50%GR	30.54	32.00	32.82	31.78	37.25	39.04	40.27	38.85
T2- 25%GR + rice straw @5 t/ha	28.72	29.68	31.15	29.85	35.04	36.21	37.75	36.33
T3- 25%GR + GM @5 t/ha	29.46	30.35	32.00	30.60	36.54	38.10	39.35	37.99
T4- 25%GR + GM @5 t/ha + M C	32.27	33.88	35.12	33.76	39.52	41.67	43.20	41.46
T5- 25%GR + P M @3t/ha	35.34	36.75	38.25	36.78	43.11	44.83	46.24	44.73
T6- 25%GR + C W M@5 t/ha	33.83	35.16	36.42	35.14	40.82	43.24	44.26	42.77
T7 - Control.	19.12	19.56	20.10	19.59	23.33	24.27	24.78	24.13
CD = 0.05	1.92	1.86	1.89	--	2.11	2.24	2.33	--

Physico chemical Properties of Soil

The improvement of soil properties with the application of different treatments over control plot (Table 3.11). The maximum changes in pH, electrical conductivity, exchangeable sodium percentage (ESP) and organic carbon (OC) were observed in 50% GR treated plot followed by 25%GR + Poultry manure @3t/ha and 25%GR + GM @5 t/ha + Microbial culture than other treatment.

Table 3.11 Effect of treatments on soil properties after three year

Treatments	pH	EC (dS/m)	ESP	OC (%)
T_1- 50%GR	8.7	0.89	30.8	0.26
T_2- 25%GR + rice straw @5 t/ha	9.0	0.90	36.3	0.29
T_3- 25%GR + GM @5 t/ha	8.9	0.92	35.8	0.30
T_4- 25%GR + GM @5 t/ha + Microbial culture	8.8	0.89	34.5	0.34
T_5- 25%GR + Poultry manure @3t/ha.	8.8	0.89	32.2	0.36
T_6- 25%GR + City Waste Manure @5 t/ha	8.9	0.91	35.1	0.32
T_7 - Control	9.3	0.94	44.4	0.23
Initial Soil Status	9.5	0.94	48.2	0.21

- **Evaluating the reclamation efficiency of different sources of Gypsum for Sodic Soil Management (Tiruchirapalli)**

An experiment was initiated to assess the reclamation efficiency of different sources of Gypsum as an alternate to mineral gypsum and to know thereof performance of rice in reclaimed sodic soil.

2019

Samples of Marine gypsum and Mineral gypsum were sourced for laboratory analysis. Marine gypsum samples were cleaned, powdered and sieved into two size group of 2 mm and 0.2 mm. The samples were prepared for characterization of physical and chemical parameters with the facilities available at Dept. of Nano Science & Technology, Tamil Nadu Agricultural University, Coimbatore.

2020

A field experiment was planned on basis of different gypsum sources. The initial properties of experimental field are given in Table 3.12.

Table 3.12 Initial experimental field soil properties

S.No	Particulars	*Kharif* 2020	*Rabi* 2020-21
1	pH	9.32	9.48
2	EC (dSm^{-1})	0.46	0.44
3	Organic (Carbon %)	4.9	4.7
4	Available N ($kg\ ha^{-1}$)	221	207
5	Available P($kg\ ha^{-1}$)	12.6	11.4
6	Available K ($kg\ ha^{-1}$)	236	224
7	ESP %	34.87	36.23

A Field experiment was conducted during *kharif* 2020 to study the effect of sodic soil reclamation using different sources of gypsum on plant height. At Active tillering stage, results showed that, T_4 recorded the highest plant height followed by T_2, T_3. The least plant height was recorded in T_1. The same trend was observed in panicle initiation stage and flowering stage also (Table 3.13).

The same experiment was conducted during *Rabi* 2020-21and results showed that with respect to active tillering stage and panicle initiation stage,T_4 recorded the highest plant height followed by T_2 and T_3. However, T_4 and T_2 are statistically on par with each other. Lowest plant height was recorded in T_1. At flowering stage, T_4 recorded the highest plant height followed by T_2 and T_3. Least plant height was recorded in T_1 (Table 3.13).

Table 3.13. Effect of sodic soil reclamation using different sources of Gypsum on plant height

Treatment	*Kharif* 2020			*Rabi* 2020-21		
	Active Tillering stage	Panicle initiation stage	Flowering Stage	Active Tillering stage	Panicle initiation stage	Flowering Stage
T_1: Control	42.6	50.4	84.7	46.7	61.3	92.1
T_2: Mineral Gypsum (50 % GR)	48.3	58.2	90.5	50.8	69.9	99.2
T_3: Phospho Gypsum (50 % GR)	45.8	54.7	87.2	48.3	67.9	96.1
T_4: Marine Gypsum (50 % GR)	54.4	60.6	94.9	52.3	70.7	102.0
SEd	0.65	0.91	0.70	0.68	1.07	0.77
CD($p=0.05$)	1.4	2.0	1.5	1.5	2.3	1.7

A Field experiment was conducted during *kharif* 2020, to study the effect of sodic soil reclamation using different sources of gypsum on Leaf Area Index. The experiment result shows that at 10 DAT,T_4 recorded the highest LAI, followed by T_2 and T_3. However, T_4,T_2 and T_2,T_3 are statistically on par with each other respectively. Lowest LAI was recorded in T_1. At 30 DAT among all the treatments, recorded data shows that T_4 has highest LAI, followed by T_2 and T_3. However, T_2 and T_3 are statistically on par. T_1 recorded the lowest Leaf Area Index. Here also, T3 and T1 are statistically on par with each other. At 50 DAT highest LAI was recorded in T_4, followed by T_2 and T_3. Lowest LAI was recorded in T_1. At 70 DAT, T_4 recorded the highest LAI, followed by T_2 and T_3. However, T_4 and T_2 are statistically on par. Lowest LAI was recorded in T_1. At 90 DAT, highest LAI was recorded in T_4 followed by T2, T3. However, T2 and T3 are statistically on par with each other. Lowest LAI was recorded in T1. However, T3 and T1 are statistically on par with each other (Table 3.14).

The same experiment was conducted during *k*2020-21 and experimental results showed that, at 10DAT, T_4 recorded the highest LAI followed by T_2 and T_3. However T_2 and T_3 are statistically on par. Least LAI was recorded T_1. However, T_3, T_1 are statistically on par with each other. At 30 DAT and 70 DAT data recorded that, T_4 has the highest LAI followed T_2 and T_3. However, T_4 and T_2 are statistically on par with each other. Lowest LAI was recorded in T_1. At 50 DAT, T4 recorded the highest LAI, followed by T_2 and T_3. However T_2, T_3 are statistically on par with each other. Lowest LAI was recorded in T_1. AT 90 DATT4 recorded the highest LAI followed by T_2 and T_3. Lowest LAI was recorded in T_1 (Table 3.14).

Table 3.14 Effect of sodic soil reclamation using different sources of Gypsum on Leaf Area Index

Treatment	Kharif 2020					Rabi 2020-21				
	10 DAT	30 DAT	50 DAT	70 DAT	90 DAT	10 DAT	30 DAT	50 DAT	70 DAT	90 DAT
T1: Control	0.80	1.80	4.67	4.78	2.89	0.90	1.85	4.88	5.28	3.19
T2: Mineral Gypsum (50 % GR)	0.86	1.87	4.85	5.22	3.06	0.93	2.18	5.24	5.61	3.72
T3: Phospho Gypsum (50 % GR)	0.83	1.84	4.75	5.03	2.98	0.92	2.01	5.19	5.49	3.62
T4: Marine Gypsum (50 % GR)	0.88	1.94	4.95	5.33	3.15	0.95	2.27	5.30	5.66	3.87
SEd	0.014	0.019	0.035	0.057	0.058	0.009	0.042	0.025	0.034	0.034
CD(0.05)	0.03	0.04	0.08	0.12	0.13	0.02	0.09	0.05	0.07	0.07

A Field experiment was conducted to study the effect of sodic soil reclamation using different sources of gypsum during *kharif* 2020 on Dry matter production (kg/ha). The experimental data revealed that, at 10 DAT Highest DMP was recorded in T_4 followed by T_2 and T_3. However, T_4 and T_2 are statistically on par with each other. At 30, 50, 70 DAT and at harvest, the recorded data shows that highest DMP was produced in T_4, followed by T_2 and T_3. Least DMP was recorded in T_1. The same trend continued at 90DAT with highest DMP recorded in T_4 followed by T_2 and T_3. However, T_2 and T_3 are statistically on par with each other. Lowest DMP was recorded in T_1 (Table 3.15).

The same experiment was conducted during *Rabi* 2020-21 and the recorded data reveals that, at 10DAT,T_4 recorded the highest DMP followed by T_2 and T_3. However, T_2 and T_3 are statistically on par with each other. The Lowest DMP was recorded in T_1. However,T_3 and T_1 are statistically on par with each other. From the observed that, it also found that at 30, 70 and 90 DAT maximum DMP was produced in T_4 followed by T_2 and T_3. The lowest DMP was recorded in T_1. At 50 DAT, Maximum DMP was recorded in T4 followed by T_2 and T_3. However, T_4 and T_2 are statistically on par with each other and the lowest DMP was recorded in T_1. Finally at the harvest, Maximum DMP was recorded in T_4, followed by T_2 and T_3. However, T_2 and T_3 are statistically on par with each other. Lowest DMP was recorded in T1 at the harvest (Table 3.15).

Table 3.15. Effect of sodic soil reclamation using different sources of Gypsum on dry matter production (kg/ha)

Treatment	Kharif 2020						Rabi 2020-21					
	10 DAT	30 DAT	50 DAT	70 DAT	90 DAT	Harvest	10 DAT	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
T_1: Control	664	2555	4027	5094	6367	6865	757	2711	4239	5515	6503	7040
T_2: Mineral Gypsum (50 % GR)	760	3355	4964	5810	7053	10006	776	3630	5425	6215	7229	13097
T_3: Phospho Gypsum (50 % GR)	726	3248	4570	5589	6922	9662	766	3515	5233	6075	7082	12728
T_4: Marine Gypsum (50 % GR)	773	3613	5265	6098	7241	10426	793	3842	5532	6315	7515	14384
SEd	12.6	46.6	71.4	80.9	70.5	96.8	7.3	34.0	49.8	52.2	45.0	224.9
CD(0.05)	28.0	102	156	176	154	211	16	74	109	114	98	490

A Field experiment was conducted during *kharif* 2020, to study the effect of sodic soil reclamation using different sources of gypsum on Total tillers and unproductive tillers per hill. The experimental results revealed that at 50, 70 and 90 DAT, maximum total tillers were recorded in T4 followed by T2 and T3. The lowest tillers were recorded in T_1. At Harvest, recorded data shows that, maximum total tillers production was observed in T_4 followed by T_2 and T_3. However, T_4, T_2 and T_2, T_3 are statistically on par with each other respectively. Regarding Unproductive tillers, data recorded shows that, Maximum unproductive tillers are observed in T1 followed by T_3 and T_2. However, T_3 and T_2 are statistically on par with each other. Lowest unproductive tillers are recorded in T_4. However, T_2 and T_4 are statistically on par with each other (Table 3.16).

The same experiment was conducted during *rabi* 2020-21 and the recorded data showed that, at 50 DAT maximum total tillers recorded in T_4 followed by T_2 and T_3. However T_4, T_2 and T_2, T_3 are statistically on par with each other respectively. Lowest total tillers are recorded in T1. At 70 DAT Maximum total tillers was observed in T_4 followed by T_2 and T_3. However, T_4 and T_2 are statistically on par with each other. T_1 recorded the lowest total tillers. At 90 DAT, data recorded revealed that, maximum Total tillers are observed in T_4 followed by T_2 and T_3. Least total tillers recorded in T_1. At harvest the experiment data revealed that, T_4 recorded the maximum total tillers followed by T_2 and T_3. Howe ever, T_2 and T_3 are statistically onpar with each other. Lowest total tillers are recorded in T_1. Regarding Unproductive tillers, recorded data shows that, lowest unproductive tillers are recorded in T_4, followed by T_2 and T_3. However T_4 and T_2 are statistically on par with each other. T_1 recorded the Highest Unproductive tillers (Table 3.16).

A Field experiment was conducted during *kharif* 2020, to study the effect of sodic soil reclamation using different sources of gypsum on Grain and straw yield (kg/ha). The experimental data revealed that, maximum grain yield was recorded in T_4 followed by T_2 and T_3. Lowest grain yield recorded in T_1. Regarding the straw yield, maximum data was recorded in T_4 followed by T_2 and T_3. However, T_4, T_2 and T_2, T_3 are statistically on par with each other respectively. Lowest straw yield was recorded in T_1 (Table 3.17).

The same experiment was conducted during ***rabi*** 2020-21 and the recorded data shows that, Maximum grain yield was observed in T_4 followed by T_2 and T_3. Lowest grain yield was recorded in T_1. Regarding the straw yield, maximum yield was recorded in T_4 followed by T_2 and T_3. Howe ever, T_2 and T_3 are statistically on par with each other. Lowest straw yield was recorded in T_1 (Table 3.17).

Table 3.16. Effect of sodic soil reclamation using different sources of Gypsum on Total tiller and Unproductive tiller per hill

Treatment	Kharif 2020					Rabi 2020-21				
	50 DAT	70 DAT	90 DAT	Harvest	Unproductive tillers	50 DAT	70 DAT	90 DAT	Harvest	Unproductive tillers
T1: Control	10.9	15.6	16.6	12.0	4.5	12.6	17.5	20.3	13.4	4.4
T2: Mineral Gypsum (50 % GR)	15.8	21.1	22.9	17.7	3.4	18.1	23.5	24.5	20.7	3.4
T3: Phospho Gypsum (50 % GR)	14.8	19.3	21.3	17.3	3.8	17.5	21.3	23.4	20.2	3.8
T4: Marine Gypsum (50 % GR)	16.8	23.1	24.0	18.5	3.1	18.8	24.7	26.3	22.8	3.2
SEd	0.38	0.55	0.25	0.48	0.19	0.40	0.62	0.50	0.46	0.15
CD(0.05)	0.8	1.2	0.5	1.0	0.4	0.9	1.3	1.1	1.0	0.3

Table 3.17. Effect of sodic soil reclamation using different sources of Gypsum on Grain and Straw yield (kg/ha)

Treatment	Kharif 2020		Rabi 2020-21	
	Grain yield	Straw yield	Grain yield	Straw yield
T1: Control	2802	4063	2980	4060
T2: Mineral Gypsum (50 % GR)	4218	5788	5681	7416
T3: Phospho Gypsum (50 % GR)	4020	5642	5415	7314
T4: Marine Gypsum (50 % GR)	4511	5916	6367	8017
SEd	56.0	100.2	57.1	212.8
CD(0.05)	122	218	124	463

A Field experiment was conducted during *kharif* 2020, to study the effect of sodic soil reclamation using different sources of gypsum on Exchangeable Ca, Mg, Na, K(c mol $(p^{+)}$ kg $^{-1}$)The experimental data reveals that, maximum Exchangeable Calcium, Magnesium was recorded in T_4 followed by T_2 and T_3. Lowest Exchangeable Calcium, Magnesium recorded in T_1.Regarding Exchangeable Sodium, Lowest Exchangeable Sodium was recorded in T_4 followed by T_2 and T_3. Highest Exchangeable Sodium was recorded in T_1. Maximum Exchangeable potassium was recorded in T_4 followed by T_2 and T_3. However, T_4 and T_2 are statistically on par with each other. Lowest Exchangeable potassium was recorded in T_1 (Table 3.18).

The same experiment was conducted during *rabi* 2020-21 and the recorded data revealed that, maximum exchangeable Calcium, Magnesium was observed in T_4 followed by T_2 and T_3. Lowest exchangeable Calcium, Magnesium was recorded in T_1. Lowest exchangeable Sodium was recorded in T_4 followed by T_2 and T_3. Highest Exchangeable sodium was recorded in T_1. Maximum exchangeable potassium was recorded in T_4 followed by T_2 and T_3. However, T_4 and T_2 are statistically on par with each other. Lowest Exchangeable potassium was recorded in T_1 (Table 3.18).

Table 3.18. Effect of sodic soil reclamation using different sources of Gypsum on Exchangeable Ca, Mg, Na, K (c mol ($p^{+)}$ kg $^{-1}$)

Treatment	Kharif 2020				Rabi 2020-21			
	Ca	Mg	Na	K	Ca	Mg	Na	K
T1: Control	7.67	3.78	6.03	0.21	7.40	3.40	6.17	0.20
T2: Mineral Gypsum (50 % GR)	11.81	4.67	2.79	0.34	11.49	4.54	2.95	0.29
T3: Phospho Gypsum (50 % GR)	10.74	4.49	3.25	0.29	10.25	4.37	3.22	0.23
T4: Marine Gypsum (50 % GR)	12.80	5.33	2.51	0.37	12.31	4.86	2.61	0.31
SEd	0.084	0.064	0.073	0.018	0.037	0.044	0.045	0.011
CD(0.05)	0.18	0.14	0.16	0.04	0.08	0.09	0.09	0.02

A Field experiment was conducted during *kharif* 2020, to study the effect of sodic soil reclamation using different sources of gypsum on pH, EC(dSm^{-1}), Exchangeable Sodium Percentage (ESP). The experimental data reveals that, highest pH was recorded in T_1 followed by T_3 and T_2. Lowest pH was recorded in T_4. With respect to EC, the highest data was recorded in T_3 followed by T_2 and T_4. The lowest EC was recorded in T_1. The experimental data revealed that lowest Exchangeable Sodium Percentage (ESP) was recorded in T_4 followed by T_2 and T_3. Highest ESP was recorded in T_1 (Table 3.19).

The same experiment was conducted during *rabi* 2020-21 and the recorded data revealed that, Highest pH was recorded in T_1 followed by T_3 and T_2. Lowest pH was recorded in T_4. However, T_2 and T_4 are on par with each other. With respect to EC, the highest data was recorded in T_3 followed by T_2 and T_4. However, T_3 and T_2 are statistically on par with each other. The lowest EC was recorded in T_1. The experimental data revealed that highest Exchangeable Sodium Percentage (ESP) was recorded in T_1 followed by T_3 and T_2. Lowest Exchangeable Sodium Percentage (ESP) was recorded in T_4 (Table 3.19).

Table 3.19. Effect of sodic soil reclamation using different sources of Gypsum on pH, EC and ESP

Treatment	*Kharif* 2020			*Rabi* 2020-21		
	pH	EC	ESP	pH	EC	ESP
T1: Control	9.37	0.43	34.09	9.50	0.45	35.96
T2: Mineral Gypsum (50 % GR)	8.66	0.50	14.21	8.70	0.54	15.29
T3: Phospho Gypsum (50 % GR)	8.89	0.54	17.30	9.01	0.58	17.81
T4: Marine Gypsum (50 % GR)	8.52	0.46	11.95	8.67	0.50	13.00
SEd	0.052	0.012	0.299	0.046	0.017	0.181
CD($p=0.05$)	0.11	0.03	0.65	0.10	0.04	0.39

3.2 Management of Irrigation Induced Waterlogged Saline Soils and Coastal Saline Soils

- **Evaluation of spacing and controlled subsurface drainage system on soil properties, water table, crop yield and nutrient losses in rice fields of TBP Command (Gangavathi)**

The continuous violation of guidelines for crop areas in TBP command created canal water shortages for paddy crops in tail-end areas and also developed a secondary salinization (96215 ha) in the downstream/tail end in the command (CADA, 2013). In order to reclaim these salt-affected lands, TBP-CADA (Tungabhadra Project-Command Area Development Authority) undertook surface and subsurface drainage (SSD) works in the TBP command. However, farmers, particularly in tail-end areas, started blocking outlets of lateral drains to avoid over draining in view of the shortage of canal irrigation supply. In addition, farmers are also resorted to using natural stream/ drain/ Nala waters (locally called Halla) added a new dimension to the salinity problem. On the basis of a simulation study using SALTMOD model it was predicted that complete blocking of the SSD system during both the cropping seasons had adverse effects on the performance of the SSD system and increased soil salinity in the drainage area.

In view of this background, there were two thoughts among the researchers, the first was drain spacing might be increased to avoid over-draining and the second option was adoption controlled drainage. It was thought to increase lateral drain spacing by 10 m from present recommended the spacing of 50 m for TBP Command. As controlled drainage was found effective in reducing drain flow in different drainage project world-wide, controlled drainage was also considered as one option. Therefore, an experiment was planned at the Agriculture Research Station, Gangavathi in rice fields with conventional and controlled SSD with 50 and 60 m drain spacing with an objective to find a suitable drainage management strategy to manage soil salinity as well as to address irrigation water shortage during paddy crop. The drainage water quantity and quality, soil salinity, salt balance, water table, paddy yield nitrate losses, economic analysis for 50 and 60 m drain spacing with conventional and controlled drainage were monitored for seven seasons to search for better drainage water management strategy for the tail-end areas of TBP Command. It was also considered 40 m drain spacing both under conventional and controlled SSD, however, due to inadequate water supply to this area, only 50 and 60 m SSD spacing are discussed in this report.

Over seven seasons (2013 to 2019), the quantity of irrigation water applied at each irrigation event was measured by using the Parshall flume in both 50 and 60 m spacing. The daily rainfall data was collected from the meteorological observatory at Agricultural Research Station (ARS), Gangavathi. The drain flows were measured manually at all lateral drains by using a bucket and stopwatch at two days interval during drainage events (mm/d) and collected drain water (leachate) samples were analyzed for soluble salt concentration (EC, dSm^{-1}), pH and Nitrate–N concentration (mg/L). The salt and nitrate concentrations in the leachate were multiplied by their corresponding drainage discharge of each lateral were used to estimate salt load and loss of Nitrate-N on a kg/ha basis. There were 16 PVC observation wells installed to a depth of 1.0 m and depth to the water table was measured manually by tape once in two days interval. A total of 44 soil samples were collected before and after transplanting of each season up to a depth of 90 cm, with 15 cm increment and analyzed electrical conductivity (EC_e). Paddy grain yield was recorded at 10 grid points of 2 x 2 m from each SSD site and expressed the yield as q/ha. Looking into economics, three methods were used to evaluate the investment in SSD system viz., payback period, the simple rate of return and the internal rate of return on the investment for each of the drain spacing. These three measures are considered to be the most appropriate since it is based on the present value of future revenue obtained from the investment in drainage. The cost per hectare of installation of SSD system with considering the nominal length (up to 200 m) of Nala cleaning for 50 and 60 m drain spacing was ₹ 96661 and ₹ 83005, respectively.

Drainage discharges: After transplanting of paddy plots, conventional SSD mode was applied for about 10 days in both the treatments to ensure that drain discharge is similar and then adopted controlled SSD mode in respective plots. The drain discharge collected from the outlet in each treatment varied from 0.61 to 3.04 and 0.36 to 1.86 mm/d with a mean value of 1.88 and 0.87 mm/d under conventional SSD at 50 and 60 m spacing respectively (Table 3.20). Similarly under controlled SSD drain discharge varied from 0.16 to 1.23 and 0.14 to 1.25 mm/d with a mean value of 0.55 and 0.53 mm/d, respectively (Fig. 3.2) at 50 and 60 m spacing, respectively. Irrespective of the spacing, drainage discharge was significantly higher under conventional than controlled SSD system over seven seasons. The results of the seven season data in all the spacing depicted that controlled SSD treatment reduced about 70% and 39% drainage discharge than conventional SSD treatment. The monthly drain discharge was maximum during October (1.61 vs.0.43 and 0.66 vs.0.37 mm/d) and November (2.15 vs.0.54 and 0.54 vs.0.29 mm/d) months. It coincided with monsoon rains and minimum during December month (0.73 vs.0.11 and 0.21 vs.0.11 mm/d) due to withdrawal of irrigation water from the paddy fields as crop reach to maturity in both the conventional and controlled SSD treatment at 50 and 60 m spacing, respectively. Among these two drain spacings, 50 m drain spacing gave higher drain discharge under both conventional and controlled SSD. Seasonal and monthly drain discharges confirm that controlled SSD device playing a major role in reducing rate of drain discharge. Hence, results of the data clearly showed that instead of complete blocking of the existing systems, a controlled drainage approach would help to reduce the drainage outflow by effective utilization of irrigation water to the paddy crop at the tail end of a command.

Table -3.20. Drainage discharge (mm/d) under conventional and controlled sub-surface system

Season	50 m		60 m	
	CNV	CTD	CNV	CTD
Rabi 13-14	2.40	1.23	1.86	1.25
Kharif-14	2.03	0.42	0.97	0.60
Kharif-15	2.61	0.81	0.87	0.56
Kharif-16	3.04	0.66	0.93	0.50
Kharif-17	1.26	0.18	0.60	0.35
Kharif-18	1.25	0.37	0.48	0.30
Kharif-19	0.61	0.16	0.36	0.14
Average	1.88	0.55	0.87	0.53

Note : CNV= Conventional SSD; CTD= Controlled SSD

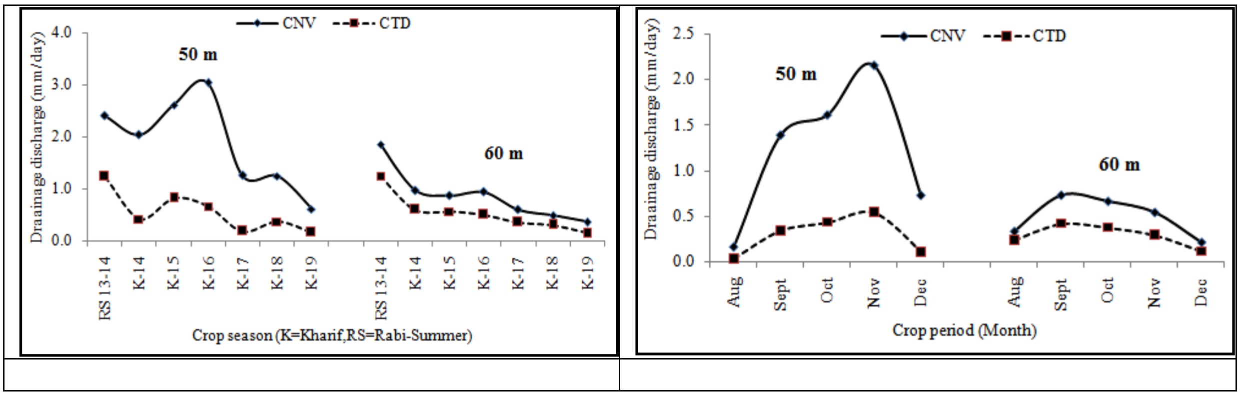


Fig.3.2 Season wise and monthly average drainage outflow in conventional and controlled SSD under different spacing

Drainage water salinity: The analysis of drain drainage samples revealed that higher drainage water salinity under conventional than controlled SSD system in both the spacing over seven seasons. The average drainage water salinity in each treatment varied from 1.55 to 3.05 and 1.76 to 4.79 dS/m with a mean value of 2.09 and 2.89 dS/m (Table 3.21) under conventional SSD at 50 and 60 m spacing. Similarly under controlled SSD drain water salinity varied and from 1.34 to 3.07 and 1.59 to 2.74 dS/m with a mean value of 1.93 and 2.37 dS/m at 50 and 60 m spacing, respectively (Fig. 3.3). The results of the data clearly showed that the higher average salinity level of the effluent (8% and 18%) due to high flow rate under conventional SSD would help faster movement of soluble salts from the soil than corresponding controlled SSD systems at 50 and 60 m spacing respectively. The monthly drainage water salinity was maximum during October (1.95 vs.1.69 and 2.22 vs.1.84 dS/m) and November (1.87 vs.2.04 and 2.72 vs.2.59 dS/m) months. It coincided with monsoon rains and minimum during December (1.50 vs.1.77 and 2.22 vs.2.27 dS/m) month due to withdrawal of irrigation water from the paddy fields at physiological maturity of crops. This caused low flow rate with a low salinity level of drainage effluent in both the conventional and controlled SSD treatment at 50 and 60 m spacing respectively. Though the drain discharge was low under 60 m spacing but it had higher salinity level of the effluent than 50 m spacing under conventional and controlled SSD respectively.

Table 3.21. Salinity of drainage effluent (dS/m) as influenced by different spacing under conventional and controlled SSD

Season	50 m		60 m	
	CNV	CTD	CNV	CTD
R/S'13-14	3.05	2.02	4.79	2.74
Kharif-14	2.51	3.07	2.48	1.59
Kharif-15	1.97	1.76	2.14	1.86
Kharif-16	1.55	1.48	2.65	1.84
Kharif-17	1.98	2.21	3.81	2.68
Kharif-18	1.81	1.65	1.76	2.55
Kharif-19	1.73	1.34	2.63	3.31
Average	2.09	1.93	2.89	2.37

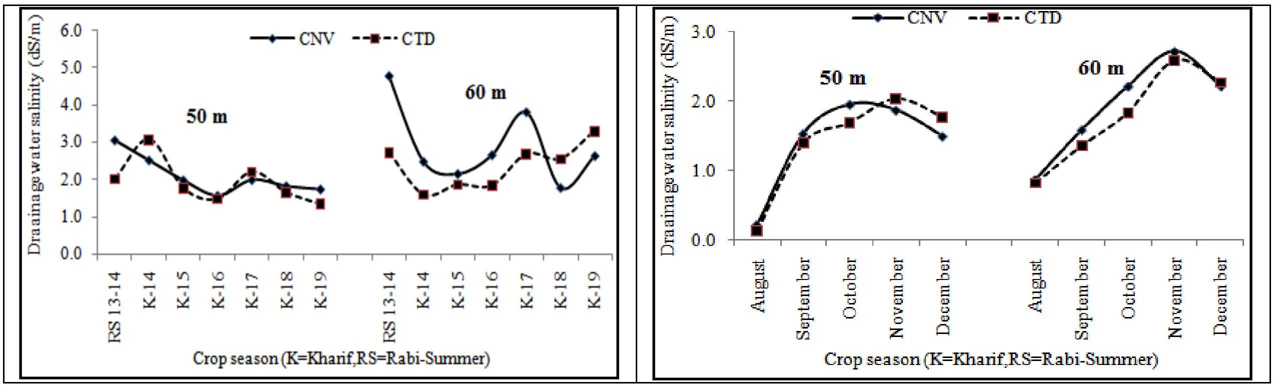


Fig. 3.3 Season-wise and monthly average drainage water salinity (dS/m) for the conventional and controlled SSD under different spacing

Seasonal water balance under different drain spacing: Seasonal water balance of the study area was worked out by considering the quantity of irrigation water applied for paddy crop including rainfall and also the quantity of drainage water outflow (Table 3.22 and 3.23) at different SSD spacing under both conventional and controlled SSD systems. Table 3.22 is related to 50 m spacing and all details of water balance components are provided while Table 3.23 is related to 60 m spacing and only average values are given. The average water used over seven seasons was 125 vs. 97.8 and 110 vs. 81.7 cm under conventional and controlled SSD at 50 and 60 m spacing respectively. This indicated that the controlled SSD system saved 27 cm (28%) and 28 cm (35%) depth of irrigation at 50 and 60 m spacing, respectively. Similarly, average drainage outflow over seven seasons was 179 vs. 51 and 78 vs. 47 mm under conventional and controlled SSD at 50 and 60 m spacing, respectively, indicating that the controlled drainage system not only saved irrigation water but also reduced 128 mm (70%) and 31 mm (39%) drainage water outflow compared to conventional SSD at 50 and 60 m spacing, respectively. Hence the results clearly showed that the use of controlled drainage in TBP command can be a key strategy to address issue of shortage of irrigation water particularly at the tail end of the command.

Table 3.22. Seasonal water balance (mm) in conventional and controlled drainage systems under 50 m spacing

Water balance component	Irrigation water applied Irrigation water applied	Rainfall	Total input	Difference in input of Conven. & controlled	Drainage outflow	Reduction in drainage outflow	Total input-drainage outflow (Water storage)
Conventional Subsurface Drainage System							
R/S-13-14	1380	0	1380	0	216	0	1164
K-14	1300	228	1528	0	248	0	1280
K-15	1040	225	1265	0	235	0	1030
K-16	1084	124	1208	0	274	0	934
K-17	913	255	1168	0	113	0	1055
K-18	922	123	1045	0	112	0	933
K-19	745	430	1175	0	55	0	1120
Avg	1055	231	1253	0	179	0	1074
Controlled Subsurface Drainage System							
R/S-13-14	1120	0	1120	260	108	108	1012
K-14	963	228	1191	337	51	197	1140
K-15	708	225	933	332	73	162	860
K-16	699	124	823	385	59	215	764
K-17	646	255	901	267	16	97	885
K-18	673	123	796	249	33	79	763
K-19	649	430	1079	96	14	41	1065
Avg	780	231	978	275	51	128	927

Table 3.23. Average Seasonal water balance (mm) in conventional and controlled drainage systems under 60 m spacing

Water balance component	Irrigation water applied Irrigation water applied	Rainfall	Total input	Difference in input of Conven. & controlled	Drainage outflow	Reduction in drainage outflow	Total input-drainage outflow (Water storage)
Conventional Subsurface Drainage System							
Avg	904	231	1102	0	78	0	1024
Controlled Subsurface Drainage System							
Avg	619	231	817	285	47	30	769

Effect of subsurface drainage spacing on depth to water table: The depth to water table was measured from the observation wells under the spacing of both conventional and controlled SSD systems over seven cropping seasons. During canal ON period (July to December), in the conventional subsurface drainage system, the monthly average depth to water table varied from

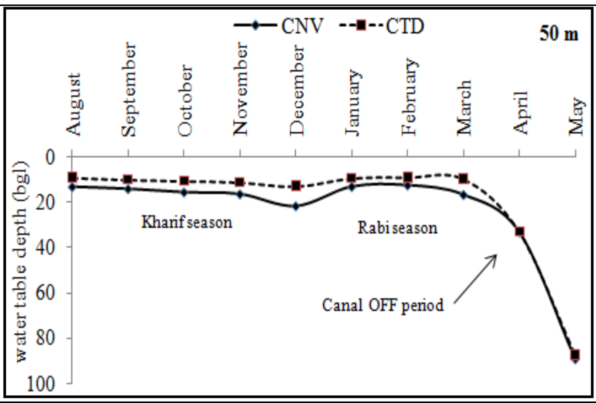
13.2 to 21.7 and 12.3 to 18.7cm with an average value of 19.1 and 16.8 cm as against, 9.3 to 13.1 and 9.1 to 14.1cm with an average value of 13.8 and 12.7 cm under the controlled drainage system at 50 and 60 m spacing, respectively. Similarly during the rabi season, in the conventional subsurface drainage system, the monthly average depth to water table varied from 12.5 to 16.7 and 13.1 to 14.9 cm with an average value of 14.1 and 13.8 cm as against 9.5 and 9.7 cm under the controlled drainage system at 50 and 60 m spacing, respectively (Table 3.24 and Fig. 3.4). The results of the seven season data indicated that controlled drainage system maintained a shallower depth of water table both in Kharif (5.3 and 4.1 cm) and rabi season (4.6 and 4.1cm) as compared to the conventional drainage system at 50 and 60 m spacing, respectively.

During canal OFF period (After April), the monthly average depth to water table under conventional drainage system varied from 33.2 to 89.4 and 36.1 to 95.7 cm as against 33.1 to 87.3 and 31.7 to 89.5 cm under a controlled drainage system at 50 and 60 m spacing, respectively (Table 3.24 and Fig. 3.5). During the harvesting stage all the controlled drainage accessories were removed and maintained as conventional SSD for easy machinery operation. Usually by the end of May, depth to water table reached beyond the depth of observational wells (>1.0 m).

Table 3.24. Average depth to water table, bgl (cm) as influenced by different subsurface drainage spacing under conventional and controlled SSD system.

Month	50 m		60 m	
	CNV	CTD	CNV	CTD
Canal ON period (Kharif season)				
August	13.2	9.3	14.1	10.1
September	14.1	10.2	12.3	9.8
October	15.6	10.7	12.4	9.1
November	16.4	11.3	13.1	9.4
December	21.7	13.1	18.7	14.1
Average	19.1	13.8	16.8	12.7
Canal ON period (Rabi season)				
January	13.1	9.5	13.4	9.8
February	12.5	9.1	13.1	9.3
March	16.7	9.8	14.9	10.1
Average	14.1	9.5	13.8	9.7
Canal OFF period (after rabi)				
April	33.2	33.1	36.1	31.7
May	89.4	87.3	95.7	89.5

Note: bgl- below ground level



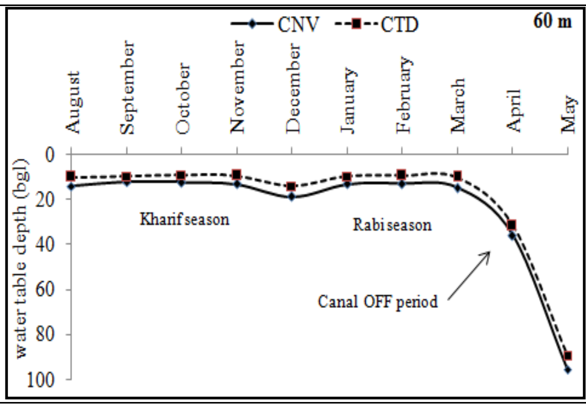


Fig. 3.4 Variation in depth to water table under conventional and controlled SSD

Seasonal salt balance under different drain spacing

Salt balance of the study area was worked out by considering the amount of salts added via irrigation and fertiliser as input and salts removed through the different spacing of both conventional and controlled SSD systems as output over seven seasons (Table 3.25 and 3.26). The salinity of irrigation water (canal water) applied varied from 0.05 to 0.19 dS/m. To calculate the salt balance study the EC of irrigation or drainage water was multiplied by a standard factor of 640 to get the salt load in mg/L (ppm). The recommended dose of fertilizers for paddy crop in these areas was 150N, 75P, and 75K kg/ha. Hence, salt added through fertilizer application alone was 0.045 t/ha per season. The combined average salt load added through irrigation and with fertilizers over seven crop seasons was 0.91 vs 0.69 and 0.79 vs 0.56 t/ha under conventional and controlled SSD at 50 and 60 m spacing respectively. The average salt load removed through drainage discharge over seven crop seasons was 2.34 vs. 0.64 and 1.23 vs. 0.52 t/ha under conventional and controlled SSD at 50 and 60 m spacing, respectively. The data indicated that in conventional SSD system, salt load added through irrigation and fertilizers was more to the extent of 0.22 (24%) and 0.23 t/ha (29%) so also salt load removed through drainage discharge 1.7 (73%) and 0.71 t/ha higher (58%) than controlled SSD at 50 and 60 m spacing, respectively. The monthly salt removal was maximum during October (0.73 vs.0.14 and 0.37 vs.0.17 t/ha) and November (0.71 vs.0.16 and 0.27 vs.0.11 t/ha) due to high drain discharge and was minimum during December (0.15 vs.0.03 and 0.10 vs.0.03 t/ha) month due to low drain discharge under both 50 and 60 m spacing respectively. Among two drain spacing 50 m gave higher salt removal due to higher volume of drain discharge than 60 m spacing under both conventional and controlled SSD respectively. The data of the cumulative amount of salt load added through irrigation and fertilizers and salt discharged through drainage (Fig. 3.5) was also higher under conventional compared to corresponding controlled SSD. The data clearly indicated that reclamation was faster under conventional compared to a controlled SSD system in both the spacing. However, compared to farmers' approach of complete blockage of the outlet, controlled drainage approach appears to be better as some extent of salts is being leached through the system.

Table 3.25**.** Seasonal salt balance (t/ha) in conventional and controlled drainage systems under 50 m spacing

Water balance component	Salt added through irrigation	Salt added through fertilizer	Total amount	Difference in salt input of convent.& controlled	Salt removed through drainage	Difference in salt output of conventional and controlled
Conventional Subsurface Drainage System						
R/S-13-14	1.77	0.045	1.81	0	3.68	1.89
K-14	0.92	0.045	0.96	0	3.08	2.27
K-15	0.73	0.045	0.78	0	2.87	2.11
K-16	0.76	0.045	0.81	0	2.56	2.10
K-17	0.64	0.045	0.69	0	1.35	1.16
K-18	0.65	0.045	0.69	0	2.09	1.76
K-19	0.61	0.045	0.65	0	0.75	0.63
Avg	0.61	0.045	0.91	0	2.34	0.63
Controlled Subsurface Drainage System						
R/S-13-14	1.43	0.045	1.48	0.33	1.79	NA
K-14	0.68	0.045	0.72	0.24	0.81	NA
K-15	0.43	0.045	0.54	0.23	0.76	
K-16	0.42	0.045	0.54	0.27	0.46	NA
K-17	0.38	0.045	0.50	0.19	0.19	NA
K-18	0.40	0.045	0.52	0.18	0.33	NA
K-19	0.39	0.045	0.50	0.15	0.12	NA
Avg	0.59	0.045	0.69	0.23	0.64	NA

Table 3.26. Average seasonal salt balance (t/ha) in conventional and controlled drainage systems under 60 m spacing

Water balance component	Salt added through irrigation	Salt added through fertilizer	Total amount	Difference in salt input of convent.& controlled	Salt removed through drainage	Difference in salt output of conventional and controlled
Conventional Subsurface Drainage System						
Avg	0.75	0.045	0.79	0	1.23	0.71
Controlled Subsurface Drainage System						
Avg	0.51	0.045	0.56	0.24	0.52	NA

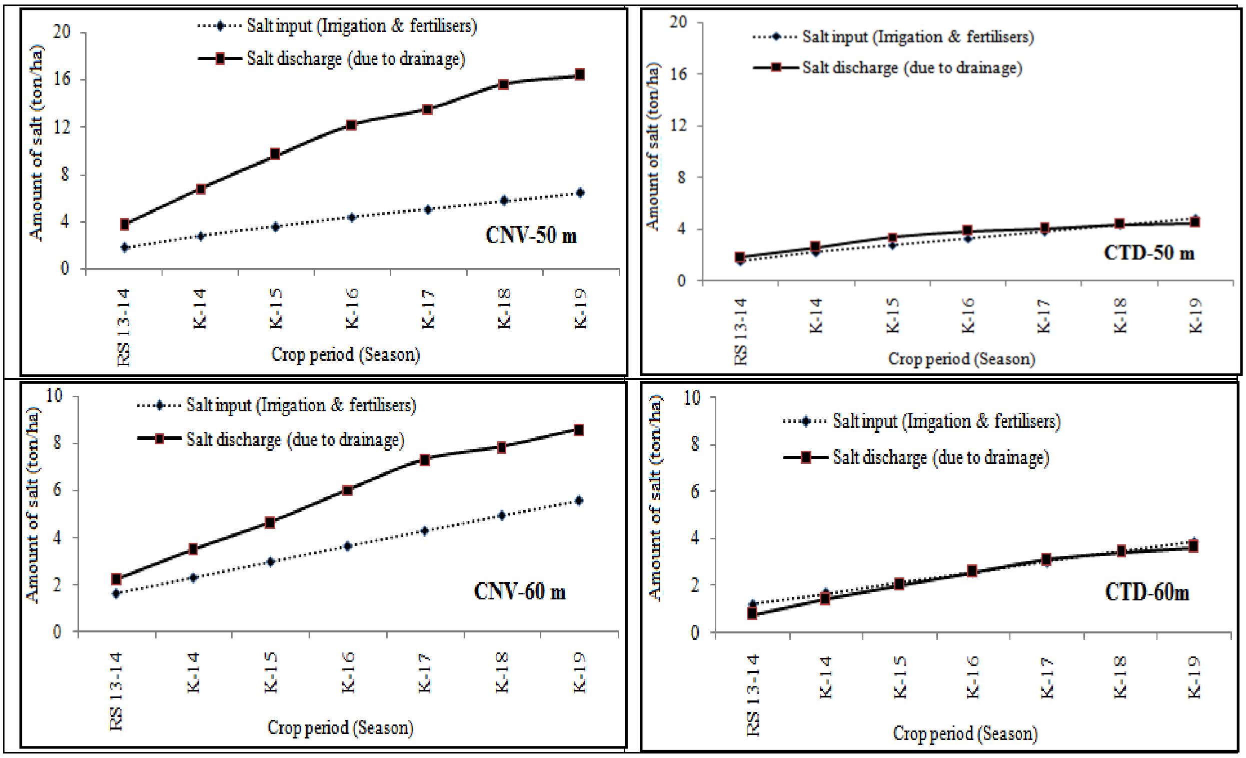


Fig. 3.5 Cumulative salt input and discharge showing leaching and storage of salts in different spacing under conventional and controlled SSD.

Nitrogen-Nitrate loss (NO_3-N)

The average flow weighted NO_3-N concentration mg/L in drainage discharge varied from 7.5 vs.6.45 mg/L and 6.47 vs. 6.23 mg/L under conventional and controlled SSD over seven cropping seasons at 50 and 60 m spacing, respectively (Table 3.27). The results of the data indicated that the average concentration of drainage effluent was (14% and 4%) higher under conventional SSD due to high drainage discharge rate than corresponding with controlled SSD system at 50 and 60 m spacing, respectively. Observed monthly nitrate concentration through drainage discharge was maximum during October and November months which coincided with a time of fertilizer application and also monsoon rains and minimum during December month due to the withdrawal of irrigation water resulting in reduced drain discharge (Fig. 3.6).

The average nitrate losses were 13.95 vs. 4.17 and 5.09 vs. 2.94 kg/ha under conventional and controlled SSD over seven cropping seasons at 50 and 60 m spacing, respectively (Table 3.27). The nitrogen loss through drainage effluent was 70% and 42% higher under conventional than controlled

SSD systems at 50 and 60 m spacing, respectively. The highest nitrogen loss occurred in October and November months under conventional in both the spacing compared to the controlled SSD (Fig. 3.6). The nitrate concentration between conventional and controlled SSD treatments were more or less similar but higher drain discharge (0.87 to 1.88 mm/d) gave higher nitrate loss (5.1 to 14.0 kg/ha) especially under conventional than controlled SSD system at 50 and 60 m spacing. The results of the data indicated that under controlled drainage treatment reduction of nitrate load could be attributed to a reduction of drainage volume rather than a reduction in nitrate concentrations. The data clearly showed that due to regulation of drainage discharge not only addressed the issue of water shortage but also reduced the nitrate loss by adopting a controlled drainage approach in the TBP command.

Soil salinity: The soil salinity up to 90 cm depth at the end of each season under both conventional and controlled SSD as shown in Table 3.28 and 3.29. The mean root zone soil salinity (0-30 cm) reduced (Fig. 3.7) from initial to Kharif-19 was 8.26 to 1.25 dS/m, 4.7 to 0.61 dS/m and 8.97 to 1.37 dS/m and 6.14 to 1.22 dS/m under conventional and controlled SSD system at 50 and 60 m spacing, respectively. In other depths also mean soil salinity was reduced compared to initial soil salinity.

In controlled drainage plots, due to regulation of drainage outflow, at initial seasons some salts were noticed at lower depth (30-90 cm) and in subsequent years it was in decreasing trend. Among the two drain spacing, 50 m drain spacing the rate of decrease in soil salinity was faster than 60 m spacing due to lower initial soil salinity in the profile and also higher drain discharge influencing faster movement of salts through the profile. Reports elsewhere indicated that adoption of controlled drainage in an arable situation resulted marked increase in soil salinity especially at root zone level due to capillary up-flow from the soil profile. Whereas in paddy saturated situation, pushing of salts towards downward depth help to decrease in root zone salinity (0-30 cm) under both conventional and controlled SSD plots (Fig. 3.7). So the farmers of the tail end can adopt this technology to the existing conventional system without accumulation of salts at root zone depth.

Table 3.27. Nitrogen loss through drainage discharge under conventional and controlled SSD

Season	Nitrogen loss (mg/l)				Nitrogen loss (kg/ha)			
	50 m		60 m		50 m		60 m	
	CNV	CTD	CNV	CTD	CNV	CTD	CNV	CTD
R/S'13-14	10.17	7.72	13.23	12.42	20.90	16.54	9.88	6.48
Kharif-14	8.30	7.34	5.80	5.15	15.24	2.57	6.97	3.99
Kharif-15	6.88	5.74	4.78	3.88	15.36	3.33	3.70	1.88
Kharif-16	7.78	7.12	6.26	5.95	20.03	3.89	6.09	3.16
Kharif-17	10.54	11.56	8.31	8.56	12.07	1.63	4.68	2.72
Kharif-18	6.26	4.22	5.15	5.21	12.13	1.01	3.54	1.95
Kharif-19	2.58	1.43	1.77	2.47	1.91	0.19	0.77	0.42
Average	7.50	6.45	6.47	6.23	13.95	4.17	5.09	2.94

Grain yield: As the root zone soil salinity (0-30 cm) decreases (Fig. 3.7), increase in grain yield was observed under both conventional and controlled drainage systems. The grain yield increase was from 46.8 to 58, 45.8 to 50.4 and 36.3 to 56.4, and 36.5 to 54.2 q/ha under conventional and controlled drainage systems at 50 and 60 m drain spacing, respectively. Among two drain spacing, 50m gave higher yield due to lower initial salinity than 60m spacing under both conventional and controlled SSD respectively. Further, irrespective of the spacing, marginally higher grain yield (15.0 and 9.0%) was observed under conventional compared controlled SSD system over the seven cropping seasons at 50 and 60 m drain spacing respectively (Table 3.30).

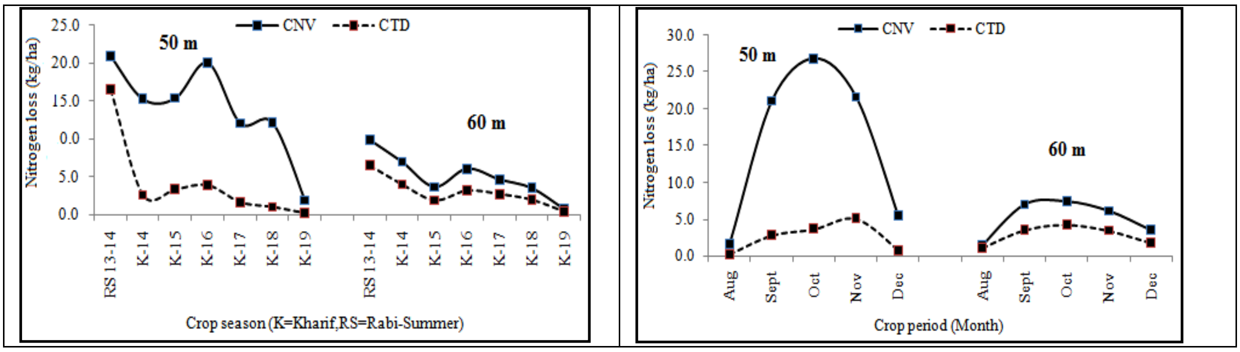


Fig. 3.6 Season wise and monthly nitrogen loss (kg/ha) for the conventional and controlled SSD under different spacing

Table 3.28. Soil salinity (ECe, dS/m) at different soil depth (cm) as influenced by conventional and controlled SSD at 50m spacing

Season	CNV				CTD			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Initial	4.30	5.10	5.93	5.25	6.28	8.30	12.01	13.85
R/S-2013-14	7.79	7.79	8.03	7.95	3.72	6.22	8.33	10.91
Kharif-14	2.50	1.97	3.70	5.32	1.86	4.52	6.94	6.62
R/S-2014-15	2.20	2.03	3.73	4.42	4.14	5.26	8.64	9.01
Kharif-15	2.56	3.36	3.06	2.91	4.87	7.63	9.28	6.86
Kharif-2016	1.41	1.97	2.58	5.14	3.93	3.84	5.59	6.54
Kharif-2017	1.44	1.44	NA	NA	1.91	3.54	NA	NA
Kharif-2018	1.3	2.09	5.43	7.96	0.98	1.12	2.47	2.90
Kharif-2019	0.48	0.74	1.04	1.15	1.34	1.22	2.21	3.50

Table 3.29. Soil salinity (ECe, dS/m) at different soil depth (cm) as influenced by conventional and controlled SSD at 60m spacing

Season	CNV				CTD			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Initial	7.69	10.25	11.01	11.55	5.99	6.29	6.43	6.10
R/S-2013-14	7.80	8.33	7.76	8.93	6.58	7.24	6.53	6.67
Kharif-14	6.83	7.20	7.46	7.31	5.47	6.02	7.12	7.46
R/S-2014-15	5.62	7.67	8.35	9.47	4.39	5.78	5.27	5.68
Kharif-15	6.51	8.15	9.33	10.03	5.34	6.48	6.93	6.75
Kharif-2016	3.96	5.83	6.44	6.48	5.71	7.24	8.64	7.90
Kharif-2017	3.06	3.83	7.45	6.97	3.34	3.37	NA	NA
Kharif-2018	2.85	3.58	7.21	8.79	2.79	4.62	5.02	6.31
Kharif-2019	1.25	1.49	4.58	4.28	1.09	1.35	2.86	2.66

Note: NA Indicates sampling was not possible due to dry condition.

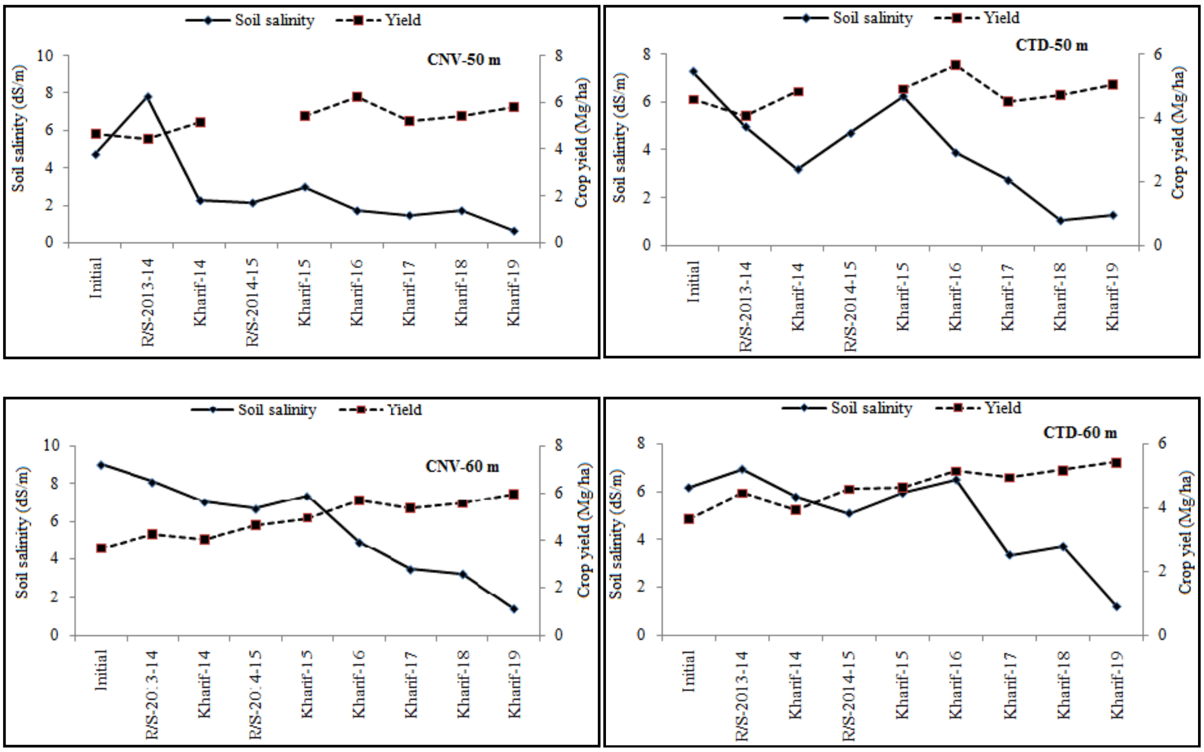


Fig. 3.7 Influence on conventional and controlled SSD on soil salinity (0-30cm) and crop yield

Table 3.30. Variation of crop yield (q/ha) as influenced by spacing of conventional and controlled SSD systems

Season	CNV		CTD	
	50 m	60 m	50 m	60 m
Initial	46.8	36.3	45.8	36.5
R/S-13-14	44.4	42.4	40.6	44.5
Kharif-14	51.4	40.2	48.3	39.4
R/S-14-15	-	46.3	-	45.8
Kharif-15	54.3	49.2	49.1	46.3
Kharif-16	62.3	56.4	56.7	51.43
Kharif-17	52	53.4	45.3	49.4
Kharif-18	54	55.3	47.2	51.6
Kharif-19	58	59.4	50.4	54.2

Economic analysis:

The economic feasibility, the investment in subsurface drainage systems was found to be profitable even though the investment was very high. The initial investment cost of the sub-surface drainage system was worked out to be ₹ 96661 and ₹ 83005 for 50 and 60 m drain spacing respectively. The adoption of a controlled drainage system to the existing SSD required an additional cost of about ₹ 1000/ha. Looking into economics for a period of 20 years, the projected data revealed that (Table 3.31), higher B-C ratios, positive NPV, a higher value of IRR, and lesser payback period at all the different spacing under conventional SSD compared to controlled drainage systems. Based on economic analysis (BCR and payback period), it is evident 50 m drain spacing appears to be suitable for the study region. Considering the additional yields gained, the amount we spent on land reclamation through SSD system could be reimbursed in about 2-3 seasons, indicating that the system is quite remunerative and cost- effective.

Table 3.31. Economics of conventional and controlled SSD system (20 years life period)

Treatment	Drain spacing (m)	Total returns, Rs /ha	Total cost of cultivation, Rs /ha	Net returns, Rs /ha	Net Present Value, Rs /ha	BCR	IRR (%)	Payback period (seasons)
CNV	50	164421.00	78583.00	85838.00	419005.00	1.73	62	1.84
	60	159404.00	77900.00	81504.00	372341.00	1.66	49	2.15
CTD	50	148354.00	78583.00	69770.00	324355.00	1.56	51	1.88
	60	146604.00	77900.00	68704.00	311371.00	1.55	47	2.14

- **Evaluation of different depth (head) of controlled drainage system in saline vertisols of TBP command (Gangavathi)**

2019

A field experiment was laid out at Thimmapur village (Farmers field) in an area of 2 ha block by taking three treatments i.e., Controlled SSD with 50 m spacing each with a raised lateral head upto root zone, 0.3 m and 0.6 m including conventional, fixed and variable outlet heads during *Kharif* 2015. The topography of the area is about 0.165% sloping towards east direction. Considering the topography, the main collector line of the sub surface drainage was planned west to east direction with provision of outlet in east end. The experimental site was divided into eight blocks based on soil salinity so as to accommodate the treatments. A total of 17 soil samples to a depth of 90 cm from 2.0 ha area were collected for characterization. Based on the analysis the ECe of experimental area varied from 4.04 to 23.41 dS/m with an average of 13.48 dS/m, 4.76 to 26.07 dS/m with mean of 14.40 dS/m, 4.39 to 22.88 dS/m with a mean of 12.29 dS/m and 3.06 to 23.41 dS/m with a mean of 11.67 dS/m at 0-15, 15-30, 30-60 and 60-90 cm, respectively.

During Rabi/summer 2018 and Kharif 2018, paddy was transplanted in all the seven block except the first block and as per the suggestions of QRT. Only the conventional SSD system was introduced so as to attain faster reclamation and impose the actual variable outlet head concept during Kharif 2019, depending on the availability of water and soil salinity status.

At crop harvest during Kharif-19 (Table 3.32), out of seven blocks the surface (0-15 cm) soil salinity (ECe) slightly increased from 9.43 to 10.4 (block I), 16.2 to 17.8 (block II), 12.0 to 14.6 (block IV), 10.7 to 13.7(block VI), 9.17 to 13.7 (block VII) and 11.2 to 12.7 dS/m (block VIII), whereas it decreased from 7.54 to 6.3 (block III), 11.0 to 10.2 (block V). Except block III and IV, slightly higher soil salinity was observed at lower depths which could be attributed to the use of nala/bore well water during water shortage from the canals.

Temporal changes in drainage discharge

The drain discharge collected from the outlet of the each treatment during *Kharif*-2019 revealed that the monthly drain discharge varied from 0.89 to 2.84, 0.43 to 0.96, 0.43 to 0.93 and 0.29 to 2.01 mm d^{-1} with a mean value of 1.6, 0.74, 0.71 and 0.87 mm d^{-1} under conventional drainage system, Controlled with 0.3 m height, Controlled with 0.6 m height and Controlled with root zone (0.7m height) respectively. It was observed that highest drainage discharge was recorded under conventional and it followed by controlled drainage at 0.3 m and 0.6 m (Table 3.33). It appeared that controlled at 0.7 m gave unexpected high value during December month and hence data of this set up were not considered.

Table 3.32. Average soil salinity (ECe,dS/m) as influenced by variable lateral head system

Season	0-15 cm	15-30 cm	30-60 cm	60-90 cm	Season	0-15 cm	15-30 cm	30-60 cm	60-90 cm
Block-I					**Block-II**				
Initial	9.43	13.9	11.46	10.4	Initial	16.2	18.3	12.2	9.4
R-17-18	7.5	13.4	12.7	8.78	R-17-18	11.1	16.0	14.3	NA
Kharif-18	17.41	11.86	9.49	9.13	Kharif-18	14.85	10.0	7.9	5.67
Kharif-19	10.4	11.3	15.0	18.9	Kharif-19	17.8	15.2	16.6	15.1
Block-III					**Block-IV**				
Initial	7.54	10.42	14.67	12.0	Initial	12.0	12.3	10.0	7.27
R-17-18	9.19	10.6	16.30	NA	R-17-18	13.8	13.6	9.15	5.72
Kharif-18	5.15	5.59	10.95	8.36	Kharif-18	12.5	10.82	9.26	NA
Kharif-19	6.30	5.40	12.7	16.7	Kharif-19	14.6	14.0	15.7	NA
Block-V					**Block-VI**				
Initial	11.0	13.8	12.4	9.40	Initial	10.7	14.6	13.8	14.8
R-17-18	8.4	8.86	6.54	8.33	R-17-18	7.06	10.8	10.0	13.9
Kharif-18	7.37	7.06	6.42	6.51	Kharif-18	6.04	12.6	14.5	NA
Kharif-19	10.2	6.51	9.10	8.3	Kharif-19	13.7	12.8	16.1	16.1
Block-VII					**Block-VIII**				
Initial	9.17	12.3	11.0	8.63	Initial	11.2	16.1	16.0	13.5
R-17-18	9.15	10.9	11.0	10.7	R-17-18	10.5	14.8	16.2	12.6
Kharif-18	12.8	8.5	10.5	13.0	Kharif-18	13.6	9.1	9.0	8.8
Kharif-19	13.7	11.5	13.9	16.4	Kharif-19	12.7	13.5	17.2	16.9

Table 3.33. Drainage discharge (mm d^{-1}) as influenced by variable depth of drainage systems.

S.No.	Treatments	Sep	Oct	Nov	Dec	**Avg**
1	Conventional drainage	2.84	1.46	1.22	0.89	**1.60**
2	Controlled with 0.3m height	0.93	0.96	0.43	0.62	**0.74**
3	Controlled with 0.6m height	0.93	0.80	0.43	0.69	**0.71**
4	Controlled with root zone (0.7m height)	0.61	2.01	0.29	0.57	**0.87**

Temporal changes in drainage water salinity

The monthly drainage water salinity varied from 3.51 to 12.1, 4.67 to 8.6, 5.93 to 11.6 with a mean value of 6.84, 6.14 and 8.01 dSm^{-1} under conventional drainage system, Controlled with 0.3 m height and Controlled with 0.6 m height, respectively (Table 3.34). As drainage water salinity is influenced by the initial salts in root zone, variations in drainage water quality are expected. Also it is assumed that conventional drainage would give higher salinity compared to controlled drainage.

Table 3.34. Drainage water salinity (dSm^{-1}) as influenced by variable depth of drainage systems

S.No.	**Treatments**	**Sep**	**Oct**	**Nov**	**Dec**	**Avg**
1	Conventional drainage	12.1	7.03	4.7	3.51	6.84
2	Controlled with 0.3m height	4.67	4.93	6.35	8.6	6.14
3	Controlled with 0.6m height	6.79	5.93	7.7	11.6	8.01

Salt removed

The monthly salt removal varied from 0.3 to 3.6, 0.3 to 0.93 and 0.06 to 0.93 t ha^{-1} with a total value of 6.97, 2.43 and 2.49 ha^{-1} under conventional drainage system, Controlled with 0.30 m height and Controlled with 0.60 m height, respectively (Table 3.35).

Table 3.35. Salt removed (t ha^{-1}) as influenced by variable depth of drainage Systems.

S.No.	Treatments	Sep	Oct	Nov	Dec	Avg
1	Conventional drainage	3.60	2.17	0.90	0.30	6.97
2	Controlled with 0.3m height	0.60	0.93	0.60	0.30	2.43
3	Controlled with 0.6m height	0.90	0.93	0.60	0.06	2.49

Nitrogen loss (NO_3-N) through drainage system

The monthly Nitrogen concentration loss varied from 5.37 to 8.26, 5.7 to 8.54 and 6.35 to 11.6 mg L^{-1} with a mean value of 6.78, 7.14 and 8.49 mg L^{-1} under conventional drainage system, Controlled with 0.30 m height and Controlled with 0.60 m height, respectively (Table 3.36).

Table 3.36. Nitrogen loss (NO_3-N) (mg L^{-1}) as influenced by variable depth of drainage systems

S.No.	Treatments	Sep	Oct	Nov	Dec	Avg
1	Conventional drainage	6.2	8.26	7.28	5.37	6.78
2	Controlled with 0.3m height	5.7	8.54	6.16	8.17	7.14
3	Controlled with 0.6m height	6.35	11.6	9.24	6.78	8.49

Total Nitrogen loss (NO_3-N) through drainage system

The monthly Nitrogen loss varied from 0.9 to 3.72, 0.6 to 2.79 and 0.45 to 2.79 kg ha^{-1} with a total value of 9.72, 6.09 and 5.94 kg ha^{-1} under conventional drainage system, Controlled with 0.30 m height and Controlled with 0.60 m height, respectively (Table 3.37).

Table 3.37. Nitrogen loss (NO_3-N) (kg ha^{-1}) as influenced by variable depth of drainage systems

S.No.	Treatments	Sep	Oct	Nov	Dec	Total
1	Conventional drainage	2.70	3.72	2.40	0.90	9.72
2	Controlled with 0.3m height	1.80	2.79	0.90	0.60	6.09
3	Controlled with 0.6m height	1.50	2.79	1.20	0.45	5.94

The experiment was conducted on farmer's field. There were many limitations with respect to irrigation water availability, large variations in initial soil salinity and data collection. Despite of the difficulties, few things have been understood that risers of different heights can be adopted in controlled drainage system. As height of riser is increased, there would be less leaching. Less leaching results in less nitrogen loss and more saving of irrigation water. Important output of the project is that once reclamation leaching is completed, controlled drainage riser height can be selected depending on the irrigation water availability and this can be good management strategy.

- **Assessing pre and post canal irrigation effect on soil, water and crops in Vertisols of Narmada Sagar Command (Indore)**

2019

Pre and post monsoon depth to water tables were recorded at 13 wells situated in five different villages (viz. Mohna, Khutala, Piprad, Donger Gaon and Kalmukhi) in head reach of Indira Sagar Command (Fig. 3.8) during the pre canal irrigation period (2005 and 2012) and post canal irrigation period (2015 and 2019) and are given in Table 3.38. The same were used to calculate the rise of water table in the command.

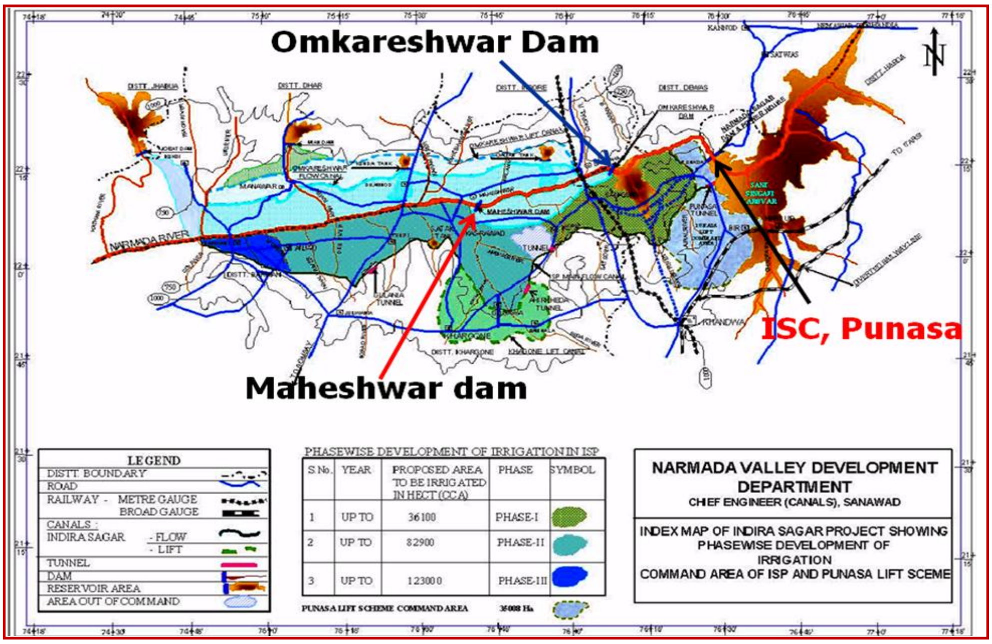


Fig. 3.8 Indira Sagar command of Narmada Sagar Command

Actually irrigation was not commissioned in the year 2012 but there was huge impounding behind the dam and water was allowed to flow in the canal distribution system. It induced percolation losses resulting rise in water table in the command. The average depth to water table in the command is shown in Fig. 3.9. In 2005, depth to water table was around 9.00 m, slowly it reduced. In post monsoon of 2015, it was 3.00 m. However, it became 2.30 m in post monsoon of 2019. It was less 3.00 (i.e. depth of capillary rise) and it might affect agricultural production adversely. Out of 13 locations, depth to water table was less than 1.5 m at 4 locations; between 1.5 to 3.0 at 5 locations and above 3.0 m at 4 locations. Thus water logging is serious problem in the command and subsurface drainage is urgently required to control water table. If possible, irrigation water allocation to the command may be reduced to avoid water logging.

Table 3.38 Water Table fluctuations recorded during pre and post canal irrigation period in head reaches of Narmada Sagar Command

Well No.	Initial Depth (m)	Latitude	Longitude	Water Table (m)											
				2005			2012			2015			2019		
				Pre	Post	Fluct-uation	Pre	Post	Fluct-uation	Pre	Post	Fluct-uation	Pre	Post	Fluct-uation
1	09.60	22°09'06.5"	76° 17'59.6"	8.00	5.20	2.80	5.90	1.00	4.90	5.20	3.15	2.05	4.8	3.1	1.7
2	13.00	22°09'08.9"	76° 18'18.0"	11.00	6.70	4.30	10.00	5.40	4.60	4.90	3.50	1.40	3.0	1.1	1.9
3	12.00	22°08'38.5"	76° 18'48.9"	10.00	5.40	4.60	7.00	3.70	3.30	2.45	2.40	0.05	2.9	2.7	0.2
4	10.55	22°07' 4.2"	76° 20' 4.3"	8.80	4.60	4.20	4.10	0.90	3.20	4.40	3.00	1.40	4.1	3.8	0.3
5	08.70	22° 7'44.2"	76° 20' 2.9"	8.70	3.80	4.90	3.90	1.40	2.50	4.75	4.50	0.25	2.7	0.8	1.9
6	09.00	22°07' 4.2"	76° 20' 9.0"	9.00	3.90	5.10	4.10	2.80	1.30	5.00	2.00	3.00	3.1	0.7	2.4
7	09.50	22°07' 1.5"	76° 19' 0.0"	8.50	6.00	2.50	5.80	3.90	1.90	6.15	4.00	2.15	4.6	2.1	2.5
8	09.50	22°08' 0.5"	76° 19' 4.0"	9.05	4.75	4.30	1.50	1.00	0.50	3.70	1.40	2.30	3.4	2.7	0.7
9	11.00	22° 4'25.0"	76° 18'23.7"	9.00	5.70	3.30	5.20	3.40	1.80	3.50	2.20	1.30	2.2	2.0	0.2
10	11.00	22° 2'05.1"	76° 16'23.2"	9.20	5.90	3.30	5.20	3.80	1.40	5.00	3.30	1.70	4.9	4.1	0.8
11	10.00	22° 2'40.8"	76° 16' 4.8"	8.70	4.90	3.80	1.00	1.00	0.00	6.70	4.20	2.50	5.4	3.0	2.4
12	09.00	22° 3'47.6"	76° 15' 8.4"	8.00	2.90	5.10	6.50	2.80	3.70	4.20	3.30	0.90	3.5	2.2	1.3
13	09.00	22° 8'10.3"	76° 9'44.7"	9.00	2.50	6.50	5.00	4.30	0.70	2.40	1.50	0.90	2.3	1.1	1.2
	10.1			9.0	4.8	4.2	5.0	2.7	2.3	4.5	3.0	1.5	3.6	2.3	1.3

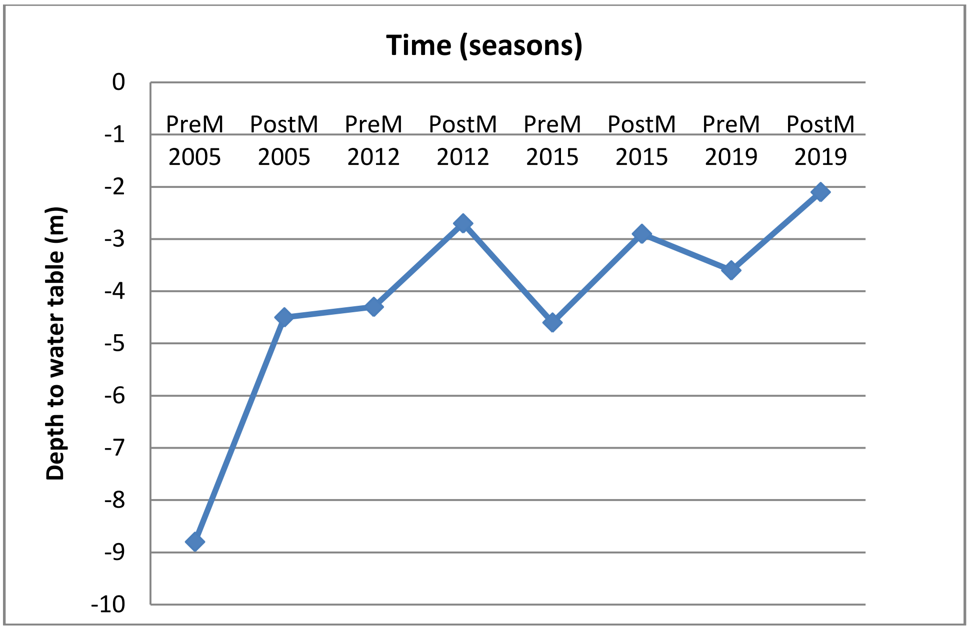


Fig. 3.9 Depth to water table with time in canal command

Soil properties around main canal

Surface and subsurface soil samples were collected during post irrigation period (2018-19) around main canal with the distance of 1, 2, 3, and 5 km. The samples were analysed for EC, pH and organic carbon content (Table 3.39). Soil pH, EC and OC ranged from 7.40 - 7.79, 0.18-0.36 dSm-1 and 0.28-0.65%, respectively, in surface and subsurface samples. The surface soil samples depicted higher pH, EC and OC content.

Table 3.39 Soil properties around main canal

Distance from Main canal	Depth (cm)	pH	ECe (dSm^{-1})	OC (%)
1 km	0-30	7.53	0.20	0.53
	30-60	7.40	0.18	0.44
2 km	0-30	7.39	0.26	0.29
	30-60	7.38	0.21	0.28
3 km	0-30	7.79	0.32	0.50
	30-60	7.64	0.28	0.47
5 km	0-30	7.61	0.36	0.65
	30-60	7.41	0.24	0.60

It was observed that there was severe waterlogging in the command. However, soil salinity was not major issue as values of soil salinity are relatively low.

The canal water quality parameters are given in Table 3.40. Accordingly, EC of canal water is around 0.5 dS/m, pH is less than 7.45 and SAR is less than 1. Thus canal water quality is excellent.

Table 3.40 Water quality of canal water

Water Quality	2012-13	2018-19
pH	7.21-7.40	7.31-7.42
EC (dSm^{-1})	0.36-0.39	0.38-0.68
SAR	0.82-0.95	0.77-0.89
RSC (me L^{-1})	Nil	Nil

- **Effect of different levels of organic manures and mulching on yields of vegetables (Chilli, Brinjal and Tomato) under drip irrigation on coastal saline soils (Panvel)**

Before conducting full-fledged experiment, observational trial was planned to know feasibility of growing vegetable crops on coastal saline soils having water table at shallow depth (less than 2 m from soil surface) with drip irrigation. Details of observational trial 2018-19 are given below.

Objectives	:	• To assess the effect of organic manures and mulching on performance of vegetables in coastal saline soils of Konkan. • To study the effect of organic manures and mulching on soil salinity.
Experimental details:		
Design:		Split plot design
Replication		Three
Plot size		4.20 X 1.2 m
Date of Sowing		20/12/2018
Crop & Variety		Tomato-Sungro F1 hybrid 3618 Chilli-Semimis hybrid SHP 4884 Brinjal-Mahyco MEBH 10
Plastic mulch (Black)		50 micron
Straw mulch		20 kg/plot
Paired row plantation		1.0 m X 0.30 m
Treatments:		T_1Plastic mulch (Black):T_1-Plastic polythene mulch + FYM @15 t ha^{-1} T_2-Paddy straw mulch @ 20 kg/plot + Vermicompost @ 5 t ha^{-1} T_3-Plastic polythene mulch + Vermicompost @ 5 t ha^{-1} T_4- Paddy straw mulch @ 20 kg/plot + Vermicompost (50%) + FYM (50%) T_5- Plastic polythene mulch + Vermicompost (50%) + FYM (50%) T_6- Plastic polythene mulch + Vermicompost @ 5 t ha^{-1} T_7- Control

The observational trial was conducted on experimental field of Panvel farm during rabi 2018-19 and the yield of vegetables was recorded. From Table 3.41 it is observed that the treatment T_3*i.e.*plastic polythene mulch + Vermicompost @ 5 t ha^{-1}recorded higher yield of brinjal (61.25t ha^{-1}), Tomato (90.07t ha^{-1}) and Chilli (31.67 t ha^{-1}) over rest of treatments. The replicated trial is being conducted during current *rabi* season 2019-20 (Plate 3.2)

Table 3.41. Yield data of vegetables (Brinjal, Chilli and Tomato).

Treatment	Yield (t/ha)		
	Brinjal	Tomato	Chilli
T_1-Plastic polythene mulch + FYM @15 t ha^{-1}	48.40	58.22	18.57
T_2-Paddy straw mulch @ 20 kg/plot + Vermicompost @ 5 t ha^{-1}	43.30	65.49	17.02
T_3- Plastic polythene mulch + Vermicompost @ 5 t ha^{-1}	61.25	90.07	31.67
T_4- Paddy straw mulch @ 20 kg/plot + Vermicompost (50%) + FYM (50%)	60.84	57.18	23.84
T_5- Plastic polythene mulch + Vermicompost (50%) + FYM (50%)	47.51	74.63	21.26
T_6- Plastic polythene mulch + Vermicompost @ 5 t ha^{-1}	54.40	68.57	20.96
T_7- Control	40.21	42.82	9.82

Plate 3.2 General view of Experimental plot

Results 2020:

The experiment was conducted at Khar Land Research Station, Panvel farm by using various mulches *i.e.* Plastic mulch (M_1) and Paddy straw mulch (M_2) and as control no mulch (M_3) by using organic manures FYM @ 15 t ha^{-1} (F_1), Vermicompost @ 5 t ha^{-1} (F_2), FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (F_3) and Control (No organic manure) (F_4). Method of irrigation was drip and harvested rain water was used as irrigation water for drip system. The data presented is as under.

Brinjal crop:

Soil salinity, EC (1:2), pH (1:2) and soil moisture at 30 days and 90 days were studied all three crops. In case of Brinjal crop, EC (1:2) values at 30 and 90 days are presented in Table 3.42 and Table 3.43. Respective pH(1:2) values are given Table 3.44 and 3.45. Similarly respective soil moisture content values are presented in Table 3.46 and 3.47, respectively. It was assumed that mulching of soil surface would reduce soil evaporation. It may help in reduction of soil salinity as well as higher soil moisture.

Data pertaining to soil EC at 30 days after planting (Table 3.42) revealed that the treatment of plastic mulch (M_1) was found to be statistically significant and the lowest EC (1:2) value of 3.74 dSm^{-1} over rest of the mulching treatments containing paddy straw mulch M_2 (3.95 dSm^{-1}) and no mulch M_3 (6.60 dSm^{-1}). Similarly the data on different treatments of organic manures further recorded that the EC value of 4.37 dSm^{-1} was found to be statistically significant and recorded the lowest value as a result of application FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (F_3) over rest of the treatments

FYM @ 15 t ha^{-1} (F_1), Vermicompost @ 5 t ha^{-1} (F_2) and No organic manure (F_4). A critical look on the data of interaction effect indicated that the M_1F_3 interaction was statistically significant and registered the lowest value of EC (3.06 dSm^{-1}) over rest of the treatments of interactions.

Table3.42. Soil Electrical Conductivity (EC 1:2) at 30 days after planting (dSm^{-1})

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	3.58	3.88	3.06	4.44	3.74
M_2	3.86	3.89	3.78	4.25	3.95
M_3	6.46	6.62	6.28	7.06	6.60
Mean	4.63	4.80	4.37	5.25	
SE± m for Mulching	0.06	SE± m for organic manure	0.06	SE± m for Interaction	0.11
CD @ 5%	0.19	CD @ 5%	0.16	CD @ 5%	0.33

It is evident from data in Table 3.43 that the among various mulching treatments, plastic mulch (M_1) was found to be lowest and statistically significant and recorded the lowest EC value of 1.66 dSm^{-1} over paddy straw mulch (M_2) and no mulch (M_3) as 1.95 dSm^{-1} and 9.57 dSm^{-1}), respectively. Application of FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (F_3) exhibited significant and lowest EC value (4.03 dSm^{-1}) over rest of the treatments ($F_{1,}$ F_3 and F_3). When interaction effect was studied revealed that the interaction of M_1F_3 showed statistically significant and the lowest EC value of 1.18 dSm^{-1} over rest of the interactions.

Table 3.43 Soil Electrical Conductivity (EC 1:2) at 90 days after planting (dSm^{-1})

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	1.76	1.84	1.18	1.86	1.66
M_2	1.96	2.01	1.81	2.04	1.95
M_3	9.23	9.55	9.10	10.41	9.57
Mean	4.32	4.47	4.03	4.77	
SE± m for Mulching	0.07	SE± m for organic manure	0.08	SE± m for Interaction	0.13
CD @ 5%	0.20	CD @ 5%	0.23	CD @ 5%	0.39

The plastic mulch was found to be statistically significant and recorded the lowest pH value of 6.65 over other mulches at 30 days after planting. Data on organic manures when studied further indicated that the treatment without application of organic manures (F_4) was found to be statistically significant and registered the highest pH value of 6.99 over FYM @ 15 t ha^{-1} FYM (F_1), Vermicompost @ 5 t ha^{-1} (F_2) and FYM @ 7.5 t ha^{-1} FYM + Vermicompost @ 2.5 t ha^{-1} (F_3). Similarly when interaction effect was studied it indicated that the treatment without mulch and without use of organic manures (M_3F_4) recorded significantly higher pH value of 7.47 over rest of the interactions (Table 3.44).

Table 3.44. Soil pH (1:2) at 30 days after planting

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	6.64	6.66	6.62	6.69	6.65
M_2	6.75	6.77	6.73	6.80	6.76
M_3	7.35	7.37	7.26	7.47	7.36
Mean	6.91	6.93	6.87	6.99	
SE± m for Mulching	0.02	SE± m for organic manure	0.02	SE± m for Interaction	0.03
CD @ 5%	0.05	CD @ 5%	0.05	CD @ 5%	0.09

Data on pH at 90 days (Table 3.45) revealed that, the effect of mulching was observed on soil pH at 90 days after planting and M_3 recorded significantly higher pH value of 7.77 over the treatments, paddy straw mulch M_2 and plastic mulch M_1. While no organic manures, treatment F_4 (no mulch) showed statistically significant higher pH value of 7.09 over the treatment of F_3, however it was statistically at par with the treatment F_1 (7.04) and F_2 (7.07). The data on interaction effect indicated that, interaction effect of application of organic manures and no mulch (M_3F_4) interaction recorded statistically higher pH value of 7.81 over M_3F_3 and remained at par with M_3F_1 (7.78) and M_3F_2 (7.80).

Table 3.45 Soil pH (1:2) at 90 days after planting

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	6.63	6.67	6.56	6.70	6.64
M_2	6.72	6.74	6.70	6.77	6.73
M_3	7.78	7.80	7.68	7.81	7.77
Mean	7.04	7.07	6.98	7.09	
SE± m for Mulching	0.02	SE± m for organic manure	0.02	SE± m for Interaction	0.04
CD @ 5%	0.06	CD @ 5%	0.07	CD @ 5%	0.12

From data presented in Table 3.46, on soil moisture content when studied it was observed that, the application of plastic mulch M_1 recorded statistically significant and higher moisture content (54.22 per cent) at 30 days after planting over the treatment (M_2) *i.e.* paddy straw mulch (49.96 per cent) and no mulching *i.e.* M_3 (43.27 per cent). Among various treatments of organic manures FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (F_3) produced significantly higher soil moisture content (54.86 per cent) over F_1 (51.22 per cent), F_2 (46.31 per cent) and F_4 (44.21 per cent). The interaction effect of M_3F_4 showed statistically significant and lowest soil moisture content (37.04 per cent) over rest of the treatments of interactions.

Table 3.46. Soil moisture (per cent) at 30 days after planting

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	55.15	51.91	59.13	50.69	54.22
M_2	52.60	46.93	55.42	44.91	49.96
M_3	45.92	40.08	50.03	37.04	43.27
Mean	51.22	46.31	54.86	44.21	
SE± m for Mulching	0.15	SE± m for organic manure	0.17	SE± m for Interaction	0.30
CD @ 5%	0.44	CD @ 5%	0.51	CD @ 5%	0.88

Perusal of data on soil moisture presented in Table 3.47 indicated that the plastic mulch treatment M_1 recorded statistical significant and higher soil moisture value of 62.94 per cent over rest of the treatments containing paddy straw mulch (M_2) and no mulch (M_3) at 90 days after sowing. The application of organic manures, of FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (F_3) produced significantly higher moisture content value of 56.50 over the organic treatments F_1 (FYM @ 15 t ha^{-1}), F_2 (Vermicompost @ 5 t ha^{-1}) and F_4 (no organic manures). A critical look on data of interaction effect further indicated that, the interaction of M_1F_3 showed statistically higher soil moisture content (66.04 per cent) over all remaining treatments of interactions.

Table 3.47. Soil moisture (per cent) at 90 days after planting

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	63.46	61.70	66.04	60.58	62.94
M_2	52.58	50.61	59.53	46.94	52.41
M_3	40.98	35.87	43.93	31.81	38.15
Mean	52.34	49.39	56.50	46.44	
SE± m for Mulching	0.06	SE± m for organic manure	0.07	SE± m for Interaction	0.13
CD @ 5%	0.18	CD @ 5%	0.21	CD @ 5%	0.37

The data on yield of brinjal crop (Table 3.48) indicated that the application of paddy straw mulch (M_2) showed statistically significant and higher yield (166.60 qtl ha^{-1}) over plastic mulch M_1 (131.96 qtl ha^{-1}) and no mulch M_3 (90.68 qtl ha^{-1}). Critical look on the data on application of organic manures further indicated that, the application of FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} (F_3) produced significantly higher yield (191.96 qtl ha^{-1}) over rest of the treatments containing application of FYM @ 15 t ha^{-1} (144.0 qtl ha^{-1}), Vermicompost @ 5 t ha^{-1} (96.79 qtl ha^{-1}) and no organic manures (86.24 qtl ha^{-1}). Interaction of Paddy straw mulching with FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} produced statistically significant yield (267.36 qtl ha^{-1}) over plastic mulch and no mulch treatments.

Table 3.48. Yield of Brinjal (q ha^{-1})

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	156.16	89.24	201.03	81.41	131.96
M_2	184.68	115.24	267.36	99.11	166.60
M_3	91.17	85.90	107.48	78.19	90.68
Mean	144.00	96.79	191.96	86.24	
SE± m for Mulching	10.30	SE± m for organic manure	11.89	SE± m for Interaction	20.60
CD @ 5%	30.21	CD @ 5%	34.89	CD @ 5%	60.43

Similar trends of soil salinity (EC 1:2), pH (1:2) and soil moisture at 30 and 90 days were observed in case of chilly and tomato crop. The yields of Chilly and Tomato under different treatments are given in Table 3.49 and Table 3.50.

Chilli yield (q ha^{-1})

Data on yield of chilli (Table 3.49) indicated that the among various treatments of mulching, the treatment of paddy straw mulch (M_2) recorded statistically significant and higher yield of 46.11 qtl ha^{-1} over the treatments of plastic mulch M_1 (40.52 q ha^{-1}) and no mulch M_3 (27.24 q ha^{-1}). The data on various organic manures when studied further revealed that the application of FYM @ 7.5 t ha^{-1} +

Vermicompost @ 2.5 t ha^{-1} (F_3) produced statistically higher yield (46.81 q ha^{-1}) over F_1 (38.99 q ha^{-1}), F_2 (35.76 q ha^{-1}) and F_4 (30.25 q ha^{-1}) the treatments. Interaction effect of M_2F_3 (Paddy straw mulching with FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}) produced statistically significant and higher yield of (59.13 q ha^{-1}) over remaining treatments of interactions.

Table 3.49. Yield of Chilli (q ha^{-1})

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	42.85	38.33	45.81	35.08	40.52
M_2	46.00	43.38	59.13	35.91	46.11
M_3	28.13	25.58	35.48	19.75	27.24
Mean	38.99	35.76	46.81	30.25	
SE± m for Mulching	0.87	SE± m for organic manure	1.01	SE± m for Interaction	1.75
CD @ 5%	2.58	CD @ 5%	2.97	CD @ 5%	5.16

Tomato yield

Data on yield of tomato crop (Table 3.50) indicated that the among various treatments of mulching, the treatment of paddy straw mulch (M_2) 193.39 q ha^{-1} recorded statistically significant and higher yield over rest of all treatments containing plastic mulch (M_1) 148.98 q ha^{-1} and no mulch (M_3) 90.57 q ha^{-1}. Critical look on the data further revealed that the F_3 produced statistically higher yield (193.01 q ha^{-1}) over the organic treatments of manure FYM @ 15 t ha^{-1} (F_1) (151.58 q ha^{-1}), Vermicompost @ 5 t ha^{-1} (F_2) (128.89 q ha^{-1}) and without application of organic manure (F_4) (103.77 q ha^{-1}). Interaction effect of M_2F_3 (Paddy straw mulching with FYM @ 7.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}) produced statistically significant and higher yield of (255.01 q ha^{-1}) over remaining treatments of interactions. The photos of experimental field are given in Plate 3.3

Table 3.50. Yield of Tomato (q ha^{-1})

Treatments	F_1	F_2	F_3	F_4	Mean
M_1	149.38	130.41	215.41	100.70	148.98
M_2	207.65	175.50	255.01	135.40	193.39
M_3	97.70	80.75	108.61	75.21	90.57
Mean	151.58	128.89	193.01	103.77	
SE± m for Mulching	7.39	SE± m for organic manure	8.54	SE± m for Interaction	14.79
CD @ 5%	21.69	CD @ 5%	25.04	CD @ 5%	43.38

Comparison of initial and final soil properties

The average changes in soil properties were also studied. It was observed that there was increase in $pH_{(1:2.5)}$ and $EC_{(1:2.5)}$, organic carbon, P_2O5 (kg ha^{-1}) and K_2O (kg ha^{-1}) at time harvest of crop compared to initial stage of the crop (Table 3.51).

Table 3.51. Soil properties of experimental plot

Sr. No	Particulars	At initial stage	After harvest of crop
1.	pH 1:2.5	6.75	6.79
2.	EC 1:2.5 (dSm^{-1})	3.74	9.35
3.	OC (%)	1.26	2.06
4.	P_2O5 (kg ha^{-1})	81.25	95.92
5.	K_2O (kg ha^{-1})	913.65	1275.25

Plate 3.3 General View of Experimental Field

- **Effect planting windows and irrigation on dibbling of wal (Field bean) grown under zero tillage in coastal saline soils of Konkan (Panvel)**

This field experiment was planned to study Effect planting windows and irrigation on dibbling of wal (Field bean) grown under zero tillage in coastal saline soils of Konkan. The experiment as planned in Factorial Randomized Block design. There were four replications. Thus there were 36 treatment combinations. Plant to plant and row to rowing spacing were 30x 30 cm. Plot size was 20.40 m x 1.5m. The dates of sowing were 06/12/2019, 16/12/19 and 26/12/19. Konkan wal-1 was variety of Wal (Field bean). The main irrigation treatment levels were I_0- No Irrigation; I_1- One irrigation (At flowering) and I_2- Two irrigation (At flowering and pod formation). The sub treatments were related to planting window such as P_1-After harvest of Rice and P_2- 10 days after harvest of Rice and P_3- 20 days after harvest of Rice. Different soil properties such as $pH_{(1:2.5)}$, OC, P_2O_5 and K_2O were recorded at initial stage and at harvest. Also data on soil moisture and $EC_{(1:2.5)}$ at 30 days after sowing and at harvest (90 days after sowing) and seed yield were recorded.

Results and discussion Rabi 2019-20:

The data in Table 3.52 revealed that the treatment without irrigation (I_0) was observed EC $_{(1:2.5)}$ value to be statistically significant (3.40 dSm^{-1}) over rest of the treatments. In case of date of planting it was found that, the treatment P_3 (20 days AHR) was found to be statistically significant (3.01 dSm^{-1}) over all treatments with exception of the treatment P_2 (10 days AHR) which recorded EC value of 2.74 dSm^{-1}. However, interaction effect of irrigation water and planting windows was observed, in I_0P_3 interaction which showed significantly higher EC $_{(1:2.5)}$ as 3.85 dSm^{-1} over all remaining interactions.

Table 3.52. Soil Electrical Conductivity (EC $_{(1:2.5)}$) at 30 days after sowing (dSm^{-1})

Treatments	P_1 (AHR)	P_2 (10 days AHR)	P_3 (20 days AHR)	Mean	
I_0	3.16	3.21	3.85	3.40	
I_1	2.61	2.78	2.83	2.74	
I_2	1.60	2.25	2.34	2.06	
Mean	2.45	2.74	3.01		
SE± m for Irrigation	0.11	SE± m for Planting window	0.11	SE± m for Interaction	0.19
CD @ 5%	0.32	CD @ 5%	0.32	CD @ 5%	0.56

* AHR- After Harvest of Rice

It is evident from the data presented in Table 3.53 that, the higher EC $_{(1:2.5)}$ value of 6.92 dSm^{-1} was recorded in the no irrigation treatment *i.e.* I_0. However, the lowest and statistically significant EC value of 4.53 dSm^{-1} was observed as a result of two irrigations at flowering and at pod formation (I_2) at 90 days after sowing. A critical look on data further revealed that the treatment (P_3) recorded significantly highest EC $_{(1:2.5)}$ value of 5.89 dSm^{-1} over rest of the treatments (P_1 and P_2). When interaction effect was studied it is evident from the data that with no irrigation and sowing 20 days after harvest of rice produced statistically significant highest value of EC $_{(1:2.5)}$ as 7.79 dSm^{-1} over rest of the treatments.

Table 3.53 Soil EC $_{(1:2.5)}$ at 90 days after sowing (dSm^{-1})

Treatments	P_1 (AHR)	P_2 (10 days AHR)	P_3 (20 days AHR)	Mean	
I_0	6.52	6.47	7.79	6.92	
I_1	5.61	5.37	5.08	5.35	
I_2	4.15	4.63	4.81	4.53	
Mean	5.43	5.49	5.89		
SE± m for Irrigation	0.09	SE± m for Planting window	0.09	SE± m for Interaction	0.15
CD @ 5%	0.26	CD @ 5%	0.26	CD @ 5%	0.45

* AHR- After Harvest of Rice

The data on soil $pH_{(1:2.5)}$ at 30 days after sowing are presented in Table 3.54 when studied revealed that the treatment I_0 produced statistically significant and highest pH value of 6.84 over other irrigation treatments containing one irrigation at flowering (I_1) and two irrigations at flowering and at pod formation (I_2). The treatment of planting 20 days after harvest of rice P_3 was statistically significant and highest pH value of 6.83 over rest of the treatments with exception of the treatment P_2 which was found to be statistically at par (6.71). The data on interaction effect of the treatments, I_0P_3 exhibited statistically significant and highest pH value of 7.01 over the rest of interactions.

Table 3.54 Soil $pH_{(1:2.5)}$ at 30 days after sowing

Treatments	P_1 (AHR)	P_2 (10 days AHR)	P_3 (20 days AHR)	Mean	
I_0	6.72	6.78	7.01	6.84	
I_1	6.64	6.70	6.73	6.69	
I_2	6.61	6.66	6.73	6.67	
Mean	6.66	6.71	6.83		
SE± m for Irrigation	0.04	SE± m for Planting window	0.04	SE± m for Interaction	0.7
CD @ 5%	0.12	CD @ 5%	0.12	CD @ 5%	0.21

* AHR- After Harvest of Rice

It is seen from the data presented in Table 3.55 that without application of irrigation water I_0 treatment showed significantly higher value of 7.21 over rest of the treatments containing one irrigation at flowering and two irrigations at flowering and at pod formation. Application of different time of planting, the treatment of planting 20 days after harvest of rice (P_3) produced statistically significant and higher pH value of 7.14 with exception of treatment of planting 20 days after harvest of rice (P_2-7.06). Interaction effect of I_0P_3 (7.35) showed significantly higher value of soil pH over rest of the interactions.

Table 3.55. Soil $pH_{(1:2.5)}$ at 90 days after sowing

Treatments	P_1 (AHR)	P_2 (10 days AHR)	P_3 (20 days AHR)	Mean	
I_0	7.11	7.17	7.35	7.21	
I_1	7.05	7.10	7.08	7.07	
I_2	6.73	6.90	6.99	6.87	
Mean	6.96	7.06	7.14		
SE± m for Irrigation	0.03	SE± m for Planting window	0.03	SE± m for Interaction	0.06
CD @ 5%	0.10	CD @ 5%	0.10	CD @ 5%	0.16

* AHR- After Harvest of Rice

Data pertaining to soil moisture content at 30 days after sowing (Table 3.56) revealed that the treatment with two irrigations (I_2) recorded statistically higher soil moisture value of 48.42 per cent over one irrigation at flowering (I_1) and with no irrigation (I_0). Similarly, planting immediately after harvest of rice (P_1) recorded the highest soil moisture content value of 47.03 per cent which was found to be statistically significant over rest of the treatments containing P_2 and P_3. Interaction of the treatment I_2P_1 exhibited statistically significant soil moisture content (52.38 per cent) over rest of the interactions.

Table 3.56. Soil moisture (per cent) at 30 days after sowing

Treatments	P_1 (AHR)	P_2 (10 days AHR)	P_3 (20 days AHR)	Mean	
I_0	40.62	36.75	32.77	36.71	
I_1	48.08	44.19	40.01	44.09	
I_2	52.38	49.22	43.67	48.42	
Mean	47.03	43.39	38.82		
SE± m for Irrigation	0.44	SE± m for Planting window	0.44	SE± m for Interaction	0.75
CD @ 5%	1.27	CD @ 5%	1.27	CD @ 5%	2.20

* AHR- After Harvest of Rice

Data in Table 3.57 on per cent moisture content presented. A critically look on the data on soil moisture at 90 days after sowing indicated that treatment with the application of two irrigations (I_2- at time of flowering and at pod formation) recorded statistically significant and higher soil moisture content value of 45.11 per cent followed by the treatments receiving no irrigation (I_0) and one irrigation at flowering (I_1) soil moisture content value of 31.25 per cent and 40.03 per cent, respectively. However, planting immediately after harvest of rice (P_1) showed statistically significant and higher soil moisture (43.28 per cent) over P_2 (39.34 per cent) and P_3 (33.89 per cent). The data on interaction effect indicated that the treatment with planting window of wal crop immediately after harvest of rice with two irrigations (I_2P_1) produced significantly higher soil moisture content (49.93 per cent) over rest of the interactions *viz.,* I_0P_1, I_0P_2, I_0P_3, I_1P_1, I_1P_2, I_1P_3, I_2P_2, and I_2P_3.

Table 3.57. Soil moisture (per cent) at 90 days after sowing

Treatments	P_1 (AHR)	P_2 (10 days AHR)	P_3 (20 days AHR)	Mean	
I_0	35.06	32.96	26.05	31.35	
I_1	44.85	38.97	36.27	40.03	
I_2	49.93	46.08	39.33	45.11	
Mean	43.28	39.34	33.89		
SE± m for Irrigation	0.08	SE± m for Planting window	0.08	SE± m for Interaction	0.14
CD @ 5%	0.24	CD @ 5%	0.24	CD @ 5%	0.41

* AHR- After Harvest of Rice

Seed yield:

The data on seed yield of wal is presented in Table 3.58 indicated that, yield of wal was found to be affected due to no irrigation water and late planting of crop. In general the higher yield was produced with two irrigations (I_2- at flowering and pod formation) and planting immediately after harvest of rice (P_1- after harvest of rice).

Table 3.58 Seed yield of wal (qha^{-1})

Treatments	P_1 (AHR)	P_2 (10 days AHR)	P_3 (20 days AHR)	Mean	
I_0	7.87	5.23	4.90	6.00	
I_1	10.55	7.96	5.79	8.10	
I_2	21.14	17.06	14.70	17.63	
Mean	13.19	10.08	8.46		
SE± m for Irrigation	0.77	SE± m for Planting window	0.77	SE± m for Interaction	1.34
CD @ 5%	2.26	CD @ 5%	2.26	CD @ 5%	3.92

* AHR- After Harvest of Rice

The data on yield of wal (Table 3.58) indicated that the among various treatments of irrigations, the treatment receiving application irrigation water for the two times *i.e*. at the time of flowering and at the time of pod formation (I_2) recorded statistically significant and higher yield of 17.63 quintal ha^{-1} over one irrigation at flowering I_1 (8.10 quintal ha^{-1}) and no irrigation I_0 (06.00 quintal ha^{-1}). Critical look on the data further revealed that the planting windows for the wal crop seed produced statistically higher yield (13.19 quintal ha^{-1}) over the treatments of planting after immediate after harvest of rice P_1 over P_2 (10.08 quintal ha^{-1}) and P_3 (8.46 quintal ha^{-1}). Interaction effect of I_2P_1 (two irrigations at the time of flowering and at the time of pod formation with planting immediate after harvest of rice) produced statistically significant and higher yield of (21.14 quintal ha^{-1}) over remaining interactions. The general view of experimental field is shown in Plate 3.4.

Comparison of initial and final soil properties

The average changes in soil properties were also studied. It was observed that there was increase in $pH_{(1:2.5)}$ and $EC_{(1:2.5)}$, organic carbon, P_2O5 (kg ha^{-1}) and K_2O (kg ha^{-1}) at time harvest of crop compared to initial stage of the crop (Table 3.59).

Table 3.59. Changes in soil properties of experimental plot with time

Sr. No	Particulars	At initial stage	After harvest of crop
1.	$pH_{(1:2.5)}$	6.31	6.57
2.	$EC_{(1:2.5)}$ (dSm^{-1})	2.84	7.15
3.	OC (%)	0.84	1.02
4.	P_2O5 (kg ha^{-1})	75.09	77.25
5.	K_2O (kg ha^{-1})	783.25	956.37

Plate 3.4 General View of Experimental Field

- **Effect of organics and raised bed on Okra in coastal saline soils of A&N Islands (Port Blair)**

2019

The performance of raised bed system (alternate land management) for vegetable cultivation under lowland condition was very significant. Therefore, an experiment was conducted to assess the effect of saline tolerant PGPR (Plant Growth-Promoting Rhizobacteria) prepared as Biogel (bioconsortia + seaweed extract) and other organics on Okra in a raised bed system during monsoon season (July – October) of 2019. The results showed that organic treatments significantly increased the fruit number, fruit weight and per plant fruit yield ($p > 0.05$) (Table 3.60 and Plate 3.5). Mixture of Biogel + panchagavya was found to be superior over all other organic treatments which increased fruit yield by 31% than control. Although biogel formulation, bioconsortia and panchagavya were at par for all other yield parameters, saline tolerant PGPR in biogel formulation significantly increased fruit weight by 27% and fruit yield by 18.7% over control. The results demonstrated the potential of saline tolerant PGPR in biogel formulation either alone or in combination with panchagavya for improving crop performance under island condition.

Table 3.60 Effect of organic treatments on yield parameters of Okra grown on raised bed

Treatments	Fruit weight (g)	Fruit Number	Fruit yield / plant (g)	Fruit yield/ha (ton)
Control	9.0 [a]	10.2[a]	106.6[a]	5.93[a]
Biogel (Bioconsortia + Seaweed extract)	11.5 [c]	11.4[b]	126.5[b]	6.96[bc]
Biogel+ Panchagavya	12.9 [d]	11.8 [b]	140.0[c]	7.70[c]
Panchagavya	11.7 [c]	11.6 [b]	125.5 [b]	6.90[bc]
Bioconsortia	10.6 [b]	12.0 [b]	121.6 [b]	6.75[b]
CD (0.05)	**0.945**	**1.051**	**15.024**	**0.823**

Plate 3.5 Effect of organics on Okra grown in raised bed

- **Evaluation of saline tolerant bio-consortia on brinjal and tomato in coastal saline soils of A&N Islands (Port Blair)**

2019

A pot culture experiment was conducted to study the effect of saline tolerant bioconsortia (seed treatment and soil application) on brinjal and tomato under varying salinity level (2, 4, 6 dSm^{-1}). The result indicated that bioconsortia treatment significantly increased the plant height and biomass at all levels of salinity however, the effect was more pronounced in brinjal (Table 3.61 and Plate 3.6). The study also showed the effect of saline tolerant bioconsortia on plant physiological parameters (proline) involved in defense systems against oxidative stress. The concentration of proline in plants was significantly increased by the bioconsortia inoculation with increase in salinity level in brinjal (0.9, 1.1 and 1.3 mM/g fresh wt) and in tomato (0.8, 1.0 and 1.1 mM/g fresh wt). However the effect was highly pronounced at higher salinity level and in brinjal than tomato. The results demonstrated that salt stress inhibited the plant fresh weight, whereas bioconsortia treatment increased the plant height and biomass at all levels of salinity in both brinjal and tomato. Thus, the bioconsortia can be a potential organic material to enhance the performance of brinjal and tomato under moderate saline condition. Further field evaluation and analysis of biochemical properties are in progress.

Table 3.61 Effect of salinity tolerant bioconsortia on growth parameters of brinjal and tomato under varying salinity level

Salinity level	Plant height (cm)				Biomass (g)				Proline (mM/g fresh wt)			
	Brinjal		Tomato		Brinjal		Tomato		Brinjal		Tomato	
	+ Bio	- Bio	+ Bio	- Bio	+ Bio	- Bio	+ Bio	- Bio	+ Bio	- Bio	+ Bio	- Bio
2 dSm^{-1}	18.5	15.4	16.5	13.2	16.8	15.3	14.5	14.2	2.7	1.8	2.5	1.7
4 dSm^{-1}	17.3	15.1	15.3	12.2	13.1	12.7	12.8	12.1	2.2	1.1	1.9	0.9
6 dSm^{-1}	13.8	12.7	11.8	10.4	11.5	11.1	10.4	9.8	2.1	0.8	1.8	0.7
Control (no salinity)	31.2	27.6	23.4	22.1	22.4	20.3	18.5	15.6	2.9	2.2	2.7	2.1

Plate 3.6 Effect of saline tolerant bioconsortia on crop performance in pot experiment

3.3 Management of Saline-Acidic Soils

- **Integrated farming system: Rice-vegetable-fish-duck for sustainability in Pokkali lands at RRS, Vyttila (Vytilla)**

2019

Integrated farming system for sustainable land use in Pokkali lands – vegetable cultivation

The experiment was conducted in the pokkali field bunds of Rice Research Station, Vyttila to compare the effect of salinity on yield of vegetables. Both winter season vegetables (cauliflower and cabbage) and summer season vegetables (cowpea and okra) were raised to study the adaptability of these vegetables in *Pokkali* lands and to find out the most suitable winter season and summer season vegetables for *Pokkali* field bunds as per Table 3.62.

Table 3.62.Details of treatments

SN	Treatments	Crops	mulch	Other details
1	T_1C_1	Cauliflower	With mulch	• Number of treatments: 8 • Design: RBD • No. of replications: 3 • Plot Size: 3m X 2m
2	T_2C_2	Cabbage		
3	T_3C_3	Cowpea		
4	T_4C_4	Okra		
5	T_5C_1	Cauliflower	Without mulch	
6	T_6C_2	Cabbage		
7	T_7C_3	Cowpea		
8	T_8C_4	Okra		

The bunds in between the fields were selected for planting vegetables. After leveling of fields and preparation of ridges and furrows, polythene mulches were spread over the fields. The planting was done on ridges according to spacing of KAU POP for each crop. Recommended doses (KAU POP) of manures and fertilizers were applied through drip fertigation. The planting date for all crops was 13-11-2018 and harvesting date was 20-02-2019. The initial and final soil samples were collected for analyzing pH, EC, OC, available P, K, Na, Ca, Mg, S, B, Fe, Zn, Cu and Mn. The analysis data is shown in the Table3.63.

Table 3.63. Changes in soil properties before and after harvest of vegetables at RRS, Vyttila (2018-19)

Soil Properties	Unit	Initial	Cauliflower		Cabbage		Cowpea		Okra	
			WM	WOM	WM	WOM	WM	WOM	WM	WOM
pH		3.83	4.19	4.12	3.36	4.08	3.50	6.03	3.38	6.94
EC	dS m^{-1}	0.54	0.40	0.41	0.76	0.33	0.51	1.08	1.29	0.60
OC	%	1.37	1.08	1.94	0.99	1.21	1.38	1.15	1.21	0.93
P	kg ha^{-1}	64.75	104.75	183.25	81.00	157.70	95.50	131.00	86.50	157.20
K		74.50	114.40	83.60	146.30	92.40	62.70	313.50	114.40	488.40
Na		45.50	56.50	70.50	43.00	78.50	76.50	122.00	101.00	130.00
Ca	mg kg^{-1}	215.30	594.50	605.50	265.00	587.00	189.50	1955.00	398.50	1705.00
Mg		17.78	41.35	46.85	36.18	46.80	33.57	50.85	38.15	50.80
S		143.00	120.00	424.00	208.50	71.50	152.50	578.50	380.00	162.00
B		0.73	0.12	0.22	0.34	0.14	0.76	0.73	0.29	ND
Fe		356.50	347.40	402.30	394.40	399.20	381.80	400.60	393.60	395.50
Zn		3.51	1.87	3.54	2.47	13.54	2.24	5.47	2.95	7.70
Cu		1.66	ND	ND	0.13	0.061	0.087	ND	0.24	ND
Mn		1.73	3.20	8.32	1.35	38.07	4.95	172.00	71.42	42.23

WM= with Mulch and WOM= Without Mulch

As per the analysis data initial pH of the soil sample of RRS, Vyttila was 3.83. In general, pH was lower in treatments with mulch as compared to without mulch in case of all the vegetables. On observing the electrical conductivity of soil samples in all treatments, it was clear that treatments without mulch were having higher EC values in most of the treatments. The organic carbon per cent of the soil samples were found to be decreased from the initial value (1.37 %) in various treatments. The available phosphorus content in soil was found to increase in all the treatments with respect to initial soil phosphorus status. The available K content of the soil samples was found to be increase in most of the treatments with respect to initial soil nutrient status. The sodium content increased in all treatments compared to initial value and treatment with mulch reported lower sodium content. Among the secondary nutrients, available calcium and magnesium content increased in all the treatments with respect to the initial value. An increment recorded in available sulphur content in most of the treatments from the initial soil status.

Harvesting of crops was started during first week of January. The highest yield of crop was obtained in treatment T_4C_4, ie. Okra with mulch in 2018-2019. The performance of okra and cowpea was very good compared to the winter season vegetables like cauliflower and cabbage in both the cases i.e. treatments with mulch and without mulch. Cauliflower was not able to produce flower bud because of the intense heat exposure in the field. Average maximum temperature was recorded as 33.2 degree Celsius. In addition to this performance of Cabbage was also affected resulting in lower yield. The yield data from each treatment plots revealed that higher yield were obtained from treatments with mulch rather than without mulch. (Table 3.64).

Table 3.64. Total yield of vegetables at field experiment in RRS, Vyttila (2018-19)

Sl. No.	Treatments	Yield (t ha^{-1})	Sl. No.	Treatments	Yield (t ha^{-1})
1	T_1C_1	0.138	5	T_5C_1	4.20
2	T_2C_2	-	6	T_6C_2	5.02
3	T_3C_3	13.01	7	T_7C_3	5.56
4	T_4C_4	9.61			
8	T_8C_4				7.93

With the support of analytical data, it was very evident that mulching with polythene sheet was having a significant effect on crop growth and yield of vegetables viz. cauliflower, cabbage, cowpea and okra. The effect of mulching and drip fertigation was evident from the higher yields obtained. Treatments with mulch were found to have significantly higher yield than treatments without mulch. Hence we can go forward for vegetable cultivation of cowpea and okra with mulch and drip fertigation for more pronounced yield on *Pokkali* bunds. It was also observed that yields obtained from winter season vegetables were very low and this reduction in yield might be due to the very high temperature. Hence the experiment showed that growth as well as productivity of winter season vegetables is not as expected in typical *Pokkali* lands.

2020

Integrated farming: Rice-vegetable-fish-duck at RRS, Vyttila in 2020

Rice cultivation: The study was conducted in the *Pokkali* rice fields of Rice Research Station, Vyttila. The field was prepared for rice cultivation. By April 2020, the bunds are being strengthened and sluices repaired for regulating water level. Fields are then drained during low tide and the sluices are closed. When the soil in the field becomes dry, mounds of 1 m base and 0.5 m height are formed. This facilitates the washing down of the dissolved salts from the surface of the mounds with the onset of monsoon, which are ultimately removed from the field by tidal action. The mounds in the field were raked and top leveled by last week of July. The sprouted seeds are sown on the top of mounds, and the mounds are cut into pieces with a few seedlings, which are uniformly spread in the field.

Changes in soil properties before and after rice harvest (2020) were given in Table 3.65. The data showed a slight decrease in soil pH after harvest of crop compared to initial value. The electrical conductivity of soil was also got reduced after rice harvest. Organic carbon content of the soil increased as compared to initial content. The data also showed decrease in content of available P, Ca and Mg compared to initial values before sowing whereas available K, Na and S content got increased. The micronutrients content *viz*., Fe, Mn, Zn and Cu in soil was high compared to initial value.

Table 3.65. Changes in soil properties before and after harvest of rice at RRS, Vyttila (2020)

Soil properties	Unit	Initial	Final	Soil properties	Unit	Initial	Final
pH		6.64	5.72	Ca	mg/kg	1315	698.17
EC	dS/m	1.50	1.41	Mg		34.4	26.70
OC	%	1.36	1.50	S		1.87	18.09
P	kg /ha	148.6	93.44	B		0.04	0.66
K		327.04	436.80	Fe		216.8	276.57
Na		339.36	512.21	Zn		1.4	12.20
				Cu		0.1	1.17
				Mn		4.68	5.03

Vegetable cultivation

The experiment was conducted to compare the effect of salinity on yield of vegetables. Summer season vegetables (chilli, brinjal, cowpea and bhindi) were selected to check the adaptability of these vegetables in *Pokkali* lands and to find the most suitable summer season vegetables for *Pokkali* fields. . The planting date for all crops was 6.01.2020 and harvesting date was 12.05.2020.

- Number of treatments: 8
- Design: RBD
- No. of replications: 3
- Plot Size: 3m X 2m

Initial soil properties of the field are given in Table 3.66.

Table 3.66. Soil properties before sowing vegetables at RRS, Vyttila

Soil properties	pH	EC	OC	P	K	Na	Ca	Mg	S	B	Fe	Zn	Cu	Mn
Unit		dS/m	%	kg/ha			mg/kg							
Initial	4.55	0.46	1.83	184.8	172.48	12	527	38.25	53.8	0.12	213.1	0.48	BDL	4.97

The yield data from each treatment plots revealed that higher yield were obtained from treatments with mulch rather than without mulch. It was seen that, mulching with polythene sheet is having a significant effect on crop growth and yield of vegetables viz. brinjal, cowpea and bhindi (Table 3.67).

Table 3.67. Total yield of vegetables at field experiment in RRS, Vyttila (2020)

SN.	Treatments	Crop	Yield (t ha^{-1})	SN	Treatments	Crops	Yield (t ha^{-1})
	With mulch				Without mulch		
1	T_1C_1	Chilli	-	5	T_5C_1	Chilli	-
2	T_2C_2	Brinjal	21.68	6	T_6C_2	Brinjal	12.71
3	T_3C_3	Cowpea	11.26	7	T_7C_3	Cowpea	11.00
4	T_4C_4	Bhindi	9.06	8	T_8C_4	Bhindi	4.32

Duck and fish farming

The farming system involved integration of duck and fish along with *Pokkali* rice and vegetable cultivation. Various kinds of fishes *viz.,Thilapia, Karimeen, Varal*and *Palomkanni* were grown in the ponds. Ducks are reared in duck cages in ponds in which fishes are reared. The properties of pond water and pond soil are given Table 3.68 and Table 3.69. The soil and water analysis data revealed that, the conditions available in the pond ecosystem were favourable for the growth and development of both fish and duck. The pH (6.32) and EC (3 dS/m) values of water were within the permissible limits for rearing the both.

Table 3.68. Analysis of water in the pond for duck-fish integration

Properties	**Units**	**Initial**
pH		6.32
EC	dS/m	3.00
Nitrite	mg/L	0
Nitrate		3.00
Ammonia		0.50
TDS		1920
Total hardness		184.26
Total alkalinity		187.00
Total salinity		1.33

Table 3.69. Analysis of soil in the pond for duck-fish integration

Soil properties	Units	Initial
pH		5.95
EC	dS/m	2.54
OC	%	2.29
P	kg /ha	276.24
K		381.45
Ca	mg/kg	518.50
Mg		553.42
S		307.45

Duck droppings acts as feed for fishes. No additional feed is required for fishes. Normally ducks were released after the harvest of paddy cultivation in *Pokkali* fields. Remaining paddy waste acted as feed for them. Ducks were also fed with broken rice and pellet feed (Table 3.70). Ducks were also released in standing crop fields so that pest population can be controlled. Analysis of feed and droppings were also done to notice the intake of nutrients by the duck and addition of those nutrients back to the pond. The data showed that nutrient uptake by the duck as feed got returned back to soil without loss (Plate 3.7).

Table 3.70. Analysis of feed and droppings of duck

Properties	Unit	Feed (rice bran)	Pellet feed	Droppings
Total N	%	1.42	2.71	1.85
P		0.31	0.69	0.77
K		0.164	0.27	0.29
Ca		0.102	2.34	3.66
Mg		0.124	0.43	0.63
S		0.033	0.13	0.20

Plate 3.7 Integrated Rice-vegetable-fish-duck farming

Benefit-Cost Ratio of integrated farming system

The rice-vegetables-duck-fish integration was found economical (Table 3.71, 3.72, 3.73 and 3.74) and eco friendly to the farmer. Analysis of Benefit-Cost ratio also confirmed same.

Table.3.71 Cost and returns of Cultivation of Rice (2020)

SN	Cultural operations	Quantity/ No	Rate (Rs.)	Total cost (Rs.)
1	Seed cost	100 Kg	65	6,500
2	Strengthening of bunds	10 Labourers	750	7,500
5	Land and mound preparation	31 Labourers	750	23,250
6	Preparing top of mound for sowing	10 Labourers	750	7,500
7	Sowing seeds on the mound	12 Labourers	750	9,000
8	Dismantling	15 Labourers	750	11,250
10	Harvesting and handling	40 Labourers	750	30,000
11	Threshing and drying	14 Labourers	750	10,500
12	Weeding	15 Labourers	750	11,250
13	Electricity	100 Units	2.5	250
14	Diesel	2 Litres	76	152
Total				90,152

Yield : 2t @ Rs. 65 per kg of rice = **1,30,000.00**

B/C Ratio = 1.44

Table 3.72 Cost and returns of Cultivation of Vegetables (2020)

Sl. No.	Cultural operations	No. of labourers	Rate (Rs.)	Total cost (Rs.)
1.	Land preparation and tillering, ridges and furrow preparation	35	750	26250
2.	Sowing and drip irrigation work	14	750	10500
3.	Weeding	14	750	10500
4.	Harvesting and drying	16	750	12000
	Total			59250/-
	Returns			1,75,075/-
	BC Ratio			2.95

Table 3.73. Costs and benefits of duck and fish farming

Sl no	Components	Cost (Rs)
	Expenditure	
1	Pellet feed	181040.00
	Total	181040.00
	Returns	
1	Eggs (17314 eggs @ Rs. 10/egg)	173140
2	Duck (20ducks @ Rs.350/duck)	7000
3	Fish	421278.5
	Total	601418.5
	BC Ratio	3.32

Table 3.74. BC ratio of integrated farming (2020)

Gross expenditure (Rs)	330442.0
Gross Returns (Rs)	776493.5
BC ratio	2.35

On the basis of study, it was observed that mulching with polythene sheet was having a significant effect on crop growth and yield of vegetables. The data showed that treatments with mulch were found to have significantly higher yield than treatments without mulch. Hence for vegetable cultivation on *Pokkali* bunds mulch and drip fertigation attained a great scope. Integrated farming may enhance the soil qualities as well as the growth and yield of following rice crop. Duck droppings acted as feed for fish, where we did not require additional cost for feeding fish. The farming system obtained a BC ratio of 2.35, which showed that the rice-vegetables-duck-fish integration was found to very beneficial and successful in *Pokkali* lands.

- **Rice – prawn integration in Pokkali lands (Kumbalangi, Ernakulam)**

2019

Rice-prawn integration was planned under pokkali system for maximum productivity. The changes in soil properties were also studied (Table 3.75)

Techniques adopted for Pokkali rice are as below

- ✓ Site selected: *Pokkali* land at farmer's field, Kumbalangi, Ernakulam
- ✓ Field preparation for rice cultivation
- ✓ Water from pokkali field was drained out, field was ploughed and leveled and prepared for rice cultivation
- ✓ Ridges and furrows were taken
- ✓ Germinated seeds were sown on ridges on 20.06.2019 respectively
- ✓ Harvesting was started on 28th to 30th October 2019 respectively and done manually
- ✓ Only panicles were harvested
- ✓ Straw was kept in the field itself
- ✓ Harvested bundles of panicles were brought to the bund using a small boat by farmer
- ✓ Rice grain yield: 1.5 t ha^{-}
- ✓ Rice field preparation was stared for prawn cultivation will be started in January 2020

Prawn culture (Previous year)

- ✓ Tiger prawn seedlings was released during February 2019
- ✓ Harvesting took place in the month of May 2019
- ✓ Total yield of about 300 kg/ha of prawn were harvested May 2019

Soil properties of Kumbalangi after rice cultivation

Soil Properties	Kumbalangi
pH	7.24
EC dS m^{-1}	2.24
OC (%)	1.95
Available P (kg ha^{-1})	66.88
Available Na (kg ha^{-1})	8086.40
Available K (kg ha^{-1})	523.04
Available Ca (mg kg^{-1})	661.50
Available Mg (mg kg^{-1})	42.83
Available S (mg kg^{-1})	375.00
Available B (mg kg^{-1})	1.72
Available Fe (mg kg^{-1})	564.90
Available Zn (mg kg^{-1})	4.96
Available Cu (mg kg^{-1})	0.846
Available Mn (mg kg^{-1})	7.50

Table 3.75. Chemical properties of soil samples from Kumbalangi field

Particulars	pH	EC dSm^{-1}	OC %	P Kg ha^{-1}	K Kg ha^{-1}	Ca mg kg^{-1}	Mg mg kg^{-1}	S mg kg^{-1}	Fe mg kg^{-1}	Mn mg kg^{-1}	Cu mg kg^{-1}	Zn mg kg^{-1}	B mg kg^{-1}
	Before prawn release												
Plot 1	7.66	4.20	0.67	86	576.4	952.00	64.80	2.17	391.40	3.48	BDL	4.95	0.99
Plot 2	6.97	4.50	1.59	58.25	517.0	681.50	62.15	2.35	398.70	2.51	BDL	5.88	0.37
Plot 3	6.52	6.00	1.42	96.50	729.3	802.00	65.75	2.05	402.10	2.90	BDL	5.55	1.41
	After prawn Harvest												
Plot 1	7.86	5.50	1.05	68.50	817.3	648.50	76.00	802	331.40	2.46	BDL	2.14	0.27
Plot 2	7.63	5.50	1.15	77.25	696.3	639.00	82.00	960.5	455.40	5.40	BDL	2.93	0.24

The tidal and fluvial effect varied with the climate in each year and this resulted in variation in chemical characteristics of Pokkali soil. Soil pH was neutral before the prawn release and it became slightly alkaline after the prawn harvest. Electrical conductivity of the soil was above 4 ds m^{-1} before release of prawn and after prawn harvest. This specified the importance of low and high saline phases in *Pokkali* cultivation. An increment in organic carbon content was observed in plot 1 after prawn harvest. Available P content was high in both the plots. Available K content increased after the cultivation of prawn and rated as high. Available Ca status decreased from the initial value i.e before prawn release. It was in the sufficient category after the prawn harvest. The available Mg content remained low. High level of available S was observed in two stages. Regarding micro nutrients, high increment was noticed in case of available Fe, Zn, Mn after the prawn harvest and remained high in status. Available Cu and boron content was reduced from sufficient limit to deficiency level after prawn harvest.

Benefit-Cost Ratio of Rice prawn integration

The traditional practice of rice prawn integration was indeed economical and eco friendly. Analysis of Benefit-Cost ratio is also approving the same. BC ratio of the farming is as given In Table 3.76.

Table 3.76. B:C ratio of Rice and prawn/ha

Crop	Rice	Prawn
Cost of Cultivation (Rs	62500	64000
Returns (Rs)	1,30,000	1,65000
BC Ratio	2.08	2.57

Benefit-Cost Ratio of Rice-Prawn integration: 2.33

Thus, traditional rice-prawn integration was found to be one of the best sustainable and eco-friendly means of integrating two different components in the *Pokkali* lands. In this system the growth of both the components are interrelated and is one of the proven technology which is very cost effective. During this year, grain yield recorded was 2.00t $ha^{-1}$and total of 300 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 2.33. This is mainly because of the fact that the left overs of prawn cultivation become manure for rice cultivation, thereby reducing the additional requirements of any external means of fertilizers. Integrating aquaculture with agriculture was found to be judicial management and ideal utilization of farm resources. Thus integrated farming is found to enhance the soil properties, cost effective and reducing input requirement.

2020

Rice – prawn integration at Kumbalangi, Ernakulam

The experiment was conducted in *Pokkali* land at farmer's field, Kumbalangi, Ernakulam (Plate 3.8). The field was prepared for rice cultivation by draining out water from the field and was ploughed and leveled. Ridges and furrows were taken and germinated seeds were sown on ridges.

In 2019, after rice cultivation, soil pH slightly decreased from initial value (7.24) and slightly acidic soil became neutral. The EC of the soil decreased to 2.07 from 2.24. The soil properties like OC, available K, Ca, Na, and micronutrients Cu and Mn, showed decrease in their values after rice harvest. The decrease in the content of Ca and Na was noticeable (Table 3.77).

In 2020, after rice cultivation, soil pH slightly increased from initial value (6.18) and slightly acidic soil became neutral. The EC of the soil decreased to 1.57 from 1.81. The soil properties like OC, available K, Ca, Mg, S, B and micronutrients Fe, Mn, and Zn showed decrease in their values after rice harvest (Table 3.77).


Plate 3.8 *Pokkali* rice field at Kumbalangi

Table 3.77.Changes in soil properties before and after rice cultivation

		2019		2020	
Properties	**Unit**	**Initial**	**Final**	**Initial**	**Final**
pH		7.24	6.95	6.18	6.96
EC	dS m^{-1}	2.24	2.07	1.81	1.57
OC	%	1.95	1.63	1.32	1.06
P	kg ha^{-1}	66.88	152.65	21.50	52.75
K		523.04	423.25	462.32	865.39
Na		8086.40	4214.30	611.60	68.21
Ca	mg kg^{-1}	661.50	62.49	609.13	32.51
Mg		42.83	85.36	63.05	39.25
S		375.00	78.24	308.57	58.05
Fe		564.90	597.12	1.20	0.20
Zn		4.96	85.01	450.70	163.63
Cu		0.846	0.21	2.23	1.96
Mn		7.50	1.02	BDL	BDL
B		1.72	2.54	2.87	2.20

Chemical properties of soil samples from Kumbalangi field before prawn release (2019) and after prawn release (2019) are given in Table 3.78 and 3.79. Chemical properties of soil samples from Kumbalangi field before prawn release (2020) and after prawn release (2020) are given in Table 3.80 and 3.81.

Table 3.78: Chemical properties of soil samples from Kumbalangi field before prawn release (2019)

Parti-culars	pH	EC	OC	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
		dSm^{-1}	%	kg ha^{-1}		mg kg^{-1}							
Plot 1	7.66	4.2	0.67	86.00	576.4	952.0	64.80	2.17	391.4	3.48	BDL	4.95	0.99
Plot 2	6.97	4.5	1.59	58.25	517.0	681.5	62.15	2.35	398.7	2.51	BDL	5.88	0.37
Plot 3	6.52	6.0	1.42	96.50	729.30	802.0	65.75	2.05	402.1	2.90	BDL	5.55	1.41

Table 3.79: Chemical properties of soil samples from Kumbalangi field after prawn release (2019)

Parti-culars	pH	EC	OC	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
		dSm^{-1}	%	kg ha^{-1}		mg kg^{-1}							
Plot 1	5.75	1.81	1.20	21.5	625.9	609.0	63.05	308.52	486.10	2.80	1.30	BDL	1.20
Plot 2	5.68	1.84	1.15	20.7	627.2	587.92	58.74	329.11	492.33	1.98	1.45	BDL	1.56

Table 3.80: Chemical properties of soil samples from Kumbalangi field before prawn release (2020)

Parti-culars	pH	EC	OC	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
		dSm^{-1}	%	kg ha^{-1}		mg kg^{-1}							
Plot 1	7.75	1.81	1.20	21.5	625.9	609.00	63.05	308.52	486.10	2.80	1.30	BDL	1.20
Plot 2	7.68	1.84	1.15	20.7	627.2	587.92	58.74	329.11	492.33	1.98	1.45	BDL	1.56

Table 3.81. Chemical properties of soil samples from Kumbalangi field after prawn release (2020)

Parti-culars	pH	EC	OC	P	K	Ca	Mg	S	Fe	Mn	Cu	Zn	B
		dSm^{-1}	%	kg ha^{-1}		mg kg^{-1}							
Plot 1	6.92	2.20	1.52	82.96	526.43	189.63	29.06	19.36	270.06	2.14	1.35	BDL	1.19
Plot 2	6.58	2.01	1.80	56.87	385.94	187.32	42.61	29.19	324.56	2.84	0.95	BDL	1.05

Harvesting of rice was started on 28.10.2019 and 23.10.2020 respectively and was done manually. Only the panicles were harvested and were brought to the bund using a small boat by farmer. The Straw was kept in the field itself. The grain yield was 1.3 t/ ha in the year 2019 and 1.0 t/ha in the year 2020.

Rice field was prepared for prawn cultivation in January. Tiger prawn seedlings was released during February. The prawns were harvested during first week of May. The prawn yield was 300 kg ha^{-1} in the year 2019 and 200 kg ha^{-1} in the year 2020 (Plate 3.9).

In 2019, analytical data of soil samples before and after cultivation of prawn showed that there was a change in chemical soil properties after the cultivation of prawn. Soil pH was neutral before the prawn release and it became slightly alkaline after the prawn harvest. Electrical conductivity of the soil was above 4 dS m^{-1} before release of prawn and after prawn harvest. This specifies the importance of low and high saline phases in *Pokkali* cultivation. Organic carbon content was found to be increased in plot 1 after prawn harvest. Available P content was high in both the plots. Available K content increased after the cultivation of prawn and rated as high. Though available Ca status decreased from the initial value i.e before prawn release it was in the sufficient category even after the prawn harvest. The available Mg content remained low. High level of available S was observed in two stages.

Regarding micro nutrients, high increment was noticed in case of available Fe, Zn, and Mn after the prawn harvest and remained high in status. Available Cu and boron content was reduced from sufficient limit to deficiency level after prawn harvest. In 2020, soil pH was neutral before the prawn release and it became slightly alkaline after the prawn harvest. Electrical conductivity of the soil was below 4 ds m^{-1} before release of prawn and after prawn harvest. This specifies the importance of low and high saline phases in *Pokkali* cultivation. A decrease in organic carbon content was observed in both plots after prawn harvest. Available K, Ca, Mg, S, Fe, Mn and Cu content was high in both the plots before prawn release. After prawn harvest their content got though available Ca status decreased from the initial value i.e before prawn release it was in the sufficient category even after the prawn harvest.

Plate 3 9 Harvested tiger prawn

Benefit-Cost Ratio of Rice prawn integration

The cost- benefit ratios for rice, prawn and rice-prawn integration system were calculated separately. The traditional practice of rice prawn integration was indeed economical and eco friendly. As the left over's of prawn cultivation become manure for rice cultivation, there would not be any additional application of fertilizers. It may enhance the soil qualities as well as the growth and yield of following rice crop. Analysis of Benefit-Cost ratio is also approving the same. BC ratio of the farming is as given below (Table 3.82, 3.83 and 3.84).

Table 3.82.Cost of Cultivation of Rice/ha

SN	Components	Cost (Rs.)	
		2019	2020
1.	Seed	6500	6500
2.	Land preparation, ploughing, ridges and furrow preparation	18000	22200
3.	Weeding	3500	2400
4.	Transplanting	9000	9200
5.	Harvesting	17000	13000
6.	Threshing	4000	4200
7	Drying	4500	3000
	Total	**62500**	**60500**

Returns

Yield –2.00 t ha^{-1}@ Rs.65/ kg = Rs.1,30,000/- for 2019
Yield –1.0 t ha^{-1} @ Rs.65/ kg = Rs.65000/- for 2020

Table 3.83.Cost of Cultivation of prawn/ha

SN	Components	2019 Cost (Rs)	2020 Cost (Rs)
1	Field preparation and sluice maintenance	10000	15000
2	Prawn seedlings	15000	15000
3	Transportation charge	6000	6000
4	Feed	15000	20000
5	Harvest (labour charge, pumpset)	18000	20000
	Total	**64000**	**76,000**

Returns

Yield -300 kg ha^{-1} @ Rs.550/ kg = Rs.1,65000/- for 2019
Yield -400 kg ha^{-1} @ Rs.550/ kg = Rs. 2,20,000/- for 2020

Table 3.84. BC ratio of rice and prawn/ha

	Rice (2019)	Rice (2020)	Prawn (2019)	Prawn (2020)
Cost of Cultivation (Rs)	62500	60500	64000	76,000
Returns (Rs)	1,30,000	65,000	1,65,000	2,20,000
BC Ratio	2.08	1.07	2.57	2.89

Benefit-Cost Ratio of Rice-Prawn integration (2019): 2.33
Benefit-Cost Ratio of Rice-Prawn integration (2020): 1.98

The traditional rice-prawn integration was one of the best sustainable and eco-friendly means of integrated farming in *Pokkali* lands. In this system the growth of both the components are interrelated, where the rice residues acts as feed for prawn and the leftovers of prawn cultivation become manure for rice cultivation, thereby reducing the additional requirements of any external means of fertilizers. During the year 2019, grain yield recorded was 2.00 t/ha and total of 300 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 2.33. During the year 2020, grain yield recorded was 1.00 t/ha and total of 400 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 1.98.It may enhance the soil qualities as well as the growth and yield of following rice crop. Integrating aquaculture with agriculture was found to be judicial management and ideal utilization of farm resources. Thus integrated farming is found to be very beneficial and successful, enhance the soil properties, cost effective and reducing input requirements.

4. ALTERNATE LAND USE

- **Studies on performance of fodder crops in salt affected soils (Bapatla)**

2019

Six fodder crops (T_1- Stylo-Stylosanthus, T_2-Hedge lucerne, T_3- Lucerne, T_4- Fodder sorghum (panthchari-6), T_5- COFS-29 (fodder jowar) and T_6- Sweet sudan grass-Sorghum Sudanese) were tested on large plots in farmers fields at Nidubrolu, Guntur district. The bore well water having salinity of 7.1 was used for irrigation. The initial soil salinity was recorded as 1.1 dS/m and the soil salinity raised to 5.6 dS/m after irrigation with saline water. Out of six crops tested, sweet sudan grass recorded the maximum biomass yield of 42.8 t/ha followed by CoFS-29 (39.7 t/ha) and Panthchari-6 (36.5 t/ha.). Hedge lucerne yielded the biomass of 31.4 t/ha. Stylo and Lucerne recorded the biomass yield of 7.2 and 8.7 t/ha, respectively (Table 4.1).

Table 4.1 Influence of soil salinity on Biomass yield of different fodder crops

Treatments	Plant height (m)	Biomass yield (t/ha)	Treatments	Plant height (m)	Biomass yield (t/ha)
T1-Stylo	0.45	7.2	T4-Panthchari-6	1.46	36.5
T2-Hedge lucerne	1.25	31.4	T5-CoFS-29	1.55	39.7
T3-Lucerne	0.62	8.7	T6-Sweet sudan grass	1.72	42.8

- **Survey of existing plantations and characterization in coastal area (Bapatla)**

2020

A study about existing major plantations of coastal areas is being conducted in coastal districts of Guntur and Prakasam district. The major plantations found in coastal area are cashew, casuarina, eucalyptus, subabul and mango. Some plantations of citrus, amla, guava and ber were also observed. Prosopis was observed in abandoned lands. The soil samples were collected from locations of plantations and were analyzed for pH and EC $_{(1:2)}$. The pH varied from 5.8 – 10.5. The highest pH was noticed in abandoned land. The soil salinity ranged between 0.1 – 15.0 dSm^{-1}. The highest soil salinity of 15.0 dSm^{-1} was found at casuarina location while highest pH of 9.0 was recorded at Subabul (Table 4.2). Results suggested that Casuarina is most suitable for saline conditions and Subabul is suitable for alkali conditions.

Table 4.2: Analysis of soil samples collected from Plantation crops

SN	**Name of the plantation**	**pH**	**EC$_{(1:2)}$ (dSm^{-1})**	**SN**	**Name of the plantation**	**pH**	**EC$_{(1:2)}$ (dSm^{-1})**
1.	Eucalyptus	6.7	0.10	9.	Ber	8.5	0.30
2.	Eucalyptus	5.8	0.30	10.	Citrus	8.5	0.30
3.	Casuarina	7.8	15.0	11.	Cashew	7.5	0.10
4.	Casuarina	7.0	7.60	12.	Eucalyptus	6.3	0.10
5.	Cashew	6.0	0.10	13.	Casuarina	6.9	0.40
6.	Subabul	7.7	0.40	14.	Wild neem	7.7	0.10
7.	Amla	7.9	0.30	15.	Prosopis in Abandoned land	10.5	6.90
8.	Subabul	9.0	0.70				

- **Development of horticulture based agri-horti system under saline water condition (Bikaner)**

This experiment was started during Rabi 2018-19 to develop horticulture based agri-horti system under saline water. The treatments comprised of three levels of ECiw (BAW, 2. 4 and 6 dS/m) with four intercrops (mustard, taramira, oat and barley) between alleys of bael trees. Results of the experiment (Table 4.3) indicated that seed and straw yield of mustard, taramira, oat and barley decreased with increase of ECiw from 0.25 dS/m, but the difference in yield was statistically at par over BAW except in oat during both the years. In case of oat as compared to ECiw 0.25(BAW) with ECiw 2.40 and ECiw 6.0 dS/m showed significant reduction of 1.86 and 7.06 per cent, respectively. In terms of straw yield similar trend was observed.

Table 4.3. Effect of irrigation water salinity on yields of crops between alleys of beal tree

Treatments	Seed yield q/ha)			Straw yield (q/ha)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Mustard						
BAW (EC 0.25 dS/m)	17.58	25.38	21.48	52.49	58.70	55.59
Tube-well water (EC 2.4 dS/m)	17.25	24.26	20.76	51.43	57.99	54.71
Saline Irrigation water (EC 6.0 dS/m)	16.58	23.58	20.08	51.19	55.40	53.30
SEm±	0.34	0.59	0.34	0.40	1.48	0.77
CD(P= 0.05%)	1.17	2.05	1.05	1.39	5.11	2.36
Taramira						
BAW (EC 0.25 dS/m)	12.68	16.35	14.52	75.15	54.03	64.59
Tube-well water (EC 2.4 dS/m)	12.43	15.76	14.09	74.98	53.17	64.07
Saline Irrigation water (EC 6.0 dS/m)	11.95	14.80	13.38	73.25	49.16	61.21
SEm±	0.32	0.77	0.42	0.55	1.46	0.78
CD(P= 0.05%)	1.10	2.68	1.29	1.91	5.07	2.41
Oat						
BAW (EC 0.25 dS/m)	21.06	21.98	21.52	47.85	52.08	49.96
Tube-well water (EC 2.4 dS/m)	20.68	21.56	21.12	47.07	50.70	48.89
Saline Irrigation water (EC 6.0 dS/m)	19.44	20.55	20.00	46.34	49.20	47.77
SEm±	0.37	0.31	0.24	0.28	0.58	0.32
CD(P= 0.05%)	1.27	1.06	0.74	0.97	2.01	0.99
Barley						
BAW (EC 0.25 dS/m)	37.46	48.76	43.11	51.20	66.75	58.97
Tube-well water (EC 2.4 dS/m)	36.80	47.70	42.25	51.02	66.50	58.76
Saline Irrigation water (EC 6.0 dS/m)	36.01	45.84	40.92	50.11	64.50	57.31
SEm±	0.81	0.92	0.61	0.37	1.15	0.61
CD(P= 0.05%)	2.81	3.19	1.89	1.28	3.99	1.86

5. SCREENING OF CROP CULTIVARS AND GENOTYPES

- **Screening of mustard cultivars under saline irrigation (Agra)**

The experiment was conducted in micro-plots 3.0 m x 1.35 m size for AVT each plot. The irrigation water was prepared synthetically for water salinity.

Details of experimentation (2018-19)

Treatments:

Water salinity	:EC_{iw} 12dS/m for all cultivars
Cultivars	: AVT CSCN 18-1 to CSCN 18-12
Design	: Randomized Block Design (RBD)
Replication	:Three
Crop	: Rape seed mustard
Date of sowing	: **31.10.2018**
Doses of fertilizer (kg/ha)	:N:P:K (120:60:60)
Number of irrigations	: 3 (Pre-sowing, flowering stage and siliqua stage)
Depth of irrigation	: 7 cm
Total rainfall during crop period	: 25.6mm
Date of harvesting	: 14.03.2019

Details of experimentation (2019-20)

Treatments:

Water salinity	:EC_{iw} 12dS/m for all cultivars
Cultivars	: AVT CSCN 19-1 to CSCN 19-8
Design	: Randomized Block Design (RBD)
Replication	:Three
Crop	: Rape seed mustard
Date of sowing	: **29.10.2019**
Doses of fertilizer (kg/ha)	:N:P:K (120:60:60)
Number of irrigations	: 3 (Pre-sowing, flowering stage and siliqua stage)
Depth of irrigation	: 7 cm
Total rainfall during crop period	: 25.6mm
Date of harvesting	: 17.03.2020

Seed yield:

The yield data (2018-19 and 2019-20) of different mustard genotype are presented in Table 5.1. In 2018-19 the yield of genotype (AVT) was significantly affected in saline water irrigation. The significantly higher yield was produced in genotype CSCN 18-7 (1975.50 kg/ha) and lowest was recorded for genotype CSCN 18-4 (1646.60 kg/ha). During 2019-20 also, the yield of genotype (AVT) was significantly affected in saline water irrigation. The significantly higher yield was produced in genotype CSCN 19-8 (2472.22 kg/ha) and lowest was recorded in genotype CSCN 19-2 (1812.35 kg/ha).

Table 5.1: Effect of saline water irrigation on yield and yield attributing characters of mustard (AVT) genotype 2018-19

Cultivars	Grain yield (kg/ha)	Cultivars	Grain yield (kg/ha)
2018-19		**2019-20**	
CSCN 18-1	1892.79	CSCN 19-1	2014.81
CSCN 18-2	1913.46	CSCN 19-2	1812.35
CSCN 18-3	1678.39	CSCN 19-3	1845.68
CSCN 18-4	1646.60	CSCN 19-4	1930.86
CSCN 18-5	1716.66	CSCN 19-5	2061.73
CSCN 18-6	1885.79	CSCN 19-6	2009.88
CSCN 18-7	1975.50	CSCN 19-7	2221.02
CSCN 18-8	1786.00	CSCN 19-8	2472.22
CSCN 18-9	1678.38	CD (P=0.05)	350.68
CSCN 18-10	1779.82	C.V. (%)	9.80
CSCN 18-11	1800.61		
CSCN 18-12	1794.23		
CD (P=0.05)	242.15		
C.V. (%)	9.38		

Plot size: 3.0m x 1.35m

- **Performance of promising mustard (*Brassica Juncea*) entries under different fertility levels irrigated with saline water (Agra)**

Details of experimentation (2018-19)

Crop : Mustard
Date of sowing :31-10-2018
Doses of fertilizer (kg/ha) :N:P:K (120:60:60)
Plot size : 4.5m x 3.0m
Salinity of irrigation water : 12 dS/m
Number of irrigations : 2 (Pre-sowing and flowering stage)
Depth of irrigation : 7 cm
Total rainfall during crop period : 25.6 mm
Date of harvesting : 14-03-2019

Seed yield (kg/ha):

The data of mustard grain yield $kgha^{-1}$ clearly indicated that the entries of mustard had significant differences in grain yields (Table 5.2). The highest grain yield was recorded for AG-2 (2141.9 kg/ha) and lowest AG-7 (1691.4 kg/ha) but AG-1 and AG-4 produced at par grain yield. The grain yield of mustard increased significantly for 100%, 125% and 150% RDF. The increase in grain yield at 150% RDF compared to 100% was 12.8 % while it was 6.1% compared to 125% RDF. The application of 125% RDF significantly increase the grain yield of mustard by 7.2% compared with 100% RDF.

Table 5.2: Effect of different treatments on grain yield (kg/ha) of mustard (2018-19)

Entries	Different doses of fertilizer			
	100%RDF	125%RDF	150%RDF	Mean
AG-1	1699.7	1950.3	2142.7	1930.9
AG-2	2101.7	2136.0	2188.0	2141.9
AG-3	1713.0	1874.7	1938.3	1842.0
AG-4	1738.7	1946.0	2131.0	1938.6
AG-5	1818.7	1731.0	1838.7	1802.8
AG-6	2024.3	2027.7	2192.7	2081.6
AG-7	1443.3	1687.7	1943.3	1691.4
Mean	1791.3	1907.6	2056.4	-
CD at 5%	Entries(E) 150.82	Fertility(F) 75.2	Interaction(E x F)=NS	Interaction (F x E)=NS

- **Screening trial of lentil germplasm in saline and alkali irrigation waters (Agra)**

The experiment was conducted in micro-plots 4.5 m x 4.0 m size. The irrigation water was prepared synthetically for water salinity.

2018-19

General notes to be taken on growing conditions

1. Layout Design :Randomized Block Design
2. No. of germplasm :Eight
3. No. of Replication harvested :Three
4. Plot size
   - i. Number of rows : 6
   - ii. Row length : 4.0m
   - iii. Row to row distance : 22.5cm
   - iv. Plant to plant distance : 2-3cm
   - vii. ECiw : 6 (dS/m)
   - viii. RSCiw : 6 (meq/l)
5. Irrigation
   - i. Number :Two
   - ii. Dates :31.12.2018 and 12.2.2019
6. Fertilizer application :

	Basal	Top-dressed	Foliar
Nitrogen(kg/ha)	25	-	-
Phosphate (kg/ha)	60	-	-
Potash (kg/ha)	60	-	-

7. Bacterial culture : Not used
   : Source (nil)
8. Date of sowing :6.12.2018
9. Date of harvesting/picking : 12.4.2019
10. Details of intercultural operations :
    - i. Weeding (number & dates) :Two (10.1.2019 & 20.2.2019)
    - ii. Hoeing (number & dates) :No

11.(i) Soil type :Sandy loam
(ii) pH :7.9
(iii) Fertility

Status	Nitrogen	Phosphate	Potash
Low			
Medium	Yes	Yes	yes
High			

12. Geographical Information (i) Latitude :27.2°N
(ii) Longitude : 27.9°E
(ii) Altitude : -
13. Rainfall (mm) : 26.0

14. Plant Protection Measures :

	Pesticide/Fungicide	Dose of quantity used	Date of application
Spray	Not	Not	Not
Dust	Not	Not	Not
Soil application	Not	Not	Not

15. Previous crop : fallow
16. General condition of the trial : Normal
17. General remarks: Comment if any of the following factor adversely affected the crop yield.
    (i)Weeds : Not
    (ii)Untimely rain : Not
    (ii)Field preparation : yes
    (iv)Untimely sowing : No
    (v) Water stagnation : Not
    (vi) Drought : yes
    (vii) Insects : Not

17. Diseases-100% infested by YMV on Entry no.:
    (x) Shattering : Not
    (xi) Lodging : Not
    (xii) Any other reason : Salinity/sodicity develop in the soil

18. Suggestions, if any
    Some genotypes are grown successfully in ECiw 6 (dS/m) and RSCiw 6 (meq/l).

Seed yield:

The yield of lentil germplasm was significantly affected in saline water irrigation (Table 5.3). The higher yield was produced in lentil germplasm SL 18-3 (1417.84 kg/ha) and lowest was recorded in germplasm SL 18-4 (335.06 kg/ha). The yield data of different lentil germplasm in RSC treated plots are given Table 5.4. The yield of lentil germplasm was significantly differing in sodic water. The germplasm SL 18-3 gave higher grain yield (1281.17 kg/ha) and lowest yield in SL 18-8 (368.21 kg/ha).

Table 5.3: Effect of water salinity (ECiw 6 dS/m) on yield of lentil germplasm (2018-19)

S.No.	Germplasm/Code	Grain yield/plot (gm)	Grain yield (kg/ha)
1.	SL 18-1	199.37	369.20
2.	SL 18-2	257.83	477.47
3.	SL 18-3	765.63	1417.84
4.	SL 18-4	180.93	335.06
5.	SL 18-5	331.97	614.75
6.	SL 18-6	269.80	499.63
7.	SL 18-7	702.57	1301.05
8.	SL 18-8	263.17	487.35
	SEm±	55.45	102.68
	C.D. at 5%	118.94	220.26
	CV (%)	18.25	18.28

Table 5.4: Effect of water sodicity (RSCiw 6 meq/l) on yield of lentil (2018-19)

S.No.	Germplasm/Code	Grain yield/plot (gm)	Grain yield (kg/ha)
1.	SL 18-1	226.63	419.69
2.	SL 18-2	260.20	481.85
3.	SL 18-3	691.8	1281.17
4.	SL 18-4	212.10	392.78
5.	SL 18-5	326.77	605.12
6.	SL 18-6	318.57	589.94
7.	SL 18-7	648.93	1201.73
8.	SL 18-8	198.83	368.21
	SEm±	44.42	82.25
	C.D. at 5%	95.28	176.44
	CV (%)	15.09	15.09

- **Advanced Varietal Trial (AVT) of mustard under saline/ alkaline conditions (Bikaner)**

2018-19

Advanced Varietal Trial (AVT) of mustard genotypes was undertaken for their screening for salt tolerance under saline/ alkaline conditions. The experimental details are provided below.

Sr. No.	Particulars	Details
1	Advanced Varietal Trial	Mustard (CSCN-18-1 to CSCN-18-12)
2	Duration	Rabi 2018-19
3	Treatments	Mustard material (CSCN-18-1 to CSCN-18-12)
4	Replications	4
5	Design	Randomized Block Design
6	Plot Size	4.5 m x 5 m=22.5 m2
7	Net	3.6 m x 4.5 m=16.2 m2
8	Spacing	45x15cm
9	Fertilizer doses	80 :40:40, N : P2O5 : K2O kg /ha
10	Seed rate	4.0 kg/ha
11	Date of Sowing	26.10.2018

In AVT mustard, twelve entries were evaluated in randomized block design with four replications under saline conditions (ECiw 10.0 dS/m).The differences among the genotypes for seed yield was found significant. Entry CSCN-18-2 was top yielder for seed yield (20.04 q/ha) closely followed by CSCN-18-3 and CSCN-18-11. It was significantly superior over rest of the entries (Table 5.5).

Table 5.5 Advanced varietal trial (AVT) of mustard under saline/ alkaline conditions

Treatments	Days to 50% flowering	Days of maturity	Plant Height (cm)	Number of primary branches per plant	Number of Secondary branches per plant	Number of silique per plant	Number of silique on main stem	Seed yield per plant (g)	Seed yield (q/ha)
1	2	3	4	5	6	7	8	9	10
CSCN-18-1	49.00	145.00	151.50	9.00	18.90	248.00	35.00	24.60	15.92
CSCN-18-2	53.25	145.50	157.25	10.95	27.30	327.50	42.00	26.53	20.04
CSCN-18-3	46.75	145.50	155.50	9.90	19.30	289.00	37.00	25.57	18.34

CSCN-18-4	46.50	144.25	140.40	8.50	18.00	225.25	31.00	21.87	13.82
CSCN-18-5	51.50	145.00	150.80	7.20	17.20	208.00	27.00	20.15	12.08
CSCN-18-6	46.50	145.75	141.15	7.90	17.85	215.00	30.00	21.67	12.22
CSCN-18-7	54.25	146.00	151.65	7.55	17.50	214.00	28.00	21.34	12.08
CSCN-18-8	48.75	145.25	150.25	6.00	11.20	189.00	21.95	18.57	9.32
CSCN-18-9	54.50	144.50	148.90	6.75	15.00	192.75	23.00	19.51	10.26
CSCN-18-10	53.50	145.00	153.35	6.85	16.80	207.75	24.00	20.02	10.64
CSCN-18-11	52.25	145.00	172.50	9.65	19.00	287.75	36.00	25.49	18.24
CSCN-18-12	46.00	143.50	139.00	6.40	12.50	192.00	22.00	19.25	9.35
SEm±	1.70	0.68	9.93	1.49	3.55	1.01	0.79	0.61	0.40
CD(P= 0.05%)	4.90	1.96	28.58	4.30	10.22	2.91	2.28	1.75	1.15

- **Initial varietal trial (IVT) of mustard under saline/ alkaline conditions (Bikaner) 2019-20:**

Initial Varietal Trial (AVT) of mustard genotypes was undertaken for their screening for salt tolerance under saline/ alkaline conditions. Eight mustard entries were evaluated in randomized block design with three replications under saline conditions (ECiw 10.0 dS/m). Results showed that the differences among the genotypes for seed yield were found significant. Entry CSCN-19-07 was recored top yielder for seed yield (41.39 q/ha) closely followed by CSCN-19-08 and CSCN-19-03. It found significantly superior over rest of the entries (Table 5.6).

Table 5.6 Initial varietal trial (IVT) of mustard under saline conditions

Treatments	Plant height at maturity (cm)	Number of primary branches/ plant	Number of silique on main stem	Total number of silique/ plant	Test weight (g)	Seed yield (q/ha)	Straw yield (q/ha)
CSCN-19-01	167.00	4.40	73.20	236.73	5.66	25.73	58.92
CSCN-19-02	169.33	4.67	87.47	219.73	5.69	25.07	57.42
CSCN-19-03	172.67	5.00	98.53	300.67	4.84	38.20	87.47
CSCN-19-04	184.33	5.13	93.53	289.13	5.65	28.32	64.86
CSCN-19-05	167.33	4.20	67.67	258.73	4.37	26.71	61.17
CSCN-19-06	179.33	4.93	104.60	277.67	5.60	29.04	66.49
CSCN-19-07	185.33	5.00	96.93	347.60	5.75	41.39	94.78
CSCN-19-08	169.13	4.93	92.47	305.67	5.60	38.60	88.41
SEm +	3.79	0.38	2.66	11.96	0.30	2.82	6.46
CD (P= 0.05%)	11.50	1.15	8.07	36.28	0.92	8.55	19.59

- **Screening of elite varieties of crops irrigated with poor quality waters (Hisar)**

The tolerance of cotton, wheat, pearl millet and mustard genotypes under saline water irrigation treatments was evaluated in lined micro-plots of 2 m x 2 m in size. The plots were constructed above ground and filled with the sandy loam surface soil (0-15 cm). The soil was allowed to stabilize before sowing the crop. The tolerance of seven genotypes of cotton (H 1508, H 1519, H 1523, H 1525, H 1527, H 1530 and HF-2228X1117P), fourteen genotypes of wheat (WH 1237, WH 1239, WH 1255, WH 1256, WH 1257, WH 1258, WH 1259, WH 1260, WH 1261, WH 1262, WH 1263, WH 1264, Kh 65 and KRL 210), seven genotype of pearl millet (HHB 272, HHB 299, HHB 301, HHB 311, HHB 333, HHB

335 and HMS48A XSGP-10-107) and twelve genotypes of mustard (CSCN-18-1, CSCN-18-2, CSCN-18-3, CSCN-18-4, CSCN-18-5, CSCN-18-6, CSCN-18-7, CSCN-18-8, CSCN-18-9, CSCN-18-10, CSCN-18-11 and CSCN-18-12) were tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m. Recommended cultural practices and fertilizer doses were applied in raising the crops. Uniform fertilizer applications were made in all the treatments using urea, DAP and $ZnSO_4$. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. The soil samples were collected before sowing and after the harvesting of the crops. The soil samples were air dried, ground to pass through a 2 mm sieve and analyzed for electrical conductivity. The results of screening are given below.

2018-19

Cotton: Increasing salinity led to a gradual decrease in seed cotton yield (Table 5.7). Among the seven genotypes, H 1525 gave the highest (203.19 g/m^2) seed cotton yield and H 1519 resulted in the lowest seed cotton yield (155.51 g/m^2) at EC_{iw} 7.5 dS/m. The mean seed cotton yield reduced by 25.16 % at EC_{iw} 7.5 dS/m as compared to canal irrigation. Overall mean yield (241.60 g/m^2) of H 1525 was significantly higher than other genotypes followed by H 1530 (222.08 g/m^2) and H 1523 was the lowest yielder (190.29 g/m^2).

Table 5.7: Effect of saline waters on seed cotton yield (g/m^2) of cotton genotypes

Genotype	**ECiw (dS/m)**				**Mean**
	Canal	**2.5**	**5.0**	**7.5**	
H 1508	219.38	206.72	187.60	162.51	194.05
H 1519	205.77	195.55	180.61	155.51	184.36
H 1523	213.71	205.65	178.48	163.33	190.29
H 1525	272.19	256.13	234.87	203.19	241.60
H 1527	231.74	217.96	194.58	174.93	204.80
H 1530	249.45	238.59	216.89	183.38	222.08
HF-2228X1117P	224.05	214.53	190.78	166.75	199.03
Mean	230.90	219.31	197.69	172.80	
CD (p=0.05) Variety (V) =9.98, Salinity (S) = 7.54 V x S = NS					

Wheat: The data showed that the grain yield of different genotypes of wheat decreased with an increase in EC_{iw} (Table 5.8).Wheat genotype WH 1256 performed the best at EC_{iw} 7.5 dS/m and gave 17.34% higher grain yield compared with KRL 210 (check). It was followed by WH 1264 which gave 15.29 % higher grain yield than KRL 210 whereas the performance of Kh 65 (294.93 g/m^2) was the least. On the basis of overall mean, WH 1264 gave maximum grain yield (466.58 g/m^2) which was 16.74% higher than KRL 210 followed by WH 1256 (464.73 g/m^2). The overall mean yield reduction at 2.5, 5.0 and 7.5 dS/m was 3.63, 14.69 and 26.03%, respectively, as compared to canal. Physiological data was recorded for Canopy temperature (Table 5.9), Normalized Difference Vegetation Index (NDVI) indicating greenness in biomass (Table 5.10) and SPAD Chlorophyll Content of flag leaf (Table 5.11) at anthesis as affected by different saline waters. WH 1264 maintained low canopy temperature, high NDVI and Chlorophyll Content Index at 7.5 dS/m.

Table 5.8: Grain yield (g/m^2) of wheat genotypes as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal	**2.5**	**5.0**	**7.5**	
WH1237	477.50	457.23	408.67	340.80	421.05
WH 1239	435.60	421.40	376.60	328.53	390.53
WH 1255	483.53	462.73	421.87	358.10	431.56
WH 1256	520.83	506.40	438.73	392.93	464.73
WH 1257	442.63	431.93	372.90	336.47	395.98
WH 1258	463.07	446.47	395.93	346.63	413.03
WH 1259	511.10	491.73	430.47	379.53	453.21
WH 1260	518.33	497.10	449.73	374.17	459.83
WH 1261	425.37	412.13	364.23	309.67	377.85
WH 1262	467.73	447.17	393.47	342.27	412.66
WH 1263	499.27	476.30	418.03	371.13	441.18
WH 1264	528.47	506.30	445.47	386.07	466.58
Kh 65	401.87	391.50	348.63	294.93	359.23
KRL 210	444.27	431.10	382.13	334.87	398.09
Mean	472.83	455.68	403.35	349.72	
CD (p=0.05)	Variety (V) =20.72 , Salinity (S)=11.07, V x S = NS				

Table 5.9: Canopy temperature (^{0}C) of wheat genotypes at anthesis as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal	**2.5**	**5.0**	**7.5**	
WH1237	22.6	23.7	24.3	25.3	24.0
WH 1239	22.4	22.9	23.6	24.0	23.2
WH 1255	22.3	23.0	24.2	24.8	23.6
WH 1256	20.9	21.6	22.4	23.0	22.0
WH 1257	22.4	24.0	24.8	25.6	24.2
WH 1258	20.8	21.8	23.9	24.5	22.7
WH 1259	22.4	22.5	22.7	23.1	22.7
WH 1260	21.3	22.3	23.0	24.0	22.6
WH 1261	23.1	23.9	23.9	24.8	23.9
WH 1262	20.6	21.9	24.5	24.9	23.0
WH 1263	21.5	22.4	23.4	24.2	22.8
WH 1264	20.6	21.3	22.4	23.6	22.0
KH 65	21.0	22.1	23.4	24.6	22.8
KRL 210	20.7	21.5	23.5	24.0	22.4
Mean	21.6	22.5	23.6	24.3	

Table 5.10: Normalied Difference Vegetation Inde (NDVI) of wheat genotypes at anthesis as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
WH1237	0.82	0.79	0.72	0.69	0.76
WH 1239	0.82	0.80	0.74	0.63	0.75
WH 1255	0.84	0.83	0.77	0.68	0.78
WH 1256	0.87	0.87	0.81	0.79	0.84
WH 1257	0.87	0.87	0.79	0.73	0.82
WH 1258	0.81	0.80	0.72	0.66	0.75
WH 1259	0.83	0.83	0.75	0.70	0.78
WH 1260	0.85	0.84	0.72	0.69	0.78
WH 1261	0.86	0.83	0.76	0.72	0.79
WH 1262	0.83	0.83	0.74	0.71	0.78
WH 1263	0.85	0.85	0.78	0.73	0.80
WH 1264	0.87	0.88	0.81	0.73	0.82
KH 65	0.82	0.82	0.75	0.72	0.78
KRL 210	0.80	0.82	0.74	0.70	0.77
Mean	0.84	0.83	0.76	0.71	

Table 5.11: SPAD Chlorophyll Content of wheat genotypes at anthesis as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
WH1237	49.9	49.8	46.3	46.3	49.8
WH 1239	51.9	51.2	48.4	48.3	51.6
WH 1255	52.3	50.2	50.4	49.6	51.2
WH 1256	58.9	54.0	52.4	50.8	56.4
WH 1257	49.4	48.4	47.8	46.5	48.9
WH 1258	50.5	49.5	48.7	47.0	50.0
WH 1259	50.6	50.4	49.9	49.3	50.5
WH 1260	52.4	51.5	50.7	49.8	51.9
WH 1261	51.9	51.3	49.8	49.7	51.6
WH 1262	50.1	49.6	48.1	48.7	49.8
WH 1263	50.3	50.3	49.0	48.3	50.3
WH 1264	55.9	53.5	52.7	51.5	54.7
KH 65	50.9	48.1	47.4	46.5	49.5
KRL 210	54.0	52.2	52.0	50.9	53.1
Mean	52.1	50.7	49.5	48.8	

Pearl millet: The data showed that the grain yield of different genotypes of pearl millet decreased with an increase in EC of the irrigation water (Table 5.12). Among the pearl millet hybrids, HHB 335 performed best at ECiw (7.5 dS/m) followed by HHB 272 whereas the performance of HHB 301 was the poorest. The mean grain yield (258.97g/m^2) of HHB 335 was higher than other genotypes followed by HHB 272 (252.22 g/m^2) and HHB 299 (242.90 g/m^2). Whereas the parent of pearl millet hybrids HMS48A XSGP-10-107 mean grain yield was 222.07

g/m^2. The overall mean reduction in pearl millet yield at 2.5, 5.0 and 7.5 dS/m was 4.51, 14.78 and 23.82%, respectively as compared to canal.

Table 5.12: Grain yield (g/m^2) of pearl millet genotypes as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
HHB 272	283.63	269.23	239.43	216.60	252.22
HHB 299	270.83	256.93	233.52	210.33	242.90
HHB 301	242.86	229.53	208.97	185.43	216.69
HHB 311	264.30	255.17	220.33	198.13	234.48
HHB 333	257.79	246.30	226.87	195.30	231.56
HHB 335	290.27	280.67	242.47	222.50	258.97
HMS48A XSGP-10-107	249.63	237.66	212.80	188.17	222.07
Mean	265.62	253.64	226.34	202.35	
CD (p=0.05)	Variety (V) = 11.40, Salinity (S) = 8.62, V x S =NS				

Mustard: Twelve genotypes under AVT mustard were tested. The data showed that the seed yield of different genotypes of mustard decreased with an increase in EC of the irrigation water (Table 5.13). In AVT, the mustard genotypes CSCN-18-2 gave the highest seed yield (200.88 g/m^2) followed by CSCN-18-7 (200.48 g/m^2) at ECiw 7.5 dS/m and the lowest seed yield (161.27/m^2) was obtained in CSCN-18 -9. All the genotypes under AVT showed decreasing trend with the increasing levels of salinity (canal to 7.5 dS /m). The values of total chlorophyll content varied from 0.79 to 0.54 mg g^{-1} FW. Higher total chlorophyll contents were noticed in CSCN-18-2 (0.62) at ECiw 7.5 dS/m (Table 5.14). The mean salinity in the soil profile at the time of mustard harvest varied from 1.67 dS/m in canal water irrigated plot to 10.02 dS/m in plots receiving saline water irrigation of ECiw 7.5 dS/m (Table 5.15).

Table 5.13: Seed yield (g/m^2) of mustard genotypes under AVT as affected by waters of different salinities

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
CSCN-18-1	253.33	241.87	222.54	194.98	228.18
CSCN-18-2	261.04	251.26	226.97	200.88	235.04
CSCN-18-3	230.90	220.60	204.18	165.34	205.26
CSCN-18-4	208.26	197.59	180.02	163.46	187.33
CSCN-18-5	214.85	205.73	184.12	167.28	192.99
CSCN-18-6	234.28	221.85	197.69	185.40	209.81
CSCN-18-7	255.90	246.37	226.05	200.48	232.20
CSCN-18-8	225.06	215.81	191.25	174.05	201.54
CSCN-18-9	210.75	202.55	178.41	161.27	188.24
CSCN-18-10	220.50	208.24	187.38	175.93	198.01
CSCN-18-11	241.52	232.14	204.10	174.39	213.04
CSCN-18-12	238.42	229.29	210.65	188.22	216.65
Mean	232.90	222.78	201.11	179.31	
CD (p=0.05)	S = 10.76, V= 18.64 SxV= NS				

Table 5.14: Total chlorophyll content (mg g^{-1} FW) of mustard genotypes under AVT as affected by waters of different salinities

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
CSCN-18-1	0.97	0.89	0.51	0.47	0.71
CSCN-18-2	0.78	0.76	0.72	0.62	0.72
CSCN-18-3	0.73	0.68	0.60	0.55	0.64
CSCN-18-4	0.90	0.63	0.62	0.55	0.68
CSCN-18-5	0.82	0.64	0.59	0.53	0.64
CSCN-18-6	0.68	0.57	0.48	0.42	0.54
CSCN-18-7	0.78	0.72	0.72	0.67	0.72
CSCN-18-8	0.80	0.63	0.62	0.51	0.64
CSCN-18-9	0.65	0.59	0.52	0.51	0.57
CSCN-18-10	0.77	0.74	0.67	0.54	0.68
CSCN-18-11	0.77	0.76	0.71	0.55	0.70
CSCN-18-12	0.86	0.75	0.70	0.59	0.72
Mean	0.79	0.70	0.62	0.54	
CD (p=0.05)	S = 0.03 ,	V= 0.05	S x V= 0.10		

Table 5.15: Salinity at different soil depths after the mustard harvest

Depth (cm)	EC_e (dS/m)			
	Canal	2.5	5.0	7.5
0-15	1.76	4.20	7.48	10.13
15-30	1.57	3.78	6.73	9.90
Mean	1.67	3.99	7.10	10.02

2019-2020:

Cotton: Increasing salinity led to a gradual decrease in seed cotton yield (Table 5.16). Among the seven genotypes, H 1526 gave the highest (189.39 g/m^2) seed cotton yield and H 1465 resulted in the lowest seed cotton yield (138.39 g/m^2) at EC_{iw} 7.5 dS/m. The mean seed cotton yield reduced by 26.11 % at EC_{iw} 7.5 dS/m as compared to canal irrigation. Overall mean yield (229.72 g/m^2) of H 1526 was significantly higher than other genotypes followed by H 1480 (223.73 g/m^2) and H 1465 was the lowest yielder (166.11 g/m^2).

Table 5.16: Effect of saline waters on seed cotton yield (g/m^2) of cotton genotypes

Genotype	ECiw (dS/m)				Mean
	Canal	2.5	5.0	7.5	
H 1098i	241.46	233.38	208.37	174.25	214.60
H 1353	202.70	194.40	179.66	150.35	181.78
H 1465	184.61	179.95	161.50	138.39	166.11
H 1480	251.72	243.58	214.16	185.45	223.73
H 1518	205.12	197.33	172.50	154.59	182.38
H 1526	259.48	251.13	218.89	189.39	229.72
H 1530	247.63	239.56	216.67	184.31	222.04
Mean	227.53	219.90	195.96	168.11	
CD (p=0.05)	Variety (V) =11.65,	Salinity (S) = 8.81		V x S = NS	

Wheat: The data showed that the grain yield of different genotypes of wheat decreased with an increase in EC_{iw} (Table 5.17).Wheat genotype WH 1283 performed the best at EC_{iw} 7.5 dS/m and gave 16.32% higher grain yield compared with KRL 210 (check). It was followed by WH 1278 which gave 11.90 % higher grain yield than KRL 210 whereas the performance of WH 1272 (309.10 g/m^2) was the least. On the basis of overall mean, WH 1283 gave maximum grain yield (506.54 g/m^2) which was 18.26% higher than KRL 210 followed by WH 1278 (491.79 g/m^2). The overall mean yield reduction at 2.5, 5.0 and 7.5 dS/m was 4.03, 13.92 and 25.09%, respectively, as compared to canal.

Table 5.17: Grain yield (g/m^2) of wheat genotypes as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
WH1271	459.95	447.17	398.30	346.22	412.91
WH 1272	413.80	394.53	354.80	309.10	368.10
WH 1274	448.18	426.57	391.29	330.85	399.22
WH 1276	464.17	449.50	406.86	352.78	418.33
WH 1277	531.34	509.41	458.55	394.74	473.51
WH 1278	553.29	536.55	468.41	408.92	491.79
WH 1279	521.72	500.18	443.22	398.66	465.95
WH 1280	498.50	475.80	420.78	372.98	442.01
WH 1281	502.32	485.61	431.83	362.43	445.55
WH 1283	566.90	545.03	489.14	425.06	506.54
WH 1284	514.10	491.90	451.35	392.88	462.49
Kh 65	424.27	402.22	368.87	320.61	378.99
KRL 210	481.26	458.18	408.38	365.43	428.31
Mean	490.75	470.97	422.45	367.72	
CD (p=0.05)	Variety (V) = 23.32 , Salinity (S)= 12.94, V x S = NS				

Physiological data was recorded for Normalised Difference Vegetation Index (NDVI) at heading and at 15 days after anthesis (Table 5.18 & Table 5.19) indicating greenness in biomass; SPAD Chlorophyll Content of flag leaf (Table 5.20) and Canopy temperature (Table 5.21) at 15 days after anthesis as affected by different saline waters. Percent decrease in NDVI was found maximum in WH1271 (15.2 %) followed by WH1274 (14.5%), WH1276 (12.8%) and it was minimum in WH1283 (5.4%) followed by WH1280 (5.6%). Range of NDVI was from 0.680 to 0.790 at 7.5 dS/m salinity level. Mean NDVI value at 15 days after anthesis was found maximum in WH1283 (0.764) followed by WH1278 (0.748), WH1277 (0.736) and WH1284 (0.733). Range of NDVI was found between 0.635 to 0.740 at EC_{iw} 7.5 dS/m. The % decrease in SPAD value was found maximum in WH1271 (11.4 %) followed by Kh 65 (10.6 %) and it was minimum in WH1281 (3.9%) followed by WH1279 (5.4 %). Range of SPAD value was found between 47.3 to 51.4 at EC_{iw} 7.5 dS/m. Canopy temperature was found minimum in WH1278 (24.9^{0}C) followed by WH1283 (24.9^{0}C) and WH1279 (25.2^{0}C) and WH1284 (25.5^{0}C).Range of canopy temperature was found between 23.5^{0}C to 25.2 ^{0}C at EC_{iw} 7.5 dS/m. Correlation of physiological parameters with grain yield was computed and it was found that NDVI at heading (0.70), NDVI at 15 days after anthesis (0.63), SPAD Chlorophyll content at 15 days after anthesis (0.65), has positive correlation but negative correlation was observed with Canopy Temperature (-0.67).

Table 5.18: Normalised Difference Vegetation Index (NDVI) of wheat genotypes at heading as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal(0.3)	**2.5**	**5.0**	**7.5**	
WH1271	0.820	0.800	0.770	0.695	0.771
WH 1272	0.780	0.760	0.730	0.690	0.740
WH 1274	0.795	0.780	0.765	0.680	0.769
WH 1276	0.820	0.770	0.770	0.715	0.769
WH 1277	0.825	0.825	0.810	0.755	0.804
WH 1278	0.820	0.805	0.790	0.765	0.795
WH 1279	0.810	0.800	0.795	0.755	0.790
WH 1280	0.810	0.805	0.805	0.765	0.796
WH 1281	0.810	0.805	0.790	0.725	0.783
WH 1283	0.835	0.830	0.805	0.790	0.815
WH 1284	0.785	0.780	0.775	0.735	0.755
Kh 65	0.830	0.785	0.785	0.735	0.784
KRL 210	0.815	0.790	0.775	0.755	0.784
Mean	0.812	0.793	0.785	0.735	

Table 5.19: Normalied Difference Vegetation Index (NDVI) of wheat genotypes at 15 days after anthesis as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal(0.3)	**2.5**	**5.0**	**7.5**	
WH1271	0.750	0.725	0.715	0.685	0.719
WH 1272	0.760	0.700	0.690	0.635	0.696
WH 1274	0.725	0.725	0.715	0.660	0.706
WH 1276	0.725	0.730	0.725	0.685	0.716
WH 1277	0.765	0.740	0.725	0.715	0.736
WH 1278	0.770	0.760	0.745	0.715	0.748
WH 1279	0.750	0.745	0.735	0.700	0.736
WH 1280	0.745	0.735	0.715	0.705	0.725
WH 1281	0.745	0.705	0.715	0.710	0.726
WH 1283	0.785	0.770	0.760	0.740	0.764
WH 1284	0.780	0.765	0.700	0.685	0.733
Kh 65	0.730	0.710	0.710	0.660	0.703
KRL 210	0.760	0.750	0.690	0.690	0.723
Mean	0.753	0.735	0.718	0.691	

Table 5.20: SPAD Chlorophyll Content of wheat genotypes at anthesis as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal(0.3)	2.5	5.0	7.5	
WH1271	53.5	50.5	50.5	47.4	50.5
WH 1272	50.6	48.7	48.4	47.3	48.7
WH 1274	52.6	50.7	49.5	47.9	50.2
WH 1276	52.1	50.5	50.9	48.9	50.6
WH 1277	53.3	52.8	52.7	49.1	52.0
WH 1278	54.1	53.0	51.8	50.7	52.4
WH 1279	53.7	51.6	51.5	50.8	51.9
WH 1280	52.5	51.3	51.0	48.9	50.9
WH 1281	51.0	53.4	50.4	49.0	51.0
WH 1283	55.3	53.4	53.2	51.4	53.3
WH 1284	52.8	51.7	50.2	47.9	50.7
Kh 65	53.8	50.0	48.4	48.1	50.1
KRL 210	53.8	51.1	49.3	48.5	50.7
Mean	53.0	51.4	50.6	48.9	

Table 5.21: Canopy temperature (^{0}C) of wheat genotypes at 15 days after anthesis as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal(0.3)	2.5	5.0	7.5	
WH1271	26.2	26.1	25.9	24.8	25.7
WH 1272	26.8	26.5	26.2	24.7	26.0
WH 1274	26.5	26.4	25.3	25.2	25.8
WH 1276	26.5	26.0	25.2	24.2	25.4
WH 1277	26.2	26.1	24.4	24.3	25.2
WH 1278	26.0	24.8	24.6	24.3	24.9
WH 1279	26.3	25.9	24.5	24.3	25.2
WH 1280	26.8	25.5	25.2	24.0	25.4
WH 1281	26.0	25.3	25.2	25.1	25.4
WH 1283	25.9	25.5	24.5	23.5	24.9
WH 1284	26.3	25.5	25.3	24.4	25.3
Kh 65	26.5	26.5	26.1	24.9	26.0
KRL 210	26.1	26.1	25.5	24.1	25.4
Mean	26.3	25.9	25.2	24.4	

Pearl millet: The data showed that the grain yield of different genotypes of pearl millet decreased with an increase in EC of the irrigation water (Table 5.22). Among the pearl millet hybrids, HHB 272(216.60 g/m^2) performed best at EC_{iw} 7.5 dS/m followed by HHB 299 (202.17 g/m^2) whereas the performance of HMS 48A X SGP-10-107 (180.63 g/m^2) was the poorest. The mean grain yield (257.07 g/m^2) of HHB 272 was higher than other genotypes followed by HHB 299 (247.08 g/m^2) and HHB 311 (234.93 g/m^2). Whereas the parent of pearl millet hybrids

HMS48A XSGP-10-107 mean grain yield was 218.43 g/m^2 and hybrid 94555 X ISK-51 mean grain yield was 221.96 g/m^2. The overall mean reduction in pearl millet yield at 2.5, 5.0 and 7.5 dS/m was 4.09, 16.00 and 26.38%, respectively as compared to canal.

Table 5.22: Grain yield (g/m^2) of pearl millet genotypes as affected by different saline waters

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
HHB 272	289.37	278.13	241.33	216.60	257.07
HHB 299	279.2	268.93	237.02	202.17	247.08
HHB 301	243.58	232.93	204.43	182.93	216.39
HHB 311	267.17	256.13	221.09	193.87	234.93
HMS 48A X SGP-10-107	246.06	235.17	209.5	180.63	218.43
94555 X ISK-51	251.09	240.6	210.77	184.37	221.96
Mean	262.74	251.98	220.69	193.41	
CD (p=0.05)	Variety (V) =14.04, Salinity (S) =11.46, V x S =NS				

Mustard: The data showed that the seed yield of different genotypes of mustard decreased with an increase in EC of the irrigation water (Table 5.23). In IVT, the mustard genotype CSCN-19-6 gave the highest seed yield (203.92 g/m^2) followed by CSCN-19-8 (197.20 g/m^2) at ECiw 7.5 dS/m and the lowest seed yield (152.81/m^2) was obtained in CSCN-19-2. All the genotypes under IVT showed decreasing trend with the increasing levels of salinity (canal to 7.5 dS /m). Relative water content (RWC %) of mustard genotypes under initial variety trial (IVT) decreased from 85.29 to 75.04 with increasing salinity levels i.e. control to 7.5 dS m^{-1}. Maximum RWC was observed in CSCN-19-8 (81.47) which was at par with CSCN-19-6 (80.40) and minimum in CSCN-19-3 (67.89) at 7.5 dSm^{-1} of salinity (Table 5.24). Total chlorophyll content (mg g^{-1} FW) also showed declining trend from 1.97 to 1.60 (Table 5.25). Salinity susceptibility index (SSI) is used to test the sensitivity of genotypes to salinity stress. The value less <1 was recorded at 7.5 dSm^{-1} of salinity in CSCN-19-4 (0.92), CSCN-19-5 (0.88), CSCN-19-6 (0.93), CSCN-19-7 (0.91), CSCN-19-8 (0.82), in the tested mustard genotypes Fig. 5.1. The mean salinity in the soil profile at the time of mustard harvest varied from 1.86 dS/m in canal water irrigated plot to 10.12 dS/m in plots receiving saline water irrigation of ECiw 7.5 dS/m (Table 5.26).

Table 5.23: Seed yield (g/m^2) of mustard genotypes under AVT as affected by waters of different salinities

Genotype	EC_{iw} (dS/m)				Mean
	Canal	2.5	5.0	7.5	
CSCN-19-1	259.60	248.55	208.94	177.25	223.58
CSCN-19-2	230.48	217.83	189.90	152.81	197.75
CSCN-19-3	236.62	229.43	196.83	159.07	205.49
CSCN-19-4	241.86	232.10	203.51	178.97	214.11
CSCN-19-5	219.23	209.29	187.96	164.68	195.29
CSCN-19-6	288.10	278.09	246.79	203.92	254.23
CSCN-19-7	260.00	252.44	226.73	192.57	232.93
CSCN-19-8	269.62	256.60	219.55	197.20	235.74
Mean	250.69	240.54	210.03	178.31	
CD (p=0.05)	Salinity (S) = 11.11, Variety (V) = 15.71, SxV= NS				

Table 5.24: Relative water content (RWC %) of mustard genotypes under IVT as affected by waters of different salinities

Genotype	EC_{iw} (dS/m)				Mean
	Canal (0.3)	2.5	5.0	7.5	
CSCN-19-1	87.23	84.27	82.09	77.65	82.81
CSCN-19-2	88.58	88.78	78.55	78.02	83.48
CSCN-19-3	80.83	77.75	73.42	67.89	74.97
CSCN-19-4	76.93	75.39	75.04	70.40	74.44
CSCN-19-5	89.29	83.61	71.27	70.52	78.67
CSCN-19-6	82.78	82.28	75.84	80.40	80.33
CSCN-19-7	87.62	79.37	76.24	73.95	79.29
CSCN-19-8	89.05	84.94	82.96	81.47	84.61
Mean	85.29	82.05	76.93	75.04	
CD (p=0.05)	Salinity (S) = 1.89, Variety (V) = 2.67, SxV= 5.35				

Table 5.25: Total chlorophyll content (mg/g FW) of mustard genotypes under IVT as affected by waters of different salinities

Genotype	EC_{iw} (dS/m)				Mean
	Canal (0.3)	2.5	5.0	7.5	
CSCN-19-1	1.92	1.90	1.88	1.83	1.88
CSCN-19-2	1.91	1.86	1.85	1.73	1.84
CSCN-19-3	1.79	1.78	1.63	1.54	1.69
CSCN-19-4	1.87	1.82	1.81	1.51	1.75
CSCN-19-5	2.01	1.82	1.81	1.76	1.85
CSCN-19-6	2.32	1.90	1.82	1.72	1.94
CSCN-19-7	2.10	2.08	1.68	1.31	1.80
CSCN-19-8	1.86	1.62	1.50	1.40	1.60
Mean	1.97	1.85	1.75	1.60	
CD (p=0.05)	Salinity (S) = 0.08, Variety (V) = 0.11, SxV= 0.22				

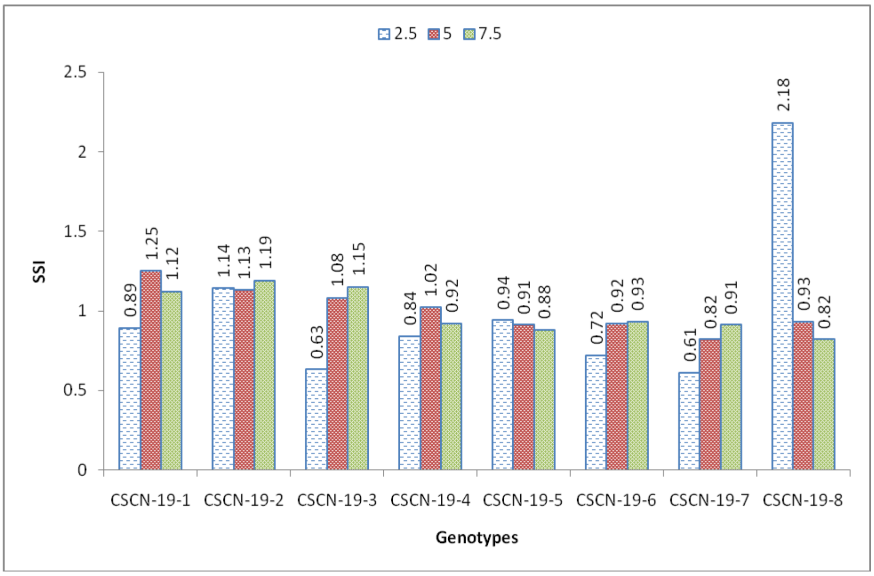


Fig 5.1: Salinity Susceptibility Index (SSI) of mustard genotypes under IVT as affected by waters of different salinities

Table 5.26: Salinity at different soil depths after the mustard harvest

Depth (cm)	**EC_e (dS/m)**			
	Canal	**2.5**	**5.0**	**7.5**
0-15	1.96	4.40	7.68	10.23
15-30	1.77	3.98	6.93	10.02
Mean	1.86	4.19	7.31	10.12

- **Screening of rice, wheat and mustard varieties/genotypes in sodic soil (Kanpur)**

2018-19:

This experiment was planned for screening of rice, wheat and mustard varieties under sodic condition. List of varieties of these crops are provided in Table 5.27.

Table 5.27. Varieties of rice, wheat and mustard used for screening

Rice	Wheat	Mustard	Other Expt. Details	
CSR-23	KRL-210	CS-52	No of replication:	Three in each crop
CSR-27	KRL-213	CS-54	Design:	RBD
CSR-30	PBW-343	CS-56	Plot size:	20 m2
CSR-36	PBW-502	Varuna	Year of start	2015
CSR-43	WH-147	Pitamvari	Location:	Crop Research Farm, Dalipnagar, Kanpur
Pant-12	K-307	Rohini	Initial soil status:	
NDR-359	K-8434	Urvashi	pH	9.30
Kranti	DBW-17	Kanti	EC (dSm^{-1})	0.89
			ESP	45.3
			O.C. (%)	0.23

The average grain yield of rice varied from 22.63-44.29 q/ha. The maximum yield 44.29 q/ha of rice was recorded from variety CSR-36 followed by 41.65 q/ha from CSR-23 and 39.03 q/ha from CSR-43 (Table 5.28). The minimum yield 22.63 q/ha was obtained from CSR-30. The average straw yield of rice varied from 27.98-53.59 q/ha. The maximum yield 53.59 q/ha of rice was recorded from variety CSR-36 followed by 51.43 q/ha from CSR-23 and 48.03 q/ha from CSR-43. The minimum yield 27.98 q/ha was obtained from CSR-30.

Table 5.28 Grain and straw yield of rice (q/ha) in sodic soil conditions

Varieties	Grain yield of rice (q/ha)					Straw yield of rice (q/ha)				
	2015	2016	2017	2018	Mean	2015	2016	2017	2018	Mean
CSR 23	39.82	41.57	42.07	43.12	41.65	48.77	51.12	52.59	53.25	51.43
CSR 27	37.65	38.24	39.35	40.21	38.86	45.68	46.65	49.18	49.68	46.56
CSR 30	21.27	22.52	23.12	23.62	22.63	26.22	27.46	28.90	29.32	27.98
CSR 43	36.38	38.85	40.25	40.65	39.03	42.38	44.89	49.31	50.62	48.03
CSR 36	43.52	42.64	44.15	44.85	44.29	52.57	52.02	54.20	55.58	53.59
Pant 12	28.69	27.83	29.30	30.12	28.98	34.86	35.53	36.63	37.85	36.22
NDR 359	35.12	36.33	38.41	39.17	37.26	42.92	44.11	47.15	46.72	45.23
Kranti	33.41	32.54	34.01	35.20	33.79	39.43	40.22	42.51	43.28	41.36
CD (0.05)	2.56	2.62	2.59	2.64	--	2.65	2.49	2.56	2.62	--

The average grain yield of wheat varied from 27.94-36.70 q/ha in different varieties. The maximum yield 36.70 q/ha of wheat was recorded from variety KRL-210 followed by 35.23 q/ha from KRL-213 and 33.98 q/ha from PBW-343 (Table 5.23). The minimum yield 27.94 q/ha was obtained from WH-147. The average straw yield of wheat varied from 33.66-45.03 q/ha in different varieties. The maximum yield 45.03 q/ha of wheat was recorded from variety KRL-210 followed by 43.20 q/ha from KRL-213 and 41.39 q/ha from PBW-343 (Table 5.29). The minimum yield 33.66 q/ha was obtained from WH-147.

Table 5.29 Grain and straw yield of wheat (q/ha) in sodic soil conditions

Varieties	Grain yield of wheat (q/ha)					Straw yield of wheat (q/ha)				
	2015-16	2016-17	2017-18	2018-19	Mean	2015-16	2016-17	2017-18	2018-19	Mean
KRL 210	34.55	36.22	37.87	38.15	36.70	42.15	44.53	46.20	47.22	45.03
KRL 213	33.84	34.87	35.77	36.42	35.23	40.94	42.12	43.63	44.12	43.20
PBW 343	32.42	33.15	34.68	35.65	33.98	39.87	40.53	42.30	42.85	41.39
PBW 502	31.27	30.20	32.22	33.20	31.75	36.89	35.86	39.30	38.00	37.01
WH 147	26.10	27.68	28.34	29.65	27.94	31.84	32.78	34.57	35.43	33.66
K 307	28.77	29.12	31.25	30.45	29.90	34.25	35.65	38.13	38.95	36.75
K 8434	29.52	28.76	30.15	32.25	30.17	36.72	36.62	36.78	37.65	36.94
DBW 17	27.33	28.44	29.84	30.65	29.07	32.54	33.74	36.40	37.78	35.12
CD (0.05)	1.67	1.72	1.69	1.76	--	1.69	1.78	1.82	1.97	--

The average grain yield of mustard varied from 10.88-16.77 q/ha in different varieties. The maximum yield 16.77 q/ha of mustard was recorded from variety CS-56 followed by 14.77 q/ha from CS-54 and 13.56 q/ha from CS-52 whereas Variety Varuna, Rohini and Kranti were at par in case of grain yield (Table 5.30). The minimum yield 10.88 q/ha was obtained from Urvasi. The average stalk yield of mustard varied from 27.23-42.14 q/ha in different varieties. The maximum yield 42.14 q/ha of mustard was recorded from variety CS-56 followed by 38.59 q/ha from CS-54 and 35.20 q/ha from CS-52 whereas Variety Varuna, Rohini and Kranti were at par in case of stalk yield (Table 6). The minimum yield 27.23 q/ha was obtained from Urvasi.

Table 5.30 Seed and stalk yield of mustard (q/ha) in sodic soil conditions

Varieties	Seed yield (q/ha)					Stalk yield (q/ha)				
	2015-16	2016-17	2017-18	2018-19	Mean	2015-16	2016-17	2017-18	2018-19	Mean
CS-52	13.25	13.34	14.10	14.55	13.81	32.92	34.10	36.27	37.52	35.20
CS-54	14.78	14.42	15.12	15.85	15.04	37.82	37.00	39.42	40.12	38.59
CS-56	16.12	16.25	17.05	17.65	16.77	40.27	41.24	43.54	43.85	42.14
Varuna	12.97	12.25	13.22	13.48	12.98	34.25	33.72	34.37	35.25	34.40
Pitambri	11.55	11.22	12.11	12.56	11.86	29.45	28.04	31.48	31.68	29.91
Rohini	12.32	11.67	12.40	12.75	12.28	33.74	34.52	32.24	33.26	33.44
Urvasi	10.63	10.29	11.15	11.46	10.88	26.73	25.88	28.55	28.76	27.23
Kranti	12.14	12.10	13.17	13.55	12.74	30.35	29.48	33.45	32.78	31.51
CD (0.05)	1.12	1.25	1.37	1.42	--	1.42	1.55	1.47	1.64	--

- **Evaluation of different crops for their tolerance to sodicity level (Tiruchirapalli)**

Investigations made to evaluate the sodicity tolerance limits for different crops and varieties under this project. So far crops and varieties viz. rice (TRY 1, CO42, TRY(R)2, ADT 39, ADT 45, White Ponni), black gram (T9 and ADT 5), green gram (Pusa Bold), okra (Parbani Kranti), vegetable cowpea (VBN 37), cluster bean (Pusa Nowbahaar), sunflower (CO 4, TCSH 1), sesame (CO 1), pearl millet (CO7, COHCu8, UCC17, ICMY221, PT1890), Maize, cotton (RCH 20, Surabhi, SVPR-2), chilly and onion have been screened for sodicity tolerance and their tolerance limits have been established under this scheme. A field experiment was conducted to assess the effect of different Exchangeable Sodium Percentage (ESP) levels of soil on growth and yield of sorghum varieties at experimental plot (Field No. A6b) of ADAC&RI farm with six ESP gradients. In existing experimental field, the sodium bicarbonate was applied to main plots and mixed thoroughly with the soil to create different gradient ESP levels viz., 8, 16, 24, 32, 40 and 48 artificially. Further, the ESP 8 and 16 were created through application of gypsum and leaching with good quality water. The experimental plot was thoroughly ploughed individually to bring optimum soil tilt and the ridges and furrows were formed and seeds of sorghum varieties viz. K12, Co30, Local –Red and Local – Irungu (Black) were sown on 08.02.2019 with a spacing of 45x15 cm. 90:45:45 kg N,P, K were applied (50% of N at basal and remaining 50% at 30 DAS). The Atrazine herbicide has also been applied on 12.02.2019 in order to control the weeds.

2019

Growth and Yield attributes

Plant height: The results revealed that the maximum mean plant height of 164.7 cm was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 143.4, 131.1, 103.9, 84.4 and 65.7 cm respectively at 64th DAS (Table 5.31). Among the different varieties evaluated the Irungu local recorded the highest plant height followed by K12, Co 30 and Red local. Similarly, at harvest also the same trend was observed.

Table 5.31: Effect of graded levels of Exchangeable Sodium Percent (ESP) on plant height at 64th DAS (cm) of sorghum cultivars

ESP level/varieties	S1 – K12	S2 – Co 30	S3 – Red local	S4 – Irungu local	Mean
M1 – 8	166.9	163.6	125.9	202.4	164.7
M2 – 16	152.9	137.2	111.3	172.1	143.4
M3 – 24	145.3	127.8	98.0	153.5	131.1
M4 – 32	129.6	75.6	83.9	126.3	103.9
M5 – 40	96.1	59.3	75.0	107.2	84.4
M6 – 48	71.3	53.4	61.9	76.1	65.7
Mean	127.0	102.8	92.7	139.6	115.5
	SED		CD(0.05)		
M	6.3		14.0		
S	6.2		12.7		
M at S	14.7		30.3		
S at M	15.3		31.0		

Grain Yield: The results revealed that the maximum mean grain yield of 885.8 kg per ha was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 728.4, 566.8, 460.7, 133 and 75.6 kg per ha respectively (Table 6). Among the different varieties evaluated the Co 30 recorded the highest mean grain yield of 793.8 kg per ha followed by K12, Red local and Irungu local by recording 510.4, 365.4 and 230.5 kg per ha respectively. Among the interaction of ESP and Cultivars, the highest grain yield of 1433.7 kg per ha was recorded by Co 30 at 8 ESP level. The lowest grain yield of 26.3 kg per ha recorded by Irungu local at 48 ESP level. However, 50 per cent grain yield was recorded in the cultivars viz., Co 30, Red local and Irungu local at the ESP of 32 per cent whereas in the cultivar K12 recorded 50 per cent yield at 24 ESP level which is clearly indicated that the cultivars Co 30, Red local and Irungu local could be grown in the sodic soil having the ESP up to 32 per cent wheras the cultivar K12 can be recommended to the sodic soil having the ESP level up to 24 per cent (Table 5.32). The effect of soil ESP on ear head of sorghum varieties is shown in Plate 5.1.

Table 5.32: Effect of graded levels of Exchangeable Sodium Percent (ESP) on Grain yield (kg/ha) of sorghum cultivars

ESP level/varieties	S1 – K12	S2 – Co 30	S3 – Red local	S4 – Irungu local	Mean
M_{1-8}	1024.7	1433.7	625.3	459.3	885.8
M_{2-16}	827.0	1162.0	593.0	331.7	728.4
M_{3-24}	660.3	944.7	419.3	242.7	566.8
M_{4-32}	392.3	855.3	360.0	235.3	460.7
M_{5-40}	102.7	201.0	140.7	87.7	133.0
M_{6-48}	55.7	166.3	54.0	26.3	75.6
Mean	510.4	793.8	365.4	230.5	

	SED	CD(0.05)
M	11.72	26.11
S	11.72	23.77
M at S	27.49	56.75
S at M	28.71	58.23

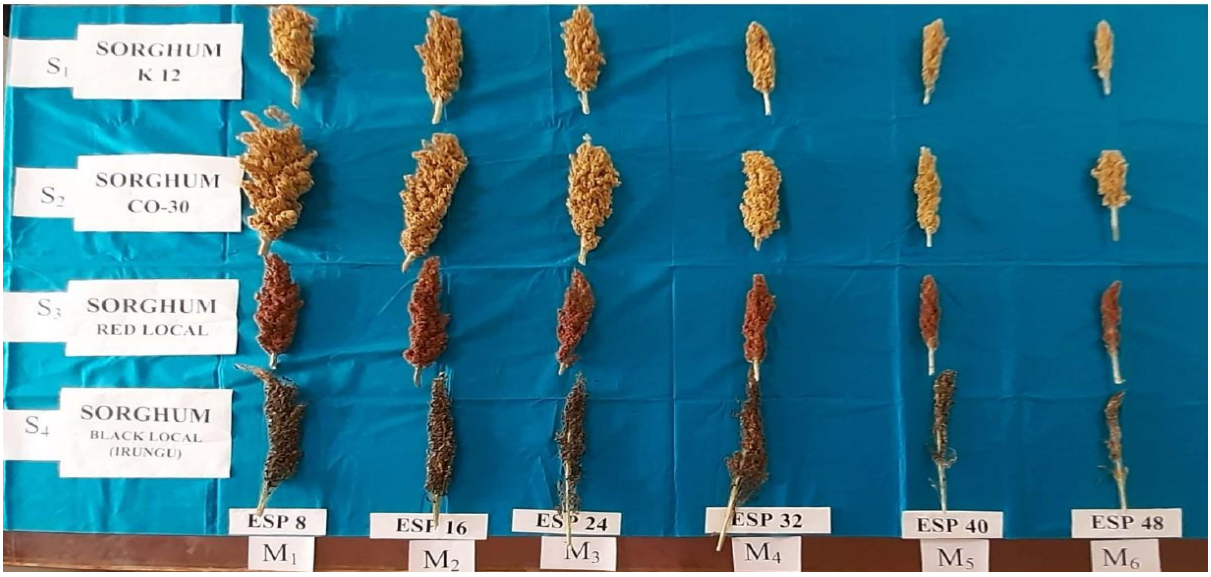


Plate 5.1: Ear head of sorghum varieties under different ESP levels

Haulm Yield: The results revealed that the maximum mean haulm yield of 1331.6 kg per ha was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 1216.1, 1146.9, 951.5, 705.5 and 539.7 kg per ha respectively (Table 7). Among the different varieties evaluated the Irungu local recorded the highest mean haulm yield of 1381 kg per ha followed by K12, Red local and Co30 by recording 1066.9, 741.6 and 738 kg per ha respectively. Among the interaction of ESP and Cultivars, the highest haulm yield of 1749.7 kg per ha was recorded by Irungu local at 8 ESP level. The lowest haulm yield of 435 kg per ha recorded by Red local at 48 ESP level. However, 50 per cent haulm yield was recorded in the cultivars viz., Red local and K12 at the ESP of 32 per cent whereas, Co 30 and Irungu local recorded 50 per cent yield at 48 and 40 ESP level respectively. The haulm yield results clearly indicated that the cultivars Co 30, though it recorded the lowest haulm yield, it tolerance to 48 ESP while obtaining 50 per cent of maximum possible haulm yield. Although, the Irungu local recorded the lowest grain yield, it recorded the highest haulm yield among the cultivar which could suitably recommended for cultivation as fodder crop in the sodic soil up to 40 per cent ESP level (Table 5.33).

Table 5.33: Effect of graded levels of Exchangeable Sodium Percent (ESP) on Halum yield (kg/ha) of sorghum cultivars

ESP level/varieties	S1 – K12	S2 – Co 30	S3 – Red local	S4 – Irungu local	Mean
M1 – 8	1540.3	915.7	1120.7	1749.7	1331.6
M2 – 16	1392.7	856.3	961.0	1654.3	1216.1
M3 – 24	1344.7	816.7	818.7	1607.7	1146.9
M4 – 32	1002.0	791.7	635.0	1377.3	951.5
M5 – 40	733.0	568.3	489.3	1031.3	705.5
M6 – 48	388.7	479.3	425.0	865.7	539.7
Mean	1066.9	738.0	741.6	1381.0	

	SED	CD(0.05)
M	28.65	63.85
S	15.54	31.51
M at S	43.67	92.34
S at M	38.06	77.19

2020

A field experiment for confirmation on the effect of different Exchangeable Sodium Percentage (ESP) levels of soil on growth and yield of sorghum varieties was conducted during 2020 to assess and fix optimum sodicity tolerance limits of sorghum varieties based on the performance under different soil sodicity levels. In existing experimental field, based on the ESP existed in the different main plots, the sodium bicarbonate was applied to main plots and mixed thoroughly with the soil to create different gradient ESP levels *viz.*, 8, 16, 24, 32, 40 and 48 were artificially. Further, the ESP 8 and 16 were created through application of gypsum and leaching with good quality water. The experimental plot was thoroughly ploughed individually to bring optimum soil tilth and the ridges and furrows were formed and seeds of sorghum varieties *viz.* K12, Co30, Local –Red and Local – Irungu (Black) were sown on 17.07.2020 with a spacing of 45x15 cm. 90:45:45 kg N,P, K were applied (50% of N at basal and remaining 50% at 30 DAS). The Atrazine herbicide has also been applied on 19.07.2020 in order to control the weeds.

Growth and Yield attributes

The results revealed that the maximum mean plant height of 202.7 cm was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 198.2, 189.6, 152.8, 119.6 and 103.0 cm, respectively at harvest. Among the different varieties evaluated the Irungu local recorded the highest plant height followed by Co 30, K12 and Red local (Table 5.34).

Table 5.34. Effect of graded levels of Exchangeable Sodium Percent (ESP) on plant height (cm) at harvest of sorghum cultivars (2020)

ESP level/varieties	S1 – K12	S2 – Co 30	S3 – Red local	S4 – Irungu local	Mean
M1 – 8	190.9	194.6	136.9	288.3	202.7
M2 – 16	188.6	193.9	132.2	278.2	198.2
M3 – 24	171.9	183.6	129.3	273.6	189.6
M4 – 32	135.9	148.7	95.6	231.0	152.8
M5 – 40	121.1	123.3	88.1	145.9	119.6
M6 - 48	108.5	83.5	79.2	140.7	103.0
Mean	152.8	154.6	110.2	226.3	-

	SED	CD(0.05)
M	1.19	2.66
S	0.85	1.73
M at S	2.17	4.53
S at M	2.09	4.24

Grain Yield

The results revealed that the maximum mean grain yield of 818 kg per ha was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 696, 519, 414, 101 and 63 kg per ha respectively (Table 5.35).

Table 5.35. Effect of graded levels of Exchangeable Sodium Percent (ESP) on Grain yield (kg/ha) of sorghum cultivars (2020)

ESP level/varieties	S1 – K12	S2 – Co 30	S3 – Red local	S4 – Irungu local	Mean
M1 – 8	925	1340	582	425	818
M2 – 16	795	1092	568	330	696
M3 – 24	616	891	330	238	519
M4 – 32	320	791	317	228	414
M5 – 40	70	155	105	72	101
M6 - 48	46	138	45	22	63
Mean	462	735	324	219	-

	SED	CD(0.05)
M	8.8	19.6
S	10.8	21.9
M at S	24.5	50.4
S at M	26.4	53.6

Among the different varieties evaluated the Co 30 recorded the highest mean grain yield of 735 kg per ha followed by K12, Red local and Irungu local by recording 462, 324 and 219 kg per ha respectively. Among the interaction of ESP and Cultivars, the highest grain yield of 1340 kg per ha was recorded by Co 30 at 8 ESP level. The lowest grain yield of 22 kg per ha recorded by Irungu local at 48 ESP level. However, 50 per cent grain yield was recorded in the cultivars *viz.*, Co 30, Red local and Irungu local at the ESP of 32 per cent whereas in the cultivar K12 recorded 50 per cent yield at 24 ESP level which is clearly indicated that the cultivars Co 30, Red local and Irungu local could be grown in the sodic soil having the ESP up to 32 per cent whereas the cultivar K12 can be recommended to the sodic soil having the ESP level up to 24 per cent (Table 5.35).

Haulm Yield

The results revealed that the maximum mean haulm yield of 1244 kg per ha was recorded in the ESP of 8 followed by 16, 24, 32, 40 and 48 by recording 1137, 1068, 870, 623 and 462 kg per ha respectively (Table 5.36, Plate 5.2). Among the different varieties evaluated the Irungu local recorded the highest mean haulm yield of 1293 kg per ha followed by K12, Red local and Co 30 by recording 977, 667 and 666 kg per ha respectively. However, the Red Local and Co 30 recoded significantly on par with each other with respect to haulm yield. Among the interaction of ESP and Cultivars, the highest haulm yield of 1640 kg per ha was recorded by Irungu local at 8 ESP level. The lowest haulm yield of 300 kg per ha recorded by K12 which was on par with Red local at 48 ESP level. However, 50 per cent haulm yield was recorded in the cultivars *viz.*, Red local and K12 at the ESP of 32 per cent whereas, Co 30 and Irungu local recorded 50 per cent yield at 40 ESP level. The haulm yield results clearly indicated that the cultivars Co 30, though it recorded the lowest haulm yield, it tolerance to 40 ESP while obtaining 50 per cent of maximum possible haulm yield. Although, the Irungu local recorded the lowest grain yield, it recorded the highest haulm yield among the cultivar which could suitably recommended for cultivation as fodder crop in the sodic soil up to 40 per cent ESP level which was on par with 48 ESP.

Table 5.36. Effect of graded levels of Exchangeable Sodium Percent (ESP) on Halum yield (kg/ha) of sorghum cultivars (2020)

ESP level/varieties	S1 – K12	S2 – Co 30	S3 – Red local	S4 – Irungu local	Mean
M1 – 8	1457	854	1025	1640	1244
M2 – 16	1290	785	894	1580	1137
M3 – 24	1257	754	758	1503	1068
M4 – 32	917	723	572	1270	870
M5 – 40	643	482	415	952	623
M6 - 48	300	397	340	810	462
Mean	977	666	667	1293	-

	SED	CD(0.05)
M	22.6	50.3
S	15.6	31.6
M at S	40.1	83.8
S at M	38.2	77.5

Plate 5.2 Field view of sorghum varieties under different ESP levels

- **Screening of salinity tolerance Clusterbean (*Cyamopsis tetragonoloba* L.) germplasm (Bathinda)**

2018-19:

Screening of cultivars of clusterbean (*Cyamopsis tetragonoloba* L.) was undertaken to find out suitable cultivar for saline water irrigation (3rd year *Kharif* 2018). Details of initial soil properties are given in Table 5.37 and composition of irrigation water is given in Table 5.38.

Observations recorded: Plant height (cm), Number of primary branches/plant, Number of secondary branches/plant, Number of cluster/plant, Number of pods /cluster, Number of pods /plant, Pod length (cm), Number of grains/ pods, Grain yield/plant and Seed index.

Table 5.37 Initial physico-chemical characteristics of soil (0-15 cm)

Parameter	Canal Water irrigated field	Tube well Water irrigated field
Soil Texture	Loamy sand	
Sand (%)	80.1	
Silt (%)	12.2	
Clay (%)	7.7	
pH $_{(1:2)}$	8.75	8.82
EC $_{1:2}$ (dSm^{-1})	0.20	0.58
$CaCO_3$ (%)	4.15	4.15
OC (%)	0.20	0.20
Available P (kg ha^{-1})	8.95	8.86
Available K (kg ha^{-1})	238	244

Table 5.38 Composition of canal and tubewell water

Particulars	Value	
	Canal water	Tubewell water
EC (dSm^{-1})	0.35	4.36
Na^+ (meq/l)	1.36	34.10
Ca^{+2}+ Mg^{+2} (meq/l)	1.88	6.95
Cl^{-1} (meq/l)	0.80	11.2
CO_3^{-2} (meq/l)	Nil	Nil
HCO_3^- (meq/l)	1.80	6.34
RSC (meq/l)	Nil	Nil
SAR	1.40	18.29

Other details are: Date of sowing: 22.06.2018; Number of cultivars: 20; Design: Split plot; 5 rows of each germ plasm (2.5 meter) in 2 replications; Date of harvesting: 24.11.2018

The data on effect of poor quality water on plant height, number of primary branches and number of secondary branches of cluster bean was presented in Table 5.39. The results revealed that quality of water significantly influences the plant height. Among the tested germplasm IC 40998 retained higher plant height followed by IC 40741> IC 40752> IC 113578>IC 40256> IC 40249> IC 40266>IC 39980. However, water quality does not significantly affect the number of primary and secondary branches.

Table 5.39 Effect of poor quality water on plant height, number of primary branches and number of secondary branches of clusterbean (*Cyamopsis tetragonoloba* L.) Germplasm

S.No	Cultivars	Plant height (cm)			Number of primary branches/plant			Number of secondary branches/plant		
		CW	TW	Mean	CW	TW	Mean	CW	TW	Mean
1	IC 39418	111.88	77.47	94.68	5.66	4.20	4.93	20.15	12.55	16.35
2	IC 39980	109.48	87.57	98.52	4.57	4.34	4.46	17.00	13.56	15.28
3	IC40004	96.24	77.47	86.86	5.04	4.68	4.86	17.75	9.84	13.80
4	IC40230	83.30	75.44	79.37	5.19	3.73	4.46	25.47	14.58	20.03
5	IC40235	111.86	91.28	101.57	5.39	3.93	4.66	30.04	26.86	28.45
6	IC40249	82.28	68.69	75.48	5.39	3.59	4.49	16.73	15.94	16.34
7	IC40256	132.94	98.79	115.86	5.32	4.27	4.79	12.98	8.82	10.90
8	IC40417	94.18	70.37	82.27	4.63	4.07	4.35	26.36	20.01	23.18
9	IC40458	91.46	83.91	87.69	5.04	3.99	4.52	15.70	14.93	15.31
10	IC40741	121.32	111.32	116.32	4.71	4.40	4.55	19.39	15.94	17.67
11	IC40752	116.96	108.94	112.95	5.12	4.27	4.69	23.90	17.98	20.94
12	IC40162	107.44	62.25	84.84	4.43	4.24	4.33	24.92	22.56	23.74
13	IC40266	118.66	91.02	104.84	4.27	4.07	4.17	24.25	21.03	22.64
14	IC40682	105.74	81.38	93.56	4.78	4.07	4.42	16.73	14.93	15.83
15	IC40763	105.32	83.56	94.44	5.12	4.75	4.93	22.20	18.65	20.42
16	IC40998	152.32	122.48	137.40	4.43	3.89	4.16	16.73	13.91	15.32
17	IC41189	90.10	78.49	84.29	5.00	4.24	4.62	24.92	17.98	21.45
18	IC41202	101.66	81.88	91.77	3.92	3.56	3.74	19.80	27.81	23.80
19	IC113578	130.70	103.53	117.11	4.94	4.57	4.76	25.27	16.96	21.12
20	IC329038	87.38	71.73	79.56	6.03	5.26	5.64	24.25	17.98	21.11
Mean		107.56	86.38		4.95	4.21		21.23	17.14	
CD (5%) water quality		3.51			0.41			1.12		
Germplasm		4.21			NS			2.75		
Interaction		5.95			NS			3.86		

Data presented in Table 5.40 showed that poor quality water significantly affect the number of cluster/plant and number of pods/plant, where as no significantly effect was reported on number of pods/cluster. The maximum cluster/plant was recorded in germplasm IC 41235 followed by IC 41202>IC 40417>IC 113578>IC40741 under poor quality water. Whereas, maximum number of pods/ plant was observed in germplasm IC 40235 followed by IC40417>IC 41202 and IC 40763.

Table 5.40 Effect of poor quality water on number of cluster and number of pods in different clusterbean (*Cyamopsis tetragonoloba* L.) germplasm

S.No	Cultivars	Number of cluster/plant			Number of pods /cluster			Number of pods /plant		
		CW	TW	Mean	CW	TW	Mean	CW	TW	Mean
1	IC 39418	16.05	9.50	12.78	4.77	4.41	4.59	76.59	41.87	59.23
2	IC 39980	17.08	11.89	14.48	3.75	3.39	3.57	64.03	40.28	52.15
3	IC40004	12.63	9.50	11.07	3.75	3.39	3.57	47.36	32.20	39.78
4	IC40230	13.32	12.56	12.94	4.42	3.73	4.08	58.91	46.90	52.91
5	IC40235	17.08	15.62	16.35	5.79	3.73	4.76	98.93	58.31	78.62
6	IC40249	10.58	8.83	9.71	4.77	3.73	4.25	50.49	32.98	41.73
7	IC40256	13.66	7.81	10.73	5.21	3.73	4.47	71.15	29.17	50.16
8	IC40417	17.75	13.58	15.67	4.19	4.07	4.13	74.37	55.26	64.81
9	IC40458	11.96	9.85	10.90	5.11	3.73	4.42	61.07	36.78	48.93

10	IC40741	16.73	12.56	14.64	4.09	3.39	3.74	68.37	42.55	55.46
11	IC40752	15.03	13.58	14.30	4.09	3.73	3.91	61.42	50.70	56.06
12	IC40162	13.66	11.89	12.77	5.45	2.72	4.08	74.36	32.29	53.33
13	IC40266	15.71	13.58	14.64	5.11	3.39	4.25	80.22	46.01	63.11
14	IC40682	14.00	8.83	11.42	4.09	3.39	3.74	57.23	29.92	43.58
15	IC40763	16.73	12.91	14.82	4.09	4.07	4.08	68.37	52.53	60.45
16	IC40998	4.78	3.74	4.26	6.81	6.11	6.46	32.60	22.82	27.71
17	IC41189	15.03	9.85	12.44	4.09	3.05	3.57	61.42	30.07	45.74
18	IC41202	16.73	15.62	16.17	4.77	3.39	4.08	79.82	52.91	66.36
19	IC113578	17.75	13.58	15.67	4.09	3.73	3.91	72.55	50.70	61.63
20	IC329038	15.71	10.87	13.29	4.09	3.05	3.57	64.18	33.18	48.68
Mean		14.60	11.31		4.63	3.70		66.17	40.87	
CD (5%) water Quality		1.55			0.54			7.52		
Germplasm		1.47			0.63			8.74		
Interaction		2.1			0.85			12.20		

Data presented in Table 5.41 revealed that pod length, number of grains/pod and seed index does not affect significantly by poor quality water, whereas, grain yield/plant was significantly influenced by poor quality water. It was also reported that maximum grain yield was observed in gremplasm IC 40235 followed by IC 40417 > IC 40752 and IC 44202.

Table 5.41 Effect of poor quality water on pod length, number of grains, grain yield and seed index of different clusterbean (*Cyamopsis tetragonoloba* L.) germplasm

S.No	Cultivars	Pod length (cm)			Number of grains/ pods			Grain yield /plant			Seed Index		
		CW	TW	Mean	CW	TW	Mean	CW	TW	Mean	CW	TW	Mean
1	IC 39418	5.50	4.81	5.16	9.33	8.13	8.73	16.61	9.33	12.97	2.89	2.83	2.86
2	IC 39980	5.75	5.40	5.57	9.02	8.54	8.78	15.61	9.43	12.52	2.86	2.82	2.84
3	IC40004	4.93	4.75	4.84	8.51	8.16	8.34	10.26	6.17	8.22	2.71	2.49	2.60
4	IC40230	5.62	5.43	5.53	8.30	7.73	8.02	13.93	9.46	11.70	2.99	2.70	2.85
5	IC40235	5.03	4.59	4.81	8.61	7.73	8.17	22.41	11.77	17.09	3.01	2.71	2.86
6	IC40249	5.37	5.00	5.18	8.72	8.54	8.63	12.51	7.81	10.16	3.00	2.91	2.95
7	IC40256	5.50	5.12	5.31	8.20	7.93	8.07	15.61	6.31	10.96	2.86	2.81	2.84
8	IC40417	5.46	5.15	5.31	8.82	7.83	8.32	16.91	11.19	14.05	2.80	2.70	2.75
9	IC40458	5.36	5.10	5.23	9.26	8.44	8.85	15.60	8.65	12.12	2.98	2.93	2.95
10	IC40741	5.41	5.25	5.33	7.28	6.00	6.64	13.25	6.76	10.01	2.82	2.74	2.78
11	IC40752	5.48	5.22	5.35	8.41	8.26	8.34	13.83	10.82	12.32	2.81	2.71	2.76
12	IC40162	5.14	5.04	5.09	8.72	8.34	8.53	17.07	7.00	12.03	2.77	2.72	2.75
13	IC40266	4.98	4.85	4.91	8.72	8.23	8.47	18.65	10.18	14.42	2.83	2.79	2.81
14	IC40682	5.23	4.98	5.11	7.89	7.42	7.66	12.18	5.97	9.08	2.85	2.79	2.82
15	IC40763	4.79	4.61	4.70	8.27	7.93	8.10	14.66	10.73	12.70	2.75	2.68	2.72
16	IC40998	4.83	4.76	4.80	8.61	7.83	8.22	7.37	4.64	6.00	2.80	2.71	2.76
17	IC41189	5.02	4.26	4.64	8.20	6.40	7.30	13.31	4.89	9.10	2.79	2.65	2.72
18	IC41202	5.29	5.25	5.27	8.23	7.83	8.03	17.64	10.81	14.22	2.83	2.75	2.79
19	IC113578	4.85	4.57	4.71	8.27	7.93	8.10	15.85	10.57	13.21	2.80	2.72	2.76
20	IC329038	4.77	4.61	4.69	8.30	7.83	8.07	14.46	7.06	10.76	2.87	2.83	2.85
Mean		5.22	4.94		8.48	7.85		14.89	8.48		2.85	2.75	
CD (5%) water Quality		0.13			0.16			1.88			NS		
Germplasm		0.35			0.52			2.10			NS		
Interaction		NS			NS			2.94			NS		

6. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS AND SCSP ACTIVITIES

- **Operational Research Programme for the use of underground saline water at farmers' fields (Agra)**

In Operational Research Project (ORP) the field demonstrations for the use of poor quality groundwater were initiated from kharif 1993 in Karanpur village of Mathura district. The village is located at Fareh-Achhnera road only 6 km away from Fareh town. In 1999 the program was extended to two other villages i.e. Nagla Hridaya and Bhojpur. At these sites, medium and high SAR saline water are available. In the year 2000 the program was further extended to Savai village of Agra district to demonstrate the technologies on the use of alkali water. In kharif 2004, ORP was also started at Odara village of Bharatpur district in medium and high SAR saline water (EC_{iw} 6.0 to 23.5 dS/m and SAR 11-30 $(mmol/l)^{1/2}$. In 2006, one more site was also selected for dry land salinity demonstrations at Nagla Parasuram in Bharatpur District. In 2015-16, eleven farmers are selected using saline water (ECiw: 7.1 to 13.0 dS/m) of different villages i.e. Deen Dayal Dham (Nagla Chandra Bhan), Dhana Khema, Nagla Jalal, Garhi Pachauri and Dalatpur in district Mathura (U.P.) and Odara in Bhratpur district (Rajasthan).

From the year 2017 this program was shifted to three other villages i.e. Signa in Bichpuri block, district Agra and Jalal and Kurkunda in block Fareh, district Mathura. At these sites medium and high SAR saline water are available.

The Table 6.1 clearly indicated that the water quality parameters pertaining to tube well water of the selected farmers. The year 2018-19 to 2019-20 fifteen farmers were selected in ORP saline water project**.** The pH of groundwater was almost normal in case of tube wells. The sodium range was recorded (28.9 to 110.7). The Ca+Mg were present in all the water samples but this value was ranged from (9.1 to 22.3). The all collected water samples, CO_3 was not found but HCO_3 was present. The chloride and sulphate were present in all the samples. The SAR ranged from 13.6 to 36.9 but RSC was absent.

Table 6.1: Water quality of farmer's tube well water

Farmers name	EC_{iw}	pH	Na	Ca+Mg	CO_3	HCO_3	Cl	SO_4	SAR	RSC
1.Mr.Kishan Gopal	6.0	7.5	47.2	12.8	-	10.5	21.7	27.8	18.7	-
2. Mr. Vijay Pal Singh	11.5	7.3	96.7	18.3	-	15.8	45.2	54.0	32.0	-
3. Mr. Mahesh Singh	5.8	7.2	47.5	10.2	-	9.7	19.6	28.7	21.1	-
4. Mr. Deepak Singh	10.2	7.4	90.2	11.9	-	10.2	31.5	60.3	36.9	-
5. Mr. Nand Kishor	6.3	7.3	49.6	13.2	-	12.7	20.8	29.5	19.3	-
6. Mr. Pratap Singh	7.2	7.4	59.1	12.8	-	11.9	27.5	32.6	23.4	-
7. Mr. Babu lal	5.3	7.6	40.3	12.7	-	11.5	20.7	20.8	15.9	-
8. Mr. Ram Veer Bhagat	13.3	7.3	110.7	22.3	-	18.7	56.5	57.8	33.2	-
9. Mr. Bhanwar Singh	6.5	7.6	54.4	10.7	-	9.5	26.6	28.9	23.5	-
10. Mr.Tufan Singh	6.4	7.5	52.1	11.9	-	11.9	27.1	25.0	21.4	-
11.Mr.Satish Sharma	3.8	7.5	28.9	9.1	-	7.8	10.2	20.0	13.6	-
12.Mr. Rajesh Singh	6.3	7.5	48.6	14.4	-	11.5	26.8	24.7	18.1	-
13.Mr.Chandra Pal	5.8	7.6	42.3	15.7	-	10.8	27.5	19.7	15.1	-
14.Mr.Nathi Lal	5.3	7.7	38.9	14.1	-	10.4	26.7	15.9	14.4	-
15.Ter Singh	8.3	7.7	61.3	21.7	-	16.8	32.3	35.9	18.5	-

The Table 6.2 clearly indicated that the all mustard growing farmers applied saline water for irrigation. Among wheat growing farmers, 2 farmers applied irrigation in 2 SW: 2CW mode and four farmers gave 1 SW: 1GW. For beet root crop one farmer applied 1SW:2GW and one farmer 2GW:1SW irrigation mode.

Table 6.2. Irrigation mode of ORP farmers and other farmers (2019-20)

Farmers name	Crop	ORP farmers	Other farmers
Mustard			
1. Mr. Vijay Pal Singh	Mustard	All saline water	All saline water
2. Mr. Nand Kishor	Mustard	All saline water	All saline water
3. Mr. Kishan Gopal	Mustard	All saline water	All saline water
4. Mr. Mahesh Singh	Mustard	All saline water	All saline water
5. Mr. Kalicharan	Mustard	All saline water	All saline water
6. Mr. Chandra Pal	Mustard	All saline water	All saline water
7. Mr. Babu Lal	Mustard	All saline water	All saline water
Wheat			
1. Mr. Deepak Singh	Wheat	1SW:2CW	All saline water
2. Mr. Prem Singh	Wheat	1SW:2CW	All saline water
3.Mr. Bhanwar Singh	Wheat	1SW:2GW	All saline water
4. Mr.Rajesh Singh	Wheat	2SW:2CW	All saline water
5. Mr.Nathi Lal	Wheat	1SW:1GW	All saline water
6.Mr. Ter Singh	Wheat	2SW:1GW	All saline water
Beet Root			
Mr. Ram veer Bhagat	Beet root	1SW:2GW	Nil
Mr Kishan Gopal	Beet root	2GW:1SW	Nil
Cauliflower			
Mr.Tufan Singh	Cauliflower(Early)	1SW:1GW	Nil
Mr. Tufan Singh	Cauliflower(late)	2SW:1GW	Nil
Tomato			
Mr.Tufan Singh	Tomato	1SW:2GW	Nil
Bottle gourd			
1.Mr.Tufan Singh	Bottle gourd	2SW:1GW	Nil
Coriander			
Mr. Tufan Singh	Coriander	1SW:1GW	Nil
Cluster bean			
Mr. Tufan Singh	Cluster bean	2SW:2GW	Nil

SW-Saline water, GW-good quality water, CW-Canal water

The ORP farmers and other farmers pearl millet yields are presented in Table 6.3. It clearly indicated that mustard grain yield of ORP farmers ranged from (24.1 to 27.9 q/ha). It was higher compared to other farmers' mustard yield (22.3 to 26.0 q/ha). At harvest of mustard crop ECe ranged from (4.1-5.0 dS/m) and pH (7.5 to 7.6).

Table 6.3: Grain yield of pearl millet (q/ha) ORP farmers' fields (2018-19 and 2019-20)

Name of farmers	ORP farmers yield	Other farmer yield	% in increase	At harvest ECe(dS/m)	pH
1.Mr.Tufan Singh	26.8	24.2	10.7	5.0	7.5
2. Mr. Vijay Pal Singh	27.9	25.9	8.2	4.1	7.6
3. Mr. Mahesh Singh	24.1	22.3	8.8	4.4	7.6
4. Mr.Nand Kishor	27.1	23.6	11.1	4.2	7.6
5. Mr. Bhawar Singh	27.7	26.0	10.0	4.3	7.6
6. Kalua	25.3	23.8	6.1	4.3	7.6
7.Nathi Lal	26.8	23.9	12.1	4.7	7.6

The Cost of cultivation, gross income, net profit and B: C ratio:

The cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio of mustard crop were calculated and presented in Table 6.4. It is clearly indicated that the cost of cultivation of ORP farmers almost was less compare to other farmers. The gross income (Rs/ha) was higher in ORP farmers field compare to other farmers field. The net profit (Rs/ha) and B: C ratio were also higher in ORP farmers compare to other farmers.

Table 6. 4: Cost of cultivation, gross income, net profit and B: C ratio of mustard growing ORP farmers and other farmers (2018-19 and 2019-20)

Farmers name	ORP farmers				Other farmers			
	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio
1.Mr.Tufan singh	20,010	60,237	40,227	3.01	22,050	54,315	32,265	2.46
2. Mr. Vijay Pal Singh	21,010	63,698	42,688	3.03	22.200	58,552	36,352	2.64
3. Mr. Mahesh Singh	20,585	59,875	40,790	2.98	22,220	55,337	33,118	2.49
4. Mr.Nand Kishor	20,060	54,698	34,638	2.72	21,925	50,363	28,438	2.30
5. Mr. Bhawar Singh	20,310	62,821	42,486	3.09	22,500	57,190	34.690	2.54
6. Kalua	20,285	57,781	37,496	2.85	22,835	54,152	31,618	2.40
7.Nathi Lal	20,410	61,790	41,380	3.02	22,780	54,520	31,740	2.39

The ORP farmers and other farmers sorghum green fodder yield is presented in Table 6.5. The Table 6.5 clearly indicated that the ORP farmers' sorghum green fodder yield ranged from 355.8 to 415.2 q/ha. It was higher compared to other farmers' fodder yield (310.1 to 368.9 q/ha). At the harvest of pearl millet crop, ECe ranged from (3.6 to 3.9 dS/m) and pH (7.5 to 7.6).

Table 6.5: Fodder yield of sorghum(fodder) (q/ha) 2018-19

Name of farmers	ORP farmers yield	Other farmer yield	% in increase	At harvest ECe(dS/m)	pH
1.Mr.Ram veer Bhagat	387.1	350.7	10.4	3.8	7.6
2. Mr. Kishan Gopal	415.2	368.9	12.6	3.6	7.5
3. Mr. Ravendra Singh	355.8	310.1	14.7	3.9	7.6

Cost of cultivation, gross income, net profit and B: C ratio:

The cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio of sorghum green fodder crop were calculated and presented in Table 6.6. It is clearly indicated that the cost of cultivation of ORP farmers' was lower. The net profit (Rs/ha) and B: C ratio were also higher for ORP farmers compared to other farmers.

Table 6.6: Cost of cultivation, gross income, net profit and B: C ratio of Sorghum (fodder) growing ORP farmers and other farmers (2018.19)

Farmer's name	ORP farmers				Other farmers			
	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio
1.Mr.Ram veer Bhagat	30,850	96,775	65,925	3.14	30,910	87,675	56,765	2.83
2. Mr. Kishan Gopal	32,932	1,03,800	70,868	3.15	30,710	92,225	61,515	3.00
3. Mr. Ravendra Singh	30,920	88,950	58,030	2.88	29,650	77,525	47,875	2.61

The sesame crop sowing Mr Ramveer Bhagat the crop yielded 8.0 q/ha. The net profit is gain Rs 56,800 and B: C ratio 3.45 (Table 6.7).

Table 6.7: Yield, cost of cultivation, gross income, net profit and B:C ratio of Sesame crop of ORP farmers field (2019-20)

Farmer's name	Sesame yield (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Mr. Ram veer Bhagat	8.0	23,200	80,000	56,800	3.45

Mustard crop in ORP farmer's field

In the rabi season 2018-19 to 2019-20 the nine farmers sown mustard crop in their fields. The mustard variety CS-58 was sown all the ORP farmers' fields other farmers sown difference wheat variety available market/own. The ORP farmers and other farmers mustard yield is presented in Table 6.8. It clearly indicated that the ORP farmers' mustard grain yield ranged from 25.2 to 27.6 q/ha. It ranged from 22.7 to 26.2 q/ha for other farmers. At the harvest of mustard crop, ECe ranged from 5.9 to 8.2 dS/m and pH from 7.5 to 7.7.

Table 6.8. Grain yield of mustard (q/ha) ORP farmers field (2018-19 and 2019-20)

Name of farmers	ORP farmers yield	Other farmer yield	% in increase	At harvest ECe(dS/m)	pH
1.Mr. Vijay Pal Singh	27.2	25.3	7.8	8.2	7.5
2. Mr. Pratap Singh	27.5	26.2	5.0	7.7	7.5
3. Mr. Nand Kishor	25.6	23.2	10.6	7.7	7.5
4. Mr.Kishan Gopal	25.2	22.7	11.0	6.2	7.5
5. Mr. Mahesh Singh	27.6	26.0	7.7	5.9	7.5
6. Kalua	26.3	24.8	6.0	6.2	7.5
7.Kalicharan	26.2	23.8	10.1	6.0	7.6
8. Candra Pal	27.2	24.5	11.0	7.2	7.7
9. Babu Lal	26.9	23.9	12.6	6.7	7.6

Cost of cultivation, gross income, net profit and B: C ratio:

In case of mustard crop, the cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio were calculated and presented in Table 6.9. It clearly indicated that the cost of cultivation of ORP farmers less compared with other farmers. The gross income (Rs/ha), net profit (Rs/ha) and B: C ratio was higher in ORP farmers compared with other farmers growing wheat crop.

Table 6.9. Cost of cultivation, gross income, net profit and B: C ratio of mustard ORP farmers and other farmers (2018-19 and 2019-20)

Farmers name	ORP farmers				Other farmers			
	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio
1.Mr. Vijay Pal Singh	25,518	95,750	74,207	3.8	26,008	88,891	62,883	3.4
2. Mr. Pratap Singh	24,443	96,250	71,807	3.9	24,658	91,700	67,042	3.7
3. Mr. Nand Kishor	23,872	90,128	66,257	3.8	25,730	81,497	55,768	3.2
4. Mr.Kishan Gopal	24,392	88,736	64,370	3.6	26,004	79,932	53,934	3.1
5. Mr. Mahesh Singh	25,611	98,808	72,954	3.9	26,604	91,522	64,918	3.5
6. Kalua	23,532	92,650	68,518	3.9	24,340	86,800	62,560	3.6
7.Kalicharan	24,853	98,748	67,895	3.7	27,997	84,252	56,255	3.0
8. Candra Pal	26,798	96,288	69,490	3.6	26,615	86,730	60,115	3.3
9. Babu Lal	24,650	95,226	70,576	3.9	27,210	84,607	57,396	3.1

Wheat crop in ORP farmer's field

In the rabi season 2018-19 to 2019-20 the eight farmers sown wheat crop in their fields. The wheat variety KRL-210 was sown all the ORP farmers' fields other farmers sown difference wheat variety available market/own. The ORP farmers and other farmers' wheat yields are presented in Table 6.10. Data indicated that the ORP farmers' wheat grain yield ranged from 45.8 to 49.2 q/ha. Other farmers' wheat yield ranged from 39.7 to 44.9 q/ha. At the harvest of mustard crop, ECe ranged from (5.9- 8.2 dS/m) and pH (7.5 to 7.7).

Table 6.10: Grain yield of wheat (q/ha) ORP farmers' field (2018-19 and 2019-20)

Name of farmers	ORP farmers yield	Other farmer yield	% in increase	At harvest ECe(dS/m)	pH
1.Mr. Deepak Singh	49.2	44.9	9.4	8.2	7.6
2. Mr. Prem Singh	47.8	44.1	8.3	6.7	7.6
3. Mr. Bhawar Singh	47.3	43.4	11.7	6.7	7.6
4. Mr.Satish Sharma	45.8	40.8	12.3	5.9	7.6
5. Mr. Babu Lal	46.1	41.2	11.9	6.8	7.5
6. Nathi Lal	48.1	44.9	7.1	5.6	7.6
7.Rajesh	44.0	39.7	10.9	5.9	7.6
8. Ter Singh	46.2	43.2	9.2	8.2	7.7

Table 6.11: Cost of cultivation, gross income, net profit and B: C ratio of wheat crop ORP farmers and other farmers (2018-19 and 2019-20)

Farmers name	ORP farmers				Other farmers			
	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio	Cost of cultivation (Rs/ha)	Gross Income Rs/ha	Net Profit Rs/ha	B:C ratio
1.Mr. Deepak Singh	36,276	1,09,213	72,937	3.0	34,665	99,930	65,265	2.9
2. Mr. Prem Singh	32,760	1,06,783	74,023	3.3	38,115	97,718	59,613	2.6
3. Mr. Bhawar Singh	33,613	1,05,695	72,082	3.1	34,740	93,970	59,230	2.7
4. Mr.Satish Sharma	33,937	98,450	64,513	2.9	36,290	86,700	50,410	2.4
5. Mr. Babu Lal	32,227	97,975	65,748	3.0	36,225	87,300	51,075	2.4
6. Nathi Lal	32,637	1,11,430	78,783	3.4	36,825	1,04,780	67,945	2.8
7.Rajesh	33,147	98,680	65,533	3.0	36,565	88,620	62,055	2.4
8. Ter Singh	32,322	1,07,490	75,168	3.3	36,750	94,260	57,510	2.6

Beet root growing in ORP farmer's field in rabi season:

In Beet root crop yield of 265.5 q/ha was recorded in the field of Mr. Ram veer Bhagat and 284.5 q/ha in Mr Kishan Gopal. The income from crop yield was Rs. 1,90,433 /ha as net profit and 4.80 benefit cost ratio for Mr Ram veer Bhagat and net profit and B:C ratio were Rs 2,32,350 and 5.63 for Mr Kishan Gopal (Table 6.12).

Table 6.12: Yield, cost of cultivation, gross income, net profit and B: C ratio of beet root crop in ORP farmer's field (2018-19 and 2019-20)

Farmers name	Beet root yield (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B: C ratio
Mr. Ram veer Bhagat	265.5	50,018	2,40,450	1,90,433	4.80
Mr Kishan Gopal	284.5	50,150	2,82,500	2,32,350	5.63

Cauliflower growing in ORP farmer's field in rabi season:

In Cauliflower (early) crop yield of 310.8 q/ha was recorded in the field of Mr. Tufan Singh. The crop gave Rs. 1, 64,350/ha as net profit and 4.09 benefit cost ratio (Table 6.13).

Table 6.13: Yield, cost of cultivation, gross income, net profit and B:C ratio of Cauliflower (early)crop of ORP farmers field (2019-20)

Farmer name	Cauliflower yield (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Mr. Toffan Singh	310.8	53,210	2,17,560	1,64,350	4.09

In Cauliflower (late) crop yield of 245.9 q/ha was recorded in the field of Mr. Tufan Singh. The crop gave Rs. 1, 41,920/ha as net profit and 3.58 benefit cost ratio (Table 6.14).

Table 6.14: Yield, cost of cultivation, gross income, net profit and B:C ratio of Cauliflower (late)crop of ORP farmers field (2019-20)

Farmer name	Cauliflower yield (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Mr. Tufan Singh	245.9	54,800	1,96,720	1,41,920	3.58

In case of Tomato, crop yield of 211.8 q/ha was recorded in the field of Mr. Tufan Singh. The crop gave Rs. 1, 22,000/ha as net profit and 3.57 benefit cost ratio (Table 6.15).

Table 6.15: Yield, cost of cultivation, gross income, net profit and B:C ratio of Tomato crop of ORP farmers field (2019-20)

Farmer name	Tomato yield (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Mr. Tufan Singh	211.8	47,440	1,69,440	1,22,000	3.57

In bottle gourd crop yield of 160.8 q/ha was recorded in the field of Mr. Tufan Singh. The crop gain Rs. 96,340/ha as net profit and 3.98 benefit cost ratio (Table 6.16).

Table 6.16: Yield, cost of cultivation, gross income, net profit and B:C ratio of Bottle gourd crop of ORP farmers field (2019-20)

Farmer name	Bottle gourd yield (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Mr. Tufan Singh	160.8	32,300	1,28,640	96,340	3.98

In case of Coriander crop, yield of 7.5 q/ha was recorded in the field of Mr. Tufan Singh. The crop gain Rs. 34,750ha as net profit and 2.4 benefit cost ratio (Table 6.17).

Table 6.17: Yield, cost of cultivation, gross income, net profit and B:C ratio of coriander crop of ORP farmers field (2018-19)

Farmer name	Coriander yield(q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Mr. Tufan Singh	7.5	25.250	60,000	34,750	2.4

In case of cluster bean, crop yield of 85.8 q/ha was recorded in the field of Mr. Tufan Singh. The crop gave Rs. 1, 38,505/ha as net profit and 5.18 benefit cost ratio (Table 6.18).

Table 6.18: Yield, cost of cultivation, gross income, net profit and B:C ratio of cluster bean crop of ORP farmers field (2018-19)

Farmer name	Pod yield of cluster bean (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Mr. Kishan Gopal	85.8	33,095	1,71,600	1,38,505	5.18

- **Demonstration on gypsum tank to reclaim sodic water for irrigation to different crops (Bapatla)**

2018-19

A demonstration under ORP was undertaken to show the farmers reclamation of sodic groundwater through gypsum tank and its positive effect of crop yield. The bore well water having RSC of 9.3 passed through gypsum beds to the existing crops of paddy, fodder jowar, pillipesara and paragrass to evaluate their performance at Elurivaripalem village of Chimakurthy mandal. The grain yield of paddy increased by 8.4% when irrigation water passing through gypsum. Similarly, the biomass of fodder jowar, pillipesara and paragrass increased to 5.7, 7.8 and 3.8 percent, respectively (Table 6.19).

Table 6.19 Effect of RSC water on grain yield of paddy and biomass of fodder crops

Treatments	Irrigation with RSC water(yield t/ha)	Irrigation with gypsum treated water(yield t/ha)	Percent yield increase
Paddy	3.75	4.07	8.4
Fodder Jowar	32.70	34.57	5.7
Pillipesara	21.9	23.6	7.8
Paragrass	65.7	68.2	3.8

- **Effect of CSR-Bio on tomato and cabbage in sodic soil at farmers' fields (Kanpur)**

2018-19

The experiment was initiated during 2015 to find out the suitable application method of CSR-Bio for vegetable production and to determine the physico-chemical changes in soil. The experiment details are given in Table 6.20.

Table 6.20. Experimental details

Sr. No.	Item	Details
1	Crop	Tomato and cabbage
2	Varieties	Azad T-5 (Tomato) and Golden acre (Cabbage)
3	No. of treatments	3; T1 (control); T2: CSR Bio (soil application); T3: CSR Bio (soil application + foliar spray).
4	No. of replication	3
5	Design	RBD
6	Plot size	20 sqm
7	Spacing	40 x40 cm (cabbage) 60 x60 cm (Tomato)
8	Year of start	2015
9	Location	Farmer's field at Vinovanagar, Kanpur Dehat
10	Initial soil status	pH (9.10); EC (0.96 dSm-1); ESP 43.6; O.C. (%) 0.29

Tomato: The maximum survival percentage, fruit/plant, diameter of fruit and yield of tomato was recorded 62.6%, 26.75, 3.63 cm and 128.35 q/ha and minimum in control plot (Table 6.21).The increment of yield was recorded 25.28% in CSR-Bio (soil application + foliar spray) and 20.18% in CSR-Bio (soil application) over control.

Table 6.21 Effect of CSR-Bio on yield and yield attributes of tomato

Treatments	Survival (%)	Fruit/ plant	Diameter of fruit (cm)	Yield (q/ha)	Increase (%)
Control	48.7	21.29	2.82	97.48	--
CSR-Bio (soil application)	59.4	24.42	3.45	122.12	20.18
CSR-Bio (soil application + foliar spray)	62.6	26.75	3.63	128.35	25.28

Physico-chemical Properties of Soil

The data presented in Table 6.22 indicated that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in both the treatments including control, maximum decrease, however was observed in CSR-Bio (soil application + foliar spray) treated plot. The organic carbon improved with the application of CSR-Bio treated plots.

Table 6.22 Effect of CSR-Bio on physico chemical properties of experimental soil for tomato experiment

Treatments	pH	EC (dS/m)	ESP	OC (%)
Control	9.0	0.92	39.5	0.31
CSR-Bio (soil application)	8.7	0.90	32.6	0.37
CSR-Bio (soil application + foliar spray)	8.8	0.59	31.2	0.39
Initial soil status	9.1	0.96	42.2	0.29

Cabbage: The maximum survival percentage, no of leaves, head weight and yield of cabbage was recorded as 70.5, 12.42, 0.99 kg and 145.37 q/ha and minimum in control plot (Table 6.23). The increase in yield was recorded as 27.03% in CSR-Bio (soil application + foliar spray) and 23.12% in CSR-Bio (soil application) over control.

Table 6.23 Effect of CSR-Bio on yield and yield attributes of cabbage

Treatments	Survival (%)	No. of leaves	Head wt (kg)	Yield (q/ha)	Inc. (%)
Control	56.4	10.22	0.83	115.22	--
CSR-Bio (soil application)	68.2	11.45	0.96	141.75	23.12
CSR-Bio (soil application + foliar spray)	70.5	12.42	0.99	145.37	27.03

Physico chemical Properties of Soil:

The data presented in Table 6.24 indicated that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in both the treatments including control. Maximum decrease, however, was observed in CSR-Bio (soil application + foliar spray) treated plot. The organic carbon improved with the application of CSR-Bio treated plots.

Table 6.24 Effect of CSR-Bio on physico chemical properties of experimental soil

Treatments	pH	EC (dS/m)	ESP	OC (%)
Control	9.0	0.91	39.2	0.31
CSR-Bio (soil application)	8.7	0.87	31.6	0.38
CSR-Bio (soil application + foliar spray)	8.6	0.85	30.4	0.42
Initial soil status	9.1	0.96	42.2	0.29

- **Demonstration of wheat varieties (KRL-210 and KRL-213) at farmer's field (Bathinda) 2018-19**

An on farm demonstration of wheat varieties (KRL-210 and KRL-213) at farmer's field was conducted in village Rama Nandi, Jhunir block, district Mansa to popularized the salt tolerance variety of wheat developed by ICAR-CSSRI, Karnal for salt affected areas during 2018-19. The selected farmer completely used tubewell water for crop cultivation in both the season. The quality of tube well water (Table 6.25) showed that the water is saline. Other details of demonstration are: Name of farmer- Paramjit Singh S/o S. Gurpiar Singh; Village –Rama Nandi, Block-Jhunir, District-Mansa (Punjab); Date of sowing: 22.11.2018; Varieties: HD 2967; KRL-210 and KRL-213; Date of harvesting: 12.04.2019

Table 6.25 Chemical composition of Tube well situated at farmer's field.

Water Quality					
CO_3 (meq/l)	HCO_3 (meq/l)	Cl^- (meq/l)	$Ca^+ + Mg^+$ (meq/l)	RSC (meq/l)	EC (dS/m)
NIL	6.4	7.9	16.8	Nil	4.8

The nutrient availability of soil is presented in Table 6.26. It showed that the soil is slightly alkaline in reaction having low organic carbon, available phosphorus and Zn. Three varieties namely HD2967, KRL-210 and KRL 213 were shown at farmer's field. Data (Table 6.27) showed that variety KRL210 showed higher plant height, whereas HD 2967 perform higher number of tillers/m^2 and ear length among the varieties tested. The variety KRL-213 showed higher number of seed/ear followed by HD 2967, whereas, higher grain yield was observed in variety HD2976 followed by KRL 210 and KRL213.

Table 6.26 Soil fertility status of farmer's field before sowing and after crop harvesting

	pH (1:2)	EC (1:2)	OC (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
Initial	8.36	00.81	0.24	10.8	348	4.9	0.38	00.48	4.12
After harvesting	8.44	0.82	0.25	10.6	375	4.6	0.33	0.51	4.16

Table 6.27 Response of wheat cultivars to saline water

S.No	Cultivars	Plant height (cm)	Number of tillers/m^2	Ear length (cm)	Number of seeds/ ear	grain yield (q/acre)
1	HD 2967	94.3	96.70	10.8	54.4	19.6
2	KRL210	95.2	91.4	10.2	49.4	15.4
3	KRL 213	89.6	84.6	10.1	65.6	13.2

Implementation of Scheduled Caste Sub Plan (SCSP) at different centres

Different centres of AICRP on SAS&USW are implementing SCSP activities. Brief details are provided below.

- **SCSP at Bikaner**

During 2019-20**,** Under SCSP head one one-day on campus training was conducted on management of salt affected soils and use of saline water in agriculture and benefitted 30 farmers and farm women of SC catogary. During the training 50kg DAP and 5kg Zinc sulphate has been provided to each farmer as a critical inputs.

- **SCSP at Tiruchirapalli**

Tiruchirapalli centre has concentrated its activities in Manikandam Block of Tiruchirappalli District where SC population is sizable and sodic soils are affecting agricultural production. The centre will try to address majority of issues related to sodic soils of SC population through SCSP.

The SCSP activities are planned at the centre with following objectives.

- Facilitating improved Farm productivity and Economic development of scheduled caste people engaged in Agriculture and allied sector through dissemination of improved farm technologies; On and Off Farm Training, Front Line Demonstration, On Farm Trail, skill development, method demonstration, exposure visit, input distribution etc.,
- Use of Information and Communications Technology (ICT) for enhancement of Agricultural and allied sector productivity for the benefit of Scheduled caste people.

The field surveys were undertaken in the Manikandam Block of Tiruchirappalli District for the identification of beneficiary areas. Seventy five families were identified as beneficiaries under the SCSP (Table 6.28 and Table 6.29). Activities for the distribution of soil health card, various agricultural inputs, imparting training and demonstration activities were undertaken (Plate 6.1).

Table 6.28 List of beneficiaries identified during 2019

S.No	Name	Aadhar No	Phone No	Male/ Female
1	Palaniyammal.P	5710 7981 4078	7010476847	F
2	Muthulaksmi.T	3039 4567 0101	9698969255	F
3	Sivagowri.S	3669 0411 3894	6381602431	F
4	Dayana.S	2200 3018 2757	6383593760	F
5	Pariyakkal.S	5972 0657 7001	8270543899	F
6	Anjalai.S	3728 0270 0106	9655333592	F
7	Roja.M	5584 1550 5216	7639329622	F
8	Karuthammal.M	6612 2510 5459	9361254725	F
9	Kanagadevi.A	8264 0264 4236	8056466521	F
10	Saranya.I	5692 2099 1552	9843852917	F
11	Prema.S	8696 5840 8430	9597115762	F
12	Ponunusamy.P	6876 2123 0235		M
13	Muthumayil.M	2273 0458 3783	9843405752	F
14	Pavani.M	9003 6474 3948	9626549916	F

15	Sinthanaiselvi.V	2070 4487 7954	8608356444	F
16	Thangamani.A	9006 2930 3639	9788677226	F
17	Mariyayi.M	8876 5880 4256	9786090800	F
18	Palaniyammal.K	2591 1422 4452	9786090800	F
19	Pragadeeshwaran	3352 0290 9819	9843613327	M
20	Muthulakshmi.P	2918 5105 0130	9843852917	F
21	Pappathi.M	7452 0729 2435	9003618830	F
22	kalpana.B	7507 7470 3161	9787446365	F
23	Dhanalakshmi.N	5801 9234 6734	9791375640	F
24	Chinnammal.C	5235 4459 5312	9578942017	F
25	Hemalatha.P	8086 8081 2218	9003618830	F
26	Palanivel.S	9023 8232 0106	9095735114	M
27	Valayi.M.	2227 2297 7502		F
28	Lingeswari.P	8842 6397 3006	9843712782	F
29	Pratheeswari.P	3064 0557 4188	9843712782	F
30	Rithiga	6933 7811 7343	8190012977	F
31	Muthulakshmi.k	8595 5047 7494	9787838448	F
32	Priyanka.M	5560 8626 2039	9361254725	F
33	Tamilselvi. T	7760 9555 6503	9788213991	F
34	Josephine Nirmala Mary	6413 9827 5723	8190012977	F
35	Chinnammal	6379 0833 0990	9489467161	F
36	Pappammal.P	7636 5526 8195	9786884220	F
37	Sumathi.K	9612 1443 4820	9597505062	F
38	Devika.K	7448 6706 1400	9597505062	F
39	Mariyamal.S	3814 8789 7355	6381833433	F
40	Latha.P	6671 0391 6045	9789165664	F
41	Chitra.M	9038 2336 9186	9095243781	F
42	Parimala.T	2215 9169 8902	9790597838	F
43	Palaniyammal.K	9408 6722 8640	9655212263	F
44	Valarmathi.N	5434 9686 8311	9842187282	F
45	Gomathi.P	4809 1155 6558	9786968694	F
46	Lakshmi.K	9061 6935 4553	8754309665	F
47	Alaku.K	9123 8220 2015	9080131034	F
48	Vijaya.M	2353 9054 6975	9843718787	F
49	Eswari.M	8413 8052 9006	8122395453	F
50	Vikkneshwari.P	6543 2159 0887	7373683822	F
51	Sarmila.P	7886 5651 9611	9626469493	F
52	Nalla Thangal.S.	6792 6116 0395	9786093656	F
53	Jothi.S	4307 8609 0735	6369759501	F
54	Muthulashmi.S.	2846 4831 5820	9865773006	F
55	Muthukannu.C	8552 0176 5105	9524071580	F
56	Jothi.M.	4257 7156 2224	8220683132	F
57	Thamaraiselvi.K	7971 0424 4412	9080131034	F
58	Nandhini.K	3681 3228 9150	9003618601	F

59	Lalitha.K	9093 7662 3400	9003618601	F
60	Manjula.S.	9107 9336 2475	9159361475	F
61	Rajeswari>S	3704 3232 7067	9786930753	F
62	Susila.K	8760 0423 5369	9159361475	F
63	Ponnammal.M	2005 3239 2100	9677733840	F
64	Pusbam.C.	4411 1614 3993	9088431251	F
65	Latha.M	9648 0811 6514	9943595393	F
66	Indirani.S	5289 5860 4043	9585269818	F
67	Karuppasamy.V.	2147 7060 2661	8384128493	M
68	Muthalagi.R	6400 5567 5147	9865196205	F
69	Rajlakshmi.P	4476 4108 3918	9787660074	F
70	Ponnusamy.A	7692 1593 9921	9698637651	M
71	Murugesan.	2618 5473 1476	9047415717	M
72	Vembu.M	4380 5763 3727	9894225101	F
73	Pushvalli.K	4305 6841 2075	9047633720	F
74	Palanimuthu.P	7082 8615 9756	9786969590	M
75	Subramanian.A	6206 7492 5897	7305735502	M

Table 6.29 List of beneficiaries identified in 2020

S.No	**Name**	**Aadhar No**	**Phone No**	**Male/ Female**
1	Alaku.K	9123 8220 2015	9080131034	F
2	Anjalai.S	3728 0270 0106	9655333592	F
3	Anuska P	5970 9932 3493	7010476847	F
4	Arun, B S	9939 5277 3555	7397117531	M
5	Balaji, M	9224 2257 0316	9361312669	M
6	Bhavani, M	9003 6474 3948	9626549916	F
7	Chandra M	9052 5723 4302	9443312630	F
8	Chinnammal	6379 0833 0990	9489467161	F
9	Chinnammal M	6379 0833 0990	7405626996	F
10	Chinnammal S	5162 0600 7934	9655939692	F
11	Chinnammal.C	5235 4459 5312	9578942017	F
12	Chitra K	5286 2331 8781	9751719793	F
13	Chitra, P	7004 9531 6624	9486896724	F
14	Chitra.M	9038 2336 9186	9095243781	F
15	Dayana.S	2200 3018 2757	6383593760	F
16	Devika.K	7448 6706 1400	9597505062	F
17	Dhanalakshmi.N	5801 9234 6734	9791375640	F
18	Dhanam M	7054 7592 0104	8946092747	F
19	Dhivyadharshini B	4184 5179 1490	9486896724	F
20	Eswari.M	8413 8052 9006	8122395453	F
21	Gomathi.P	4809 1155 6558	9786968694	F
22	Indirani.S	5289 5860 4043	9585269818	F
23	Josephine Nirmala Mary	6413 9827 5723	8190012977	F

24	Jothi.S	4307 8609 0735	6369759501	F
25	Kalpana.B	7507 7470 3161	9787446365	F
26	Kanagadevi.A	8264 0264 4236	8056466521	F
27	Kannan S	5998 9730 0435	9865920100	M
28	Karuthammal.M	6612 2510 5459	9361254725	F
29	Katturani, K	2580 8867 5244	7397117531	F
30	Lakshmi.K	9061 6935 4553	8754309665	F
31	Lalitha.K	9093 7662 3400	9003618601	F
32	Lingeswari.P	8842 6397 3006	9843712782	F
33	Manimegalai, S	8645 0555 3402	9677948957	F
34	Manjula.S.	9107 9336 2475	9159361475	F
35	Marikannu S	5591 4439 4481	9943030177	F
36	Mariyamal.S	3814 8789 7355	6381833433	F
37	Mariyammal J	4052 1943 7905	9047916985	F
38	Mariyayi.M	8876 5880 4256	9786090800	F
39	Mohan S	5611 3017 5359	7502062009	M
40	Muniyappan M	4938 4671 0476	9677948957	M
41	Muthalagi.R	6400 5567 5147	9865196205	F
42	Muthulakshmi P	3694 5518 3676	9789213645	F
43	Muthulakshmi.k	8595 5047 7494	9787838448	F
44	Muthulakshmi.P	2918 5105 0130	9843852917	F
45	Muthulaksmi.T	3039 4567 0101	9698969255	F
46	Muthulashmi.S.	2846 4831 5820	9865773006	F
47	Nalla Thangal.S.	6792 6116 0395	9786093656	F
48	Nandhini.K	3681 3228 9150	9003618601	F
49	Nathiya, T	4557 5384 8657	9092038482	F
50	Palanimuthu.P	7082 8615 9756	9786969590	M
51	Palanisamy R	3079 3324 9549	7010476847	M
52	Palanivel.S	9023 8232 0106	9095735114	M
53	Palaniyammal M	9500 8397 8677	9047916985	F
54	Palaniyammal, S	5818 2813 4760	7358928263	F
55	Palaniyammal.K	9408 6722 8640	9655212263	F
56	Palaniyammal.P	5710 7981 4078	7010476847	F
57	Pappammal.P	7636 5526 8195	9786884220	F
58	Pappathi.M	7452 0729 2435	9003618830	F
59	Pavithiran,T	9783 2770 3472	9865828291	M
60	Ponnammal.M	2005 3239 2100	9677733840	F
61	Ponnusamy.A	7692 1593 9921	9698637651	M
52	Ponunusamy.P	6876 2123 0235	9843615421	M
63	Pratheeswari.P	3064 0557 4188	9843712782	F
64	Prema.S	8696 5840 8430	9597115762	F
65	Pusbam.C.	4411 1614 3993	9088431251	F
66	Pushvalli.K	4305 6841 2075	9047633720	F
67	Rajeswari, S	3704 3232 7067	9786930753	F

68	Ranjith S	6424 6132 0045	7402222114	M
69	Rithiga	6933 7811 7343	8190012977	F
70	Roja.M	5584 1550 5216	7639329622	F
71	Sakthivel S	7855 0316 7204	7402222114	M
72	Saranya.I	5692 2099 1552	9843852917	F
73	Sarmila.P	7886 5651 9611	9626469493	F
74	Selvaraj M	8955 1765 1809	7502062009	M
75	Sinthanaiselvi.V	2070 4487 7954	8608356444	F
76	Sivagowri.S	3669 0411 3894	6381602431	F
77	Subramanian.A	6206 7492 5897	7305735502	M
78	Suganya P	4409 1694 7217	9865772751	F
79	Sumathi.K	9612 1443 4820	9597505062	F
80	Sumithra R	2790 5442 5138	9751719766	F
81	Susila.K	8760 0423 5369	9159361475	F
82	Tamilselvi. T	7760 9555 6503	9788213991	F
83	Thamaraiselvi.K	7971 0424 4412	9080131034	F
84	Thangamani.A	9006 2930 3639	9788677226	F
85	Thilagavathi P	4093 7194 7210	9965659992	F
86	Thiyagarajan, P	8462 5889 8493	9025794942	M
87	Valarmathi.N	5434 9686 8311	9842187282	F
88	Vasanthi, M	8107 7149 7441	7502062009	F
89	Velayi.M.	2227 2297 7502	7639110772	F
90	Vembu.M	4380 5763 3727	9894225101	F
91	Vijaya.M	2353 9054 6975	9843718787	F
92	Vikkneshwari.P	6543 2159 0887	7373683822	F
93	Mariyaee K	2924 1067 7252	9994983454	F
94	Ramayadharshini	5328 3992 0108	7502062009	F
95	Chinnaponnu K	3260 3209 5441	9786968694	F
96	Periyasamy M	7985 4138 3612	9786968694	M
97	Sakthikumar J	9997 0005 7167	9095406067	M
98	Velammal R	9082 2421 4899	9524429909	F
99	Muthukrishnan G	8529 5762 6836	9524429909	M
100	Amsavalli P	3282 1408 0638	9003618830	F
101	Murugayee Ammal	6123 9458 4871	--	F
102	Renugapriya M	9803 6117 8472	8098988466	F
103	Muniyappan V	2949 1680 0870	9786968694	M
104	Thavasu S	5574 1004 0900	9865828291	M
105	Muthukannu S	7938 6487 2693	9865772751	M
106	Muthukannu Chellaiah	8552 0176 5105	9524071580	M
107	Prabakaran K	9299 3396 5008	9865772751	M
108	Nataraj I	7438 1962 4453	9791375640	M

Training Programmes conducted in Aravakudi village during 2020. The following training programmes were conducted as detailed below (Table 6.30)

Table 6.30. List of training programmes under SCSP by Tiruchirapalli centre

S.No	Date of training	Name of the training	No. of members benefited
1	05.03.2020	Bee Keeping technology	20
2	13.03.2020	Bee Keeping technology	20
3	17.03.2020	Bee Keeping technology	20
4	20.03.2020	Mushroom production technology	20
5	23.03.2020	Mushroom production technology	20

The following inputs (Table 6.31) distributed to the farmers during 2020 as detailed below:-

Table 6.31. List of inputs distributed under SCSP

S.No	Name of the Input	Quantity
1.	Tree seedlings issued on 23.03.2020 and 24.03.2020	Pungam -220 Neem -290 Badam- 140 Illuppai - 50
2.	Vermi compost issued on 23.03.2020, 19.08.2020	8682 kg
3.	Kitchen garden-Vegetable seeds issued- 20.09.2020 and 05.11.2020	Chiili Hybrid, Bhedhi, Brinjal Bottle Gourd, Lab Lab, Snake Gourd Ridge Gourd, Tomatto, Cluster Bean Anuual Moringa
4.	Fertilizer (DAP) issued on 28.11.2020	80 bags (4 tonnes)

Plate 6.1 Distribution of inputs to SCSP farmers by Tiruchirapalli centre

- **SCSP at Bathinda**

2019

Distributions of farm inputs (Insecticide) to schedule caste farmers under the Scheme "AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture" to help the Schedule Caste Individuals (Table 6.32, Plate 6.2).

Table 6.32 List of beneficiaries at Bathinda

S.No	Farmer's Name/ mobile No	Father's Name	Village/ Address	Adhar No.
1	Amritpal Singh 90236 78030	Baldev Singh	Jassi Pauwali	5416 1794 4528
2	Moni Singh	Inder Singh	Gehri Devi Nagar, Gehri Bhagi	8403 3823 7130
3	Roop Singh 97815 27780	Gurdev Singh	Gehri Devi Nagar, Gehri Bhagi	2838 4886 3324
4	Baltej Singh 94642 48370	Jarnail Singh	Bandi, Bathinda	7024 4975 8453
5	Bhola Singh 94177 25577	Baldev Singh	Bandi, Bathinda	7594 7850 7369
6	Gurcharan Singh 98889 71589	Bikkar Singh	Bandi, Bathinda	5906 8033 1894
7	Amraj Singh 83609 20075	Mahinga Singh	Bandi, Bathinda	3118 9958 9299
8	Pritpal Singh 86999 38007	Jagjit Singh	Bandi, Bathinda	2571 1596 4521
9	Nachhattar Singh 9478452823	Makhan Singh	Bandi, Bathinda	3364 0848 7670
10	Harinder Singh 98766 93961	Amraj Singh	Bandi, Bathinda	6946 9007 0364
11	Gurcharn Singh	Chand Singh	Bandi, Bathinda	7525 3118 9859

Plate 6.2 Distribution of agricultural inputs at Bathinda

2020

Distribution of Agricultural inputs (Vegetable kits) to schedule cast farmers of Mansa district, Punjab under the Scheme "AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture" to help the Schedule Caste Individuals (Table 6.33, 6.34 and Plate 6.3, 6.4).

Table 6.33 List of beneficiaries at Bathinda

S.No	Farmer's Name/ Mobile No.	Father's Name	Address/Village	Adhar No.
1	Gagandeep Singh 97803 71212	Joginder Singh	Near Pashu Hospital, Sadda AinghWala, Mansa, Punjab	5417 7184 3140
2	Binder Singh	Nand Singh	Vill Khokhar Khurd, Khokhar Kalan, Mansa	7781 6294 1726
3	Paramjit Singh 84272 86583	Pohala Singh	Vill Sadda Singh Wala, Mansa, Punjab	9193 6614 6806
4	Gamdoor Singh 94163 84317	Jang Singh	Vill Khokhar Khurd, Khokhar Kalan, Mansa	9113 7544 5131
5	Amarjit Singh 94179 03199	Kapoor Singh	Khokar Khurd, Bhaini Bhaga, Mansa, Punjab	6135 6482 5348
6	Nachhatar Singh 99153 08010	Mukhtar Singh	H.N. 144, Vill Khokar Khurd, Khokhar Kalan, Mansa	6758 1398 1925
7	Jaswinder Singh W/O	Satnam Singh	Vill Sadda Singh Wala, Mansa, Punjab	8185 1093 2641
8	Nirmal Singh 87258 09362	Mithu Singh	Vill Khokhar Khurd, Khokhar Kalan, Mansa	6577 9791 0452
9	Balwinder Singh 95012 35725	Pritam Singh	Khokar Khurd, Bhaini Bhaga, Mansa, Punjab	2092 2488 7241
10	Bikker Singh 85287 69264	Mohinder Singh	Vill Khokhar Khurd, Khokhar Khurd, Mansa	9425 2870 8567
11	Balraj Singh 96533 45835	Mithu Singh	Vill Khokhar Khurd, Khokhar Khurd, Mansa	9003 9101 1603
12	Gursewak Singh 94654 01340	Mithu Singh	Vill Khokhar Khurd, Khokhar Khurd, Mansa	6287 8037 8879
13	Balkarn Singh 94642 17473	Resham Singh	Khokhar Khurd, Khokhar Khurd, Mansa	6135 9927 9610
14	Pala Singh 95013 36055	Ajmer Singh	Khokhar Khurd, Khokhar Khurd, Mansa	5980 7943 1702
15	Balwinder Singh 99144 71474	Choota Singh	Khokhar Khurd, PO Khokhar Kalan, Near Bus Stand, Mansa	7510 1686 5321
16	Kala Singh 88723 45143	Mithu Singh	Vill Khokhar Khurd, Khokhar Khurd, Mansa	9481 9514 4901
17	Raj Singh 99141 72040	Baldev Singh	Vill Khokhar Khurd, Khokhar Khurd, Khokhar Kalan, Mansa	7285 4833 5074
18	Bikkar Singh 98788 43093	Bawa Singh	H.NO 141, Khokhar Khurd, Bhaini Baga, Mansa	2115 2936 8392
19	Guljar Singh 95013 60153	Kaka Singh	H.NO 132, Khokhar Khurd, Bhaini Baga, Mansa	6891 9712 6668
20	Manjit Kaur W/o 98788 18651	Jagraj Singh	H.NO 275, Khokhar Khurd, Bhaini Baga, Mansa	9910 6251 7214

Distributions of Wheat Seed (HD 3086) to schedule cast farmers under the Scheme "AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture" to help the Schedule Cast Society/ Individuals.

Plate 6.3. Distribution of input to SCSP farmers

Table 6.34 List of beneficiaries at Bathinda

SN	Farmer's Name	Father's Name	Address	Adhar No.
1	Gobind Singh	Gurmel Singh	Vill Kot Fatta, Kot Bhara, Koth Fatta, Bathinda	8718 6178 2587
2	Amritpal Singh	Baldev Singh	Vill Jasssi Pauwali, Bathinda	5416 1794 4528
3	Sandeep Singh	Gurjant Singh	Basti no 4, Birtalab Urf Talab Neehar Bathinda	3508 2960 6685
4	Harjinder Singh	Malkit Singh	Basti no 4, Birtalab Urf Talab Neehar Bathinda	3800 3283 3727
5	Avtar Singh	Bikkar Singh	Basti no 4, Birtalab Urf Talab Neehar Bathinda	9817 3776 6078
6	Harnel Singh	Jagroop Singh	Katar Singh Wala, Gulab Garh, Bathinda	3724 8635 1290
7	Sukhminder Singh	Jaspal Singh	Katar Singh Wala, Gulab Garh, Bathinda	9490 3833 3635
8	Makhan Singh	Bhag Singh	Ward No-7, Kot Fatta, Bathinda	7141 5325 2806
9	Gurchran Singh	Veer Singh	121, Vill Kot Fatta, Kot Bhara, Koth Fatta, Bathinda	9749 2957 9886

Plate 6.4 Distribution of Agricultural inputs

- **SCSP at Vytilla**

A skill development training programme under the scheduled caste sub plan of AICRP(SAS &USW) was conducted in collaboration with Mulanthuruthy block Assistant Director (Agriculture) office on 06/03/2020 at T. M. Jacob Memorial Hall, Mulanthuruthygramapamchayat for scheduled caste farmers. A total of 100 farmers participated in the training programme. The training programme included a theory class on Organic vegetable cultivation in saline soils and a practical class cum demonstration on preparation of various biocontrol agents by Dr. Deepa Thomas, Assistant Professor (Agronomy), AMPRS(KAU), Odakkali. Various vegetable seeds, biocontrol agents and coconut seedlings were distributed to all the participants at the end of the training programme.

Smt. Indu P. Nair, Assistant Director of Agriculture, Mulanthuruthy welcomed the gathering. She pointed the importance of SCSP as it is giving thrust to family oriented schemes of economic development of SC's below poverty line by providing resources for filling the critical gaps. Sri.RenjiKurian, Kollinal, MulanthuruthyGramapanchayat President presided over the function. He briefed about the importance of organic way of cultivation. The health of ecosystem and concerned organisms can be sustained and enhanced by organic farming. All the aspects of crop production starting from farming, processing, distribution to consumption has a say in organic farming. To be specific, organic farming makes it possible to attain high quality produce, nutritious food that can help in preventive health care and well being of all inhabitants. Also as the organic farming progresses, the soil gets richer and this increases the quality of vegetables and fruits. The training programme was inaguarated by Smt. Jaya Soman, Mulanthuruthy Block President. She insisted the farmers to make maximum benefit from the class on "Organic vegetable cultivation in saline soils" and practical class on cum demonstration Preparation on biocontrol agents. She also prompted the participating farmers to cultivate the distributed vegetable seeds and coconut saplings in organic way in their field and use the biocontrol agents to eradicate pests and diseases. Sri. John Jacob, UdayamperoorPanchayat President, Smt. SudhaRajendran, Block Panchayat Developmental Standing Committee, Sri. ShajiMadhavan Nair, Vice President, Mulanthuruthy Block felicitated the training programme. Dr. Sreelatha A.K. Assistant Professor and Head, Rice Research Station, Vyttila addressed about the guidelines on utilization of special central assistance to scheduled castes sub plan and its importance. Smt. RenjiniMohanan, a participant in the training delivered the vote of thanks during the training session. Dr. Deepa Thomas, Assistant Professor (Agronomy), AMPRS, Odakali conducted a class on "Organic vegetable cultivation in saline soils" and a practical cum demonstration class on the preparation and use of bio control agents. The training programme concluded at 4 pm. The inputs such as vegetable seeds (4 packets), coconut seedlings (2 Nos.) and biocontrol agents (Verticillium, Pseudomonas, Beauveria and Trichodermaspp and vegetable trap) were distributed to the farmers.

- 200 kg seeds of newly released saline tolerant rice variety VTL 11(Jyotsna) has been distributed to 4 scheduled caste farmers in *Pokkali* area (Plate 6.5).
- High yielding varieties of vegetable seeds have been distributed to 10 SC framers
- Biocontrol agents- Pseudomonas and Verticillium have been distributed to 10 SC farmers
- Soil health cards have been distributed to above farmers
- Recommendations for salinity management in *Pokkali* fields were given to SC farmers in Kadamakudypanchayat in association with gramapanchayat

Plate 6.5 Distribution of inputs in skill development training programme at Mulamthuruthy block

7. GENERAL

7.1 Organization
7.2 Mandate of Cooperating Centres
7.3 Staff Position
7.4 Weather Data
7.5 List of Publications
7.6 Finance

7.1 ORGANIZATION

The All India Coordinated Project on Use of Saline Water in Agriculture was first sanctioned during the IVth Five Year Plan under the aegis of Indian Council of Agricultural Research, New Delhi at four research centres namely Agra, Bapatla, Dharwad and Nagpur to undertake researches on saline water use for semi–arid areas with light textured soils, arid areas of black soils region, coastal areas and on the utilization of sewage water respectively. During the Fifth Five Year plan, the work of the project continued at the above four centres. In the Sixth Five Year Plan, four centres namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water Management and Soil Salinity were transferred to this Project whereas the Nagpur Centre was dissociated. As the mandate of the Kanpur and Indore centres included reclamation and management of heavy textured alkali soils of alluvial and black soil regions, the Project was redesignated as All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture. Two of its Centres located at Dharwad and Jobner were shifted to Gangavati (w.e.f. 01.04.1989) and Bikaner (w.e.f. 01.04.1990) respectively to work right at the locations having large chunks of land afflicted with salinity problems. During the Seventh Plan, Project continued at the above locations. During Eighth Five Year Plan, two new centres at Hisar and Tiruchirappalli were added. These Centres started functioning from 1 January 1995 and 1997 respectively. Further, during Twelfth Five Year Plan, four new Volunteer centres namely Bathinda, Port Blair, Panvel and Vyttila were added to this AICRP. These four centres started functioning from 2014.

As per recommendations of QRT (2011-2017) of ICAR-CSSRI, Karnal, Indore centre was converted from main cooperating centre to volunteer centre. The Kanpur and Port Blair centre were closed on 31 March 2020. During 2017-2020 Plan, Project continued with an outlay of Rs. 2522.18 lakh at these centres with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The ICAR share was of Rs. 1980.60 Lakh while state share was of Rs. 541.58 Lakh. The year wise actual allocation in terms of ICAR share for financial year 2017-18, 2018-19, 2019-20 and 2020-21 were Rs. 615.00 Lakhs, Rs. 649.67 Lakhs, Rs. 527.03 Lakhs and Rs. 560.70 Lakhs, respectively.

7.2 MANDATES OF COOPERATING CENTRES

Centre Wise Mandate (as finalized in Annual Review Meeting 04-05 June 2018)

In view of scientific staff position reduction from 37 to 16 during SFC 2017-20, research prioritization exercise was done during Annual Review Meeting of the scheme held at ICAR- CSSRI, Karnal during 04-05 June 2018. After discussion with all concerned including ICAR nominated experts, priority areas for each centre was finalized. Priority research areas of the centres, which will continue during 2020-2025, are provided below (Table 7.1).

Table 7.1. Research priorities for different centres

Sr. No.	Name of the Centre	Priority Areas for Research
	Main Cooperating Centres	
1	Agra	• Survey and mapping of groundwater quality • Use of poor quality water use including waste water • Screening for salt tolerance • Survey and mapping of Salt Affected Soils (with ICAR-CSSRI)
2	Bapatla	• Survey and mapping of groundwater quality of AP • Conjunctive use of fresh and saline water with emphasis on *doruvu* technology upscaling • Reclamation and management of irrigation induced salinization (including sodification). • Alternate land use
3	Bikaner	• Survey and mapping for ground water quality of Rajasthan • Use of saline water through micro irrigation for vegetables/field/horticultural crops etc.
4	Gangavathi	• Reclamation and management of irrigation induced salinization (including sodification). • Subsurface drainage including controlled drainage • Micro irrigation in drainage areas/ shallow water areas/ poor quality area • Map of SAS of TBT command area
5	Hisar	• Ground water quality mapping of Haryana • Micro irrigation for saline water use along fertility treatments • Screening for salt tolerance
6	Tiruchirappalli	• Ground water survey and mapping for groundwater quality in coastal Tamil Nadu • Reclamation and management of alkali water and irrigation induced sodification • Rain water harvesting based conjunctive use • Screening of crops and varities for sodicity tolerance
	Volunteer Centres	
7	Akola	• Survey and mapping of groundwater quality • Management of saline /alkali groundwater for irrigation • Dryland salinity/sodicity management • Screening for salt tolerance
8	Bathinda	• Ground water quality mapping of South West Punjab • Land Shaping Technology for waterlogged saline soils (in collaboration with CIFE Rohtak Centre and CSSRI fishery scientist)
9	Indore	• Control of Resodification in Sodic Vertisols • Revised/Updated map of ground water quality and SAS in MP • Irrigation water management for sodic Vertisols • Alternate land use • Updated map of SAS in Madhya Pradesh (with ICAR-CSSRI)
10	Panvel	• Survey and mapping of ground water quality of Konkan region • Rainwater harvesting based IFS models • Increasing cropping inetnsity during rabi season (Establishment of vegetable crops during the Rabi season through management practices)
11	Vytilla	• Mapping of groundwater quality/ SAS in the coastal Kerala • Integrated farming system including management of acid sulphate soils

Existing and proposed mandate for the AICRP

Name of the scheme (Present):

AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture,
ICAR-Central Soil Salinity Research Institute, Karnal, Haryana- 132001

Proposed:

In the NRM Division meeting dated 18 Nov. 2019, the issue of revision of the title of AICRP was discussed and the following title was finalised.

"AICRP on Management of Saline Water & Associated Salinization in Agriculture"

Objectives of the scheme (Present):

Survey and characterization of the salt affected soils and ground water quality in major irrigation commands.

- Evaluate the effects of poor quality waters on soils and crops and plants.
- Develop standards/guidelines for assessing the quality of irrigation waters.
- Develop management practices for utilization of waters having high salinity/alkalinity and toxic ions.
- Develop and test technologies for the conjunctive use of poor quality waters in different agro-ecological zones/major irrigation commands.
- Develop alternate land use strategies for salt-affected soils
- Screen crop cultivars and tree species appropriate to saline/alkali soil conditions.

Proposed:

- Survey, characterization and mapping of groundwater quality for irrigation purpose
- Evaluation of effects of poor quality groundwater irrigation on soils and crops under different agro-climate conditions
- Development of management practices for irrigation induced salinization / guidelines for saline water irrigation (including micro irrigation) under different agro-climatic regions
- Screen crop cultivars and tree species appropriate to soil salinity and alkalinity conditions

7.3 STAFF POSITION

Sanctioned staff positions at centres as per SFC 2017-20 are provided in Table 7.2 and as per 2021-26 are provided in Table 7.3 and Table 7.4.

Table 7.2 Sanctioned staff position at the cooperating centres as per approved SFC 2017-20 (1-4-2018)

Category	Agra	Bapatla	Bikaner	Gang–avathi	Hisar	Indore	Kanpur	Tiruchir-appalli	Total
Scientific	2	2	2	2	2	2	2	2	16
Technical	2	2	2	2	2	2	1	2	15
Administrative	1	0	0	0	0	0	0	0	01
Supporting	1	0	0	0	0	0	0	0	01
Total	**6**	**4**	**4**	**4**	**4**	**4**	**3**	**4**	**33**

Table 7.3 Sanctioned staff positions at the cooperating centres as per SFC 2021-26 proposal (Status on 31-12-2020)

Category	Agra		Bapatla		Bikaner		Gangavathi		Hisar		Tiruchirappalli		Total	
	San.	Filled	San.	Filled	San.	Filled	San.	Filled	San.	Filled	San.	Filled	San.	Filled
Scientific	2	2	2	2	2	1	2	2	2	2	2	2	12	11
Technical	2	2	2	2	2	1	2	2	2	2	2	2	12	11
Admini-strative	1	1	0	0	0	0	0	0	0	0	0	0	01	01
Supporting	1	1	0	0	0	0	0	0	0	0	0	0	01	01
Total	**6**	**6**	**4**	**4**	**4**	**2**	**4**	**4**	**4**	**4**	**4**	**4**	**26**	**24**

Table 7.4. Details of centre wise staff positions (31-12-2020)

S. No	Designation	No. of posts sanctioned	No. of posts vacant	Name of the employee posted	From	To	Remarks
	Agra						
1	Jr. Soil Physicist	1	0	Dr. R.B. Singh	30.11.1987	Contd.	Filled
2	Jr. Agronomist	1	0	Dr. S.K.Chauhan	15.03.1996	Contd.	-do-
3	S.T.A. (Soils)	2	0	Dr. R.S.Chauhan	01.08.1991	Contd.	-do-
				Dr. P.K. Shishodia	11.07.1994	Contd.	-do-
4	U.D.C.	1	0	Mr. Rajeev Chauhan	04.09.1991	Contd.	-do-
5	Lab. Assistant	1	0	Mr. Sarnam Singh	18.12.1989	Contd.	-do-
	Bapatla						
1	Principal Scientist (Agro.) & Head	1	0	Dr. Y. Radha Krishna	19-07-2018	Contd.	Filled
2	Principal Scientist (Soil Science)	1	0	Dr. M.V.S. Naidu	23-07-2018	04-10-2019	Filled
	Senior Scientist (SS)			Dr. P. Venkata Subbaiah	05-10-2019	Contd.	Filled
3	Agril. Extn. Officer	2	0	1.Sri S. Baba Vali	05-09-2018	Contd.	Filled
				2.Sri M. Venkata Rao	02-01-2012	Contd.	Filled
	Bikaner						
1	Chief Scientist (in scale of Professor) Discipline of Soil Science	1	0	Dr. Ranjeet Singh, Assoc. Prof.	04.01.2019	Contd.	Filled
2	Scientist (in scale of Asstt. Prof.) Discipline of Agronomy / Soil water Conservation Engg.	1	1	Er. A. K. Singh, Assoc. Prof.	10.09.2001	30.06.2020	Superannuated
3	Field Technician/ Asstt.	1	1	Vacant		30.04.2019	Vacant
4	Lab. Technician	1	0	Sh. S.K. Bazad, Lab. Asstt.	14.02.1994	Contd.	Filled

	Gangavathi						
1.	Principal Scientist (Soil Sci)	1	0	Dr. Vishwanath J.	04.01.2012	Contd.	Filled
2.	Scientist (Drainage Engg.)	1	0	Er. A.V. Karegoudar	12.12.2009	Contd.	Filled
3.	Lab Assistant	1	0	Mr. Prakash Banakar	04.01.2012	Contd.	Filled
4.	Field Assistant	1	0	Mr. Ramappa Talwar	12-12-2009	Contd.	Filled
	Hisar						
1.	Scientist (Agronomy)	1	0	Dr. Satyavan, Principal Scientist (Agronomy)	11.03.1997	31-01-2016	Filled
			0	Officer-in-charge	01.02.2016	Contd.	
2.	Soil Scientist	1	0	Dr. Ram Prakash Assistant Scientist	24.05.2011	Contd.	Filled
3.	Field Tech./Field Assistance	1	1	Sh. Umed Singh Agriculture Inspector	07.02.2017	31.01.2019	Superannuated
				Sh. Bhagwan Dass Agriculture Inspector	03.12.2020	Contd.	Filled
4.	Lab. Tech.	1	0	Sh. Bhanwar Singh	1.11.2018	Contd.	Filled
	Tiruchirapalli						
1	Chief Scientist (Soil Science)	1	0	Dr. P. Balasubramaniam	02.03.2016	Continuing	Filled
2	Scientist (Agronomy)	1	0	Dr. A.Alagesan	07.04.2015	Continuing	Filled
3	Field Technician	1	0	Mr. K. Karikalan	09.06.2014	24.11.2019	Deceased
				Tmt. A.Arivuselvi	22.06.2020	Continuing	Filled
4	Laboratory Technician	1	0	Mr. P. Sakthivel	01.07.2016	Continuing	Filled

Indore as main cooperating centre upto 31st March 2020

S. No.	Sanctioned Post	No. of Post filled	Name of the employee posted	From	To	Remarks
1	Chief Scientist	1	Dr. U. R. Khandkar	02-09-2008	16-10-2018	The centre was converted from Main to volunteer centre as per approved QRT (2011-2017) Recommendations.
			Dr. K.S. Bangar	17-10-2018	31-03-2020	
2	Jr. Agronomist	1	Dr. Narendra Kumawat	15-05-2018	31-03-2020	
3	Lab. Asstt.	1	Ms. R. Ansari	16.11.1995	31-03-2020	
4	Field Asstt.	1	Sh. N.S. Tomar	04.04.1996	31-03-2020	

Kanpur as main cooperating centre upto 31st March 2020

S. No.	Sanctioned Post	No. of Post filled	Name of the employee posted	From	To	Remarks
1	Soil Chemist	1	Dr Ravendra Kumar	09-05-2008	31-03-2020	The centre was closed as per approved QRT (2011-17) recommendations from 1-04-2020.
2	Asstt. Agronomist	1	Shri S.N.Pandey	01-07-2009	31-03-2020	
3	Field Asstt.	1	Dr. Ved Prakash	16-08-2014	31-03-2020	

Nodal officers and SRFs at Volunteer Centres

S. No	Designation	No. of posts sanctioned	No. of posts vacant	Name of the employee	From	To
1	**Bathinda**					
	Nodal Officer	1	0	Dr. Brijesh Kumar Yadav	16.05.2014	Contd.
	SRF	2	2	NA	NA	
2	**Indore**					
	Nodal Officer	1	0	Dr. KS Bangar	01-04-2020	Contd.
	SRF	2	2	NA	NA	
3	**Panvel**					
	Nodal Officer	1	0	Dr Suresh Dodake	1-06-2017	30-06-2020
				Dr. KV Vaidya	1-07-2020	Contd.
	SRF	2	1	Smt. SS Khobragade	1-07-2021	Contd.
4	**Vytilla**					
	Nodal Officer	1	0	Dr. AK Sreelatha	3.07.2014	Contd.
	SRF	2	1	Dr. Irene Elizabeth John	05.08.2019	31.03.2020
				Ms.Nisha Paul	19.11.2020	Contd.

7.4 WEATHER DATA (2019-20)

Main Centres

AGRA

Latitude - $27^0$20' N Longitude - $77^0$90' E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)	Water table (m)
	Maximum	Minimum				
2019						
January 2019	21.5	6.3	92.5	15.0	1.3	19.7
February	23.1	10.3	89.1	7.0	1.7	19.8
March	29.8	13.7	84.5	0.5	3.4	19.9
April	39.0	22.2	87.7	22.0	5.9	20.0
May	40.5	25.5	46.1	-	8.2	20.3
June	41.7	28.5	57.4	44.3	7.1	20.4
July	35.6	27.5	71.8	253.4	4.2	20.4
August	33.9	27.3	81.7	156.5	2.1	20.5
September	32.3	25.6	81.4	226.7	2.3	20.5
October	34.3	20.5	71.2	14.3	2.5	20.6
November	29.0	16.4	69.9	7.1	1.8	20.6
December	25.0	9.2	77.0	13.0	1.2	20.5
2020						
January	19.6	8.2	84.9	24.2	1.0	21.0
February	25.5	10.6	73.9	-	1.8	21.2
March	28.9	15.6	75.2	80.1	3.2	21.2
April	36.7	21.2	59.5	54.4	5.6	21.3
May	40.4	25.0	54.9	35.6	5.7	21.6
June	39.1	27.4	61.4	3.9	5.6	21.6
July	37.2	28.1	75.0	132.1	4.4	21.9
August	33.6	26.1	87.9	247.1	2.0	21.3
September	36.5	26.0	79.0	5.0	3.4	21.3
October	35.0	19.8	67.2	0.0	3.6	21.2
November	28.5	12.6	72.3	0.0	1.7	21.2
December	22.7	9.5	77.0	0.0	1.4	21.2

BAPATLA

Latitude - 15^{o} 54’ N   Longitude - 80^{o} 28’ E

Month	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)	Rainy days
	Maximum	Minimum	Maximum	Minimum		
2019						
January	29.5	16.7	87	66	2.0	0
February	31.3	20.5	85	68	4.1	1
March	33.0	24.0	80	71	0	0
April	34.7	26.1	79	73	0	0
May	37.3	28.9	77	73	0	0
June	38.4	28.7	70	64	91.8	2
July	34.6	26.3	77	70	237.1	11
August	34.0	25.9	79	69	98.0	7
September	32.4	25.7	83	75	225.0	9
October	31.0	24.9	86	81	257.2	10
November	31.3	22.7	86	74	30.0	2
December	29.8	20.3	86	70	1.4	0
2020						
January	29.7	20.5	85	67	79.8	2
February	30.7	20.6	82	62	10.7	1
March	32.7	22.9	80	63	0	0
April	34.6	25.6	80	68	4.9	1
May	35.9	28.2	75	66	10.2	1
June	36.5	27.0	71	63	84.91	9
July	33.4	25.5	84	75	180.1	13
August	32.1	25.3	82	71	139.9	10
September	32.7	25.5	80	72	338.8	10
October	32.0	24.9	83	71	67.02	7
November	30.4	21.9	83	69	222.8	7
December	29.7	18.7	86	59	0	0

* **Note:** The data of Evaporation is not available at Saline Water Scheme, Bapatla.

BIKANER

Latitude – 28° 01' N Longitude – 73° 35' E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)	Wind velocity (km/hr)
	Maximum	Minimum	Maximum	Minimum			
2019							
January	22.1	5.9	85.3	36.8	2.7	2.8	3.5
February	23.5	7.8	82.9	38.3	0.0	3.8	4.9
March	30.5	13.1	69.8	34.1	1.8	5.6	5.2
April	39.6	22.6	87.6	76.6	31	9.9	6.1
May	41.4	25.4	72.2	53.5	9	12.2	7.4
June	43.4	29.4	85.9	66.8	12.8	12.1	8.8
July	39.8	28.7	77.4	55.2	40.6	9.0	11.5
August	36.3	26.7	84.2	63.9	128.2	8.4	6.3
September	38.0	26.0	87.4	60.9	16.2	10.1	4.89
October	34.6	18.6	71.6	39.5	28.8	10.0	3.4
November	27.1	12.8	84.2	48.6	27.2	7.8	3.5
December	20.9	5.0	86.8	45.1	6.8	6.2	3.1
2020							
January	20.0	5.1	85.9	49.3	21.8	6.5	3.8
February	27.0	8.0	76.6	31.3	0.0	9.6	4.1
March	29.6	14.1	73.4	32.3	29.8	5.0	6.1
April	37.7	21.0	58.5	26.9	7.0	9.1	6.4
May	42.3	25.2	55.3	26.0	29.4	11.3	8.2
June	42.5	28.0	57.9	35.6	2.0	11.2	10.5
July	40.6	27.9	71.4	46.9	13.4	9.0	10.1
August	37.6	27.0	80.8	55.3	128.9	6.4	8.6
September	37.5	24.9	75.4	46.3	15.6	9.3	4.7
October	35.3	16.8	55.6	20.1	0.0	8.7	3.4
November	28.5	9.4	62.0	35.7	1.2	8.4	3.1
December	24.2	5.5	72.4	36.4	0.0	8.2	3.3

GANGAVATHI

Latitude – 15° 00’N Longitude – 76° 00’ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation* (mm/day)
	Maximum	Minimum	8.0 AM	2.0 PM		
2019						
January	29.3	13.7	68.2	30.7	3.60	2.85
February	33.2	17.7	56.6	23.7	0	3.21
March	37.6	19.8	48.1	17.7	0	3.58
April	39.2	24.6	48.6	17.1	9.60	4.93
May	38.6	24.4	49.7	19.9	7.60	5.83
June	34.9	24.4	60.5	33.9	45.2	4.17
July	32.1	23.5	67.0	42.9	41.5	4.00
August	30.8	23.2	70.3	48.7	37.9	3.21
September	29.7	22.8	77.3	58.3	251.4	2.95
October	30.5	21.9	90.0	55.8	160.9	2.48
November	30.0	19.5	82.6	45.5	6.10	2.86
December	28.7	17.5	88.3	40.7	6.30	2.58
2020						
January	30.61	17.96	70.19	29.31	0	2.10
February	31.55	18.00	57.61	25.84	0	2.76
March	34.12	20.12	45.66	25.62	0	3.45
April	39.0	15.0	48.1	21.7	25.1	3.67
May	39.0	12.0	49.8	22.2	56.5	3.48
June	39.0	22.0	57.4	34.2	87.8	1.93
July	33.0	22.0	67.0	41.5	140.2	1.07
August	33.0	22.0	62.5	39.8	74.4	1.42
September	34.0	22.0	66.4	41.2	141.4	1.63
October	33.0	18.0	70.2	32.3	67.3	1.74
November	33.0	13.0	61.6	20.5	11.0	2.07
December	32.0	13.0	58.5	13.6	0	2.06

HISAR

Latitude - 29° 10′ N Longitude - 75° 46′ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	M	E		
2019						
January	19.2	5.2	94	60	13.8	1.1
February	20.4	8.0	92	59	0.3	1.6
March	26.5	10.4	87	43	6.0	3.0
April	36.7	18.4	68.8	26.9	15.5	6.5
May	39.0	21.6	59.2	25.5	59.8	7.6
June	40.5	25.8	68	33.4	104.10	7.8
July	35.4	25.7	81.8	63	120.4	4.9
August	34.7	26.1	86	63	96.1	4.3
September	34.2	25.1	83.6	52.9	29.9	4.5
October	32.6	17.9	84.8	37.6	2.6	3.5
November	26.9	12.9	88.9	45.7	12.3	2.1
December	17.1	5.7	94.4	67.7	4.5	1.1
2020						
January	17.1	5.2	97	66	1.0	10.4
February	22.7	6.8	93	51	2.1	10.9
March	25.9	12.4	92	56	3.2	6.0
April	34.1	17.6	74	33	5.1	5.3
May	39.4	22.6	61	27	8.3	36.2
June	38.2	26.1	72	42	6.7	48.8
July	36.0	26.9	87	63	6.1	172.9
August	34.8	26.6	89	69	4.6	62.0
September	36.0	24.3	88	52	4.6	39.5
October	34.4	14.8	81	26	4.1	0.0
November	26.1	9.9	89	40	2.0	19.9
December	21.6	5.0	93	41	1.4	0.0

KARNAL

Latitude – 29° 43’ N Longitude – 76° 58’ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)	Wind Velocity (km/hr)
	Maximum	Minimum	Maximum	Minimum			
2019							
January	18.9	5.84	98.32	57.15	28.8	1.39	3.15
February	20.4	7.05	96.46	65.39	20.8	1.65	7.84
March	25.13	11.01	92.94	54.97	7.4	3.16	7.77
April	35.43	18.59	74.5	31.37	0.26	6.32	10.91
May	38.62	21.76	57.39	26.65	0.66	9.32	8.93
June	38.59	26.20	67.53	43.0	18.3	9.05	12.35
July	33.08	26.33	90.32	74.35	244.8	4.71	10.85
August	32.97	26.12	94.55	78.1	101.2	3.40	1.95
September	33.07	24.99	95.66	71.66	13.4	3.57	2.99
October	31.2	18.24	98.19	56.68	2.0	2.84	1.93
November	27.06	13.42	94.33	51.4	15.0	2.29	2.55
December	16.67	7.38	98.52	71.61	24.2	1.01	2.31
2020							
January	16.2	6.6	99.0	74.0	74.4	1.5	3.0
February	21.0	7.9	97.0	62.0	21.4	2.0	3.4
March	25.3	12.4	95.0	62.0	161.7	3.0	3.9
April	33.3	17.0	77.0	37.0	25.6	5.1	4.0
May	36.8	22.0	69.0	39.0	66.8	7.7	5.8
June	35.9	25.7	84.6	59.4	103.9	6.3	5.5
July	33.5	26.3	93.7	76.0	440.6	4.5	5.2
August	32.9	26.5	95.0	81.3	384.0	3.5	3.9
September	34.3	25.1	95.0	70.6	0.0	4.0	2.1
October	33.3	16.4	94.7	47.1	0.0	3.6	1.3
November	26.2	10.6	95.6	56.7	43.6	2.2	1.7
December	20.1	7.0	97.9	71.5	2.4	1.2	1.9

TIRUCHIRAPPALLI

Latitude – 10° 45’ N Longitude – 78° 36’ E

2019

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)	Wind velocity (km/hr)
	Maximum	Minimum	Average			
January	31.1	20.7	71	-	3.5	4.0
February	34.8	22.9	65	-	5.8	4.9
March	37.3	24.5	58	-	7.9	5.3
April	39.5	25.6	53	3.2	8.0	5.3
May	41.2	27.3	54	37.3	6.8	6.3
June	37.0	27.4	57	17.0	9.6	6.7
July	38.3	26.2	50	17.6	9.3	9.9
August	32.7	25.6	63	49.2	7.1	8.8
September	36.2	27.0	62	132	6.7	7.6
October	34.5	23.9	69	162	3.1	3.6
November	31.4	24.3	75	89.9	2.9	3.2
December	31.5	22.2	69	89.4	2.7	3.3

2020

Month/year	**Temperature**		**Relative Humidity %**		**Rain fall** (mm)	**Evaporation** (mm/day)
	Max	Min	Morning	Evening		
January	32.8	21.4	88.8	55.4	0.4	3.1
February	33.4	21.7	86.3	42.5	0.0	6.3
March	37.0	23.5	84.5	47.3	0.0	6.6
April	38.5	25.6	78.9	39.8	0.4	6.8
May	39.3	27.7	72.8	41.5	0.6	7.1
June	38.1	27.0	68.6	38.0	3.9	7.5
July	35.6	26.0	75.9	45.7	3.5	5.6
August	35.5	26.0	73.2	43.5	3.6	6.6
September	34.4	24.9	83.0	48.8	5.4	4.2
October	34.3	24.4	79.1	43.6	2.9	5.3
November	32.6	23.5	87.3	53.7	4.7	3.9
December	29.9	22.7	78.9	56.4	3.9	1.7

Volunteer Centres

BATHINDA

Latitude – 30° 23' N Longitude – 74° 95' E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)	Wind velocity (km/hr)
	Maximum	Minimum	Morning	Evening			
2019							
January	18.7	5.3	97.5	52.6	6.2	2.15	1.1
February	20.6	8.1	89.8	56.4	24.6	2.59	1.0
March	26.6	11.4	79.2	43.1	10.6	5.41	1.3
April	36.7	19.6	63.7	40.4	15.8	10.65	1.8
May	39.6	21.9	55.9	32.1	31.0	11.39	1.5
June	41.2	26.1	56.3	36.2	32.0	12.05	1.9
July	35.9	25.9	80.6	65.1	397.4	5.48	1.6
August	35.5	26.1	84.9	63.7	61.2	6.27	0.9
September	34.9	25.3	85.6	63.2	9.0	6.61	0.8
October	32.1	17.9	81.8	49.4	5.6	4.96	0.4
November	26.6	12.6	86.8	59.0	30.6	2.79	0.7
December	16.9	6.0	90.9	64.7	9.2	1.28	0.7
2020							
January	16.3	6.7	90.8	68.6	30.2	1.48	0.8
February	22.9	8.1	86.4	49.7	17.6	3.50	1.4
March	25.5	12.7	86.2	56.8	73.3	4.00	5.4
April	33.6	16.8	74.3	41.7	7.8	9.49	1.4
May	38.9	21.7	62.6	28.5	27.6	12.03	10.9
June	38.8	26.6	65.1	41.5	42.0	11.38	1.8
July	35.6	26.9	82.7	61.2	218.2	7.39	1.7
August	35.2	26.9	85.2	69.4	79.8	7.19	1.4
September	36.1	24.7	85.7	59.1	66.6	5.81	0.6
October	34.3	15.9	77.4	45.5	0.0	5.63	0.3
November	26.6	9.2	82.6	42.1	6.8	2.98	0.4
December	20.6	6.0	91.3	57.2	0.4	1.95	0.6

INDORE

Latitude – 22° 14’ N Longitude - 76° 01’ E

Month	Temperature (°C)			HR (%)	Rainfall (mm)	Evaporation (mm/day)
	Max	Min	Mean	Mean		
2019						
January	10.10	18.25	45.86	45.86	-	2.00
February	28.11	13.35	21.91	40.85	-	2.61
March	32.81	17.32	26.07	31.28	-	7.77
April	38.38	22.13	31.10	25.48	-	11.8
May	39.80	25.01	33.70	26.63	-	15.5
June	37.73	25.50	31.65	52.62	52.9	12.4
July	30.27	23.46	26.83	78.50	256.6	5.1
August	27.17	22.54	24.63	90.23	250.6	1.4
September	27.75	22.44	24.91	89.46	211.6	1.4
October	28.92	20.17	24.58	70.68	79.8	2.5
November	28.61	17.93	23.49	67.11	-	2.8
December*	24.73	13.74	19.49	68.58	-	2.0
2020						
January	23.50	11.41	17.56	69.03	-	2.0
February	27.59	13.65	21.23	51.16	-	3.9
March	31.09	16.87	24.56	41.51	-	7.8
April	36.96	22.76	31.00	25.92	-	11.7
May	40.14	26.03	36.79	28.26	1.0	15.9
June	33.05	23.33	29.05	67.73	451.9	4.1
July	31.07	23.42	28.55	76.37	185.9	3.0
August	27.86	22.61	25.32	89.04	443.7	1.1
September	31.55	22.23	26.87	77.85	275.2	2.0
October	32.59	20.24	27.17	51.40	2.3	3.2
November	28.89	13.96	22.06	45.18	-	3.8
December*	26.06	11.76	19.13	54.67	14.6	1.7
* 1 Dec - 27 Dec						

PANVEL

Latitude – 18° 59’ N　　　　Longitude – 73° 06’ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)	Wind velocity (km/hr
	Maximum	Minimum				
			2019			
January	33.89	15.12	83.3	0	1.14	2.27
February	34.85	17.18	81.6	0	1.67	3.22
March	36.42	19.52	77.9	0	2.21	4.27
April	37.63	23.95	79.7	0	2.92	6.23
May	36.28	25.80	77.1	0	2.85	6.02
June	33.33	26.33	85.5	593	0.64	7.13
July	28.80	24.29	92.4	2079	0.14	6.91
August	29.64	24.37	90.4	741.2	0.13	8.40
September	29.03	24.94	94	1211	0.83	4.62
October	32.84	24.19	89.3	176.2	1.18	1.59
November	33.35	21.91	85.4	23.00	1.47	2.39
December	33.59	20.64	85	0.00	0.25	2.49
			2020			
January	32.35	17.61	79.58	0.0	2.46	2.68
February	35.58	18.78	78.38	0.0	3.43	3.02
March	35.37	21.03	71.77	0.0	4.80	5.91
April	37.43	25.31	79.26	0.0	6.10	8.71
May	36.97	27.88	78.39	0.0	5.88	8.29
June	32.81	25.65	86.7	274.2	1.98	6.63
July	29.73	24.71	94.0	890.6	0.75	5.34
August	28.96	24.0	95.9	1389.8	0.07	4.02
September	31.27	24.0	94.4	729.6	0.70	0.33
October	33.61	24.02	91.8	235.8	1.39	-
November	35.87	20.0	82.3	0.0	2.40	-
December	34.20	18.97	85.0	20.2	1.61	-

VYTTILA

Latitude –9^{0}5’35’’ N Longitude 76^{0}19’18’’

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
2019						
January	31.1	23.2	77.0	54.4	NIL	2.6
February	31.9	24.0	82.2	55.3	41.0	3.4
March	32.4	25.0	83.0	57.0	5.0	3.5
April	32.5	26.3	89.0	60.0	74.0	3.6
May	33.1	25.7	84.0	64.0	18.5	3.2
June	30.9	24.4	87.0	73.0	342.0	2.9
July	28.9	25.7	91.0	79.0	503.5	2.7
August	28.9	23.3	93.0	81.0	900.0	2.3
September	33.1	25.5	91.0	74.0	534.0	2.7
October	35.9	26.0	89.0	69.0	772.5	2.7
November	31.2	23.8	88.0	63.0	146.0	2.7
December	30.0	21.0	85.0	63.0	118.0	2.5
2020						
January	32.3	22.6	77.0	61.0	NIL	2.9
February	32.4	23.6	82.0	61.0	37.5	2.6
March	31.8	25.3	89.0	65.0	NIL	3.0
April	32.7	26.1	89.0	66.0	20.5	3.1
May	32.3	25.1	91.3	68.2	164.5	3.2
June	30.1	23.9	87.1	76.5	383.5	2.3
July	29.6	23.8	92.5	74.1	535.0	2.5
August	29.3	24.3	89.9	76.2	256.1	2.5
September	30.1	24.0	91.1	65.4	519	2.5
October	30.6	24.1	84.5	71.2	139.4	2.6
November	31.2	23.9	86.8	69.2	83.3	2.1
December	31.0	22.4	89.5	60.1	15.4	2.6

PORT BLAIR

Latitude – 11° 36' N   Longitude – 92° 42' E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)	Wind velocity (km/hr)
	Maximum	Minimum	Average			
2019						
January 2019	30.0	24.6	72	125.8	-	9.5
February	31.1	24.1	71	0.0	-	5.5
March	31.3	23.4	69	50.8	-	5.0
April	33.1	25.4	68	17.9	-	5.5
May	32.4	25.6	78	336.6	-	10.2
June	29.9	24.2	83	691	-	17.5
July	30.8	25.1	84	165.6	-	15.3
August	28.8	24.0	84	1098.8	-	17.0
September	29.1	24.1	84	540	-	11.3
October	31.6	24.9	78	270.2	-	7.5
November	31.0	24.7	78	194.5	-	7.0
December	30.3	24.9	73	1.8	-	7.7

7.5 LIST OF PUBLICATIONS (2019-20)

AGRA

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Singh PK, Anees M, Kumar M, Yadav KG, Kumar A, Kumar Mukesh, Sharma Ritesh, Singh RB and Kumar S (2019). Effect of integrated nutrient management on growth, yield and quality of moongbean (*Vigna radiate* L.). *Journal of Pharmacognosy and Phytochemistry*, SP2: 1003-1006.

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PANVEL

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VYTTILA

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7.6 FINANCE

The Three Year Plan (2017–2020) was sanctioned by the Council vide letter No. NRM-24--1/2017-IA-II dated 23-11-2017 with an outlay of Rs. 2522.18 lakh at these centres with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The ICAR share was of Rs. 1980.60 Lakh while state share was of Rs. 541.58 Lakh. The year wise actual allocation in terms of ICAR share for financial year 2017-18, 2018-19 and 2019-20 were Rs. 615.00 Lakhs, Rs. 649.67 Lakhs and Rs. 527.03 Lakhs, respectively. The budget head and Centre wise statement of expenditure for 2018-19 and 2019-20 is given below:

Main Centres

1. **Agra (100% ICAR Share)**

SN	Details	2018-19		2019-20	
		Released	**Expenditure**	**Released**	**Expenditure**
1	Capital	0.00	0.00	0.00	0.00
2	Salary	7614000.00	7082679.00	12200000.00	12195677.00
3	TA(SWS)	30000.00	29624.00	51000.00	49484.00
4	TA(ORP)	20000.00	19654.00	20000.00	15214.00
5	Res.Cont.(SWS)	100000.00	90816.00	100000.00	97042.00
6	Res.Cont.(ORP)	25000.00	24597.00	35000.00	33854.00
7	Operational(SWS)	205000.00	198392.26	290000.00	288603.00
8	Operational(ORP)	100000.00	99796.00	50000.00	46201.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	60000.00	0.00
11	Misc. Other items	10000.00	9200.00	10000.00	9800.00
	Total	**8104000.00**	**7554758.26**	**12816000.00**	**12735875.00**

2. **Bapatla (75% ICAR Share)**

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	7800000.00	4542754.00	4600000.00	4936031.00
3	TA(SWS)	40000.00	36609.00	17000.00	10110.00
4	TA(ORP)	20000.00	16755.00	25000.00	18116.00
5	Res.Cont.(SWS)	100000.00	125000.00	100000.00	99995.00
6	Res.Cont.(ORP)	25000.00	24825.00	25000.00	24806.00
7	Operational(SWS)	180000.00	210000.00	200000.00	199954.00
8	Operational(ORP)	135000.00	99070.00	100000.00	99971.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	60000.00	59929.00
11	Misc. Other items	10000.00	9962.00	10000.00	9986.00
	Total	**8310000.00**	**5064975.00**	**5137000.00**	**5458898.00**

3. Bikaner (75% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	8375000.00	4530299.00	8700000.00	4871355.00
3	TA(SWS)	25000.00	20480.00	40000.00	28766.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	75000.00	52782.00	100000.00	0.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	210000.00	198193.00	200000.00	207870.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	60000.00	59830.00
11	Misc. Other items	10000.00	10000.00	10000.00	0.00
	Total	**8695000.00**	**4811754.00**	**9110000.00**	**5167821.00**

4. Gangavathi (75% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	4200000.00	2417915.00	4100000.00	2953441.00
3	TA(SWS)	50000.00	49982.00	37000.00	21135.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	110000.00	110000.00	100000.00	100000.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	260000.00	258893.00	236000.00	233517.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	50000.00	48326.00
11	Misc. Other items	10000.00	10000.00	10000.00	2927.00
	Total	**4630000.00**	**2846790.00**	**4533000.00**	**3359346.00**

5. Hisar (75% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	2500000.00	4674910.00	3500000.00	3833452.00
3	TA(SWS)	25000.00	24863.00	30000.00	11508.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	75000.00	75000	100000.00	42054.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	190000.00	189952.00	210000.00	55323.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	40000.00	27850.00
11	Misc. Other items	10000.00	10000.00	10000.00	5010.00
	Total	**2800000.00**	**4974725.00**	**3890000.00**	**3975197.00**

6. Indore (75% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	10100000.00	5121909.00	4900000.00	4713443.00
3	TA(SWS)	40000.00	35320.00	30000.00	28412.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	75000.00	56280.00	90000.00	84242.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	210000.00	198540.00	210000.00	203776.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	50000.00	0.00
11	Misc. Other items	10000.00	10000.00	10000.00	7495.00
	Total	**10435000.00**	**5422049.00**	**5290000.00**	**5037368.00**

(Note: Indore centre acted as main centre upto 31st March 2020 and thereafter started acting as volunteer centre.)

7. Kanpur (75% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	8000000.00	4280388.00	4600000.00	5092783.00
3	TA(SWS)	50000.00	49997.00	40000.00	39874.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	75000.00	74981.00	90000.00	89998.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	200000.00	199996.00	190000.00	189997.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	40000.00	29991.00
11	Misc. Other items	10000.00	9993.00	10000.00	10000.00
	Total	**8335000.00**	**4615355.00**	**4970000.00**	**5452643.00**

(Note: Kanpur centre was closed on 31st March 2020 as per approved QRT (2011-17) recommendations.

8. Tiruchirapalli (75% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	4200000.00	3504827.00	4067000.00	4947292.00
3	TA(SWS)	55000.00	55000.00	100000.00	94541.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	120000.00	120000.00	180000.00	180000.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	260000.00	260000.00	240000.00	240000.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	89000.00	89000.00	175000.00	175000.00
11	Misc. Other items	10000.00	10000.00	10000.00	10000.00
	Total	**4734000.00**	**4038827.00**	**4772000.00**	**5646833.00**

Volunteer Centres

1. Bathinda (100% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	0.00	0.00	0.00	0.00
3	TA(SWS)	30000.00	11836.00	30000.00	14018.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	100000.00	57277.00	100000.00	95374.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	350000.00	198382.00	200000.00	181098.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	20000.00	18025.00
11	Misc. Other items	10000.00	0.00	10000.00	10000.00
	Total	**490000.00**	**267495.00**	**360000.00**	**318515.00**

2. Panvel (100% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary			0.00	0.00
3	TA(SWS)	50000.00	47230.00	30000.00	17520.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	120000.00	115648.00	100000.00	78818.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	344000.00	340256.00	250000.00	250000
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	21000.00	21000.00	40000.00	8767.00
11	Misc. Other items	5000.00	5000.00	10000.00	9905.00
	Total	**540000.00**	**529134.00**	**430000.00**	**365010.00**

3. Port Blair (100% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	0.00	0.00	0.00	0.00
3	TA(SWS)	0.00	0.00	0.00	0.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	100000.00	46000.00	100000.00	98089.00
6	Res.Cont.(ORP)	0.00	0.00	0	0.00
7	Operational(SWS)	350000.00	105022.00	200000.00	182664.00
8	Operational(ORP)	0.00	0.00	0.00	0.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	0.00	0.00	0.00	0.00
11	Misc. Other items	10000.00	6600.00	10000.00	1932.00
	Total	**460000.00**	**157622.00**	**310000.00**	**282685.00**

4. Vytilla (100% Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	0.00	0.00	0.00	0.00
3	TA(SWS)	50000.00	50000.00	30000.00	30000.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	120000.00	120000	100000.00	100000.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	0.00	0.00	0.00	0.00
8	Operational(ORP)	180000.00	350000.00	250000.00	250000.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	170000.00	10000.00	35000.00	35000.00
11	Misc. Other items	10000.00	0.00	10000.00	10000.00
	Total	**530000.00**	**530000.00**	**425000.00**	**425000.00**

5. PC Unit (100% ICAR Share)

SN	Details	2018-19		2019-20	
		Released	Expenditure	Released	Expenditure
1	Capital	0.00	0.00	0.00	0.00
2	Salary	0.00	0.00	0.00	0.00
3	TA(SWS)	0.00	0.00	0.00	0.00
4	TA(ORP)	0.00	0.00	0.00	0.00
5	Res.Cont.(SWS)	80000.00	79995.00	0.00	0.00
6	Res.Cont.(ORP)	0.00	0.00	0.00	0.00
7	Operational(SWS)	726000.00	704369.00	660000.00	628584.00
8	Operational(ORP)	0.00	0.00	0.00	0.00
9	SCSP (Capital)	0.00	0.00	0.00	0.00
10	SCSP (General)	174000.00	173465.00	0.00	0.00
11	Misc. Other items	0.00	0.00	0.00	0.00
	Total	**980000.00**	**957829.00**	**660000.00**	**628584.00**


M.M BOYS
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For Further details, contact:

Project Coordinator, ICAR-AICRP (SAS&USW)
ICAR-Central Soil Salinity Research Institute
Karnal - 132 001, Haryana (India)