अखिल भारतीय समन्वित अनुसंधान परियोजना

लवणग्रस्त मृदाओं का प्रबंधन एवं खारे जल का कृषि में उपयोग

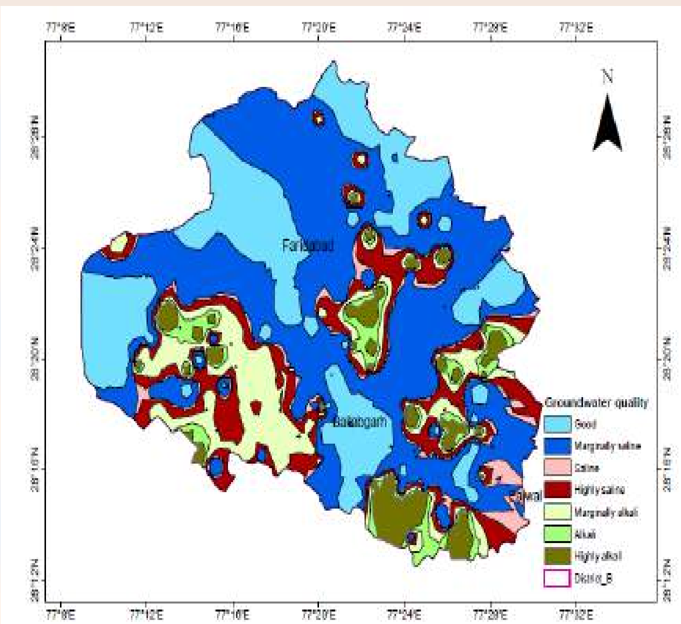
All India Coordinated Research Project

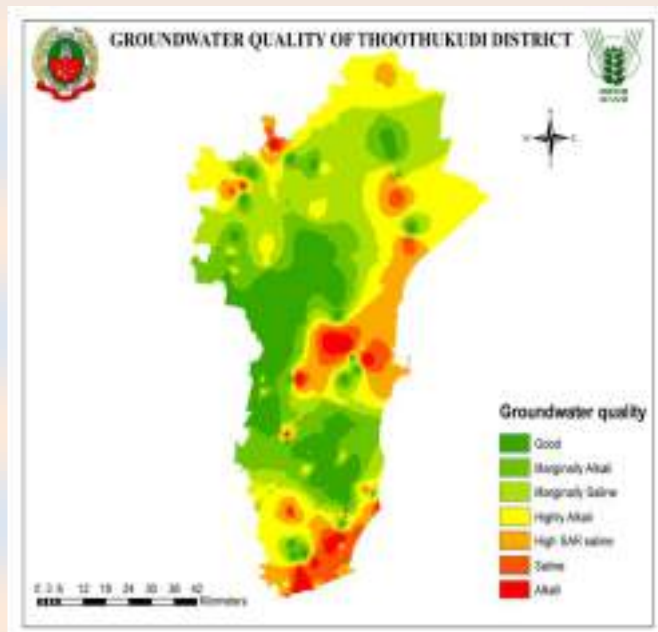
Management of Salt Affected Soils and Use of Saline Water in Agriculture

वार्षिक प्रतिवेदन

Annual Report

(2019)





परियोजना समन्वयन इकाई

भाकृअनुप–केन्द्रीय मृदा लवणता अनुसंधान संस्थान

करनाल – 132 001, हरियाणा (भारत)

Project Coordinating Unit

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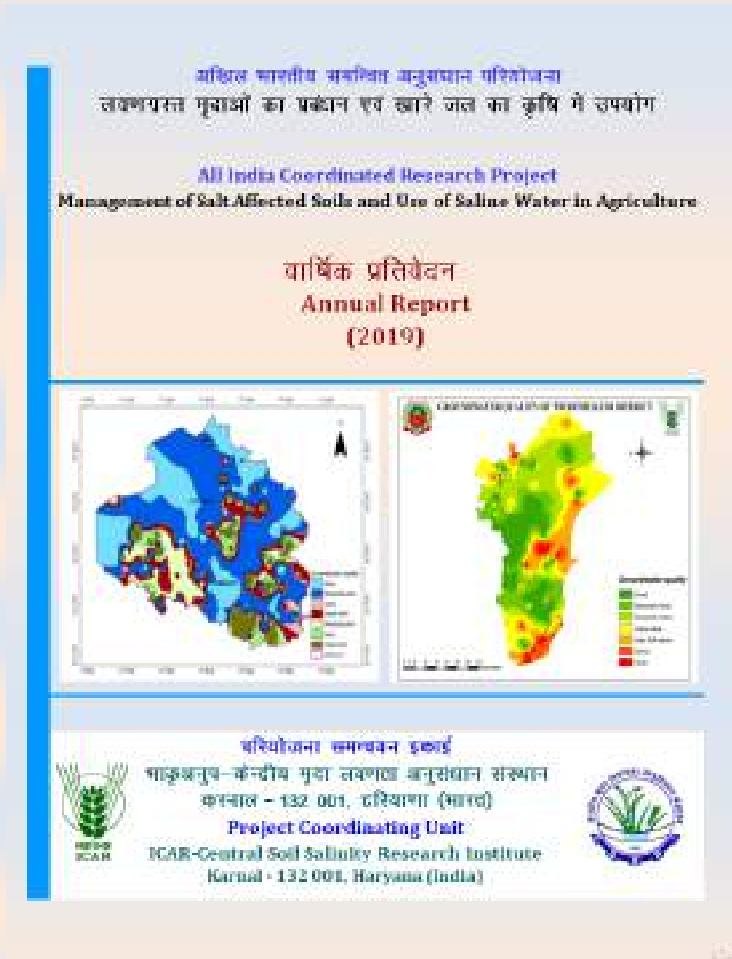

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अखिल भारतीय समन्वित अनुसंधान परियोजना
लवणग्रस्त मृदाओं का प्रबंध एवं खारे जल का कृषि में उपयोग

All India Coordinated Research Project
Management of Salt Affected Soils and Use of Saline Water in Agriculture

वार्षिक प्रतिवेदन

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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)
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3. ICAR-Central Island Agril Research Institute, Port Blair (A&N Islands)
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परियोजना समन्वयन इकाई
भाकृअनुप–केन्द्रीय मृदा लवणता अनुसंधान संस्थान
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FOREWORD

Globally about 954 Mha land is chemically degraded and it is distributed in different continents like Australia, Asia, America and Africa. Out of total degraded land of 120.70 Mha in India, salt affected land is 6.74 M ha. In view of background of inevitable pressure of feeding world population, climate change and increasing awareness about preserving natural resources, the United Nations Convention to Combat Desertification (UNCCD) provided UNCCD-2018 -2030 strategic framework to address global challenges such as desertification/land degradation and drought as they contribute to and aggravate economic, social, environmental problems such as poverty, poor health, lack of food security, bio diversity loss, water scarcity, reduced resilience to climate change and forced migration. Further, the convention discussed the concept of 'Land Degradation Neutrality (LDN)' in order to restore productivity of vast degraded lands, so as to improve livelihoods of billions. The ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) was established at Karnal (Haryana) in 1969. Since then, the Institute has made significant contributions towards the understanding of management of saline and alkali environments. 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. Both work on ecosystems, degraded due to water and salt imbalances, locally as well as regionally. Though solutions for improving salt affected ecosystems are based on corrections of water and salt balances, most of the times solutions are location specific. Hence basic and applied researches go together to find solutions for management of salt affected eco systems in different agro-ecological regions. The AICRP on SAS&USW with 12 centres has tried to give technologies to respective state departments for managing poor quality waters and reclaiming sodic and waterlogged saline soils. 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 aquifer, low cost recharge structure for poor quality semi-arid regions, 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 same have been well appreciated by planners and farmers. Thus it appears that proven technologies for LDN under salt affected ecosystems in different states are available and with financial investment from different stakeholders, forward movement towards LDN is quite possible.

At the end, efforts of Dr MJ Kaledhonkar, Project Coordinator and Dr BL Meena, Sr. Scientist in smooth running of the project are appreciated. Concerted efforts in compilation and editing of Annual Report of the scheme deserve appreciation. The help of staff of PC unit for project operations are well recorded. It would be my pleasure to extend all support to the project for addressing future challenges and achieve desirable output.

25/8/2020
(P.C. Sharma)

PREFACE

The total annual replenishable ground water recharge for India has been estimated as 432 bcm and the annual extractable ground water resource is 393 bcm. The average stage of ground water development for the country as a whole is around 63%. However, spatial availability of groundwater for irrigation and its quality are not satisfactory. Farmers are compelled to use poor quality groundwater (saline or alkali) for irrigation in arid and semi-arid regions. Irrigation induced soil salinization and alkalization are mostly observed in irrigated ecosystems of the country due to improper land and water management practices. All these things adversely affect land and water productivity and farmers have to face huge economic losses. Surprisingly, such problems are noticed in arid, semi-arid and coastal humid climate. The use of these marginal resources for agricultural purposes, in economical way, is possible through scientific management strategies which combine synergetic effect of natural resource management (NRM) strategies and biological strategies. NRM strategies give emphasis on reducing salt and water stresses in active root zone by employing different technologies. The combining of both the strategies together give much needed strength for management of these ecosystems. The AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture is a partner with ICAR-CSSRI, Karnal for management of saline and alkali problems at national level and has made significant contributions towards understanding, characterization and monitoring of salinity/ alkalinity problems of soils and of ground waters under a wide range of situations such as arid, semi-arid and coastal; devising and standardizing localized solutions and promoting those for benefits of the farmers. Newly joined centres are also doing well as they are addressing the saline-acidic (Vytilla), coastal salinity (Panvel and Port Blair) and inland salinity in Punjab (Bathinda). These issues were not intensely monitored earlier. 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 project. Heartfelt thanks are due to Dr PC Sharma, Director, ICAR-CSSRI for their excellent support to the project 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 OICs at cooperating centers; Dr RB Singh, Dr Radha Krishna, Dr AK Singh, Dr Vishwanath Jowkin, Dr Satyvan, Dr KS Bangar, Dr Ravindra Kumar and Dr P Balasubramaniam and Nodal Officers at Volunteer Centres; Dr SB Dodake, 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. All possible help from Dr BL Meena, Sr. Scientist in functioning of PC unit and compilation of annual report is highly appreciated. Support from administration and finance sections of the institute is also placed on record. I also thank other PC Unit staff members such as Shri AK Sharma, Smt. Dinesh Gugnani and Shri Pradeep for their cooperation in day to day activities.

(M J Kaledhonkar)
Project Coordinator

CONTENTS

SUMMARY OF RESEARCH ACHIEVEMENTS-2019

1. RESOURCE INVENTORIES OF SALT AFFECTED SOILS AND POOR QUALITY WATERS

1.1 Resource Inventories of Salt Affected Soils

Mapping of salt affected soils is an on-going activity aiming at classifying soils according to the nature of problem so as to help in deciding the nature of interventions needed at a location. Mapping of salt affected soils and brief results are given below.

- **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. 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 necessary for 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' = 9 x 9 km) from Siruguppa taluk in Bellary district. A total of 126 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 27 grid (52 sampling) points were collected.

The results of the study 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+SO4) ratio 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 (1:2.5), pHe, EC (1:2.5) 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. About 11 and 20% samples were with >4 dS/m 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+SO4) ratios were 79 and 65, respectively. The per cent of samples 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.

- **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)**

In general the soil samples collected from eight districts *viz.* Thiruvananthapuram, Kottayam, Kollam, Pathanamthitta, Kannur, Kozhikode, Malappuram and Kasargod were under acidic and good category. The 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 high. 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.

1.2 Resource Inventories of Poor Quality Groundwater Waters

Survey and characterization of ground water is an on-going activity aiming at classifying groundwater according to the nature of problem. The characterization of water should help in deciding the nature of interventions. Ground water quality of the following districts was surveyed. Brief results are given below.

- **Survey, characterization and mapping of groundwater quality for Mathura district of Uttar Pradesh (Agra)**

Earlier ground water quality survey of Mathura district (U.P.) was conducted during 1983-85 and recent survey was done during 2018-19, after gap after 35 years to see changes in groundwater quality. Around 406 samples were collected from Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya. It was observed that area under good quality water increased in Farah block and it was reduced in Goverdhan and Mathura block. In Baldev block, it remained almost same. No samples of good quality water were found in Chaumuha and Raya block. The major numbers of samples were observed in saline categories (i.e. marginal saline, saline and high SAR Saline) compared alkali categories. Area under high SAR category has increased in Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks. In Farah block, saline water quality area has decreased while marginal saline area has increased while marginal alkali area has increased, alkali area is absent and high alkali area remained more or less same. Marginally alkali groundwater area in Goverdhan, Mathura and Baldev blocks have decreased. However, minor changes were observed in Farah block with respect to Alkali water categories.

- **Effect of Sea Water Intrusion on Ground Water Quality in Coastal Belt of Krishna Zone Andhra Pradesh (Bapatla)**

Effect of sea water intrusion in coastal belt of Krishna zone was studied along the coastal belt of 50 km width and on 4 routes perpendicular to coast line. In each route, six villages were identified and five samples were collected in each village. Thus a total (4x6x5) of 120 points were selected by choosing thirty from each stratum considering the ingress of salinity along the coastal line. The chemical analysis of samples revealed that ground water quality varied from neutral to slightly alkaline/ saline at different sampling locations. Among the cations, sodium was dominant whereas among the anions chlorides were dominant. In general all the cations, anions, SAR and RSC were higher in pre-monsoon period as compared to post monsoon period. During pre monsoon period the highest EC (29.00) was observed in ground water of Bapatla route whereas the highest SAR (23.95) was observed in ground water of Kanaprthy route. Higher EC values were observed along Machilipatnam route (0.60-19.00 dS m^{-1}) followed by Nizampatnam route (0.80-18.00 dS m^{-1}), Kanaparthi route (0.30-10.20 dS m^{-1}) and Bapatla route (0.60 – 10.00 dS m^{-1}) in post monsoon-2018. In general, sea water intrusion was observed up to a distance of 30 km from the sea as Na/Cl ratio was >0.86, Ca/Mg was > 1 and Cl -/(CO32- +HCO3-) ratio is > 1.

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

Groundwater quality mapping of Nellore district was done during 1993-94 and it was done again during 2018-19 to see changes in quality parameters. It was observed that area under good quality water reduced from 39 to 38%; area under marginally saline water increased from 6.2 to 22.4%. Saline water area increased from 0.4 to 6.9 % and High SAR saline water area increased from 2.6 to 4.9 %.

- **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 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 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.

- **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 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 meL-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}).

- **Estimation of fluoride in ground water for Mansa, district, Punjab (Bathinda)**

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

Survey, characterization and mapping of ground quality of eleven districts of Kerala viz. Thiruvanamthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragode was done. 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, 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, respectively.

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

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 from these bore wells was 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 6.2. In general, the quality of irrigation water in shallow bore wells of sandy soils is in permissible limit.

2. MANAGEMENT OF SALT AFFECTED SOILS

2.1 Management of Alkali Soils

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

Grain and straw yield of wheat were significantly influenced by various tillage systems and mulch during the experimentation. 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 application of mulch did not influence grain yield significantly. 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). The significantly lowest value of ECe (1.39 dS/m) was recorded under conventional tillage followed by reduced tillage (1.47 dS/m) and highest in zero tillage (1.73 dS/m). ESP as 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).

- **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)**

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. Up on characterization of different gypsum sources, the quantity requirement of different gypsum source required will be calculated and experiment will be taken with soil application of the respective gypsum.

2.2 Management of Saline and Saline Waterlogged 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 the existing 50 m lateral spacing (2.8 ha) SSD experiment, additional 40 (2.62 ha) and 60 m (4.0 ha) lateral spacing SSD systems were initiated at Agricultural Research Station, Gangavathi during Rabi-Summer 2013-14. Over seven seasons, the mean surface (0-15 cm) soil salinity (ECe) reduced from 8.05 (initial) to 4.12 (K-18), 4.30 to 1.30; 7.69 to 2.85 dS/m and 7.33 to 2.35; 6.28 to 0.98 and 5.99 to 2.79 dS/m under conventional and controlled SSD at 40 m and 50 m and 60 m spacing respectively. The average drain discharge during Kharif 2018 was 0.68 vs. 0.24, 1.82 vs. 0.38 and 0.52 vs. 0.30 mm/d under conventional and controlled SSD at 40, 50 and 60 m spacing respectively. The average over seven seasons it was 0.67 vs. 0.30, 2.01 vs. 0.48 and 0.93 vs. 0.62 mm/day under conventional and controlled SSD respectively. The average salinity of drainage water over seven seasons was 3.78 vs. 3.08, 2.13 vs. 2.20 and 2.91 vs. 2.12 dS/m and salt removal was 0.56 vs. 0.22, 0.97 vs. 0.40 and 0.65 vs. 0.25 t/ha under conventional and controlled SSD at 40, 50 and 60 m spacing respectively. Similarly, the loss of N was 1.75 vs. 0.57, 5.44 vs.2.27 and 3.94 vs. 2.39 kg/ha with the paddy grain yield was from 47.3 vs. 41.3, 54.0 vs. 47.2, and 55.3 to 51.6 q/ha under conventional and controlled SSD at 40, 50 and 60 m spacing, respectively.

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

A field experiment was laid out at Thimmapur village (Farmers field) in an area of 2 ha block with three treatments i.e., Controlled SSD with 50 m spacing each with a raised of lateral head upto root zone, 0.3 m and 0.6 m including conventional, fixed and variable outlet heads during Kharif 2015. The QRT suggested to complete reclamation leaching by conventional drainage before controlled drainage. Therefore, during Rabi/summer 2018 and Kharif 2018, paddy was transplanted in all the seven blocks except the first block and conventional drainage was made operational. The average drain discharge from the individual lateral (7 Nos) during *Kharif*-2018 was 0.73 mm/d, salinity of the drainage effluent was 3.85 dS/m and amount of salt removed was about 0.87 t/ha through drainage effluent. The average paddy grain yield was 36.3 q/ha which is 10-12 per cent higher compared previous years' yield. At crop harvest during Kharif-18, out of seven blocks the surface (0-15 cm) soil salinity (ECe) reduced from 16.2 to 14.8 (block II), 7.54 to 5.15 (block III), 11.0 to 7.37 (block V) and 10.7 to 6.0 dS/m (block VI) whereas not much change was observed in other blocks. Similar reductions were observed at lower depths in these blocks.

- **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 organics and raised bed on Okra (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 (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.

- **Rain water storing in ponds for desalination of coastal saline soil on Farmers field (Panvel)**

Soil data adjacent to pond showed that leaching of salts was successful in 0-500 m area surrounding the pond as result of seepage of water from rainwater harvesting pond. This is an additional advantage from such ponds which are used for fish farming. This reclaimed land can be used effectively for growing vegetables or pulses during rabi season immediately after harvest of rice crop using residual moisture and some water from fish pond.

2.3 Management of Saline–acidic soils

- **Integrated farming system for sustainable land use in Pokkali lands – vegetable cultivation (Vyttila)**

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 yield obtained from winter season vegetable 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.

- **Rice – prawn integration in *Pokkali* (Vyttila)**

The 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. The B:C ratio for rice cultivation was 2.00, for prawn cultivation was 2.57 and integration was 2.33.   In this system the growth of both the components are interrelated and is one of the proven technology which is very cost effective *Pokkali* lands (saline acidic soils) of Kerala.

3. MANAGEMENT OF POOR QUALITY WATERS

3.1 Management of Alkali water

- **Use of Alkali ground water to supplement canal water for irrigation in Toria- Chikori crop rotation (Agra)**

The Toria and Chikori crop rotation was studied under different modes of conjunctive water use of canal and alkali water. The RSC of alkali water was 10 meq/l. The canal water irrigation gave highest yield. In case of conjunctive use mode, the initial canal water irrigation was beneficial for crops. The yield was adversely affected due to alkali water irrigation and adverse effect was more if crop was irrigated by alkali water during initial stages. The yield varied from 10.03 to 14.03 q/ha, lowest in alkali water and highest in canal water with B:C ratio as 1.70 and 2.38, respectively. The Chikori yield also varied according is conjunctive water use. It was lowest (181.9 q/ha) in alkali water and highest (302.9 q/ha) in canal water with benefit cost ratio of 1.94 to 3.2. The maximum system yield was observed in the treatment with all canal water irrigation (316.93 q/ha), and minimum in the treatment with all irrigations with alkali water (191.93 q/ha). Other better performing treatments were 1CW:1AW, 2CW:2AW and cyclic 2CW:1AW.

- **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.

3.2 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}.

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

An 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 (0.25, 2.4 dS/m, 6 dS/m and 8 dS/m). Results indicated that different treatments had significant effect on growth, yield attributes and yields of cumin. Increase in ECiw beyond 6 dS/m caused significant reduction in seed yield. As compared to 0.25 dS/m, 2.4, 6 and 8 dS/m caused yield reduction of 4.87, 6.63 and 33.72 per cent, respectively. Similar trends were noticed in almost 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.

- **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.

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

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

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

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.

- **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.

- **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)**

The observational trial to study effect of different levels of organic manures and mulching on yields of vegetables was conducted on experimental field of Panvel farm during rabi 2018-19 and the yield of vegetables was recorded. It was 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.

3.3 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 during *kharif* season, the crop cauliflower was sown in rabi season and okra crop was sown in summer season. Maximum net profit (Rs/ha) and B:C ratio were recorded in sewage water irrigation treatments for all crops and minimum in Tube well water irrigation treatment. Maximum net profit (Rs/ha) and B:C ratio were found in case of recommended dose of fertilizer (100% RDF) and lowest in 50% recommended dose of fertilizer treatment for all crops. The interaction effect of irrigation water with recommended dose of fertilizer on yields of cluster bean, cauliflower and okra crop was found to be significant. The maximum yield of particular crop was recorded in case of sewage water and with 100% RDF, which was significantly higher than rest of combinations.

4. ALTERNATE LAND MANAGEMENT

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

Six fodder crops (T1- Stylo-Stylosanthus, T2-Hedge lucerne, T3- Lucerne, T4- Fodder sorghum (panthchari-6), T5- COFS-29 (fodder jowar) and T6- 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.

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

An 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 indicate that different treatments had significant effect on growth, yield attributes and yields of cumin. Increase in ECiw beyond 6 dS/m caused significantly reduction in seed yield. As compared to ECiw of BAW with ECiw 2.4, 6 and 8 dS/m caused reduction of 4.87, 6.63 and 33.72 per cent, respectively. Similar trends were noticed in almost all the parameters studied.

5. SCREENING OF CROP CULTIVARS AND GENOTYPES

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

The centre conducted AVT trial for Mustard crop for saline water irrigation. 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 in genotype CSCN 18-4 (1646.60 kg/ha).

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

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)**

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)**

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.

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

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, ECiw 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/m2) 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/m2) 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/m2. In AVT, the mustard genotypes CSCN-18-2 gave the highest seed yield (200.88 g/m2) followed by

CSCN-18-7 (200.48 g/m2) at ECiw 7.5 dS/m and the lowest seed yield (161.27/m2) was obtained in CSCN-18 -9.

- **Screening of rice, wheat and mustard varieties/genotypes in sodic soil (Kanpur)**

The average grain yield of rice varied from 22.63-44.29 q/ha in different varieties. 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. The minimum yield 22.63 q/ha was obtained from CSR-30.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. The minimum yield 27.94 q/ha was obtained from WH-147. 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. The minimum yield 10.88 q/ha was obtained from Urvasi.

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

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.

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

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.

- **Assessment of salt tolerance efficiency of wheat cultivars (Bathinda)**

It was found that Unnat PBW 550 and PBW 725 had maximum no of seeds/ear followed by HD 2967. However, maximum grain yield was reported in variety Unnat PBW 343 followed by HD 3086, Unnat PBW 550 and PBW 725 under saline and normal conditions. The better performance of these varieties (Unnat PBW 343,HD 3086, Unnat PBW 550 and PBW 725) than KRL 210 may be due to soil salinity in the tube well irrigated field was less than threshold soil salinity for wheat (i.e. ECe 4 dS/m).

6. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

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

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.

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

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)**

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)**

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) –(Tirichirapalli)**

The AICRP on SAS&USW are involved in SCSP activities. However, Tiruchirapalli centre is concentrating on Manikandam Block of of Tiruchirappalli where SC population is sizable and sodic soils are affecting crop yields. The field surveys were undertaken in the Manikandam Block for the identification of beneficiary areas. Seventy five families were identified as beneficiaries under the SCSP. Activities for the distribution of soil health card, various agricultural inputs, imparting training and demonstration activities will be undertaken.

INTRODUCTION

The All India Coordinated Project for Research on Use of Saline Water in Agriculture was first sanctioned during the Fourth 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 and Soil Salinity Management 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 redesigned 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. 1.4.1989) amd Bikaner (w.e.f. 1.4.1990), respectively, to work right at the locations having large chunks of land afflicted with salinity problems. During the Seventh Plan, the project continued at the above locations. During Eighth Five Year Plan, Two new centres at Hisar and Tirruchirapalli were added. These centres started functioning from Ist January 1995 and 1997, respectively. During the Tenth Plan, the project continued with the same centres with an outlay of Rs. 1090.00 lakh. During the Eleventh Plan, Project Continued with an outlay of Rs. 2125.15 Lakh with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. 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. The project continued at following 12 centres and Coordinating Unit at ICAR-CSSRI, Karnal with total outlay for period 2017-2020 of Rs. 2522.18 lakhs which included ICAR and State share as Rs 1980.60 lakhs and Rs.541.58 lakh, respectively. 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.

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.

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)

Mandate

- Survey and characterization of salt affected soils and ground water quality in major irrigation Commands.
- Evaluate the effects of poor quality waters on soils and crop plants.
- Develop management practices for utilization of waters having high salinity/alkalinity and toxic ions.
- Develop and test technology for the conjunctive use of poor quality waters in different agro–ecological zones/major irrigation commands.
- Screen crop cultivars and tree species appropriate to salinity and alkalinity soil conditions
- Develop alternate land use strategies for salt affected soils (Agro-forestry).

Within the mandated tasks, following activities were initiated or strengthened at various centers

- Generation of data bases on salt affected soils and poor quality waters along with survey of bench mark sites.
- Environmental impacts of prawn culture and ground water pumping on groundwater quality in coastal districts of Andhra Pradesh
- Micro-irrigation system for saline water use to high value crops; to develop crop production functions with improved irrigation techniques
- Conjunctive use of alkali water in Kavery Delta and Uttar Pradesh for different crop rotations
- Use of treated alkali water through drip system for cash crops
- Safe use of polluted water of Agra canal for crop production
- Water quality limits for new cropping pattern for saline and alkali waters
- Development of new sources of fresh water for conjunctive use (Rainwater harvesting) and groundwater recharge
- Management of abandoned aquaculture ponds
- Seawater intrusion and modelling
- Extension of Doruvu technology and test cheaper alternatives for skimming of fresh water floating on saline water
- Re-sodification of reclaimed alkali lands and comparative performance of various amendments
- Dry land reclamation technologies
- Land drainage of waterlogged saline lands and controlled drainage for saving of irrigation water and nutrients
- Conservation agriculture/multi-enterprise agriculture/ multiple use of water/ IFS models
- Alternate land management including cultivation of unconventional medicinal and aromatic plants

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 statements of expenditure for 2016-17, 2017-18 and 2018-19 are given in the Section 7.6.

1. RESOURCE INVENTORIES OF SALT AFFECTED SOILS AND POOR QUALITY WATERS

1.1 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. 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 Siruguppa taluk in Bellary district. A total of 126 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 27 grid (52 sampling) points were collected. The results of chemical analysis of samples are given in Table 1.1 and 1.2.

Table 1.1 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 1.2. 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+SO4) 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 pHsw, pHe, 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+SO4) 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.

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

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^o 17’ to 23^o 20’ N & 75^o 50" to 77^o 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 1.3).

Table 1.3. 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 1.3 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 1.4).

Table 1.4. Area and distribution of salt affected soils in Dewas district

Category	**Tehsil**	**Area (in ha)**
Slight Saline	Dewas	361
	Hatpipliya	175
	Bagli	192
	Udaynagar	140
	Khategaon	140
Moderate Saline	Dewas	231
	Kannod	70
Slight Alkali	Tonkkhurd	194
	Sonkatchh	287
Moderate Alkali	Tonkkhurd	354
	Sonkatchh	60
Strong Alkali	Tonkkhurd	249
	Sonkatchh	83
Slight Saline Moderate Alkali	Tonkkhurd	89
Slight Saline Strong Alkali	Sonkatchh	28
Moderate Saline Strong Alkali	Sonkatchh	49
	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. 1.1).

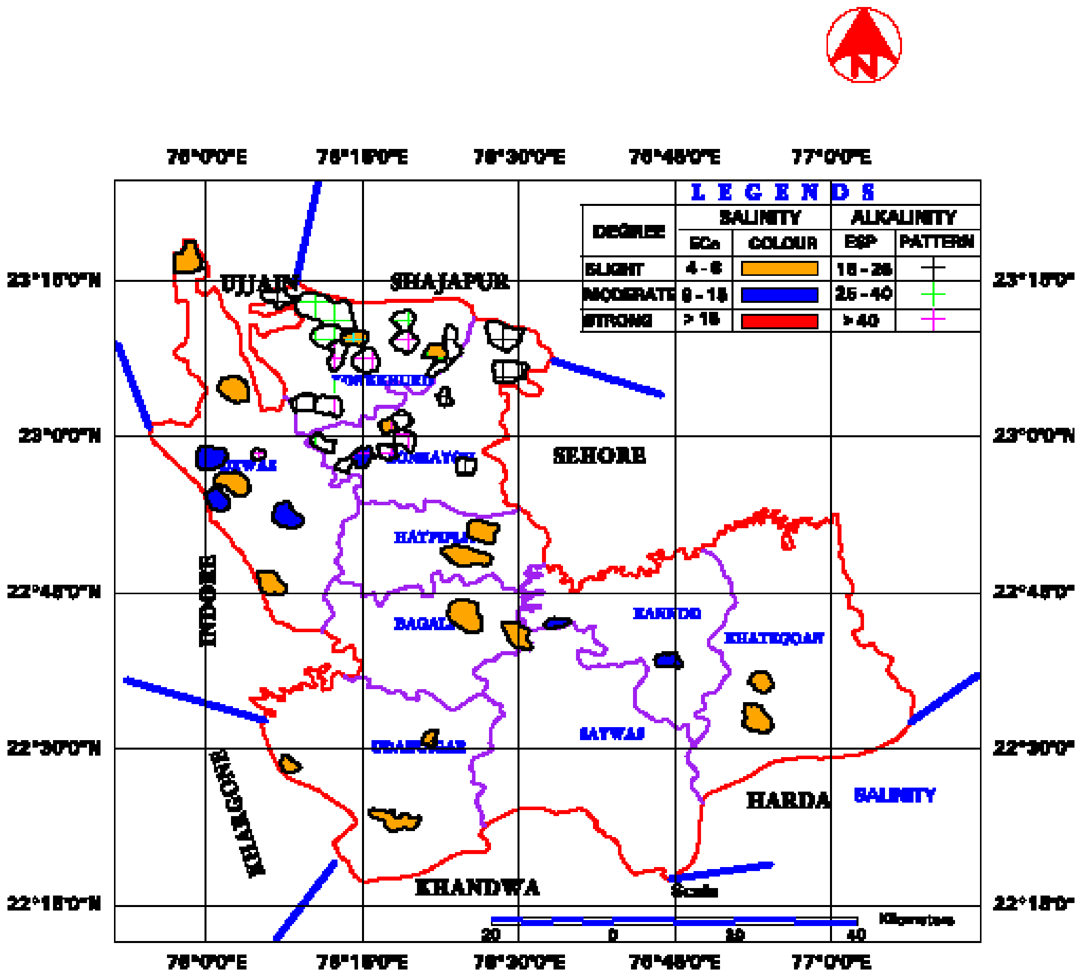
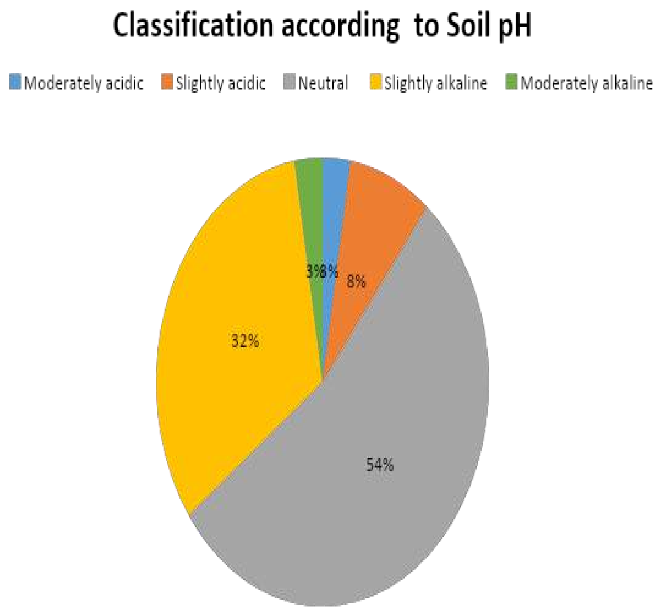


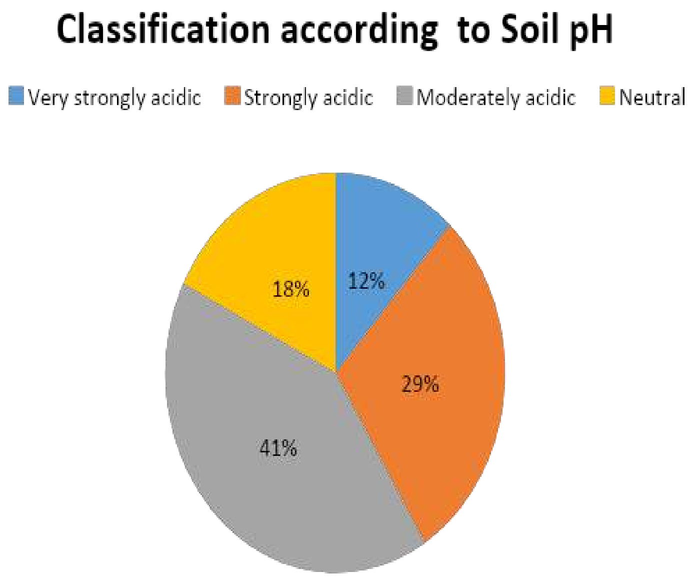
Fig. 1.1 Salt affected soils of Dewas district of MP

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

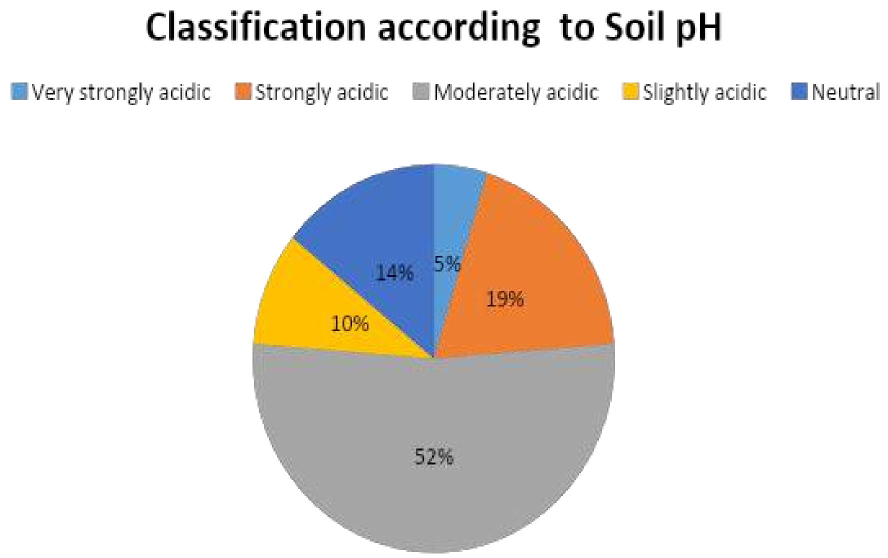
Georefernced soil samples from the coastal area of eleven districts of Kerala viz. Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod were collected and analyzed for pH, electrical conductivity, sodium, potassium, calcium, 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. 1.2.



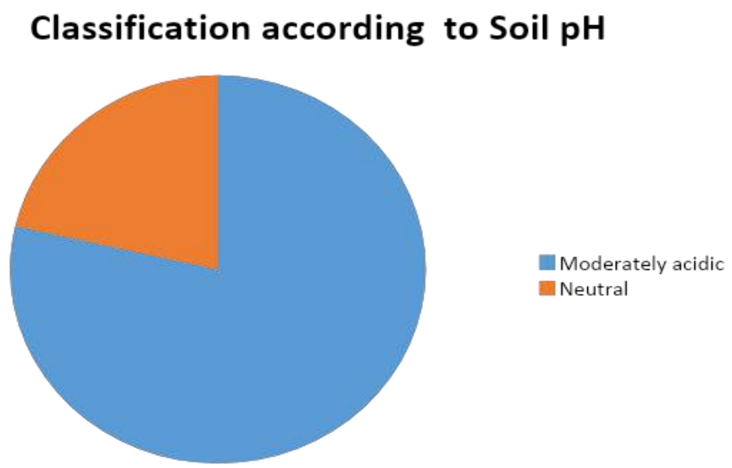
Thiruvanathapuram



Kottayam



Kollam



Pathanamthitta

Fig. 1.2 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.

1.2 Resource Inventories for Poor Quality Groundwater

- **Survey, characterization and mapping of groundwater quality for Mathura district of Uttar Pradesh (Agra)**

The ground water survey in six blocks (viz. Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya) of Mathura district in Uttar Pradesh was initiated again approximately after 32 years in year 2017. Earlier survey was done in 1983-85. Total 406 samples were collected mostly from December to March, when the maximum number of tube wells were under use for irrigation purpose and analyzed for different water constituents for their quality. The water samples were analyzed for pH, EC, Cations (Ca, Mg, Na and K) and Anions (CO_3, HCO_3, Cl and SO_4). Quality parameters like SAR and RSC were calculated. Classification of water quality is done on the basis of EC, SAR and RSC values as suggested by CSSRI, Karnal (Table 1.5).

Table 1.5 Grouping of quality irrigation waters for irrigation in India

Quality of water	**EC (dS/m)**	**SAR (mmol/l)$^{1/2}$:**	**RSC (me/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 1.6. 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 me/l was recorded in Mathura block followed by 15.6 and 15.0 me/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 block, respectively.

Table 1.6 Minimum and maximum values of different water constituents in Farah, Goverdhan, Mathura , Baldev, Chaumuha and Raya blocks of Mathura District

Blocks Name	EC (dSm^{-1})		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

Note: Mean RSC is mean of positive RSC values.

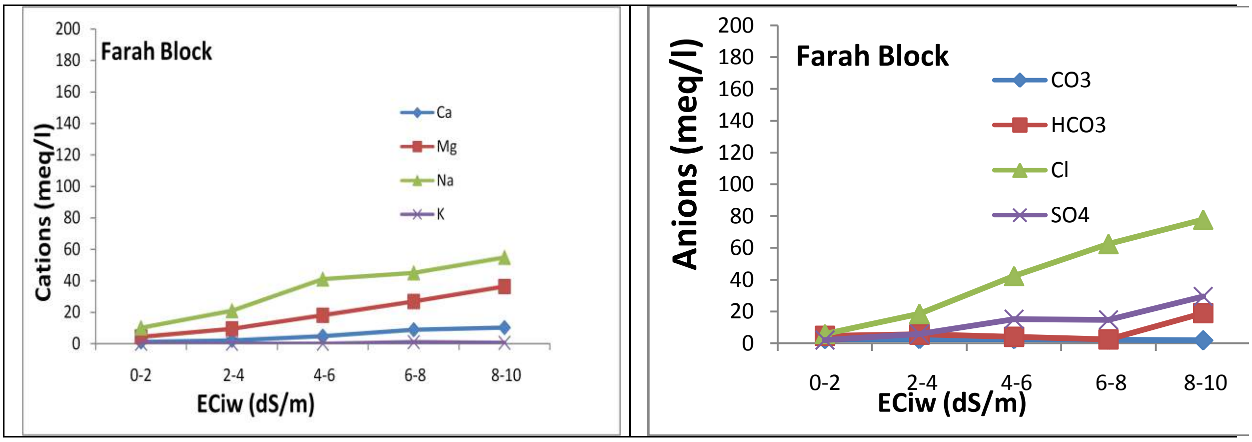
The distribution of water samples in different EC, SAR and RSC classes are presented in Table 1.7. According to EC classes 40.3, 14.5, 34.7, 21.7,45.8 and 31.8 per cent samples of were found in 1.5-

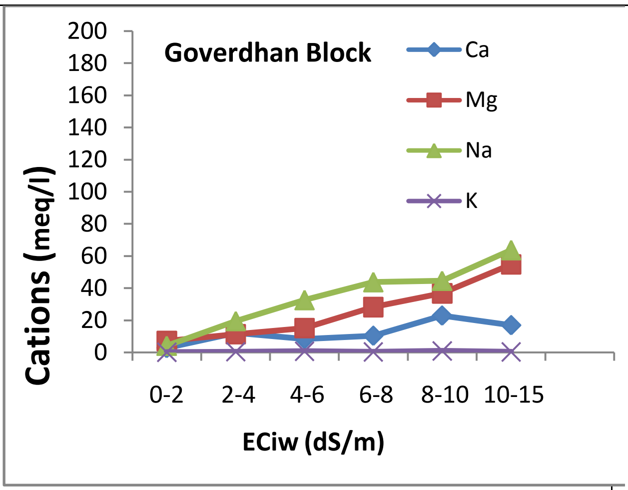
3.0 dS/m category, 23.9, 30.6, 23.6 ,31.3, 28.8 & 23.8 per cent in 3.0-5.0, while 25.4, 45.2, 20.8 , 28.9, 13.5 and 38.1 per cent samples in 5.0-10.0 dS/m category in Farah, Goverdhan, Mathura , Baldev , Chaumuha and Raya blocks were found respectively. More than 75 per cent samples in surveyed blocks were having RSC <2.5 me/l except Farah and Raya block. In category >10.0 me/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 and 4.8 per cent samples of Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya were recorded.

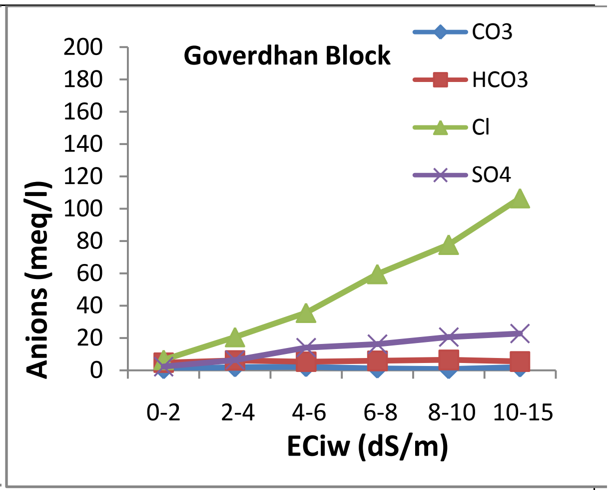
Table 1.7 Frequency distribution of water samples in different EC, RSC and SAR classes of Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks of Mathura district

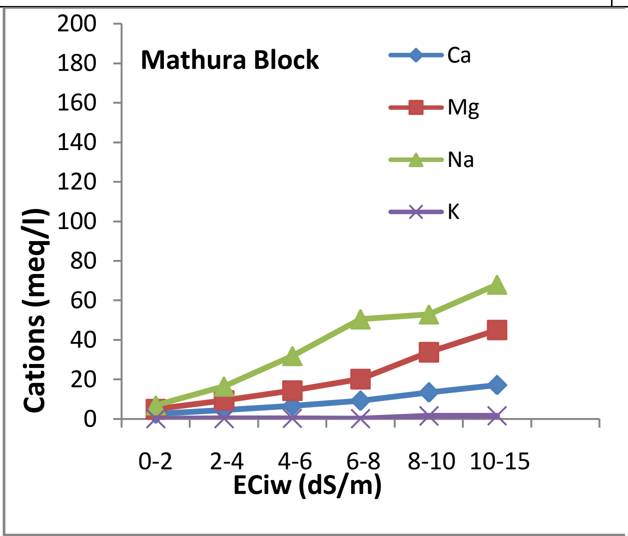
Particulars/ blocks	Farah (67)	Goverdhan (62)	Mathura (72)	Baldev (83)	Chaumuha (59)	Raya (63)
EC Classes						
0- 1.5	10.4	1.6	11.2	14.5	-	-
1.5- 3.0	40.3	14.5	34.7	21.7	45.8	31.8
3.0- 5.0	23.9	30.6	23.6	31.3	28.8	23.8
5.0-10.0	25.4	45.2	20.8	28.9	13.5	38.1
>10.0	-	8.1	9.7	3.6	11.9	6.3
RSC Classes						
Absent	65.7	93.5	84.7	73.5	61.0	69.8
0-2.5	6.0	6.5	5.6	10.8	16.9	3.2
2.5- 5.0	17.9	-	6.9	7.2	11.9	17.5
5.0-10.0	8.9	-	-	7.2	10.2	7.9
>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
10-20	32.8	40.3	29.2	56.6	65.1	68.2
20-30	4.5	3.2	4.2	6.0	7.9	4.8
30-40	-	-	1.4	1.2	-	-
>40	-	-	-	-	-	-

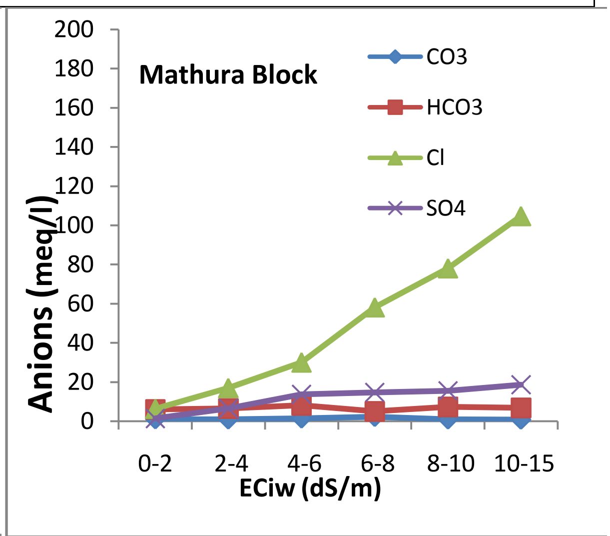
The cationic order Na>Mg>Ca>K was found in all the blocks whereas anionic order for all blocks was $Cl>SO_4>HCO_3>CO_3$. The same orders are shown in Fig. 1.3.

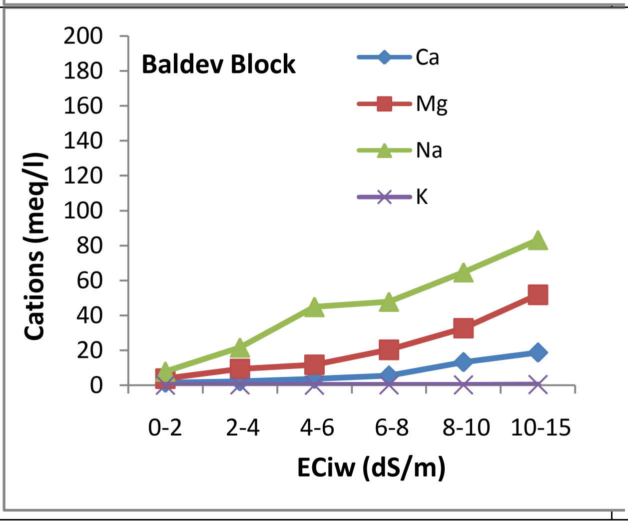


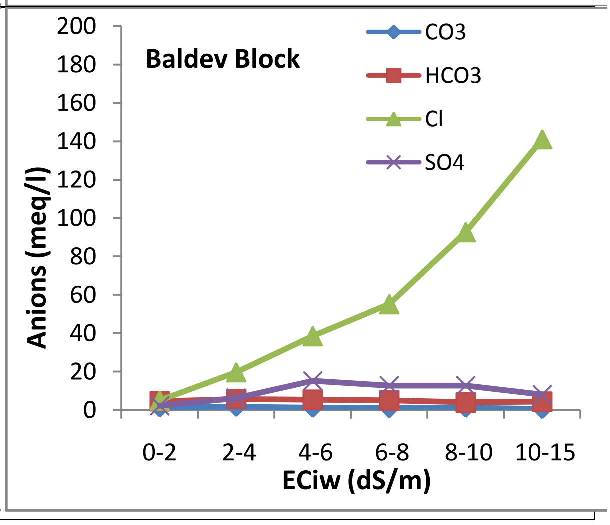

Goverdhan Block
Ca
Mg
Na
K
Cations (meq/l)
200
180
160
140
120
100
80
60
40
20
0
0-2
2-4
4-6
6-8
8-10
10-15
ECiw (dS/m)


Goverdhan Block
CO3
HCO3
Cl
SO4
Anions (meq/l)
200
180
160
140
120
100
80
60
40
20
0
0-2
2-4
4-6
6-8
8-10
10-15
ECiw (dS/m)


Mathura Block
Ca
Mg
Na
K
Cations (meq/l)
200
180
160
140
120
100
80
60
40
20
0
0-2
2-4
4-6
6-8
8-10
10-15
ECiw (dS/m)


Mathura Block
CO3
HCO3
Cl
SO4
Anions (meq/l)
200
180
160
140
120
100
80
60
40
20
0
0-2
2-4
4-6
6-8
8-10
10-15
ECiw (dS/m)


Baldev Block
Ca
Mg
Na
K
Cations (meq/l)
200
180
160
140
120
100
80
60
40
20
0
0-2
2-4
4-6
6-8
8-10
10-15
ECiw (dS/m)


Baldev Block
CO3
HCO3
Cl
SO4
Anions (meq/l)
200
180
160
140
120
100
80
60
40
20
0
0-2
2-4
4-6
6-8
8-10
10-15
ECiw (dS/m)

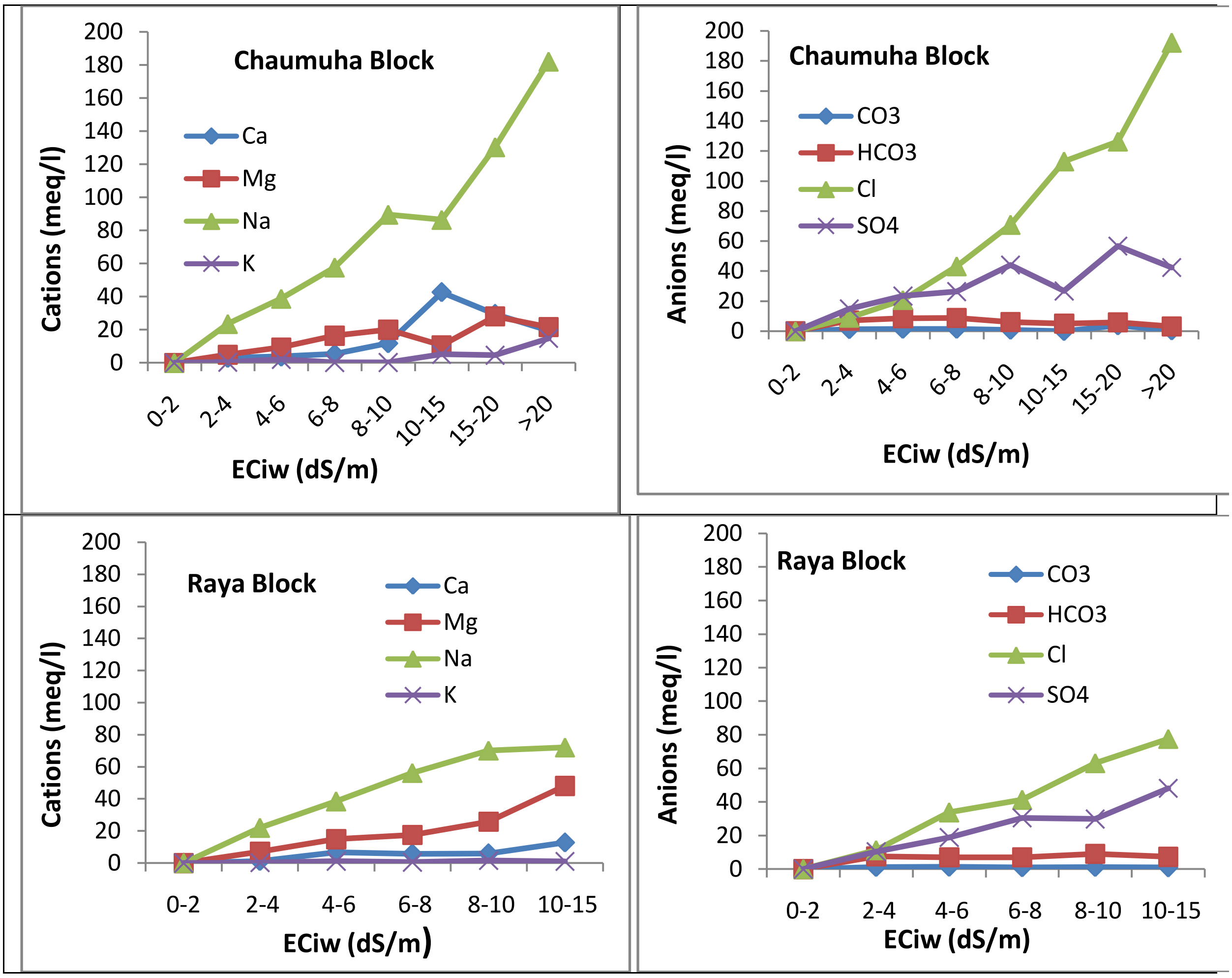


Fig. 1.3. Cationic and anionic composition with respect to EC classes of Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks of Mathura district

Nitrate:

The samples were tested for nitrate and it was found that in only 1.4 and 6.5 per cent samples of Mathura and Goverdhan block was having nitrate and in both the blocks hundred per cent samples were found in 0-2.5 me/l class only. In remaining no nitrate was noticed in water samples (Table 1.8).

Table 1.8 Nitrate in different blocks of Mathura District

Particulars	Mathura	Goverdhan
Nitrate (meq/l) :		
*Nitrate having samples (%)	1.4	6.5
** Per cent among Nitrate havingsamples		
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.

Fluoride:

It is clear from Table 1.9. 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 per cent samples were found while 10.4, 3.2, 9.7, 7.3,13.6, 12.7 per cent samples were found in 3.0-5.0 ppm category, respectively.

Table 1.9 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	-	-

The distribution of water samples in different water quality classes (Table 1.10 and Fig. 1.4) revealed that 17.9, 6.5, 22.2, 18.1 per cent sample of good quality underground irrigation water were found in Farah, Goverdhan, Mathura and Baldev blocks and none of the samples were found of good quality in Chaumuha and Raya blocks. 52.3, 88.7, 69.4, 68.7, 78.0 and 73.0 per cent samples of Farah, Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks came under saline class (Marginally saline, saline and High SAR saline) while, rest 29.8, 4.8, 8.4, 13.2, 22.0,27.0 per cent samples came in Alkali class (Marginally Alkali and High Alkali only) respectively.

Table 1.10 Per cent distribution of water samples in different water quality ratings (2018-19).

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

Comparing the water quality of latest collected samples (Table 1.10) with 32 years ago collected samples (Table 1.11) of Mathura district, it can be explained that samples under good quality water increased in Farah block and there was reduction of samples in this category in Goverdhan, Mathura, Chaumuha and Raya blocks, while in Badev it was found at par. The majority of samples were in Saline water quality in the surveyed periods and High SAR Saline water category samples increased in Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks (Table 1.11). The saline water quality (marginally saline and saline) samples increased in all blocks except Farah block and Alkali water samples decreased in Goverdhan, Mathura, Baldev, Chaumuha and Raya blocks, whereas, minute change was recorded in Farah block in respect of Alkali classes.

Table 1.11 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

Finally, a map has been prepared to show the area wise distribution of different water quality classes of Farah, Mathura, Goverdhan , Baldev, Chaumuha and Raya blocks of Mathura district. (Fig. 1.4)

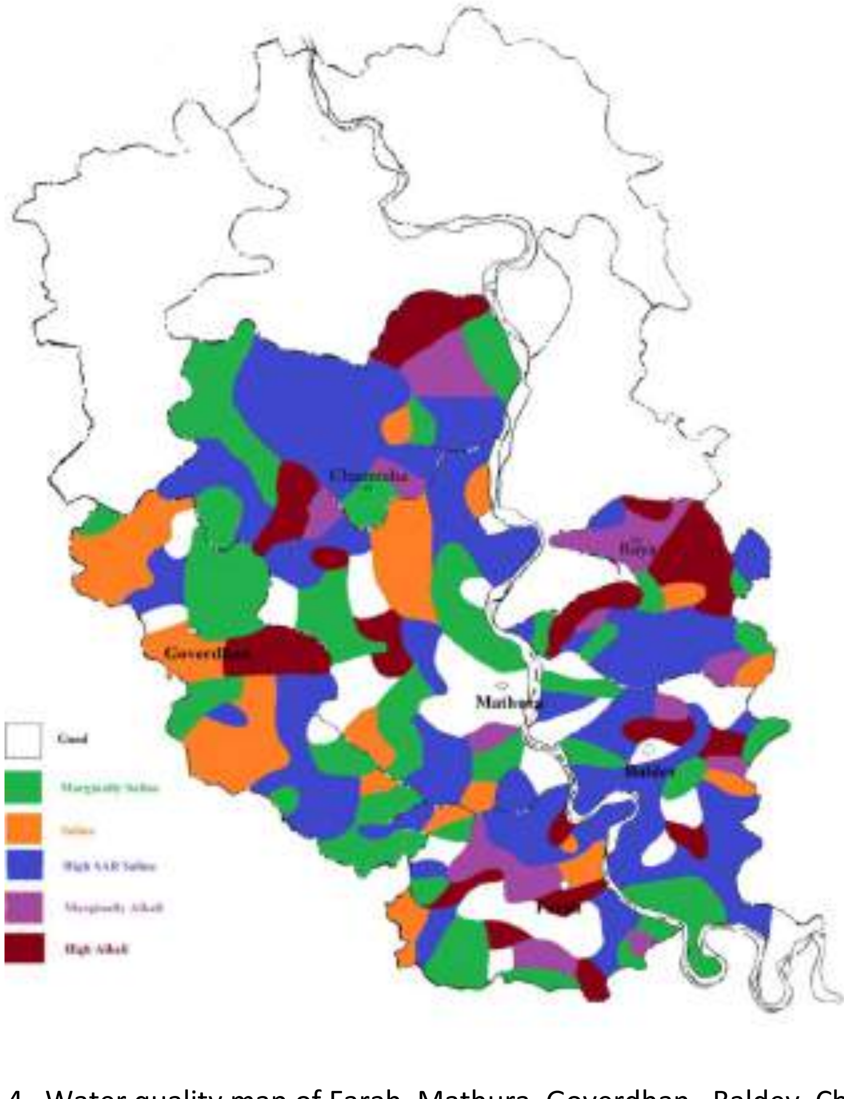


Fig. 1.4 Water quality map of Farah, Mathura, Goverdhan , Baldev, Chaumuha and Raya blocks of Mathura district.

- **Effect of Sea Water Intrusion on Ground Water Quality in Coastal Belt of Krishna Zone Andhra Pradesh (Bapatla)**

The study area, an uniform strip of 50 km wide along the sea coast covering the three districts, *viz.,* Krishna, Guntur and Prakasam, was selected and four routes (Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam) perpendicular to sea coast were identified with objectives i) to study the chemical composition of groundwater as influenced by seawater intrusion and ii) to find out the relationship between soil salinity and distance from seashore. Groundwater sampling points for different routes are given in Table 1.12. In each route six villages were identified and five samples were collected in each village. Thus a total of 120 points were selected by choosing thirty from each stratum considering the ingress of salinity along the coastal line.

Table 1.12 Selection of points for sea water intrusion in different routes

S. No	Name of the route	Distance from Sea		
		Up to 20 km	20 to 35 km	35 to 50 km
I	Machilipatnam	Machilipatnam Guduru	Nidumolu Challapalli	Vuyyuru Bhattiprolu
II	Kanaparthi	Uppugunduru Kadavakuduru	Inkollu J. Panguluru	Addanki Parchuru
III	Suryalanka	Bapatla Appikatla	Kakumanu Pedanandipadu	Prattipadu Etukuru
IV	Nizampatnam	Chandavolu Cherukupalli	Govada Ponnuru	Chebrolu Tenali

The pre and post monsoon data of water samples indicated that the pH and EC values of groundwater samples, collected during June 2018 (Table 1.13) and December 2018 (Table 1.14) ranged from 6.80 to 7.00 and 0.23 to 29.00 dS m^{-1} and 6.40 to 8.10 and 0.30 to 19.00 dS m^{-1}, respectively. Effect of dilution was on groundwater quality during post monsoon period. The pH values were neutral to alkaline in nature along all the routes.

Table 1.13 Route wise ranges of pH, EC, RSC and SAR during pre monsoon period (June, 2018)

S. No.	Route	pH	EC (dS m^{-1})	RSC (m e L^{-1})	SAR
1	Machilipatnam	6.8 to 7.5	0.70 to 24.00	0 to12.60	1.65-11.76
2	Kanaparthi	7.0 to 7.6	0.23 to 10.10	0 to 10.40	0.37 to 16.63
3	Bapatla	6.8 to 7.8	0.7 to 29.00	0 to 5.80	0.72 to 23.95
4	Nizampatnam	6.9 to 7.8	1.0 to 19.20	0 to 10.20	1.58 to 31.38

Table 1.14 Route wise ranges of pH, EC. RSC and SAR during post monsoon period (Dec., 2018)

S. No.	Route	pH	EC (dS m^{-1})	RSC (m e L^{-1})	SAR
1	Machilipatnam	6.6 to 8.0	0.60 to 19.00	0 to 12.40	0.43 -9.46
2	Kanaparthi	6.6 to 8.0	0.30 to 1..20	0 to 6.80	0.27 to 8.87
3	Bapatla	6.4 to 7.7	0.60 to 10.00	0 to 6.20	0.29 to 8.63
4	Nizampatnam	6.8 to 8.1	0.80 to 18.10	0 to 7.40	0.30 to 8.37

The study indicated that sodium and chloride were the dominant cation and anion, respectively. Data recorded in post-monsoon period indicated slight reduction in all the parameters as compared to pre-monsoon period in majority of samples. Higher EC values were observed along Machilipatnam route (0.60-19.00 dS m^{-1}) followed by Nizampatnam route (0.80-18.00 dS m^{-1}), Kanaparthi route (0.30-10.20 dS m^{-1}) and Bapatla route (0.60 – 10.00 dS m^{-1}) in post monsoon-2018. In general, sea water intrusion was observed up to a distance of 30 km from the sea.

The ground water samples for pre and –post monsoon periods for 2018 were analyzed for different ions and ionic ratios (Todd, 1959). Interpretation of Ionic ratios, shown in Fig. 1 and Fig. 2, was done to know presence of sea water intrusion in coastal aquifers. In case of sea water intrusion, Na/Cl ratio remains less than 0.86, Ca/Mg ratio remains more than 1 and $Cl^-/(CO_3^{2-} + HCO_3^-)$ ratio is remains more than 1. The interpretation of ionic ratios for pre monsoon period on basis of Fig. 1.5 is given below.

Machilipatnam route:

The mean Na/Cl ratio is more than 0.86 at all the distances from the sea indicating no sea water contamination whereas Ca/Mg ratio is more than 1 at all the distances from the sea indicating sea water contamination. However, $Cl^-/(CO_3^{2-} + HCO_3^-)$ ratio is > 1 at 7.30 km (1.14) 21.30 km (4.35) and 29.50 km (1.35) indicating sea water intrusion and is < 1 at distances of 14 km (0.87) , 43.25 km (0.40) and 46 km (0.62) away from sea indicating no contamination of sea water.

Kanaparthi route:

The mean Na/Cl ratio is < 0.86 at distances of 11.50 km (0.75) and 37.13 km (0.82) indicating sea water contamination whereas the value is > 0.86 at distances of 16 km (1.20), 26.52 km (1.18),28.30 (1.82) and 1.13 42km (1.13) away from the sea indicating no contamination. The mean Cl -/(CO32- +HCO3-) ratio is > 1 at distances of 11.50 km (1.12) , 37.13 km (1.08) and 42 km (3.29) indicating sea water intrusion and at remaining distances it is < 1 indicating no sea water intrusion . However, Ca/Mg ratio is > 1 at all the distances indicating sea water intrusion at all the distances.

Bapatla route:

As per mean Na / Cl ratio was > 086 at all the distances indicating no sea water contamination Whereas Ca/Mg ratio is >1 and Cl -/(CO32- +HCC3-) ratio is > 1 at all the distances indicating the sea water intrusion at all the distances from the sea.

Nizampatnam route:

The mean Cl -/(CO32- +HCO3-) ratio was >1 at 18.24 km (1.13) , 22.11km(38.5) and 38.80 km(2.25) away from the sea indicating sea water contamination but at the remaining distances it was < 1 indicating no contamination. The mean Na/Cl ratio was > 0.86 indicating no contamination of sea water at all the distances. Similarly, the Ca/Mg ratio was >1 at all the distances indicating sea water contamination at all the distances.

The different ionic ratios for Dec. 2018 are also given in Fig. 1.6 and these ionic ratios can be interpreted in similar fashion as in case of June 2018.

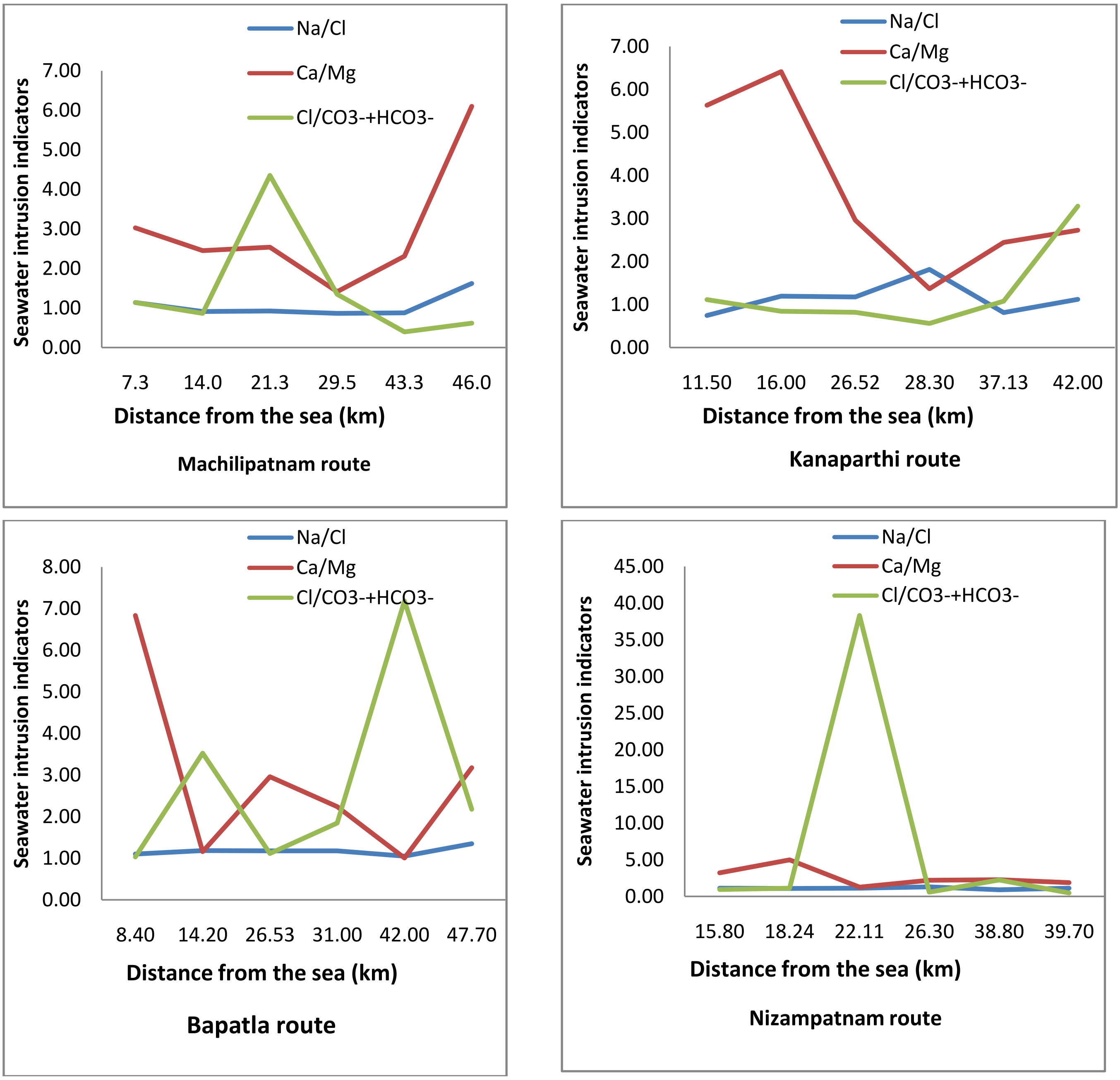


Fig. 1.5. Mean ionic ratios in different routes June 2018

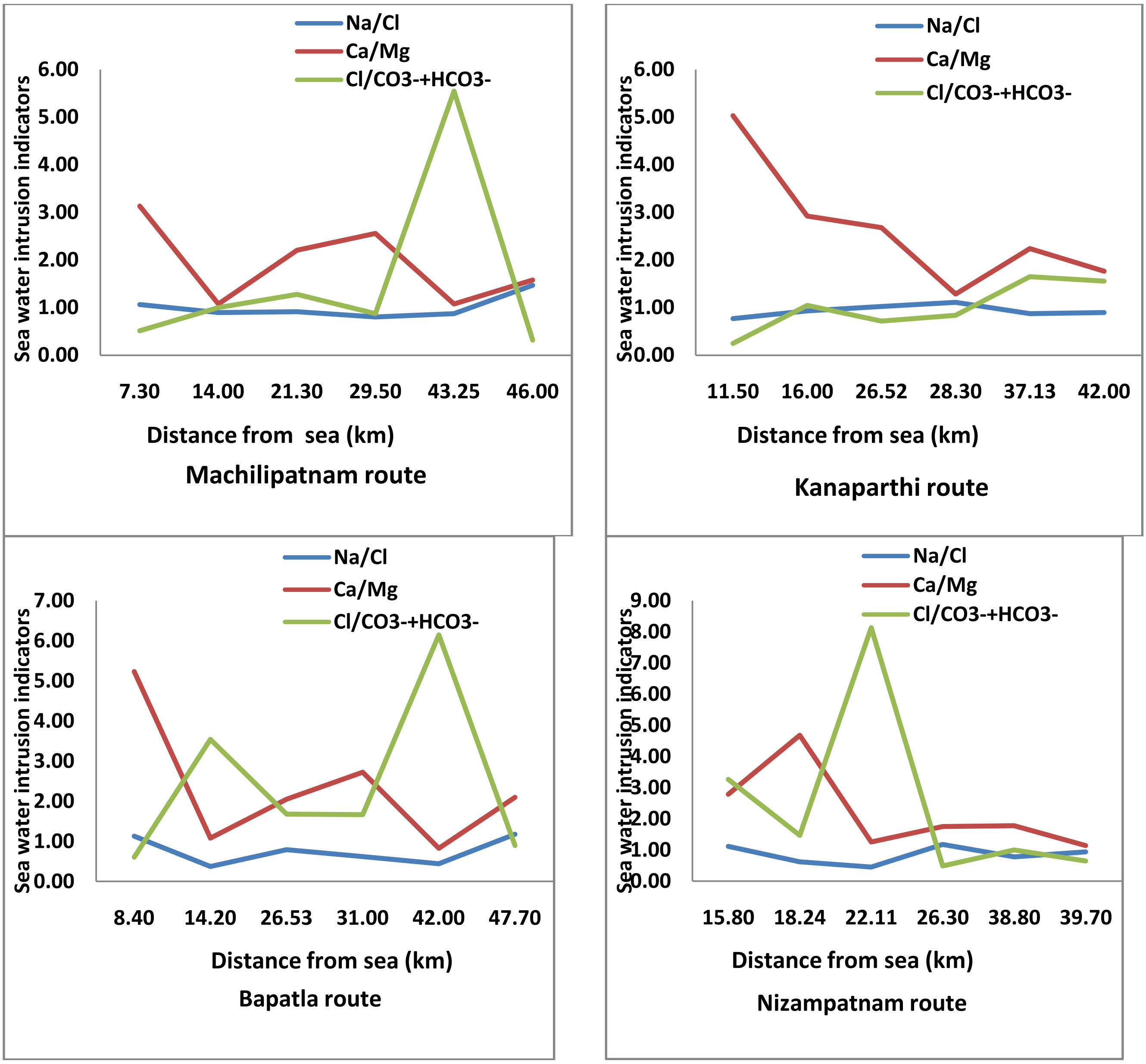


Fig.1. 6 Mean ionic ratios in different routes Dec 2018

- **Survey and characterization of ground water of Nellore district (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 1.15.

Table 1.15. Mean and ranges for different quality parameters

Particular	pH	EC ($dS\ m^{-1}$)	SO_4^{2-}	Cl^-	CO_3^{2-}	HCO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
			meL^{-1}							
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	meL^{-1}		meL^{-1}	meL^{-1}
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 1.16). 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 1.16 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. 1.7.

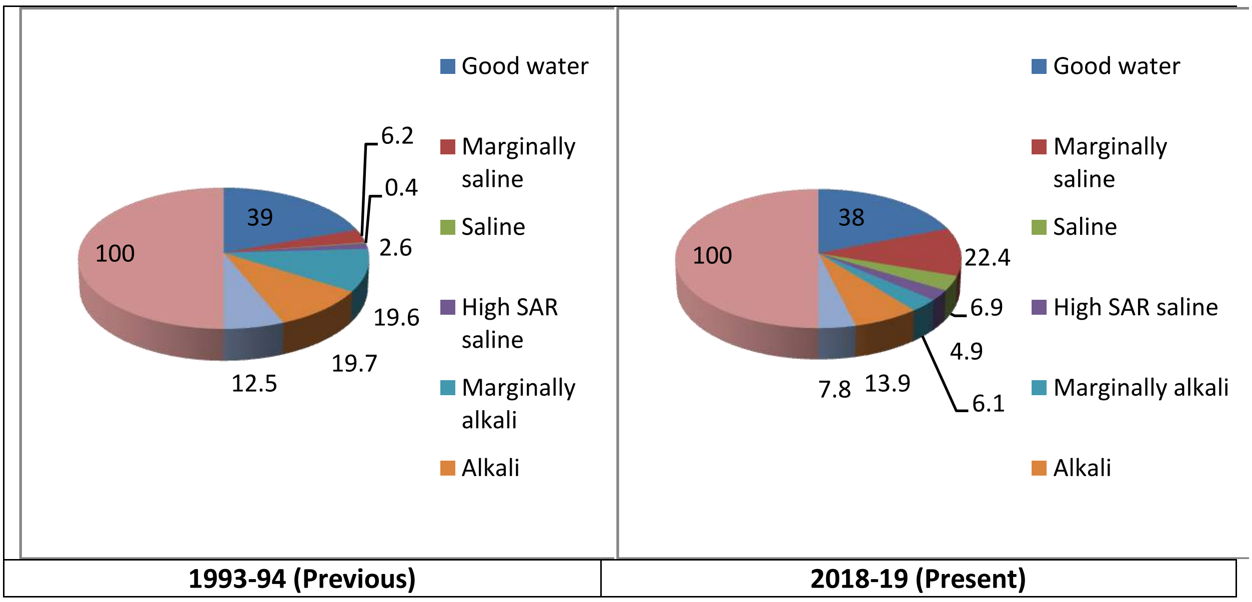


Fig. 1.7. Changes in groundwater quality in Nellore district with time

- **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 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 1.17.

Table 1.17. 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 (me/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 (me/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 (me/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 (me/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 (me/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 (me/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 (me/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 (me/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 (me/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 (me/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, me/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 1.18. 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 1.18. 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 waters of Faridabad district for irrigation (Hisar)**

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. 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 1.19. 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 1.20 and Fig. 1.8).

Table 1.19. 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^+ (me l^{-1})	2.60-63.20	16.35
2	EC (dSm^{-1})	0.50-9.91	2.57	8	K^+ (me l^{-1})	0.06-3.14	0.27
3	RSC (me l^{-1})	0.00-5.60	0.95	9	CO_3^{2-} (me l^{-1})	0.00-6.40	1.47
4	SAR (mmol $l^{-1})^{1/2}$	2.54-20.05	7.76	10	HCO_3^- (me l^{-1})	0.20-15.20	5.03
5	Ca^{2+} (me l^{-1})	5.50-8.10	2.09	11	Cl^- (me l^{-1})	1.90-68.00	12.95
6	Mg^{2+} (me l^{-1})	1.50-26.10	6.16	12	SO_4^{2-} (me l^{-1})	0.20-31.40	4.47

Table 1.20 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
		--(mel^{-1})--									mmol l^{-1})
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

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 mel^{-1} with the mean value of 12.95 me l^{-1}. The concentration of bicarbonates in groundwater samples varied from 0.20 to 15.20 mel^{-1} with a mean value of 5.03 me l^{-1}. The mean values for CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} were found to be 1.47, 5.03, 12.95 and 4.47 mel^{-1}, respectively (Table 1.19). Table 1.20 and Fig. 1.9 show distribution of samples within EC classes while Fig. 1.10 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.

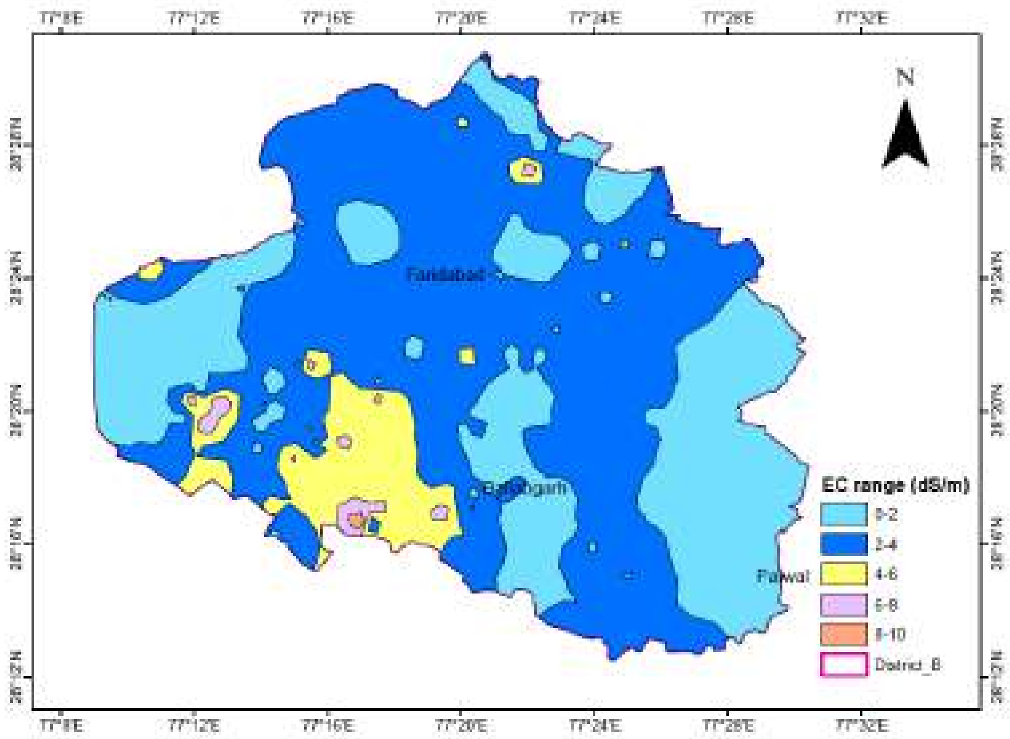


Fig.1.8 Spatial variability of EC of groundwater used for irrigation in Faridabad district

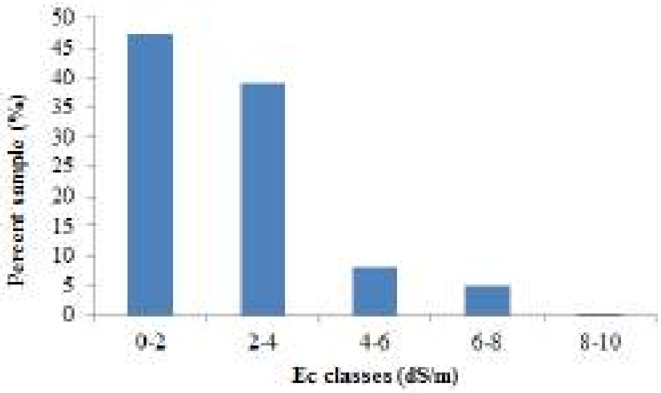


Fig. 1.9. Percent samples in different EC (dS/m) classes in Faridabad district

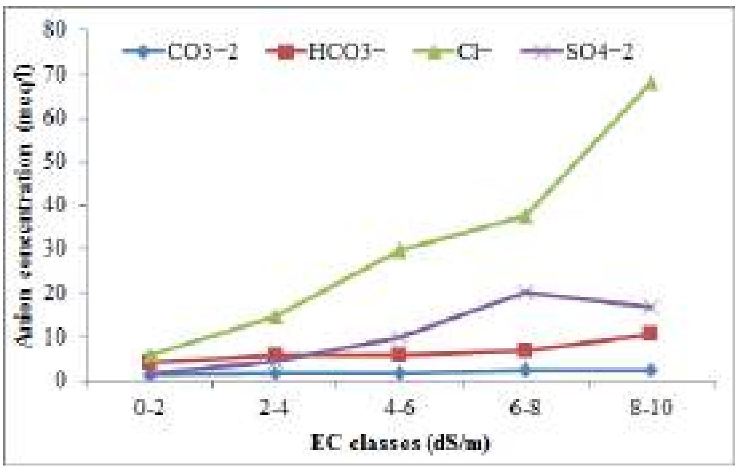


Fig. 1.10 Anions (CO_3, HCO_3, Cl, SO_4) concentration (me/l) in different EC classes of Faridabad district

The concentration of sodium in groundwater samples varied from 2.60 to 63.20 mel^{-1} with an average value of 16.35 mel^{-1} (Table 1.19), followed by magnesium (1.50 to 26.10 mel^{-1}) and calcium (5.50to 8.10 me/l). Mean values for Na^{+}, Mg^{2+}, Ca^{2+} and K^{+} were 16.35, 6.16, 2.09 and 0.27 me/l, respectively. Table 1.20 and Fig. 1.11 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 me/l) was found in the class 0-2, the highest mean value (63.20 me/l) was laid in the EC class of 8-10 dS/m.

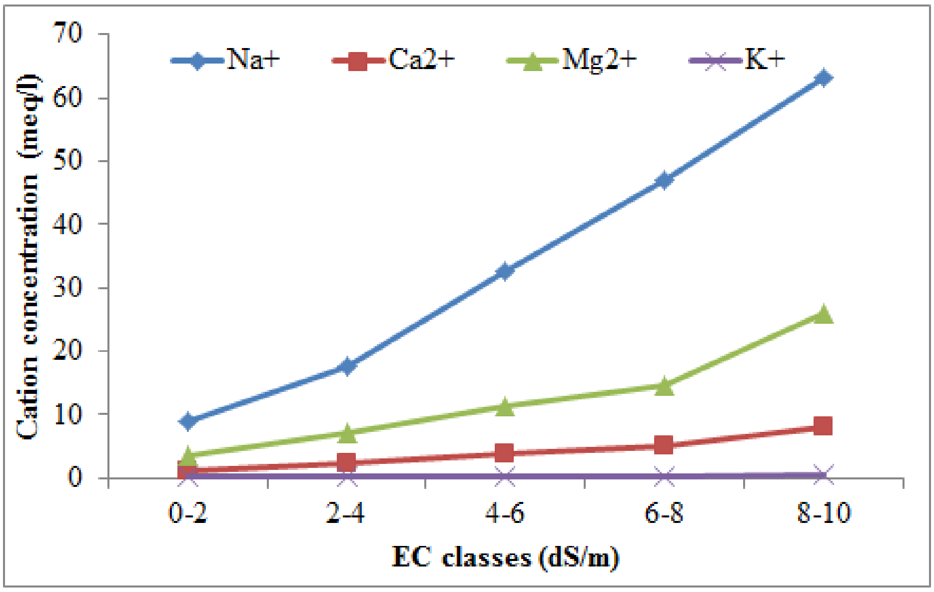


Fig. 1.11 Cations (Ca, Mg, Na, K) concentration (me/l) in different EC classes of Faridabad district

The spatial variability of RSC and SAR in the district is shown in Fig. 1.12 and Fig. 1.13.

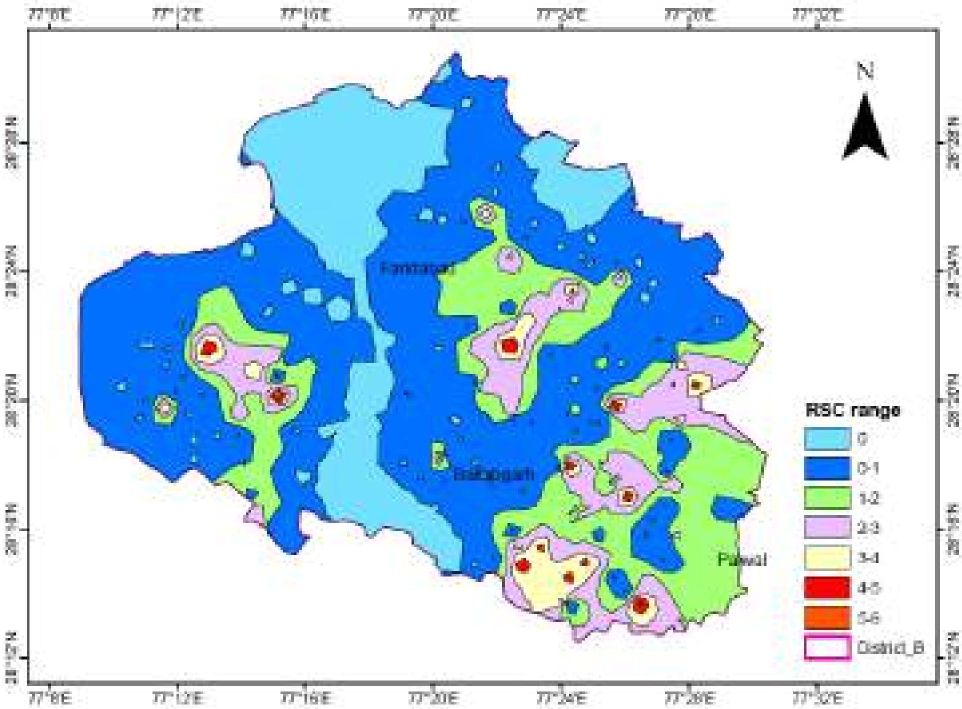


Fig. 1.12 Spatial variability of RSC of groundwater used for irrigation in Faridabad district

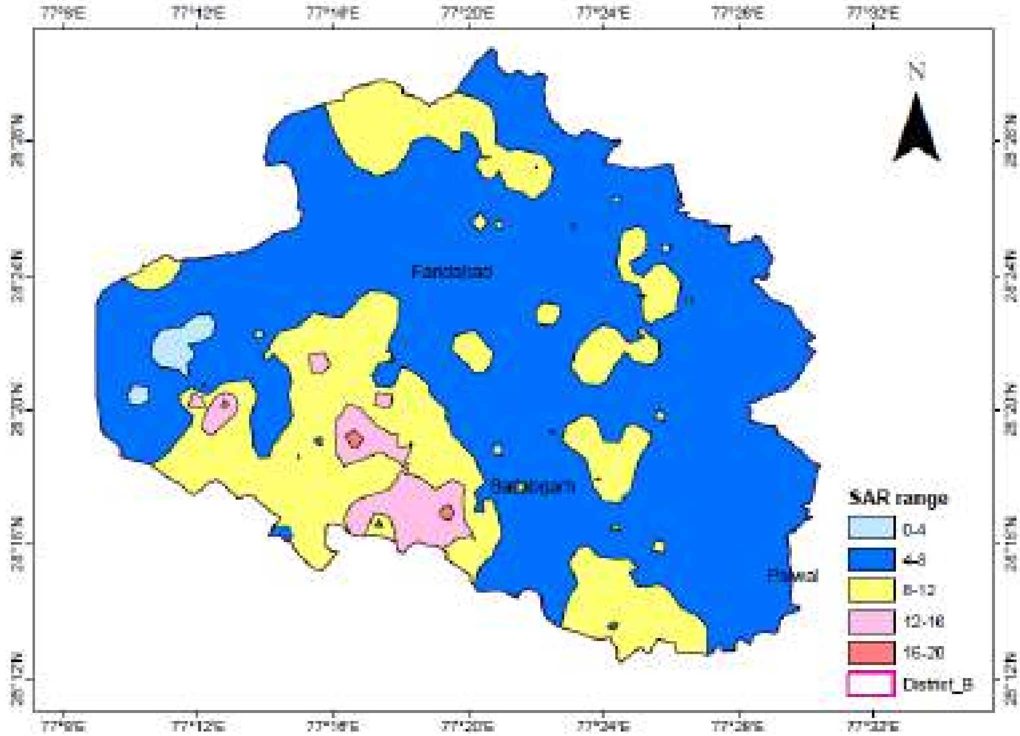


Fig. 1.13 Spatial variability of SAR of groundwater used for irrigation in Faridabad district

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. 1.14). 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.

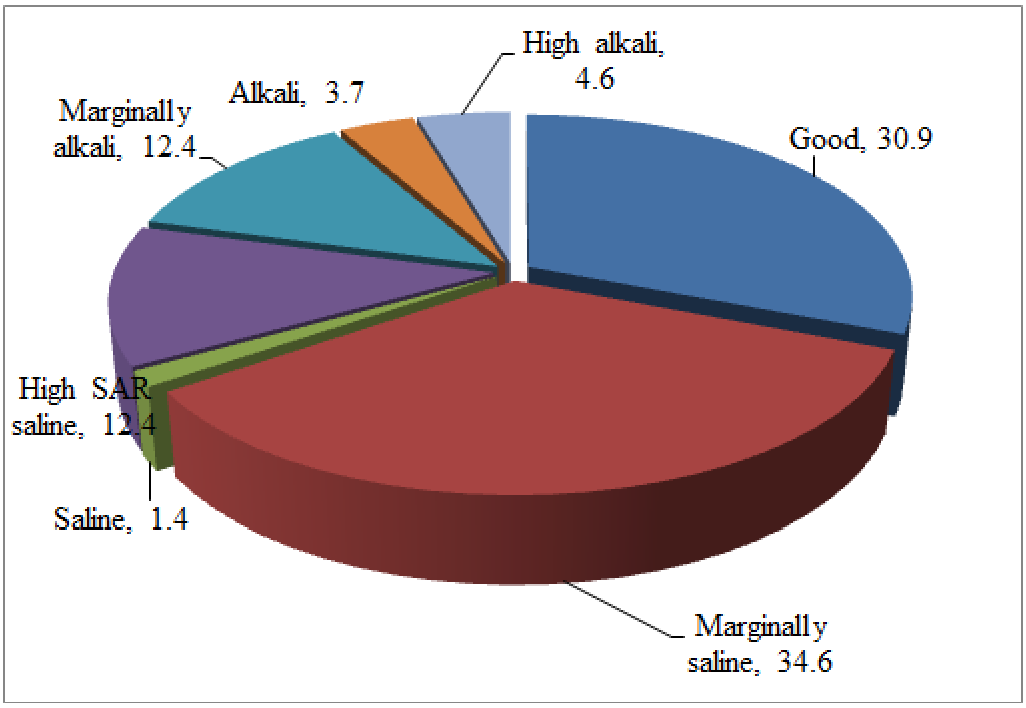


Fig. 1.14 Quality of groundwater (percent) in Faridabad district

Groundwater quality map for Faridabad district according to AICRP criteria was prepared to study its spatial variability in the district (Fig. 1.15). 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.

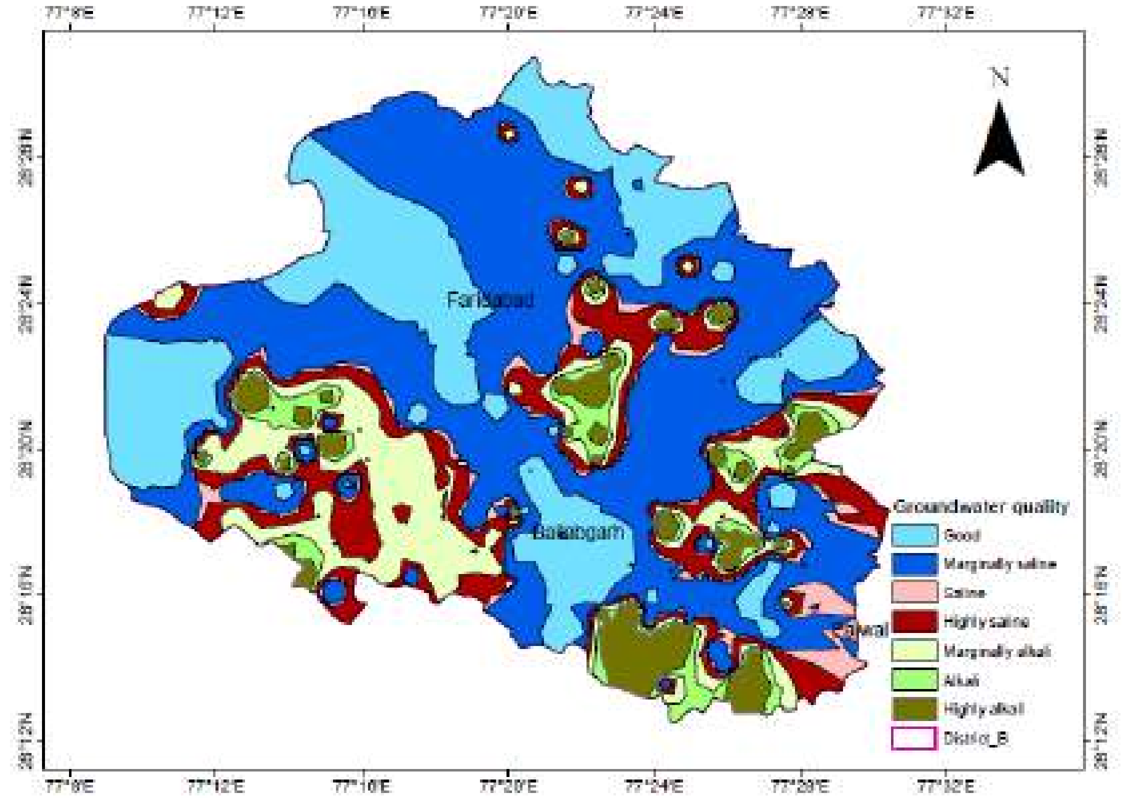


Fig. 1.15 Groundwater quality map for Faridabad district according to AICRP criteria

- **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 dSm^{-1}, 0.60 to 9.45 and Nil me L^{-1} 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 me L^{-1}, 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 1.21). 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 1.22).

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 dSm^{-1}, 0.63 to 2.28 and Nil me L^{-1} respectively (Table 2). 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 me L^{-1}, 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 1.21). Out of 14 samples, 14 (100.0 %) water samples come under good water category "A" (Table1.22).

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 dSm^{-1}, 0.03 to 2.34 and Nil me L^{-1} respectively (Table 2). 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 me L^{-1}, 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 1.21). Total 19 samples (100%) come under good water category "A" (Table 1.22).

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 dSm^{-1}, 0.12 to 2.96 and Nil me L^{-1} respectively (Table 2). 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 me L^{-1}, 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 1.21). Out of 27 samples, 26 (96.0 %) come under good water category "A" (Table 1.22).

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 dSm^{-1}, 0.42 to 1.67 and Nil me L^{-1} respectively (Table 2). 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 me L^{-1}, 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 1.21). All the 12 samples (100.0 %) come under good water category "A" (Table 1.22).

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 dSm^{-1}, 0.52 to 5.58 and Nil me L^{-1} respectively (Table 4). 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 me L^{-1}, 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 1.21). 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 1.22).

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 dSm^{-1}, 0.29 to 3.50 and Nil me L^{-1} respectively (Table 2). 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 me L^{-1}, 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 1.21). All the 24 samples (100.0 %) come under good water category “A” (Table 1.22).

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 dSm^{-1}, 0.20 to 10.99 and Nil me L^{-1} respectively (Table 2). 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 me L^{-1}**,** 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 1.21). However, 17 (42.5%) and 3 (7.5%) samples fall under marginally saline water (B_1) and saline (B_2) categories, respectively (Table 1.22).

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 dSm^{-1}, 0.07 to 1.44 and Nil me L^{-1} respectively (Table 2). 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 me L^{-1}, 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 1.21). All the 33 samples (100.0 %) come under good water category “A” (Table 1.22).

Table 1.21. 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 (dSm^{-1})	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 (meL^{-1})	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 1.22). The ground water quality map of the district was also generated with the help of software ERDAS IMAGINE 8.7 (Fig. 1.16).

Table 1.22 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

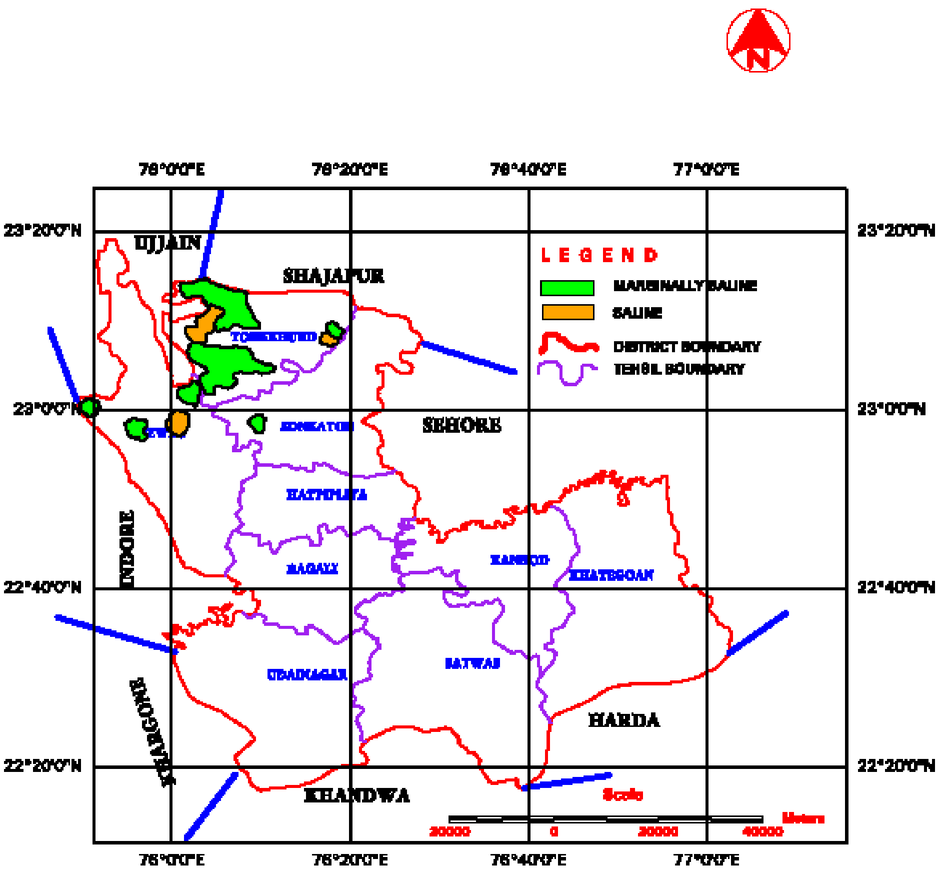


Fig. 1.16 Groundwater quality of Dewas district of Madhya Pradesh

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

Two hundred four groundwater water samples were collected from different villages of Auraiya district. Out of total samples, 32, 29, 27, 34, 43 and 39 samples were collected from Ajitmal, Bidhuna, Erwakatra, Achalda, Sahar and Bhagyanagar blocks of the district respectively. Salient features of ground water samples of different blocks of Auraiya district are given in Table 1.23.

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 dSm^{-1}, 0.7 to 10.2 and 0.0 to 7.2 $meqL^{-1}$ with the mean value of 7.84, 0.97 dSm^{-1}, 2.84 and 0.48 $meqL^{-1}$, 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 dSm^{-1}, 0.6 to 9.3 and 0.0 to 2.7 $meqL^{-1}$ with the mean value of 7.73, 0.89 dSm^{-1}, 3.22 and 0.22 $meqL^{-1}$, 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 dSm^{-1}, 0.4 to 9.5 and 0.0 to 2.5 $meqL^{-1}$ with the mean value of 7.72, 0.94 dSm^{-1}, 3.34 and 0.18 $meqL^{-1}$, 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 dSm^{-1}, 0.7 to 9.6 and 0.0 to 2.9 $meqL^{-1}$ with the mean value of 7.75, 0.88 dSm^{-1}, 3.12 and 0.24 $meqL^{-1}$, 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 dSm^{-1}, 0.4 to 10.2 and 0.0 to 7.6 $meqL^{-1}$ with the mean value of 7.43, 1.10 dSm^{-1}, 4.21 and 0.59 $meqL^{-1}$, 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 dSm^{-1}, 0.3 to 10.0 and 0.0 to 2.0 $meqL^{-1}$ with the mean value of 7.76, 1.14 dSm^{-1}, 3.52 and 0.15 $meqL^{-1}$, 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 1.23 Salient features of ground water samples of Auraiya district

Blocks	pH	Mean	EC (dSm-1)	Mean	SAR	Mean	RSC (meqL-1)	Mean
Ajitmal	7.2-8.4	7.85	0.38-3.28	0.97	0.7-10.2	2.84	0.0-7.2	0.48
Bidhuna	7.4-8.2	7.73	0.32-3.21	0.89	0.6-09.3	3.22	0.0-2.7	0.22
Erwakatra	7.3-8.6	7.72	0.35-3.25	0.94	0.4-09.5	3.34	0.0-2.5	0.18
Achalda	7.5-8.4	7.75	0.33-3.24	0.88	0.7-09.6	3.12	0.0-2.9	0.24
Sahar	7.3-8.3	7.43	0.32-3.45	1.10	0.4-10.2	4.21	0.0-7.6	0.59
Bhagyanagar	7.3-8.5	7.76	0.38-4.05	1.14	0.3-10.0	3.52	0.0-2.0	0.15

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 1.24.

Table: 1.24. 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)**

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 (Fig.1). 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 sq.km. The district receives the rain under the influence of both southwest and northeast monsoons. The northeast monsoon chiefly contributes to the rainfall in the district. Most of the precipitation occurs in the form of cyclonic storms caused due to the depressions in Bay of Bengal. The southwest monsoon rainfall is highly erratic and summer rains are negligible. Rainfall data from two stations over the period from 1901 to 2000 were utilized and a perusal of the data shows that the normal annual rainfall over the district is 827mm with the maximum around Pamban and all along the coast and it decreases towards inland. The district enjoys a Tropical climate. The period from May to June is generally hot and dry. The weather is pleasant during the period from December to January. Usually mornings are more humid than afternoons. The relative humidity is on an average between 79 and 84%. The mean minimum temperature is 25.7°C and mean maximum daily temperature is 30.6°C respectively.

A study was undertaken to assess the groundwater quality in Ramanathapuram district by collecting 116 groundwater samples using GPS and analyzed for pH, EC, anions viz ., HCO_3^-, CO_3^-, Cl^-, SO_4^{2-} and cations viz., Ca^{2+}, Mg^{2+}, Na^+ 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 1.25. 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 1.25. 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 1.26. 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.

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 1.27 and Fig. 1.17. 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. 1.18.

Table 1.26. Quality of ground waters in different blocks of Ramanathapuram District

Name of the Block	pH			EC (dSm^{-1})			SAR			RSC (meq. l^{-1})		
	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

Table: 1.27. 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

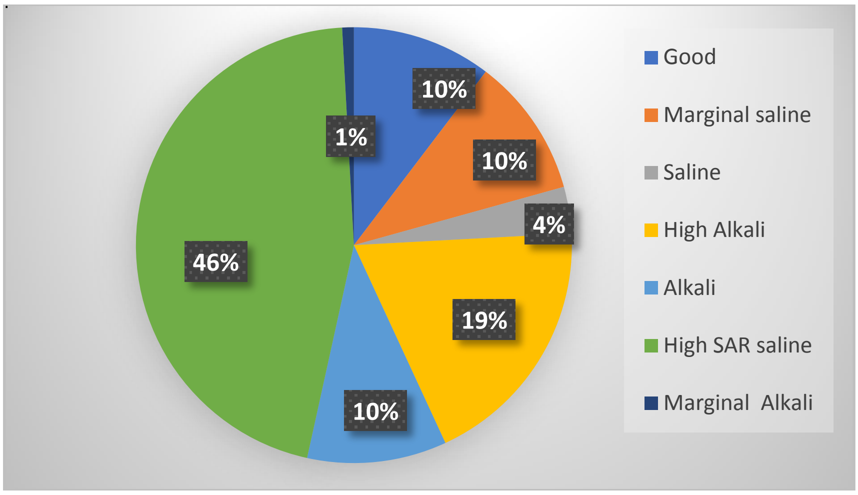


Fig. 1.17 Percentage distribution of ground water quality in Ramanathapuram district

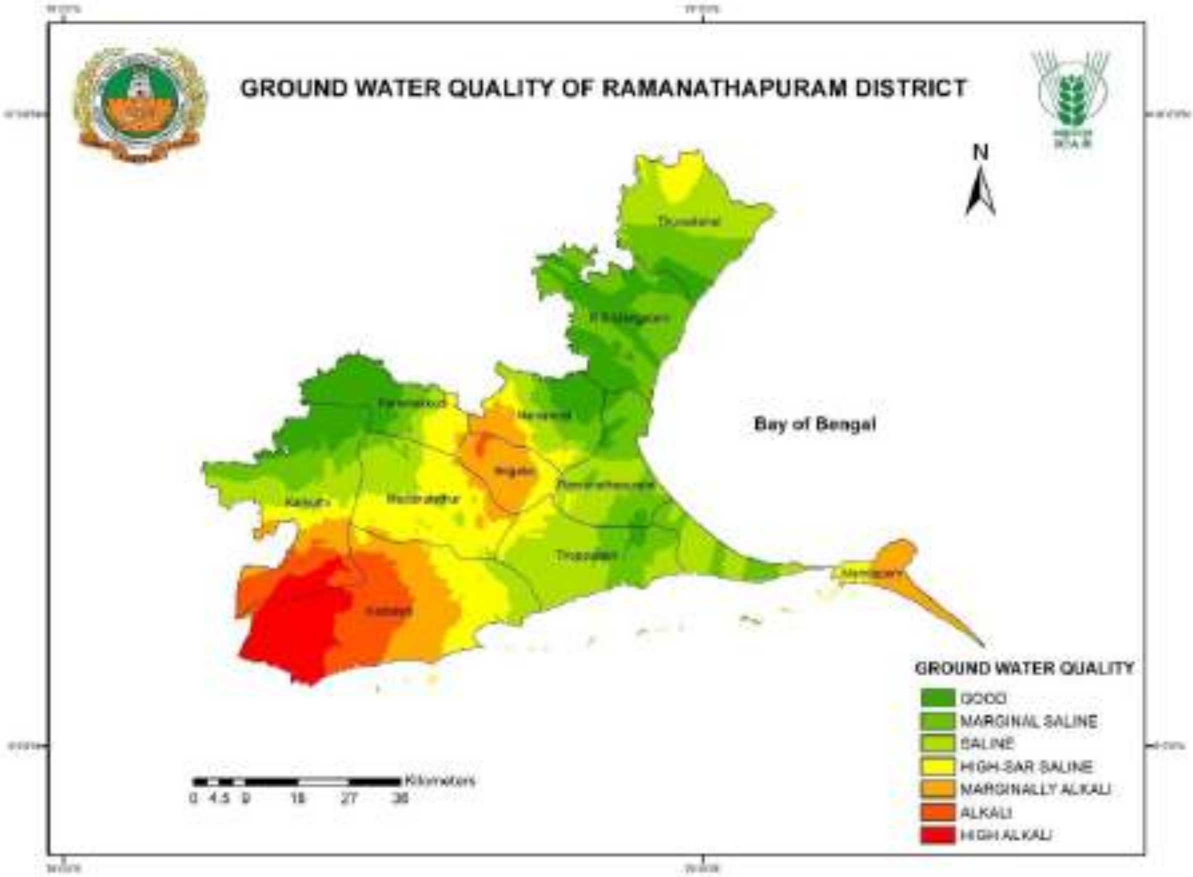


Fig. 1.18 Spatial distribution of ground water quality in Ramanathapuram district

- **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 1.28. 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 : 1.28 Average cationic and anionic concentrations in different blocks of Thoothukudi 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.	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^{-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 (Table 1.29).

Table: 1. 29 Quality of ground waters in different blocks of Ramanathapuram District

Name of the Block	pH			EC (dSm^{-1})			SAR			RSC (meq. l^{-1})		
	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

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 1.30 and Fig. 1.19). The spatial distribution of groundwater quality categories is provided in Fig. 1.20.

Table: 1.30. 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

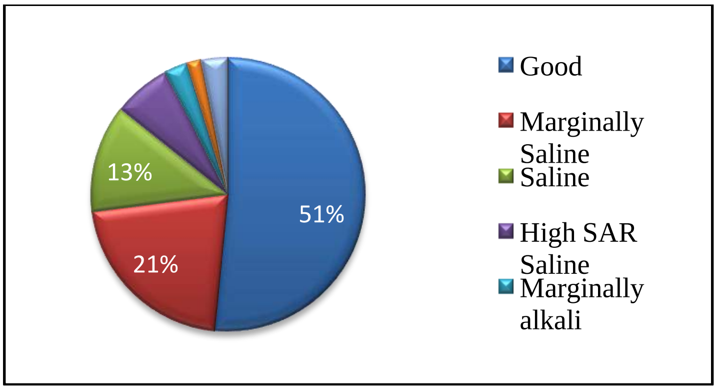


Fig. 1.19 Percentage distribution of ground water quality in Thoothukudi district

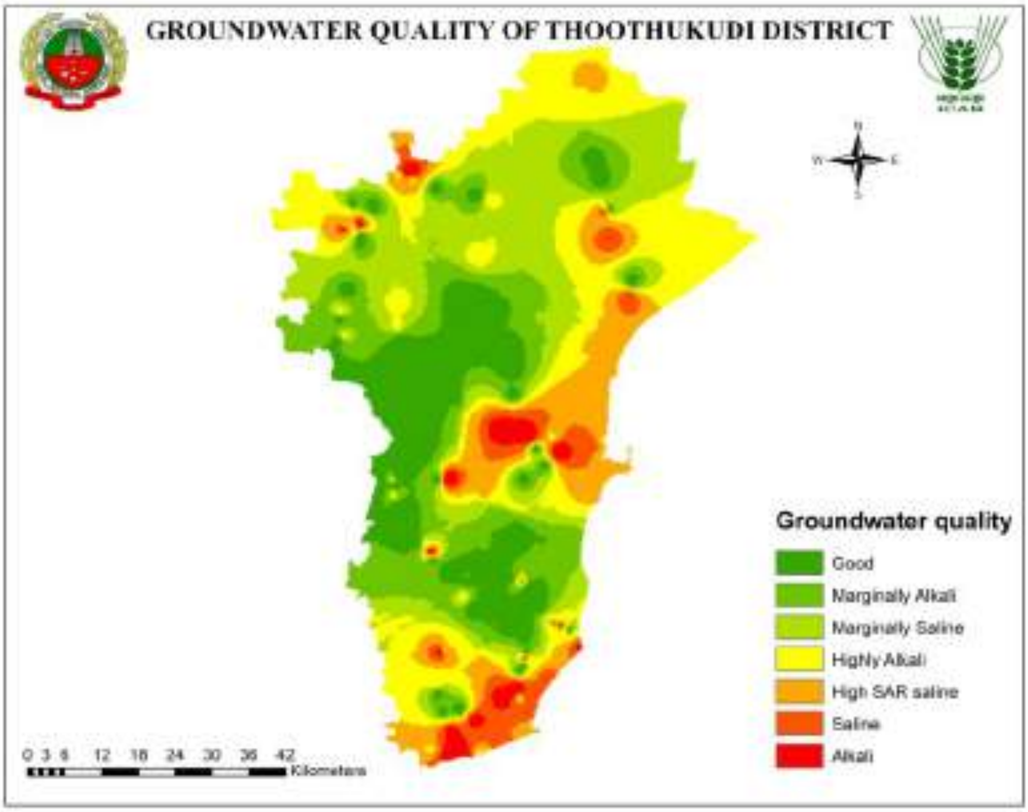


Fig. 1.20 Spatial distribution of groundwater quality categories for Thoothukudi district

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

Mansa district is located at 29.9871^{o}N and 75.4345^o 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. 1.21)

Fig. 1.21 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 1.31. The electrical conductivity (EC) ranged between 0.60-4.50 dSm^{-1} with mean value 2.17 dSm^{-1}, 0.34-5.50 dSm^{-1} with mean value 2.33 dSm^{-1}, and 1.20-12.60 dSm^{-1} with mean value 4.10 dSm^{-1} in blocks Budahlada, Mansa and Sardulgarh, respectively. Higher RSC (2.19 me L^{-1}) was reported in Budahlada as compared to Mansa (1.31 me L^{-1}) and Sardulgarh (1.25 me L^{-1}). 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 meL^{-1} followed by bicarbonate (0.80 to15.80 me L^{-1}) and carbonate (nil to 1.20 me L^{-1}) in the district.

Table 1.31**.** 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 (dSm^{-1})	0.60-4.50	2.17	0.34-5.50	2.33	1.20-12.60	4.10
Ca^{+2} +Mg^{+2} (me L^{-1})	1.50-15.70	5.84	1.90-26.50	7.44	2.80-35.00	9.26
Cl^{-1} (me L^{-1})	0.80-17.00	5.69	0.40-32.00	8.50	2.40-66.00	20.80
CO_3^{-2} (me L^{-1})	0.00-0.60	0.14	0.00-1.20	0.13	0.00-1.20	0.19
HCO_3^- (me L^{-1})	0.80-15.40	6.65	1.20-15.80	6.34	1.80-11.20	9.26
RSC (me L^{-1})	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 1.32. 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^{-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}. 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 dSm^{-1}) for irrigation and 22% water was not suitable for irrigation due to their higher electrical conductivity.

Table 1.32 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 1.32. It is 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. Further, it is reported that on the basis of RSC 76% water is safe (RSC, <2.5 meL^{-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}).

- **Estimation of fluoride in ground water for Mansa, district, Punjab (Bathinda)**

The distribution of fluoride in ground water of Mansa district is presented in Table 1.33. 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 1.33. 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, characterization and mapping of ground water quality in the coastal areas of Kerala (Vyttila)**

The survey and collection of ground water samples was initiated on 2014-15 to assess the ground water quality in the coastal areas of eleven districts of Kerala viz. Thiruvanamthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragode. Geo-referenced ground water samples were collected from ground water monitoring wells according to details given by Central Ground Water Board (CGWB), Trivandrum and also from nearby cultivated fields. In case of remaining districts viz, Idukki, Palakkad and Wayanad data from

CGWB was collected to classify the ground water quality. The survey, collection and analysis of ground water samples of all the districts were completed. To assess the salinity status of study area, samples were analyzed for pH, electrical conductivity, carbonate, bicarbonate, chloride, sulphate, sodium, potassium, calcium, magnesium and boron Quality parameters like, SAR and RSC were calculated. Classification of water quality was done on the basis of EC, SAR and RSC according to CSSRI. The ground water quality of all the districts was classified according to ICAR-CSSRI classification (Table 1.34).

Table: 1.34. 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. 1.22).

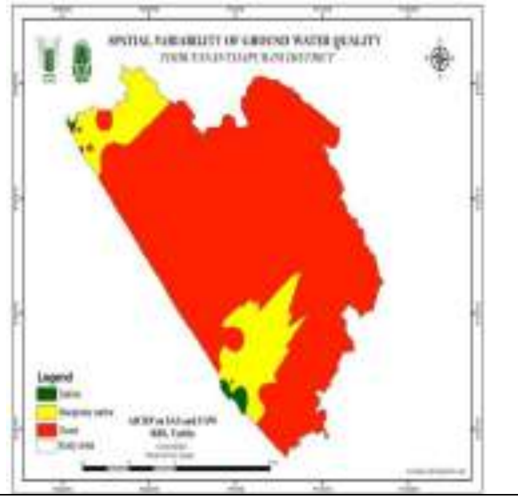
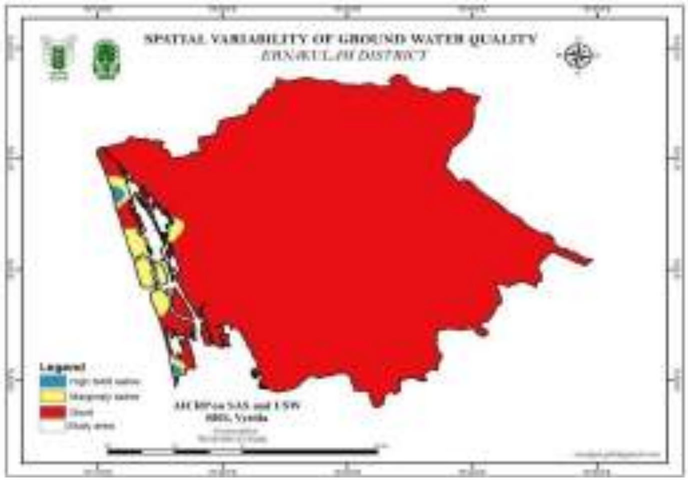
	
Thiruvananthapuram	Ernakulam

Fig 1.22 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 1.23).

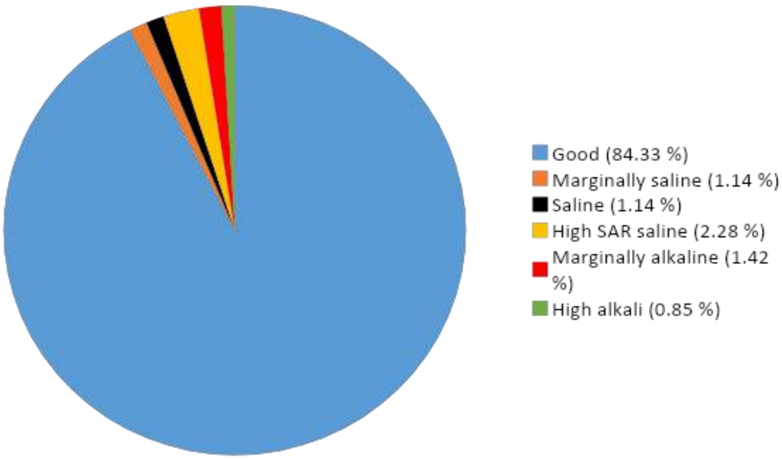


Fig. 1.23. Classification of ground water samples in Kerala for irrigation

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

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 1.35 and Table 1.36). 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 1.35 Water salinity of improved doruvu wells

S.No.	Particulars	ECiw (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 1.36 Water salinity of shallow bore wells

S.No.	Particulars	ECiw (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.

2 MANAGEMENT OF SALT AFFECTED SOILS

2.1 MANAGEMENT OF ALKALI SOILS

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

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 2.1). 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).

Table2.1 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 2.2), 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.2.1.

Table 2.2 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		

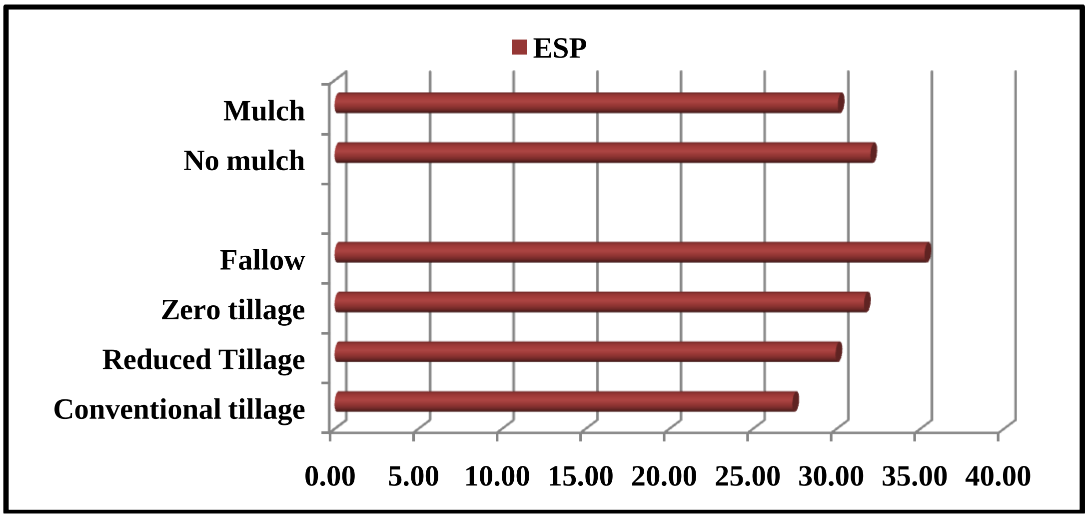


Fig. 2.1 Effect of resources conservation technologies on ESP

- **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 2.3). 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 2.3 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 2.4). 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 2.4 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 2.5). 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 2.5 Effect of treatments on soil properties after three year

Treatments	pH	EC	ESP	OC %
T1- 50%GR	8.7	0.89	30.8	0.26
T2- 25%GR + rice straw @5 t/ha	9.0	0.90	36.3	0.29
T3- 25%GR + GM @5 t/ha	8.9	0.92	35.8	0.30
T4- 25%GR + GM @5 t/ha + Microbial culture	8.8	0.89	34.5	0.34
T5- 25%GR + Poultry manure @3t/ha.	8.8	0.89	32.2	0.36
T6- 25%GR + City Waste Manure @5 t/ha	8.9	0.91	35.1	0.32
T7 - 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)**

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. Upon the characterization of different gypsum sources, the quantity requirement of different gypsum source required will be calculated and experiment will be taken with soil application of the respective gypsum.

2.2 Management of Saline and Waterlogged 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)**

A field experiment was laid out at ARS, Gangavathi on 6 ha block was initiated during 2012-13 by taking four additional treatments i.e., conventional and controlled SSD with 40 m, 50 m and 60 m spacing each with a lateral depth of 1.0 m. The initial mean soil salinity (ECe) in conventional and controlled drainage plots having 40 m and 50 m and 60 m spacing and consequent temporal changes are given in Table 2.6.

Table 2.6 Soil salinity (ECe, dS/m) at different soil depth (cm) as influenced by spacing of conventional and controlled drainage systems

Season	40 m spacing							
	Conventional drainage				Controlled drainage			
	0-15	15-30	30-60	60-90	0-15	15-30	30-60	60-90
Initial	8.05	9.94	9.70	8.66	7.33	9.18	8.63	8.16
R/S-2013-14	8.00	7.50	7.80	8.90	8.50	7.90	9.10	9.00
Kharif-14	5.00	7.10	7.30	7.30	4.90	7.80	9.50	9.60
R/S-2014-15	4.98	7.05	7.79	7.97	4.86	7.80	10.10	9.57
Kharif-15	6.39	9.38	7.63	7.61	5.30	7.53	9.72	9.92
Kharif-16	4.01	4.14	5.68	5.43	2.64	3.79	8.22	10.06
Kharif-17	3.56	4.35	NA	NA	1.88	4.15	NA	NA
Kharif-18	4.12	5.38	6.84	NA	2.35	3.33	9.59	NA

Season	50 m spacing							
	Conventional drainage				Controlled drainage			
	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

Season	60 m spacing							
	Conventional drainage				Controlled drainage			
	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

Note: NA indicates sampling was not possible due to dry soil conditions.

In general, there was reduction in soil salinity in conventional as well as controlled drainage system. Rate of reduction of salinity depended on amount of irrigation water available for leaching and initial soil salinity as good quality canal water was used for irrigation. At lower depths, 30-60 cm and 60-90 cm, rise in soil salinity was also observed at few places. It might be due to restricted drainage (as in control drainage) or seepage from surrounding area (in conventional drainage). Average salt removal (t/ha), nitrogen loss (kg/ha) and crop yield (q/ha) based on drainage events during Rabi 2013-14, Kharif 2014, Rabi 2014-15, Kharif 2015, 2016, 2017 and 2018 as influenced by spacing of SSD and controlled drainage systems are provided in Table 2.7. The crop was not taken during rabi season during few years due to non-availability of canal water.

Table 2.7 Average Drain discharge (mm/day), Drainage quality (dS/m), salt removal (t/ha), nitrogen loss (kg/ha) and crop yield (q/ha) as influenced by spacing of conventional and controlled drainage systems

Spacing (m)	Drain discharge (mm/day)	Drainage quality (dS/m)	Salt removal (t/ha)	Nitrogen loss	Initial yield (q/ha)	Final yield (q/ha)
	Conventional sub surface drainage					
40	0.67	3.78	0.56	1.75	33.2	40.4
50	2.01	2.13	0.97	5.44	46.8	52.1
60	0.93	2.91	0.65	3.94	36.3	47.4
	Controlled sub surface drainage					
40	0.30	3.08	0.22	0.57	31.4	37.9
50	0.48	2.20	0.40	2.27	45.8	47.5
60	0.62	2.12	0.25	2.39	36.5	45.6

The above results indicated that removal of salt from root zone helped in improving crop yield. Highest salt removal took place in 50 m spacing under conventional as well as controlled drainage system and highest yields were reported in those cases. The highest loss of nitrogen of 5.44 kg per ha was reported in 50 m spacing in conventional system while it was 2.39 kg per ha in case of 60 m spacing in controlled drainage. Drain discharge value under conventional and controlled drainage was 2.01 and 0.62 mm/ day respectively. These values were highest under concerned drainage category. It can be inferred from these results that highest yield was observed in case highest salt removal and highest nitrogen loss was observed in case of highest drain discharge. It suggested that reclamation leaching is very much needed for improving crop yields while improving irrigation water use efficiency is important for reducing nitrogen loss.

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

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 raise of 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-18 (Table 2.8), out of seven blocks the surface (0-15 cm) soil salinity (ECe) reduced from 16.2 to 14.8 (block II), 7.54 to 5.15 (block III), 11.0 to 7.37 (block V) and 10.7 to 6.0 dS/m (block VI) whereas not much change was observed in other blocks. Similar reductions were observed at lower depths in these blocks.

Table 2.8 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	
Kharif-18	17.41	11.86	9.49	9.13	Kharif-18	14.85	10.0	7.9	5.67
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	16.3		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	
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	
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

At crop harvest during Kharif-18, irrespective of blocks the soil pH (Table 2.9) in general increased slightly over the seasons in surface soil and not much change were observed at lower depths.

Table 2.9 Average soil pH 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	7.92	8.25	8.25	7.99	Initial	7.98	8.07	8.13	8.11
R-17-18	8.53	8.40	8.39	8.44	R-17-18	8.38	8.26	8.44	
Kharif-18	8.07	8.29	8.25	8.06	Kharif-18	7.96	8.20	8.34	8.09
Block-III					**Block-IV**				
Initial	7.91	8.01	7.85	7.96	Initial	7.92	8.04	8.12	8.24
R-17-18	8.48	8.29	8.27		R-17-18	8.31	8.15	8.53	8.69
Kharif-18	8.18	8.33	8.08	8.18	Kharif-18	7.88	8.13	8.15	
Block-V					**Block-VI**				
Initial	7.74	7.93	8.05	8.04	Initial	7.95	8.20	8.27	8.05
R-17-18	8.36	8.46	8.67	8.48	R-17-18	8.46	8.43	8.5	8.5
Kharif-18	8.08	8.24	8.34	8.42	Kharif-18	8.06	8.34	8.20	
Block-VII					**Block-VIII**				
Initial	7.94	8.19	8.19	8.26	Initial	8.05	8.14	8.13	8.26
R-17-18	8.33	8.33	8.46	8.54	R-17-18	8.29	8.27	8.40	8.42
Kharif-18	8.02	8.44	8.27	8.31	Kharif-18	8.11	8.23	8.25	8.02

As per the suggestions of the QRT team only the conventional mode of SSD was practiced during both the seasons and the average drain discharge recorded during *Kharif*-2018 was 0.73 mm/d, salinity of the drainage effluent was 3.85 dS/m and removal of salts of about 0.87 t/ha through drainage effluent. There was slight improvement in paddy grain yield (36.3 q/ha) to the extent of 15 per cent over initial year yield. Limited availability of canal water in drainage area adversely affected reclamation leaching.

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

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. 2.2) during the pre canal irrigation period (2005 and 2012) and post canal irrigation period (2015 and 2019) and are given in Table 2.10. The same were used to calculate the rise of water table in the command.

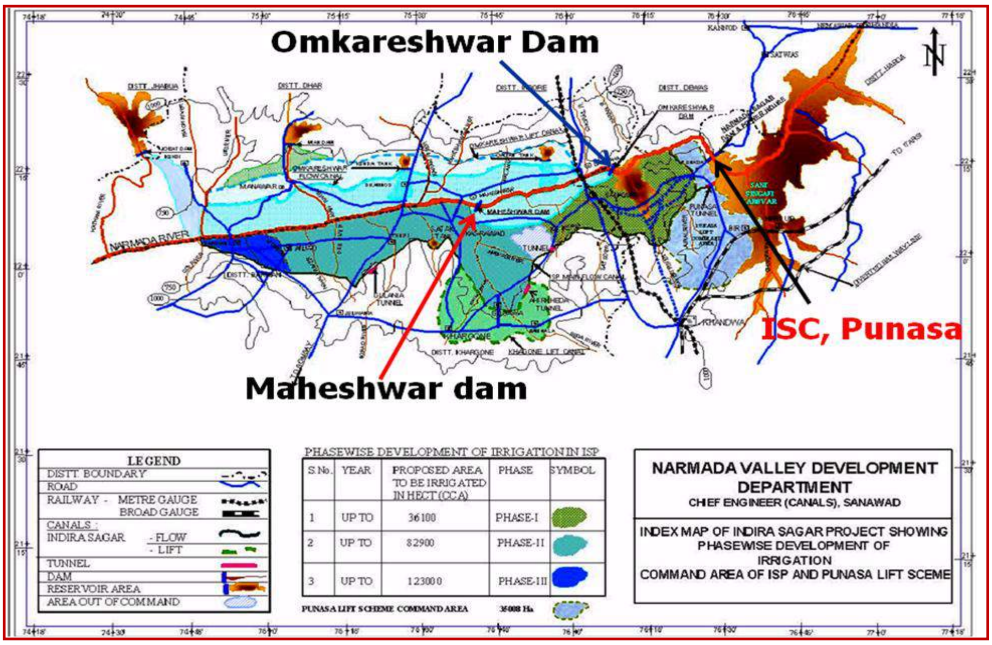


Fig. 2.2 Indira Sagar command of Narmada Sagar Command

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. 2.3. 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 2.10 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^{0}09’06.5”	76^{0}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^{0}09’08.9”	76^{0}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^{0}08’38.5”	76^{0}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^{0}07’ 4.2”	76^{0}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^{0}7’44.2”	76^{0}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^{0}07’ 4.2”	76^{0}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^{0}07’ 1.5”	76^{0}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^{0}08’ 0.5”	76^{0}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^{0}4’25.0”	76^{0}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^{0}2’05.1”	76^{0}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^{0}2’40.8”	76^{0}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^{0}3’47.6”	76^{0}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^{0}8’10.3”	76^{0}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

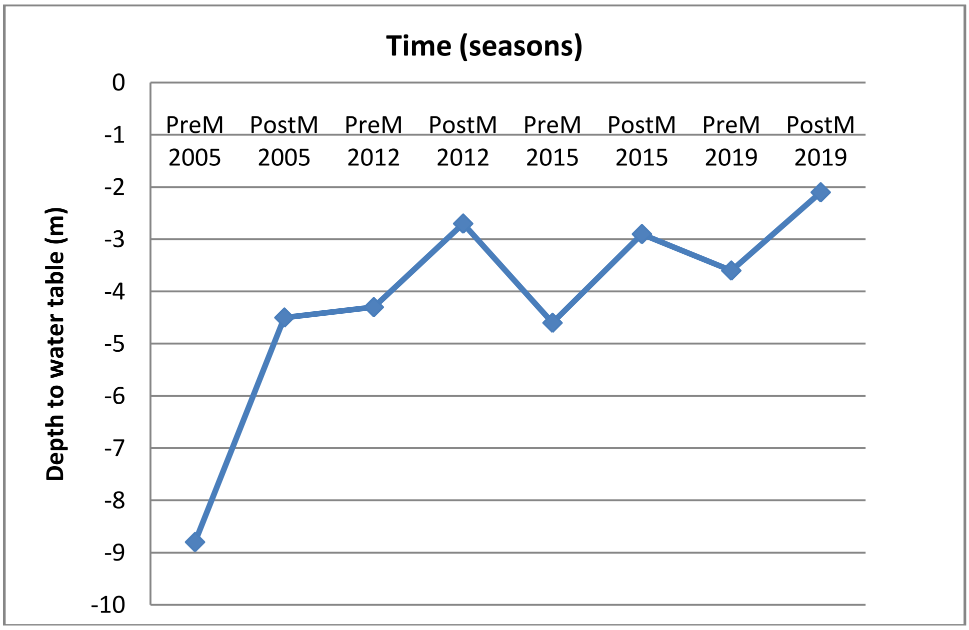


Fig. 2.3 Depth to water table with time in canal command

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 2.11). 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 2.11 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 2.12. 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 2.12 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 organics and raised bed on Okra (Port Blair)**

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 2.13 and Plate 2.1). 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 2.13 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 2.1 Effect of organics on Okra grown in raised bed

- **Evaluation of saline tolerant bioconsortia on brinjal and tomato (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 (Table 2.14 and Plate 2.2). 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 2.14 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 $dS\ m^{-1}$	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 $dS\ m^{-1}$	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 $dS\ m^{-1}$	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 2.2 Effect of saline tolerant bioconsortia on crop performance in pot experiment

- **Rain water storing in ponds for desalination of coastal saline soil on Farmers field (Panvel)**

Two farm ponds, constructed for storage of rain water, on farmers' fields i) Shri. Roshan Vinayak Mhatre, from village Koproli and ii) Shri. Chintaman Mahadev Mhatre, from village Koproliare were selected for this study. It was assumed that farm ponds would promote leaching of salts in nearby areas and nearby areas could be used to grow some short duration crop with residual moisture. Therefore, soil samples from two depths 0-22.5 and 22.5-45 cm, at 0, 10, 20, 40, 60, 80, 100, 200, 400, and 500 m distance from ponds were collected periodically twice in every month starting from outset of monsoon *i.e.* October onwards. These samples analysed for pH and EC to observe desalinization effect. The data pertaining to the pH (1: 2.5) and salinity EC (1: 2.5) of the soil samples, taken from farmers' fields are presented in Fig. 2.4 and Fig. 2.5. The samples were analysed for the soil electrical conductivity and pH by following standard procedure.

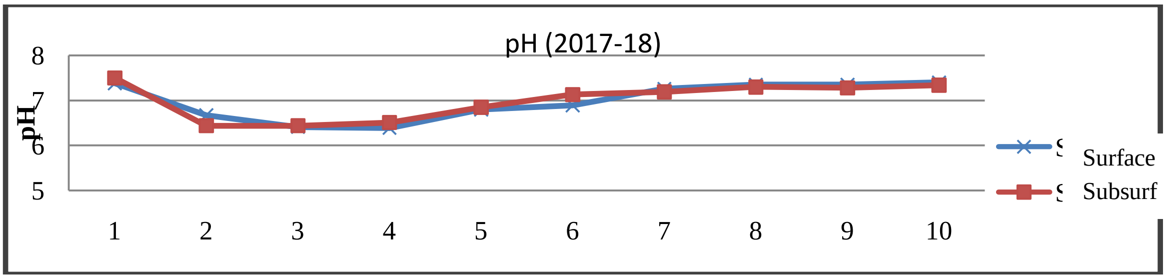
A) Farmer 1: Shri. Roshan VinayakMhatre

i) Surface pH and EC(0 to 22.5 cms) –

The overall average values of pH (1: 2.5) and EC (1:2.5) for surface soil samples collected from the distance of 0, 10, 20, 30, 40, 60, 80, 100, 200, 400 and 500 meter were 7.38,6.67, 6.41, 6.39, 6.80, 6.89, 7.26, 7.35, 7.35, 7.40and 5.28, 4.41, 3.52, 3.42, 3.50, 7.37, 8.10,11.27,11.22, 13.01dSm^{-1} respectively for the October, November, December, January, February, March and April.

ii) Sub-surface pH and EC (22.5 to 45.0 cms) –

The overall average values of pH and EC for sub surface soil samples collected from the distance of 0, 10, 20, 30, 40, 60, 80, 100, 200, 400 and 500 meter were 7.50, 6.44, 6.44, 6.51, 6.85, 7.13, 7.19, 7.30,7.28, 7.34 and 5.38, 4.60, 3.84, 4.26, 4.41, 5.08, 8.25, 11.43, 11.44, 13.21 d Sm^{-1}, respectively for the October, November, December, January, February, March and April.



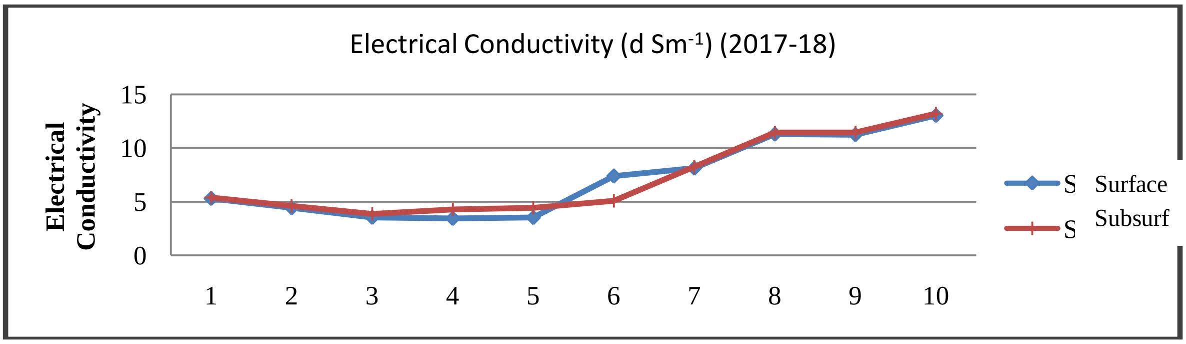


Fig 2.4 Graph of soil pH and EC of the farmers field (Farmer 1)

B) Farmer 2:Shri. Chintaman Mahadev Mhatre

i) Surface pH and EC (0 to 22.5 cms) –

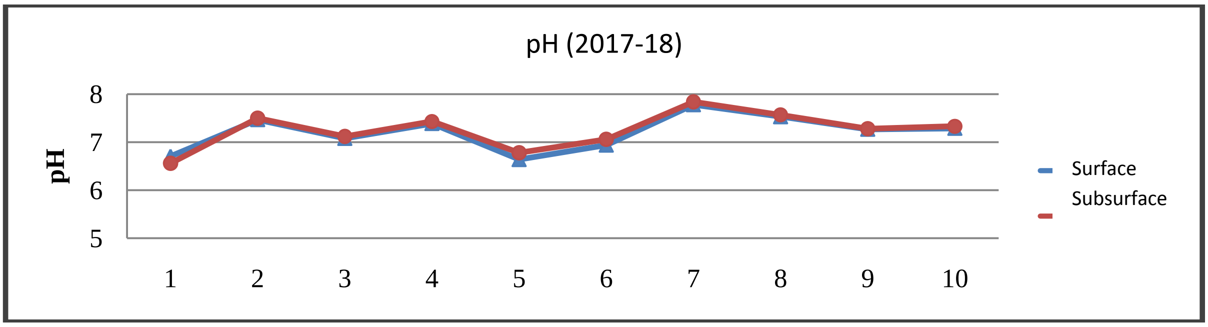
The overall average values of pH and EC for sub surface soil samples collected from the distance of 0, 10, 20, 30, 40, 60, 80, 100, 200, 400 and 500 meter were 6.71, 7.47, 7.08, 7.39, 6.64, 5.47, 7.78, 7.53, 7.27, 7.29 and 3.70,3.45,3.43, 3.60, 2.13, 2.91, 3.13, 3.67, 8.97, 9.81 dSm^{-1}, respectively for the October, November, December, January, February, March and April.

ii) Sub-surface pH and EC (22.5 to 45.0 cms) –

The overall average values of pH and EC for sub surface soil samples collected from the distance of 0, 10, 20, 30, 40, 60, 80, 100, 200, 400 and 500 meter were 6.56, 7.50, 7.12, 7.43, 6.78, 7.06, 7.84, 7.57, 7.28, 7.33 and 3.89, 3.53, 3.81, 4.05, 2.60, 3.42, 3.19, 4.01, 8.95, 9.93 dSm^{-1}, respectively for the October, November, December, January, February, March and April.

It was also evident that harvested rain water in fish pond had shown influence on EC of saline soil. It seems to be gradually increased as distance from fish pond increases. It was lowest at 0 m and maximum at 500 m. It may be attributed due to dilution and leaching of salts due to percolation of harvested rainwater from fish pond.

The pH and soil sainity data during 2017-18 followed similar trends as 2016-17. Both years' data suggested that leaching of salt was successful in 0-500 m area surrounding the pond as result of seepage of water from the pond. This is an additional advantage in case of fish pond. This reclaimed land can be used effectively for growing vegetables or pulses during rabi season immediately after harvest of rice crop using residual moisture and some water from fish pond.



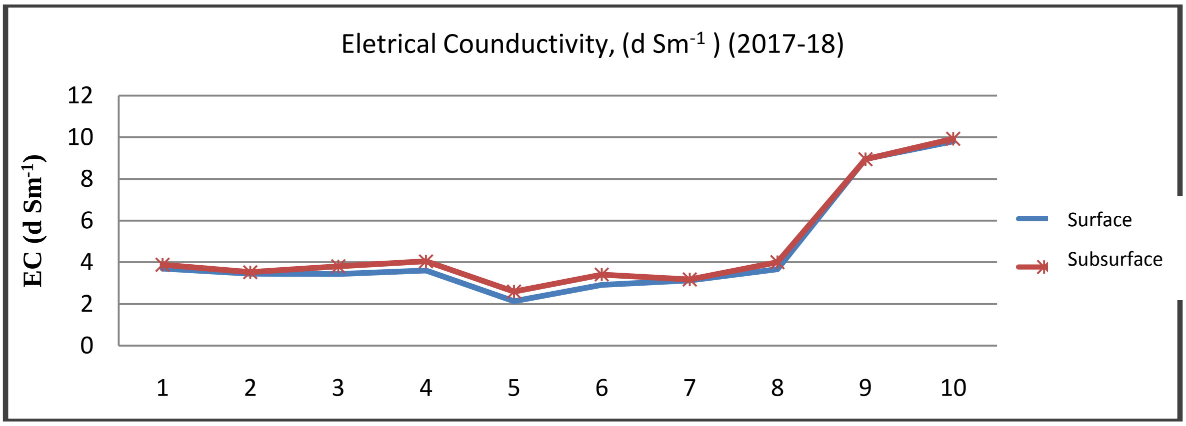


Fig 2.5 Graph of soil pH and EC of the farmers field (Farmer 2)

2.3 Management of Saline-Acidic Soils

- **Integrated farming system for sustainable land use in Pokkali lands – vegetable cultivation (Vyttila)**

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 2.15.

Table 2.15 Details of treatments

Sl. No.	Treatments	Crops	Use of 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 panting 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 Table 2.16

Table 2.16 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 2.17).

Table 2.17 Total yield of vegetables at field experiment in RRS, Vyttila

Sl. No.	Treatments	Yield (t ha^{-1})
		2018-19
1	T_1C_1	0.138
2	T_2C_2	-
3	T_3C_3	13.01
4	T_4C_4	9.61
5	T_5C_1	4.20
6	T_6C_2	5.02
7	T_7C_3	5.56
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 yield obtained from winter season vegetable 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.

- **Rice – prawn integration in *Pokkali* (Vyttila)**

Rice-prawn integration was planned under pokkali system for maximum productivity. Initial soil properties of Kumbalangi after rice cultivation (Table 2.18) and changes in soil properties after prawn were also studied (Table 2.19).

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
- ✓

Table 2.18 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

Table2.19 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 2.20.

Table 2.20 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.

3 MANAGEMENT OF POOR QUALITY WATERS

3.1 Management of Alkali Water

- **Use of Alkali ground water to supplement canal water for irrigation in Toria- Chikori crop rotation (Agra)**

This experiment was initiated during 2015-16 to study the suitable mode of using alkali groundwater for supplemental irrigation where canal supplies are inadequate/ unassured. The experiment was carried out in field plots measuring 4.0 m x 4.0 m in size and each plot was separated by polythene sheet up to 90 cm depth. The alkali water of RSC 10 meq/l was synthesized and applied in Toria-Chikori crop rotation. There were seven treatments viz., T1: All canal; T2: 1CW:1AW; T3: 2CW:2W; T4: 2AW:2CW; T5: Mixing (1 CW+2 AW); T6: Mixing (2 CW+1AW); T7: All Alkali water, in RBD and replicated thrice.

Toria: Details of experimentation in case of Toria crop are given in Table 3.1.

Table 3.1 Details of Toria in case of conjunctive water use of alkali and canal water

Observation	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Date of sowing	17-09-2015	20-09-2016	09-09-2017	19-09-2018
Variety	Kamboj-Gold	Kamboj-Gold	Kamboj-Gold	Supper Golden
Doses of N:P:K	100:60:60	100:60:60	100:60:60	10:60:60
No. & intervals of irrigation	3 (Pre, 34 & 65DAS)	2(Pre, 67DAS)	2(38 & 55DAS)	2(32 & 56DAS)
Depth of irrigation	7.0 cm	7.0cm	7.0 cm	7.0 cm
Total rainfall (mm)	27.2	11.25	14.1	10.5
Date of harvest	10.12.2015	05.01.2017	30.12.2017	14.01.2019

The crop yield data for grain, stover, biological yield and harvest index for 2018-19 are presented in Table 3.2.The grain and stover yield differ significant amongst the different mode of canal and alkali irrigations. The higher grain and stover yield recorded in canal irrigated treatment (14.02 q/ha and 26.43 q/ha) and lowest in all alkali water irrigated treatment (10.03q/ha and 17.93 q/ha). The biological yield and harvest index of toria recorded significant difference. The value of biological yield and harvest index recorded maximum in all canal irrigated plots and minimum in all alkali irrigated treatments. The net profits and B: C ratios for toria crop are given in Table 3.2. The maximum net profit was produced in canal water irrigation (Rs. 31,395) and lowest in alkali water irrigation Rs. (15,935) and all other treatments were found between in this range. In case of benefit cost ration the maximum was 2.38 in canal water irrigation and lowest in alkali water irrigation 1.70.

Table 3.2 Effect alkali water irrigation to supplemental canal water irrigation on seed yield, Stover yield, net profit and benefit cost ratio of Toria (2018-19)

Treatments	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	Net profit (Rs/ha)	B:C ratio
CW	14.03	26.43	40.46	34.93	31,395	2.38
1CW:1AW	13.00	24.03	37.03	34.13	27,415	2.20
2CW:2AW	12.87	23.50	36.37	35.43	26,912	2.18
2AW:2CW	12.16	23.13	35.39	34.10	23,936	2.05
Mix.(1:2)	12.87	24.27	37.14	34.40	26,912	2.18
Mix. (2:1)	12.95	24.93	37.88	33.90	26,642	2.18
AW	10.03	17.93	27.95	36.00	15,935	1.70
CD at 5%	1.23	3.12	5.83	1.61	-	-

Chikori:

After harvest of toria crop, the chikori crop was grown during rabi season with different alkali: canal irrigation modes. Details of experimentation are given below (Table 3.3).

Table 3.3 Details of Chikori in case of conjunctive water use of alkali and canal water

Observation	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Date of sowing	26-12-2015	15.01-2017	06-01-2018	12-01-2019
Variety	Ceriolo	Ceriolo	Ceriolo	Ceriolo
Doses of N:P:K	100:40:40	100:40:40	100:40:40	100:40:40
No. & intervals of irrigation	7; Pre., 19, 41, 58,82, 94 & 114 DAS	5;Pre,42,68,89 & 122DAS	7;Pre.18,39,66,95 105&113DAS	6;Pre.19,45,62,79 & 120DAS
Depth of irrigation	4 cm	4 cm	4 cm	4 cm
Total rainfall(mm)	90.9	113.2	227.6	92.5
Date of harvesting	11-05-2016	15-06-2017	30-06-2018	20-06-2019

The chikori root yield data for 2018-19 are presented in Table 3.4. The chikori root yields differ significantly amongst the different mode of canal and alkali irrigations. The maximum root yield was found in canal irrigation treatment (302.9 q/ha) and lowest in alkali water irrigated treatment (181.9 q/ha). The irrigation water mode 1CW:1AW, 2CW:2AW and mixing (2 CW: 1AW) were significantly at par to canal water irrigated treatment. The net profits and B: C ratios of chikori crop are also given in Table 3.4. The maximum net profit was found in canal water irrigation mode (Rs. 84,195) and lowest in alkali water irrigation mode (Rs. 37,703) and all other treatments were found in this range. In case of benefit cost ratio the maximum was 3.22 in canal water irrigation mode and lowest in alkali water irrigation mode 1.94.

Table 3.4 Effect alkali water irrigation to supplemental canal water irrigation on yield, net profit and benefit cost ratio of chikori (2019)

Treatments	Circumference of chikori root(cm)	Length of chikori root (cm)	Yield of chikori root (q/ha)	Net profit (Rs/ha)	B:C ratio
CW	13.79	25.25	302.9	88,828	3.22
1CW:1AW	12.78	22.46	292.0	84,195	3.11
2CW:2AW	12.49	22.48	287.7	82,368	3.06
2AW:2CW	11.27	20.88	253.1	67,663	2.69
Mix.(1:2)	11.81	21.88	277.0	77,820	2.95
Mix. (2:1)	11.30	22.79	285.5	81,433	3.05
AW	9.73	19.05	181.9	37,703	1.94
CD at 5%	0.58	1.11	16.11	-	-

Cropping System productivity:

The system productivity of different crops in toria –chikory cropping sequence presented in Table 3.5. The maximum system yield was observed in all canal (CW) treatment 316.93 q/ha and minimum in all alkali treatment (AW) 191.93 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 for these treatments.

Soil salinity:

The ECe, SAR, pH and ESP values were determined depth wise at sowing and after harvest of toria crop and harvest of chikory crop under different treatments and reported in Table 3.6. In general the

ECe, pH, SAR and ESP at sowing and harvest of toria crop was same causes of number of irrigations was not more and there was some rain fall during crop period. In case of chikory crop the value of ECe , SAR, pH and ESP increased slightly.

Table 3.5 Effect of modes of irrigation on system productivity (2018-19)

Treatments	Toria yield (q/ha)	Chikory yield (q/ha)	System yield (q/ha)
CW	14.03	302.9	316.93
1CW:1AW	13.00	292.0	305.00
2CW:2AW	12.87	287.7	300.57
2AW:2CW	12.10	253.1	265.20
Mix.(1:2)	12.87	277.0	289.87
Mix. (2:1)	12.80	285.5	298.30
AW	10.03	181.9	191.93

Table 3.6 Soil analysis of toria at sowing & after harvest and at harvest of toria and at harvest of chikory crop (2018-19)

Treat	Soil Depth (cm)	Toria at sowing				Toria at harvest/ Chicory at sowing				Chicory at harvest			
		ECe	pH	SAR	ESP	ECe	pH	SAR	ESP	ECe	pH	SAR	ESP
T1	0-15	2.3	7.5	2.7	7.8	2.5	7.6	2.9	7.8	2.5	7.6	2.8	7.8
	15-30	2.3	7.5	2.7	8.1	2.5	7.6	2.8	8.3	2.5	7.6	2.6	7.6
	30-60	2.2	7.5	2.6	-	2.4	7.5	3.0	-	2.4	7.5	2.6	-
	60-90	2.1	7.5	2.8	-	2.5	7.5	3.7	-	2.4	7.5	2.8	-
T2	0-15	2.4	7.7	3.5	7.8	2.6	7.8	4.1	8.6	2.5	7.6	3.4	8.1
	15-30	2.3	7.6	3.5	8.2	2.4	7.5	4.1	8.8	2.5	7.5	3.4	8.5
	30-60	2.2	7.6	3.7	-	3.4	7.5	3.8	-	2.3	7.5	3.7	-
	60-90	2.2	7.6	3.7	-	2.3	7.5	3.9	-	2.3	7.5	3.4	-
T3	0-15	2.4	7.5	3.5	7.8	2.5	7.6	4.6	8.5	2.5	7.6	3.6	8.1
	15-30	2.4	7.5	3.5	8.3	2.6	7.6	4.4	9.1	2.5	7.6	3.6	8.7
	30-60	2.3	7.5	3.6	-	2.5	7.5	4.1	-	2.4	7.5	3.5	-
	60-90	2.2	7.5	3.6	-	2.5	7.5	3.8	-	2.4	7.5	3.5	-
T4	0-15	2.5	7.8	6.8	8.7	2.7	7.8	7.8	9.8	2.5	7.6	6.8	9.2
	15-30	2.3	7.7	6.5	9.2	2.6	7.7	7.5	10.7	2.4	7.6	6.6	9.5
	30-60	2.3	7.7	6.1	-	2.5	7.5	6.8	-	2.4	7.5	6.1	-
	60-90	2.2	7.6	5.5	-	2.4	7.5	6.1	-	2.3	7.5	5.7	-
T5	0-15	2.4	7.7	6.3	8.3	2.6	7.9	7.5	8.6	2.5	7.5	6.7	9.2
	15-30	2.3	7.6	5.2	8.8	2.7	7.6	7.1	8.5	2.5	7.5	6.3	9.8
	30-60	2.2	7.6	5.1	-	2.6	7.6	5.2	-	2.4	7.5	5.1	-
	60-90	2.2	7.5	4.3	-	2.5	7.5	4.8	-	2.4	7.5	5.0	-
T6	0-15	2.4	7.6	3.8	8.2	2.6	7.8	4.8	8.4	2.5	7.6	4.9	9.5
	15-30	2.3	7.5	3.6	8.6	2.5	7.6	4.7	8.7	2.5	7.5	4.8	9.9
	30-60	2.3	7.5	3.8	-	2.5	7.6	4.2	-	2.4	7.5	3.8	-
	60-90	2.2	7.5	3.7	-	2.3	7.5	3.9	-	2.4	7.6	3.2	-
T7	0-15	2.5	7.9	8.8	9.3	2.8	8.3	11.2	10.1	2.8	8.2	10.8	11.7
	15-30	2.4	7.8	8.5	9.8	2.7	8.1	10.1	11.4	2.6	8.1	10.7	13.2
	30-60	2.4	7.6	7.8	-	2.5	7.9	8.8	-	2.5	3.9	8.5	-
	60-90	2.3	7.6	6.5	-	2.5	7.8	7.5	-	2.5	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 3.7). Initially pH, ECe, ESP and Organic Carbon of soil were 9.10, 093 dS/m, 42.2 and 0.28%, respectively.

Table 3.7 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 m2
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 3.8.

Table 3.8 Chemical composition of irrigation waters

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

The average grain yield of rice varied from 23.13-40.07 q/ha in rice- wheat cropping system, (Table 3.9). 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, (Table-B2). 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 3.9 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
T1: 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
T2: 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
T3: 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
T4: 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
T5: 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
T6: 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 3.10). 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, (Table 3.10). 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 3.10 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
T1: 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
T2: 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
T3: 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
T4: 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
T5: 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
T6: 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 (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 3.11). 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 3.11). 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 3.11 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
T1: 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
T2: 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
T3: 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
T4: 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
T5: 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
T6: 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 (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 3.12). 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 3.12). 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 3.12 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
T1: 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
T2: 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
T3: 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
T4: 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
T5: 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
T6: 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 (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 3.13.

Table 3.13 Effect of treatments on physico-chemical properties of soil after two years

Treatments	Rice-wheat				Pearl millet-wheat			
	pH	EC	ESP	OC	pH	EC	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)**

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 3.14). 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 3.14 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 lit hr^{-1} 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 3.15). Gypsum bed treatment reduced the RSC to 3.4.

Table 3.15 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 3.16. 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 3.16 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 3.17. 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 3.18. 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 3.17 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 3.18 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 liters ha^{-1})	S_3: (Control)	Mean
M_1: (Gypsum bed)	14.13	12.48	22.43	16.34
M_2: (DSW treated)	13.98	11.28	21.68	15.64
M_3: (Alkali water)	18.10	17.28	24.10	19.81
Mean	15.40	13.68	22.72	
		SED	CD(0.05)	
	M	0.190	0.46	
	S	0.210	0.44	
	M at S	0.353	0.78	
	S at M	0.364	0.77	

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 3.19. 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 3.19 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(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 3.20.

Table 3.20 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)			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
M1	12.2	14.5	8.2	11.6	33.2	37.2	28.3	30.2	1541	1718	1237	1499
M2	11.8	12.2	7.9	10.6	29.0	31.2	15.1	25.1	1357	1601	958	1305
M3	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	

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 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.

3.2 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 3.21) 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 3.21 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 3.22. 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 3.1).

Table 3.22 Irrigation water salinity with respect to different yield levels of crops

Yield Level	Chrysanthemum		Marygold		Tulasi	
	No. of flowers/plant	ECiw	No. of flowers/plant	ECiw	Biomass (t/ha)	ECiw
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 3.1 Field view of flower/medicinal plants with saline irrigation water through drip system

- **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 indicate that different treatments had significant effect on growth, yield attributes and yields of cumin (Table 3.23). Increase in ECiw beyond 6 dS/m caused significantly reduction in seed yield. As compared to ECiw of BAW with ECiw 2.4, 6 and 8 dS/m caused reduction of 4.87, 6.63 and 33.72 per cent, respectively. Similar trends were noticed in almost all the parameters studied.

Table 3.23: Effect of water salinity on yield attributes and yields of Cumin

Treatments	Plant Height (cm)	Number of branches per plant	Test weight (g)	seed yield (q/ha)
BAW EC 0.25dS/m	32.60	13.00	4.19	5.13
Tube-well water EC 2.40 dS/m	31.40	12.50	4.02	4.88
Irrigation water EC 6 dS/m	31.17	12.05	3.79	4.79
Irrigation water EC 8 dS/m	24.50	9.28	2.93	3.40
SEm±	0.58	0.32	0.16	0.12
CD (P=0.05%)	1.78	0.99	0.51	0.37

- **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)**

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 3.24). 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 3.24 Details of the experiment

Crop	Tomato (Solanum Lycopersicum *L.*)	Nursery	December 2017
Variety/Hybrid	Lakshmi F1 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 3.25).

Table 3.25 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 3.26), 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 3.26 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 3.27) 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 3.27 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 3.28) 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 3.28 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 3.29).

Table 3.29 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 3.30), 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 3.31) with 0.65 dS m^{-1} followed by subsurface drip irrigation (0.544) with 0.65 dS m^{-1}, surface drip irrigation with 2 dS m^{-1} and subsurface drip irrigation with 2 dS m^{-1} treatment and maximum under subsurface drip with 5 dS m^{-1} treatment (0.779). The highest benefit cost ratio of 1.84 was obtained under subsurface drip irrigation in normal irrigation (0.65 dS m^{-1}) water followed by surface drip irrigation (1.80), subsurface drip in 2 dS m^{-1} irrigation saline water level (1.78), surface drip irrigation in 2 dS m^{-1} irrigation saline water level (1.69) and lowest (1.06) in furrow irrigation technique in 5 dS m^{-1} treatment.

Table 3.30 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 dS m^{-1}) water followed by surface drip irrigation in normal irrigation (0.65 dS m^{-1}) water (₹. 957831), subsurface drip in 2 dS m^{-1} irrigation saline water level (₹. 920650), surface drip irrigation in 2 dS m^{-1} irrigation saline water level (₹. 832542) and lowest (₹. 52618) in furrow irrigation technique in 5 dS m^{-1} treatment. The highest internal rate of return of 350 percentages was obtained under furrow irrigation in normal irrigation (0.65 dS m^{-1}) water followed by furrow irrigation in 2 dS m^{-1} and lowest in case of subsurface drip irrigation in 5 dS m^{-1} treatment. Among surface drip irrigation under different salinity levels, highest IRR was found in normal irrigation (0.65 dS m^{-1}) water followed by 2 dS m^{-1} treatment and lowest in 5 dS m^{-1}. Among subsurface drip irrigation under different salinity levels, highest IRR was found in normal irrigation water followed by 2 dS m^{-1} treatment and lowest in 5 dS m^{-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 dS m^{-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 3.31 Economic feasibility of tomato under different irrigation techniques and saline water

Sl.No.	Treatments	BC 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. The details of the experiment are given in Table 3.32. The crops were harvested at maturity and yield data were recorded for each plot.

Table 3.32 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 3.33. The minimum grain and stover yield (24.22 and 68.15 q/ha) was recorded with 75% RDF alone.

Table 3.33 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 chrocucuum,* Biomix = *Azotobacter chrocucuum* (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%

The maximum plant height (203.90 cm), yield attributes viz., effective tillers/plant (3.03), earhead length (22.73cm) Table 3.34.

Table 3.34 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

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 3.35).

Table 3.35 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

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

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 3.36).

Table 3.36 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 3.37).

***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 3.38). 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 3.39).

Table 3.37 Effect of sewage sludge on grain yield (q/ha) of pearl millet irrigated with saline water of different salinity

Treatment	Canal (0.3)	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 3.38 Effect of sewage sludge on grain yield (q/ha) of wheat irrigated with saline water of different salinity

Treatment	Canal (0.3)	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 3.39 ECe (dS/m) of the soil at different depths (0-15cm) after harvest of wheat in different treatment plots

Treatment	Canal	8.0	10.0
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 3.40) 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 3.40 Effect of various treatments on soil organic carbon (%) different quality of irrigation water

Treatment	Canal	8.0	10.0
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 3.41) 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 3.41 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 3.41) 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 3.41) 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 3.41) 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 3.42. 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 3.43. 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 3.42 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 3.43 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. 3.1) 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.

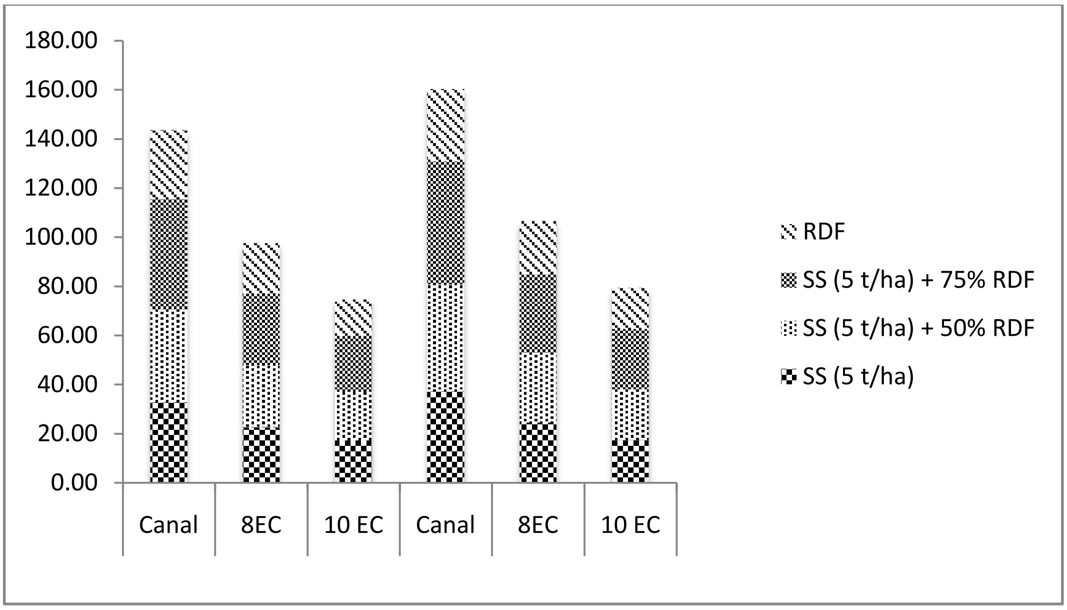


Fig. 3.1 Effect of sewage sludge application on soil dehydrogenase activity (µg TPF/g /24 hr) at pearl millet and wheat crop harvest under saline water irrigation

Microbial biomass carbon: A critical perusal of data depicted in (Fig. 3.2) 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.

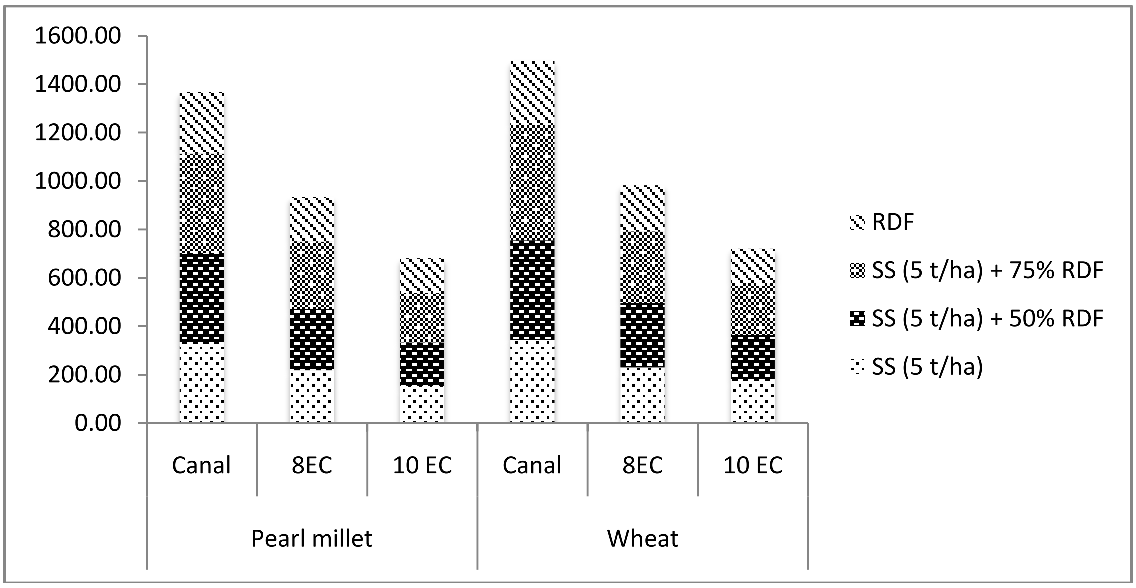


Fig. 3.2 Effect of sewage sludge application on soil microbial biomass carbon (µg/g) at pearl millet and wheat crop harvest under saline water irrigation

Economic analysis: Data (Table 3.44) 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 3.45) 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 3.44 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 3.45 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

- **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:

- Canal water EC_{iw} = 0.3 dS/m
- Saline water EC_{iw} = 2.5 dS/m
- Saline water EC_{iw} = 5.0 dS/m

b) Nitrogen fertigation levels: three

- 75% of RDN
- RDN
- 125% of RDN

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. 3.3. 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.

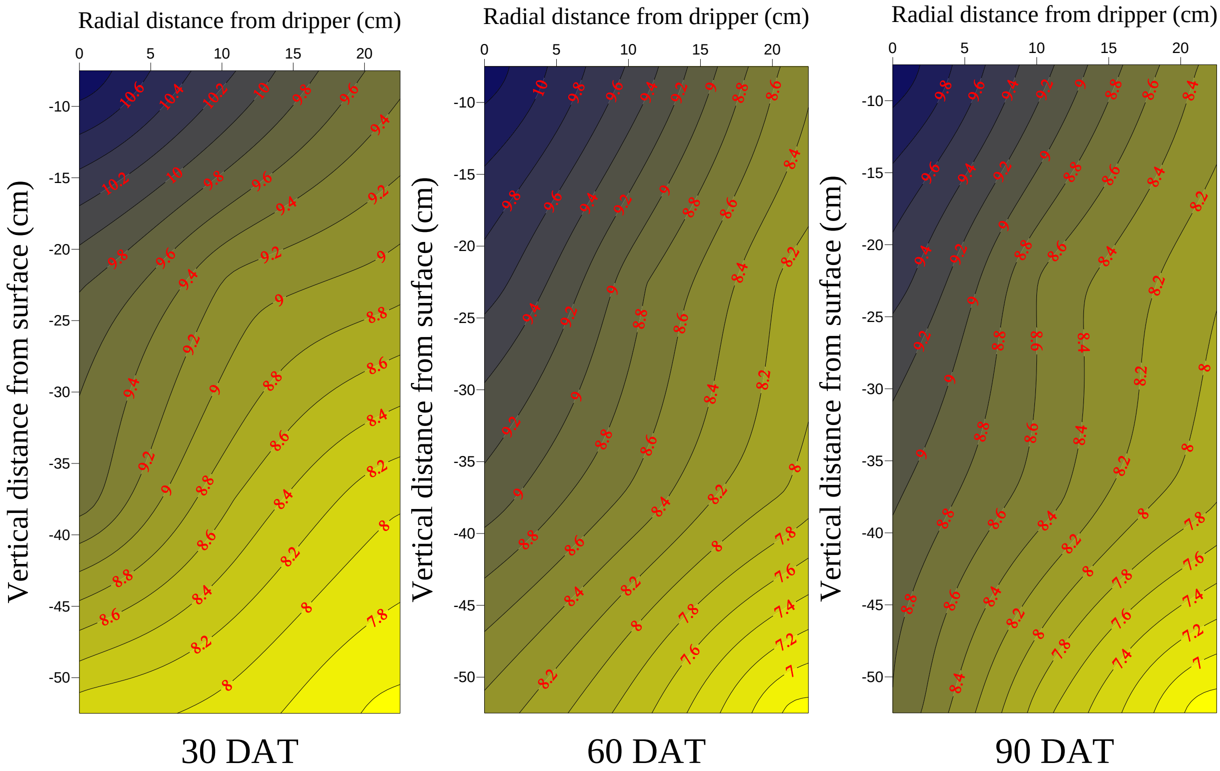


Fig. 3.3 Spatial and temporal movement of moisture content in S_1F_1

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. 3.4. 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.

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 dS m^{-1}). Whereas a decreasing trend was observed as the irrigation water changes from good quality to poor quality water (2.5 dS m^{-1} and 5 dS m^{-1}). 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. 3.5, 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.

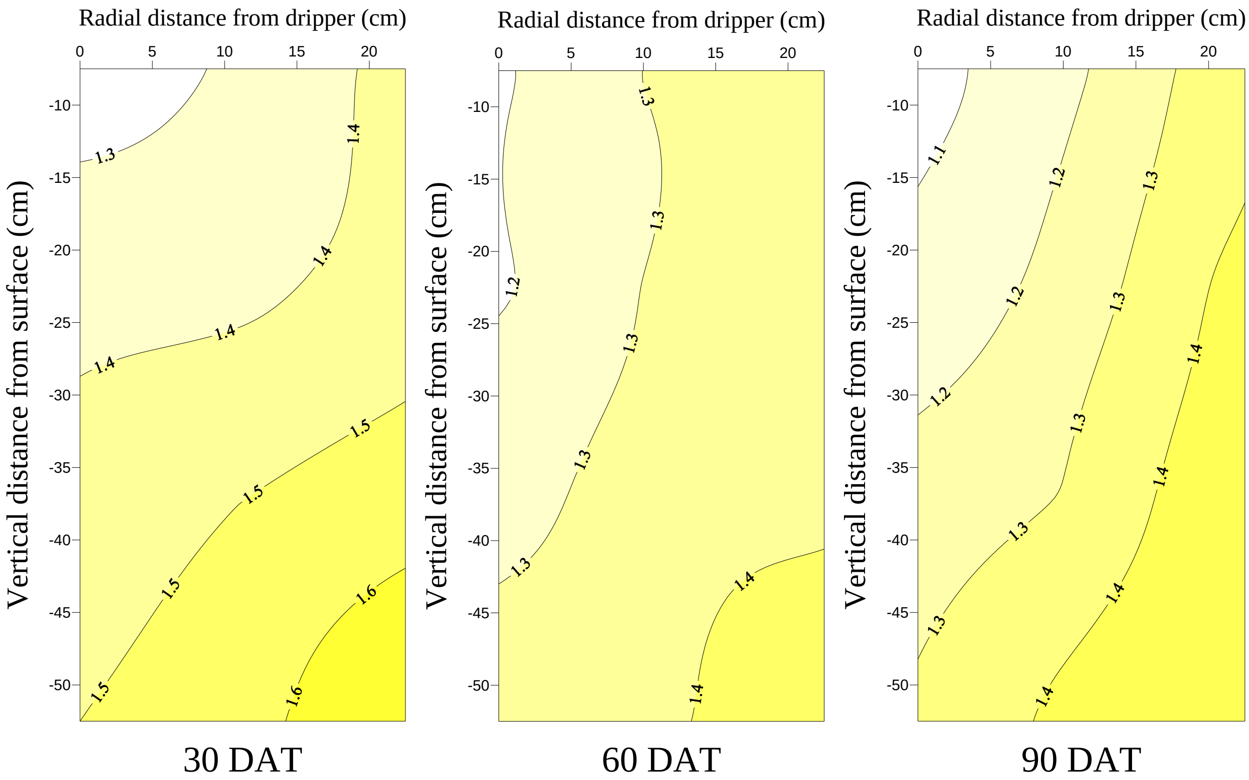


Fig. 3.4 Spatial and temporal movement of salt in S_1F_3

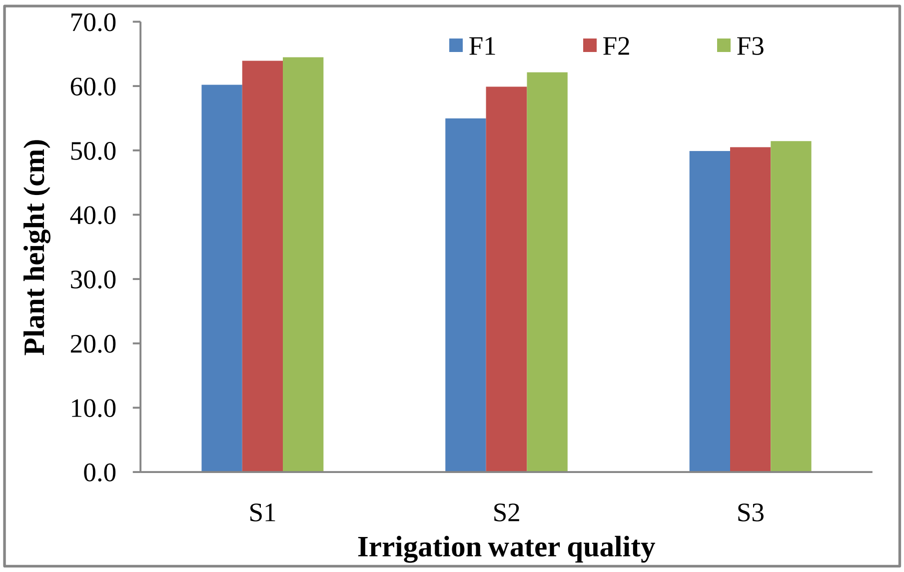


Fig. 3.5 Plant height of onion of different treatments at harvest

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. 3.6, 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.

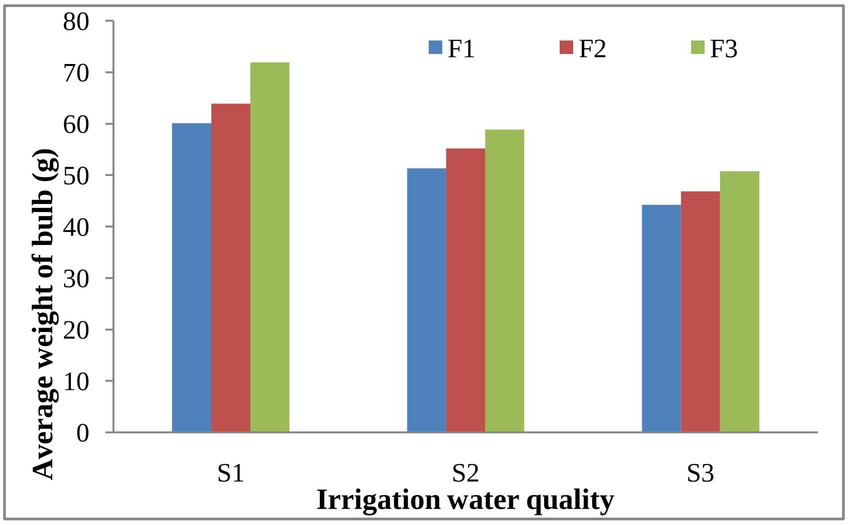


Fig. 3.6 Average weight of bulb under different treatments

Yield of Onion: The data on yield of onion under different N and salinity levels with drip irrigation (Table 3.46) 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 3.46 Effect of nitrogen fertigation under different saline water in drip irrigation system onion yield (q/ha)

N Level	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. 3.7, 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.

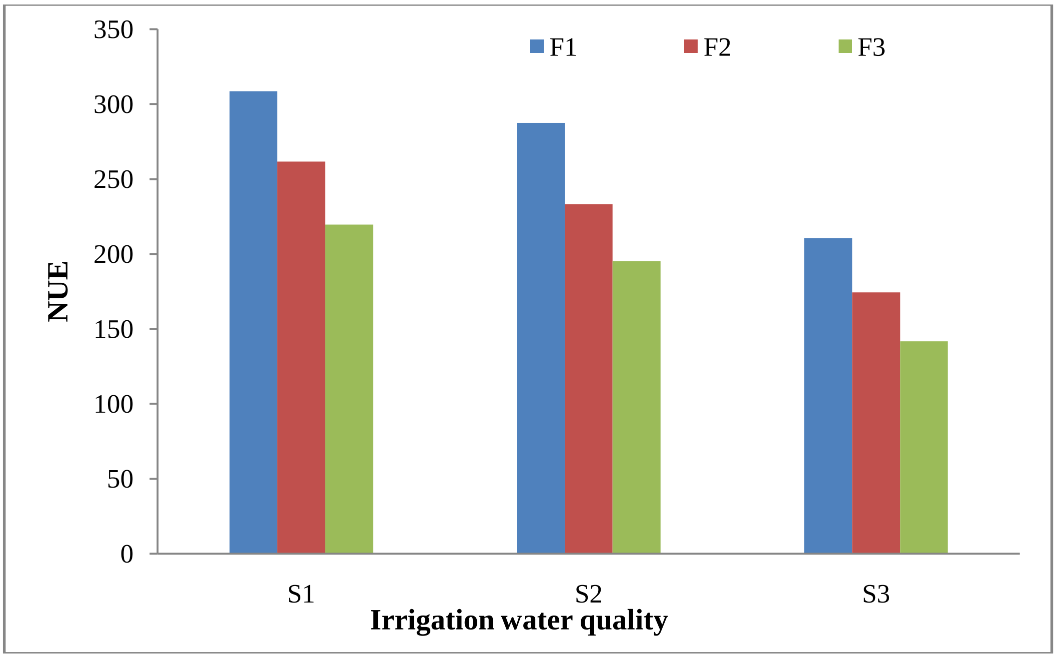


Fig. 3.7 NUE under different treatment

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

The experiment was laid out with five levels of irrigation water. The objective of the experiment was to study response of leafy vegetables to saline water irrigation and to study the changes in soil properties. The experiment was conducted during *rabi* 2018-19 for Radish, Dill and Spinach with five levels of saline water irrigation. The initial pH and EC of experimental soil were 6.82 and 2.35 dS/m, respectively. Other chemical properties are provided in Table 3.47. 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 3.48.

Table 3.47. Initial soil properties of experimental plot

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

Table 3.48 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 3.49 and 3.50. 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 3.49). 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 3.49: 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 3.50. 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 3.50 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 3.51).

Table 3.51 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

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 3.52). 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 3.52 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 d Sm^{-1} (T_2)	7.82	7.95	7.89	7.89	
4 d Sm^{-1} (T_3)	7.71	7.68	7.57	7.65	
6 d Sm^{-1} (T_4)	7.81	7.72	7.79	7.78	
8 d Sm^{-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 3.53. As far as effect of salinity of irrigation water is concerned, application of pond water T_1 (13.62 tha^{-1}) showed significantly higher vegetable yield over rest of all treatments. The crop C_3 i.e. radish (15.47 t ha^{-1}) produced significantly higher yield over C_1 (Spinach 9.49 t ha^{-1}) and C_2 (Dill 8.31 t ha^{-1}). In case of interaction effect, T_1C_3 i.e. irrigation of radish crop with pond water recorded significantly higher yield (18.78 t ha^{-1}) over rest of all the interactions. It will be interesting to understand economics of growing different vegetables with saline water considering their market prices.

Table 3.53 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 d Sm^{-1} (T_2)	10.49	7.49	16.46	11.48	
4 d Sm^{-1} (T_3)	7.61	10.30	10.34	9.42	
6 d Sm^{-1} (T_4)	8.91	8.06	16.11	11.02	
8 d Sm^{-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 3.54.

Table 3.54 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 (dS m^{-1}) +17.45	$R^2 = 0.113$
2.	Dill	Y (t ha^{-1}) = -1.240*EC (dS m^{-1}) + 12.03	$R^2 = 0.588$
3.	Radish	Y (t ha^{-1}) = -0.331*EC (dS m^{-1}) + 16.79	$R^2 = 0.113$

- **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). Details of observational trial 2018-19 are given below (Table 3.55).

Table 3.55 Experimental details

<table>
<tr><th>Treatments</th><th colspan="2">Other Details</th></tr>
<tr><td rowspan="9">i. Plastic mulch (Black):T_1-Plastic polythene mulch + FYM @15 t ha^{-1}
ii. T_2-Paddy straw mulch @ 20 kg/plot + Vermicompost @ 5 t ha^{-1}
iii. T_3-Plastic polythene mulch + Vermicompost @ 5 t ha^{-1}
iv. T_4- Paddy straw mulch @ 20 kg/plot + Vermicompost (50%) + FYM (50%)
v. T_5- Plastic polythene mulch + Vermicompost (50%) + FYM (50%)
vi. T_6- Plastic polythene mulch + Vermicompost @ 5 t ha^{-1}
vii. T_7- Control</td><td>Design:</td><td>Split plot design</td></tr>
<tr><td>Replication</td><td>Three</td></tr>
<tr><td>Plot size</td><td>4.20 X 1.2 m</td></tr>
<tr><td>Date of Sowing</td><td>20/12/2018</td></tr>
<tr><td>Crop & Variety</td><td>Tomato-Sungro F1 hybrid 3618
Chilli-Semimis hybrid SHP 4884
Brinjal-Mahyco MEBH 10</td></tr>
<tr><td>Plastic mulch (Black)</td><td>50 micron</td></tr>
<tr><td>Straw mulch</td><td>20 kg/plot</td></tr>
<tr><td>Paired row plantation</td><td>1.0 m X 0.30 m</td></tr>
<tr><td>Treatments:</td><td>7</td></tr>
</table>

The observational trial (Plate 3.2) was conducted on experimental field of Panvel farm during rabi 2018-19 and the yield of vegetables was recorded. From Table 3.56 it is observed that the treatment T_3*i.e.*plastic polythene mulch + Vermicompost @ 5 t ha^{-1}recorded higher yield ofbrinjal (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.

Table 3.56 Yield data of vegetables (Brinjal, Chilli and Tomato)

Treatment	Yield (t/ha)		
	Brinjal	Tomato	Chilli
T1-Plastic polythene mulch + FYM @15 t ha^{-1}	48.40	58.22	18.57
T2-Paddy straw mulch @ 20 kg/plot + Vermicompost @ 5 t ha^{-1}	43.30	65.49	17.02
T3- Plastic polythene mulch + Vermicompost @ 5 t ha^{-1}	61.25	90.07	31.67
T4- Paddy straw mulch @ 20 kg/plot + Vermicompost (50%) + FYM (50%)	60.84	57.18	23.84
T5- Plastic polythene mulch + Vermicompost (50%) + FYM (50%)	47.51	74.63	21.26
T6- Plastic polythene mulch + Vermicompost @ 5 t ha^{-1}	54.40	68.57	20.96
T7- Control	40.21	42.82	9.82

Plate 3.2 General view of Experimental plot

3.3 Management of Waste Water

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

A field experiment was initiated during 2015-16 to evaluate the sewage water, tube well water and sewage + tube well water irrigation in cluster bean -cauliflower-okra crop rotation. The treatment comprised of three irrigation water SW (sewage water), TW (tube well water) and 1SW: 1TW with three recommended dose of fertilizer i.e. 50%, 75% and 100% RDF.

Cluster bean

The first crop was Cluster bean during kharif. Details of cluster bean crop during various years are given below (Table 3.57).

Table 3.57 Details of Cluster bean experiment

Observation	2015	2016	2017	2018
Date of sowing	14-07-2015	28-06-2016	06-07-2017	11-07-2018
Variety	Ankur Rani	Ankur Rani	Ankur Rani	Ankur Rani
Doses of N:P:K	40:60:60	40:60:60	40:60:60	40:60:60
No. & intervals of irrigation	4 (Pre. 32,78 & 93 DAS)	3 (Pre. 68 & 82DAS)	6 (Pre. 28,36,65 ,79 & 89 DAS)	1(65 DAS)
Depth of irrigation	4.0 cm	4 cm	4 cm	4 cm
Total rainfall(mm)	110.8	862.3	176.5	691.0
Date of harvesting	12-11-2015	9-11-2016	9-11-2017	21-11-2018

The data (Table 3.58) revealed that the 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 highest pod length (11.97 cm) was recorded in sewage water and lowest (10.19 cm) was recorded in Tubewell water irrigation. The pod yield per plant were found maximum in sewage water irrigation treatment (350.56 g) and lowest in tube well water irrigation treatment (315.94 g), tube well water and 1SW:1TW water irrigation gave pod yield/plant at par. Table 3.58 further clearly indicated that by application of 100% recommended dose of fertilizer (RDF) and 75% RDF, no significant difference occurred in pod length and pod yield per plant of cluster bean. By the application of 50% RDF, significantly lowest pod length and pod yield per plant was recorded. The application of sewage water irrigation gave significantly maximum pods yield q/ha (130.8q/ha) and minimum pod yield was recorded with tube well water irrigation (86.5 q/ha). There was no significant difference was found with application of 75% RDF and 100% RDF. By the application of 50% RDF significantly lowest pod yield was recorded as compared with to 75% and 100% RDF (Table 3.58).

The net profits in different treatments of cluster bean are given in Table 3.58. Maximum net profit (Rs/ha) and B:C ratio were recorded in sewage water irrigation treatments (Rs 70,600/- and 2.17) and minimum in Tube well water irrigation treatment (Rs. 26,335/- and 1.43). By the use of recommended dose of fertilizer (100% RDF) maximum net profit (Rs/ha) and B:C ratio (Rs. 55,752/- and 1.92) and with 50% recommended dose of fertilizer treatments (Rs. 51,584 and 1.88) net profit was recorded.

Interaction:

The interaction effect of irrigation water with recommended dose of fertilizer on pod yield of clusterbean was found to be significant. A critical examination of the data displayed in Table 3.59. The cluster bean pod yield increased with every increase in the rate of RDF up to 100%. However, rate of RDF was increased from 75% to 100% RDF, the pod yield per hectare increased marginally.

The maximum pod yield was obtained with the use of sewage water and 100% RDF, which was significantly higher than rest of combinations.

Table 3.58 Effect of different treatments on yield attributes and yields of cluster bean (2018-19)

Treatments	Pod length (cm)	Pod yield / plant (g)	Pod yield (q/ha)	Net profit (Rs./ha)	B: C ratio
Irrigation water					
SW	11.97	350.56	130.8	70,600	2.17
TW	10.19	315.94	86.5	26,335	1.43
1 SW:1TW	11.63	341.88	125.6	65,402	2.09
CD at 5%	0.89	4.19	3.59	-	-
Recommended dose of fertilizer					
50%	10.01	331.26	109.5	51,584	1.88
75%	11.19	335.69	115.2	55,002	1.87
100%	11.97	341.43	118.22	55,752	1.92
CD at 5%	0.89	4.19	3.59	-	-
IW X F	NS	NS	4.40	-	-

Table 3.59 Interaction effect of irrigation water x fertilizer dose (2018-19)

Irrigation water	Fertilizer dose ((%)			Total	Av.
	50%	75%	100%		
SW	125.8	131.7	134.9	392.4	130.8
TW	81.8	87.6	90.2	259.6	86.5
1SW:1TW	120.8	126.3	129.7	376.8	125.6
Total	328.4	345.6	354.8	-	-
Av	109.5	115.2	118.3	-	--
CD at 5% = 7.40					

The cauliflower was second crop in sequence after harvest of cluster bean crop during rabi crop. The experimental details of the crop are as below (Table 3.60).

Table 3.60 Details of Cauliflower experiment

Observation	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Date of sowing	12-12-2015	19-11-2016	24-11-2017	05-12-2018
Variety	Mahima-80	Mahima-80	Mahima-80	Mahima-80
Doses of N:P:K	120:60:60	120:60:60	120:60:60	120:60:60
No. & intervals of irrigation	4(Pre., 25, 45, and 62DAS)	4 (Pre.,28,48, and 64DAS)	5 (Pre.,26,45,62 and 72 DAS	3(Pre., 32and 65 DAS)
Depth of irrigation	7.0 cm	7.0cm	7.0cm	7.0 cm
Total rainfall(mm)	0.50	26.5	2.1	21.6
Date of harvesting	14-03-2016	02-03-2017	23-2-2018	02-03-2019

The application of irrigation water and dose of fertilizer gave significant results in no. of leaves per plant, circumference of head (cm) and weight of head (g). All attributes characters were found maximum with sewage irrigated treatments and minimum in tube well irrigated treatments. In case of application of fertilizer, no. of leaves per plant, circumference (cm) and weight of head (g) were found highest in 100% RDF and lowest in 50% RDF (Table 3.61). The yield data of cauliflower crop are also given in Table 3.61. By the application of sewage water irrigation cauliflower crop produced significant flower yield, and significantly maximum cauliflower yield (282.69 q/ha) was produced in sewage water irrigation and minimum (209.42 q/ha) in tube well water irrigation. By the application of recommended dose of fertilizer, significantly higher flower yield (284.28 q/ha) was produced in 100% RDF and lowest (217.50 q/ha) in 50% RDF.

Table 3.61 Effect of different treatments on yield attributes and yields of cauliflower (2018-19)

Treatments	No. of green leaves/plant	Cauliflower circumference (cm)	Flower weight (g)	Yield (q/ha)	Net profit (RS/ha)	B:C ratio
Irrigation water						
SW	22.33	57.60	546.88	282.69	70,812	2.00
TW	14.78	41.28	413.82	209.42	34,212	1.48
1 SW:1TW	19.67	49.44	478.28	265.57	62,212	1.88
CD at 5%	2.20	3.20	9.65	12.94	-	-
Recommended dose of fertilizer						
50%	17.78	46.03	469.03	217.50	41,075	1.61
75%	18.89	49.81	478.74	255.94	57,378	1.81
100%	20.11	52.48	492.20	284.28	68,782	1.94
CD at 5%	2.20	3.20	9.65	12.94	-	-
IW X F	NS	NS	NS	15.88	-	-

In cauliflower crop, net profit of different treatments were calculated and presented in table 4.9 and fig 4.4 (a and b). Maximum net profit (Rs/ha) and B: C ratio was produced in sewage water irrigation treatment (70,812 and 2.00) and minimum in tube water irrigation treatments (34,212 & 1.48). By the use of recommended dose of fertilizer, 100% RDF gave maximum net profit (Rs/ha) and B:C ratio (68,782 and 1.94) and minimum was in 50% recommended dose of fertilizer treatments (40,075 and 1.61).

Interaction:

The interaction effect of irrigation water with recommended dose of fertilizer on head yield of cauliflower was found to be significant. A critical examination of the data revealed that irrigation water exhibited differential response to RDF. Cauliflower yield increased with increase in the rate of RDF up to 100%. 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 3.62).

Table 3.62 Interaction effect of irrigation water x fertilizer dose (2018-19)

Irrigation water	Fertilizer dose ((%)			Total	Av.
	50%	75%	100%		
SW	242.70	284.63	320.73	848.06	282.69
TW	186.90	214.70	226.80	628.40	209.47
1SW:1TW	222.90	268.50	305.00	796.40	265.47
Total	652.50	767.83	852.33		
Av	217.50	255.94	284.28		
CD at 5% = 15.88					

Okra:

After harvest of cauliflower crop, the okra crop was taken during summer season with different irrigation water and recommended dose of fertilizer. Details of experimentation are given below (Table 3.63).

Table 3.63 Details of Okra experiment

Observation	2015-16	2016-17	2017-18	2018-19
Date of sowing	21-3-2016	10-03-2017	8-3-2018	12-03-2019
Variety	Mahyco-777	Moona-002	Moona-002	Moona-002
Doses of N:P:K	120:60:40	120:60:40	120:60:40	120:60:40
No. & intervals of irrigation	9(Pre,13,19,26,33,45,51,58 & 65DAS)	11(Pre; 12,19,24,33,44,50,59,80,.& 99 DAS)	10(Pre.15,20,26,35,40,48,55, 61&68DAS)	7(Pre.22,32,41,58,65 &69DAS)
Depth of irrigation	6 cm	4cm	4cm	4 cm
Total rainfall (mm)	62.5	98.5	148.9	22.5
Date of harvesting	15-06-2016	30-06-2017	20-6-2018	11-06-2019

Table 3.64 clearly indicated that the application of irrigation water and doses of fertilizer gave significant results in length of pod (cm) and pod yield per plant (g). The all attributes were maximum in sewage water irrigated treatments and minimum in tube well water irrigated treatments. In case of application of fertilizer the highest length of pod and pod yield per plant were recorded in 100% RDF and lowest in 50% RDF.

Table 3.64 Effect of different treatments on yield and economics in okra crop (2018-19)

Treatments	Length of pod (cm)	Pod yield per plant (g)	Yield (q/ha)	Net profit (RS/ha)	B:C ratio
Irrigation water					
SW	9.35	327.44	123.82	98,673	2.12
TW	8.10	280.44	68.00	14,590	1.16
1 SW:1TW	9.16	293.00	108.68	75,390	1.86
CD at 5%	0.32	6.11	5.24	-	-
Recommended dose of fertilizer					
50%	7.10	294.33	93.89	56,315	1.67
75%	9.38	300.67	99.53	61,882	1.71
100%	10.03	305.89	107.08	70,657	1.77
CD at 5%	0.32	6.11	5.24	-	-
IW X F	NS	NS	10.10	-	-

By the application of sewage water irrigation in okra crop, produced significant pod yield,maximum pod yield (123.82 q/ha) was recorded in sewage water irrigation and minimum (68.0q/ha) in tube well water irrigation. By application of recommended dose of fertilizer significantly higher pod yield (107.08 q/ha) was recorded in 100% RDF and lowest in (93.89 q/ha) in 50% RDF. In okra crop net profit of different treatments were calculated and presented in Table 3.64. In okra crop maximum net profit (Rs/ha) and B: C ratio was recorded in sewage water irrigation treatment (Rs. 98,673/- and 2.12) and minimum was tube well water irrigation treatments (Rs. 14,590/-& 1.16). The use of recommended dose of fertilizer 100% RDF gave maximum net profit (Rs/ha) and B:C ratio (70,657 and 1.77) and 50% RDF treatments gave minimum (56,315 and 1.67), respectively.

Interaction:

The interaction effect of irrigation water with recommended dose of fertilizer on pod yield of okra crop found to be significant (Table 3.65). A critical examination of the data revealed that irrigation water exhibited differential response to RDF. In all mode of irrigation water use in okra crop the pod yield increased with every increase in the rate of RDF up to 100%. But from 75% to 100% RDF the pod yield per hectare increased marginally. The maximum pod yield was obtained with the use of sewage water and 100% RDF which was significantly higher than that of rest combinations.

Table 3.65 Interaction effect of irrigation water x fertilizer dose (2018-19)

Irrigation water	Fertilizer dose ((%)			Total	Av.
	50%	75%	100%		
SW	117.30	123.90	130.27	371.47	123.82
TW	64.33	67.27	72.40	204.00	68.00
1SW:1TW	100.03	107.43	118.56	326.02	108.68
Total	281.66	298.60	321.23	-	-
Av	93.88	99.53	107.07	-	-
CD at 5% =10.10					

Rotational net profit and B: C ratio:

The annually net profit for rotation cluster bean-cauliflower-okra was calculated and presented in Table 3.66. The maximum net profit of the three crops grown in one year found in sewage water irrigation treatment (Rs. 2,91,960) and lowest in tube well water irrigated treatment (Rs. 1,17,958). The benefit cost ratio in this rotation was calculated and maximum in sewage water irrigation treatment (6.18) and minimum in tube well irrigated treatment (3.77).The application of recommended dose of fertilizer the maximum net profit and B:C ratio was found in 100% RDF (Rs.2,43,169 and 5.34) and minimum 50% RDF (Rs. 1,86.512 and 4.79).

Table 3.66 Effect of different treatments on net profit and benefit cost ratio of cluster bean, cauliflower and okra (2018-19)

Treat	Net profit(Rs./ha)			Total	B:C ratio			Total
	Cluster bean	Cauliflower	Okra	Total	Cluster bean	Cauliflower	Okra	Total
SW	70,600	98,673	1,22,687	2,91,960	2.17	2.12	1.89	6.18
TW	26,355	14,590	77,033	1,17,958	1.43	1.16	1.18	3.77
1 SW:1TW	45,402	75,590	1,09,210	2,50,212	2.09	1.86	1.67	5.62
Recommended dose of fertilizer								
50%	51,584	56,315	78,613	1,86,512	1.88	1.64	1.27	4.79
75%	55,002	61,882	1,13,567	2,30,451	1.89	1.71	1.75	5.35
100%	55,752	70,657	1,16,460	2,43,169	1.82	1.77	1.75	5.34

Cropping System Productivity:

The system productivity of different crops in cluster bean-cauliflower-okra cropping sequence is given in Table 3.67. In irrigation water the maximum system yield was observed in treated sewage water irrigation treatment 537.31 q/ha and minimum in tube well irrigated treatments 363.97 q/ha.

The use of recommended dose of fertilizer maximum system productivity produced in 100% RDF 509.63q/ha and lowest in 50% RDF 420.89 q/ha.

Table 3.67 Effect of different treatments on system productivity (2018-19)

Treatments	Cluster bean yield (q/ha)	Cauliflower yield (q/ha)	Okra yield (q/ha)	System yield (q/ha)
Irrigation water				
SW	130.80	282.69	123.82	537.31
TW	86.50	209.47	68.00	363.97
1SW:1TW	125.60	265.57	108.68	499.85
Recommended dose of fertilizer				
50%	109.50	217.50	93.89	420.89
75%	115.20	255.94	99.53	470.67
100%	118.27	284.28	107.08	509.63

Soil analysis at sowing of cluster bean:

The pH recorded at sowing time was in normal range in all the treatments. The ECe in Sewage Water treated plots was slightly lesser (3.3- 3.4 dS/m) than tube well treated plots (3.8 -4.0 dS/m) in 0-15 cm. This might be variation in EC of sewage water and tube well water. The sewage water EC ranged from 2.6 to 3.6 dS/m. It was 2.6 dS/m during cluster bean period; it increased to 3.5 during Cauliflower period while it was 3.6 dS/m during Okra period. The sodium in soil samples was in range of 18.9-30.8 me/l in all the treatments of the experiment. The Ca+Mg found present in all the soil samples collected at sowing time. In all collected soil samples, CO3 was absent. The chloride and sulphate found present in all the samples collected at sowing of cluster bean crop. The SAR was also present in all the collected soil samples but RSC did not found in any samples of at sowing (Table 3.68).

Table 3.68 Soil analysis at sowing of cluster bean crop (2018-19))

Treatment	Soil Depth (cm)	ECe (dS/m)	pH	Na (me/l)	Ca+Mg (me/l)	CO3 (me/l)	HCO3 (me/l)	Cl (me/l)	SO4 (me/l)	SAR (mmol/l)1/2	RSC (me/l)
SW 50%RDF	0-15	3.4	7.6	22.4	11.6	-	9.0	11.8	13.2	9.3	-
	15-30	3.2	7.6	21.6	10.4	-	6.0	10.8	15.2	9.5	-
	30-60	3.2	7.6	20.8	11.2	-	7.0	13.2	11.8	9.2	-
	60-90	3.2	7.6	19.2	12.8	-	7.0	12.4	12.6	7.6	-
SW 75%RDF	0-15	3.3	7.7	22.6	10.4	-	7.0	12.8	13.2	9.9	-
	15-30	3.2	7.6	21.7	10.3	-	6.0	12.9	13.1	9.6	-
	30-60	3.2	7.6	21.5	10.5	-	8.0	11.5	12.5	9.4	-
	60-90	3.1	7.6	18.9	12.1	-	7.0	11.8	12.2	7.7	-
SW 100%RDF	0-15	3.3	7.7	22.7	10.3	-	6.0	12.9	14.1	10.0	-
	15-30	3.3	7.6	23.2	9.8	-	6.0	11.7	15.3	10.5	-
	30-60	3.2	7.6	21.5	10.5	-	7.0	12.2	12.8	9.4	-
	60-90	3.2	7.6	21.6	10.4	-	6.0	12.5	13.5	9.5	-
TW 50%RDF	0-15	3.8	7.6	26.5	11.5	-	6.0	11.8	20.2	11.1	-
	15-30	3.6	7.6	25.7	10.3	-	7.0	11.7	17.3	11.4	-
	30-60	3.4	7.5	22.8	11.2	-	7.0	11.9	15.1	10.1	-
	60-90	3.4	7.6	21.6	12.4	-	7.0	12.5	14.5	9.5	-
TW 75%RDF	0-15	4.0	7.8	30.8	9.2	-	6.0	13.6	20.4	14.4	-
	15-30	3.7	7.8	26.2	10.8	-	8.0	12.2	16.8	11.3	-

	30-60	3.6	7.6	21.8	14.2	-	7.0	11.5	17.5	8.2	-
	60-90	3.5	7.6	22.5	12.5	-	7.0	11.8	16.2	9.0	-
TW 100%RDF	0-15	3.9	7.7	29.9	9.1	-	6.0	11.0	22.0	13.1	-
	15-30	3.7	7.6	25.0	12.0	-	8.0	12.5	16.5	10.2	-
	30-60	3.6	7.5	23.6	12.4	-	7.0	12.8	16.2	9.5	-
	60-90	3.5	7.6	22.7	12.3	-	7.0	12.1	15.9	9.2	-
1SW:1TW 50%RDF	0-15	3.6	7.6	26.2	9.8	-	7.0	11.8	17.2	11.9	-
	15-30	3.4	7.6	21.8	12.2	-	7.0	11.5	15.5	8.9	-
	30-60	3.4	7.5	20.7	13.3	-	7.0	12.7	14.3	8.0	-
	60-90	3.3	7.5	21.2	11.8	-	6.0	11.2	15.8	8.8	-
1SW:1TW 75%RDF	0.-15	3.6	7.6	23.9	12.1	-	7.0	11.8	17.2	9.8	-
	15-30	3.5	7.6	22.6	12.4	-	7.0	11.2	16.8	9.1	-
	30-60	3.4	7.6	20.8	13.2	-	6.0	11.5	16.5	8.1	-
	60-90	3.4	7.5	21.2	12.8	-	7.0	11.8	15.2	8.4	-
1SW:1TW 100%RDF	0-15	3.6	7.6	23.2	12.8	-	8.0	12.5	15.5	9.2	-
	15-30	3.5	7.7	22.8	12.2	-	6.0	11.8	17.2	9.3	-
	30-60	3.5	7.6	21.9	13.1	-	6.0	11.2	17.8	8.6	-
	60-90	3.4	7.6	22.5	11.5	-	7.0	10.8	16.2	9.4	-

Table 3.69 clearly indicates that the organic carbon content was lower in all the collected soil samples with soil depth. However, it was slightly higher in sewage treated soils (0.32-0.35%) compared tube well treated soils (0.24-0.31 %). It was in between for mixed type of water (1SW:1TW). Also organic carbon increased with increase in rate of fertilizer application. In all the collected soil samples of at sowing time of cluster bean crop, the available nitrogen and potassium found in medium range and available phosphorus was in lower range.

Table 3.69 Organic carbon, organic matter and available nutrients in the soil at sowing time of cluster bean (2018-19)

Treat.	Soil Depth (cm)	O.C. (%)	O.M. (%)	Av.N (kg/ha)	Av.P2O5 (kg/ha)	Av.K2O (kg/ha)
SW+ 50%RDF	0-15	0.35	0.61	286.8	14.7	202.6
	15-30	0.32	0.55	278.5	13.8	188.7
SW+ 75%RDF	0-15	0.34	0.59	288.9	14.8	201.6
	15-30	0.33	0.57	281.5	13.7	189.8
SW+ 100%RDF	0-15	0.35	0.61	292.7	15.2	205.8
	15-30	0.33	0.52	288.6	14.1	200.2
TW+ 50%RDF	0-15	0.26	0.45	208.7	11.8	181.5
	15-30	0.24	0.42	206.5	10.7	164.6
TW+ 75%RDF	0-15	0.29	0.51	210.2	12.1	188.7
	15-30	0.26	0.45	208.7	11.2	172.6
TW+ 100%RDF	0-15	0.31	0.51	212.9	12.8	191.6
	15-30	0.28	0.48	211.5	11.5	182.7
1SW:1TW+ 50%RDF	0-15	0.31	0.54	281.5	12.7	192.7
	15-30	0.28	0.48	264.2	11.8	178.6
1SW:1TW+ 75%RDF	0-15	0.32	0.55	283.9	13.2	196.3
	15-30	0.29	0.51	278.2	12.1	179.2
1SW:1TW+ 100%RDF	0-15	0.33	0.57	290.8	13.8	198.5
	15-30	0.30	0.52	286.8	12.2	18.3

Soil analysis at harvest of okra crop:

The pH recorded in all the treatments at harvesting time was normal range. The ECe in Sewage Water treated plots was slightly lesser (3.4- 3.6 dS/m) than tube well treated plots (4.2-4.8 dS/m).

There was slight increase in soil salinity in both plots. The sodium range was recorded (22.2-36.2) 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 CO3 was not found but HCO3 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 3.70)

Table 3.70 Soil analysis at harvest of Okra crop (2018-19)

Treat.	Soil Depth (cm)	ECe	pH	Na	Ca+Mg	CO3	HCO3	Cl	SO4	SAR	RSC
SW	0-15	3.6	7.6	23.2	12.8	-	8.0	13.5	14.5	9.2	-
50%RDF	15-30	3.6	7.6	24.5	11.5	-	7.0	12.8	16.2	10.3	-
	30-60	3.5	7.5	22.8	12.2	-	7.0	12.5	15.5	9.3	-
	60-90	3.4	7.5	23.2	10.8	-	6.0	12.9	15.1	10.0	-
SW	0-15	3.6	7.7	23.5	12.5	-	8.0	14.1	13.9	9.4	-
75%RDF	15-30	3.6	7.7	23.2	11.8	-	7.0	12.8	15.2	9.6	-
	30-60	3.5	7.7	23.5	11.5	-	8.0	11.8	15.2	9.8	-
	60-90	3.5	7.6	23.8	11.2	-	6.0	12.5	16.5	10.1	-
SW	0-15	3.5	7.5	24.1	10.9	-	8.0	12.8	14.2	10.3	-
100%RDF	15-30	3.6	7.6	23.5	12.5	-	7.0	13.1	15.9	9.4	-
	30-60	3.5	7.7	22.8	12.2	-	7.0	12.8	15.2	9.3	-
	60-90	3.5	7.7	22.7	12.3	-	6.0	11.5	17.5	9.2	-
TW	0-15	4.8	7.6	36.2	11.8	-	8.0	16.2	27.8	14.9	-
50%RDF	15-30	4.7	7.6	35.8	11.2	-	7.0	14.2	26.8	15.2	-
	30-60	4.5	7.5	33.3	11.7	-	7.0	13.8	24.2	13.8	-
	60-90	4.0	7.5	32.7	7.3	-	7.0	13.5	19.5	17.2	-
TW	0-15	4.7	7.7	32.2	14.8	-	7.0	15.1	24.9	11.8	-
75%RDF	15-30	4.6	7.7	30.8	15.2	-	6.0	14.2	25.8	11.2	-
	30-60	4.5	7.7	28.9	16.1	-	6.0	12.8	26.2	10.2	-
	60-90	4.2	7.6	27.6	14.4	-	7.0	13.5	21.5	10.3	-
TW	0-15	4.8	7.7	33.7	14.3	-	7.0	14.8	26.2	12.6	-
100%RDF	15-30	4.6	7.6	33.2	12.8	-	7.0	15.5	23.5	13.2	-
	30-60	4.5	7.6	33.1	11.9	-	6.0	14.3	24.7	13.6	-
	60-90	4.4	7.5	32.8	11.2	-	6.0	14.2	22.8	13.8	-
1SW:1TW	0-15	3.8	7.5	26.5	11.5	-	8.0	13.5	16.5	11.0	-
50%RDF	15-30	3.6	7.6	25.8	10.2	-	8.0	12.8	15.2	11.5	-
	30-60	3.6	7.6	22.2	13.8	-	7.0	12.5	16.5	8.5	-
	60-90	3.5	7.5	21.9	13.1	-	6.0	12.6	16.4	8.6	-
1SW:1TW	0-15	3.7	7.7	23.5	13.5	-	7.0	13.7	16.3	9.1	-
-75%RDF	15-30	3.6	7.6	24.2	11.8	-	6.0	13.2	16.8	10.0	-
	30-60	3.5	7.6	22.8	12.2	-	6.0	12.8	16.2	9.3	-
	60-90	3.5	7.5	23.5	11.5	-	7.0	12.5	15.5	14.7	-
1SW:1TW	0-15	3.8	7.7	24.5	13.5	-	8.0	12.8	17.2	9.4	-
100%RDF	15-30	3.6	7.6	23.6	12.4	-	7.0	13.5	15.5	9.5	-
	30-60	3.6	7.6	24.1	11.9	-	6.0	12.9	17.1	9.9	-
	60-90	3.5	7.6	22.2	11.8	-	6.0	13.5	15.5	9.6	-

Table 3.71 clearly indicated that the organic carbon content increased in all the collected soil samples as well as depth of the soil samples compared with at harvest of cauliflower crop time soil samples values. However, it was slightly higher in sewage treated soils (0.34%) compared tube well treated soils (0.27-0.31 %) in 0-15 cm. The all the collected soil samples of at harvest time of okra crop the available nitrogen found in medium range and available phosphorus was in lower range but

potassium in medium range. These values were slightly higher compared to harvest of cauliflower crop.

Table 3.71 Organic carbon, organic matter and available nutrients in the soil (at harvest time of okra crop)-2018-19

Treat.	Soil Depth (cm)	O.C. (%)	O.M. (%)	Av.N (kg/ha)	Av.P2O5 (kg/ha)	Av.K2O (kg/ha)
SW	0-15	0.34	0.59	287.6	14.8	202.1
50%RDF	15-30	0.32	0.55	282.8	13.9	189.5
SW	0-15	0.34	0.59	286.3	15.1	203.2
75%RDF	15-30	0.33	0.57	282.8	13.2	188.8
SW	0-15	0.34	0.59	293.9	15.2	204.6
100%RDF	15-30	0.34	0.59	287.5	13.8	189.7
TW	0-15	0.27	0.47	204.8	12.2	181.3
50%RDF	15-30	0.25	0.43	189.7	11.2	164.5
TW	0-15	0.29	0.50	205.2	12.8	188.6
75%RDF	15-30	0.28	0.48	201.7	10.9	181.2
TW	0-15	0.31	0.54	211.3	12.2	189.5
100%RDF	15-30	0.28	0.48	208.5	11.7	178.3
1SW:1TW	0-15	0.31	0.54	281.3	13.7	191.5
50%RDF	15-30	0.29	0.50	272.3	12.5	181.2
1SW:1TW	0-15	0.31	0.50	285.9	13.9	199.3
75%RDF	15-30	0.30	0.52	280.1	12.8	184.5
1SW:1TW	0-15	0.32	0.55	293.2	13.8	201.7
100%RDF	15-30	0.30	0.52	283.8	12.8	188.5

The irrigation water quality parameters are also shown in Table 3.72. The BOD, COD and CO3 were absent in tube well water. The EC of tubwell water was higher than sewage water during all three cropping seasons.

Table 3.72 Irrigation water analysis (sewage water and tube well water (2018-19)

Particulars	Sewage water (Inlet)			Sewage water (Outlet)			Tube well water		
	Cluster bean	Cauliflower	Okra	Cluster bean	Cauliflower	Okra	Cluster bean	Cauliflower	Okra
pH	7.5	7.6	7.5	7.5	7.5	7.5	7.6	7.5	7.6
ECe dS/m	2.5	3.4	3.7	2.6	3.5	3.6	3.8	3.8	3.8
BOD mgL-1	180	170	210	62	65	70	-	-	-
COD mgL-1	270	214	240	108	109	116	-	-	-
CO3mgL-1	23.2	47.5	30.5	55.2	24.5	50.3	00	00	00
HCO3 mgL-1	441.5	498.3	488.5	432.2	451.5	512.6	245.7	289.3	289.5
Chloride mgL-1	498.6	505.3	522.2	596.3	599.2	518.7	202.6	216.5	225.3
Sulphate mgL-1	585.6	520.8	698.2	478.1	520.2	538.3	1108.6	1198.2	1218.5
Nitrate mgL-1	22.5	30.2	28.7	22.6	24.8	25.2	00	00	00
Calcium mgL-1	148.3	118.7	159.3	165.2	151.8	139.3	151.6	165.8	158.7
Magnesium mgL-1	191.8	193.6	212.3	181.7	214.5	252.8	241.5	251.5	237.5
Sodium mgL-1	532.6	640.8	618.2	610.5	659.5	610.3	562.7	618.2	628.3
Potassium mgL-1	25.7	27.7	22.9	23.3	24.8	20.6	12.5	11.8	11.8
SAR (mmol/l)1/2	8.6	8.2	9.8	8.2	8.5	8.6	11.7	11.2	13.9
RSC meq/l	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL

4. ALTERNATE LAND USE

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

Six fodder crops (T1- Stylo-Stylosanthus, T2-Hedge lucerne, T3- Lucerne, T4- Fodder sorghum (panthchari-6), T5- COFS-29 (fodder jowar) and T6- 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.)
T1-Stylo	0.45	7.2
T2-Hedge lucerne	1.25	31.4
T3-Lucerne	0.62	8.7
T4-Panthchari-6	1.46	36.5
T5-CoFS-29	1.55	39.7
T6-Sweet sudan grass	1.72	42.8

- **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. Data 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 BAW and ECiw of 2.4 dS/m, ECiw of 6.0 dS/m showed significant reduction of 1.8 and 7.69 per cent, respectively. In terms of straw yield similar trend was observed (Table 4.2).

Table 4.2 Effect of water salinity on yields of crops

Treatments	Seed yield (q/ha)	Straw yield (q/ha)	Seed yield (q/ha)	Straw yield (q/ha)	Seed yield (q/ha)	Straw yield (q/ha)	Seed yield (q/ha)	Straw yield (q/ha)
	Mustard		Taramira		Oat		Barley	
BAW EC 0.25dS/m	17.58	52.49	12.68	75.15	21.06	47.85	37.46	51.20
Tube-well water EC 2.40 dS/m	17.25	51.43	12.43	74.98	20.68	47.07	36.80	51.02
Irrigation water EC 6 dS/m	16.58	51.19	11.95	73.25	19.44	46.34	36.01	50.11
SEm±	0.34	0.40	0.32	0.55	0.37	0.28	0.81	0.37
CD(P= 0.05%)	1.17	1.39	1.10	1.91	1.27	0.97	2.81	1.28

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 under Advanced Varietal Trials (AVT) The irrigation water was prepared synthetically for water salinity.

Treatments:

Water salinity : ECiw 12dS/m for all cultivars
Cultivars : AVT CSCN 18-1 to CSCN 18-12
Design : Randomized Block Design (RBD)
Replication :Three

Details of experimentation:

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

Yield attributing characteristics and seed yield:

The yield attributing characteristics of mustard genotype (AVT) i.e. germination, days of 50% flowering, plant height, No. of primary branches, No. of secondary branches and No. of siliqua per plant were recorded at harvest of crop (Table 5.1). All the characters were found significant effect in genotypes. The significantly maximum No. of primary branches, No. of secondary branches and No. of siliqua per plant were found in genotype CSCN 18-2 and lowest in CSCN 18-11, respectively. The yield data of different mustard genotype is presented in Table 5.1 and Fig. 5.1. 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 in genotype CSCN 18-4 (1646.60 kg/ha).

Table 5.1 Effect of saline water irrigation on yield and yield attributing characters of mustard (AVT) genotype 2018-19

Genotype	Germination (%)	Days to 50% Flowering	Plant height (cm)	No. of primary Branches	No. of Secondary Branches	No. of siliqua/plant	Grain yield (kg/ha)
CSCN 18-1	82.75	62.00	207.38	8.33	10.00	274.78	1892.79
CSCN 18-2	81.00	60.75	211.75	8.58	13.00	338.00	1913.46
CSCN 18-3	81.75	63.00	184.00	5.17	8.33	243.88	1678.39
CSCN 18-4	83.25	60.75	200.25	8.50	10.67	349.75	1646.60
CSCN 18-5	83.75	64.00	207.75	6.17	6.92	237.13	1716.66
CSCN 18-6	81.00	63.75	193.13	6.33	7.17	242.88	1885.79
CSCN 18-7	80.00	63.00	211.00	6.00	8.00	253.00	1975.50
CSCN 18-8	82.00	63.00	188.13	7.17	10.33	316.50	1786.00
CSCN 18-9	82.75	62.25	207.00	8.17	10.46	328.38	1678.38
CSCN 18-10	85.00	61.75	229.13	6.54	6.67	248.00	1779.82
CSCN 18-11	83.25	62.25	214.50	5.17	6.67	189.88	1800.61
CSCN 18-12	85.00	63.00	207.88	8.00	11.00	277.38	1794.23
CD (P=0.05)	2.65	1.62	11.14	1.97	3.01	67.76	242.15
C.V. (%)	1.93	1.56	3.27	16.92	19.91	14.82	9.38

Plot size: 3.0m x 1.35m

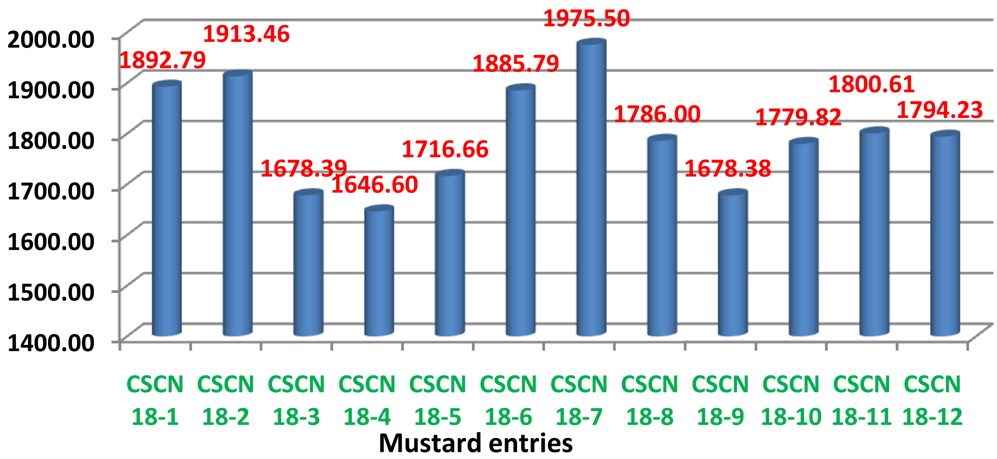


Fig 5.1 Grain yield (kg/ha) of different entries of mustard (2018-19)

The soil salinity builds up at sowing and at harvest of crop is presented in Table 5.2. The salinity was higher in upper layers at sowing as well as at harvest time.

Table 5.2 Soil salinity buildup at sowing and at harvest of mustard (2018-19)

Treatments	Soil depth(cm)	ECe (dS/m)	
		At sowing	At harvest
ECiw-12dS/m	0-15	6.3	10.8
	15-30	5.8	9.0
	30-60	4.8	8.2
	60-90	3.5	4.5

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

Details of experimentation

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

The mustard germination (%) clearly indicated that the entries of mustard were no difference in fertility doses, plant spacing and mustard entries (Table 5.3).The plant height, no. of primary and secondary branches of mustard crop was observed and presented in table5 b. 1. The fertilizer dosed gave higher results in 150 % RDF compared with 100% RDF but 125% show the at par result of 150% RDF. The yield attributing characters of mustard crop i.e. No. of siliqua /plant, No. of seed /siliqua, grain yield /plant and grain yield /plot (gm) were observed and presented in Table 5.4. The fertilizer dose gave higher value in these characters in 150% RDF compared with 100% RDF. The fertilizer dose 125% RDF and 125% gave at par result.

Table 5.3 Effect of different treatments on growth parameters of mustard (2018-19)

Entries	Germination (%)	Plant height (cm)	Primary branches	Secondary branches
100% recommended dose of fertilizer				
AG-1	82.7	198.3	7.8	10.5
AG-2	82.6	188.7	5.5	8.2
AG-3	82.7	184.3	5.3	8.1
AG-4	81.9	188.3	6.5	8.5
AG-5	82.8	191.0	6.6	8.3
AG-6	82.1	194.3	6.9	8.9
AG-7	82.7	197.7	6.7	8.7
125% recommended dose of fertilizer				
AG-1	82.7	200.0	7.9	10.8
AG-2	81.8	189.7	5.6	8.7
AG-3	83.0	186.7	5.5	8.4
AG-4	82.5	193.0	6.6	8.6
AG-5	83.4	196.0	6.8	8.5
AG-6	82.5	199.7	7.1	9.3
AG-7	82.5	203.7	6.9	8.8
125% recommended dose of fertilizer				
AG-1	82.9	191.7	8.0	11.4
AG-2	82.8	195.3	5.9	9.1
AG-3	82.8	199.0	5.6	8.7
AG-4	81.5	201.3	6.8	8.9
AG-5	82.5	202.1	6.9	8.6
AG-6	81.7	199.3	7.3	8.9
AG-7	81.6	198.5	7.1	9.1

Table 5.4 Effect of different treatments on yield attributing parameters of mustard (2018-19)

Entries	No.of siliqua /plant	No.of seed /siliqua	Grain yield per plant (gm)	Grain yield per plot (gm)
100% recommended dose of fertilizer				
AG-1	344.3	11.0	11.8	2296
AG-2	267.3	10.3	12.1	2841
AG-3	287.7	11.2	12.8	2315
AG-4	291.0	11.7	11.9	2349
AG-5	275.0	11.9	12.5	2458
AG-6	298.7	11.5	12.5	2736
AG-7	288.0	13.2	12.9	1950
125% recommended dose of fertilizer				
AG-1	347.3	11.8	12.7	2636
AG-2	270.7	11.3	12.9	2886
AG-3	288.7	12.2	12.6	2533
AG-4	294.7	12.0	12.8	2629
AG-5	298.7	12.5	12.9	2339
AG-6	301.0	12.4	13.2	2740
AG-7	295.0	14.0	13.1	2281
125% recommended dose of fertilizer				
AG-1	321.0	12.4	12.8	2896
AG-2	273.3	11.9	12.9	2957
AG-3	292.7	12.5	12.8	2619
AG-4	302.7	12.6	13.1	2879
AG-5	306.0	13.1	13.5	2484
AG-6	312.0	13.3	13.2	2963
AG-7	305.0	13.1	13.4	2626

Seed yield (kg/ha)

The data of mustard grain yield kg ha^{-1} clearly indicated that the entries of mustard were found significant difference in grain yield (Table 5.5). The highest grain yield was found in AG-2 (2141.9 kg/ha) and lowest AG-7 (1691.4 kg/ha) but AG-1and AG-4 produce at par grain yield. The grain yield of mustard increased significantly for 100%, 125% and 150% RDF. The 150% RDF increase the grain yield of mustard 12.8 % in 100% RDF and 6.1 % in 125% RDF. The application of 125% RDF significantly increase the grain yield of mustard 7.2 % compared with 100% RDF.

Table 5.5 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

The soil salinity of at sowing and at harvest of mustard experiment field is given in Table 5.6. The salinity of soil is higher in upper layer at sowing as well as at harvest and reduced in lower layers of soil.

Table 5.6 Soil salinity buildup at sowing and at harvest of mustard (dS/m)

Treatments	Soil depth(cm)	ECe (dS/m)	
		At sowing	At harvest
ECiw 12dS/m	0-15	5.5	10.8
	15-30	5.2	8.5
	30-60	5.9	6.3
	60-90	5.7	5.5

- **Screening trials 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.

Details of experimentation:

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 :27.2oN

(ii) Longitude : 27.9oE

(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 5.7). 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 plot was presented in Table 5.8. 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 5.7 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 5.8 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

The soil salinity of at sowing and at harvest of lentil crop is given in Table 5.9. The ECe of soil is higher in upper layer at sowing and harvest. At harvest ECe increase in whole profile

Table 5.9 Soil pH and salinity buildup at sowing and at harvest of lentil (dS/m) 2018-19

Treatments	Soil depth(cm)	At sowing		At harvest	
		pH	ECe (dS/m)	pH	ECe (dS/m)
ECiw 6 dS/m	0-15	8.1	4.0	8.0	6.8
	15-30	8.3	2.1	8.3	3.8
	30-60	8.4	2.0	8.3	2.6
	60-90	8.5	2.2	8.5	2.3

The ESP of soil at sowing and at harvest of lentil crop is given in Table 5.10. The ESP of soil is higher at the time of harvesting.

Table 5.10 Status of pH and ESP at sowing and at harvest of lentil in sodic water

Treatments	Soil depth(cm)	At sowing		At harvest	
		pH	ESP	pH	ESP
RSCiw 6 (meq/l)	0-15	8.1	13.1	8.5	17.9
	15-30	8.3	15.4	8.6	20.2

- **Advanced Varietal Trials (AVT) of mustard under saline/ alkaline conditions (Bikaner)**

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 Zone II
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 5.11).

Table 5.11 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

- **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.

Cotton: Increasing salinity led to a gradual decrease in seed cotton yield (Table 5.12). 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 5.12 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 5.13).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 5.14), Normalized Difference Vegetation Index (NDVI) indicating greenness in biomass (Table 5.15) and SPAD Chlorophyll Content of flag leaf (Table 5.16) 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 5.13 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 5.14 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 5.15 Normalized Difference Vegetation Index (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 5.16 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 5.17). 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 5.17: 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 5.18). 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 5.19). 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 5.20).

Table 5.18: 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 5.19 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 5.20 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

- **Screening of rice, wheat and mustard varieties/genotypes in sodic soil (Kanpur)**

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 5.21.

Table 5.21. 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 5.22). 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 5.22 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 5.23). The minimum yield 33.66 q/ha was obtained from WH-147.

Table 5.23 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 5.24). 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 5.24 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.

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 5.25). 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 5.25 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 5.26). The effect of soil ESP on ear head of sorghum varieties is shown in Plate 5.1.

Table5.26 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
M1 – 8	1024.7	1433.7	625.3	459.3	885.8
M2 – 16	827.0	1162.0	593.0	331.7	728.4
M3 – 24	660.3	944.7	419.3	242.7	566.8
M4 – 32	392.3	855.3	360.0	235.3	460.7
M5 – 40	102.7	201.0	140.7	87.7	133.0
M6 – 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

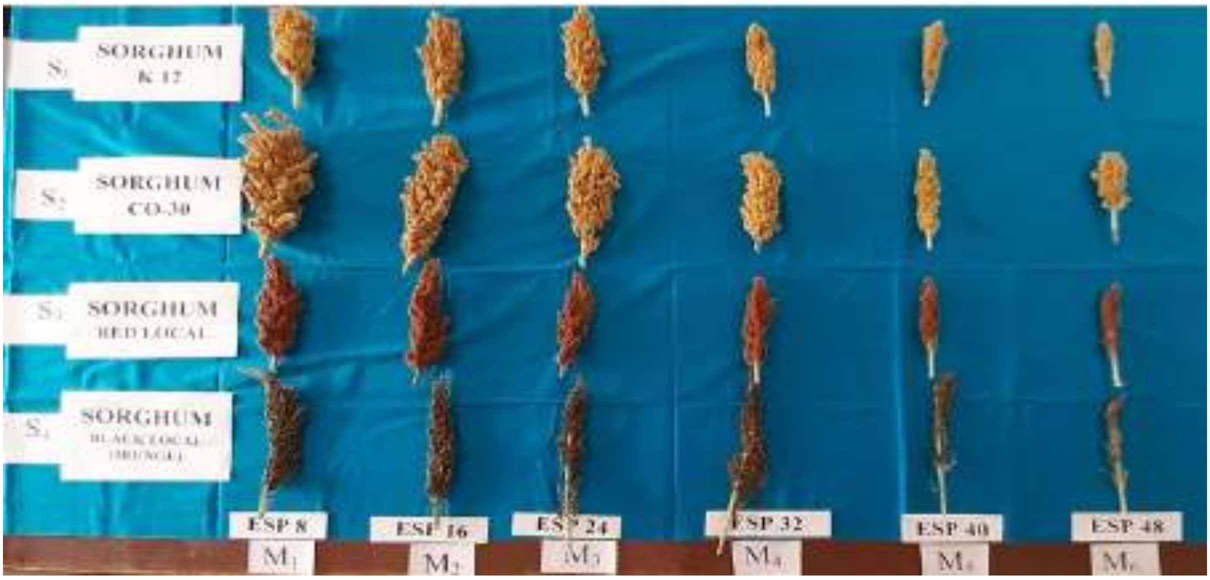


Plate 5.1 Ear head of sorghum varieties under different ESP levels

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 5.27).

Table 5.27 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

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

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 5.28 and composition of irrigation water is given in Table 5.29.

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 5.28 Initial physico-chemical characteristics of soil (0-15 cm)

Parameter	Canal Water irrigated field	Tube well Water irrigated field
Soil Texture Sand (%) Silt (%) Clay (%)	Loamy sand 80.1 12.2 7.7	
pH (1:2)	8.75	8.82
$EC_{1:2}$(dS m^{-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 5.29 Composition of canal and tubewell water

Particulars	Value	
	Canal water	Tubewell water
EC (dS m^{-1})	0.35	4.36
Na^{+} (me/l)	1.36	34.10
Ca^{+2}+ Mg^{+2} (me/l)	1.88	6.95
Cl^{-1} (me/l)	0.80	11.2
CO_3^{-2} (me/l)	Nil	nil
HCO_3^{-} (me/l)	1.80	6.34
RSC (me/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 5.30. 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 5.30 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 5.31 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 5.31 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 5.32 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 5.32 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		

- **Assessment of salt tolerance efficiency of wheat cultivars (Bathinda)**

Screening of cultivars of wheat (*Triticum estivum* L.) was undertaken to find out suitable cultivar for saline water irrigation. Details of initial soil properties are given in Table 5.33 and composition of canal and tube well water is given in Table 5.34.

Table 5.33 Initial physico-chemical characteristics of soil (0-15 cm)

Parameter	Canal water irrigated field	Tubewell water irrigated field
Soil Texture	Loamy sand	
Sand (%)	80.1	
Silt (%)	12.2	
Clay (%)	7.7	
pH (1:2)	8.65	8.95
EC $_{1:2}$(dS m^{-1})	0.22	0.58
$CaCO_3$ (%)	4.11	4.11
OC (%)	0.23	0.23
Available P (kg ha^{-1})	8.68	8.55
Available K (kg ha^{-1})	241	247

Table 5.34 Composition of canal and tubewell water

Particulars	**Values**	
	Canal water	**Tubewell water**
EC (dS m^{-1})	0.35	4.36
Na^{+} (me/l)	1.36	34.10
Ca^{+2}+ Mg^{+2} (me/l)	1.91	6.88
Cl^{-1} (me/l)	0.80	11.2
CO_3^{-2} (me/l)	nil	Nil
HCO_3^{-} (me/l)	1.85	6.14
RSC (me/l)	nil	Nil
SAR	1.3	18.39

Other details: Date of sowing: 26.11.2018; Number of cultivars: 7; 10 rows of each cultivates (11 meter); Design: Split plot; Date of harvesting: 23.04.2019.

Observations recorded: Plant height (cm), Number of tillers/m^2, Ear length (cm), Number of seeds/ ear grain yield (kg/acre).

The experiment was conducted for second season during *Rabi* 2018-19 to asses to salt tolerance efficiency of wheat cultivars popularly grown in the region. The seven varieties namely HD 3086, HD 2967, KR L 213, Unnat PBW 550, PBW 725, KRL210 and Unnat PBW343 were grown under two quality water (canal water and Tube well water) having different chemical compositions (Table 5.34).

Results of the study (Table 5.35) showed that height of the plant were non significant, whereas significantly varietals differences were observed in number of tillers and ear length of the cultivars. The maximum number of tillers/ m^2 was reported in HD 2967 followed by PBW 725, whereas maximum ear length was reported in Unnat PBW 550 followed by HD 2967.

Table 5.35 Effect of poor quality water on plant height, number of tillers and ear length of wheat (*Triticum aestivum* L.) cultivars

S.No	Cultivars	Plant height (cm)			Number of tillers/m^2			Ear length (cm)		
		CW	TW	Mean	CW	TW	Mean	CW	TW	Mean
1	HD 3086	96.4	93.7	95.1	104.3	101.6	102.9	11.2	10.7	10.9
2	HD 2967	98.3	97.6	97.9	111.3	110.0	110.6	12.1	11.6	11.8
3	KRL 213	95.8	90.8	93.3	102.9	88.7	95.8	11.1	10.3	10.7
4	Unnat PBW 550	89.9	82.7	86.3	96.9	89.6	93.2	13.1	12.1	12.6
5	PBW 725	101.5	99.9	100.7	107.0	101.9	104.4	11.3	10.9	11.1
6	KRL210	103.6	98.8	101.2	103.9	101.8	102.8	11.2	10.5	10.9
7	Unnat PBW343	102.8	95.7	99.3	100.8	82.5	91.7	12.0	11.2	11.6
CD (5%) water Quality		NS			2.4			0.29		
Cultivars		1.5			1.9			0.19		
Interaction		1.9			2.3			0.28		

Similarly, Table 5.36 showed the number of seeds/ear and grain yield of each cultivars. It is reported that Unnat PBW 550 and PBW 725 had maximum no of seeds/ear followed by HD 2967. However, maximum grain yield was reported in variety Unnat PBW 343 followed by HD 3086, Unnat PBW 550 and PBW 725 under the both conditions. The better performance of these varieties (Unnat PBW

343,HD 3086, Unnat PBW 550 and PBW 725) than KRL 210 may be due to soil salinity in the tube well irrigated field was less than threshold soil salinity for wheat (i.e. ECe 4 dS/m).

Table 5.36 Effect of poor quality water on number of seeds/ear and grain yield of wheat (*Triticum aestivum* L.) cultivars

S.No	Cultivars	Number of seeds/ ear			grain yield (q/acre)		
		CW	TW	Mean	CW	TW	Mean
1	HD 3086	60.3	59.3	59.8	18.5	15.4	16.9
2	HD 2967	70.7	57.7	64.2	17.2	14.3	15.7
3	KRL 213	58.1	67.6	62.9	12.4	10.3	11.3
4	Unnat PBW 550	69.0	62.3	65.7	18.3	15.2	16.7
5	PBW 725	61.9	69.1	65.5	17.9	14.9	16.4
6	KRL210	58.7	55.0	56.8	13.7	11.4	12.5
7	UnnatPBW343	60.5	60.2	60.4	18.6	15.4	17.0
CD (5%) water Quality		0.79			0.36		
Cultivars		0.51			0.60		
Interaction		0.66			0.85		

6. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

- **Operational Research Programme for the use of underground saline water at farmers' fields (Agra)**

Under Operational Research Project (ORP) the field demonstrations for the use of poor quality ground water were initiated since kharif 1993 in Karanpur village of Mathura district. In 1999 the program was extended to two other villages' i.e. Nagla Hridaya and Bhojpur. At these sites, medium and high SAR saline ground waters were noticed. 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 were selected from different villages such as 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) for demonstrations on saline ground water (ECiw: 7.1 to 13.0 dS/m) irrigation. In the year 2017, ORP activities were extended to three other villages namely Signa in Bichpuri block of Agra district, Jalal and Kurkunda in Fareh block of Mathura district. At these sites medium and high SAR saline waters are observed. The year 2018-19, twelve farmers were selected. The groundwater quality parameters of farmers' tubewells are given in Table 6.1. ECiw, SARiw and RSCiw of tube well waters varied from 3.8 to 13.3 (dS/m), 13.6 to 36.9 $(mmol/l)^{1/2}$ and nil, respectively. The pH was almost normal in all samples. The sodium varied from 28.9-110.7 meq/l. The Ca and Mg were present in all the water samples but their concentration ranged from 9.1 to 22.3 meq/l. In all collected water samples, CO_3 was absent but HCO_3 was present.

Table 6.1 Water quality of farmer's tube well water

Farmers name	ECe	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.Toffan 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	-

Demonstrations were conducted for 9 farmers during Kharif, 12 farmers during rabi season and for 3 farmers during summer season of 2018-19. Out of 12 selected farmers, pearl millet crop was sown on 6 farmers' fields, sorghum (fodder) on 3 farmers' fields, mustard crop on 6 farmers' fields and wheat on 6 farmers' fields. In rabi one farmer preferred cauliflower and one farmer preferred Beet root. In summer season, one farmer preferred onion crop and two farmers preferred okra crop under ORP. The N.P.K fertilizer was applied @ 120:60:60 kg/ha and same dose of N.P.K fertilizer gave in wheat crop. The variety Rohini and Anmol of mustard and KRL-210 of wheat crop were selected. In mustard crop two irrigations of saline water were given at 25 DAS and flowering stage, in wheat, cauliflower, onion, beet root crops five irrigations and in okra crop, six irrigations were given by the farmers. Saline water and good water irrigation details are provided in Table 6.2.

Table 6.2 Irrigation details/ mode of ORP farmers and other farmers (2018-19)

Sr. No.	Farmers name	Crop	Irrigation scheme for ORP farmers	Irrigation scheme for other farmers
		Rabi season		
1	Mr. Vijay Pal Singh	Mustard	All saline water	All saline water
2	Mr. Pratap Singh	Mustard	All saline water	All saline water
3	Mr. Nand Kishor	Mustard	All saline water	All saline water
4	Mr. Kishan Gopal	Mustard	All saline water	All saline water
5	Mr. Mahesh Singh	Mustard	All saline water	All saline water
6	Mr. Kalua	Mustard	All saline water	All saline water
7	Mr. Deepak Singh	Wheat	2SW:2CW	All saline water
8	Mr. Prem Singh	Wheat	2SW:2CW	All saline water
9	Mr. Bhanwar Singh	Wheat	1SW:IGW	All saline water
10	Mr. Satish Sharma	Wheat	1SW:1CW	All saline water
11	Mr. Babu Lal	Wheat	2SW:2GW	All saline water
12	Mr. Rajesh Singh	Wheat	1SW:1GW	All saline water
13	Mr. Ram veer Bhagat	Beet root	2SW:2GW	Nil
14	Mr. Toffan Singh	Cauliflower	1SW:1GW	Nil
15	Mr. Toffan Singh	Onion	1SW:1GW	Nil
		Summer		
16	Mr.Kishan Gopal	Okra	2SW:1GW	Nil
17	Mr.Vijay Pal Singh	Okra	1SW:GW	Nil

SW-Saline water, GW-Good quality water, CW-Canal water

The crop wise details of different demonstrations are provided below.

Pearl millet

The general information of pearl millet cultivation with reference to variety, number of irrigations, date of sowing and date of harvest, etc are given in Table 6.3.

Table 6.3 General operations on farmers field in Pearl millet crop (2018-19)

Name	Variety	No.of irrigations	Date of sowing	Date of harvesting
1.Mr.Toffan Singh	Chetak	1	12-07-2018	26-09-2018
2. Mr. Vijay Pal Singh	Chetak	1	10-07-2018	24-09-2018
3. Mr. Mahesh Singh	Chetak	1	10-07-2018	20-09-2018
4. Mr. Nand Kishor	Chetak	1	14-07-2018	21-09-2018
5. Mr. Bhawar Singh	Chetak	1	13-07-2018	18-09-2018
6. Mr.Kalua	Chetak	1	12-07-2018	16-09-2018

The ORP farmers and other farmers pearl millet yield is presented in Table 6.4 which indicates that ORP farmers' grain yield ranged from 22.3 to 27.9 q/ha. It was higher compared to other farmers (20.8 to 25.9 q/ha). At the harvest of pearl millet crop, ECe ranged from 3.7 to 5.0 (dS/m) and pH value ranged from 7.5-7.6.

Table 6.4 Grain yield of Pearl millet at ORP and other farmers' fields and soil characteristics (0-30cm) at harvest (2018-19)

Name of farmers	ORP farmers yield (q/ha)	Other farmer yield (q/ha)	% in increase over farmers field	At harvest ECe(dS/m) (0-30cm)	pH (0-30cm)
1.Mr.Toffan Singh	26.8	24.2	10.7	3.7	7.5
2. Mr. Vijay Pal Singh	27.3	25.8	5.8	5.0	7.5
3. Mr. Mahesh Singh	22.6	20.8	8.7	4.5	7.5
4. Mr. Nand Kishor	25.9	22.7	14.1	4.2	7.5
5Mr. Bhawar Singh	27.9	25.9	7.7	4.5	7.6
6. Mr.Kalua	22.3	21.4	4.2	4.7	7.5

The cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio of pearl millet crop were calculated and presented in Table 6.5 which indicated that the cost of cultivation of ORP farmers was less as compared to other farmers. The gross income (Rs/ha), net profit (Rs/ha) and B: C ratio were also higher in ORP farmers as compared to other farmers.

Table 6.5 Cost of cultivation, gross income, net profit and B: C ratio of pearl millet growing on ORP farmers and other farmers field (2018-19)

Name of farmer	Details of ORP farmers				Details of 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.Toffan Singh	20,010	60,237	40,227	3.01	22,050	54,315	32,265	2.46
2. Mr. Vijay Pal Singh	20,510	61,652	41,142	3.00	22,000	57,990	35,990	2.64
3. Mr. Mahesh Singh	20,060	57,740	37,680	2.88	22,190	51,045	28,855	2.30
4. Mr. Nand Kishor	19,860	50,860	31,002	2.56	21,740	46,350	24,610	2.13
5. Mr. Bhanwar Singh	20,210	62,982	42,772	3.12	22,400	58,275	35,875	2.60
6. Mr.Kalua	20,010	50,402	30,393	2.52	22,460	48,125	25,665	2.15

At the time of sowing and harvest of pearl millet crop, the soil ECe and pH were calculated and presented in Table 6.6. In surface layer at sowing (0-15 cm), the ECe and pH ranged from 3.8 to 5.8(dS/m) and 7.5 to 7.6, respectively. At harvest of pearl millet crop, soil salinity decreased due to sample collected after rain, the ECe and pH ranged from 3.5 to 5.5(dS/m) and 7.5 to 7.6.

Table 6.6 Soil studies at sowing and harvest of pearl millet crop in ORP farmer's field (2018-19)

Farmers name	Soil Depth (cm)	At sowing		At harvest	
		ECe (dS/m)	pH	ECe (dS/m)	pH
Mr.Toffan Singh	0-15	3.8	7.6	3.5	7.5
	15-30	4.0	7.6	3.8	7.5
Mr.Vijay Pal Singh	0-15	5.8	7.5	5.5	7.6
	15-30	5.7	7.6	4.5	7.5
Mr.Nand Kishore	0-15	5.0	7.5	4.7	7.6
	15-30	4.4	7.5	4.2	7.5
Mr.Mahesh Singh	0-15	4.3	7.6	4.1	7.6
	15-30	4.5	7.6	4.3	7.5
Mr.Bhawar Singh	0-15	4.8	7.5	4.6	7.5
	15-30	4.6	7.6	4.3	7.6
Mr.Kalua	0-15	4.8	7.5	4.8	7.5
	16-30	4.2	7.6	4.5	7.5

Sorghum

The general information of sorghum (green fodder) cultivation with reference to variety, number of irrigations, date of sowing and date of harvest, etc are given in Table 6.7.

Table 6.7 General operations on farmers' fields at Sorghum green fodder (2018-19)

Name of farmers	Crop	Variety	No. of irrigations	Date of sowing	Date of harvesting
1.Mr.Kishan Gopal	Sorghum	Purvi white	1	18-06-2018	18-08-2018
2. Mr. Ram Veer Bhagat	Sorghum	Purvi white	1	16-06-2018	20-08-2018
3. Mr. Ravendra Singh	Sorghum	Purvi white	1	15-06-2018	20-08-2018

Table 6.8 clearly indicated that sorghum (green fodder) yield for ORP farmers ranged from 355.8 to 415.2 q/ha and it was higher compared to other farmers (310.1 to 368.9 q/ha). At the harvest of sorghum crop, ECe and pH ranged from 3.3 to 5.4 dS/mand pH 7.5 to 7.6, respectively.

Table 6.8 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) (0-30cm)	pH 0-30cm
1.Mr.Ram veer Bhagat	387.1	350.7	10.4	5.4	7.6
2. Mr. Kishan Gopal	415.2	368.9	12.6	3.5	7.5
3. Mr. Ravendra Singh	355.8	310.1	14.7	3.3	7.6

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 6.9. It clearly indicated that ORP farmers got higher net profit (Rs/ha) and B: C ratio.

Table 6.9 Cost of cultivation, gross income, net profit and B: C ratio of Sorghum (fodder) growing on ORP farmers and other farmers field (2018-19)

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.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 soil ECe and pH at the time of sowing and at harvest of sorghum green fodder crop were also determined and presented in Table 6.10. In surface layer (0-15 cm), the ECe and pH ranged from 3.5 to 6.8(dS/m) and 7.5 to 7.6. At harvest of sorghum green fodder crop, soil salinity decrease due to collection of samples after rain. The ECe and pH ranged from 3.4 to 6.3 dS/m and 7.5 to 7.6, respectively.

Table 6.10 Soil ECe, pH at sowing and at harvest of sorghum fodder at ORP farmer's field (2018-19)

Name of farmer	Soil Depth (cm)	At sowing		At harvest	
		ECe (dS/m)	pH	ECe (dS/m)	pH
Mr.Ram veer Bhagat	0-15	6.8	7.5	6.3	7.6
	15-30	4.8	7.6	4.4	7.5
Mr.Kishan Gopal	0-15	3.8	7.6	3.5	7.6
	15-30	3.7	7.6	3.4	7.6
Mr.Ravendra Singh	0-15	3.5	7.6	3.4	7.6
	15-30	3.2	7.5	3.1	7.5

Mustard

The general information of mustard crop cultivation with reference to variety, number of irrigations, date of sowing and date of harvest, etc are given in Table 6.11.

Table 6.11 General operations on farmer's field at Mustard crop rabi (2018-19)

Name of farmer	Crop	Variety	No. of irrigations	Date of sowing	Date of harvesting
1.Mr.Kishan Gopal	Mustard	Rohini	2	2-10-2018	26-02-2019
2. Mr. Vijay Pal Singh	Mustard	Rohini	2	3-10-2018	26-02-2019
3. Mr. Mahesh Singh	Mustard	Rohini	2	3-10-2018	24-02-2019
4. Mr. Nand Kishor	Mustard	Anmol	2	10-10-2018	03-03-2019
5. Mr. Pratap Singh	Mustard	Anmol	2	10-10-2018	04-03-2019
6. Mr. Babu lal	Mustard	Anmol	2	8-10-2018	26-02-2019

The mustard yield in case of ORP farmers and other farmers is presented in Table 6.12. It was observed that the grain yield in case of ORP farmers ranged from 23.6 to 27.5 q/ha. It was higher than other farmers (21.3 to 26.2 q/ha). At the harvest of mustard crop, ECe ranged from (5.4 to 7.8 dS/m) and pH (7.4 to 7.5).

Table 6.12: Grain yield of mustard in ORP and other farmers field (q/ha) and soil ECe and pH (0-30 cm) of ORP farmers field at harvest 2018-19

Name of farmers	ORP farmers yield	Other farmer yield	% increase over other farmer	At harvest ECe(dS/m) (0-30cm)	pH (0-30cm)
1. Mr. Vijay Pal Singh	26.9	24.7	8.9	7.8	7.5
2. Mr. Pratap Singh	27.5	26.2	5.0	7.7	7.5
3. Mr. Nand Kishor	24.8	22.7	9.3	6.3	7.4
4. Mr. Kishan Gopal	23.6	21.3	10.8	6.2	7.5
5. Mr. Mahesh Singh	27.0	25.9	7.4	5.4	7.5
6. Mr. Kalua	26.3	24.8	6.0	6.2	7.5

The cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio in mustard crop were calculated and presented in Table 6.13. The gross income (Rs/ha) was higher in case of ORP farmers. Also net profit (Rs/ha) and B: C ratios were higher for ORP farmers.

Table 6.13 Cost of cultivation, gross income, net profit and B: C ratio of mustard growing on ORP farmers and other farmers field (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. Vijay Pal Singh	24,893	94,150	69,257	3.78	24,878	86,450	61,572	3.47
2. Mr. Pratap Singh	24,443	96,250	71,807	3.94	24,658	91,700	67,042	3.72
3. Mr. Nand Kishor	22,040	86,800	64,760	3.94	24,491	79,450	54,959	3.24
4. Mr. Kishan Gopal	22,433	82,600	60,167	3.68	24,231	74,550	50,319	3.08
5. Mr. Mahesh Singh	24,513	97,787	72,787	3.97	24,697	90,650	65,953	3.66
6. Mr. Kalua	23,532	92,650	68,518	3.92	24,340	86,800	62,560	3.58

The soil ECe and pH at the time of sowing and harvest of mustard crop are presented in Table 6.14. In surface layer (0-15 cm), the ECe and pH ranged from 4.3 to 4.8(dS/m) and 7.5 to 7.6. At harvest of mustard crop, soil salinity increased due to high SAR saline water irrigation. The ECe and pH ranged from 5.8 to 8.8(dS/m) and 7.5 to 7.6.

Table 6.14: Soil analysis at sowing of Mustard of ORP farmers' fields (2018-19)

Farmers name	Soil Depth (cm)	At sowing		At harvest	
		ECe (dS/m)	pH	ECe (dS/m)	pH
Mr.Vijay PalSingh	0-15	4.8	7.5	9.5	7.5
	15-30	4.2	7.4	6.8	7.6
Mr.Pratap Singh	0-15	4.7	7.6	9.1	7.6
	15-30	4.5	7.5	6.2	7.4
Mr.Nand Kishore	0-15	4.6	7.5	6.9	7.5
	15-30	4.2	7.3	5.7	7.4
Mr.Kishan Gopal	0-15	4.5	7.6	6.7	7.5
	15-30	4.3	7.6	5.7	7.5
Mr.Mahesh Singh	0-15	4.3	7.5	5.8	7.6
	15-30	4.2	7.4	4.9	7.4
Mr.Kalua	0-15	4.4	7.5	6.2	7.5
	16-30	4.1	7.5	6.1	7.5

Wheat:

The general information of wheat crop cultivation with reference to variety, number of irrigations, date of sowing and date of harvest, etc are given in Table 6.15.

Table 6.15 General operations on farmer's field at Wheat crop rabi (2018-19)

Name	Crop	Variety	No.of irrigations	Date of sowing	Date of harvesting
1.Mr.Deepak Singh	Wheat	KRL-210	5	28-11-2018	14-04-2019
2. Mr.Prem Singh	Wheat	KRL-210	5	28-11-2018	16-04-2019
3. Mr.Bhanwar Singh	Wheat	KRL-210	5	28-11-2018	18-04-2019
4. Mr. Satish Sharma	Wheat	KRL-210	5	30-11-2018	23-04-2019
5.Mr.Babu Lal	Wheat	KRL-210	4	1-12-2018	27-04-2019
6.Mr.Rajesh Singh	Wheat	KRL-210	4	23-11-2018	19-04-2019

The wheat variety KRL-210 was sown by all the ORP farmers while other farmers used different wheat varieties available in local market or available at personal level.

The grain yield data of ORP farmers and other farmers are presented in Table 6.16 which clearly indicated that ORP farmers' wheat grain yield ranged from 42.7 to 48.8 q/ha while it ranged from 38.2 to 44.1 q/ha for other farmers. The straw yield of wheat crop also gave the same trend. The average increase of ORP farmers was 11.5 % more over other farmers grain yield. At harvest of wheat crop the ECe and pH ranged from 5.9 to 8.5 dS/m, pH 7.5 - 7.6, respectively.

Table 6.16 Grain yield of wheat for ORP and other farmers (q/ha) and soil ECe and pH (0-30 cm) of ORP farmers field at harvest 2018-19

Name of farmer	ORP farmers yield		Other farmer yield		Grain yield increase over traditional farming (%)	ECe at harvest (dS/m) (0-30cm)	pH (0-30cm)
	Grain	Straw	Grain	Straw			
1.Mr.Deepak Singh	48.8	73.2	44.1	66.7	10.7	8.5	7.6
2. Mr.Prem Singh	47.3	75.6	43.3	64.9	9.2	6.8	7.5
3. Mr.Bhanwar Singh	46.9	70.4	41.5	62.6	13.0	6.7	7.5
4. Mr. Satish Sharma	45.8	73.2	40.8	61.2	12.3	5.9	7.6
5.Mr.Babu Lal	46.1	69.2	41.2	60.8	11.9	6.8	7.5
6.Mr.Rajesh Singh	42.7	68.3	38.2	58.4	11.8	6.2	7.5

In wheat crop, the cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio were calculated and presented in Table 6.17. The gross income (Rs/ha), net profit (Rs/ha) and B: C ratios were higher in ORP farmers compared with other farmers.

Table 6.17 Cost of cultivation, gross income, net profit and B: C ratio of ORP farmers and other farmers in wheat crop (2018-19)

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	36,077	1,03,700	67,623	2.87	34,365	93,600	59.235	2.72
2. Mr.Prem Singh	32,535	1,01,675	69,140	3.13	37,775	92,000	54,225	2.43
3. Mr.Bhanwar Singh	33,425	99,675	66,250	2.98	34,415	88,275	53,860	2.56
4. Mr. Satish Sharma	33,937	98,450	64,513	2.90	36,290	86,700	50,410	2.39
5.Mr.Babu Lal	32,227	97,975	65,748	3.04	36,225	87,300	51,075	2.40
6.Mr.Rajesh Singh	31,997	91,800	59,803	2.86	36,290	81,450	45,160	2.24

The soil ECe and pH at the time of sowing and harvest of wheat crop were determined and presented in Table 6.18. In surface layer (0-15 cm), the ECe and pH ranged from 3.8 to 5.8(dS/m) and 7.5 to 7.7, respectively. At harvest of wheat crop, soil salinity increase due to high SAR saline water irrigation. The ECe and pH ranged from 6.3 to 9.2(dS/m) and 7.5 to 7.6.

Table 6.18 Soil ECe and pH at sowing and at harvest of wheat crop in ORP farmer's field (2018-19)

Farmers name	SoilDepth (cm)	At sowing		At harvest	
		ECe (dS/m)	pH	ECe (dS/m)	pH
Mr.Deepak Singh	0-15	5.8	7.5	9.2	7.6
	15-30	4.7	7.6	7.8	7.6
Mr.Prem Singh	0-15	5.3	7.7	7.8	7.5
	15-30	4.8	7.5	5.7	7.6
Mr.Bhawar Singh	0-15	4.8	7.5	7.2	7.5
	15-30	4.5	7.6	6.1	7.6
Mr.Satish Sharma	0-15	4.5	7.6	6.3	7.7
	15-30	4.3	7.5	5.5	7.5
Mr Babu Lal	0-15	3.8	7.6	7.2	7.6
	15-30	3.5	7.7	6.3	7.5
Mr.Rajash Singh	0-15	4.2	7.5	6.5	7.5
	16-30	4.0	7.6	5.8	7.6

Vegetable crops

Details of different vegetable crops grown under ORP are provided in Table 6.19 while gross income, net profit and B:C ratio are provided in Table 6.20.

Table 6.19 General operations on farmers field in rabi and summer crops (2018-19)

Name	Crop	Variety	No. of irrigations	Date of sowing	Date of harvesting
Mr. Ram Veer Bhagat	Beet root	Myhico hybrid	5	22-09-2018	10-01-2019
Mr. Toffan Singh	Cauliflower	MH-555	5	15-11-2018	03-02-2019
Mr.Toffan Singh	Onion	Nasik Red	5	10-02-2019	15-04-2019
Mr.Kishan Gopal	Okra	Myhico-747	6	14-02-2019	22-06-2019
Mr.Vijay Pal Singh	Okra	Myhico-747	6	16-02-2019	24-06-2019

Table 6.20 Yield, cost of cultivation, gross income, net profit and B: C ratio of beet root crop in ORP farmer's field (2018-19)

Crop	yield (q/ha)	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net profit (Rs/ha)	B: C ratio
Beet root	260.7	48,775	2,10,700	1,61,925	4.32
Cauliflower	262.7	46,360	1,57,620	1,11,260	3.40
Onion	235.9	35,665	1,17,950	82,285	3.30
Okra (Mr.Kishan Gopal)	108.9	40,813	1,08,900	68,087	2.67
Okra (Mr.Vijay Pal Singh)	98.6	40,813	98,600	57,787	2.42

Soil ECe and pH at the time of sowing and harvest of beet root, Cauliflower, Onion and Okra crop (Plate 6.1) are presented in Table 6.21. In general, there was increase in soil salinity (ECe) in 0-15 cm and 15-30 cm soil layers due to use saline water for irrigation. There was no significant change in soil pH.

Table 6.21 Soil analysis at sowing and at harvest of different rabi and summer crops in ORP farmers field (2018-19)

Crop	Soil Depth (cm)	At sowing		At harvest	
		ECe (dS/m)	pH	ECe (dS/m)	pH
Beet root	0-15	8.7	7.7	12.3	7.6
	15-30	6.3	7.6	9.3	7.5
Cauliflower	0-15	4.8	7.6	5.2	7.6
	15-30	4.5	7.5	4.8	7.6
Onion	0-15	5.3	7.6	6.8	7.5
	15-30	4.7	7.5	5.9	7.5
Okra (Mr.Kishan Gopal)	0-15	4.5	7.5	6.9	7.6
	15-30	4.6	7.5	6.5	7.5
Okra (Mr.Vijay Pal Singh)	0-15	5.2	7.6	8.2	7.6
	16-30	4.8	7.5	7.3	7.5

Plate 6.1 Soil sampling in ORP farmer's field

- **Demonstration on gypsum tank to reclaim sodic water for irrigation to different crops (Bapatla)**

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 6.22).

Table 6.22 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)**

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 6.23.

Table 6.23. 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 6.24).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 6.24 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 6.25 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 6.25 Effect of CSR-Bio on physico chemical properties of experimental soil for tomato experiment

Treatments	pH	EC	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 6.26). 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 6.26 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 6.27 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 6.27 Effect of CSR-Bio on physico chemical properties of experimental soil

Treatments	pH	EC	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)**

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 6.28) 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 6.28 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 6.29. 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 6.30) 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 6.29 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 6.30 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) –(Tiruchirapalli)**

Different centres of AICRP on SAS&USW are implementing SCSP activities. However, 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.
- Engaging qualified Technical Manpower belonging to Scheduled Caste community for effective implementation of SCSP programme as per the University norms

Progress

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 6.31). Activities for the distribution of soil health card, various agricultural inputs, imparting training and demonstration activities will be undertaken continuously further.

Table 6.31 List of beneficiaries identified

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

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. 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 and 2019-20 were Rs. 615.00 Lakhs, Rs. 649.67 Lakhs and Rs. 527.03 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.

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 Madhya Pradesh • 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

7.3 STAFF POSITION

SANCTIONED STAFF POSITION AT THE COOPERATING CENTRES AS PER APPROVED SFC 2017-20 (1-4-2018)

XI plan	Agra	Bapatla	Bikaner	Gang–avati	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**

All staff positions remained filled during from April 2028 to December 2019.

7.4 WEATHER DATA (2018-19)

Main Centre

AGRA

Latitude - 27⁰20' N Longitude - 77⁰90' E

Months	Temperature (°C) Maximum	Temperature (°C) Minimum	Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)	Water table (m)
			2018			
April 2018	38.4	22.5	74.5	98.9	5.9	20.3
May	41.8	26.4	84.4	38.0	7.1	20.3
June	40.5	29.3	84.5	172.1	7.5	20.4
July	35.0	27.3	94.2	533.8	3.6	19.8
August	33.4	26.0	93.5	200.0	3.0	19.7
September	33.3	24.4	92.5	98.0	2.8	19.5
October	34.3	19.4	86.0	5.0	3.8	19.5
November	29.6	13.2	86.7	-	2.0	19.6
December	23.1	6.1	97.2		1.2	19.7
			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

BAPATLA

Latitude - 15° 54' N						Longitude - 80° 28' E
Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	*Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2018-19			
April 2018	34.1	25.9		73	52.8	-
May	35.9	27.7		70.5	17.2	-
June	37.8	27.0		62.5	79.1	-
July	34.6	25.7		68.5	79.9	-
August	33.6	25.1		73.4	195.7	-
September	34.1	25.4		78.5	64.6	-
October	33.4	23.9		78.5	34.7	-
November	31.3	21.7		80	57.1	-
December	29.1	19.3		79.5	48.0	-
			2019			
January, 2019	29.5	16.7		76.5	2.0	-
February	31.3	20.5		76.5	4.1	-
March	33.0	24.0		75.5	0	-
pril	34.7	26.1		76	0	-
May	37.3	28.9		74.7	0.1	-
June	38.4	28.7		67	91.8	-
July	34.6	26.3		73.5	237.1	-
August	34.0	25.9		74	98.0	-
September	32.4	25.7		79	225	-
October	31.0	24.9		83.5	257.2	-
November	31.3	22.7		80	30.0	-
December	29.8	20.3		78	1.4	-

* **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			
			2018				
April 2018	40.3	21.8	41.3	18.3	4.2	10.0	5.8
May	43.7	27.0	36.0	18.2	5.6	12.2	7.1
June	41.3	28.7	62.3	35.4	54.3	9.8	11.2
July	37.8	28.1	84.1	51.3	189.8	6.1	8.9
August	36.2	26.6	82.5	50.4	54.8	5.3	8.9
September	36.5	24.0	69.6	41.2	0.0	6.7	7.6
October	36.6	18.6	55.0	21.7	0.0	6.1	4.1
November	30.8	11.4	69.6	27.4	0.8	3.7	2.86
December	24.7	5.0	75.3	31.7	0.0	3.0	2.8
			2019				
January 2019	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

GANGAVATI

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		
			2018			
April 2018	38.4	21.8	54.5	21.3	3.0	3.83
May	37.6	24.4	57.1	22.7	107.9	2.64
June	32.4	23.4	89.3	43.4	78.3	1.80
July	31.9	23.4	65.7	46.5	15.2	2.90
August	30.0	22.8	73.0	57.6	44.5	1.73
September	31.9	21.8	73.3	48.2	35.7	2.10
October	30.3	19.8	68.8	41.2	42.4	2.41
November	30.7	17.2	70.6	40.1	0	2.20
December	29.1	15.9	71.7	36.9	0	2.00
			2019			
January 2019	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

HISAR

Latitude - 29° 10′ N Longitude - 75° 46′ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	M	E		
			2018			
April 2018	36.7	19.5	60	33	14.0	6.4
May	40.6	23.7	57	29	0.0	8.6
June	39.6	27.7	72	47	58.9	8.9
July	35.0	26.7	88	69	158.5	4.8
August	35.2	26.7	88	64	23.5	4.6
September	33.3	23.6	92	70	115.8	4.3
October	32.7	16.3	84	38	0.0	3.4
November	27.9	11.7	90	48	0.0	2.1
December	21.9	4.9	93	50	0.0	1.2
			2019			
January 2019	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

INDORE

Latitude – 22° 14’ N Longitude - 76° 01’ E

Months	Temperature* (°C)		Relative humidity* (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2018			
April 2018	-	-	-	-	-	13.30
May	-	-	-	-	5.8	17.29
June	-	-	-	-	130.6	10.27
July	-	-	-	-	166.5	4.71
August	-	-	-	-	303.5	2.90
September	-	-	-	-	161.4	3.23
October	-	-	-	-	-	3.74
November	-	-	-	-	-	2.68
December	-	-	-	-	-	2.26
			2019			
January 2019	-	-	-	-	-	2.00
February	-	-	-	-	-	2.61
March	-	-	-	-	-	7.77
April	-	-	-	-	-	11.8
May	-	-	-	-	-	15.5
June	-	-	-	-	52.9	12.4
July	-	-	-	-	256.6	5.1
August	-	-	-	-	250.6	1.4
September	-	-	-	-	211.6	1.4
October	-	-	-	-	79.8	2.5
November	-	-	-	-	-	2.8
December	-	-	-	-	-	2.0

** Data not available*

KANPUR

Latitude – 29° 27′ N Longitude – 80° 20′ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2018			
April 2018	21.4	37.5	59	37	10.4	4.4
May	25.3	40.1	64	37	8.0	6.5
June	27.5	39.8	62	40	63.4	8.2
July	26.3	34.2	85	70	386.0	5.5
August	25.0	32.1	89	75	365.3	3.3
September	23.5	32.4	84	64	143.8	3.2
October	17.2	34.3	74	35	0.0	3.3
November	12.1	28.8	84	40	0.0	2.7
December	6.9	23.0	88	38	0.0	2.0
			2019			
January 2019	21.6	7.9	85	47	13.5	1.1
February	23.4	10.9	88	53	17.5	1.3
March	29.5	13.8	77	41	4.2	2.1
April	-	-	-	-	-	-
May	-	-	-	-	-	-
June	-	-	-	-	-	-
July	-	-	-	-	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	-	-	-	-	-	-
November	-	-	-	-	-	-
December	-	-	-	-	-	-

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			
			2018				
April 2018	35.4	18.7	61	28	15.2	6.4	6.3
May	38.6	22.5	52	24	34.0	7.7	7.8
June	36.3	26.0	74	49	268.4	7.7	12.9
July	33.4	26.0	88	73	549	5.9	14.9
August	32.5	25.9	90	73	125.2	5.2	10.5
September	31.5	23.2	93	70	310	3.4	9.0
October	31.3	16.8	91	40	0.00	2.9	3.8
November	27.0	12.2	90	42	0.00	2.0	3.3
December	21.0	5.7	98	51	14.8	1.3	1.8
			2019				
January 2019	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

TIRUCHIRAPPALLI

Latitude – 10° 45’ N Longitude – 78° 36’ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)	Wind velocity (km/hr)
	Maximum	Minimum	Average			
2018						
April 2018	36.9	27.01	63	2.6	7.2	5.42
May	38	26.1	61	75.4	7.1	5.7
June	37.4	27.25	56	14.2	9.3	5.7
July	37.0	26.46	57	60.2	10.6	14.5
August	33.6	25.9	57	42.4	9.6	13.4
September	36.0	25.6	61	61.0	6.7	6.1
October	33.6	24.2	75	120	3.5	3.5
November	31.0	24.0	76	127	3.0	3.0
December	31.0	22.7	78	3.0	3.0	4.0
2019						
January 2019	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

Volunteer Centre
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			
2018							
April 2018	37.0	18.7	56.2	29.9	7.4	333.5	0.9
May	39.7	23.3	50.7	26.4	6.2	454.4	1.1
June	37.9	24.7	64.0	44.3	91.2	344.3	1.9
July	35.5	23.7	81.1	57.6	147.4	230	1.5
August	34.7	26.1	80.5	60.1	51.4	219.2	0.9
September	33.6	23.6	84.8	57.1	43.2	194.4	0.9
October	32.3	17.1	78.9	40.2	0.0	162.8	0.5
November	27.2	11.5	80.7	39.0	0.0	104.6	0.6
December	21.8	4.5	89.3	44.4	0.0	60.2	0.4
2019							
January 2019	18.7	5.3	97.5	52.6	6.2	66.6	1.1
February	20.6	8.1	89.8	56.4	24.6	72.6	1.0
March	26.6	11.4	79.2	43.1	10.6	167.6	1.3
April	36.7	19.6	63.7	40.4	15.8	319.4	1.8
May	39.6	21.9	55.9	32.1	31.0	353.0	1.5
June	41.2	26.1	56.3	36.2	32.0	361.4	1.9
July	35.9	25.9	80.6	65.1	397.4	169.8	1.6
August	35.5	26.1	84.9	63.7	61.2	194.5	0.9
September	34.9	25.3	85.6	63.2	9.0	198.2	0.8
October	32.1	17.9	81.8	49.4	5.6	153.8	0.4
November	26.6	12.6	86.8	59.0	30.6	83.6	0.7
December	16.9	6.0	90.9	64.7	9.2	39.8	0.7

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				
		2018				
April 2018	38.04	24.0	84.2	0	2.17	5.11
May	36.63	26.92	82.9	0	1.92	6.42
June	33.58	23.54	87.5	848.1	0.23	5.5
July	30.05	22.90	93.9	1289	2.10	8.62
August	30.0	23.00	92.5	612.6	1.09	8.60
September	32.70	24.00	90.7	100.0	0.20	3.6
October	36.30	20.70	87.1	68.40	1.01	2.5
November	38.50	18.00	84.4	10.80	0.86	2.6
December	33.68	16.78	77.6	0	1.12	2.22
		2019				
January 2019	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

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			
			2018			
April 2018	33.5	24.1	69	64.8	180.0	6.9
May	31.7	25.0	78	596.9	138.3	14.5
June	29.6	23.8	86	665.3	122.1	15.5
July	29.8	25.5	85	203	113.5	10.9
August	28.9	25.0	88	522.2	120.5	11.8
September	30.4	24.7	82	340	112.5	10.6
October	30.6	25.3	79	335.6	98.9	6.7
November	30.5	24.6	75	331.6	97.2	10.6
December	30.2	24.3	78	203.8	119.0	8.0
			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

VYTTILA

Latitude – 09° 97′ N　　　　　　　　　　　　　　　　　　　　　　Longitude – 76° 32′ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)	
	Maximum	Minimum	Maximum	Minimum			
			2018				
April 2018	32.7	25.0	75		98		
May	31.7	24.4	64		352	2.7	2.1
June	29.3	24.7	84		745	2.05	1.88
July	27.9	26.4	79		771.8	2.1	1.83
August	27.8	23.5	74		*		1.2
September	30.0	26.6	68		91	3.5	2.0
October	30.3	23.8	68.9		328.5	3.4	1.6
November	30.5	23.2	66.5		205	3.1	1.5
December	31.6	22.7	64.8		26	3.0	1.2
January 2019	31.1	23.2	65.7		Nil		1.3
February	31.9	24.0	68.7		41.0	2.6	1.87
March	32.4	25.0	70		5.0	3.4	2.54
April	32.5	26.3	74.5		74.0	3.5	2.47
May	33.1	25.7	74		18.5	3.6	2.39
June	30.9	24.4	80		342.0	3.27	2.5
July	28.9	25.7	85		503.5	2.9	1.97
August	28.9	23.3	87		900.0	2.71	1.97
September	33.1	25.5	82		534.0	2.37	1.86
October	30.9	26.0	79		772.5	2.79	1.65
November	31.2	23.8	-		155.0		-
December	30.0	21.0	-		129.0		-

***Rainfall for August 2018 not recorded completely due to flood**

7.5 LIST OF PUBLICATIONS (2018-19)

AGRA
Research Papers

Chauhan SK (2018) Effect of irrigation water salinity on yield attributes and yields of fennel (*Foeniculum Volker* Mill.) in semi-arid condition of Western part of Uttar Pradesh. *Annals of Agriculture Research New Series* 39(1):96-98.

Chauhan SK (2018) Effect of nitrogen, salinity and water regimes on crop growth and yield of Aloe in semi-arid regions. *Annals of Agriculture Research New Series*, 39(3):1-5.

Chauhan SK and Kaledhonkar MJ (2018) Effect of bed planting technique on pearl millet in saline water irrigation condition in semi-arid region Western part of Uttar Pradesh. *The Indian Research Journal of Genetics and Biotechnology*, 10(1):134-138.

Chauhan SK and MJ Kaledhonker (2018) Conjunctive use of alkali/tube wellwater on the yield and yield attributes of Onion (*Allium Cepa*) in semi-arid condition of Western part of UP. *Technofame- A Journal of Multidisciplinary Advance Research*, 7(1) 85-89.

Chauhan SK and MJ Kaledhonker (2018) Wheat crop growing in FIRBS technique in saline irrigation condition of semi-arid region. *The Indian Research Journal of Genetics and Biotechnology* 10(2):304-310-138.

Lal Munna, Singh RB, Pal Devendra, Ahire LM and Singh AP (2018) Response of Broad bean (Vicia faba L.) to phosphorus and molybdenum. *The Journal of Rural and Agricultural Research18* (1):71-73.

Lal Munna, Singh RB, Pal Devendra, Yadav HMS, Pal AK and Singh AP (2018). Effect of Phosphorus and molybdenum on nutrients content of broad bean (*Vicia fava* L). *Journal of Pharmacognosy and Phytochemistry,* 7(6):1560-1562.

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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 2016-17 and 2017–18 is given below:

MAIN CENTRE

Agra

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	6200000	7084127	7500000	7741580	7614000	7082679
TA & POL	100000	61260	55000	13590	30000	29624
Contingencies						
Recurring/Res.	350000	349383	95000	94024	315000	298408
Non-recurring	0	0	0	0	0	0
Works	0	0	0	0	0	0
Subtotal	6650000	7494770	7650000	7849194	7959000	**7410711**
ORP						
TA	100000	72336	30000	10146	20000	19654
Rec.conti./Misce.	250000	258970	290000	285095	125000	124393
Subtotal	350000	331306	320000	295241	145000	**144047**
Grand Total	**7000000**	7826076	**7970000**	**8144435**	**8104000**	**7554758**

Bapatla

Budget head	**2016-17**		**2017-18**		**2018-19**	
	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5000000	7349355	7400000	7733063	7800000	4542754
TA & POL	130000	129878	85000	84524	40000	36609
Contingencies						
Recurring	300000	349603	115000	114850	280000	335000
Non-recurring	0	0	0	0	0	0
Works	0	0	0	0	0	0
Total	5430000	7828836	7600000	7932437	8120000	4914363
ORP						
TA	100000	99736	40000	39994	20000	16755
Rec.contingencies/Misc	200000	249268	250000	248832	170000	133857
Total	300000	349004	290000	288826	190000	150612
Grand Total	**5730000**	8177840	7890000	8221263	8310000	5064975

Bikaner

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5700000	7612103	7300000	Awaited	8375000	4811754
TA & POL Contingencies	75000	74360	60000		25000	0
Recurring	400000	378288	200000		75000	0
Non-recurring	0	0	0		220000	0
Total	**6175000**	**8064751**	**7560000**	**-**	**8695000**	**4811754**

Gangavathi

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	3800000	4934513	5000000	5662573	4200000	2846790
TA & POL Contingencies	150000	135664	70000	0	50000	0
Recurring	500000	496304	95000	0	110000	0
Non-recur.	0	0	230000	0	270000	0
Total	**4450000**	**5566481**	**5395000**	**5662573**	**4630000**	**2846790**

Hisar

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	2850000	3422384	5000000	3418184	2500000	4974725
TA & POL Contingencies	75000	26862	45000	16729	25000	0
Recurring+ works	500000	518048	80000	266468	75000	0
Non-recurring	0	0	180000	0	200000	0
Total	**3425000**	**3967294**	**5305000**	**3701381**	**2800000**	**4974725**

Indore

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	6450000	9182006	8500000	89988391	10100000	4066537
TA & POL Contingencies	100000		75000	0	40000	0
Recurring	450000	0	90000	0	75000	0
Non-recurring	0	0	220000	0	220000	0
Total	**7000000**	**9182006**	**8885000**	**89988391**	**10435000**	**4066537**

Kanpur

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5000000	6836412	7800000	7665682	8000000	4280388
TA & POL	100000	99463	75000	74935	50000	49997
Contingencies						
Recurring	400000	396937	80000	79985	75000	74981
Non-recurring	0		170000	169942	210000	209989
Total	**5500000**	**7332812**	**8125000**	**7990544**	**8335000**	**4615355**

Karnal

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0	0	0	0	0
TA & POL	49000	39680	0	0	0	0
Contingencies						
Recurring	1300000	1263426	1130000	1163322	980000	980000
NRC (Capital)	0	0	0	0	0	0
Total	**1349000**	**1303106**	**1130000**	**1163322**	**980000**	**980000**

Tiruchirappalli

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5000000	6152731	7000000	6428321	5700000	4038827
TA & POL	130000	129683	90000	30432	55000	0
Contingencies						
Recurring	590000	589995	85000	85000	120000	0
Non-recurring	0	0	255000	255000	359000	0
Total	**5720000**	**6872409**	**7430000**	**6798753**	**6234000**	**4038827**

VOLUNTEER CENTRE

Bathinda

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0	0	339637	0	0
TA & POL	75000	1212009	40000	0	30000	267495
Contingencies						
Recurring	675000	0	100000	0	100000	0
Non- recurring	0	0	200000	0	360000	0
Total	**750000**	**1212009**	**340000**	**339637**	**490000**	**267495**

Port Blair

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	562374	295000	295000	0	0
TA & POL Contingencies	100000	78430	0	0	0	157622
Recurring	700000	237606	0	0	100000	0
Non-recurring	0	30267	0	0	360000	0
Total	**800000**	**908677**	**295000**	**295000**	**460000**	**157622**

Panvel

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0	0	0	0	0
TA & POL Contingencies	100000	88354	55000	335370	50000	529134 0
Recurring	700000	788782	100000	0	120000	0
Non-recurring	0	0	205000	0	370000	0
Total	**800000**	**877136**	**360000**	**335370**	**540000**	**529134**

Vyttila

Budget head	2016-17		2017-18		2018-19	
	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	831351	0	360000	0	0
TA & POL Contingencies	100000	0	55000	0	50000	530000
Recurring	700000	0	100000	0	120000	0
Non-recurring	0	0	205000	0	360000	0
Total	**800000**	**831351**	**360000**	**360000**	**530000**	**530000**


26वीं द्विवार्षिक कार्यशाला
XXVI BIENNIAL WORKSHOP


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भाकृअनुप
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हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

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