अखिल भारतीय समन्वित अनुसंधान परियोजना

लवणग्रस्त मृदाओं का प्रबंधन एवं खारे जल का कृषि में उपयोग

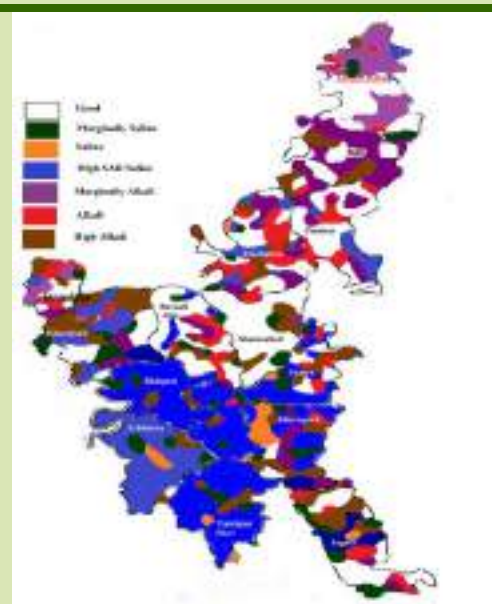
All India Coordinated Research Project

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

वार्षिक प्रतिवेदन

Annual Report

(2016-17)



परियोजना समन्वयन इकाई

भाकृअनुप–केन्द्रीय मृदा लवणता अनुसंधान संस्थान

करनाल – 132 001,हरियाणा (भारत)

Project Coordinating Unit

ICAR-Central Soil Salinity Research Institute

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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

Annual Report
2016-17

Cooperating Centres

1. Raja Balwant Singh College, Bichpuri, Agra (Uttar Pradesh)
2. Regional Research Station, ANG Ranga Agricultural University Bapatla (Andhra Pradesh)
3. SK Rajasthan Agricultural University, Bikaner (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences, Gangawati (Karnataka)
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3. ICAR-Central Island Agril Research Institute, Port Blair (A&N Islands)
4. Rice Research Station, Kerala Agril University, Vyttila, Kochi (Kerala)

परियोजना समन्वयन इकाई
भाकृअनुप–केन्द्रीय मृदा लवणता अनुसंधान संस्थान
करनाल – 132 001 (भारत)

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FOREWORD

The genesis of salt affected soils and poor quality groundwater is natural process and it is influenced by parent material, mineralogy, topography and human activities. Inefficient irrigation water management including canal network losses is leading to the waterlogging and soil salinity/ sodicity while use of poor quality waters for crop production, without due consideration to leaching requirement of soil, is responsible for soil salinization and sodification in semi-arid and arid regions. Further, hydrological imbalance of coastal aquifers with sea water induces sea water intrusion. Thus, the problems of salt affected soils and poor quality waters are observed in wide range agro-ecological regions in Indian subcontinent. At national level around 6.73 million ha (M ha) area has been characterized as salt affected, out of which 3.77 M ha is sodic and the remaining 2.96 M ha is saline. Besides, use of poor quality water in different states varies from 32-84%. Uttar Pradesh, Gujarat, Maharashtra, Tamil Nadu, Haryana and Punjab are having about 80% of the total sodic lands. Similarly, salinity is a serious problem across 13 states of the country with Gujarat having largest area of 1.68 M ha. Gujarat, West Bengal, Rajasthan and Maharashtra are severely affected states. Also crop production loss due to salinity at the national level is 5.66 million tonnes (M t), accounting for the annual monetary loss of Rs. 80,000 million (Rs. 8,000 Crores), at prevailing Minimum Support Prices (MSP) of different crops during 2015.

The 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 got associated with ICAR-CSSRI's vision and efforts in 1972. During initial phases, attempts were made for understanding the problems and developing technologies for reclamation of alkali soils of the Indo-Gangetic Plains focusing on rice-wheat cropping system. Alternate use of alkali lands for agro-forestry and afforestation, subsurface drainage for waterlogged saline soils, sustainable use of poor quality waters in crop production; salt tolerant varieties of rice, wheat and mustard and nowadays development of microbial consortia are important mile stones in salinity and sodicity management. AICRP centres are our active partners in fine tuning of reclamation technologies, delineation of salt affected soils and poor quality waters and screening of newly developed varieties. It is my pleasure to mention that technologies for management of salt affected soils and waters have entered into schemes of many state governments for ensuring welfare of farmers' communities. However problems do not end here. Now the nation faces second and third generation problems, arising from land reclamation, degradation of soil and groundwater resources, emerging realities from the climate change and changing scenarios of agricultural education, research and extension. Despite difficulties and challenges, we need to arrest land degradation due to soil salinity and sodicity and sustain crop production from these marginalized resources. It is need to remember that national priorities such as efficient application of irrigation water, judicious use of organic and inorganic fertilizers and chemicals, adoption of conservation agricultural practices for better soil health and climate resilience are to be appropriately incorporated in our technologies with focus on doubling farmers' income. The ICAR-CSSRI and 12 centres of AICRP have to optimize resources and efforts for better output in near future.

At the end, an excellent cooperation received from Dr MJ Kaledhonkar, Project Coordinator and Dr RL Meena, Pr. Scientist and Dr BL Meena, Scientist (Sr. Scale) and Dr. R.K. Fagodiya, Scientist in smooth running of the project is placed on the record. Concerted efforts in compilation and editing of Annual Report of the scheme and organization of review meeting deserve appreciation. The help of staff of PC unit for project operations is thankfully acknowledged. It would be my pleasure to extend all support to the project to achieve future research targets.

(PC Sharma)
Director

PREFACE

The soil salinity and soil sodicity are considered as land degradation processes in agricultural lands and both affect crop yields adversely. Management of such lands includes reclamation, salt leaching, improved agronomic, irrigation water and nutrient practices, alternate land uses and use of salt tolerant varieties. The solute transport in case of sodicity is reactive and hence addition of chemical amendment is important requirement. The AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture as partner with ICAR-CSSRI, Karnal in this national mission, has made significant contributions in understanding of characterization and monitoring of salinity problems of soils and of ground waters under a wide range of situations such as arid, semi-arid and coastal; and addressing management related issues (crop varieties, identification of salt tolerant germplasm, defining drainage needs, use of amendments, alternate land uses, use of poor quality groundwater and waste water reuse, etc.), and creating greater over-all awareness about salinity issues in the country. As result of these efforts, delineation of salt affected soils and poor quality waters is being done by all 12 centres full vigour and this activity provides basic information for reclamation plans. Reclamation of sodic soils has got momentum in Tamil Nadu, Andhra Pradesh and Uttar Pradesh. Along with gypsum, role of distillery spent wash, green manuring, crop residue/ organics is duly recognized by Indore, Gangavathi, Bapatla, Tiruchirapalli and Kanpur centres. The reclamation of alkali water through chemical amendments and use of its irrigation through drip is getting farmers' acceptance in Tamil Nadu. Technology of subsurface drainage is being fine tuned with addition of controlled drainage aspect in TBP command of Karnataka, besides giving due attention to water management by promoting laser leveling in drainage areas. Water resource creation for agricultural use through skimming of fresh water in coastal aquifers (Bapatla), groundwater recharge by low cost structure (Agra) and rainwater harvesting (Indore and Panvel) is remarkable achievement. Adoption of micro irrigation for use of poor quality waters to reduce adverse effects has been successfully introduced by Bikaner, Hisar, Bapatla and Tiruchirapalli centres. 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) which were not intensely monitored earlier. The scheme is moving ahead with concept of converge of ideas. Fortification of reclamation technologies is being done by adding preventive measures, conservation agriculture practices, salt tolerant varieties, alternate land uses and developing multi-enterprise or IFS models so that second generation issues will be appropriately addressed, cost of management of these soils will be less, practices will be climate resilient and farmers' income will be enhanced and whole production system will be sustainable in long-term.

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 K Alagusundaram, DDG (Agricultural Engineering) & DDG (NRM) (Acting), ICAR for guiding the technical program and providing unstinted support to the project.

Heartfelt thanks are due to Dr SK Chaudhari, ADG (SWM) and Dr PC Sharma, Director, ICAR-CSSRI for their excellent support to the project and cooperation in all spheres. I also thank to Dr SK Gupta, former, Project Coordinator for their support as and when needed during the period. I wish to extend my sincere thanks to OICs at cooperating centers; Dr RB Singh, Dr Sailaja Vinnakota, Dr SR Yadav, Dr Vishwanath Jowkin, Dr Satyvan, Dr UR Khandkar, Dr Ravindra Kumar and Dr P Subramaniam 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 RL Meena, Pr. Scientist, Dr BL Meena, Scientist (Sr. Scale) and Dr. RK Fagodiya, 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, Shri Mahinder Sigh (retd.), Shri Sukhbir Singh for their cooperation in day to day activities.

(M J Kaledhonkar)
Project Coordinator

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

1.1 Resource Inventories of Salt Affected Soils

- **Delineation and mapping of salt affected soils of Andhra Pradesh (Kurnool district) (Bapatla)**

Soil samples (0-25 and 25-50 cm) representing salt affected soils of Kurnool district were collected from 53 locations identified through LISS III data and ground truth. The soils were slightly acidic to strongly alkaline (5.5 to 10.3) in reaction and the electrical conductivity of soils ranged from 0.3 to 33.0 dS m^{-1} (normal to very high saline in nature).

- **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. With the aid of GPS and toposheet, soil samples were collected on a grid basis (5' x 5' = 9 x 9 km) from Sindhanur, Manvi, Devadurga and Raichur taluks in Raichur district during May 2015. A total of 339 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 53 grids (107 sampling points) were collected. Similarly, 172 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 27 grid points (52 sampling points) were collected from Bellary taluk in Bellary district.

In Raichur district, at surface soil (0-15 cm) pH(1:2.5), pHs, EC(1:2.5) and ECe varied from 9.0 to 5.80, 8.50 to 4.86, 21.0 to 0.13 (dS/m) and 47 to 0.14 (dS/m) respectively with an average of 8.09, 7.56, 1.19, and 2.68 respectively. Among cations, average Na content was more than Ca+Mg followed by K. In case of anions, average Cl- content was more than HCO3- followed by SO42-. Nearly 14 per cent of surface samples had ECe > 4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 (CO3+HCO3)/(Cl+SO4) and (Na/(Cl+SO4) ratios were to the extent of nearly 6 and 97 respectively indicating that the soils could be sodic or developing into sodic. Accordingly, nearly 17 per cent of surface samples had SAR >13.

Sub-surface (15-30 cm) soils had pH(1:2.5), pHs, EC(1:2.5) and ECe varied from 9.66 to 6.14, 8.42 to 6.66, 12.5 to 0.11 (dS/m), and 24 to 0.28 (dS/m) with an average of 8.33, 7.75, 1.08 dS/m and 2.25 dS/m respectively. Nearly 10 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 (CO3+HCO3)/(Cl+SO4) was less than 1 whereas Na/(Cl+SO4) ratio was >1. However, about 13 and 48 percent of these samples had values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodicity. Nearly 12 per cent of the samples had SAR >13.

At 30-60 cm, the pH(1:2.5), pHs, EC(1:2.5), and ECe varied from 9.21 to 6.54, 8.24 to 6.94,6.90 to 0.24 dS/m and 14.0 to 0.38 dS/m with an average of 8.38, 7.66, 1.32 dS/m and 2.70 dS/m respectively. Similar to above depths, Na+ and Cl- were the dominant cation and anion respectively. Nearly 15.5 per cent of samples were found to be saline as their ECe was >4.0 dS/m. The overall mean of the (CO3+HCO3)/(Cl+SO4) was less than 1 whereas Na/(Cl+SO4) ratio was >1. However, about 16 and 59 percent of these samples had values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodicity. Nearly 27 per cent of the samples had SAR >13.

At 60+ cm, the pH(1:2.5), pHs, EC(1:2.5), and ECe varied from 9.58 to 7.87, 9.03 to 7.48,5.4 to 0.30 dS/m and 11.6 to 0.52 dS/m with an average of 8.67, 8.14, 1.26 dS/m and 2.51 dS/m respectively. Similar to above depths, Na+ and Cl- were the dominant cation and anion respectively. Nearly 16.3 per cent of samples were found to be saline as their ECe was >4.0 dS/m. The overall mean of the (CO3+HCO3)/(Cl+SO4) was less than 1 whereas Na/(Cl+SO4) ratio was >1. However, about 21 and 53 percent of these samples had values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodicity. Nearly 35 per cent of the samples had SAR >13.

In Bellary taluk (Bellary district), at surface soil (0-15 cm) pH(1:2.5), pHs, EC(1:2.5) and ECe varied from 10.76 to 7.82, 10.23 to 7.45, 31.0 to 0.19 (dS/m) and 106.0 to 0.64 (dS/m) respectively with an average of 8.55, 8.11, 5.39, and 15.0 dS/m respectively. Among cations, average Na content (244.6 meq/L) was more than Ca+Mg (20.62 meq/L) followed by K. In case of anions, average Cl- content was more (120.4 meq/L) than HCO3- (15.06 meq/L) followed SO42-. Nearly 40 per cent of surface samples had ECe > 4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 (CO3+HCO3)/(Cl+SO4) were nil whereas (Na/(Cl+SO4) samples were to the extent of nearly 56. Accordingly, nearly 48 per cent of surface samples had SAR >13.

Sub-surface (15-30 cm) soils had pH(1:2.5), pHs, EC(1:2.5) and ECe varying from 10.55 to 7.43, 10.33 to 7.55, 19.9 to 0.12 (dS/m), and 35.0 to 0.37(dS/m) respectively with an average of 8.34, 8.21, 2.90 dS/m and 7.18 dS/m respectively (Table 7). Similar to surface soils, average Na content (90.78 meq/L) was more than Ca+Mg (13.06 meq/L) followed by K. In case of anions, average Cl- content was more (41.49 meq/L) than HCO3- (9.49 meq/L) followed by SO42-.

Nearly 40 per cent of sub surface samples were considered to be saline as the ECe of these samples was >4.0 dS/m. The overall mean of the (CO3+HCO3)/(Cl+SO4) was less than 1 whereas Na/(Cl+SO4) was >1. However, about 8 and 66 percent of these samples had values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodicity. Similar to surface samples, about 50 per cent of samples analyzed had SAR >13.

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

The remote sensing data of two different seasons were used to identify the signature of saline alkali soils. The villages with such soils were identified and area estimated as 2448 and 76 ha in Khargone and Khandwa district, respectively. The maps showing salt affected soils in Khargone and Khandwa districts were prepared using Remote Sensing and GIS techniques.

- **Assessment of soil salinity status of A & N Islands and areas vulnerable to sea water (Port Blair)**

The results showed that soil pH varied widely from 3.5 -10.4, 4.2-7.8 and 6.2-8.3 respectively in South, North & Middle and Nicobar district. In general, soil salinity was EC was low but in some lowlying areas it was as high as 10.1 (dS/m) due to sea water intrusion. In some locations, acid saline soils are also noticed which exhibited high salinity as well as acidity. In summary, the soil salinity status of Andaman and Nicobar Islands showed that 34% of the samples are non-saline while 47 % of samples are saline and 18.7% samples are slightly saline. Only 14% of the samples are strongly saline. Among the three districts, 39%, 36% and 26% of samples from South Andaman, North & Middle Andaman and Nicobar, respectively are found to be non-saline whereas, only 12%, 11% and

19% are found to be strongly saline. The analysis of DEM of Andaman Islands showed that nearly 1.5% of the area of Andaman is affected by salinity due to sea water intrusion in the coastal areas.

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

In general, the soil samples from four districts *viz.* Thiruvananthapuram, Kottayam, Kollam and Patthanamthitta were acidic and EC values were in the good category. Organic carbon per cent of the samples were found to be in medium and higher levels. The available phosphorus content was also sufficient in almost all the samples. But wide spread deficiency of secondary nutrients especially calcium and magnesium was observed whereas sulphur content was found to be in medium category.

1.2 Resource Inventories of Poor Quality Groundwater Waters

- **Survey and characterization of underground waters (Agra)**

The groundwater survey of Agra district (UP) was revisited to see the temporal changes in water quality over past 35 years. Survey of all 13 blocks viz. Fatehpur Sikri, Akola, Bichpuri, Achhnera, Jagner, Sainya, Kheragarh, Barauli Ahir, Khandauli, Shamsabad, Bad, Pinahat and Fatehabad were completed during 2012-2016 and two blocks Etmadpur and Jaitpur Kalan have been completed during 2016-17, samples were collected and analyzed for quality parameters. The distribution of water samples in different water quality classes revealed that no sample of good quality ground water was found in Fatehpur Sikri, Akola and Achhnera blocks. The maximum (53.6 percent) good quality water was in Barauli Ahir block followed by 50.7 per cent in Jaitpur Kalan and 44.0 per cent in Pinahat blocks. The most of poor quality water samples were of high SAR saline followed by Alkali (Marginally Alkali, Alkali & High Alkali) and Marginally Saline. In Agra district, 29.3 per cent water samples were of good quality, whereas 45.6 per cent Saline (Marginally Saline, Saline & High SAR Saline) and rest 30.5 per cent samples were of Alkali (Marginally Alkali, Alkali & High Alkali). Comparing the water quality of recent water samples with 35 years ago samples of Agra district, it can be explained that the good quality water in the surveyed blocks have been reduced sharply except Jagner, Sainya, Barauli Ahir, Khandauli and Kheragarh blocks. The majority of samples falls in high SAR saline water quality in both the surveyed periods except Jagner, Sainya, Barauli Ahir and Kheragarh blocks, the High SAR Saline water quality has been increased in seven blocks. The saline water quality (marginally saline and saline) decreased in Fatehpur Sikri, Bichpuri Jagner, Sainya, Kheragarh, Barauli Ahir, Shamsabad and Bah. Slight increased trend was observed in alkali water whereas the water quality of three blocks i.e. Jagner, Sainya and Kheragarh remained unchanged even after three decades of time period.

- **Survey and characterization of ground water of West Godavari district (Revisiting the sites) (Bapatla)**

The survey work was initiated for purpose of characterization and classification of ground water in West Godavari district by collecting 228 groundwater samples from 46 mandals during pre and post monsoon period, 2016 along with GPS locations. During pre monsoon season, pH and EC values of water samples ranged from 6.5 to 8.6 and 0.3 to 26.0 dS m^{-1}, respectively. Whereas, pH and EC of post monsoon water samples varied from 6.2 to 8.8 and 0.3 to 26.0, respectively. The SAR ranged from 0.07 to 21.1 during pre monsoon period, while, it ranged from 0.73 to 13.26 with a mean value of 4.11 during post monsoon period. The residual sodium carbonate values of water samples ranged from -25.8 to -4.5 me L^{-1} with a mean of -2.79 me L^{-1} during pre monsoon period and from -14.2 to 7.0 with a mean value of -2.48 me L^{-1} during post monsoon period. A total of 180 water samples were found to be good (58.6%) and 93 samples were marginally saline (30.3%). Based on RSC classification of water samples, 78 per cent of samples were categorized as safe for irrigation. Per cent area under good quality water reduced to 58.3 per cent as compared to 81.9 per cent recorded during 1989-90. On the other side, the per cent alkali water increased to 8.8 as compared to 0.1 in 1989-90.

- **Effect of sea water intrusion on ground water quality in coastal belt of Krishna Zone A P (Bapatla)**

A total of 120 groundwater samples were collected along 4 routes *viz.*, Machilipatnam, Kanaparthi, Bapatla and Nizampatnam from sea coast to 50 km inward. The analytical data indicated no particular trend in EC, pH or ionic composition with distances from sea coast in both pre and post monsoon samples. However, a slight reduction in EC was observed in post monsoon samples, particularly in areas with high rainfall. The ionic ratios indicated that the seawater mixing is more towards inland than near coast due to high recharge of groundwater in coastal sandy soils.

- **Survey and characterization of underground waters for irrigation (Bikaner)**

Survey and characterization of underground waters was done for two tehsils of Jodhpur district viz., Bilara and Pipad tehsils by analyzing samples from 44 villages i.e 20 villages of Bilara and 24 villages of Pipar city tehsil. The range of EC and pH of samples in Bilara ranged from 2.47 to 10.52 dS/m and7.33 to 8.42 while Pipar City ranged from 0.56 to 19.50 dS/m and 7.10 to 9.13, respectively. RSC of water samples ranged between 0 to 4.0 and 0.0 to 4.2 meq/L in Bilara and Pipar city tehsil, respectively. About 90 and 87.5 per cent water samples in Bilara and Pipar city tehsils had RSC in the range of < 2.5, meq/L. ECiw ranged between 2 -3, 3 - 4 and >4 dS/m in 7.5, 10 and 82.5 per cent water samples in Bilara tehsil, while in Pipar city tehsil ECiw ranged from <1, 1 to 2, 3 to 4 and > 4 dS/m in 5, 5, 15, 12.5 and 62.5 per cent water samples, respectively. About 15, 70 and 15 per cent water samples in Bilara tehsil are under saline, high SAR saline and marginally alkali while 10, 17.50, 60 and 12.50 per cent water samples of Pipar tehsil under good, marginally saline, High SAR saline and high alkali, respectively. The SAR of water samples ranged from 8.22 to 20.68 and 2.10 to 76.08, whereas soluble sodium percentage (SSP) of water samples ranged from 47.03 to 80.39 and 42.97 to 95.49, respectively, for Bilara and Pipar city tehsils.

- **Survey and characterization of underground waters of Kaithal district for irrigation (Hisar)**

The survey and characterization of underground irrigation water of all blocks namely Kaithal, Guhla, Kalayat, Pundari, Rajound and Siwan of Kaithal district was completed during 2016-17 with analysis of 530 samples with GPS locations. Among the six blocks of Kaithal district, Guhla and Pundri blocks have the best groundwater quality in which 63.2 and 60.3 per cent samples were in good quality category. In Kaithal district, 47.2, 12.1, 0.0, 7.7, 11.3, 13.0 and 8.7 per cent samples were found in good, marginally saline, saline, high SAR saline, marginally alkali, alkali and highly alkali, categories, respectively.

Survey and characterization of ground water for irrigation, salinity associated problems of Khargone and Khandwa district of Madhya Pradesh (Indore)

Ground water samples (253 no.) were collected from different villages from different tehsils of the Khargone district. Out of these 253 samples, 208 (82.2 %) belonged to Good category, 44 (17.4 %) belonged to Marginal Saline category and 1 (0.4 %) belonged to Saline category. In case of Khandwa district, 180 ground water samples were collected. Out of these 180 samples, 158 (87.8 %) belonged to Good category and 22 (12.2 %) belong to category Marginal Saline.

- **Survey and Characterization of underground irrigation water of Kanpur dehat district of Uttar Pradesh (Kanpur)**

Three hundred fifteen underground irrigation water samples were collected from different villages of Kanpur Dehat district. Out of total samples, 27, 22, 35, 32, 40, 32, 30, 33, 37 and 27 samples were collected from Akbarpur, Amraudha, Derapur, Jhinjhak, Maitha, Malasa, Rajpur, Rasulabad, Sandalpur and Sarwankhera blocks of the district respectively. Out of the 315 samples, 251 samples (78.68 %) belong to category good, 47 samples (14.92 %) belong to category marginally saline, 04 samples (1.27 %) belong to saline water, 05 samples (1.59 %) belong to highly saline water, 04 samples (1.27 %) belong to marginally alkaline, 03 samples (0.95 %) belong to alkaline and 01 sample (0.32 %) sample belongs to highly alkaline category.

- **Survey and characterization of ground water of Coastal districts of Tamil Nadu for Irrigation (Tiruchirapalli)**

Survey and characterization of ground water for Kanyakumari district was by analyzing 215 water samples (open and bore wells) from different parts of district. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions (CO3, HCO3, Cl and SO4). Quality parameters like Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC). Classification of water quality is done on the basis of EC, SAR and RSC values. Kanyakumari District has 8 blocks viz., Thovalai block, Kuruthencode block, Munchirai block, Thiruvattar block, Kiliiiyur block, Thucklay (Kozhipulai) block, Agastheeswaram block and Rajakamangalam block. Among the 8 blocks, the distribution of 100 % good quality ground water were observed in Thucklay block followed by Rajakkamangalm (89.7%), Agastheeswaram (80.0 %), Munchirai (81.25 %) and Thiruvattar blocks (80.95 %). The good quality water was absent in Thovalai block and almost 73.68 % of ground water samples were saline water. Marginally saline water is also seen in Thovalai block (26.32%), Thiruvarttar block (28.57 %), Munchirai (18.75%) and Killiyur block (16.66%). High SAR saline water was found in Agastheeswaram (15%) and Rajakamangalam block (10.3%) only. Alkali water was almost absent in all the blocks. Out of the total samples collected from Kanyalumari district, 73.02% is coming under good quality, 12.57% is marginally saline, 14.81% is saline water and 3.16 % is under high SAR saline categories.

- **Survey and characterization of underground irrigation water of Bathinda, district, Punjab (Bathinda)**

The EC of majority of samples i.e. Maur (18%), Nathana (54%), Bhagta Bhai Ka (72%) and Rampura (33%) block were having ECiw less than 2 dSm^{-1}. Whereas, 62% in Maur, 46% in Nathana, 28% in Bhagta Bhai Ka and 56% in Rampura blocks were between 2 to 4 dSm^{-1} and rests was more than 4 dSm^{-1}. On basis of EC, we can say that only 44% water samples could be used for irrigation without any possible risk of soil salinization. Further, 48% water samples having marginal EC (2 to 4 dSm^{-1}) and 8% samples were not very suitable for irrigation. Overall on the basis of RSC, 67% water samples is safe (RSC <2.5 meL^{-1}), 29% water is marginal (RSC 2.5-5.0 meL^{-1}) and 4% water is not very much good for irrigation (RSC > 5.0 meL^{-1}).

- **Estimation of fluoride in underground water of Bathinda, district, Punjab (Bathinda)**

Among the all blocks average fluoride concentration was highest in Talandi sabo block followed by Bathinda block. Overall the average concentration of fluoride in Bathinda, Talwandi Sabo and Bhagta Bhai Ka blocks were higher than safe limit (<1.5 mg L^{-1}). Overall, about half of the samples falls within safe limit (<1.5 mgL^{-1}), in which 26.6% samples having fluoride less than 1.0 mgL^{-1}, and 23.9 % samples having fluoride between 1.0-1.5 mgL^{-1}. Whereas, 49.5% samples having fluoride beyond permissible limits (>1.5 mgL^{-1}) (WHO, 1994).

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

In Thiruvananthapuram district, water samples from Vizhinjam, Kovalam beach and Kappilkayal were coming under saline category (7.89%) and Varkala beach under marginally saline category. Almost 89.4% samples were of good category and 2.6% samples belonged to marginally saline category. Water samples were having SAR in Kottayam district except the sample collected from Kudavechoor which was good for irrigation purpose. Ground water sample from Murinjapuzha was saline in nature. In Kollam, 52.38 per cent of the samples were having high SAR whereas 94.11 per cent in Kottayam. It is important to note except few samples, EC of all samples was below 2 dS/m, RSC was absent. SAR in Kollam and Kottayam was high but as EC was less. Hence groundwater is good for irrigation in general. Again these districts receive lot of rainfall which helps for reaching. On comparing the boron content of ground water samples of Thiruvananthapuram, Kottayam, Kollam and Pathanamthitta district it was observed that all samples came under safe category for irrigation. There was no RSC in groundwater in all samples of four districts. Similarly, Mg/Ca ratio was also found to be under safe levels.

2. MANAGEMENT OF SALT AFFECTED SOILS

2.1 Management of Alkali Soils

- **Reclamation of abandoned aqua ponds (Bapatla)**

The experiment was planned in 10 farmers' fields at Nizampatnam, Guntur district during *kharif*, 2016-17 in soil having the pH ranging from 7.9 to 8.5 and ECe ranging from 30 to 74 dS m^{-1}, low in available N, medium in available phosphorus and high in K. Adoption of reclamation practices resulted in 17 to 18 % increase in yield over non reclaimed soil.

- **Effect of chemical and organic amendments in reclamation of salt affected soils under rice (Bapatla)**

The experiment was carried out at Narravari palem during *kharif*, 2016. Biocompost @ 4t ha^{-1} and gypsum based on soil test were applied to the field, which resulted in higher grain yield of 5000 kg ha^{-1} over 3600 kg ha^{-1} obtained in farmers practice. The lowest pH of 8.2 at harvest of paddy was observed when Biocompost @ 4t ha^{-1} + gypsum @ 50 GR with EC of 4.3 dS m^{-1} against pH and EC 8.6 and 5.6 dS m^{-1} when farmers practice was adopted.

- **Studies on performance of safflower in alkali soils with different agronomic management practices (Bapatla)**

The treatment that received gypsum + FYM + 25% extra nitrogen treatment recorded the highest plant height (63.7 cm) followed by gypsum+25% extra nitrogen application treatment (61.3 cm). The lowest plant height was recorded in farmers practice (45.9 cm). The seed yield (1114 kg ha^{-1}) was significantly higher in gypsum + FYM + 25% extra nitrogen treatment when compared to all other treatments and the lowest seed yield (530 kg ha^{-1}) was recorded in farmer's practice.

- **Evaluation of distillery spent wash as an amendment for reclamation of sodic soils of TBP command (Gangavathi)**

Sodic soils are constrained not only with respect to nutrient availability for crops but also with regards to their degraded physical properties. Distillery spent wash (DSW) a bio-product of alcohol industry is gaining its importance in the reclamation of non-saline sodic soils as it is highly acidic and contains fairly good amount of Ca, Mg and other essential plant nutrients. The experiment consisted of main plot (DSW @1.0, 1.5, 2.0, 2.5 and 3.0 lakh lit/ha) and sub-plots (NPK @ 75, 100 and 125% RDF) arranged in a split-plot design with three replications each. The mean initial surface soil pH, ECe, Org. C, BD and ESP of the experimental site was 8.82, 1.32 dS/m, 0.56%, 1.33 Mgm-3 and 21.3 respectively. The pH and EC of the applied distillery spent wash was 3.7 and 36.1 dS/m. Soil samples were collected at harvest of Kharif 2014 and 2015. Paddy (var BPT 5204) was transplanted during Kharif 2016. Observations on growth, yield attributes and yield (grain and straw) in both the years were recorded.

At the end of the second Kharif season, surface soil pH was reduced at all the DSW treated plots compared to its initial value. However, the values observed were of the same level as that of Kharif 2014. The treatment M6 (3.0 lakh lit/ha) had significantly lower pH (7.66) compared to M1 (control), M2 (1.0 lakh lit/ha) and M3 (1.5 lakh lit/ha) but at par with M4 (2.0 lakh lit/ha) and M5 (2.5 lakh lit/ha). Similar to Kharif 2014, soil ECe was found to be significantly higher at M6 (6.02 dS/m) compared to rest of the treatments with the least change in M1 (1.44) compared to its initial value of 1.32 dS/m. Soil organic carbon content increased significantly with M6 (1.12%) compared to rest of the treatments except M5. Though not much differences were observed compared to Kharif 2014, the treatment M6 had significantly lower ESP (10.0) compared to M1, M2, M3 and M4 but was at par with M5 (10.6). Soil B.D. was significantly lower under M5 (1.05 Mgm-3) compared to M1, M2, M3 and M4 but at par with M6 (1.10 Mgm-3). There were no effects of either fertilizer levels or interaction effects on soil properties.

Pooled analysis over three seasons revealed that significantly higher grain yield was observed with M5 (5244 kg/ha) compared to M1, M2 and M3 but was on par with M4 (5040 kg/ha) and M6 (5155 kg/ha). The N3 (125% N) had significantly higher grain yield (4798 kg/ha) compared to N1 (75%) but was on par with N2 (100%). The straw yield was significantly higher at M6 (6841 kg/ha) compared to M1, M2 and M3 but was on par with M4 and M5. The N3 had significantly higher straw yield (6175 kg/ha) compared to N1 but was on par with N2. The interaction effects on grain and straw yield were non-significant in both the years. Plant height, no. of tillers/hill, panicle length and test weight were also positively influenced due to application of DSW in both the years. Based on the three seasons results available it could be thus inferred that application of DSW @ 2.0 lakh/ha is beneficial for increasing grain yield to the extent of 26% over control for soils and crop under investigation.

Effect of long-term application of organic/ green manures at different soil ESP in sodic Vertisols (Indore)

Effects of organic/ green manuring on soil properties and crop yield in an alkali soil were studied. Four treatments (i.e. control, FYM @ 10 t ha-1, sunhemp and dhaincha as green manuring crops) were tested at four soil ESP levels (25, 35, 45 and 50 ± 2). The paddy and wheat yield decreased with increase in soil ESP. The maximum yield of paddy and wheat was recorded at soil ESP of 25 as 3.71 and 3.47 t ha-1 and lowest yield as 1.25 and 1.51 t ha-1, respectively, at soil ESP of 50. Among various treatments incorporation of dhaincha gave highest yield and lowest was observed in control plot for both the crops.

Performance of wheat crop as influenced by different depth and frequency of irrigation under different methods of irrigation in sodic Vertisols (Indore)

The minimum water expense (WE) was obtained 39 cm in case of Sprinkler Irrigation with irrigation depth 3 cm followed by 40 cm in Sprinkler Irrigation with irrigation depth 2 cm and maximum WE was 51.84 cm in case of Border Surface Irrigation (BSI) with COD 65 % followed by 48.96 cm in BSI with COD 85 %. The highest yield of 2869 kg ha^{-1} and the lowest yield of 1941 kg ha^{-1} were obtained in case of SI with irrigation depth 3 cm and BSI with COD 65%, respectively. Similar trend was obtained in case of water productivity with values of 73.6 and 37.4 kg/ha-cm.

Evaluating performance of drip irrigation under different discharge rate and schedules for growing vegetable crop in sodic black soils (Indore)

The total water expense was estimated around 53 cm in case of daily, alternate and third day irrigation schedules with respective depth of irrigation as 0.50, 1.00 and 1.50 cm. The highest curd yield 20976 kg/ha was obtained in case of drip irrigation system scheduled daily with 1.3 LPH dripper discharge rate followed by the lowest 10588 kg/ha in case of drip irrigation system scheduled every third day with 4.0 LPH dripper discharge rate. Similarly, highest water productivity (WP) of 395.77 kg/ha-cm was observed in case of drip irrigation system scheduled daily with 1.3 LPH dripper discharge rate followed by 365.75 kg/ha-cm in case of drip irrigation system scheduled every alternate day with 1.3 LPH dripper discharge rate. The lowest WP was observed 197.40 kg/ha-cm in case of drip irrigation system scheduled every third day with 4.0 LPH dripper discharge rate followed by 228.44 kg/ha-cm in case of drip irrigation system scheduled alternate day with 4.0 LPH dripper discharge rate.

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

The grain and straw yield of rice varied from 23.82- 40.68 q/ha, 28.44- 49.65 q/ha and wheat from 19.12-35.34 q/ha and 23.33-43.11 q/ha respectively in different treatments. The highest yield of rice and wheat was obtained from 25%GR + Poultry manure @3t/ha followed by 25%GR + GM @5 t/ha + Microbial culture and lowest yield was received from control plot. The data indicated that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in all treatments excluding control, maximum decrease was observed in 50%GR treatment. The organic carbon was improved in all treatments. The maximum increment of organic carbon was recorded with the application of 25%GR + Poultry manure @3t/ha followed by 25%GR + GM @5 t/ha + Microbial culture and 25%GR + City Waste Manure @5 t/ha treatment.

- **Integrated Farming System suitable for problem soil areas of Tamil Nadu (Tiruchirapalli)**

Integrated farming system for sustainable income in sodic environment of Tamil Nadu with main components as agricultural crop (rice), vegetables, fish and poultry was tested. The green manuring was also adopted for nutrient recycling. The B:C ratio for IFS was 2.54 compared to sole rice crop with B:C ratio as 2.16.

2.2 Management of Saline and Saline Waterlogged Soils

- **Influence of silicon on alleviation of salinity effect on rice (Bapatla)**

Among different sources of silicon, application of potassium silicate recorded significantly higher grain yield (5686 kg ha^{-1}) and straw yield (6237 kg ha^{-1}) with corresponding yields of 4631 and 5118 kg ha^{-1} in control which was on par with calcium silicate application.

- **Investigation, design, installation and evaluation of mole drainage systems in black soils of Andhra Pradesh for control of waterlogging (Bapatla)**

Mole drainage systems were designed for Vertisols of East Godavari district for sugarcane crop and were installed. The drains laid at 3 m spacing with 0.4 m & 0.5 m depths performed better when compared other spacing. The results from one year study revealed that the temporarily waterlogged soils can be reclaimed with low cost mole drainage systems and addition of soil oxygenation agents (placement of Calcium peroxide granular powder @ 2 g/plant at 15 cm deep and 15 cm away from the plant) during monsoon season will ensure good aeration. The combined effect of mole drainage and soil oxygenation resulted in 25-38% increase in the sugarcane yields of Co 86032 variety.

- **Response of cotton to drip irrigation in saline soils under conservation agricultural practices (Gangavathi)**

The experiment was initiated during Kharif 2013 and continued in Kharif 2016 on response of cotton to fertigation through drip irrigation in saline soils under conservation agriculture practices at Agricultural Research Station, Gangavati. The initial soil salinity of the experimental plot varied from 5.30 dS/m to 7.0 dS/m and 5.27 dS/m to 9.24 dS/m at 0-15 and 15-30 cm, respectively. The main treatments were without mulch and with mulch and sub treatments were fertigation with 50 % Recommended dose of fertilizers (RDF), 75 % RDF, 100 % RDF and 125 % RDF. The fourth year study revealed that seed cotton yield was significantly higher in 125% RDF (27.3 q/ha) compared to 50 % RDF (24.13 q/ha) but was on par with 75 % (25.37 q/ha) and 100 % RDF (26.00 q/ha). In case of conservation practices, significantly higher seed cotton yield was recorded in mulch treatment (27.9 q/ha) compared to no mulch treatments (23.5 q/ha). The interaction effects between main and sub plots were non-significant. The experiment was concluded.

- **Evaluation of subsurface drip irrigation on soil physico-chemical properties, growth and yield of salt tolerant sugarcane in saline Vertisols of Tungabhadra command area (Gangavathi)**

Evaluation of subsurface drip irrigation on soil physico-chemical properties, growth and yield of salt tolerant sugarcane in saline vertisols was initiated during summer 2013-14 and continued during 2016-17 at Agricultural Research Station, Gangavathi. The experiment was laid out in three replications with main treatments (method of irrigation) viz., surface drip, subsurface drip and furrow irrigation (control) and sub treatments (irrigation levels) viz., 0.8, 1.0 and 1.2 ET. A salt tolerant sugarcane variety Co-91010 (Dhanush) procured from Mudhol was planted (single eye bud sets) during Feb-2014 in paired row system (0.6x1.20x0.6 m). Depth to water table was monitored through nine observation wells. The results revealed that more soil moisture was retained in surface drip irrigation method compared to subsurface drip irrigation at 0-15 cm soil whereas in subsurface soil (15-30, 30-45 and 45-60 cm) more moisture was retained in subsurface drip compared to surface drip irrigation method. The higher soil moisture content was observed in Y-direction (along drip lateral) compared to X-direction (perpendicular to drip lateral) because of strip wetting. In case of vertical (Z-direction) soil profiles, soil moisture retained was less compared to lateral directions (X & Y direction) in both the methods of drip irrigation.

The results for the year 2016-17 experiment revealed that among irrigation methods, significantly higher cane yield (129.7 t/ha) was recorded in subsurface drip compared to furrow irrigation (103.2 t/ha) method but on par with surface drip irrigation method (123.3 t/ha). Among irrigation levels, significantly higher yield (122.6 t/ha) was recorded at 1.2 ET irrigation level followed by 1.0 ET (120.4 t/ha) and least in case of 0.8 ET (113.3 t/ha). Significantly higher water use efficiency (WUE) of 85.1 kg/ha/mm was recorded in subsurface drip irrigation compared to furrow irrigation (67.6 kg/ha/mm) but was on par with the surface drip irrigation (80.6 kg/ha/mm) method. Among irrigation levels, significantly higher WUE (86.4 kg/ha/mm) was recorded at 0.8 ET followed by 1.0 ET (77.9 kg/ha/mm) and least in case of 1.2 ET (68.9 kg/ha-/m).

The brix percentage was not affected by either irrigation methods or irrigation levels. The sugar water use efficiency (S-WUE) was calculated based on brix percentage, yield and total water applied. In case of irrigation methods, significantly higher S-WUE was recorded in subsurface drip irrigation (1.79 kg/m3) followed by surface drip irrigation (1.62 kg/m3) and least in furrow irrigation (1.37 kg/m3) method. Among irrigation levels, significantly higher S-WUE was recorded at 0.8 ET (1.74 kg/m3) followed by 1.0 ET (1.62 kg/m3) and least in case of 1.2 ET (1.43 kg/m3) irrigation level. The experiment will continue for 2017-18.

- **Development of profitable Integrated Farming System (IFS) module for saline Vertisols of Thunga Bhadra Project (TBP) command area of Karnataka (Gangavathi)**

During the year 2016-17 finger millet, bajra and paddy grown in cropping components. The yield data indicated that 450 kg of grain yield of finger millet and 170 kg paddy grain yields were obtained. Paddy grain yield was very low yield due to low crop stand because of high soil salinity in that area. Five hundred fingerlings were released to the pond and harvested 85 kg of fish in the pond component. Under vegetable components, 130 kg of brinjal and 120 kg of beet root and 15 kg of drum stick were harvested during Kharif and Rabi respectively. In horticulture component, 50 kg of first bearing fruits of pomegranate was recorded. Under Vermicomposting, about 1000 kg of vermicompost was produced during the year. Benefit cost ratio of all the components of IFS was averaged and compared with conventional farming system of rice- rice monoculture. It was noticed that average B:C ratio (2.74) of all components in IFS was higher than the conventional farming system (1.52).

- **Utilization of saline tolerant microbes (Port Blair)**

Twenty salinity tolerant microbes have been isolated from the rhizosphere soils of selected plants growing in saline condition, characterized and maintained by sub-culturing. After laboratory testing for salinity tolerance, five most promising isolates were used as consortia for further evaluation. A field study was conducted to evaluate the effectiveness bioconsortia on Okra. Saline tolerant bio-consortia were inoculated by seed priming and application to soil through compost in order to assess its effectiveness in promoting plant growth and nutrient uptake. The maximum plant dry biomass was recorded for TA1+ NFB3 (150 gm) which was 60% higher than the control followed by NFB3+ SM4 (144 gm). The results highlighted the usefulness of salinity tolerant bioconsortia (NFB3+ SM4) in promoting plant growth and yield.

2.3 Management of Saline–acidic soils

- **Integrated farming system for sustainable land use in Pokkali lands (Vytilla)**

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. In this system the growth of both the components are interrelated and is one of the proven technology which is very cost effective. During the year 2016-17, grain yield recorded was 2.38 t ha^{-1} and total of 375 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 2.29. This is mainly because of the fact that the leftover of prawn cultivation become manure for rice cultivation, thereby reducing the additional requirements of any external means of fertilisers. This 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 water to supplement Canal waters (Agra)**

Toria–chikori crop rotation was grown with different conjuctive modes of canal and alkali (RSC 10 meq/l) waters, to find out the most suitable cyclic and mixing mode of the toria-chikori crop rotation, in case of toria crop all the irrigation modes i.e. cyclic and mixing mode etc, were found statistically at par. The chikori crop root yield was found significantly higher in canal water (CW) treatment and lowest in alkali water (AW) treatment. The maximum net profit (Rs. 1, 10,257), from two crops grown in one year rotation, was recorded in canal water irrigation and lowest (Rs. 65,867) in alkali water irrigation. The benefit cost ratio was maximum (1.98) in canal irrigation and minimum (1.20) in alkali irrigation.

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

Irrigation with gypsum treated water resulted in better performance of all the crops tested (safflower, chickpea, black gram and green gram) when compared to irrigation with untreated water.

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

The average yield varied from 23.51-38.85 and 17.10-.34.49 q/ha of rice and wheat respectively in rice- wheat cropping system. The highest yield was obtained from best available water (BAW) followed by RSCW - (Rest irrigation with BAW) and lowest yield was received from residual sodium carbonate water (RSCW) treatment. The average yield varied from 08.44-15.35 and 17.97-33.32 q/ha of pearl millet and wheat respectively in pearl millet - wheat cropping system. The highest yield was obtained from best available water (BAW) followed by RSCW - (Rest irrigation with BAW) and lowest yield was received from residual sodium carbonate water (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 RSCW.

- **Pressurized irrigation methods for vegetable crops in sodic soils (Tiruchirapalli)**

Performance of drip, sprinkler and furrow irrigation methods on vegetable crops (cluster bean, bhendi, vegetable cowpea and onion) under sodic environment was studied. The yield increase in vegetables under drip irrigation over furrow irrigation was 43% in cluster bean, 34% in bhendi, 71% in vegetable cowpea and 49% in onion, respectively. Therefore, it is recommended the drip irrigation method for vegetable crops cultivation under sodic soil environment to a sustainable use of water resources with improved efficiency.

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

Field experiment was conducted during 2016 at Anbil Dharmalingam Agricultural College and Research Institute, Trichirappalli to study the efficacy of irrigation with ameliorated alkali water using gypsum bed and distillery spentwash through drip system on cotton BG II hybrid RCH – 20 under sodic soil. The experiment consists of drip irrigation of different ameliorated water in main plots viz. gypsum bed treated water, spentwash treated water and untreated alkali water, and reclamation of sodic soil in sub plots viz., reclamation through gypsum @ 50% GR, reclamation through one time application of raw distillery spentwash @ 5 lakh liters ha^{-1} and unamended sodic soil. The pH of alkali irrigation water is 8.96, and EC and RSC of alkali irrigation water are 1.62 dS m-1 and 7.6 meq $L^{-1.}$ Amelioration of alkali water through distillery spentwash injection 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. Gypsum bed amelioration reduced the irrigation water pH from 8.96 to 8.20 and RSC from 7.6 to 3.4 meq L-1. The results showed that irrigation with gypsum bed treated alkali water with reclamation of soil through one time application of DSW @ 5 lakh liters ha^{-1} recorded the highest seed cotton yield of 3014 kg ha^{-1} and the lowest of 1410 kg ha^{-1} was recorded in the untreated alkali water irrigated through drip system at unamended soil. Ameliorating alkali water through gypsum bed recorded the highest seed cotton yield of 2581 kg ha-1 followed by the treatment of irrigation water with DSW which is 2423 kg ha-1. Drip irrigation with alkali water recorded the lowest seed cotton yield of 1880 kg ha-1. Therefore, it is recommended that the drip irrigation with gypsum bed treated alkali water along with sodic soil reclamation using distillery spentwash @ 5 lakh litres ha-1 for enhancing cotton productivity in sodic soil with a sustainable use of alkali water.

3.2 Management of Saline Water

- **Micro (Drip) Irrigation system with saline water for different vegetable crops in coastal sandy soils (Bapatla)**

The results indicated that the highest yield of cabbage, cauliflower and drumstick were obtained with best available water (BAW) whose EC is 0.6 dS m^{-1} followed by 2 and 4 dS m^{-1}. Physiological damage to crops was observed with EC of irrigation water beyond 4.0 dS m^{-1}. The salinity buildup in the soil took place temporarily, which got leached by the regular rainfall events received. Build up of salinity and its vectors are limited to 30 cm either way from the emitter. There is no observed deposition of salts in the drip lateral pipe.

- **Use of saline water in shadenets for different vegetable crops in Krishna Western Delta (Bapatla)**

The production functions of cabbage and cauliflower were found to be following linear relationship in shadenets where as the same in open field cultivation followed exponential relationship, which presents a possibility of better control over irrigation water salinity stress in shadenets cultivation over open field cultivation.

- **Optimization of water requirement of groundnut-wheat cropping sequence using saline water under drip irrigation (Bikaner)**

Salinity of irrigation water, its volume and drip geometries have significant effect on yields of groundnut and wheat. Increase in salinity of irrigation water beyond 4 dS/m caused drastic reduction in the pod yield of groundnut whereas wheat yield showed sharp decline beyond ECiw 8 dS/m. Drip geometry of 60 cm x 30 cm found superior to 90 cm x 30 cm in terms of yields of both crops. ET 0.8 found at par with ET 1.0 in the yields of both crops.

- **Effect of fertility levels on isabgol- pearlmillet crop sequence under drip irrigation using saline water (Bikaner)**

An experiment was conducted during Rabi 2016-17 to optimize water requirement of pearl millet – isabgol cropping sequence using saline water under drip irrigation. Data indicated that different treatments had significant effect on seed yield of pearl-millet and isabgol. Increase in the ECiw beyond 4 dS/m caused significant reduction in the seed yield. In respect of fertility levels, it is noted that application of 100% and 125% recommended dose of NPK registered significant increase of seed yield over 75% RDF. However, levels 100% RDF and 125% RDF were statistically at par.

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

The maximum grain yield (32.54 q/ha) of pearl millet (HHB-226) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (31.97 q/ha). The maximum grain yield (50.01 q/ha) of wheat (WH-1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (49.40 q /ha).

- **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 22.9 and 30.6% in all saline irrigation of 8 and 10 dS/m as compared to canal irrigation. A reduction of 20.0, 10.2 and 2.8% in grain yield of pearl millet was observed under 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 9.8 and 20.5% in all saline irrigation 8 and 10 dS/m as compared to canal irrigation. Reduction of 31.1, 9.8 and 2.7% 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.

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

In case of drip irrigation, in 75% RDN of nitrogen application, the relative fruit yields of tomato were obtained 96.9, 88.7 and 76.6% when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in RDN application, the relative fruit yields of tomato were obtained 99.60, 87.50 and 77.00% when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in 125% RDN application, the relative fruit yields of tomato were obtained 98.90, 87.50 and 76.70% when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Significant reductions in tomato fruit yield were recorded at ECiw 5.0 and 7.5 dS/m as compared to canal water irrigation.

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

On the basis of irrigation water salinity and yield relation, it was observed that rate of yield reduction with irrigation water salinity was highest in Dill followed by Spinach and was least in case of radish.

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 three irrigation water i.e. sewage water, tube well water and 1 SW: 1 TW and three fertilizer levels i.e. 50, 75 and 100 % RDF. Cluster bean was sown as a first crop during *kharif* and second crop cauliflower was sown during winter season and third okra was sown during summer season. The maximum net profit of the three crops grown in one year rotation in sewage water irrigation was Rs. 277355/ha and lowest in tube well water irrigated (Rs. 1 43098/ha). The benefit: cost ratio in this rotation was the maximum in sewage water irrigation (1.53) and minimum (0.91) in tube well water irrigation. The application of 100% recommended dose of fertilizer produced maximum net profit and B:C ratio (Rs. 243227/ha and 1.35) and minimum (Rs. 164507/ha and 1.02) with 50% RDF. The maximum system productivity in cluster bean-cauliflower-okra cropping sequence was observed in treated sewage water irrigation i.e. 547.24 q/ha and minimum (399.10q/ha) in tube well water irrigation. The use of 100% recommended dose of fertilizer produced maximum system productivity of 523.74 q/ha and lowest of 406.78 q/ha in 50% RDF.

4. ALTERNATE LAND MANAGEMENT

- **Evaluation of Silvi-horticultural crops in saline/ Alkali soils under rainfed conditions (Bapatla)**

The experiment was conducted at Panduranga Puram and Pedavodarevu villages in soils having a pH of 8.6 and 7.8 and EC of 2.1 and 4.5 dS m^{-1}, respectively. All the saplings of casuarina, eucalyptus and sapota planted at Panduranga Puram site and saplings of sapota, guava, pomegranate at Pedavodarevu established well.

5. SCREENING OF CROP CULTIVARS AND GENOTYPES

- **Screening of crop cultivars for saline/alkali water irrigation (Agra)**

Mustard: During 2016-17, two sets of rapeseed mustard cultivars were tested for salinity tolerance (EC_{iw}12 dS/m). In line trial of IVT the highest yield potential was recorded in CSCN-16-10 (25.48 q/ha) and lowest yield (20.04 q/ha) was found in CSCN 16-6. In case of AVT, the genotype CSCN 16-19 yield was highest (26.56 q/ha) and lowest in CSCN 16-13 (19.98 q/ha).

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

Mustard: The grain yield of mustard increased at 125% and 150% dose of fertilizers over 100% dose of fertilizer. Significantly highest grain yield was found in AG-19 (28.04 q/ha) and lowest AG-17 (21.83 q/ha) while AG-18 and AG-20 produced at par grain yield.

Lentil: Fifteen entries of lentil were tested under saline water (ECiw 6 dS/m) and alkali water irrigation (RSCiw 6 meq/l). The yield of Lentil was significantly affected under saline irrigation. Significantly higher yield was produced in variety LSL 16-3 (514.32 kg/ha) and lowest in variety LSL 16-6 (200.00 kg/ha). Significant difference was observed with alkali water in lentil entries, LSD 16-7 found highest yield (739.38 kg/ha) and lowest yield was recorded in LSD 16-6 (293.46 kg/ha).

- **Screening of Newly released rice varieties for salinity tolerance (Bapatla)**

The experiment was carried out at Bavanam varipalem village in Guntur district during *kharif*, 2016. Among the varieties tested viz., MCM-103, BPT-4455, MCM-101, MCM-110, CSR-27, CSR-36 and BPT-5204, the highest grain yield was recorded with CSR 27 (6017 kg ha^{-1}) followed by MCM-110 (5850 kg ha^{-1}) whereas, the maximum straw yield was noticed with the variety CSR 36 (6150kg ha^{-1}) followed by MCM 110 (5500kg ha^{-1}). Soil Nutrient status at the harvest of highest yielder, CSR 27 indicates that, a built up in available N to the tune of 23 % and depletion in available P and K to the extent of 39.5 and 14.4 % were observed.

- **Screening of different crop varieties under drip with saline water irrigation (Bikaner)**

The experiment was initiated in kharif 2015. Four varieties of cluster bean namely, RGC 1066, RGC 936, RGC 1017 and RGC 1003 and were evaluated under three levels of irrigation water salinity viz. BAW, 4 dS/m and 8 dS/m. Results pooled over two years showed that up to ECiw of 4 dS/m there was no significant reduction in the grain of cluster bean, however, ECiw of 8 dS/m caused significant reduction of 37.9 and 34.9 per cent in grain yield, respectively, over BAW and ECiw of 4 dS/m. Variety RGC 1066 established its superiority in grain yield over RGC 936, RGC 1017 and RGC 1003, respectively.

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

The tolerance of seven genotypes of cotton, fourteen genotypes of wheat, seven genotype of pearl millet and nineteen genotypes of mustard were tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m. Among the seven cotton genotypes, overall mean yield (210.81 g/m^2) of H-1472 was significantly higher than other genotypes followed by H-1098i (199.25 g/m^2) and H-1465 was the lowest yielder (157.44 g/m^2). The overall mean reduction in seed cotton yield at 2.5, 5.0 and 7.5 dS/m was 4.55, 15.99 and 25.98%, respectively as compared to canal irrigation. Wheat genotype P-12908 performed best at the highest saline water irrigation (7.5 dS/m) and gave 31.67% higher yield compared with KRL-210 (check). It was followed by P-9142 which gave 29.54% higher yield than KRL-210 whereas the performance of Kh-65 was the poorest. Pearl-millet variety HHB-226 performed best at the highest saline water irrigation (7.5 dS/m) whereas the performance of ICMB-843-22 was the poorest. In IVT, the mustard genotypes CSCN-16-3 gave the highest seed yield (241.90 g/m^2) followed by CSCN-16-9 (239.30 g/m^2) at EC_{iw} of 7.5 dS/m and the lowest yield (172.67 g/m^2) was obtained in CSCN-16-5. In AVT, the mustard genotypes CSCN-16-13 gave the highest seed yield (250.44 g/m^2) followed by CSCN-16-12 (233.87 g/m^2) at EC_{iw} of 7.5 dS/m and the lowest yield (167.48 g/m^2) was obtained in CSCN-16-14.

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

The average grain and straw yield of different varieties of rice varied from 21.89-43.08 q/ha and 26.84-52.29 q/ha respectively. The maximum yield 43.08 q/ha of rice was recorded from variety CSR-36 followed by CSR-23 and CSR-27. The minimum yield 21.89 q/ha was obtained from CSR-30.The average grain and straw yield of different varieties of wheat varied from 26.89-35.38 q/ha and 32.31-43.34 q/ha respectively. The maximum yield 35.38 q/ha of wheat was recorded from variety KRL-210 followed by KRL-213 and PBW-343. The minimum yield 26.89 q/ha was obtained from WH-147. The average grain yield of different varieties of mustard varied from 10.46-16.18 q/ha and stalk yield from 26.30-40.75 q/ha. The maximum yield 16.18 q/ha of mustard was recorded from variety CS-56 followed by CS-54 and CS-52. The minimum yield 10.46 q/ha was obtained from Urvasi.

- **Evaluation of chilly hybrid and varieties for their tolerance to sodicity levels (Tiruchirapalli)**

An experimental result showed that chilly is not suitable crop for cultivation on the sodic soil. Further, the use of alkali water even under the normal ESP, the performance of Chilly was very poor.

- **Screening of salinity tolerance Cluster bean (Cyamopsis tetragonoloba L.) Germplasm (Bathinda)**

The maximum cluster per plant was recorded in Germplasm IC 41202 followed by IC 40235 > IC 40417 > IC 113578 > IC40752 under poor quality water. Whereas, maximum number of pods per plant was observed in Germplasm IC 40235 followed by IC40417 > IC 41202 and IC 40752. It was observed that pod length, number of grains per pod and seed index does not affect significantly by poor quality water. Whereas, grain yield per plant significantly influenced by poor quality water. It was also reported that maximum grain yield was observed in IC 40235 Germplasm followed by IC 40417 > IC 40752 and IC 40266.

- **Screening of salinity tolerance Chickpea (*Cicer arietinum* L.) Germplasm (Bathinda)**

The maximum plant height was reported in germplasm PDG 4 followed by PDG 5 > L 552 > JG62 and Karnal Channa-1. Lowest number of primary branches was reported in germplasm GLK 14311 followed by GLK-07-042 > L-556 > PDG 3 and L552. The germplasm karnal channa-1 showed maximum number of secondary branches followed by L-552 > PDG-3 > PBG7 and PDG 4. The use of poor quality water adversely affects the yield of chickpea. Maximum grain yield was reported in Karnal channa-1 followed by PBG7 > PDG4 and PBG5.

6. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

- **ORP for use of underground poor quality waters for irrigation at farmer's field (Agra)**

During 2016-17, the technology transfer program for saline water use was undertaken at village Odara, in Bharatpur district using rain water harvesting at 8 farmers field and at Savai village in Agra district with alkali water using gypsum application in 3 farmers field. Seven farmers are selected using saline water (ECiw ranges 4.3 to 7.1 dS/m) of different villeges i.e. Deen Dayal Dham (Nagla Chandra Bhan), Dhana Khema, Nagla Jalal, Garhi Pachauri and Daulatpur in Mathura (UP) and Odara in Bhratpur (Rajasthan). The technologies were used according to the nature of the water problem viz. application of gypsum, conjunctive use of saline and low saline waters, sowing with rain conserved moisture and saline water recharge technique along with recommended agronomic practices. It was observed that with the use of improved technologies, the crop yield increased over the field what farmers were getting previously with traditional agricultural practices. The use of forate and zinc also gave fruitful results by controlling the effect of termite and zinc deficiencies.

In alkali water irrigated conditions at three farmers' fields, wheat yield increased by 12.2 per cent (Average) in gypsum treated fields over control (without gypsum). At recharge sites, wheat yield ranges between 3.75 to 5.00 t/ha with average yield increase by 11.3 per cent over traditional farmers. At other farmer's field using saline water irrigation, the wheat yield increased by 10.2 per cent. In case of mustard, yield increased by 12.5 per cent in rain water recharge site.

- **Effect of Lagoon Sludge/Spent application on crop production and soil chemical environment on farmers' fields (Indore)**

The demonstrations on technology for reclaiming salt affected soils were conducted at the field of Mr, Hariram Malviya in village Bapalgaon of district Khargone of Nimar agro-climatic zones. The paddy and wheat were taken as test crop. Application of Lagoon Sludge (LS) @ 5.0 t ha^{-1} along with Raw Spent Wash (RSW) @ 2.5 lakh L ha^{-1} increased seed and straw yield of paddy by 97 and 127 % over control. The significant reduction in ESP was noticed with the addition of LS @ 5.0 t ha^{-1}+ RSW @ 2.5 lakh L ha^{-1} as compared to control.

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

The maximum survival percentage, fruit/plant, diameter of fruit and yield of tomato was recorded 56.7%, 22.12, 3.24 cm and 117.98 q/ha and minimum in control plot. The increment of yield was recorded 24.78% more treated with CSR-Bio (soil application + foliar spray) and 19.85% with CSR-

Bio (soil application) over control. The data indicate that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in both the treatments including control. However, maximum reduction was observed in CSR-Bio (soil application + foliar spray) treated plot. The organic carbon improved with the application of CSR-Bio treated plots.The maximum survival percentage, no of leaves, head weight and yield was recorded 67.5%, 10.45, 0.89 kg and 141.50 q/ha and minimum in control plot. The increment of yield was recorded 26.06% more treated with CSR-Bio (soil application + foliar spray) and 21.90% with CSR-Bio (soil application) over control. The data indicate 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.

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 semiarid 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 of the XII plan of Rs. 4638.67 lakh which included ICAR and State share as Rs. 3675.00 lakh and Rs. 963.67 lakh, 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 Agril University 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 Gangavati were transferred to these respective universities.

Volunteer Centres

1. Regional Research Station, Punjab Agril University, Bathinda (Punjab)
2. Khar Land Research Station, Dr. Balasaheb Sawant 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)

XII Plan 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 during XII plan.

- Generation of data bases on salt affected soils and poor quality waters
- Environmental impacts of irrigation and agriculture in irrigation commands and at benchmark sites
- Micro-irrigation system for saline water use to high value crops; to develop crop production functions with improved irrigation techniques
- Crop production with polluted (Agra Canal) and toxic water and bio-remediation strategies
- Water quality limits for new cropping pattern
- Development of new sources of fresh water for conjunctive use (Rainwater harvesting) and groundwater recharge
- Pollution of surface and ground water including modelling
- Reclamation and management of salt affected soils and water in Nagaur area in Rajasthan
- 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
- Survey and characterization of toxic elements in coastal groundwater
- Re-sodification of reclaimed alkali lands and comparative performance of various amendments
- Dry land reclamation technologies
- Land drainage of waterlogged saline lands for cost minimization
- Conservation agriculture/multi-enterprise agriculture/ multiple use of water
- Alternate land management including cultivation of unconventional petro-plants, medicinal, aromatic and plants of industrial application

Finance

The Twelfth Five Year Plan (2012–2017) was sanctioned by the Council vide letter No. NRM-24-4/2013-III dated 28-02-2014 with an outlay of Rs 4638.67 lakh (ICAR Share Rs 3675.00 lakh). The budget head and centre wise statements of expenditure for 2016-17 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

- **Delineation and Mapping of Salt Affected Soils of Ananthapur district Andhra Pradesh (Bapatla)**

The salt affected soils of seven districts of Andhra Pradesh viz., Chittoor, Vizianagaram, Visakhapatnam, Srikakulam, East Godavari, West Godavari, Krishna and Nellore districts were delineated and mapped using remote sensing data acquired from NRSA and were classified as per CSSRI classification.

The results of the survey conducted in Ananthapur district, given in Table 1.1, during 2015-16 indicated that the soils were neutral to strongly alkaline (7.0 to 9.4) and non saline to very highly saline (0.4 to 14.1 dS m-1) in nature. Regarding fertility, the soils were low to high in available phosphorous (19.3 to 62.3 kg ha^{-1}) and available potassium (120 to779 kg ha^{-1}) and low to medium in available nitrogen (126 to 472 kg ha^{-1}).

Ground truth survey was carried out in salt affected areas of Kurnool district, identified from LISS-III data. Representative samples from surface and sub surface were collected from 57 locations along with GPS coordinates during March, 2017. In this study, the pH values of surface soils observed in between 5.5 and 10.3, while in subsurface varied from 4.8 to 10.2. Electrical conductivity of surface soils ranged from 0.3 to 33.0 dS m^{-1} with an average value of 4.71 dS m^{-1}, while, in subsurface soils it varied from 0.2 to 16.1 dS m^{-1} with an average value of 3.31 dS m^{-1}.

Table 1.1 Physico-chemical properties of salt affected soils of Kurnool district

SN	pHe		ECe (dS m^{-1})		SN	pHe		ECe (dS m^{-1})	
	Sur-face soil (0-15cm)	Sub-surface (15-30 cm)	Surface soil (0-15cm)	Sub-surface (15-30 cm)		Surface soil (0-15cm)	Sub-surface (15-30 cm)	Surface soil (0-15cm)	Sub-surface (15-30 cm)
1	6.4	7.7	0.3	0.3	21	9.9	9.6	19.3	7.2
2	5.5	4.8	1.6	0.7	22	7.1	7.1	10.6	16.1
3	7.3	7.5	0.8	1.1	23	7.6	7.1	5.7	3.2
4	10.3	10.2	18.1	16.1	24	7.4	Rocky area	2.9	Rocky area
5	7.7	8.0	1.7	1.0	25	9.7	9.6	7.9	7.7
6	8.5	8.3	2.1	2.9	26	8.9	8.9	2.7	1.7
7	8.1	8.0	5.7	5.9	27	8.2	8.4	1.9	1.6
8	7.7	8.3	6.1	2.6	28	7.9	8.4	0.4	0.5
9	8.2	8.5	4.2	1.9	29	8.7	8.4	0.9	0.8
10	8.3	8.3	1.9	1.4	30	7.8	8.1	1.1	0.5
11	8.4	7.1	2.2	2.3	31	8.6	8.9	1.8	3.6
12	6.5	6.4	0.4	0.2	32	8.5	7.2	0.7	0.7
13	7.5	7.6	0.4	0.4	33	7.9	8.0	0.9	0.7
14	7.5	8.3	2.1	1.5	34	7.7	Rocky area	2.2	Rocky area
15	7.8	7.6	16.4	10.6	35	8.0	8.4	1.8	1.0
16	8.0	8.1	0.4	0.4	36	8.3	8.5	0.7	0.7
17	8.4	7.5	2.3	2.0	37	8.2	8.1	33	13.7
18	8.6	7.5	3.2	1.9	38	7.9	8.1	19.5	9.0
19	7.0	7.6	1.1	1.2	39	8.1	8.1	0.5	0.6
20	8.6	7.6	2.5	1.7	40	7.8	8.1	0.4	0.4
Max	10.3	10.2	33.0	16.1					
Min	5.5	4.8	0.3	0.2					
Ave	-	-	4.71	3.31					

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

Soil salinity and water logging are the twin problems of TBP command due to unscientific land and water management and violation of cropping pattern over the years. A proper delineation of the salt affected area through ground truth is imperative in arriving at a close approximate of salt affected area. No such delineation of salt affected soils in TBP command is available. Therefore, a clear assessment and mapping of salinity in the command may thus help policy makers and researcher to take up appropriate measures to arrest further increase in salt affected area and also to make salt affected soils productive again.

With the aid of GPS and toposheet, soil samples were collected on a grid basis (5' x 5' = 9 x 9 km) from Sindhanur, Manvi, Devadurga and Raichur taluks in Raichur district during May 2015. A total of 339 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 53 grid points (107 sampling points) were collected. Similarly, during May 2016 a total of 172 soil samples (0-15, 15-30, 30-60 and 60+ cm) from 27 grid points (52 sampling points) were collected from Bellary taluk in Bellary district.

Soil pH and EC were determined with soil: water extract (1:2.5). Further, these samples were subjected to saturation paste extract for the determination of pHs, ECe, cations (Ca+Mg, Na, K) and anions (Cl, SO4, CO3, HCO3). With the available data, SAR, (CO3+HCO3)/(Cl+SO4) and (Na/(Cl+SO4) ratios were calculated.

Sindhanur taluk (Raichur district)

Characterization of soil samples from Sindhanur taluk revealed that soil pH varied from 7.30 to 8.90, 7.59-9.03, 7.60-9.0 and 7.87-9.0 with a mean value of 8.10, 8.30, 8.30 and 8.54 at 0-15, 15-30, 30-60 and 60+ cm depths respectively (Table 1.2).

Table 1.2 Characterization of soil samples collected from Sindhanur taluk in Raichur 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)	8.90	7.30	8.10	9.03	7.59	8.30	9.00	7.60	8.30	9.00	7.87	8.54
EC (1:2.5)	21.0	0.20	1.90	12.5	0.30	1.43	6.90	0.30	1.50	3.30	0.30	1.17
pHs	8.10	1.80	7.40	8.34	7.00	7.86	8.20	7.30	7.70	8.59	7.48	7.99
ECe (dS/m)	47.0	0.50	4.40	24.0	0.47	3.04	14.0	0.40	3.00	6.40	0.52	2.35
Cation/Anion												
Ca+Mg	154.8	2.30	14.0	49.2	3.10	9.29	29.0	1.90	7.40	25.8	2.20	6.10
Na+	81.7	1.91	21.1	49.3	2.17	15.15	44.6	2.10	15.5	50.0	3.50	19.9
K+	0.43	0.02	0.18	0.43	0.04	0.16	0.41	0.02	0.07	0.15	0.02	0.05
HCO3-	28.0	4.50	9.10	18.0	3.50	7.70	12.0	3.00	7.30	10.5	4.00	6.93
Cl-	139.0	7.00	22.2	115	5.00	18.2	76.0	5.50	17.1	53.0	7.00	12.9
SO42-	2.29	0.09	0.61	2.10	Tr	0.40	2.08	0.02	0.47	1.64	0.04	0.55
SAR	26.8	1.43	8.83	22.1	1.56	7.45	19.8	1.80	9.26	21.3	2.79	11.8
(CO3+HCO3)/ (Cl+SO4)	0.97	0.20	0.54	1.13	0.12	0.63	1.40	0.06	0.67	1.09	0.16	0.65
Na/(Cl+SO4)	2.26	0.22	0.98	2.79	0.12	0.98	2.59	0.21	1.14	2.76	0.43	1.52

Note: Total number of samples was 42, 42, 36 and 21 at 0-15, 15-30, 30-60 and 60+ depths respectively.

Soil salinity expressed as ECe varied from 0.50-47.0, 0.47-24.0, 0.40-14.0 and 0.52-6.40 dS/m with a mean value of 4.40, 3.04, 3.00 and 2.35 dS/m, at 0-15, 15-30, 30-60 and 60+ cm depths respectively. Among cations and anions, the mean values indicated that Na+ (21.1, 15.15, 15.5 and 19.9 meq/L) and Cl- (22.2, 18.2, 17.1 and 12.9 meq/L at 0-15, 15-30, 30-60 and 60+ cm depths respectively) ions are the dominating ones at all depths. The SAR values varied from 1.43-26.8, 1.56-22.1, 1.80-19.8 and 2.79-21.3 with a mean value of 8.83, 7.45, 9.26 and 11.8 at 0-15, 15-30, 30-60 and 60+ cm depths respectively. The mean (CO3+HCO3)/ (Cl+SO4) ratios were less than 1.0 at all the depths. Whereas, Na/(Cl+SO4) ratios were either close to 1.0 ato 0-15 and 15-30 cm but were more than 1.0 (1.14 and 1.52) at 30-60 and 60+ cm depths.

Percent distribution of soil properties (Table 1.3) revealed that 66.6 (0-15 cm) to 95.2 (60+ cm) per cent of samples had pHs in the range of 7.5-8.5 and none in >8.5 category at all depths. As far as soil salinity is concerned 14.3 (60+ cm)-21.4 (0-15 cm) dS/m per cent of samples had ECe > 4.0 dS/m respectively. At 0-15 cm, one hundred per cent of sample had (CO3+HCO3)/ (Cl+SO4) of <1.0. However, at lower depths the per cent of samples with (CO3+HCO3)/ (Cl+SO4) of >1.0 varied from 7.14 (15-30 cm) to 13.9 (30-60 cm) respectively. Unlike (CO3+HCO3)/ (Cl+SO4), the Na/(Cl+SO4) ratio of >1.0 increased with depth varying from 35.7 (0-15 cm) to 61.9 per cent (60+ cm) reflecting the dominance of Na+ and the possibility of soils becoming sodic. Accordingly, SAR (>13) also found to increase with depth varying from 9.5 (15-30 cm) to 42.9 per cent (60+ cm) respectively.

Table 1.3 Percent distribution of soil samples collected from Sindhanur taluk in Raichur district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pHs			ECe (dS/m)			(CO3+HCO3)/ (Cl+SO4)		Na/(Cl+SO4)		SAR	
	<7.5	7.5-8.5	>8.5	<2.0	2-4	>4	<1	>1	<1	>1	<13	>13
0-15	33.33 (14)	66.66 (28)	0	57.1 (24)	21.4 (9)	21.4 (9)	100 (42)	0	64.3 (27)	35.7 (15)	85.7 (36)	14.3 (6)
15-30	9.52 (4)	90.5 (38)	0	59.5 (25)	23.8 (10)	16.7 (7)	92.9 (39)	7.14 (3)	54.8 (23)	45.2 (19)	90.5 (38)	9.5 (4)
30-60	25.00 (9)	75.00 (27)	0	55.6 (20)	25.0 (9)	19.4 (7)	86.1 (31)	13.9 (5)	41.7 (15)	58.3 (21)	77.8 (28)	22.2 (8)
60+	4.80 (1)	95.2 (20)	0	42.9 (9)	42.9 (9)	14.3 (3)	90.5 (19)	9.50 (2)	38.1 (8)	61.9 (13)	57.1 (12)	42.9 (9)

Manvi taluk (Raichur district)

Characterization of soil samples from Manvi taluk revealed that soil pH varied from 5.80 to 9.00, 6.14-9.66, 6.54-9.60 and 8.0-9.48 with a mean value of 8.06, 8.32, 8.56 and 8.77 at 0-15, 15-30, 30-60 and 60+ cm depths respectively (Table 1.4).

Table 1.4 Characterization of soil samples collected from Manvi taluk in Raichur 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)	9.00	5.80	8.06	9.66	6.14	8.32	9.60	6.54	8.56	9.48	8.00	8.77
EC (1:2.5)	2.00	0.17	0.78	3.40	0.11	0.80	4.30	0.20	1.00	5.40	0.37	1.32
pHs	8.49	4.86	7.52	8.05	6.66	7.67	8.52	6.94	7.74	9.03	7.52	8.24
ECe (dS/m)	6.60	0.14	1.79	6.60	0.28	1.64	9.90	0.48	2.23	11.60	0.68	2.67
Cation/Anion												
Ca+Mg	45.7	1.20	6.73	31.4	2.10	5.77	29.5	2.40	6.47	22.6	2.60	7.56
Na+	69.6	0.46	15.8	69.6	1.39	14.1	99.0	1.80	19.0	123.9	5.30	23.9
K+	5.36	0.03	0.28	0.37	0.02	0.10	0.68	0.03	0.13	0.26	0.02	0.11
HCO3-	12.0	4.00	8.00	13.5	4.50	7.63	10.5	5.50	7.87	13.5	6.50	11.4
Cl-	61.00	7.00	14.7	46.5	6.50	11.70	27.0	6.50	11.0	49.5	9.50	16.0
SO42-	1.67	Tr	0.39	1.48	0.02	0.25	1.02	0.04	0.40	1.96	0.05	0.66
SAR	23.2	0.44	8.72	57.1	1.02	9.03	33.2	1.23	10.4	36.9	3.95	11.8

(CO3+HCO3)/ (Cl+SO4)	1.25	0.14	0.62	1.51	0.19	0.74	1.26	0.27	0.77	1.41	0.24	0.81
Na/(Cl+SO4)	3.34	0.05	0.99	7.67	0.17	1.19	7.33	0.26	1.55	2.89	0.41	1.24

Note: Total number of samples was 50, 46, 30 and 18 at 0-15, 15-30, 30-60 and 60+ depths respectively.

Soil salinity expressed as ECe varied from 0.14-6.60, 0.28-6.60, 0.48-9.90 and 0.68-11.60 dS/m with a mean value of 1.79, 1.64, 2.23 and 2.67 dS/m, at 0-15, 15-30, 30-60 and 60+ cm depths respectively. Among cations and anions, the mean values indicated that Na+ (15.8, 14.1, 19.0 and 23.9 meq/L) and Cl- (14.7, 11.7, 11.0 and 16.0 meq/L at 0-15, 15-30, 30-60 and 60+ cm depths respectively) ions are the dominating ones at all depths. The SAR values varied from 0.44-23.2, 1.02-57.1, 1.23-33.2 and 3.95-36.9 with a mean value of 8.72, 9.03, 10.4 and 11.8 at 0-15, 15-30, 30-60 and 60+ cm depths respectively. The mean (CO3+HCO3)/ (Cl+SO4) ratios were less than 1.0 at all the depths. Whereas, Na/(Cl+SO4) ratios were either close to 1.0 at 0-15 cm but were more than 1.0 (1.19, 1.55 and 1.24) at 15-30, 30-60 and 60+ cm depths respectively.

Percent distribution of soil properties (Table 1.5) revealed that 56.7 (30-60 cm) to 100 per cent (60+ cm) of samples had pHs in the range of 7.5-8.5 and none in >8.5 category at all depths. As far as soil salinity is concerned 4.35 (15-30 cm)-16.7 (60+cm) per cent of samples had ECe > 4.0 dS/m respectively. The per cent of samples with (CO3+HCO3)/ (Cl+SO4) of >1.0 increased with depth varying from 4.0 (0-15 cm) to 27.8 (60+ cm) respectively. Similarly, the Na/(Cl+SO4) ratio of >1.0 also increased with depth varying from 42.0 (0-15 cm) to 63.3 per cent (30-60 cm) reflecting the dominance of Na+ and the possibility of soils becoming sodic. Accordingly, SAR (>13) also found to increase with depth varying from 8.70 (15-30 cm) to 33.3 per cent (30-60 cm) respectively.

Table 1.5 Percent distribution of soil samples collected from Manvi taluk in Raichur district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pHs			ECe (dS/m)			(CO3+HCO3)/ (Cl+SO4)		Na/(Cl+SO4)		SAR	
	<7.5	7.5-8.5	>8.5	<2.0	2-4	>4	<1	>1	<1	>1	<13	>13
0-15	30.0 (15)	70.0 (35)	0	62.0(31)	30.0 (15)	8.00 (4)	96.0 (48)	4.00 (2)	58.0 (29)	42.0 (21)	82.0 (41)	18.0 (9)
15-30	15.22 (7)	84.8 (39)	0	67.4 (31)	28.3 (13)	4.35 (2)	87.0 (40)	13.0 (6)	50.0 (23)	50.0 (23)	91.3 (42)	8.70 (4)
30-60	43.3 (13)	56.7 (17)	0	66.7 (20)	23.3 (7)	10.0 (3)	83.4 (25)	16.6 (5)	36.7 (11)	63.3 (19)	66.7 (20)	33.3 (10)
60+	0	100 (18)	0	50.0 (9)	33.3 (6)	16.7 (3)	72.2 (13)	27.8 (5)	55.5 (10)	44.5 (8)	72.2 (13)	27.8 (5)

Raichur District:

At surface soil (0-15 cm) pH(1:2.5), pHs, EC(1:2.5) and ECe varied from 9.0 to 5.80, 8.50 to 4.86, 21.0 to 0.13 (dS/m) and 47 to 0.14 (dS/m) respectively with an average of 8.09, 7.56, 1.19, and 2.68 respectively (Table 1.6).

Table 1.6 Characterization of soil samples collected from Raichur 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)	9.0	5.80	8.09	9.66	6.14	8.33	9.21	6.54	8.38	9.58	7.87	8.67
EC (1:2.5)	21.0	0.13	1.19	12.5	0.11	1.08	6.90	0.24	1.32	5.40	0.30	1.26
pHs	8.49	4.86	7.56	8.42	6.66	7.75	8.24	6.94	7.66	9.03	7.48	8.14
ECe (dS/m)	47.0	0.14	2.68	24.0	0.28	2.25	14.0	0.38	2.70	11.6	0.52	2.51
Cations/Anions (meq/L)												
Ca+Mg	154.8	1.20	9.54	49.2	2.1	7.44	31.5	1.90	7.16	25.80	2.20	6.93
Na+	4400	7.83	390.1	110.9	1.39	15.11	117	1.80	17.9	123.9	3.48	22.2
K+	5.36	0.02	0.22	0.43	0.02	0.12	0.68	0.02	0.10	0.26	0.02	0.08
HCO3-	144.0	4.0	9.77	18.0	3.5	7.79	14.0	3.00	7.69	19.0	4.00	9.28
Cl-	139.0	7.0	17.84	115.0	5.0	14.35	76.0	5.50	14.6	53.0	7.00	14.1
SO42-	2.50	Tr	0.46	2.08	Tr	0.32	2.40	0.02	0.46	1.96	0.04	0.59
SAR	615.5	3.18	187.9	57.07	1.02	8.42	33.2	1.23	9.78	36.9	2.79	11.8
(CO3+HCO3)/ (Cl+SO4)	7.94	0.14	0.68	1.51	0.12	0.72	1.40	0.06	0.72	1.72	0.16	0.75
Na/(Cl+SO4)	76.8	0.24	21.27	7.67	0.12	1.14	7.33	0.21	1.31	2.89	0.41	1.39

Note: Total number of samples was 107, 102, 71 and 43 at 0-15, 15-30, 30-60 and 60+ depths respectively.

Among cations, average Na content (390.1 meq/L) was more than Ca+Mg (9.54 meq/L) followed by K. In case of anions, average Cl- content was more (17.84 meq/L) than HCO3- (9.77 meq/L) followed SO42-. Nearly 13 per cent of surface samples had ECe > 4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 (CO3+HCO3)/(Cl+SO4) and (Na/(Cl+SO4) ratios were to the extent of nearly 6 and 36 respectively indicating that the soils could be sodic or developing into sodic. Accordingly, nearly 16 per cent of surface samples had SAR >13.

Sub-surface (15-30 cm) soils had pH(1:2.5), pHs, EC(1:2.5) and ECe varying from 9.66 to 6.14, 8.42 to 6.66, 12.5 to 0.11 (dS/m), and 24 to 0.28 (dS/m) respectively with an average of 8.33, 7.75, 1.08 dS/m and 2.25 dS/m respectively (Table 5). Similar to surface soils, average Na content (15.1 meq/L) was more than Ca+Mg (7.44 meq/L) followed by K. In case of anions, average Cl- content was more (14.35 meq/L) than HCO3- (7.79 meq/L) followed by SO42-. Nearly 10 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 (CO3+HCO3)/(Cl+SO4) was less than 1 whereas Na/(Cl+SO4) was >1. However, about 13 and 48 percent of these samples had values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodicity. About 12 per cent of samples analyzed had SAR >13.

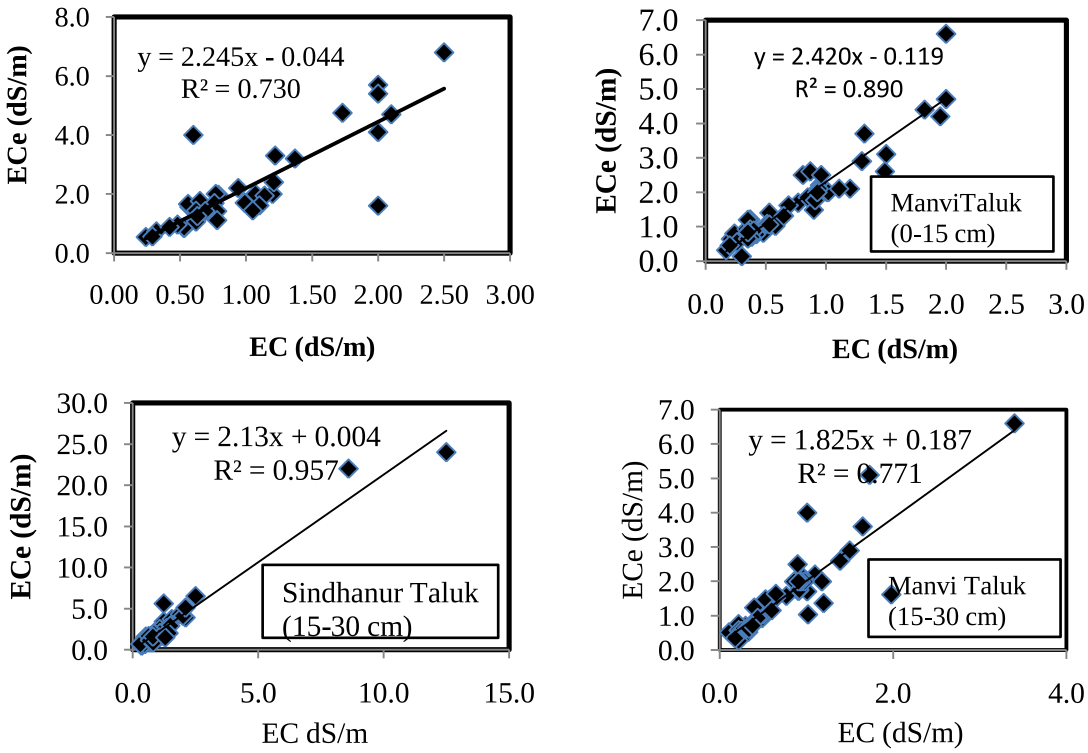
Though a slight increase in soil pH was observed at 30-60 and 60+ cm depths compared to upper layers not much variations were observed with respect to mean ECe, Ca+Mg, K+, Cl-, HCO3-, (CO3+HCO3)/(Cl+SO4) and Na/(Cl+SO4) contents at 30-60 and 60+ cm depths (Table 1.7). However, Na+ and SAR values were higher than the corresponding 0-15 and 15-30 cm depths. As far as per cent distribution is considered, 30-60 and 60+ cm depths samples had higher (15.5) percentage of ECe (>4.0 dS/m), SAR (>13), and (CO3+HCO3)/(Cl+SO4) and Na/(Cl+SO4) >1 compared to respective 0-15 and 15-30 cm depths.

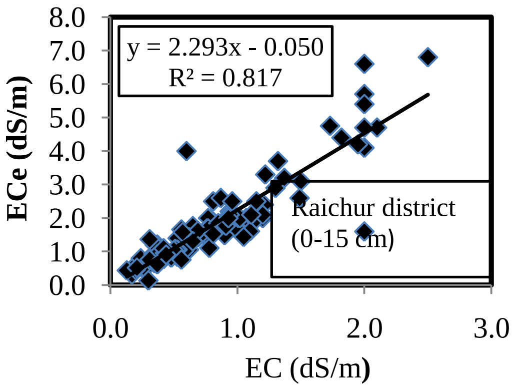
Table 1.7 Percent distribution of soil samples collected from Raichur district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pHs			ECe (dS/m)			(CO3+HCO3)/ (Cl+SO4)		Na/(Cl+SO4)		SAR	
	<7.5	7.5-8.5	>8.5	<2.0	2-4	>4	<1	>1	<1	>1	<13	>13
0-15	31.8 (34)	68.2 (73)	0	64.5 (69)	22.4 (24)	13.1 (14)	94.4 (101)	5.6 (6)	64.2 (68)	35.8 (39)	84.0 (89)	16.0 (18)
15-30	15.7 (16)	84.3 (86)	0	66.64 (68)	23.5 (24)	9.80 (10)	87.2 (89)	12.7 (13)	51.9 (53)	48.1 (49)	88.2 (90)	11.8 (12)
30-60	32.4 (23)	67.6 (48)	0	62.0 (44)	22.5 (16)	15.5 (11)	84.5 (60)	15.5 (11)	40.8 (29)	59.2 (42)	73.2 (52)	26.8 (19)
60+	2.33 (1)	97.7 (42)	0	48.8 (21)	34.9 (15)	16.3 (7)	79.1 (34)	20.9 (9)	46.5 (20)	53.5 (23)	65.1 (28)	34.9 (15)

Note: Total number of samples was 107, 102, 71 and 43 at 0-15, 15-30, 30-60 and 60+ depths respectively. Numbers in parenthesis indicate number of samples under each category.

As shown in Fig. 1.1, the relationship between ECe and EC(1:2.5) revealed that the conversion factor from EC (1:2.5) to ECe (saturation paste extract) would be around 2.24 to 2.42 at 0-15 cm and 2.13 to 1.83 at 15-30 cm depths for soils of Sindhanur and Manvi taluks respectively. District as a whole, the factor was 2.29 and 1.80 for surface and sub-surface soils respectively.





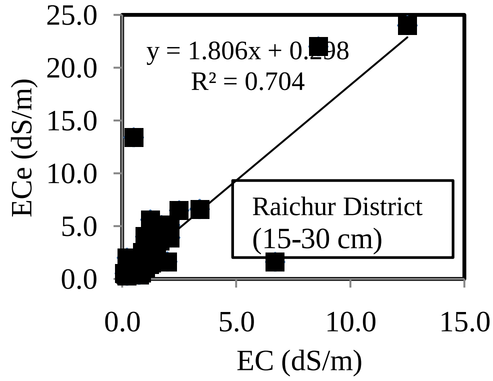


Fig 1.1 Relationship between ECe and EC(1:2.5) at different depths in Sindhanur and Manvi taluks and Raichur district.

Bellary taluk (Bellary District)

The data on soil pH, EC, saturation paste extract for pHs, ECe, cations, anions, SAR, and (CO3+HCO3)/(Cl+SO4) and (Na/(Cl+SO4) ratios at 0-15 and 15-30 cm depths of Bellary taluk are presented in Table 1.8.

Table 1.8 Characterization of soil samples collected from Bellary taluk in Bellary district, Karnataka for soil salinity appraisal.

Properties	Depth (cm)					
	0-15 cm			15-30 cm		
	Max	Min	Avg	Max	Min	Avg
pH (1:2.5)	10.76	7.82	8.55	10.55	7.43	8.34
EC (1:2.5)	31.0	0.19	5.39	19.90	0.12	2.90
pHs	10.23	7.45	8.11	10.33	7.55	8.21
ECe (dS/m)	106.0	0.64	15.00	35.00	0.37	7.18
Cations/Anions (meq/L)						
Ca+Mg	126.0	3.20	20.62	40.10	2.70	13.06
Na+	2422	1.83	244.6	628.3	1.43	90.78
K+	1.56	0.04	0.30	0.60	0.02	0.16
HCO3-	98.00	7.00	15.06	39.50	6.00	9.49
Cl-	1350	10.00	120.4	197.0	7.50	41.49
SO42-	2.92	0.06	1.20	3.68	0.03	1.42
SAR	1211.2	1.07	94.5	145.9	1.16	30.33
(CO3+HCO3)/ (Cl+SO4)	0.99	0.01	0.41	1.50	0.04	0.49
Na/(Cl+SO4)	8.80	0.06	1.42	7.57	0.19	1.80

Note: Total number of samples was 52 and 50 at 0-15 and 15-30 cm depths respectively.

At surface soil (0-15 cm) pH(1:2.5), pHs, EC(1:2.5) and ECe varied from 10.76 to 7.82, 10.23 to 7.45, 31.0 to 0.19 (dS/m) and 106.0 to 0.64 (dS/m) respectively with an average of 8.55, 8.11, 5.39, and 15.0 dS/m respectively. Among cations, average Na content (244.6 meq/L) was more than Ca+Mg (20.62 meq/L) followed by K. In case of anions, average Cl- content was more (120.4 meq/L) than HCO3- (15.06 meq/L) followed SO42-. Nearly 40 per cent of surface samples had ECe > 4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 (CO3+HCO3)/(Cl+SO4) were nil whereas (Na/(Cl+SO4) samples were to the extent of nearly 56. Accordingly, nearly 48 per cent of surface samples had SAR >13.

Sub-surface (15-30 cm) soils had pH(1:2.5), pHs, EC(1:2.5) and ECe varying from 10.55 to 7.43, 10.33 to 7.55, 19.9 to 0.12 (dS/m), and 35.0 to 0.37(dS/m) respectively with an average of 8.34, 8.21, 2.90 dS/m and 7.18 dS/m respectively (Table 7). Similar to surface soils, average Na content (90.78 meq/L) was more than Ca+Mg (13.06 meq/L) followed by K. In case of anions, average Cl- content was more (41.49 meq/L) than HCO3- (9.49 meq/L) followed by SO42-.

Percent distribution of these parameters pHs ECe (dS/m), (CO3+HCO3)/ (Cl+SO4), Na/(Cl+SO4) and SAR at various depths are provided in Table 1.9 Nearly 40 per cent of sub surface samples were considered to be saline as the ECe of these samples was >4.0 dS/m. The overall mean of the (CO3+HCO3)/(Cl+SO4) was less than 1 whereas Na/(Cl+SO4) was >1. However, about 8 and 66 percent of these samples had values more than 1 indicating that these samples could be considered as salt affected soil in particular sodic or developing into sodicity. Similar to surface samples, about 50 per cent of samples analyzed had SAR >13.

Table 1.9 Percent distribution of soil samples collected from Bellary taluk, Bellary district, Karnataka for soil salinity appraisal

Soil Depth (Cm)	pHs			ECe (dS/m)			(CO3+HCO3)/ (Cl+SO4)		Na/(Cl+SO4)		SAR	
	<7.5	7.5-8.5	>8.5	<2.0	2-4	>4	<1	>1	<1	>1	<13	>13
0-15	1.92 (1)	84.6 (44)	13.5 (7)	25.0 (13)	34.6 (18)	40.4 (21)	100 (52)	0	44.2 (23)	55.8 (29)	51.9 (27)	48.1 (25)
15-30	0.00	80.0 (40)	20.0 (10)	34.0 (17)	26.0 (13)	40.0 (20)	92.0 (46)	8.00 (4)	34.0 (17)	66.0 (33)	50.0 (25)	50.0 (25)

As shown in Fig. 1.2 the relationship between ECe and EC(1:2.5) revealed that the conversion factor from EC (1:2.5) to ECe (saturation paste extract) would be around 3.0 and 1.86 at 0-15 cm and 15-30 cm depths respectively.

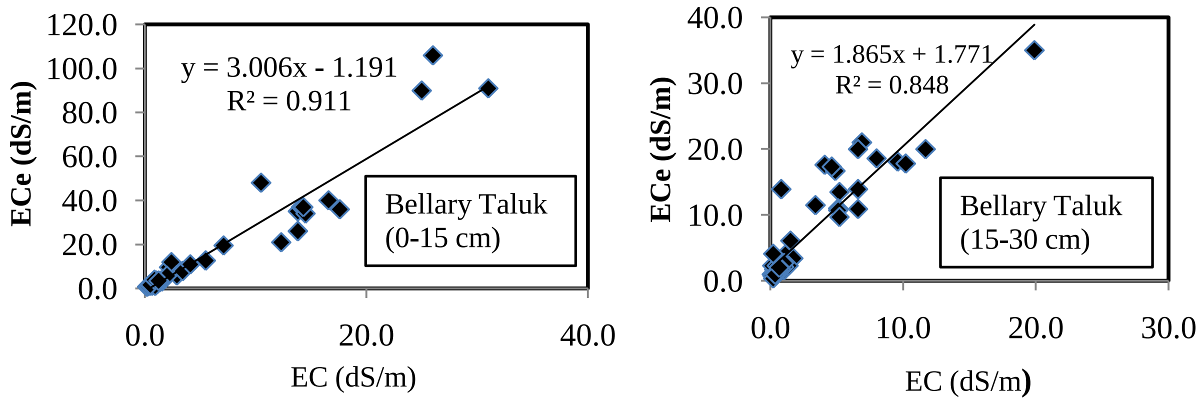


Fig 1.2 Relationship between ECe and EC(1:2.5) at different depths in Bellary taluk in Bellary district.

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

Detailed reconnaissance soil survey was carried in different tehsils of Khargone and Khandwa districts of Madhya Pradesh to find out locations, extent and nature of salt affected soil. The districts are situated in the southern part of Madhya Pradesh. On the basis of physiography and geographical regional characteristics, Khargone and Khandwa districts are lying in between 21o 33’ to 22o 33’ N &

75o 13" to 76o 14’ E and 21o 32" to 22o 25" N & 76o 00" to 77o 12" E respectively. A variety of crops like cotton, soybean, wheat, maize, sorghum, vegetables, gram and castor are the main crops grown in the districts. Canal as well as open/tube wells usually irrigate these crops. The Khargone and Khandwa districts has hot sub-humid climate characterized by hot summers and mild winters. The average annual rainfall is about 835 and 855 mm respectively. Maximum and minimum temperatures are 43 & 42°C and 10.0 & 10.0 °C, respectively.

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. 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. 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 - ECe 8 to 15 dSm-1 and high - ECe >15 dSm-1) and alkalinity (slight - ESP 15 to 25), moderate - ESP 25 to 40) and high - ESP > 40). After identification of areas falling under different categories of salt affected soils with the help of band combinations, colour, texture and tone through available software (ERDAS imagine, 8.7) the map of district was generated.

Khargone district

Two hundred fifty three surface soil samples were collected from different villages of Khargone district (Table 1). The reaction of soil (pHs) in the surface layer is alkaline. pHs of the saturation paste ranged from 7.03 to 8.41. The ECe of saturation extract is an important property to judge the behaviour of soil in respect of salinity/ alkalinity. ECe velues ranged from 0.35 to 3.95 dSm-1. Among different cations, Na ranged from 0.30 to 18.20 me L-1. The SAR values ranged between 0.23 and 10.51. The data pertaining to exchangeable cations, CEC and ESP revealed that exchangeable Ca, Mg and Na ranged from 14.0 to 34.6, 5.8 to 19.7 and 1.12 to 19.00 cmol (p+) kg-1, respectively. Cation exchange capacity (CEC) ranged from 26.00 to 54.60 cmol (p+) kg-1, whereas, exchangeable sodium percentage (ESP) varied from 2.15 to 47.70 respectively.

All salt affected soils comes under the category of slightly saline and slightly alkali (2448 ha) (Table 1.10). On the basis of degree of salinity and alkalinity, the soils were classified and map of the district was generated (Fig. 1.3). The areas falling under different categories were estimated with the help of software and affected villages were identified after opening this map over scanned tehsil maps having village boundaries (Table, 1.11).

Table 1.10 Area of salt affected soils in different categories of Khargone district

S.No.	Category	Area (ha)
1	Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	2448
	Total	2448

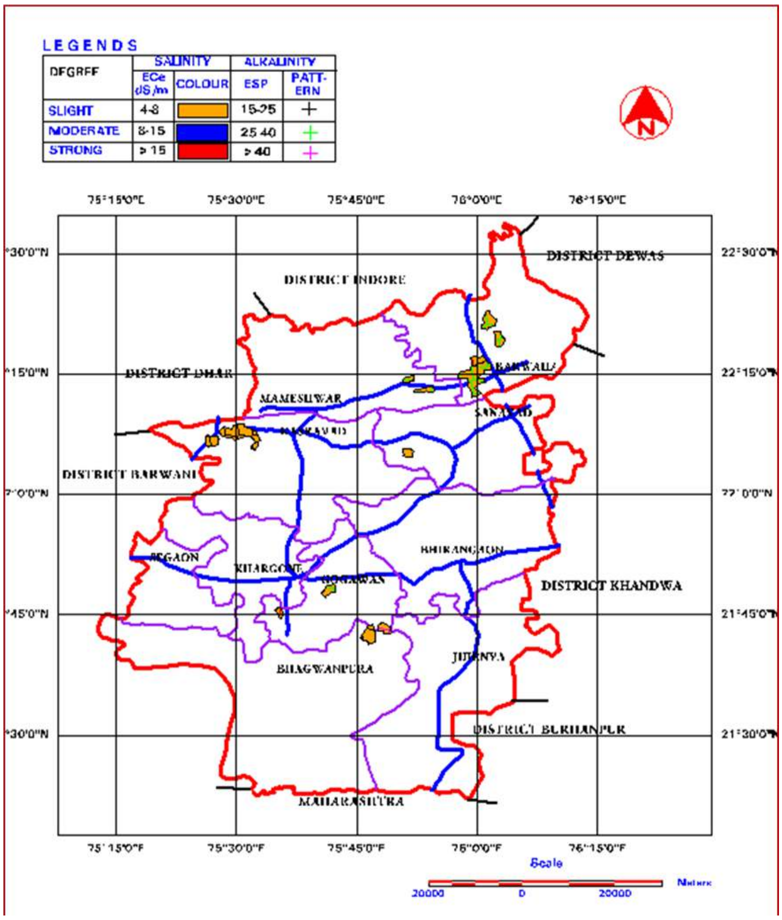


Fig. 1.3 Distribution of salt affected soils in Khargone district of Madhya Pradesh

Table 1.11 Distribution of salt affected soils in different categories in villages of Khargone district

Category	Tehsil	Area (ha)	No. of Villages	Name of villages
Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	Sanavad	40	01	Jamaniya
	Bhagwanpura	164	03	Maharel, Momdiya and Rasgangli
	Kasravad	423	05	Sathkur, Baalsamund, Paanava, Balkhad and Balgaon
Slightly saline and moderate alkali (EC 4-8 dS/m and ESP 25-40)	Bhagwanpura	117	01	Dautkhedi
	Gogawan	51	02	Badgoan and Mehraja
	Barwaha	1279	09	Basarkhedi, Barjhar, Lakhanpura, Khedi, Bafalgaon, Muralla, Ratanpur, Sirlay and Amlatha
	Maheshwar	114	03	Barlay, Palsood and Pipliya Khurd
Slightly saline and moderate alkali (EC 4-8 dS/m and ESP > 40.0)	Gogawan	54	01	Randi
	Barwaha	206	02	Agarwada and Nandiya
Total		2448	27	

Khandwa district

One hundred eighty surface soil samples were collected from different villages of Khandwa district (Table 4). The reaction of soil (pHs) in the surface layer is alkaline. pHs of the saturation extract ranged from 7.04 to 8.05. The ECe of saturation extract is an important property to judge the behaviour of soil in respect of salinity/ alkalinity. ECe values ranged from 0.20 to 3.51 dSm-1. Among different cations, Ca, Mg and Na ranged from 0.80 to 14.0, 0.00 to 8.00 and 0.20 to 12.86 me L-1 respectively. The SAR values ranged between 0.19 and 4.66. The data pertaining to exchangeable cations, CEC and ESP revealed that exchangeable Ca, Mg and Na ranged from 17.6 to 32.6, 8.4 to 19.8 and 1.1 to 7.0 cmol (p+) kg-1, respectively. Cation exchange capacity (CEC) ranged from 31.25 to 56.26 cmol (p+)kg-1, whereas, exchangeable sodium percentage (ESP) varied from 2.88 to 18.64 respectively. All salt affected soils comes under the category of slightly saline and slightly alkali (76 ha) (Table 1.12). On the basis of degree of salinity and alkalinity, the soils were classified and map of the district was generated (Fig. 1.4). The areas falling under different categories were estimated with the help of software and affected villages were identified after opening the map over scanned tehsil maps having village boundaries (Table 1.13).

Table 1.12 Area of salt affected soils in different categories of Khandwa district

S.No.	Category	Area (ha)
1	Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	76
	Total	76

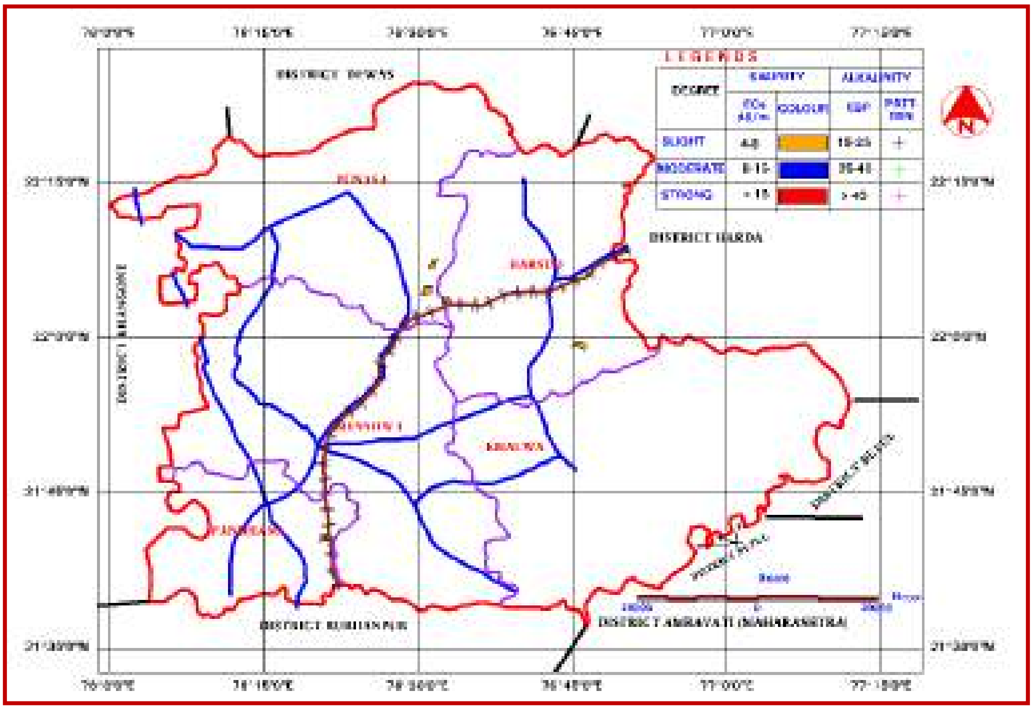


Fig. 1.4 Distribution of salt affected soils in Khandwa district of Madhya Pradesh

Table 1.13 Distribution of salt affected soils in different categories in villages of Khandwa district

Category	Tehsil	Area (ha)	No. of Villages	Name of villages
Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	Punasa	38	04	Beed, Dohad, Mundi and Dharakwadi
	Harsud	22	01	Kherkheda
	Pandhana	16	01	Takli
Total		76	06	

- **Assessment of soil salinity status of A & N Islands and areas vulnerable to sea water (Port Blair)**

The study was initiated to assess and characterize the salt affected coastal soils of the Andaman & Nicobar Islands. The soil samples were collected from all the three districts and analyzed for salinity and other physic-chemical parameters. The results showed that soil pH varied widely from 3.5 -10.4, 4.2-7.8 and 6.2-8.3 respectively in South, North & Middle and Nicobar district (Table 1.14). In general, soil salinity was EC was low but in some lowlying areas it was as high as 10.1 (dS/m) due to sea water intrusion. In some locations, acid saline soils are also noticed which exhibited high salinity as well as acidity. In summary, the soil salinity status of Andaman and Nicobar Islands showed that 34% of the samples are non-saline while 47 % of samples are saline and 18.7% samples are slightly saline. Only 14% of the samples are strongly saline. Among the three districts, 39%, 36% and 26% of samples from South Andaman, North & Middle Andaman and Nicobar, respectively are found to be non-saline whereas, only 12%, 11% and 19% are found to be strongly saline.

Table 1.14 Soil salinity status of Andaman & Nicobar Islands

Parameters	South Andaman		N& M Andaman		Nicobar	
	Range	Average	Range	Average	Range	Average
pH	3.5 -10.4	6.8	4.2-7.8	6.4	6.2-8.3	7.4
EC (dS/m)	0.5 -9.1	2.5	0.6-10.1	3.9	0.03-0.4	0.2
Ca^{2+} (meq/L)	1.5 -72.0	23.1	10.1-66.0	31.8	51.0-62.0	62.3
Mg^{2+} (meq/L)	4.5-58.0	23.7	24.2-158.0	76.3	6.2-75.5	21.9
Na^{+} (meq/L)	6.0-158.2	69.0	18.0-74.3	20.2	0.1-124.3	7.3
K^{+} (meq/L)	0.7-89.7	40.7	1.5-92.6	51.4	1.3 – 53.7	21.8
CO_3 + HCO_3^-(meq/L)	0.0-0.9	0.5	7.25-40.0	21.1	12.5-166.6	56.3
Cl^- (meq/L)	1.6-118.9	17.7	18.0-74.3	31.9	1.40-285.8	122.8
SO_4^{2-} (meq/L)	0.2-3.0	0.8	0.1-5.6	0.9	0.06-1.05	0.4
RSC (meq/L)	0.0	0.0	0.0	0.0	0.0	0.0
SAR (meq/L)	1.8-8.1	4.6	0.3-5.1	2.1	0-.0-0.88	0.1

Identification and monitoring of vulnerable areas to sea water ingress

The Digital Elevation Model is a simple tool was used to map the vulnerable coastal areas to the sea level rise for identification and monitoring purpose. Due to which these areas and its surrounding will experience rise in salinity of ground water and soil salinity. The analysis of DEM of Andaman Islands showed that nearly 1.5% of the area of Andaman is affected by salinity due to sea water intrusion in the coastal areas (Fig. 1.5). Soil and ground water samples from these areas needs to be collected for analysis and monitoring of rise in salinity level.

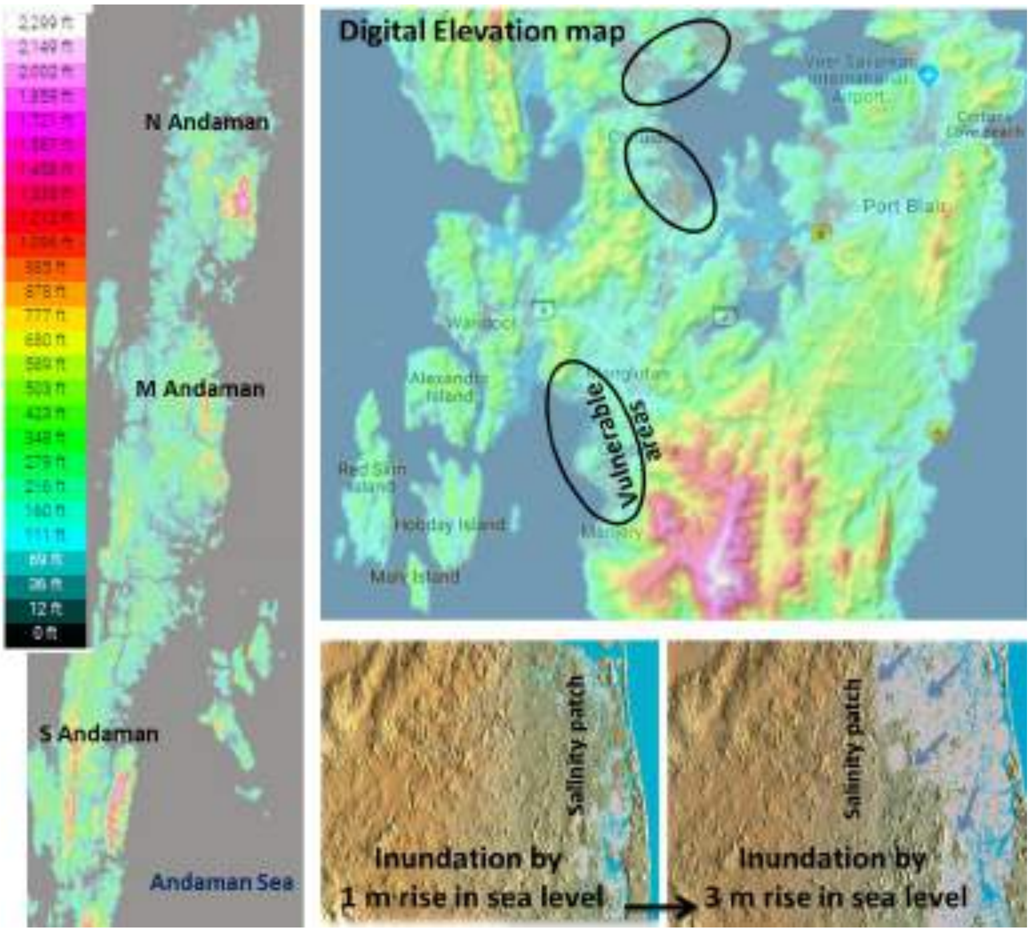


Fig.1.5 Terrain analysis for vulnerability mapping

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

This project was planned to survey the salt affected soils using GPS, to study the chemical properties of soils and to prepare geo-referenced map of salt affected soils of coastal belts of Kerala. Work of survey and collection of soil samples is proposed in coastal belts of eleven districts of Kerala viz. Thiruvanamthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod. Geo-referenced soil samples were collected from cultivated fields of coastal belts of Kerala. To study the soil properties of study area, samples were analyzed for pH, electrical conductivity, sodium, potassium, calcium, magnesium, sulphur, boron, iron, copper, manganese and zinc. Collection of soil samples of Thiruvananthapuram, Kottayam, Kollam and Pathanamthitta districts were completed during the first and second phase of the survey. Results of the data analysed are presented below.

Thiruvananthapuram district

About thirty-eight soil samples were collected from different locations of Thiruvananthapuram districts and the soil samples were analysed for various chemical parameters. The analytical data indicated that soil pH values ranged from 5.87 to 7.89 while electrical conductivity (EC) values ranged from 0.43 to 1.5 dS m^{-1}. This shows that soil samples ranged from slightly acidic to normal. The electrical conductivity of soil samples is also within the favorable range for crop growth. The organic carbon per cent ranged from 0.74 to 2.475 which shows that organic carbon content falls under the medium to high category. Sodium, Potassium and Phosphorus values ranged from 0.45 to 301.6, 116.2 to 377.9 and 7.75 to 86.5 kg ha^{-1} respectively. The sodium content of soils was very high due to intrusion of saline or brackish water after monsoon. The available potassium and phosphorus contents of soils were in medium to high range in majority of the soils. The values of calcium, magnesium and sulphur ranged from 49.5 to 376.1, 10.62 to 45.58 and 0.69 to 19.5 mg kg^{-1}. In all the soil samples, available calcium and magnesium content were in the lower range. The available sulphur content of the soils was in general sufficient for plant growth. On analysis, the micronutrient status was studied and available boron, iron, zinc, copper and manganese ranged from 0.083 to 4.104, 107.5 to 247.8, 0.35 to 2.63, 0.1818 to 5.223 and 27.25 to 93.75 mg kg^{-1} respectively. The contents of available micronutrients such as boron, zinc, copper and manganese were very low in most of the soils, but iron was very high in all the soils.

Kottayam district

The soil samples from Kottayam district were taken during the survey and analysed. It was observed that soil pH values ranged from 4.69 to 6.89 while electrical conductivity (EC) values ranged from 0.49 to 1.9dS m^{-1}. From the analytical data it was evident that the pH of soil samples ranges from acidic to slightly acidic and the electrical conductivity of soil samples were also within the optimum range. Organic carbon content was in general high in the soil samples and the values ranged from 1.05 to 1.765 per cent. Sodium, Potassium and Phosphorus values ranged from 6.34 to 76.4, 169.4 to 293.16 and 48.25 to 80.75 kg ha^{-1} respectively. The sodium content of soils was very high whereas the available potassium and phosphorus content were in medium to high range in all soils. Among the secondary nutrients, available calcium and magnesium content were lower in most of the soils whereas the available sulphur content of the soils was in general sufficient. The values of calcium, magnesium and sulphur ranged from 82.51 to 342.96, 41.63 to 172.6 and 6.5 to 17.0 mg kg^{-1} respectively. The boron, iron, zinc, copper and manganese ranged from 0.1468 to 0.96, 110.8 to 241.6, 0.892 to 3.338, 0.33 to 2.25 and 39.62 to 136.8 mg kg^{-1} respectively. The contents of available micronutrients such as boron, zinc and copper were very low in most of the soils, but iron and manganese content were very high in all the soils.

Kollam district

The analytical soil data of Kollam district indicated that soil pH values ranged from 4.84 to 6.89 while electrical conductivity (EC) values ranged from 0.54 to 2.87dS m^{-1}. The pH of soil samples ranges from acidic to slightly acidic group. The electrical conductivity of soil samples was found to be in safe levels. The soils were having high organic carbon per cent ranging from 0.925 to 2.72 %. The sodium content of soils is very high and values ranged from 59.2 to 192.3kg ha^{-1}. Available potassium and phosphorus values ranged from 145.2 to 333.01 and 23.62 to 86.5 kg ha^{-1} respectively which implies that the available potassium contents of soils are in medium range and available phosphorus was high in all soils. Considering the secondary nutrient status, the available calcium and magnesium content was found to be lower in the soil samples whereas available sulphur content ranged from low to medium. The values of calcium, magnesium and sulphur ranged from 89.26 to 2372.1, 9.97 to 96.5, 1.29 to 17.0 mg kg^{-1} respectively. The boron, iron, zinc, copper and manganese content ranged from 0.03 to 5.47, 110.5 to 263.6, 0.16 to 2.967, 0.01 to 2.622 and 53.0 to 121.9 mg kg^{-1} respectively.

Pathanamthitta district

As part of the survey, soil samples were collected from Pathanamthitta district also and the analytical data indicated that soil pH values ranged from 5.77 to 6.81 while electrical conductivity (EC) values ranged from 0.98 to 2.5dS m^{-1}. As per the values the pH of soil samples ranges from acidic to slightly acidic group. The electrical conductivity of soil samples is also within the favorable range for crop growth. Percentage of organic carbon ranged from 1.092 to 1.95 which was high in category. The sodium content of soils was in general high due to intrusion of saline or brackish water after monsoon and the content ranged from 4.75 to 114.9 kg ha^{-1}. Potassium and Phosphorus values ranged from 266.7 to 357.5 and 54.0 to 83.25 kg ha^{-1} respectively. The available potassium and phosphorus was high in all soils. The values of calcium, magnesium, sulphur, boron, iron, zinc, copper and manganese ranged from 82.56 to 1243.9, 32.54 to 104.21, 6.5 to 14.5, 0.332 to 0.559, 112.65 to 221.25, 0.769 to 3.562, 0.849 to 2.45 and 24.63 to 82.17 mg kg^{-1} respectively. As per the data, available calcium ranged from very low to high whereas magnesium content was very low in all the soil samples. The available sulphur content of the soils ranged from low to medium as indicated by the values. The status of available micronutrients in soil samples was very low except for iron and manganese which was in general very high in all these soils.

In general, the soil samples from four districts *viz.* Thiruvananthapuram, Kottayam, Kollam and Patthanamthitta were acidic and EC values were in the good category. Organic carbon per cent of the samples were found to be in medium and higher levels. The available phosphorus content was also sufficient in almost all the samples. But wide spread deficiency of secondary nutrients especially calcium and magnesium was observed whereas sulphur content was found to be in medium category.

1.2 Resource Inventories of Poor Quality Groundwater Waters

- **Survey and characterization of underground waters of Agra district for irrigation purpose (Agra)**

Survey and characterization of groundwater of Agra district (UP) (revisiting) was initiated during 2012 and completed in 2017. Two blocks Etmadpur and Jaitpur Kalan were surveyed during 2016-17. Samples were collected during December to March as maximum number of tube wells were under operation for irrigation. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions (CO_3, HCO_3, Cl and SO_4). The classification of water quality is done on the basis of EC, SAR and RSC values as suggested by CSSRI, Karnal. The maximum ECiw 26.3 dS/m was recorded in Fatehpur Sikri followed by 25.4 dS/m in Achhnera and 23.2 dS/m in Bichpuri block. The highest RSC value of 28.2 meq/l was recorded in Akola block followed by 13.8 and 13.2 meq/l in Fatehpur Sikri and Jagner block respectively. Whereas the highest SAR 55.1 $(mmol.l)^{1/2}$ was recorded in Fatehpur Sikri followed by 52.4 and 48.9 $(mmol.l)^{1/2}$ in Achhnera and Shamsabad block, respectively (Table 1.15).

Table 1.15 Range and mean of water quality constituents

Blocks	ECiw (dSm^{-1})		pH		RSC (meq/l)		SAR $(mmol/l)^{1/2}$	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
2012-14								
Fatehpur Sikri	2.1-26.3	7.6	7.9-9.0	8.4	Nil-13.8	6.1	1.4-55.1	16.0
Akola	2.0-19.5	6.2	7.8-8.8	8.3	Nil-28.2	5.5	7.5-38.6	18.2
Achhnera	1.9-25.4	6.4	8.1-9.3	8.6	Nil- 9.4	2.7	5.2-52.4	18.5
Bichpuri	1.7-23.2	7.3	7.5-9.1	8.4	Nil- 8.4	2.8	6.5-37.9	18.2
Jagner	0.7-11.2	2.8	7.5-8.8	8.2	Nil- 8.2	5.0	1.0-39.2	8.7
Sainya	0.6-13.9	4.2	7.4-8.5	8.0	Nil-13.2	4.0	1.6-15.6	9.7
Kheragarh	0.8-12.0	4.0	7.8-8.6	8.5	Nil-12.2	5.2	2.5-31.3	10.3
2014-16								
Barauli Ahir	0.8-7.1	1.8	7.9-9.0	8.5	Nil- 9.0	3.2	1.1-16.7	6.5
Khandauli	0.9-16.7	2.7	7.1-8.9	7.8	Nil-10.0	3.7	1.6-35.2	11.2
Shamsabad	0.7-8.9	2.1	7.3-9.0	8.1	Nil-8.4	2.9	1.3-48.9	9.5
Bah	0.8-2.4	1.2	8.1-9.1	8.6	Nil-11.0	3.5	0.2-15.2	4.2
Pinahat	0.6-5.4	1.4	7.5-10.7	8.3	Nil-7.6	3.2	1.1-15.8	5.3
Fatehabad	0.7-5.9	1.7	7.8-9.5	8.6	Nil-9.8	3.9	1.4-23.0	7.4
2016-17								
Etmadpur	0.8-13.5	3.1	7.6-9.1	8.4	Nil-9.4	3.3	3.0-22.7	11.5
Jaitpur Kalan	0.6-3.3	1.0	8.0-9.1	8.5	Nil-9.0	2.5	1.9-13.8	4.4

*Mean RSC of the positive values

The percent distribution of water samples showed that more than 50 per cent samples of Fatehpur Sikri, Akola, Achhnera and Bichpuri blocks were found in more than 5.0 dS/m EC class. In EC class <1.5 dS/m, 88.7 per cent water samples were found in Jaitpur Kalan followed by 84.4 per cent in Bah and 76.0 per cent in Pinahat block (Table 1.16). The major number of water samples were found in 0-10 and 10-20 $(mmol.l)^{1/2}$ SAR classes. More than 85 per cent samples having SAR >10 $(mmol.l)^{1/2}$ were recorded in three blocks i.e. Fatehpur Sikri, Akola and Achhnera blocks.

Table 1.16 Distribution of water samples in EC, RSC and SAR classes of blocks of Agra district (2014-17)

Particulars	Barauli Ahir(69)	Khandauli (70)	Shamsabad (68)	Bah (64)	Pinahat (50)	Fatehabad (90)	Etmadpur (73)	Jaitpur Kalan(71)
EC classes (dS/m)								
0- 1.5	46.4	31.4	48.5	84.4	76.0	62.2	24.7	88.7
1.5- 3.0	46.4	40.0	30.9	15.6	20.0	30.0	41.1	6.5
3.0- 5.0	5.8	18.6	17.7	-	2.0	6.7	20.6	2.8
5.0-10.0	1.4	7.1	2.9	-	2.0	1.1	6.8	-
>10.0	-	2.9	-	-	-	-	6.8	-
RSC Classes (meq/l)								
Absent	39.1	38.6	39.7	6.2	16.0	18.9	23.3	8.5
0-2.5	27.6	22.9	27.9	28.1	34.0	27.8	20.5	50.7
2.5- 5.0	17.4	22.8	22.1	50.0	34.0	30.0	31.5	38.0
5.0-10.0	15.9	15.7	10.3	14.1	16.0	23.3	24.7	2.8
>10.0	-	-	-	1.6	-	-	-	-
SAR Classes $(mmol/l)^{1/2}$								
0-10	82.6	45.7	64.7	95.3	88.0	70.0	45.2	93.0
10-20	17.4	48.6	29.4	4.7	12.0	27.8	49.3	7.0
20-30	-	4.3	4.4	-	-	2.2	5.5	-
30-40	-	1.4	-	-	-	-	-	-
>40	-	-	1.5	-	-	-	-	-

Fluoride: Most of the samples (>85%) in all surveyed blocks falls in class 0-2.5 ppm F category, whereas in Bichpuri, Sainya, Kheragarh and Bah blocks, 100 per cent samples were found in 0-2.5 ppm fluoride class. Only three blocks have more than 10 per cent samples in 2.5- 5.0 ppm fluoride class. Two blocks were completed during 2016-17 (Table 1.17).

Table 1.17 Percent of samples in different Fluoride classes in blocks of Agra district (2012-17)

Blocks 2012-14	Fluoride classes (ppm)		Blocks 2014-16	Fluoride classes (ppm)		Blocks 2016-17	Fluoride classes (ppm)	
	0-2.5	2.5-5.0		0-2.5	2.5-5.0		0-2.5	2.5-5.0
Fatehpur Sikri	95.0	5.0	Barauli Ahir	98.5	1.5	Etmadpur	89.0	11.0
Akola	90.0	10.0	Khandauli	98.6	1.4	Jaitpur Kalan	98.6	1.4
Achhnera	94.8	5.2	Shamsabad	97.1	2.9	-	-	-
Bichpuri	100.0	-	Bah	100.0	-	-	-	-
Jagner	87.7	12.3	Pinahat	100.0	-	-	-	-
Sainya	100.0	-	Fatehabad	85.6	14.4	-	-	-
Kheragarh	100.0	-	-	-	-	-	-	-

The distribution of water samples in different water quality classes as given in Table 1.18 revealed that no sample of good quality ground water was found in Fatehpur Sikri, Akola and Achhnera blocks. The maximum (53.6 percent) good quality water was in Barauli Ahir block followed by 50.7 per cent in Jaitpur Kalan and 44.0 per cent in Pinahat blocks. The most of poor quality water samples were of high SAR saline followed by Alkali (Marginally Alkali, Alkali & High Alkali) and Marginally Saline. In Agra district, 29.3 per cent water samples were of good quality, whereas 45.6 per cent Saline (Marginally

Saline, Saline & High SAR Saline) and rest 30.5 per cent samples were of Alkali (Marginally Alkali, Alkali & High Alkali). The distribution waterquality classes for Agra district is shown in Fig. 1.6 while spatial distribution is shown in Fig. 1.7.

Table 1.18. Distribution of water samples in different water quality ratings (2016-17)

Blocks	No. of Samples	Good	Marginally Saline	Saline	High SAR Saline	Marginally Alkali	Alkali	High Alkali
2012-14								
Fatehpur Sikri	60	-	6.7	3.4	80.0	-	-	10.0
Akola	40	-	5.0	-	80.0	-	2.5	12.5
Achhnera	58	-	10.3	1.7	79.3	-	-	8.6
Bichpuri	45	4.4	8.9	-	80.0	-	-	6.7
Jagner	50	38.0	10.0	4.0	14.0	6.0	12.0	16.0
Sainya	54	18.5	11.1	3.7	38.9	1.9	11.1	14.8
Kheragarh	59	5.1	11.9	10.2	39.0	15.2	-	18.6
2014-16								
Barauli Ahir	69	53.6	7.3	-	8.7	7.3	15.9	7.2
Khandauli	70	32.9	20.0	-	17.1	14.3	-	15.7
Shamsabad	68	39.7	10.3	-	-	20.6	4.4	25.0
Bah	64	28.1	4.7	-	-	45.3	-	21.9
Pinahat	50	44.0	10.0	26.0	18.0	2.0	-	-
Fatehabad	90	32.2	2.2	1.1	15.6	15.6	22.2	11.1
2016-17								
Etmadpur	73	11.0	2.7	-	32.9	16.4	16.4	20.5
Jaitpur Kalan	71	50.7	4.2	-	2.8	32.4	7.1	2.8
Agra District	**951**	**23.9**	**8.4**	**3.4**	**33.8**	**11.9**	**6.2**	**12.4**

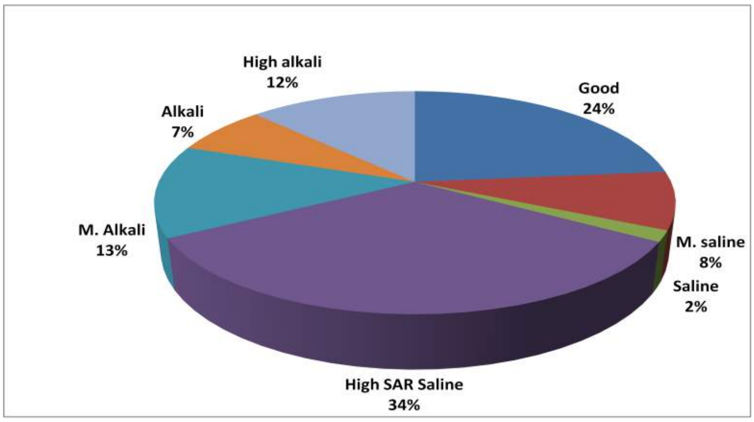


Fig. 1.3: Average Per cent distribution of water quality classes in Agra district

Fig. 1.6 Distribition of water quality classes in Agra district

Comparing the water quality of recent water samples with 35 years ago samples of Agra district, it can be explained that the good quality water in the surveyed blocks have been reduced sharply except Jagner, Sainya, Barauli Ahir, Khandauli and Kheragarh blocks. The majority of samples falls in high SAR saline water quality in both the surveyed periods except Jagner, Sainya, Barauli Ahir and Kheragarh blocks, the High SAR Saline water quality has been increased in seven blocks (Table 1.19). The saline water quality (marginally saline and saline) decreased in Fatehpur Sikri, Bichpuri Jagner, Sainya, Kheragarh, Barauli Ahir, Shamsabad and Bah. Slight increased trend was observed in alkali water whereas the water quality of three blocks i.e. Jagner, Sainya and Kheragarh remained unchanged even after three decades of time period.

Table 1.19 Distribution of water samples in different water quality ratings (1975-1979).

Blocks	No. of Samples	Good	Marginally Saline	Saline	High SAR Saline	Marginally Alkali	Alkali	High Alkali
Fatehpur Sikri	86	4.65	4.65	8.14	80.23	1.16	-	1.16
Akola	29	-	6.9	17.24	58.62	-	3.45	13.79
Achhnera	77	1.30	6.49	20.78	64.94	-	-	6.49
Bichpuri	38	15.79	23.68	15.79	26.32	-	7.89	10.53
Jagner	40	5.0	20.0	15.0	40.0	5.0	5.0	10.0
Sainya	52	7.7	7.7	25.0	40.4	3.8	7.7	7.7
Kheragarh	55	0.0	1.8	20.2	63.6	3.7	0.0	10.9
Barauli Ahir	53	32.1	9.4	1.9	7.5	9.4	24.5	15.1
Khandauli	40	20	12.5	2.5	10.0	5.0	22.5	27.5
Shamsabad	68	62.3	-	-	3.5	10.4	10.4	13.4
Bah	64	67.5	-	-	-	20.9	9.3	2.3
Pinahat	50	70.4	-	-	3.7	14.8	11.1	-
Fatehabad	90	64.0	4.2	-	4.2	17.2	10.4	-
Etmadpur	49	22.4	14.3	4.1	10.2	8.2	18.4	22.4
Jaitpur Kalan	38	76.3	-	-	5.3	10.5	7.9	-
Agra district	**829**	**29.96**	**7.44**	**8.70**	**27.90**	**7.34**	**9.24**	**9.42**

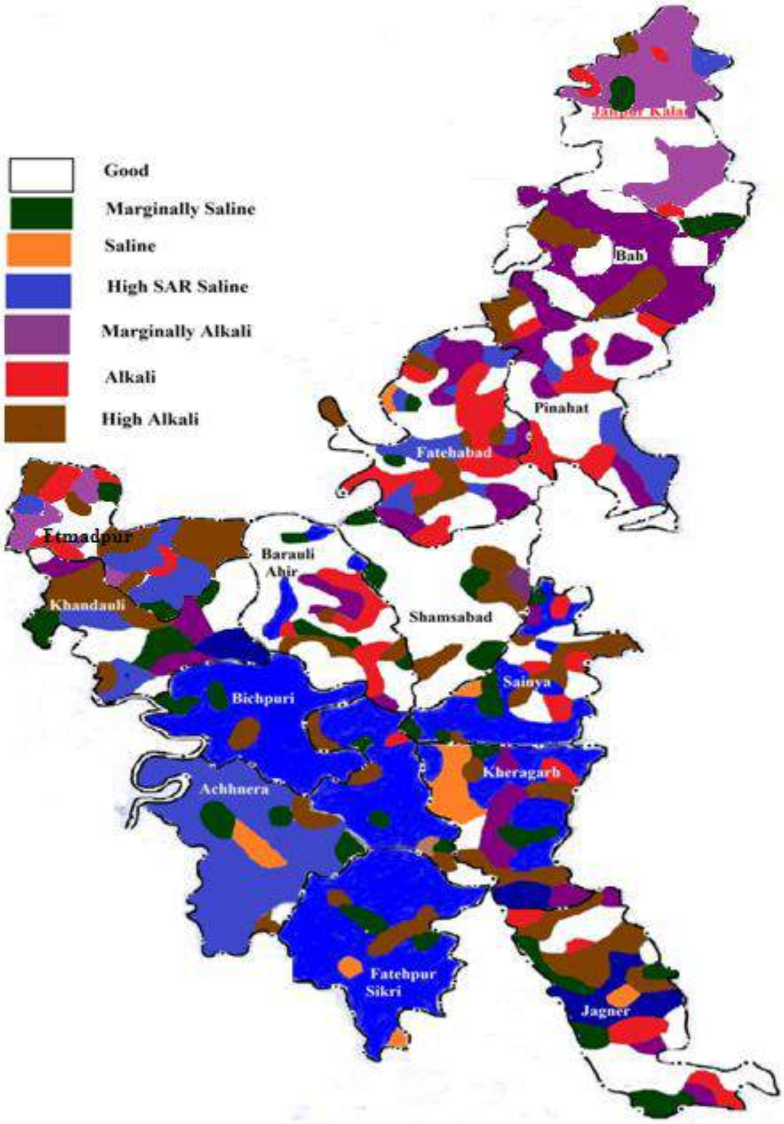


Fig. 1.7 Water quality map of Agra district (2017)

- **Survey and characterization of underground waters in West Godavari district-Revisiting the sites (Bapatla)**

The survey work was initiated for purpose of characterization and classification of ground water in West Godavari district by collecting 228 groundwater samples from 46 mandals during pre and post monsoon period, 2016 along with GPS locations. During pre monsoon season, pH and EC values of water samples ranged from 6.5 to 8.6 and 0.3 to 26.0 dS m-1, respectively. Whereas, pH and EC of post monsoon water samples varied from 6.2 to 8.8 and 0.3 to 26.0, respectively (Table 1.20).

Table 1.20 Physico-chemical and chemical properties of groundwater samples of West Godavari district

Parameters	Pre monsoon (2016)		Post monsoon (2016)	
	Range	Mean	Range	Mean
pH	6.5 to 8.6	-	6.2 to 8.8	-
EC (dS m-1)	0.3 to 26	2.0	0.3 to 26	1.9
CO32- (me L-1)	-	-	-	-
HCO3- (me L-1)	0.4 to 23.4	7.3	0.6 to 23.4	7.6
Cl- (me L-1)	0.4 to 235.2	12.4	-0.4 to 245.2	11.0
SO42- (me L-1)	0.001 to 0.75	0.031	0.01 to 0.81	0.116
Ca2+ (me L-1)	0.4 to 41.4	4.7	0.8-41.4	4.7
Mg2+ (me L-1)	0.4 to 52.1	3.7	0.4 to 52.1	4.0
Na+ (me L-1)	0.03 to 229.3	10.7	0.36 to 179.6	9.5
K+ (me L-1)	0.003 to 15.5	0.8	0.01 to 14.5	0.9
RSC (me L-1)	-69.0 to 13.2	-1.0	-65.0 to 11.8	-1.1
SAR	0.02 to 63.1	4.7	0.25 to 29.2	4.2

The sodium was found to be the dominant cation ranging from 0.8 to 57.7 me L-1 with a mean value of 10.4 me L-1. While the chloride ion dominated the anions with values ranging from 0.4 to 156 me L-1 with a mean value of 12.2 me L-1. The SAR ranged from 0.07 to 21.1 during pre monsoon period, while, it ranged from 0.73 to 13.26 with a mean value of 4.11 during post monsoon period. The residual sodium carbonate values of water samples ranged from -25.8 to -4.5 me L-1 with a mean of -2.79 me L-1 during pre monsoon period and from -14.2 to 7.0 with a mean value of -2.48 me L-1 during post monsoon period.

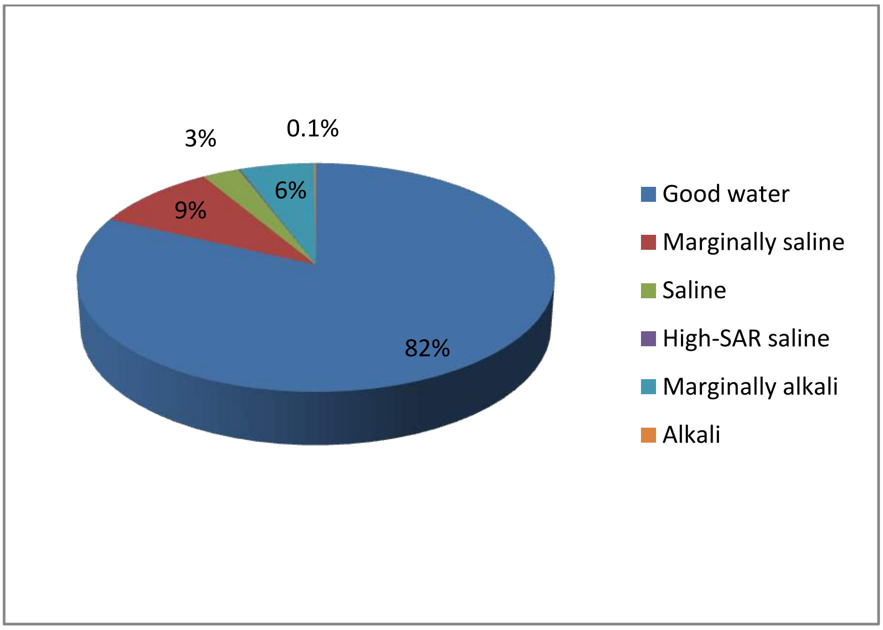
The pre monsoon water samples were classified based on rating chart of CSSRI, Karnal. A total of 180 water samples were found to be good (58.6 %) and 93 samples were marginally saline (30.3 %) as given in Table 1.21 Based on RSC classification of water samples, 78 per cent of samples were categorized as safe for irrigation.

Table 1.21 Groundwater quality of West Godavari district

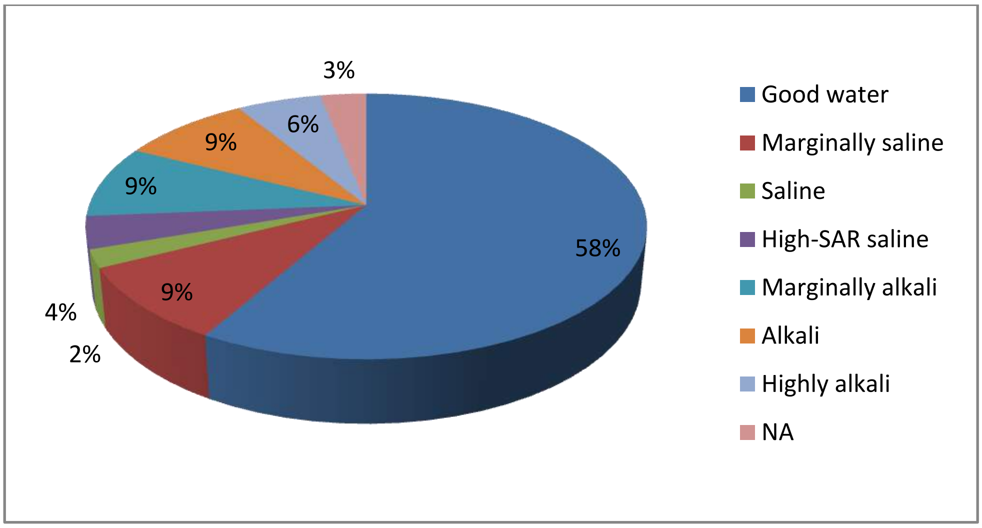
S. No.	Quality	No. of samples			Percent of samples		
		Previous (1989-90)	Pre monsoon (2016-17)	Post monsoon (2016-17)	Previous (1989-90)	Pre monsoon (2016-17)	Post monsoon (2016-17)
1	Good water	642	133	139	81.9	58.3	61.0
2	Marginally saline	74	21	32	9.4	9.2	14.0
3	Saline	22	5	3	2.8	2.2	1.3
4	High-SAR saline	1	9	7	0.1	3.9	3.1
5	Marginally	44	20	13	5.6	8.8	5.7

	alkali						
6	Alkali	1	20	19	0.1	8.8	8.3
7	Highly alkali	0	13	12	0.0	5.7	5.3
8	NA	0	7	3	0.0	3.1	1.3
Total		784	228	228	100	100	100

Quality of irrigation water was found to be deteriorated as compared to earlier studies. Per cent good quality water came down to 58.3 per cent as compared to 81.9 per cent recorded during 1989-90. On the other side, the per cent alkali water increased to 8.8 as compared to 0.1 in 1989-90 (Fig. 1.8).



(a) Changes in groundwater quality during 1989-90



(b) Changes in groundwater quality during pre monsoon (2016-17)

Fig. 1.8 Temporal changes in Groundwater quality in West Godavari 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. Ground water sampling was done from 120 points from this strip. Groundwater sampling points for different routes are given in Table 1.22

Table 1.22 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 route wise pH, EC, RSC and SAR values for pre-monsoon and post monsoon period are given in Table 1.23 and Table 1.24

Table 1.23 Route wise pH, EC, RSC and SAR values during pre monsoon period (Jun. 2016)

S. No.	Route	pH	EC (dS m^{-1})	RSC (me L^{-1})	SAR
1	Machilipatnam	7.1 to 8.3	1.00 to 5.10	0 to 13.60	2.56 to 19.15
2	Kanaparthi	7.0 to 8.0	0.50 to 4.60	0 to 10.40	1.21 to 22.68
3	Suryalanka	6.6 to 8.0	0.30 to 10.70	0 to 6.20	0.67 to 22.66
4	Nizampatnam	7.1 to 7.8	0.9 to 8.6	0 to 13.00	2.44 to 19.94

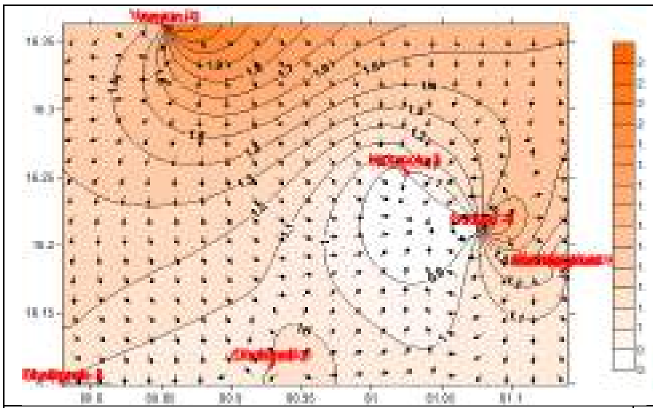
Table 1.24 Route wise ranges of pH and EC values during post monsoon period (Dec. 2016)

S. No.	Route	pH	EC (dS m^{-1})	RSC (me L^{-1})	SAR
1	Machilipatnam	6.9 to 7.6	0.40 to 5.40	0 to 4.40	1.72 to 13.30
2	Kanaparthi	6.7 to 7.8	0.50 to 4.20	0 to 8.20	1.25 to 25.11
3	Suryalanka	6.9 to 8.1	0.60 to 9.40	0 to 9.80	1.91 to 18.51
4	Nizampatnam	7.1 to 8.0	0.70 to 7.90	0 to 9.00	2.60 to 17.03

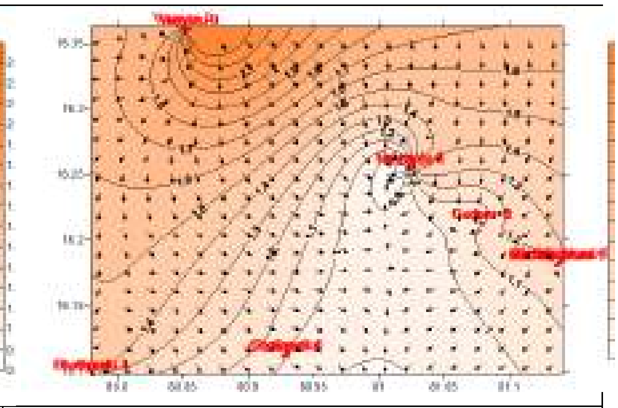
As per pre monsoon data, higher EC values were observed along Suryalanka route (0.30 to 10.70 dS m^{-1}) followed by Nizampatnam route (0.9 to 8.6 dS m^{-1}), Machilipatnam route (1.00 to 5.10 dS m^{-1}) and Kanaparthi route (0.50 to 4.60 dS m^{-1}). Data related to post-monsoon period indicated slight reduction in values of all the parameters compared to pre-monsoon period in majority of samples, except Machilipatnam route. The ground water samples for pre and –post monsoon periods were analyzed for different ions and ionic ratios (Todd, 1959) and the following observations were made about sea water intrusion.

- Majority of the samples from the four routes showed a high $Cl^-/(CO_3^{2-} + HCO_3^-)$ of > 1, comprising of 87, 100, 100 and 90 per cent of the samples from Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam routes indicating seawater intrusion, while around 13, 6, 33 and 3 per cent samples respectively are injuriously contaminated.
- Out of the samples collected from the four routes (Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam), 50, 33, 40 and 77 per cent of the samples are showing a high Ca^{2+}/Mg^{2+} (>1) indicating seawater intrusion.
- On basis of Na^+/Cl^- (<0.86), 27, 33, 33 and 13 per cent of the samples, respectively, from Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam routes are showing seawater intrusion.
- In general, sea water intrusion was observed upto a distance of 30 km from the sea. However, certain locations, there were variations in different ionic ratios indicating local effects of surface and ground water hydrology.

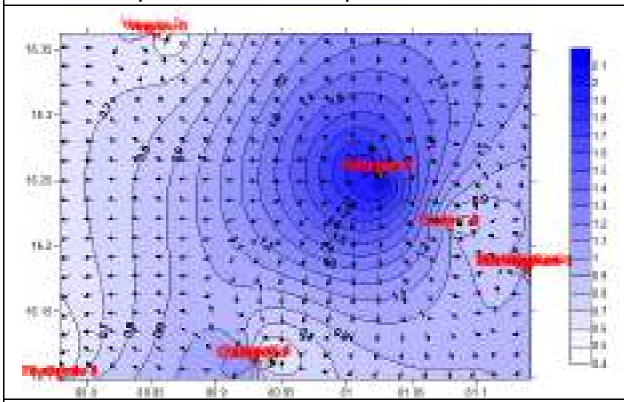
The Na^+/Cl^- and $Cl^-/(CO_3^{-2}+HCO_3^-)$ ratio values of groundwater from sea towards inland during pre and post monsoon periods along different routes are presented in Fig. 1.9. Lower Na^+/Cl^- and higher $Cl^-/(CO_3^{-2}+HCO_3^-$ ratios were observed at Nidumolu (20 km), Inkollu (27km), Kakumanu (27km) and Chebrolu (39km) villages in Machilipatnam, Kanaparthi, Suryalanka and Nizampatnam routes, respectively indicating sea water intrusion in inland areas compared to coastal region having light textured soils with high recharge.



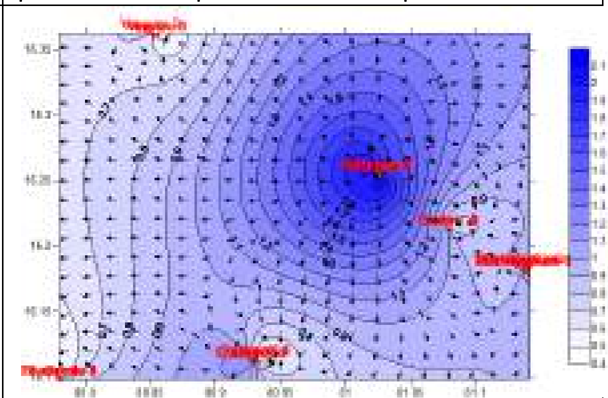
a) Na^+/Cl^- ratio distribution from sea during pre monsoon period in Machili patnam route



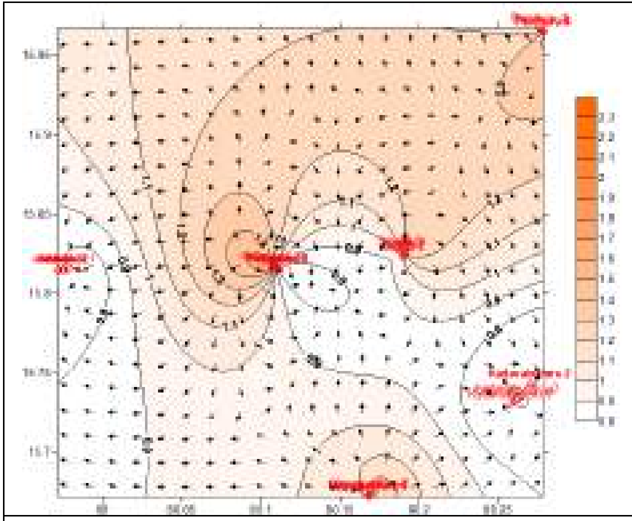
b) Na^+/Cl^- ratio distribution from sea during post monsoon period in Machili patnam route



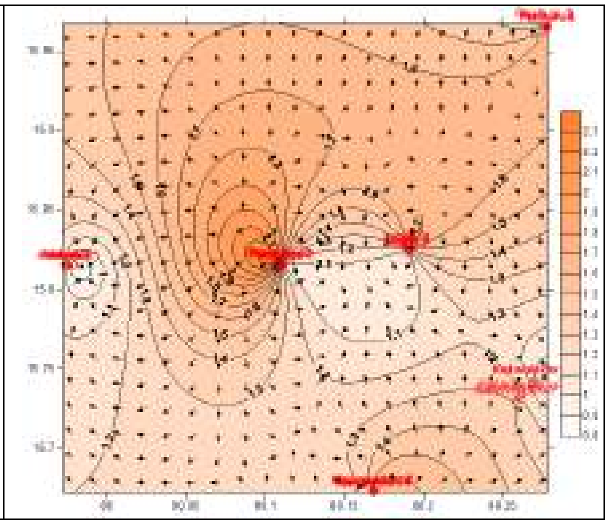
c) $Cl^-/(CO_3^{-2}+HCO_3^-)$ratio distribution from sea during pre monsoon period in Machili patnam route



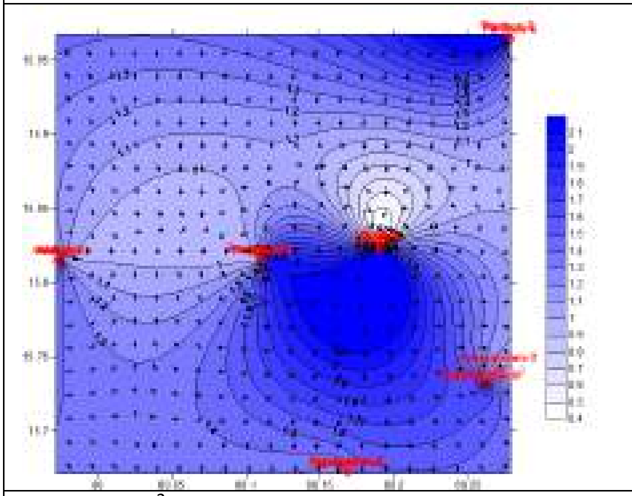
d) $Cl^-/(CO_3^{-2}+HCO_3^-)$ratio distribution from sea during post monsoon period in Machili patnam route



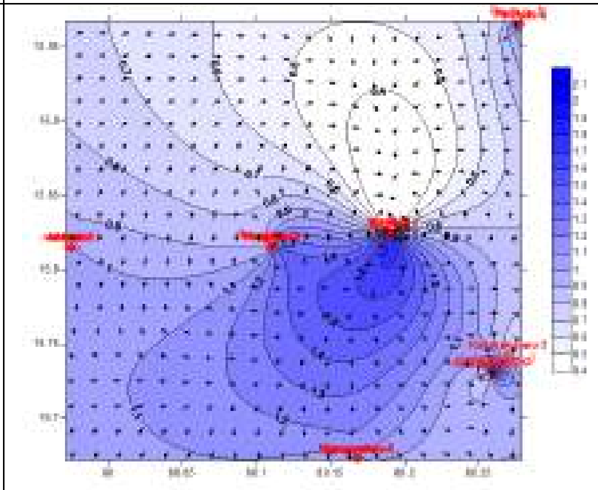
e) Na^+/Cl^- ratio distribution from sea during pre monsoon period in Kanaparthi route



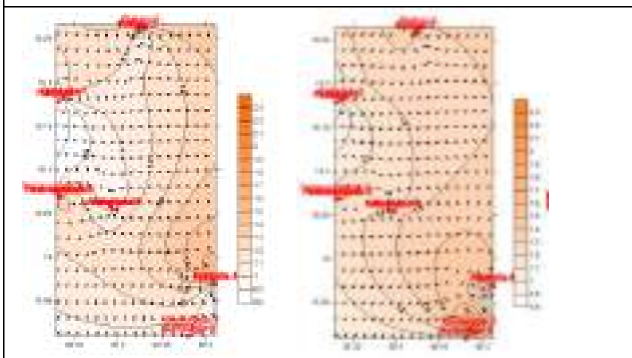
f) Na^+/Cl^- ratio distribution from sea during post monsoon period in Kanaparthi route



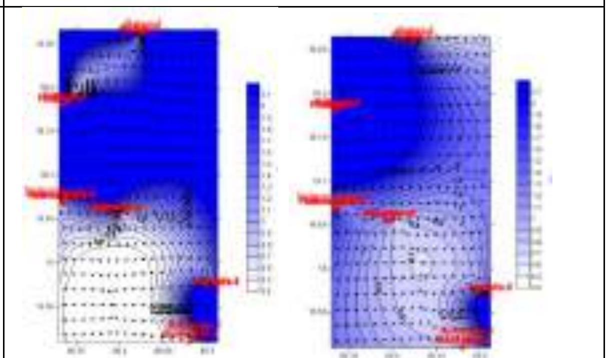
g) $Cl^-/(CO_3^{-2}+HCO_3^-)$ ratio distribution from sea during pre monsoon period in Kanaparthi route



h) $Cl^-/(CO_3^{-2}+HCO_3^-)$ ratio distribution from sea during post monsoon period in Kanaparthi route



i) Na^+/Cl^- ratio distribution from sea during pre and post monsoon periods, respectively in Suryalanka route



j) $Cl^-/(CO_3^{-2}+HCO_3^-)$ ratio distribution from sea during pre and post monsoon periods, respectively in Suryalanka route

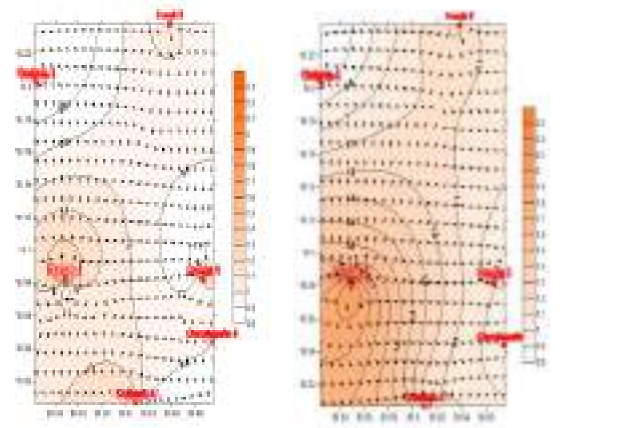
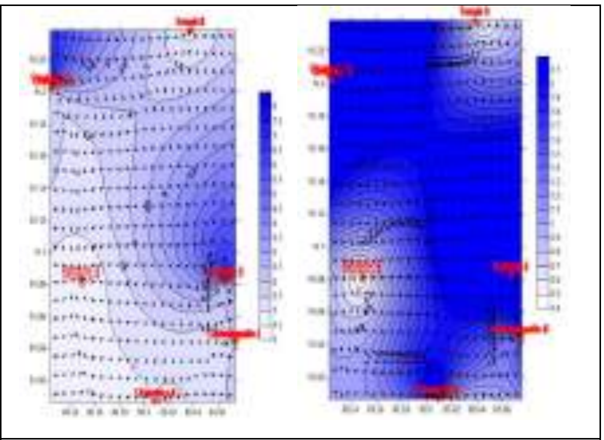
	
k) Na^+/Cl^- ratio distribution from sea during pre and post monsoon periods, respectively in Nizampatnam route	l) $Cl^-/(CO_3^{-2}+HCO_3^-)$ ratio distribution from sea during pre and post monsoon periods, respectively, in Nizampatnam route

Fig. 1.9 Distribution of ionic ratios in groundwater in coastal region in Andhra Pradesh

- **Survey and characterization of underground waters of tehsils of Jodhpur district for irrigation(Bikaner)**

Survey of two districts viz., Ajmer and Jodhpur to be completed during 2015-2017. During 2016-17, survey of only two tehsils of Jodhpur were initiated in Bilara and Pipar City tehsils of Jodhpur district to study the ground water quality and to categorize the water according to their suitability for irrigation. Water samples from tube wells distributed in 44 villages *i.e* 20 villages of Bilara and 24 villages of Pipar city tehsils of Jodhpur district were collected and analyzed for various chemical characteristics. Surface soil samples were also collected from the fields irrigated with corresponding water and analyzed for their characterization. All soil and water samples were analysed for EC, pH, cations (Ca^{++}, Mg^{++}, Na^+, K^+) and anions (CO_3^-, HCO_3^-, Cl^- and SO_4^{2-}).

The data of water samples from Bilara and Pipar city tehsils showed that EC ranged from 2.47 to 10.52 dS/m and 0.56 to 19.50 dS/m, whereas, pH ranged from 7.33 to 8.42 and 7.10 to 9.13, respectively. The concentration of calcium varied from 3.36 to 27.40 and 0.80 to 4.00 meq/L and magnesium varied from 3.54 to 28.00 and 1.20 to 11.60 meq/L in Bilara and Pipar city tehsils of Jodhpur district, respectively. Sodium concentration ranged from 16.80 to 55.13 meq/L in Bilara tehsil and 2.48 to 183.22 meq/L in Pipar city tehsil whereas concentration of potassium ion for Bilara and Pipar city tehsils varied from 0.06 to 0.32 and 0.07 to 0.70 mqe/L, respectively. Soluble carbonates varied from 0.20 to 0.80 meq/L in Bilara and 0.00 to 4.20 meq/L in Pipar city tehsils while bicarbonates varied from 6.80 to 17.60 me/L in Bilara and 2.60 to 12.80 meq/L in Pipar city tehsils. The concentration of chloride varied between 11.25 - 80.15 and 1.60 - 152.42 meq/L while sulphate varied from 0.53 to 8.09 and 0.50 to 29.48 meq/L for Bilara and Pipar city tehsils, respectively. Chloride and sodium were dominant anion and cation, respectively (Table 1.25).

Table 1.25: Range of chemical characteristics of tube well water and soils of Bilara and Pipar city tehsils of Jodhpur district

Characteristics	Bilara Tehsil		Pipar city Tehsil	
	Water (40)*	Soil (40)*	Water (40)*	Soil (40)*
pH	7.33 - 8.42 (7.84)	8.00 – 9.49 (8.59)	7.10 – 9.13 (7.22)	8.03 – 9.53 (8.72)

EC (dS/m)	2.47 – 10.52 (5.78)	0.74 – 3.12 (1.50)	0.56 - 19.5 (5.27)	0.12 – 4.53 (0.68)
Ca (meq/L)	3.36 – 27.40 (9.82)	0.52 – 5.00 (1.95)	0.8 – 4.00 (1.88)	0.20 – 1.80 (0.91)
Mg (meq/L)	3.54 – 28.00 (9.86)	0.58 – 4.60 (1.85)	1.2 – 11.6 (3.78)	0.00 - 2.40 (0.80)
Na (meq/L)	16.80 – 55.13 (37.66)	4.30 – 21.09 (9.03)	2.48 – 183.22 (46.67)	0.50 – 38.12 (4.38)
K (meq/L)	0.06 – 0.32 (0.16)	0.84 – 3.59 (1.90)	0.07 – 0.70 (0.28)	0.10 – 4.48 (0.72)
CO_3 (meq/L)	0.20 – 0.80 (0.44)	0.20 – 1.20 (0.66)	0.00-4.20 (1.12)	0.20 – 1.60 (0.89)
HCO_3 (meq/L)	6.80 – 17.60 (10.01)	2.10 – 7.10 (4.55)	2.60 – 12.8 (5.74)	0.40 – 2.40 (1.40)
Cl (meq/L)	11.25 – 80.15 (44.44)	2.42 – 23.72 (9.11)	1.60 – 152.42 (37.40)	0.30 – 29.40 (3.42)
SO_4 (meq/L)	0.53 – 8.09 (2.68)	0.13 – 0.89 (0.55)	0.50 – 29.48 (8.39)	0.00 – 12.00 (1.12)
RSC (meq/L)	0.00 - 4.00 (0.56)	-	0.00 – 4.20 (1.34)	-
SAR	8.22 – 20.68 (8.22)	3.96 – 13.85 (6.84)	2.10 – 76.08 (27.96)	0.85 – 34.10 (4.26)
SSP	47.03 – 80.39 (67.04)	42.29 – 77.94 (61.11)	42.97 – 95.49 (83.95)	33.33 – 84.52 (52.75)
Water table (ft)	100 – 550 (354)			

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

The SAR of water samples ranged from 8.22 to 20.68 and 2.10 to 76.08, whereas soluble sodium percentage (SSP) of water samples ranged from 47.03 to 80.39 and 42.97 to 95.49, respectively for Bilara and Pipar city tehsils, respectively (Table 1.25).

The distribution of water samples showed that RSC ranged from 0.0 to 4.0 and 0.0 to 4.2 meq/L in Bilara and Pipar city tehsils, respectively. About 90.0 and 87.5 per cent water samples in Bilara and Pipar city tehsils had RSC in the range of < 2.5, meq/L, respectively. The ECiw ranged from 2 to 3, 3 to 4 and >4 dS/m in 7.5, 10.0 and 82.5 per cent water samples in Bilara tehsil while in Pipar city tehsil 5.0, 5.0, 15.0, 12.5 and 62.5 per cent water samples had EC in the range of <1, 1-2, 3-4 and >4 dS/m.

About 15, 70 and 15 per cent water samples in Bilara tehsil are saline, high SAR saline and marginally alkali while 10, 17.50, 60 and 12.50 per cent water samples of Pipar tehsil are good, marginally saline, High SAR saline and high alkali, respectively. Villages falling under different water quality are reported in Table 1.26 and water quality map is depicted in Fig 1.10

Table 1.26 Groundwater quality in Bilara and Pipar city tehsils of Jodhpur district

Water quality	Name of villages in tehsils	
	Bilara	Pipar city
Good (EC<2 dSm^{-1}, SAR <10 RSC <2.5 $meqL^{-1}$)	-	Sindhipura, Nanan-3, Khudecha-1, Gadsuriya (10%)
Marginally saline (EC 2-4 dSm^{-1}, SAR <10	-	Siyara, Basani Khariya-1, Basani Khariya-2, Sargiya, Malawas-1,

RSC <2.5 $meqL^{-1}$)		Madaliya-2, Madaliya-3, (17.50%)
Saline (EC >4 dSm^{-1}, SAR <10 RSC <2.5 $meqL^{-1}$)	Jhurli-1, Jhurli-2, Udaliyawas-2, Birawas-1, Birawas-2, Birawas-3 (15%)	-
High- SAR saline (EC >4 dSm^{-1}, SAR >10 RSC <2.5 $meqL^{-1}$)	Sindhi Nagar-2, Bhavi-1, Bhavi-2, Bilara Chak-I, Bilara Chak-II, Jelwa-1, Jaitiwas-1, Jaitiwas-2, Jelwa-2, Uchirda-1, Uchirda-2, Khariya-2, Udaliyawas-1, Jhak-2, Kuprawas-1, Kuprawas-2, Kalawana-1, Kalawana-2, Rampuriya-1, Rampuriya-2, Pichiyak-1, Pichiyak-2, Ghanamagra-1, Ransigaon-1, Ransigaon-2, Patel Nagar-1, Patel Nagar-2, Patel Nagar-3 (70%)	Khosana-1, Khosana-2, Chokari Kallan-1, Chokari Kallan-2, Khawaspura, Sargiya Kala, Buchakallan-1, Buchakallan-2, Bankaliya, Jalka-1, Pipar, Nanan-1, Nanan-2, Khudecha-2, Chirdani, Jaliwara Kala, Malawas-2, Madaliya-1, Mahadev Nagar-1, Mahadev Nagar-2, Borunda-3, Bhakro Ki Dhani-1, Bhakro Ki Dhani-2, Borunda-2 (60%)
Marginally alkali (EC <4 dSm^{-1},SAR <10 RSC 2-4 $meqL^{-1}$)	Sindhi Nagar-1, Olvi-1, Olvi-2, Khariya-1, Jhak-1, Khejarla (15%)	-
Alkali (EC <4 dSm^{-1}, SAR <10 RSC >4.0 $meqL^{-1}$)	-	-
Highly alkali (EC <4 dSm^{-1}, SAR >10 RSC >4.0 $meqL^{-1}$)	-	Pipar Road, Riyan Seta Ri-1, Riyan Seta Ri-2, Jalka-2, Borunda-1 (12.50%)

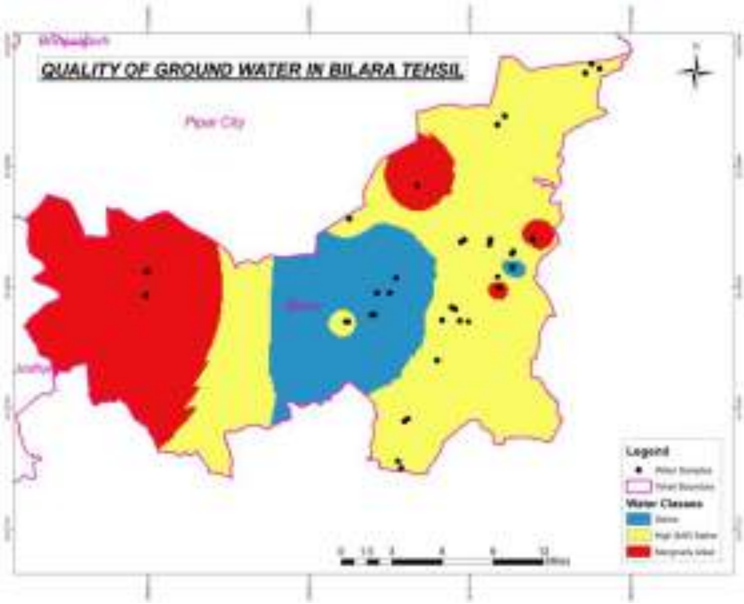


Fig. 1.10 Groundwater quality of Bilara Tehsil

Table 1.27 Distribution of water samples (%) in relation to pH, EC, SAR and SSP of Bilara and Pipar city tehsils of Jodhpur district

Characteristics	Bilara (%)	Pipar city (%)
pH		
7.0-7.5	10.0	37.5
7.5-8.0	62.5	42.5
8.0-8.5	27.5	15.0
> 8.5	0.0	5.0
ECiw (dS/m)		
<2	0.0	10.0
2-4	17.5	27.5
4-6	42.5	27.5
>6	40.0	35.0
SAR		
0-10	30.0	25.0
10-20	67.5	7.5
20-30	2.5	27.5
> 30	0.0	40.0
SSP		
< 50	10.0	5.0
50-60	2.5	0.0
60-70	47.5	2.5
70-80	37.5	20.0
> 80	2.5	72.5

Data in Table 1.27 indicated that Percent distribution of water samples showed that about 10, 62.50, 27.50 per cent water samples showed pH range of 7.0-7.5, 7.5 - 8.0 and 8.0 - 8.5 in Bilara tehsil whereas, 37.50, 42.50, 15.0 and 5.0 per cent water samples in Pipar tehsil showed pH in the range of 7.0 - 7.5, 7.5 - 8.0, 8.0 - 8.5 and >8.5, respectively. In Bilara and Pipar tehsils 40.0 and 35.0 per cent water samples showed EC >6 dS/m. About 30, 67.50 and 2.50 per cent water samples having SAR in the range of <10, 10-20 and 20-30 in Bilara tehsil whereas, 25, 7.50, 27.50 and 40.0 per cent water samples in Pipar tehsil having SAR in the range of <10, 10-20, 20-30 and >30, respectively. About 47.50 per cent water samples of Bilara tehsil showed SSP in the range of 60-70, whereas, 72.50 per cent water samples of Pipar tehsil showed SSP in the range of >80.

The range of chemical characteristics of soil samples in both tehsils indicated that $pH_{2.5}$ of soil samples in Bilara tehsil varied from 8.00 to 9.49 and Pipar city from 8.03 to 9.53, whereas, the corresponding $EC_{2.5}$ ranged from 0.74 to 3.12 and 0.12 to 4.53 dS/m, respectively. There is problem of high SAR saline water in 70 and 60 per cent villages of Bilara and Pipar tehsils of Jodhpur district.

- ✓ Farmers are advised to mix ground water with good quality water for raising crops.
- ✓ Deep tillage, use of gypsum or pyrite as per soil requirement, green manuring through sesbania and also suggested to grow salt resistant crops e.g. pearl millet, sorghum, cotton, chilly, brinjal during kharif and barley, wheat and mustard during rabi season, use of nutrients as per soil test.
- ✓ Micro irrigation system for using poor quality water.
- ✓ Application of 25% more seed and fertilizers as per recommendations.

- **Survey and characterization of underground waters of Kaithal district for irrigation (Hisar)**

The survey and characterization of underground irrigation water of Kaithal district was undertaken during 2016-17. Kaithal is the north eastern district of Haryana State. It has a total geographical area of 2317 sq. km and is located between 29o31'- 30o12' north latitudes and 76o10'- 76o42' east longitudes. District mainly receives annual rainfall of 563 mm which is unevenly distributed over the area.

Total 530 water samples were collected from six blocks of Kaithal district from crop growing area from running tube wells and their locations were recorded in the form of latitudes and longitudes using GPS **(Fig. 1.11)**.

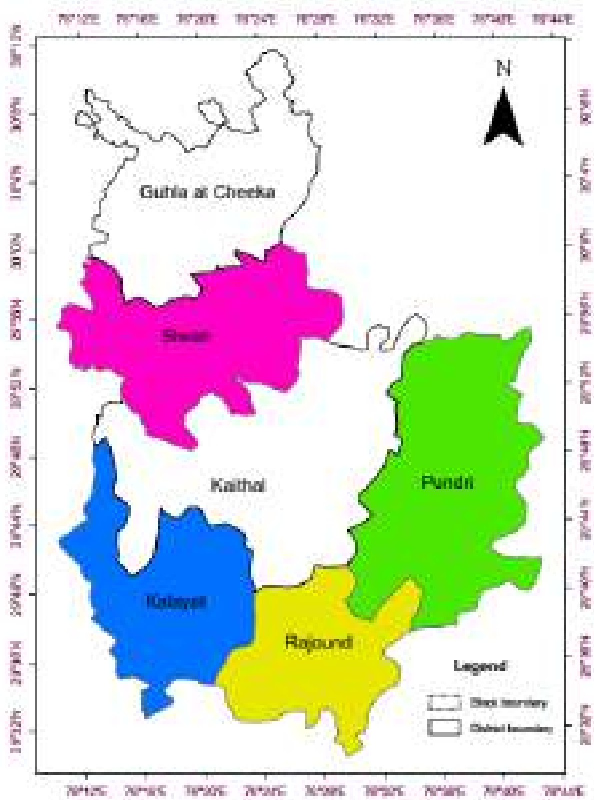


Fig.1.11 Location Map of Kaithal district representing its block and villages

Water samples were collected at an interval of three to four kilometers on the kachcha, link and main roads along with elevation, longitude and latitude angles of the sampling points as per GPS system for each location. All the 530 groundwater samples (109 from Guhla, 137 from Kaithal, 51 from Rajound and 98 from Pundri, 59 from Kalyat and 76 from Siwan block) were analyzed for various chemical parameters, viz. pH, EC, cations (Na^+, Ca^{+2}, Mg^{+2} and K^+) and anions (CO_3^{-2}, HCO_3^-, Cl^- and SO_4^{-2}). Subsequently, SAR and RSC were calculated for these samples. In the Kaithal district, electrical conductivity (EC) ranged from 0.30 to 8.25 dS/m with a mean of 1.80 dS/m (Table 1.28).

Table 1.28 Irrigation water quality parameters for Kaithal district

Water quality parameters	**Range**	**Mean**	**Water quality parameters**	**Range**	**Mean**
pH	7.01 – 9.80	8.20	Na^+ (meq/L)	1.80-61.10	12.89
EC (dSm^{-1})	0.30 -8.25	1.80	K^+ (meq/L)	0.04-3.20	0.20
RSC (meq/L)	0.00 – 6.90	1.60	CO_3^{2-} (meq/L)	0.00-5.30	1.21
SAR $(mmol\ l^{-1})^{1/2}$	2.51 – 27.67	2.55	HCO_3^- (meq/L)	0.00-10.50	3.64
Ca^{2+} (meq/L)	0.20-5.30	1.18	Cl^- (meq/L)	0.40-48.00	8.30
Mg^{2+} (meq/L)	0.80-14.84	3.45	SO_4^{2-} (meq/L)	0.00-40.10	4.10

The lowest EC of 0.30 dS/m in water samples was observed in village Azimgarh in Gulla block and the highest EC of 8.25 dS/m was observed in village Kachana of Gulla block. To study the spatial distribution of EC in the whole district, a spatial variable map was prepared by using ArcGIS through the interpolation of the available data at 530 sampling points (Fig. 1.12).

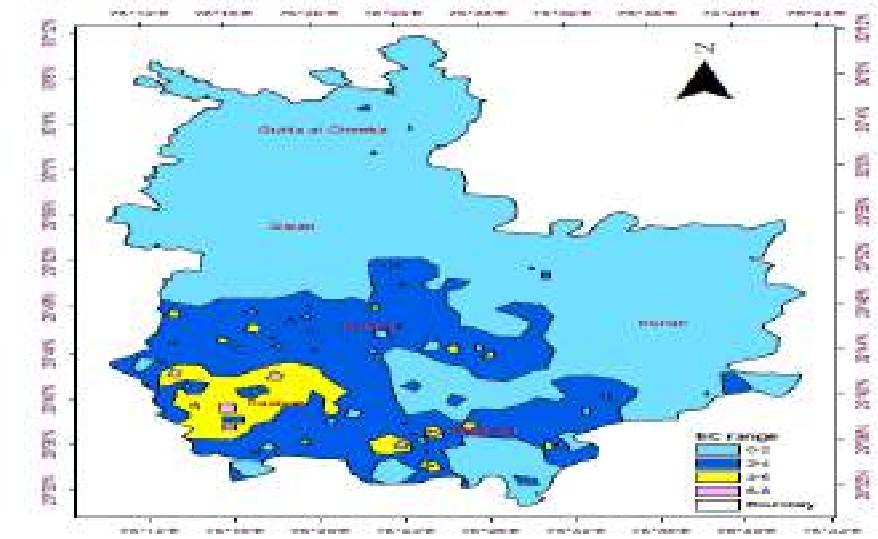


Fig. 1.12 Spatial variability of EC of groundwater used for irrigation in Kaithal district

The variation of EC in Kaithal district is grouped into 3 classes with a class interval of 2 dS/m. The most dominating range of EC is 0-2 dS/m which occupied maximum area in the district and covering all the blocks of the district. The next dominating range was 2-4 dS/m which is covering a large portion of the district. The pH ranged from 7.01 to 9.80 with a mean of 8.20). The sodium adsorption ratio (SAR) ranged between 2.51 - 27.67 (mmol $l^{-1})^{1/2}$ with a mean value of 2.55 (mmol $l^{-1})^{1/2}$. The residual sodium carbonate (RSC) was ranged from nil to 6.90 meql^{-1} with a mean value of 1.60 meql^{-1}. EC classes were grouped into 3 different classes with an interval of two units. The percent distribution of sample in different EC classes is shown in Table 1.29 Percentage of samples in different EC classes is different, its highest percentage (76.60) was found in EC class of 0-2 dS/m and its lowest percentage (7.73) was found in EC class ≥4 dS/m.

Table 1.29 Chemical composition of groundwater of Kaithal district in different EC classes

EC Classes (dSm^{-1})	Percent samples	Na^+	Ca^{2+}	Mg^{2+}	K^+	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	RSC	SAR
		--(meql^{-1})------------------------------------									(mmol $l^{-1})^{1/2}$
0-2	76.60	8.73	0.84	2.43	0.17	1.16	3.54	8.02	1.90	1.80	6.83
2-4	15.67	19.67	1.88	5.66	0.10	1.44	4.24	13.12	8.20	1.20	10.65
≥4	7.73	39.98	3.21	9.26	0.30	1.20	3.02	30.61	17.60	0.30	16.60

In case of anions, chloride was the dominant anion with maximum the concentration of chlorides in groundwater samples varied from 0.40 to 48.00 mel^{-1} with the mean value of 8.30 meq l^{-1}. The concentration of bicarbonates in groundwater samples varied from 0.0 to 10.50 meql^{-1} with a mean value of 3.64 meq l^{-1}. The mean values for CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} were found to be 1.21, 3.64, 8.30 and 4.10 meql^{-1}, respectively (Table 1.28). Table 1.29 and Fig. 1.13 illustrate the mean of anions according to the EC classes in district, the Cl^- was the highest and its value increased with the increase in EC.

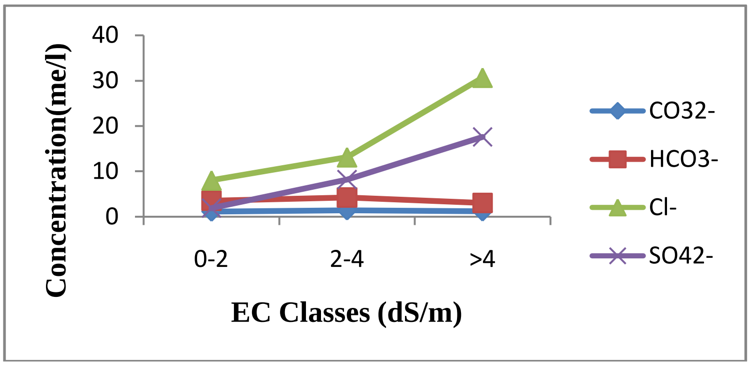


Fig.1.13 Anion concentration in different EC classes of Kaithal district

The concentration of sodium in groundwater samples varied from 1.80 to 61.10 $meql^{-1}$ with an average value of 12.89 mel^{-1} (Table 1.28), followed by magnesium (0.80 to 14.84 $meql^{-1}$) and calcium (0.20 to 5.30 me/l). Mean values for Na^+, Mg^{2+}, Ca^{2+} and K^+ were 12.89, 3.45, 1.18 and 0.22 meq/l, respectively. Table 1.29 and Fig. 1.14 illustrate the mean of cation according to the different EC classes in Kaithal district, Na^+ was the highest and its value increased with the increase in EC. Its lowest mean value (8.73 meq/l) was found in the class 0-2, the highest mean value (39.98 me/l) was laid in the EC class of ≥4 dS/m.

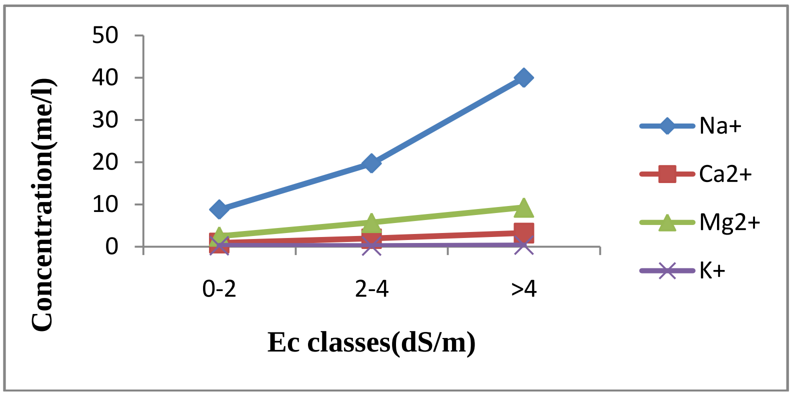


Fig.1.14 Cations concentration in different EC classes of Kaithal district

According to AICRP classification, it was found that 47.2 percent samples were of good quality, 19.8 percent saline and 33 percent alkali in nature (Fig. 1.15). Out of the saline water, 12.1 and 7.7 percent were in marginally saline and high SAR saline, respectively. In alkali group 11.3, 13 and 8.7 percent were in marginally alkali, alkali and high alkali, respectively. Out of seven categories of water, maximum 47.2 percent of samples were found in good quality.

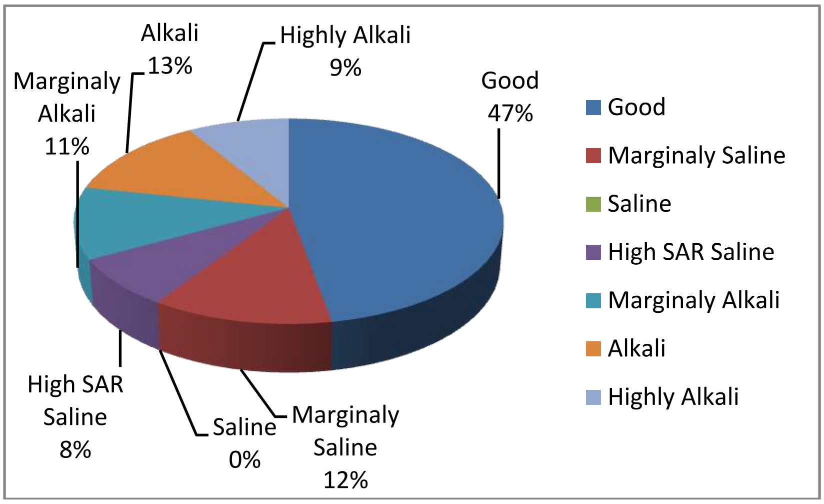


Fig.1.15 Quality of groundwater (percent) in Kaithal district

Groundwater quality map for Kaithal district according to AICRP criteria was prepared to study its spatial variability in the district (Fig. 1.16). In the district, 47 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 tube wells in that area and accordingly more samples were collected from that area. Good category groundwater is mostly lying in Guhla and Pundri blocks of the district and highly scattered in other blocks. 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.

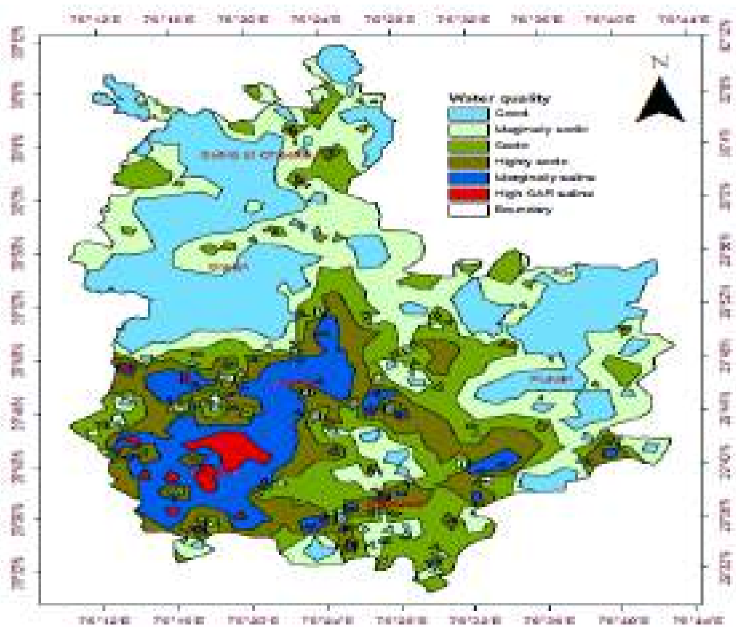


Fig. 1.16. Groundwater quality map of Kaithal district of Haryana

- **Survey and characterization of underground irrigation waters, salinity associated problems in Khargone and Khandwa districts of Madhya Pradesh (Indore)**

The survey and characterization of underground irrigation water of Khargone and Khandwa districts of Madhya Pradesh was undertaken during 2016-17. These districts are situated in the southern part of the state. District Khargone and Khandwa lies in between 21o 33’ to 22o 33’ N &

75o 13" to 76o 14’ E and 21o 32" to 22o 25" N & 76o 00" to 77o 12" E respectively. The Districts has hot sub-humid climate characterized by hot summers and mild winters. The average annual rainfall is about 835 and 855 mm respectively. Maximum and minimum temperatures are 43 & 42°C and 10.0 & 10.0 °C respectively. 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. Two hundred fifty three and one hundred eighty water samples were collected from different tehsils of Khargone and Khandwa districts respectively. These include samples from open wells and tube wells. The wells/ tube wells vary in depth from 7 to 250 and 5 to 233 m depth in Khargone and Khandwa districts respectively.

Quality of Groundwater in Khargone district

Sanavad Tehsil: The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 7.0 to 7.9, 0.53 to 2.53 dSm-1, 0.55 to 6.12 and Nil me L-1 , respectively (Table 4). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 0.4 to 2.84, 2.0 to 15.2 and 0.4 to 9.8 me L-1., respectively. Similarly the cations like Ca2+ , Mg2+, Na+ and K+ varied from 1.0 to 8.4, 0.4 to 6.0, 0.79 to 13.6 and 0.0 to 1.36, respectively.. Out of twenty five samples, 19 (76.0 %) water samples come under good water category “A”. However, 6 (24.0%) samples fall under marginally saline water category (B1) (Table 1.30).

Bhikangaon Tehsil: The quality of groundwater of Bhikangaon tehsil indicate that pH, EC, SAR and RSC ranged from 7.0 to 7.7, 0.35 to 2.58 dS m-1, 0.81 to 8.82 and Nil me L-1 respectively (Table 4). Out of 20 samples, 17 (85.0 %) water samples come under good water category “A”. However, 3 (15.0 %) samples fall under marginally saline water category (B1) (Table 1.30).

Jhirnya Tehsil: The quality of groundwater samples indicate that pH, EC, SAR and RSC range from 7.0 to 7.9, 0.43 to 2.78 dSm-1, 1.62 to 6.46 and Nil me L-1 respectively (Table 4). Out of 17 samples, 2 (11.8 %) samples belong to good water category ‘A’, whereas 15 (88.2 %) ground water sample belongs to marginally saline (B1) category (Table 1.30).

Bhagwanpura Tehsil: The pH, EC SAR and RSC ranged from 7.2 to 7.9, 0.24 to 0.40 dS m-1, 1.00 to 2.16 and Nil me L-1 respectively (Table 4). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 0.6 to 1.2, 1.2 to 2.2 and 0.2 to 0.9 me L-1 respectively (Table 4). Similarly the cations like Ca2+ , Mg2+, Na+ and K+ varied from 0.8 to 1.6, 0.4 to 1.2, 0.89 to 1.93 and 0.00 to 0.06 me L-1 respectively.. All 18 ground water samples belong to category “A” (Table 1.30).

Gogawan Tehsil: The quality of groundwater of Gogawan tehsil indicated that pH, EC, SAR and RSC ranged from 7.3 to 8.4, 0.23 to 2.26 dSm-1, 1.60 to 4.39 and Nil meL-1 respectively (Table 4). Out of 16 samples, 13 (81.3 %) samples belong to good water category ‘A’, whereas 3 (18.7 %) ground water sample belongs to marginally saline (B1) category (Table 1.30).

Khargone Tehsil: The quality of groundwater samples showed that pH, EC, SAR and RSC range from 7.3 to 8.5, 0.40 to 2.64 dSm-1, 0.37 to 4.24 and Nil meL-1 respectively (Table 1.30). Out of 36 samples, 32 (88.9 %) samples belong to good water category ‘A’, whereas 4 (11.1 %) ground water sample belongs to marginally saline (B1) category (Table1.30).

BarwahaTehsil: The pH, EC, SAR and RSC ranged from 7.5 to 8.6, 0.41 to 4.10 dSm-1, 0.50 to 4.57 and Nil meL-1 respectively (Table 4). Out of 26 samples, 20 (77.0 %) samples belong to good water category ‘A’, whereas 5 (19.2 %) and 1 (3.8 %) ground water sample belongs to marginally saline (B1) and saline (B2) categories respectively (Table 1.30).

Maheshwar Tehsil: The quality of groundwater samples indicate that pH, EC, SAR and RSC range from 7.6 to 8.70, 0.50 to 2.64 dSm-1, 0.30 to 4.50 and Nil meL-1 respectively (Table 4). Out of 43 samples, 35 (83.3 %) samples belong to good water category 'A', whereas 7 (16.7 %) ground water sample belongs to marginally saline (B1) category (Table 1.30).

Kasravad Tehsil: The quality of groundwater samples indicates that pH, EC SAR and RSC ranged from 8.0 to 8.8, 0.40 to 2.46 dSm-1, 0.46 to 3.82 and Nil me L-1, respectively (Table 4). Carbonate, bicarbonate, chloride and sulphate ions ranged from 0.0 to 2.4, 0.4 to 4.9, 0.7 to 18.0 and 0.2 to 5.8 me L-1., respectively. Similarly the cations like Ca2+ , Mg2+, Na+ and K+ varied from 1.2 to 10.0, 0.8 to 6.6, 0.73 to 7.98 and 0.0 to 1.42, respectively.. Out of thirty one samples, 30 (96.8 %) water samples come under good water category "A". However, 1 (3.2 %) sample falls under marginally saline water category (B1) (Table 1.30).

Segaon Tehsil: The quality of groundwater samples indicate that pH, EC, SAR and RSC range from 7.7 to 8.50, 0.50 to 1.23 dSm-1, 0.55 to 3.98 and Nil meL-1 respectively (Table 4). All 18 ground water samples belong to category "A" (Table 1.30).

Frequency distribution of water samples*:*

Out of these 253 samples, 208 (82.2 %) belongs to category "A", 44 (17.4 %) belong to category "B1" and 1 (0.4 %) belong to category "B2" as given in Table 1.30 while salient features of ground water samples of Khargone district are provided in Table 1.31 Similarly spatial distribution is provided in Fig. 1.17

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

Category	Tehsils										Total
	Sana-vad	Bhikan-gaon	Jhirnya	Bhagwan-pura	Goga-wan	Khar-gone	Bar-waha	Mahe-shwar	Kasra-vad	Segaon	
A	19 (76.0)	17 (85.0)	2 (11.8)	18 (100.0)	13 (81.3)	32 (88.9)	20 (80.0)	35 (81.4)	30 (96.8)	22 (100)	208 (82.2)
B1	6 (24.0)	3 (15.0)	15 (88.2)	0	3 (18.7)	4 (11.1)	5 (20.0)	7 (16.3)	1 (3.2)	0	44 (17.4)
B2	0	0	0	0	0	0	1 (4.0)	0	0	0	1 (0.4)
B3	0	0	0	0	0	0	0	0	0	0	0
C1	0	0	0	0	0	0	0	0	0	0	0
C2	0	0	0	0	0	0	0	0	0	0	0
C 3	0	0	0	0	0	0	0	0	0	0	0
Total	25	20	17	18	16	36	25	43	31	22	253

Figures in parenthesis are percentage of the samples

Table 1.31 Salient Features of ground water samples of Khargone district

Parameter	Sana-vad	Bhikan-gaon	Jhirnya	Bhagwan-pura	Goga-wan	Khar-gone	Bar-waha	Mahe-shwar	Kasra-vad	Segaon
pH	7.00-7.90 (7.50)	7.00-7.70 (7.40)	7.00-7.90 (7.49)	7.20-7.90 (7.57)	7.30-8.40 (7.71)	7.30-8.50 (8.24)	7.50-8.60 (8.08)	7.60-8.70 (8.25)	8.00-8.80 (8.32)	7.70-8.50 (8.23)
EC (dSm-1)	0.53-2.53 (1.37)	0.35-2.58 (1.05)	0.43-2.78 (2.32)	0.24-0.40 (0.31)	0.23-2.26 (1.00)	0.40-2.64 (0.96)	0.41-4.10 (1.19)	0.50-2.64 (1.22)	0.40-2.46 (0.83)	0.50-1.23 (0.80)
CO32-	Nil	Nil	Nil	Nil	Nil	0.00-1.60 (0.16)	0.00-1.70 (0.10)	0.00-1.70 (0.07)	0.00-2.40 (0.70)	0.00-1.20 (0.14)
HCO3-	0.40-2.80 (1.37)	0.60-3.20 (1.34)	0.60-4.20 (2.34)	0.60-1.20 (0.90)	0.60-3.60 (2.03)	0.40-3.60 (1.19)	0.40-7.10 (1.20)	0.60-4.00 (1.18)	0.40-4.90 (2.00)	0.80-3.40 (1.51)
Cl-	2.00-15.20 (7.07)	1.20-13.60 (5.17)	2.00-14.80 (13.19)	1.2-2.20 (1.76)	1.40-18.80 (5.83)	0.70-17.60 (5.61)	2.80-27.20 (6.84)	1.00-19.00 (7.28)	0.70-18.00 (3.63)	1.30-8.60 (4.14)
SO42-	0.40-9.80 (5.30)	0.20-12.60 (4.03)	0.70-11.80 (7.79)	0.20-0.90 (0.43)	0.20-10.40 (2.12)	0.00-8.00 (2.62)	0.30-13.40 (3.74)	0.50-17.60 (3.67)	0.20-5.80 (1.97)	0.00-5.50 (2.26)
Ca2+	1.00-8.40 (3.78)	1.20-8.60 (3.21)	1.60-9.00 (6.93)	0.80-1.60 (1.12)	0.60-7.00 (2.53)	1.60-9.00 (4.15)	1.40-25.70 (4.79)	1.00-11.20 (5.03)	1.20-10.00 (3.17)	2.00-4.60 (3.15)
Mg2+	0.40-6.00 (3.03)	0.40-4.60 (1.96)	0.80-7.00 (4.61)	0.40-1.20 (0.70)	0.20-6.80 (2.61)	0.40-7.20 (2.39)	2.20-42.70 (8.78)	0.40-11.00 (3.99)	0.80-6.60 (1.95)	1.20-3.20 (2.03)
Na+	0.79-13.60 (6.99)	0.96-16.09 (5.43	1.77-15.28 (11.87	0.89-1.93 (1.32)	1.24-10.40 (4.85)	0.64-11.49 (3.09)	0.89-11.66 (3.42)	0.66-12.08 (3.14)	0.73-7.98 (3.21_	0.80-6.07 (2.92)
K+	0.00-1.36 (0.17)	0.00-0.18 (0.03)	0.00-0.19 (0.07)	0.00-0.06 (0.02)	0.00-0.10 (0.02)	0.00-0.17 (0.04)	0.02-0.49 (0.14)	0.00-1.04 (0.14)	0.00-1.42 (0.12)	0.00-0.53 (0.05)
SAR	0.55-6.12 (3.71)	0.81-8.82 (3.28)	1.62-6.46 (5.21)	1.00-2.16 (1.40)	1.60-4.39 (2.96)	0.37-4.24 (1.63)	0.50-4.57 (1.34)	0.30-4.50 (1.48)	0.46-3.82 (2.06)	0.55-3.98 (1.87)
RSC (meL-1)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Data in parenthesis are mean values of the parameters

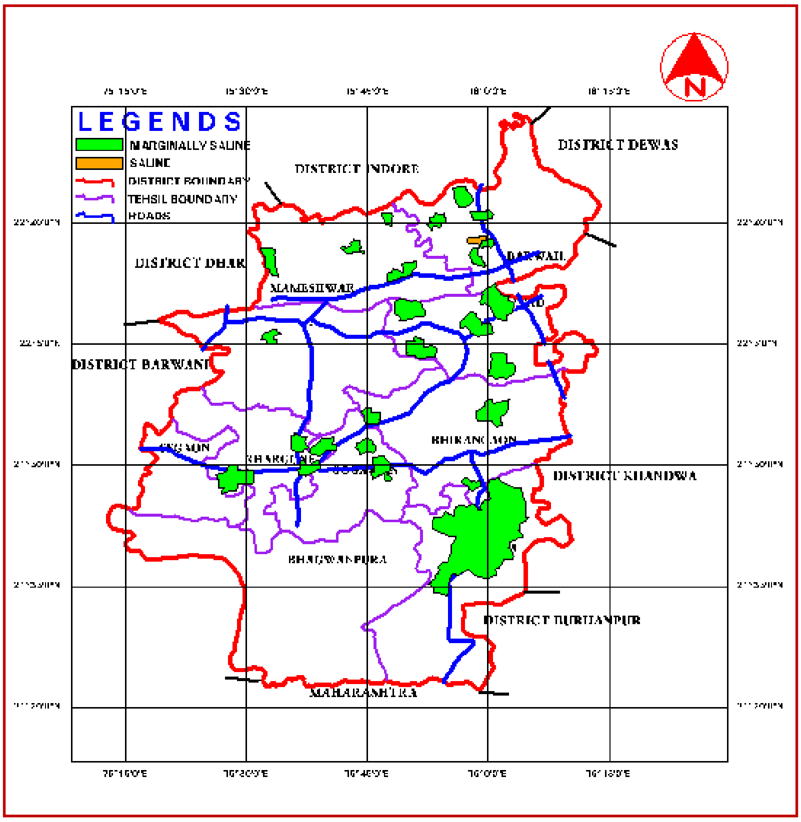


Fig. 1.17 Groundwater quality map of Khargone district

Quality of Groundwater in Khandwa district

Khandwa Tehsil: The quality of ground water samples collected from Khandwa tehsil indicated that pH, EC SAR and RSC ranged from 6.80 to 8.80, 0.40 to 2.68 dSm-1, 0.32 to 8.57 and Nil meL-1 respectively (Table 8). Carbonate, bicarbonate, chloride and sulphate ions ranged from 0.0 to 1.6, 0.0 to 4.0, 1.0 to 16.8 and 0.2 to 14.0 me L-1, respectively. Similarly the cations like Ca2+, Mg2+, Na+ and K+ varied from 2.0 to 15.0, 1.0 to 7.2, 0.59 to 17.98 and 0.0 to 0.8 me L-1, respectively. Out of 52 samples 10 (19.2 %) sample belongs to marginally saline water category (B1) (Table 7).

Pandhana Tehsil: The quality of ground water of Pandhana tehsil revealed that pH, EC, SAR and RSC ranged from 7.15 to 8.70, 0.47 to 3.42 dSm-1, 0.33 to 2.83 and Nil meL-1 respectively (Table 8). Out of 31 samples, 25 (80.6 %) water samples come under good water category “A” . However, 6 (19.4 %) samples fall under marginally saline water category (B1) (Table 7).

Khalwa Tehsil: The quality of ground water samples received from Khalwa tehsil indicated that pH, EC, SAR and RSC range from 7.51 to 8.80, 0.44 to 2.66 dSm-1, 0.35 to 6.66 and Nil meL-1 respectively (Table 8). Out of 23 samples, 22 (95.7 %) water samples come under good water category “A”. However, 1 (4.3 %) samples come under marginally saline water category (B1) (Table 7).

Harsud Tehsil: The pH, EC SAR and RSC ranged from 7.24 to 8.50, 0.42 to 1.09 dSm-1, 0.36 to 4.00 and Nil respectively (Table 8). Carbonate, bicarbonate, chloride and sulphate ions ranged from 0.0 to 1.2, 0.0 to 5.0, 1.0 to 7.0 and 0.8 to 5.0 me L-1, respectively. Similarly the cations like Ca2+ , Mg2+, Na+ and K+ varied from 1.4 to 4.6, 1.0 to 2.6 , 0.60 to 6.32 and 0.0 to 0.6 me L-1, respectively.. All 25 ground water samples belong to good category (A) (Table 7).

Punasa Tehsil: The quality of groundwater of Punasa tehsil indicated that pH, EC, SAR and RSC ranged from 7.30 to 8.45, 0.41 to 2.70 dSm-1, 0.23 to 5.91 and Nil meL-1 respectively (Table 8). Out of 49 samples, 44 (89.8 %) samples belong to good water category 'A', whereas, 5 (10.2 %) ground water sample belongs to marginally saline (B1) category (Table 7).

Frequency distribution of water samples*:*

A ground water survey of the Khandwa district was conducted by Salt Affected Soils Project, College of Agriculture, Indore. 180 ground water samples were collected from different villages of different tehsils of the district. Out of these 180 samples, 158 (87.8 %) belongs to category "A" and 22 (12.2 %) belong to category "B1" (Table 1.32) while salient features of ground water samples of Khandwa district are provided in Table 1.33. Similarly spatial distribution is provided in Fig. 1.18.

Table 1.32 Frequency distribution of water samples into different categories of water quality in Khandwa district

Category	Tehsils					Total
	Khandwa	Pandhana	Khalwa	Harsud	Punasa	
A	42 (80.8)	25 (80.6)	22 (95.7)	25 (100)	44 (89.8)	158 (87.8)
B1	10 (19.2)	6 (19.4)	1 (4.3)	0 (0.0)	5 (10.2)	22 (12.2)
B2	0	0	0	0	0	0
B3	0	0	0	0	0	0
C1	0	0	0	0	0	0
C2	0	0	0	0	0	0
C 3	0	0	0	0	0	0
Total	52	31	23	25	49	180

Figures in parenthesis are percentage of the samples

Table 1.33 Salient Features of ground water samples of Khandwa district

Parameter	Khandwa	Pandhana	Khalwa	Harsud	Punasa
pH	6.80-8.80 (7.90)	7.15-8.70 (7.97)	7.51-8.80 (8.10)	7.24-8.50 (7.95)	7.30-8.45 (8.02)
EC (dSm-1)	0.40-2.68 (1.07)	0.47-3.42 (1.20)	0.44-2.66 (0.86)	0.42-1.09 (0.72)	0.41-2.70 (0.870
CO32-	0.00-1.60 (0.15)	0.00-2.00 (0.15)	0.00-1.20 (0.31)	0.00-1.20 (0.20)	0.00-1.00 (0.08)
HCO3-	0.00-4.00 (1.36)	0.00-7.00 (1.74)	0.00-5.20 (1.40)	0.00-5.00 (1.20)	0.00-4.80 (1.00)
Cl-	1.00-16.80 (5.53)	2.00-22.00 (6.15)	1.60-16.00 (4.21)	1.00-7.00 (3.10)	1.20-14.40 (4.16)
SO42-	0.20-14.00 (3.67)	0.20-14.00 (4.01)	0.40-5.40 (2.63)	0.80-5.00 (2.72)	0.40-11.20 (3.44)
Ca2+	2.00-15.00 (4.87)	2.00-17.60 (5.90)	1.20-12.80 (3.14)	1.40-4.60 (3.14)	1.00-12.00 (4.10)
Mg2+	1.00-7.20 (2.62)	1.00-9.60 (3.35)	0.80-8.00 (1.83)	1.00-2.60 (1.66)	0.40-6.80 (2.08)
Na+	0.59-17.98 (2.97)	0.72-8.85 (2.600	0.50-12.10 (3.47)	0.60-6.32 (2.37)	0.32-14.60 (2.42)
K+	0.00-0.80 (0.17)	0.00-0.90 (0.14)	0.02-0.34 (0.11)	0.00-0.60 (0.10)	0.00-0.24 (0.08)
SAR	0.32-8.57 (1.51)	0.33-2.83 (1.18)	0.35-6.66 (2.27)	0.36-4.00 (1.57)	0.23-5.91 (1.30)
RSC (meL-1)	Nil	Nil	Nil	Nil	Nil

Data in parenthesis are mean values of the parameters

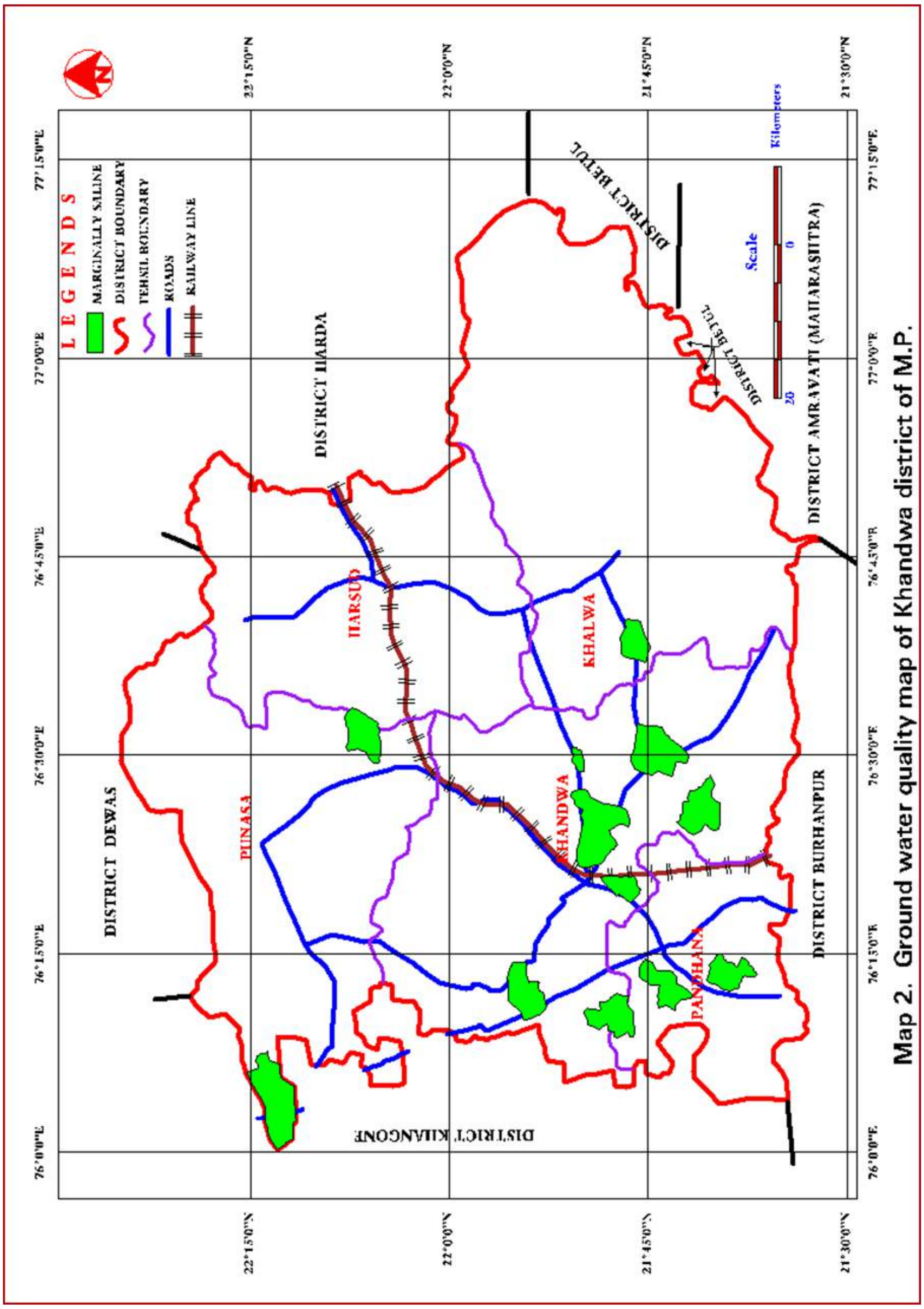


Fig. 1.18 Groundwater quality map of Khandwa district

- **Survey and characterization of underground irrigation water of Kanpur Dehat district of Uttar Pradesh (Kanpur)**

Three hundred fifteen underground irrigation water samples were collected from different villages of Kanpur Dehat district. Out of total samples, 234 samples were collected from Derapur (35), Jhinjhak (32), Maitha (40), Malasa (32), Rajpur (30), Rasulabad (33), Sandalpur (37) and Sarwankhera (27) blocks of the district, respectively. The results of those samples were reported in biennial workshop. Later on, two blocks of Kanpur Dehat namely Akbarpur, Amraudha were studied by analyzing 27 and 22 samples, respectively. Total 315 groundwater samples were analyzed totality.

Results of Akbarpur and Amraudha blocks are given initially and then summary of whole district is provided in Table 1.34.

Block-Akbarpur

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The quality of underground irrigation water samples of Akbarpur block indicate that pH, EC, SAR and RSC ranges from 7.1 to 8.4, 0.37 to 3.29 dSm-1, 0.6 to 10.8 and 0.0 to 7.4 meqL-1 with the mean value of 7.82, 0.97 dSm-1, 2.87 and 0.48 meqL-1 respectively. Most of the water samples belong to good category (20 samples). Out of 27 samples, only five (5) samples come in the category of marginally saline and two (02) of highly saline water. In the water sample chloride is the dominant anion among others anion, whereas calcium is the dominant cation followed by sodium.

Block-Amraudha

The quality of underground irrigation water samples of Amraudha block indicate that pH, EC, SAR and RSC varies from 7.2 to 8.6, 0.34 to 3.28 dSm-1, 0.5 to 9.2 and 0.0 to 2.5 meqL-1 with the mean value of 7.72, 0.95 dSm-1, 3.31 and 0.16 meqL-1, respectively. Out of 22 groundwater samples, 15 samples are falling in good and 05 water samples were found marginally saline categories and two (02) of marginali alkaline. The Na, Ca, Cl and HCO3 are dominant ions in the groundwater samples.

Table 1.34 Salient features of ground water samples of Kanpur Dehat district

Blocks	pH	Mean	EC (dSm-1)	Mean	SAR	Mean	RSC meqL-1	Mean
Akbarpur	7.1-8.4	7.73	0.37-3.29	0.99	0.6-10.8	2.98	0.0-7.4	0.35
Amraudha	7.2-8.6	7.85	0.34-3.28	0.85	0.5-9.2	2.72	0.0-2.5	0.20
Derapur	7.2-8.4	7.84	0.38-3.27	0.98	0.7-10.2	2.85	0.0-7.2	0.49
Jhinjhak	7.4-8.2	7.74	0.32-3.20	0.88	0.6-09.1	3.21	0.0-2.8	0.21
Maitha	7.3-8.5	7.71	0.35-3.26	0.94	0.4-09.3	3.36	0.0-2.6	0.17
Malasa	7.6-8.6	7.81	0.36-3.25	0.95	0.6-10.0	2.97	0.0-7.6	0.48
Rajpur	7.1-8.3	7.75	0.40-4.11	1.01	1.1-10.0	3.01	0.0-2.0	0.13
Rasulabad	7.6-8.0	7.83	0.33-4.06	0.83	0.8-09.0	1.91	0.0-5.2	0.20
Sandalpur	7.5-8.6	7.76	0.37-3.28	0.99	0.7-10.1	2.89	0.0-7.5	0.57
Sarwankhera	7.2-8.2	7.89	0.42-4.10	0.95	1.0-10.2	3.18	0.0-7.3	0.45

Frequency distribution of water samples:

Three hundred fifteen underground irrigation water samples were collected from different villages of Kanpur Dehat district. Out of total samples, 27, 22, 35, 32, 40, 32, 30, 33, 37 and 27 samples were collected from Akbarpur, Amraudha, Derapur, Jhinjhak, Maitha, Malasa, Rajpur, Rasulabad, Sandalpur and Sarwankhera blocks of the district respectively. Out of the 315 samples, 251 (78.68 %) belongs to category good, 47 (14.92 %) belong to category marginally saline, 04 (1.27 %) sample belongs to saline water, 05 (1.59 %) sample belongs to highly saline water, 04 (1.27 %) sample belongs to marginally alkaline, 03 (0.95 %) sample belongs to alkaline and 01 (0.32 %) sample belongs to highly alkaline water (Table 1.35).

Table 1.35 frequency of different categories of groundwater quality of Kanpur Dehat district

Block	Samples	Good	M. Saline	Saline	H. Saline	M. Alkali	Alkali	H. Alkali
Akbarpur	27	20	5	-	2	-	-	-
Amraudha	22	15	5	-	-	2	-	-
Derapur	35	28	6	-	1	-	-	
Jhinjhak	32	26	5	-	-	1	-	-
Maitha:	40	32	7	-	-	1	-	-
Malasa	32	24	5	2	-	-	1	-
Rajpur	30	25	4	-	1	-	-	-
Rasulabad	33	29	2	1	-	-	1	-
Sandalpur	37	30	5	1	-	-	1	-
Sarwankhera	27	22	3	-	1	-	-	1
Total	315	251	47	4	5	4	3	1
Percent	-	79.68	14.92	1.27	1.59	1.27	0.95	0.32

- **Survey and characterization of ground water of Coastal districts of Tamil Nadu for Irrigation (Tiruchirapalli)**

To characterize the ground water quality of Kanyakumari District, 215 water samples (open and bore wells) were collected from different parts of Kanyakumari district. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions (CO3, HCO3, Cl and SO4). 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. Kanyakumari District has 8 blocks viz., Thovalai block, Kuruthencode block, Munchirai block, Thiruvattar block, Kiliiiyur block, Thucklay (Kozhipulai) block, Agastheeswaram block and Rajakamangalam block. Among the 8 blocks, the distribution of 100% good quality ground water samples were observed in Thucklay block followed by Rajakkamangalm (89.7%), Agastheeswaram (80.0 %), Munchirai (81.25 %) and Thiruvattar blocks (80.95 %) (Table 1.36). The good quality water was absent in Thovalai block and almost 73.68 % of ground water samples were saline water. Marginally saline water is also seen in Thovalai block (26.32%), Thiruvarttar block (28.57 %), Munchirai (18.75 %) and Killiyur block (16.66 %). High SAR saline water was found in Agastheeswaram (15%) and Rajakamangalam block only (10.3%). Alkali water was almost absent in all the blocks. Out of the total samples collected from Kanyalumari district, 73.02% is coming under good quality, 12.57 % is marginally saline, 14.81% is saline water and 3.16 % is under high SAR saline categories.

Table 1.36 Quality of ground waters in different blocks of Kanyakumari District

Blocks	pH		EC (dSm-1)		RSC (meq. l-1)		SAR	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Agastheeswaram	7.35 -8.56	7.95	0.6-5.59	1.89	Nil-1.98	0.71	1.41-13.4	5.7
Rajakamangalam	7.52-8.24	8.02	0.2-5.91	1.25	Nil-1.12	0.15	0.12-11.0	4.04
Thucklay (Kozhipulai)	7.46-8.64	8.03	0.25-1.73	0.864	Nil-0.25	0.02	0.81-4.73	2.07
Killiyur	7.17-8.23	7.91	0.12-6.83	1.14	Nil-1.55	0.32	0.24-8.46	1.58
Thiruvattar	7.85-8.36	8.10	0.08-3.61	0.73	Nil-1.15	0.34	0.03-3.87	1.23
Munchirai	7.57-8.23	7.97	0.48-3.21	1.34	Nil-1.25	0.42	0.92-4.28	2.23
Kuruthencode	7.97-8.51	8.16	0.12-4.16	3.70	Nil-1.98	0.75	0.15-5.85	2.60
Thovalai	7.37-8.62	8.19	2.56-5.71	4.36	Nil-1.98	0.97	2.58-7.54	5.35

The range of pH, EC, SAR and RSC characters are presented in Table. 1.36.The maximum EC 6.83 dS/m was recorded in Killiyur block followed by 5.91 dS/m in Rajakamangalam block and 5.71 dS/m in Thovalai block. The RSC value of all the water samples are below 2.5 (meq L-1) indicating there is no alkali water in Kanyakumari district.The highest SAR of 13.4(mmol/L) was seen in Agastheeswaram block followed by Rajakamangalam block (11.00 mmol/L)) in Kanyakumari district. Spatial distribution of EC and pH, SAR and groundwater quality distribution in Kanyakumari district are provided in Fig. 1.19, 1.20 and 1.21, respectively.

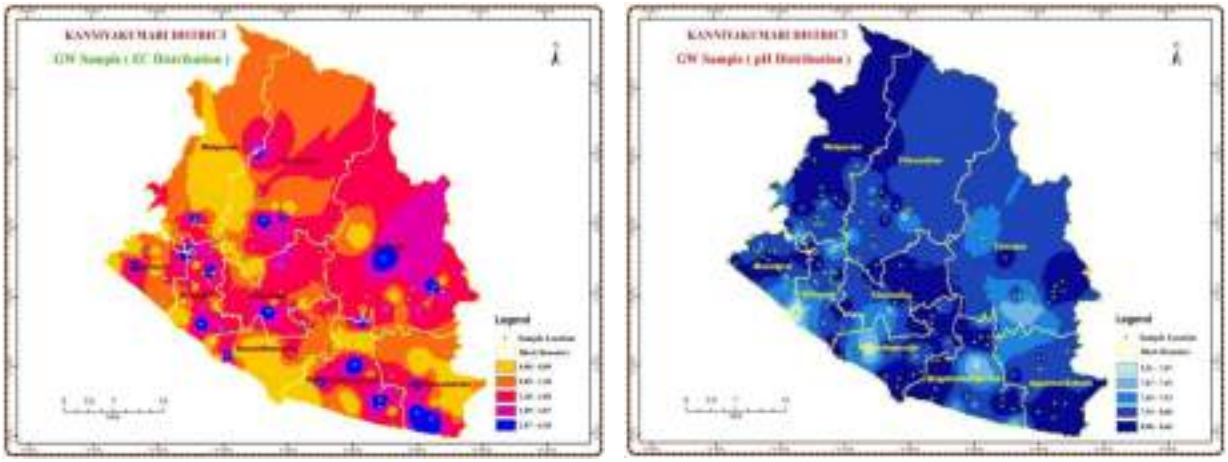


Fig. 1.19 Spatial distribution of a) Ground water EC and b) Groundwater pH in Kanyakumari district (TN)

Fig. 1.20 Spatial Distribution of groundwater SAR in Kanyakumari district (TN)

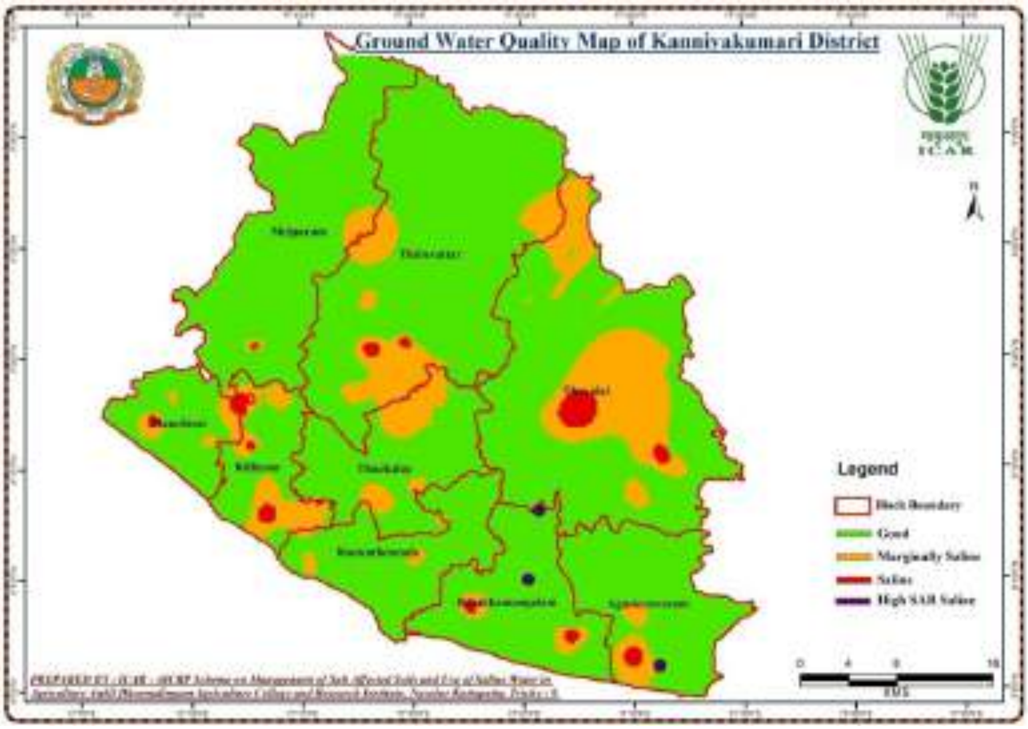


Fig. 1.21 Spatial distribution of Groundwater quality in Kanyakumari district (TN)

The distribution of water samples in different water quality classes (Table 1.37) reveals that the samples of good quality underground irrigation water was found in almost all the blocks Thucklay (100%), Rajakamangalam (89.7%) Munchirai (81.25%) Thiruvattar (80.95 %), Kuruthencode (73.7%) except Thovalai block. Thovalai block in Kanyakumari district is seen with saline water (73.68 %) and marginally saline water (26.32%). In case of Kanyakumari district, Good quality water is present in 73.02% area, Marginal saline water in 12.57% area, saline water in 14.81% area and High SAR Saline in 3.16% area.

Table 1.37 Distribution of water samples in different water quality category in Kanyakumari district

S.No	Block	No. of samples	Good (%)	MS (%)	Saline (%)	HSS (%)	MA (%)	Alkali (%)	HA (%)
1.	Agastheeswaram	20	80.0	5.00	-	15.0	-	-	-
2.	Rajakamangalam	39	89.7	-	-	10.3	-	-	-
3.	Thucklay (Kozhipulai)	39	100.0	-	-	-	-	-	-
4.	Killiyur	42	78.57	16.66	4.76	-	-	-	-
5.	Thiruvattar	21	80.95	28.57	19.05	-	-	-	-
6.	Munchirai	16	81.25	18.75	-	-	-	-	-
7.	Kuruthencode	19	73.7	5.26	21.05	-	-	-	-
8.	Thovalai	19	-	26.32	73.68	-	-	-	
	Total	215	-	-	-	-	-	-	
	Average		73.02	12.57	14.81	3.16	-	-	-

MS= Marginal Saline, HSS= High SAR Saline; MA= Marginal Alkali, HA=High Alkali

The relationship between electrical conductivity (EC) with anionic and cationic composition of irrigation waters, sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were studied. In general, the distribution of cations followed the order of Ca, Mg >Na > K. Similarly the distribution of anions followed the order of HCO3>Cl>SO4 when the irrigation water quality is good (EC < 2 dSm^{-1}). But the distribution of anions followed the order of Cl>HCO3>SO4 in the EC range of 2 to 4 dS/m and Cl > CO3> HCO3> SO4 in the EC range >4.0 dS/m (Table 1.38).

Table 1.38 Cationic and Anionic distribution in ground water samples of Kanyakumari district

Blocks	Cationic order	Anionic order
Agastheeswaram	Ca>Mg>Na>K	HCO3> Cl > CO3 > SO4
Rajakamangalam	Na>Ca>Mg>K	HCO3> Cl > CO3 > SO4
Thucklay (Kozhipulai)	Ca>Na>Mg>K	CO3> HCO3> Cl > SO4
Killiyur	Ca>Mg>Na>K	HCO3> Cl > CO3 > SO4
Thiruvattar	Ca>Mg>Na>K	HCO3> Cl > CO3 > SO4
Munchirai	Na>Ca>Mg>K	HCO3> Cl > CO3 > SO4
Kuruthencode	Ca>Mg>Na>K	CO3> HCO3> Cl > SO4
Thovalai	Ca>Mg>Na>K	Cl > CO3> HCO3> SO4

The distribution of ground water samples in different EC, SAR and RSC classes are presented in Table.5.According to EC classes, more than 75% of the collected ground water samples were found in classes of 0 -1.5 dS/m-1.All the ground water samples collected from Kanyakumari district were having RSC <2.5 m.eq/l. In case of SAR classes, more than 90 % of ground water samples were found in 0-10 classes.

- **Survey and characterization of underground irrigation water of Bathinda, district, Punjab (Bathinda)**

The groundwater survey of Maur, Nathana, Bhagta Bhai Ka and Rampura blocks of Bathinda district was carried out. Total 34 samples from Maur, 39 from Nathana, 36 from Bhagta Bhai ka and 9 from Rampura block were collected and analysed for chemical properties/constituents. The results are presented in Table 1.39. The electrical conductivity (EC) of samples ranged 0.38-6.5, 0.48-3.5, 1.3-3.5 and 1.3-4.2 dSm^{-1} in Maur, Nathana, Bhagta Bhai Ka and Rampura blocks, respectively. Bhagta Bhai Ka and Rampura blocks contain higher RSC as compared to Maur and Nathana blocks. The Ca^{+2}+Mg^{+2} was higher in Maur block and lower in Bhagta Bhai ka.

Table 1.39 Range and average value of different chemical constituents of ground water in different blocks of Bathinda

Name of Blocks		Maur (34)*		Nathana (39)		Bhagta Bhai ka (36)		Rampura (9)	
Parameter		Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.
pH		7.4-8.9	7.9	8.2-9.4	8.6	7.4-8.8	8.6	7.6-8.8	8.5
EC	dSm^{-1}	0.38-6.5	3.2	0.48-3.5	2	1.3-3.5	1.8	1.3-4.2	2.4
Ca^{+2} +Mg^{+2}	meL^{-1}	3.3-26.4	9.5	1.7-9.3	5	3.1-9.5	4.8	3.5-10.5	6
Cl^{-1}		2.0-28.6	10.4	0.2-5.0	2.5	0.7-7.2	2.2	1.8-12.8	4.4
CO_3^{-2}		0.0-0.20	0.2	0.0-0.10	0.1	0.1-0.3	0.2	0.2-0.3	0.2
HCO_3^-		2.6-10.6	5.3	2.0-8.6	5.7	3.0-10.4	6.8	2.8-9.6	7.2
RSC		0.0-6.1	1	0.0-4.0	1	0.0-5.9	2.3	0.0-5.8	2.3

*Values in parenthesis are number of water samples

The percent distribution of water samples, in different ranges of electrical conductivity (EC) are given in Table 1.40. The EC of majority of samples i.e. Maur (18%), Nathana (54%), Bhagta Bhai Ka

(72%) and Rampura (33%) block was less than 2 dSm^{-1}. Whereas, 62% in Maur, 46% in Nathana, 28% in Bhagta Bhai Ka and 56% in Rampura blocks were between 2 to 4 dSm^{-1} and rests was more than 4 dSm^{-1}. On basis of EC, we can say that only 44% water samples could be used for irrigation without any possible risk of soil salinization. Further, 48% water samples having marginal EC (2 to 4 dSm^{-1}) and 8% samples were not suitable for irrigation.

Table 1.40 Block-wise percent distribution of water samples in various categories with respect to electrical conductivity

EC (dSm^{-1} at 25º C)	Percent distribution				
	Maur (34)*	Nathana (39)	Bhagta Bhai ka (36)	Rampura (9)	Average
< 2.0	18	54	72	33	44
2.0-4.0	62	46	28	56	48
> 4.0	21	0	0	11	08

The distribution of water samples in different ranges of residual sodium carbonate (RSC) are mentioned in Table 1.41. It is reported that 79, 85, 47 and 56% water samples have RSC less than 2.5 me L^{-1}; 18, 15, 50 and 33 % of water samples showed RSC between 2.5-5.0 me L^{-1} in the Maur, Nathana, Bhagta Bhai Ka and Rampura blocks, respectively. Overall on the basis of RSC, 67% water samples is safe (RSC, <2.5 meL^{-1}), 29% water is marginal (RSC, 2.5-5.0 meL^{-1}) and 4% water is unsuitable for irrigation (RSC, > 5.0 meL^{-1}).

Table 1.41 Block-wise percent distribution of water samples in various categories with respect to residual sodium carbonate (RSC)

RSC (meL^{-1})	Percent distribution				
	Maur (34)*	Nathana (39)	Bhagta Bhai ka (36)	Rampura (9)	Average
< 2.5	79	85	47	56	67
2.5-5.0	18	15	50	33	29
>5.0	3	-	3	11	4

- **Estimation of fluoride in underground water of Bathinda, district, Punjab (Bathinda)**

The groundwater samples from Bathinda, Sangat, Talwandi Sabo, Maur, Nathana, Rampura, Phul and Bhagta Bhai Ka blocks of Bathinda district were collected and analysed for fluoride contents. The fluoride distribution in ground water of Bathinda district is presented in Table 1.42. Fluoride content ranged from 0.10 - 5.0 mg L^{-1}, 0.23 - 2.92 mg L^{-1}, 0.06 - 3.74 mg L^{-1}, 0.20 -3.70 mg L^{-1}, 0.22 - 2.89 mg L^{-1}, 0.31 - 3.49 mg L^{-1}, 0.06 - 1.86 mg L^{-1} and 0.17 - 2.89 mg L^{-1}, in Bathinda, Sangat, Talwandi Sabo, Maur, Nathana, Rampura, Phul and Bhagta Bhai Ka blocks, respectively. The maximum fluoride content was reported in Bathinda followed by Talwandi sabo and Maur blocks. The minimum fluoride content reported in Phul block. Among the all blocks average fluoride concentration was highest in Talandi sabo block followed by Bathinda block. Overall the average concentration of fluoride in Bathinda, Talwandi Sabo and Bhagta Bhai Ka blocks were higher than safe limit (<1.5 mg L^{-1}). Overall, about half of the samples falls within safe limit (<1.5 mgL^{-1}), in which 26.6% samples having fluoride less than 1.0 mgL^{-1}, and 23.9 % samples having fluoride between 1.0-1.5 mgL^{-1}. Whereas, 49.5% samples having fluoride beyond permissible limits (>1.5 mgL^{-1}) (WHO, 1994).

Table 1.42 Block wise distribution of fluoride (mg/L) in Bathinda district

Blocks	No. of Samples	Minimum	Maximum	Average	Distribution of samples (%)		
					Safe	Margin	Unsafe
Bathinda	93	0.10	5.00	2.10	21	12	67
Sangat	59	0.23	2.92	1.44	24	30	46
Talwandi sabo	94	0.06	3.74	2.23	9	13	78
Maur	34	0.20	3.70	1.40	44	21	35
Nathana	39	0.22	2.89	1.42	18	33	49
Rampura	09	0.31	3.49	1.40	22	45	33
Phul	10	0.06	1.86	0.81	60	20	20
Bhagta Bhai Ka	36	0.17	2.89	1.63	14	17	69

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

This project was planned to study the chemical composition of ground water as influenced by seawater/ brackish water intrusion, to assess the ground water quality for irrigation and to prepare geo-referenced map of ground water quality for affected areas of Kerala. The whole study area falls under eleven districts of Kerala viz. Thiruvananthapuram, 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. To assess the ground water quality of study area, samples were analyzed for pH, electrical conductivity, carbonate, bicarbonate, chloride, sulphate, sodium, potassium, calcium, magnesium, boron, SAR and RSC. Total thirty-eight ground water samples from Thiruvananthapuram district; 17 from Kottayam district; 21 from Kollam district and 5 from Pathanamthitta district were collected. The survey of Pathanamthitta district was completed by collecting the ground water samples from the areas near to backwaters. Other locations in the district are midlands, miduplands and forest and there is no chance of saline water intrusion into these areas. The latitude and longitude details of sampling sites were also collected. Details of chemical properties are described here.

Thiruvananthapuram district

The analytical data showed that pH values of water samples ranged from 5.7 to 7.2 while EC values ranged from 0.10 to 4.2dS m^{-1}. Potassium content of water samples ranged from 1.32 to 7.7 me L^{-1}. Carbonate and bicarbonate values ranged from 1.1 to 3.8 and 0.4 to 3.6 me L^{-1} respectively. Chloride values ranged from 0.26 to 0.77 me L^{-1}. Nitrate values ranged from 0.1 to 15.4 me L^{-1}. Calcium and magnesium content ranged from 2.697 to 205.10 and 0.98 to 7.14 me L^{-1} respectively. Iron and zinc content ranged from 0.077 to 0.178 and 0.047 to 1.85 ppm respectively. Sulphur, copper and manganese contents were not in detectable level. Mg/Ca ratio ranged from 0.034 to 1.448. The highest value of SAR was 7.736 and lowest value was 1.354. RSC of water samples ranged from 0.0 to 0.924 me L^{-1}. Out of 38 samples, 1 sample is under marginally saline; 3 samples are saline and remaining samples of good quality. As per pH range ground water is slightly acidic to normal.

Kottayam district

The analytical data of the Kottayam district showed that pH values of water samples ranged from 5.7 to 7.4 while EC values ranged from 0.23 to 5.1 dS m^{-1}. Potassium content of water samples ranged from 1.05 to 2.301 me L^{-1}. Carbonate and bicarbonate values ranged from 1.1 to 1.8 and 0.12

to 1.5 me L^{-1} respectively. Chloride values ranged from 4.55 to 14.13 me L^{-1}. Sodium values ranged from 59.2 to 134.2me L^{-1}. Calcium and magnesium content ranged from 32.32 o 132.6 and 0.146 to 2.09 me L^{-1}respectively. Iron and zinc content ranged from 0.067 to 0.178 and 0.012 to 0.133 ppm respectively. Copper and manganese contents were found in range of 0.007 to 0.133 and 0.88 to 4.649 ppm respectively. Mg/Ca ratio ranged from .0018 to 0.328. The highest value of SAR is 30.362 and lowest value is 9.924. RSC was absent. Out 17 samples, 13 samples have EC less than 2 dS/m; 3 samples have EC more than 2 dS/m while 1 sample has EC more than 5.1 dS/m. Thus, 3 samples are maginally saline and 1 is high SAR saline. Remaining samples are good.

Pathanamthitta district

The survey of Pathanamthitta district was completed by collecting the ground water samples from the areas near to backwaters. Other locations in the district are midlands, miduplands and forest and there is no chance of saline water intrusion into these areas. The analytical data showed that pH values of water samples ranged from 6.3 to 7.08 while EC values ranged from 0.15 to 0.50 dS m^{-1}. Potassium content of water samples ranged from 24.42 to 51.24 ppm. Carbonate and bicarbonate values ranged from 0.8 to 1.4 and 1.1 to 4.6 me L^{-1} respectively. Chloride values ranged from 0.30 to 0.579 me L^{-1}. Sodium values ranged from 2.23 to 6.21me L^{-1}. Calcium and magnesium content ranged from 1.55 to 4.33 and 0.03 to 0.094 me L^{-1} respectively. Iron and zinc content ranged from 0.0 to 0.229 and 0.009 to 0.081 ppm respectively. Copper and manganese contents ranged from 0.093 to 0.193 and 0.28 to 0.380 ppm respectively. Mg/Ca ratio ranged from 0.0019 to 0.0221. The highest value of SAR is 2.184 and lowest value is 0.7765. RSC of water samples ranged from 0.0 to 1.131 me L^{-1}. All samples of good quality.

Kollam district

The analytical data of the Kollam district showed that pH values of water samples ranged from 5.4 to 7.2 while EC values ranged from 0.5 to 3.9 dS m^{-1}. Potassium content of water samples ranged from 22.5 to 107.1 ppm. Carbonate and bicarbonate values ranged from 0.4 to 3.2 and 0.1 to 2.5 me L^{-1} respectively. Chloride values ranged from 0.2 to 1.7 me L^{-1}. Sodium values ranged from 12.9 to 78me L^{-1}. Calcium and magnesium content ranged from 0.09 to 16.03 and 0.03 to 0.62 me L^{-1} respectively. Iron and zinc content ranged from .0049 to 0.063 and 0.068 to 1.08 ppm respectively. Copper and manganese contents were found in lowest range with 0.004 to 0.106 and 0.112 to 0.7005 ppm respectively. The Mg/Ca ratio in the samples ranged from 0 to 0.3. The highest value of SAR is 109.40 and lowest value is 2.23. The RSC of water samples ranged from 0.0 to 0.98 me L^{-1}. There are few samples with saline and having high SAR. Remaining samples are of good quality.

In Thiruvananthapuram district, water samples from Vizhinjam, Kovalam beach and Kappilkayal were coming under saline category (7.89%) and Varkala beach under marginally saline category. Almost 89.4% samples were of good category and 2.6% samples belonged to marginally saline category. Water samples were having SAR in Kottayam district except the sample collected from Kudavechoor which was good for irrigation purpose. Ground water sample from Murinjapuzha was saline in nature. In Kollam, 52.38 per cent of the samples were having high SAR whereas 94.11 per cent in Kottayam. It is important to note only few samples were having high EC (>4 dS/m) and high SAR (>10). For remaining samples, EC was below 2 dS/m, RSC was absent. SAR in Kollam and Kottayam was high but as EC was less. Hence groundwater is good for irrigation in general. Again these districts receive lot of rainfall which helps for reaching. On comparing the boron content of ground water samples of Thiruvananthapuram, Kottayam, Kollam and Pathanamthitta district it was observed that all samples came under safe category for irrigation. There was no RSC in groundwater in all samples of four districts. Similarly, Mg/Ca ratio was also found to be under safe levels. Salinity can be reduced to a certain level by adoption of proper management techniques such as mixing up of saline water with fresh water/rain water, rainwater harvesting, use of surface or sub-surface drainage systems, bunds to prevent the intrusion of saline water, etc.

2. MANAGEMENT OF SALT AFFECTED SOILS

2.1 Management of Alkali Soils

- **Reclamation of Abandoned aqua ponds in Coastal Andhra Pradesh (Bapatla)**

The reclamation abandoned aqua pond was undertaken by centre to provide relief to small and marginal farmers who have gave up shrimp farming. The package consists of Selection of site (abandoned aqua ponds of small and marginal farmers (of < 5 acres) with good irrigation facility were selected); Leveling of aqua ponds; Preparation of field channels; Application of gypsum; Leaching of soluble salts; Incorporation of green manure; Increasing plant population to 150%; Application of 50% extra dose of N than recommended dose.

The experiment was carried out in 10 farmer's fields at Nizampatnam, Guntur district during kharif, 2016-17 in the soils having the pH ranging from 7.9 to 8.5 and ECe ranging from 30 to 74 dS m-1, low in available N, medium in available P and high in K (Table 2.1).

Table 2.1 Initial soil properties of identified fields at Nizampatnam

Farmer	pH (1:2)	ECe (dS m-1)	Available Nutrients (kg ha-1)		
			N	P2O5	K2O
Sri. M. Venkateswarlu	8.1	45.0	272	29.3	1512
Sri.K.Naghabhusanam	8.4	52.0	105	26.7	1543
Sri. S.Basavaiah	8.5	43.0	209	23.3	1073
Sri. P. Babu	8.3	49.0	125	21.4	1052
Sri. M.Verraju	8.0	29.0	230	26.8	783
Sri. K.Danamurthy	8.3	74.0	251	32.7	1249
Smt. K. Kanakadurga	8.4	62.0	230	22.7	1120
Sri. K.Mallikharjuna Rao	8.5	59.0	230	30.0	1271
Sri. K.Jagan Mohana Rao	8	30.0	251	28.4	947
Sri. P. Jagan Mohana Rao	7.9	48.0	230	57.9	1042

Due to unfavourable conditions the technical programme could be implemented at two locations. Reclamation practices viz. leveling, application of gypsum, leaching the soluble salts with fresh water 2-3 times, in-situ incorporation of green manure (dhaincha) at 50 % flowering stage were adopted in selected fields. Rice variety, MTU-1010 was taken as test variety. The recommended dose of fertilizers (180:40:40 N, P2O5 and K2O kg ha-1, respectively and basal application of ZnSO4 @ 50 kg ha-1) was applied. Considerable reduction in salinity of the soil was observed in both the fields at harvest of the crop (Table 2.2).

Table 2.2 Physico-chemical properties and fertility status of soils of different farmers at harvest of crop in Nizampatnam

Farmer	pH (1:2)	ECe (dS m-1)	Available Nutrients (kg ha-1)		
			N	P2O5	K2O
Sri. P. Babu	7.8	9.5	188	42.3	908
Sri. M.Verraju	8.3	5.2	212	52.0	736

The yield obtained in the fields of Sri P Babu and Sri M Verraju were 5231 and 5269 kg ha-1, respectively (Table 2.3).

Table 2.3 Biometric observations and yield of rice crop in Nizampatnam

Farmer	Pant height (cm)	No of tillers per hill	No of productive tillers per hill	Grain (kg ha-1)	Straw (kg ha-1)
Sri. P. Babu	77.5	16.0	14.0	5231	5362
Sri. M.Verraju	86.5	13.6	13.6	5269	5663
Check	75.0	13.0	11.0	4459	4675

- **Effect of chemical and organic amendments in reclamation of Saline-sodic soils under rice (Bapatla)**

The purpose of experiment was to study response of paddy crop to chemical and organic amendments and to assess their effect on soil properties. Details of experiment are as given below.

Treatments	Site of experiment	:	Nizampatnam
1.Biocompost @ 4t ha-1 + gypsum @ 50% GR	Season	:	Kharif, 2016
2. Biocompost @ 4t ha-1.	Crop	:	Paddy (BPT 5204)
3. Gypsum @ 50% GR	Design	:	RBD
4. Farmers practice	Replications	:	4

The experiment was conducted at Narravaripalem during kharif, 2016. Biocompost @ 4t ha-1 and gypsum were applied to the field. Application of biocompost @ 4t ha-1 along with gypsum recorded higher yield (5000 kg ha-1) over biocompost treatment (4630kg ha-1) (Table 2.4).

Table 2.4 Effect of bio-compost and gypsum application on yield of rice crop

Treatment	Yield (kg ha-1)	
	Grain	Straw
Boicompost @ 4t ha-1 + Gypsum @ 50 GR	5000	5700
Boicompost @ 4t ha-1	4630	5100
Gypsum @ 50% GR	4520	4820
Farmers practice	3600	3790

Soil pH at the harvest of the crop showed a decline to 8.2 from initial 8.6 when biocompost was applied along with gypsum while it was 8.4 when biocompost was applied alone. Available nutrient status declined after the crop against initial due to crop removal, the depletion was more with integrated application of biocompost and gypsum which resulted in highest yield of 5000 kg ha^{-1} (Table 2.5).

Table 2.5 Effect of biocompost on soil properties

Name of the Farmer	pH	ECe (dS m-1)	Available nutrients (kg ha-1)			OC %
			N	P2O5	K2O	
Boicompost @ 4t ha-1 + Gypsum @ 50 GR	8.20	4.3	135	25	989	0.38
Boicompost @ 4t ha-1	8.4	4.1	148	27.1	1050	0.38
Gypsum @ 50% GR	8.31	4.0	130	26.6	880	0.36
Farmers practice	8.6	5.6	124	20.4	678	0.30
Initial	8.6	4.6	146	28.2	1130	0.44

The lowest pH of 8.2 at harvest of paddy was observed when Biocompost @ 4t ha-1 + gypsum @ 50 GR with EC of 4.3 dS m-1 against pH and EC 8.6 and 5.6 dS m-1 when farmers practice was adopted.

- **Studies on performance of safflower in alkali soils with different agronomic management practices (Bapatla)**

At Alakapuram experimental site, initial soil was found to have a pH of 9.6 and EC of 5.6 dS m^{-1}. At harvesting stage, the application of FYM + Gypsum application + 25% extra recommended dose of nitrogen fertilizer treatment recorded significantly the lowest pH (8.0) when compared to farmers practice and it was on par with all other treatments (Table 2.6). Electrical conductivity also followed the same trend.

Table 2.6 Influence of different management practices on soil pH and EC of safflower in alkali soils

Treatments	Harvesting	
	pH	EC (dS m^{-1})
T1- Farmers practice	8.8	11.8
T2- Gypsum application	8.2	7.0
T3- FYM + Gypsum application	8.2	7.1
T4- Gypsum application + 25% extra recommended dose of nitrogen fertilizer	8.1	7.3
T5-FYM+ Gypsum application + 25% extra recommended dose of nitrogen fertilizer	8.0	7.6
SEm +	0.3	0.6
CD(0.05)	0.5	1.8
CV (%)	5.1	16.2

The treatment supplied with gypsum + FYM + 25% extra nitrogen treatment recorded significantly the highest seed (1114 kg ha^{-1}) and biological yield (2477 kg ha^{-1}) when compared to all other treatments and the lowest seed yield (530 kg ha^{-1}) was recorded in farmers practice (Table 2.7) and biological yield (1111 kg ha^{-1}).

Table 2.7 Influence of different management practices on yield of safflower in alkali soils

Treatments	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index
T1- Farmers practice	530	1111	47.7
T2- Gypsum application	639	1588	40.2
T3- FYM + Gypsum application	882	1800	49.0
T4-Gypsum application + 25% extra recommended dose of nitrogen fertilizer	906	1944	46.6
T5- FYM+ Gypsum application + 25% extra recommended dose of nitrogen fertilizer	1114	2477	44.9
SEm+	23	45	
CD(0.05)	71	136	
CV(%)	6	5	

- **Evaluation of distillery spent wash as an amendment for reclamation of sodic soils of TBP command (Gangavathi)**

Distillery spent wash (DSW) a bio-product of alcohol industry is gaining its importance in the reclamation of non-saline sodic soils as it is highly acidic and contains fairly good amount of Ca, Mg and other essential plant nutrients Information is lacking on use of DSW as an organic amendment for sodic soils of North Karnataka where heavy textured (clay/clay loam) soils are prominent. Hence, a field experiment was conducted to optimize the dose of DSW and NPK levels for the reclamation of a sodic soil and to assess its effect on performance of paddy. Hence, a field experiment was conducted to study the effect of distillery spent wash (DSW) on reclamation of a sodic soil and performance of paddy during Kharif 2014 and its residual effect during Kharif 2015 and 2016.

Prior to imposition of treatments soil samples were collected randomly from the experimental site and analyzed for basic properties. The surface soil (0-15 cm) pH, ECe and ESP of the experimental site varied from 8.61 to 8.93, 0.82 to 2.82 dS/m and 19.3 to 24.8 with a mean value of 8.82, 1.32 dS/m and 21.3 respectively. The organic carbon content, available N, P2O5, K2O contents were 0.56%, 213, 55 and 310 kg ha-1 respectively. With regard to the mean Zn, Fe, Mn and Cu contents in surface soil were 0.51, 3.1, 2.0 and 0.75 ppm respectively. The B.D. of surface soil varied from 1.31 to 1.40 Mgm-3 with a mean value of 1.33 Mgm-3. At sub-surface soil (15-30 cm), the mean pH, ECe, Org.C, ESP and BD was 8.91, 1.68, 0.48, 23.2% and 1.38 Mgm-3. At 30-60 cm soil depth, the mean pH, ECe, Org.C, and ESP was 9.02, 1.73, 0.29, and 21.2% respectively. The characterization of DSW revealed that its pH was acidic i.e., 3.7 with EC of 31.6 dS/m. The NPK contents were 5850, 210 and 14700 mg lit-1. With regard to secondary nutrients, Ca, Mg, S and Na contents were 6377, 3600, 2250 and 385 mg lit-1 respectively. The BOD, COD, TDS, total suspended solids and Cl values of DSW were found to be 38500, 96500, 81500, 28200 and 9285 mg lit-1 respectively. The Zn, Fe, Mn and Cu contents were 7, 85, 13.6 and 5.8 mg lit-1.

The required quantity of DSW was applied to the plots as per the treatments in May 2014. The treatment details are as below.

Main plot:	Sub plot	Other details
(DSW @ Lakh lit/ha)	(Levels of NPK)	
M_1- 0	F_1-75% RDF	Design : Split plot;
M_2- 1	F_2- 100% RDF	Replication: 3;
M_3- 1.5	F_3- 125% RDF	Season : Kharif 2014 & Kharif 2015
M_4- 2.0		Crop: Paddy (BPT-5204)
M_5- 2.5		Plot size:5 x 5 m
M_6- 3.0		Season: Kharif 2014, 2015 and 2016

During Kharif 2014, paddy crop was taken and in Kharif 2015 & 2016 the experiment was continued to study the residual effect of raw spent wash application on soil properties and crop performance. At its physiological maturity, data on plant height, number of tillers/hill, panicle length, test weight, grain and straw yields were recorded.

The treatment M6 (3.0 lakh lit/ha) had significantly lower pH (7.66) compared to M1 (control), M2 (1.0 lakh lit/ha) and M3 (1.5 lakh lit/ha) but at par with M4 (2.0 lakh lit/ha) and M5 (2.5 lakh lit/ha). Similar to Kharif 2014, soil ECe was found to be significantly higher at M6 (6.02 dS/m) compared to rest of the treatments with the least change in M1 (1.44) compared to its initial value of 1.32 dS/m. Soil organic carbon content increased significantly with M6 (1.12%) compared to rest of the treatments except M5. Though not much differences were observed compared to Kharif 2014, the treatment M6 had significantly lower ESP (10.0) compared to M1, M2, M3 and M4 but was at par with M5 (10.6). Soil B.D. was significantly lower under M5 (1.05 Mgm-3) compared to M1, M2, M3 and M4 but at par with M6 (1.10 Mgm-3).

During Kharif 2016 where the residual effect of application of DSW on soil properties and crop performance was assessed, growth, yield attributes and yield followed similar pattern as that of Kharif 2014 and 2015 (Table2.8).

Table 2.8 Plant height, yield attributes and grain and straw yield of paddy as influenced by the treatments during Kharif 2016.

Treatment	Plant ht (cm)	No. of Tillers/hill	Panicle length (cm)	Test weight (g)	Grain yield (qt/ha)	Straw yield (qt/ha)
M1	81.1	13.6	13.0	12.59	3639	4299
M2	87.4	16.6	16.1	14.31	4286	5205
M3	90.7	19.5	17.3	14.79	4623	5784
M4	99.6	21.7	18.0	14.83	5103	6287
M5	100.9	21.1	18.2	14.93	5298	6427
M6	100.0	20.3	17.8	14.85	5165	6769
N1	91.9	17.8	16.1	14.19	4551	5554
N2	93.1	18.6	16.9	14.50	4713	5858
N3	94.9	19.9	17.2	14.46	4794	5973
Main Plot						
SEm	0.89	0.61	0.50	0.29	907	119.6

CD0.05	2.79	1.93	1.58	0.92	285.8	376.9
Sub Plot						
SEm	0.67	0.28	0.17	NS	51.5	72.1
CD0.05	1.95	0.83	0.50		150.2	210.4
M x S	NS	NS	NS	NS	NS	NS

Significantly higher grain yield was observed with M5 (5298 kg/ha) compared to M1, M2 and M3 but was on par with M4 (5103 kg/ha) and M6 (5165 kg/ha). The N3 (125% N) had significantly higher grain yield (4794 kg/ha) compared to N1 (75%) but was on par with N2 (100%). The straw yield was significantly higher at M6 (6769 kg/ha) compared to M1, M2 and M3 but was on par with M4 and M5. The N3 had significantly higher straw yield (5973 kg/ha) compared to N1 but was on par with N2. The interaction effects on grain and straw yield were non-significant. Plant height was significantly higher under M5 (100.9 cm) compared to M1, M2 and M3 but at par with M4 and M5 during Kharif 2016. Among nitrogen levels, N3 had significantly higher plant height (94.9 cm) compared to N1 but at par with N2. Number of tillers per hill was significantly higher under M4 (21.7) compared to M1, M2 and M3 but at par with M5 and M6. Among N levels, N3 had significantly higher number of tillers per hill (19.9) compared to N1 but at par with N2 (18.6). Panicle length was significantly higher under M5 (18.2 cm) compared to M1 and M2 but at par with M3, M4 and M6. Among N levels N3 (17.2 cm) had significantly higher panicle length compared to N1 but at with N2. With regard to the test weight, M5 had significantly higher test weight (14.93) compared to M1 only. For all these parameters, interaction effects were non-significant.

Pooled analysis over three Kharif seasons (Table 2.9) revealed that significantly higher grain yield with M5 (5244 kg/ha) compared to M1, M2 and M3 but was on par with M4 (5040 kg/ha) and M6 (5155 kg/ha). The N3 (125% N) had significantly higher grain yield (4798 kg/ha) compared to N1 (75%) but was on par with N2 (100%). The straw yield was significantly higher at M6 (6841 kg/ha) compared to M1, M2 and M3 but was on par with M4 and M5. The N3 had significantly higher straw yield (6175 kg/ha) compared to N1 but was on par with N2. The interaction effects on grain and straw yield were non-significant. Plant height, no. of tillers/hill, panicle length and test weight were also positively influenced due to application of DSW.

Table 2.9 Pooled analysis of plant height, yield attributes and grain and straw yield of paddy as influenced by the treatments.

Treatment	Plant ht (cm)	No. of Tillers/hill	Panicle length (cm)	Test weight (g)	Grain yield (qt/ha)	Straw yield (qt/ha)
M1	81.2	13.2	13.2	12.66	3729	4397
M2	87.0	16.2	15.7	14.68	4301	5377
M3	91.2	18.9	16.9	14.61	4668	6005
M4	99.1	21.4	18.0	14.64	5040	6482
M5	99.7	20.9	18.2	14.75	5244	6722
M6	98.9	20.6	17.8	14.51	5155	6841
N1	91.6	17.6	16.1	14.26	4555	5707
N2	92.8	18.5	16.7	14.27	4716	6030

N3	94.3	19.5	17.1	14.39	4798	6175
Main Plot						
SEm	0.49	0.36	0.16	0.23	68.72	131.79
CD0.05	1.53	1.14	0.51	0.71	216.55	415.3
Sub Plot						
SEm	0.28	0.15	0.11		33.00	73.61
CD0.05	0.81	0.45	0.31	NS	96.33	214.9
M x S	NS	NS	NS	NS	NS	NS

Based on the results on soil and crop data it could be thus inferred that application of DSW @ 2.0 lakh/ha is beneficial for increasing grain yield to the extent of 35% for soils and crop under investigation as compared to control.

- **Effect of long-term application of organic/ green manures at different soil ESP in sodic Vertisols (Indore)**

This experiment was initiated to find out effect of various green manuring crops on physico-chemical properties of sodic Vertisols including fertility status. The various green manuring crops were cultivated in gypsum-treated plots having different levels of ESP as requirement of treatments. The application of gypsum was done once only and that to before sowing of green manuring crop in the month of April/ May 2005. The green manure crop was cultivated and buried in soil at the age of 45 days well before the sowing of the kharif crop. The experiment will be carried out at least for ten years so that impact can be identified. The paddy – wheat crop rotation, recommended for such soils, would be followed. Main treatments comprised of ESP Levels 4 no. {(25, 35, 45 and 50) ± 2) while sub-treatments comprised of organic/ Green manure 4 no. (Control, FYM @ 10 t/ha, Dhaincha and Sunhemp). The experimental design was split plot with 4 replications. The crop rotation was paddy- wheat.

Paddy

The data revealed that significant increase in number of tillers per hill, plant height and length of panicle due to incorporation of dhaincha followed by sunhemp as green manure. Highest number of tillers per hill (17.58), plant height (115.5 cm) and length of panicle (20.2 cm) were noticed in case of dhaincha treated plots at soil ESP of 25. However, the lowest values were noticed in control at all the ESP levels. The grain and straw yield of paddy as influenced by application of green manures and FYM at different soil ESP given in Table 2.10 and Fig 2.1 indicated that grain and straw yield of paddy decreased significantly with increase in soil ESP. Incorporation of green manure significantly enhanced the paddy yield (grain and straw) over control. Maximum grain and straw yield of paddy was recorded in case of dhaincha (3.71 and 8.68 t ha-1) followed by sunhemp (3.42 and 7.55 t ha-1) at soil ESP of 25, while, lowest yield was observed in control plots.

Table 2.10 Grain and straw yield (t ha-1) of paddy as influenced by application of green manures/ FYM at different ESP levels

Green manures	ESP Levels				Mean
	25±2	35±2	45±2	50±2	
Grain					
Control	2.62	2.45	1.75	1.25	2.02
FYM @ 10 t ha-1	2.95	2.61	1.93	1.64	2.28
Sunhemp	3.42	2.88	2.29	1.94	2.63
Dhaincha	3.71	3.02	2.45	2.18	2.84
Mean	3.17	2.74	2.10	1.75	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD 5 %	0.13	0.23	NS	NS	
Straw					
Control	5.40	5.16	4.05	3.42	4.51
FYM @ 10 t ha-1	7.25	6.42	5.00	4.71	5.84
Sunhemp	7.55	6.80	5.25	5.36	6.24
Dhaincha	8.68	7.24	6.15	5.92	6.99
Mean	7.22	6.40	5.11	4.85	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD 5 %	0.39	0.44	NS	NS	

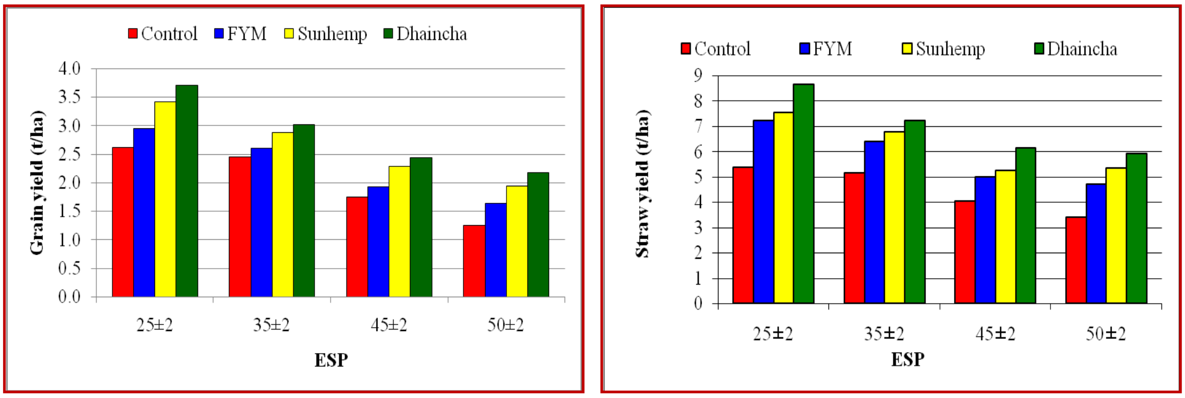


Fig 2.1 Effect of incorporation of green manures/ FYM on grain and straw yield of paddy

Wheat:

The data pertaining to number of effective tillers per meter row length, plant height and length of earhead of wheat indicated significant increase due to incorporation of dhaincha followed by sunhemp as green manure. Maximum number of effective tillers per meter row length (55.0), plant height (107.4 cm) and length of earhead (8.70 cm) were noticed in case of dhaincha treated plots at soil ESP of 25. Number of effective tillers per meter row length, plant height and plant height was decreased significantly with the increase in soil ESP. However, lowest values were recorded under control. Grain and straw yield of wheat decreased significantly with increase in soil ESP. Incorporation of green manure significantly increased the wheat grain and straw yield over control (Table 2.11 and Fig. 2.2). Highest grain and straw yield of wheat was recorded in case of dhaincha (3.47and 4.71 t ha-1) followed by sunhemp (3.21and 4.30 t ha-1) at soil ESP of 25. Lowest grain and straw yield was observed in control plot. The interactions between ESP and FYM/ GM were also found significant for grain and straw yield of wheat.

Table 2.11. Grain and straw yield (t ha-1) of wheat as influenced by application of green manures/ FYM at different ESP levels

Green manures	ESP Levels				Mean
	25±2	35±2	45±2	50±2	
Grain					
Control	2.16	1.99	1.67	1.51	1.83
FYM @ 10 t ha-1	2.84	2.44	2.12	1.84	2.31
Sunhemp	3.21	2.97	2.55	2.04	2.69
Dhaincha	3.47	3.17	2.73	2.15	2.88
Mean	2.92	2.64	2.26	1.89	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD 5 %	0.10	0.07	0.16	0.15	
Straw					
Control	2.81	2.65	2.22	2.12	2.45
FYM @ 10 t ha-1	3.78	3.33	2.90	2.65	3.16
Sunhemp	4.30	3.87	3.47	3.00	3.66
Dhaincha	4.71	4.20	3.73	3.06	3.92
Mean	3.90	3.51	3.08	2.71	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD 5 %	0.18	0.14	0.29	0.27	

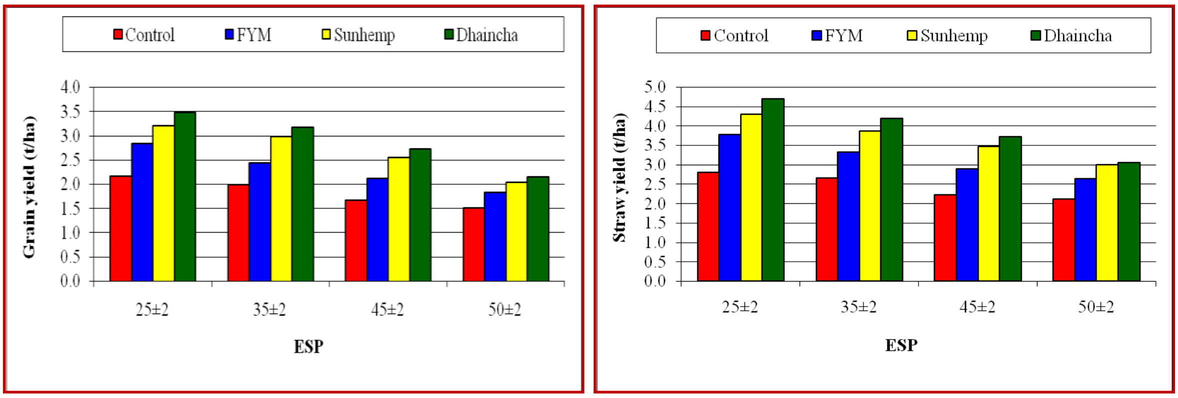


Fig 2.2 Effect of incorporation of green manures/ FYM on grain and straw yield of wheat

The data presented in Table 2.12 indicated that incorporation of green manures/ FYM significantly decreased the ESP at all the levels. The lowest average ESP (23.54) was recorded under incorporation of Dhaincha followed by Sunhemp (26.70). However the pHs and ECe of soil did not alter significantly.

Table 2.12 Soil properties as influenced by application of green manures/ FYM after harvest of wheat

Green manures	ESP Levels				Mean
	25	35	45	50	
pHs					
Control	8.20	8.28	8.30	8.31	8.27
FYM @ 10 t ha-1	8.21	8.27	8.29	8.30	8.27
Sunhemp	8.18	8.23	8.25	8.26	8.23
Dhaincha	8.15	8.20	8.21	8.23	8.20

Mean	8.18	8.24	8.26	8.27	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD 5 %	NS	NS	NS	NS	
ECe (dSm-1)					
Control	2.22	2.16	2.15	2.10	2.16
FYM @ 10 t ha-1	2.18	2.11	2.12	2.07	2.12
Sunhemp	2.05	2.09	2.10	2.08	2.08
Dhaincha	2.19	2.09	2.16	2.07	2.13
Mean	2.16	2.11	2.13	2.08	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD 5 %	NS	NS	NS	NS	
ESP					
Control	22.69	31.59	39.88	43.95	34.53
FYM @ 10 t ha-1	18.48	25.95	34.51	39.33	29.57
Sunhemp	17.46	23.85	32.07	33.42	26.70
Dhaincha	14.95	21.54	27.92	29.76	23.54
Mean	18.39	25.73	33.59	36.62	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD 5 %	0.64	0.58	1.18	1.16	

Performance of paddy under different treatments in sodic soil condition is shown in Plate 2.1 and performance of wheat under different treatments in sodic soil condition is shown in Plate 2.2.

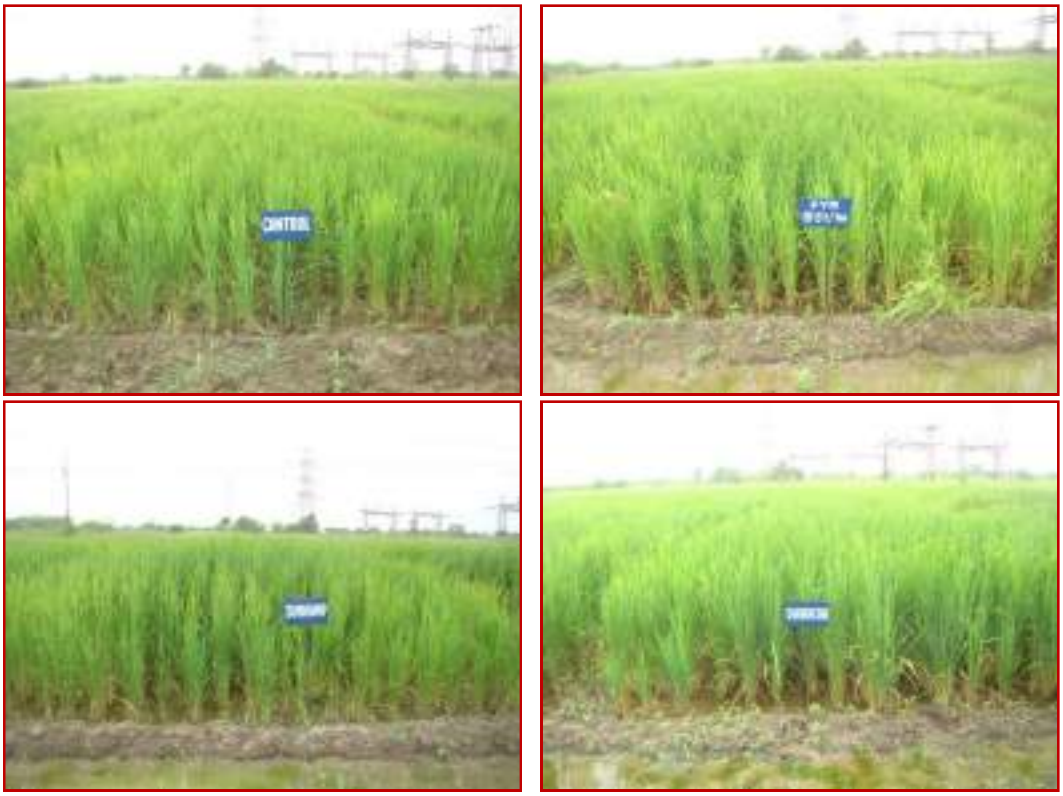


Plate 2.1 Performance of paddy under different treatments in sodic soil condition

Plate2.2 Performance of wheat under different treatments in sodic soil condition

- **Performance of wheat crop as influenced by different depth and frequency of irrigation under different methods of irrigation in sodic Vertisols (Indore)**

Sodic black soils are known to occur with scarcity of water in semi-arid and arid regions which stress the need to utilize irrigation water judiciously. Farmers of the area are still practicing flood irrigation with very high water expense which in turn adversely affects crop growth during initial stage due to poor hydraulic conductivity of such soil. Improved methods of irrigation can play vital role in effective use of irrigation. The information lacks on comparative performance of methods of irrigation under stressed environment of sodic black soils. Wheat is being grown on substantial area in Malwa and Nimar region. The study was carried out during the year 2016-17 in sodic black soils of Salinity Research Station, Barwaha having ESP 35±2. The wheat crop (HI 1077) was sown on 25th of November 2016 and harvested on 21st of March 2017. The stream size used to irrigate borders was 8LPS. Average time taken by the irrigation water stream to travel cut of distance 65%, 75% and 85% were also recorded. Treatments were as below.

M1- Border strip irrigation (BSI) with 8 LPS stream size at 65, 75 and 85 % cut off distance (COD) (Plot size – 50 x 6 m).
M2- Sprinkler irrigation (SI) – 2, 3 and 5 cm. Irrigation was scheduled on the basis of IW/CPE ratio as 1.2.

Soil moisture was also estimated by gravimetric method before sowing and after harvesting to know soil profile contribution during crop season. The study also dealt with evaluation of distribution pattern for sprinkler irrigation system by collecting water in containers placed in a 3 x 3 m grid arrangement around the sprinklers in the wetted area.

Water expense, yield and Water productivity

Three borders each one of size 50 x 6m were irrigated up to COD 65, 75 and 85% respectively by BSI. Similarly, three plots each one of size 50 x 24 m were irrigated to depth of 2, 3 and 5 cm respectively by SI. The stream size used to irrigate borders was 8 LPS. Average time taken by the irrigation water stream to travel cut of distances 65, 75 and 85 % were 36, 43 and 51 minutes respectively. The minimum water expense (WE) was obtained 39 cm in case of SI with irrigation depth 3 cm followed by 40 cm in SI with irrigation depth 2 and cm during the years 2016-17 respectively (Table 2.13). The maximum WE was 51.84 cm in case of BSI with COD 65% followed by 48.96 cm in BSI with COD 85%. It implies that minimum water expense was observed in case of SI with irrigation depth 3 cm among the tried various depths and frequencies in sprinkler as well as border strip irrigation. If water saving is object, one may irrigate wheat crop in sodic black soils by sprinkler irrigation with 3 cm depth scheduled on the basis of 1.2 IW/CPE ratio.

The yields obtained during the years 2016-17 under different depths and frequencies in case of boarder strip and sprinkler irrigation are shown in Table 2.13 The highest yield of 2869 kg/ha, was obtained in case of SI with irrigation depth 3cm and the lowest yield of 1941kg/ha was obtained in case of BSI with COD 65% during the years 2016-17. The data clearly indicates that to obtain higher yield of wheat crop in sodic black soils, one should opt SI with irrigation depth 3cm scheduled on the basis of 1.2 IW/CPE ratio among the tried various depths and frequencies in sprinkler as well as border strip irrigation. However, to obtain higher yield of wheat crop in sodic black soils in case of Border strip irrigation one should opt BSI with COD 85% and scheduled on the basis of 1.2 IW/CPE ratio.

The highest water productivity (WP) of 73.6 kg/ha-cm was obtained in case of SI with depth 3cm during the years 2016-17 respectively and the lowest water productivity (WP) of 37.4 kg/ha-cm was obtained in case of BSI with COD 65% during the years 2016-17 respectively (Table 2.13). However, the maximum water productivity (WP) was 45.5 kg/ha-cm in case of BSI with COD 85% followed by 41.7 kg/ha-cm in BSI with COD 75% during the year 2016-17. The data indicates superiority of sprinkler irrigation over BSI in respect of water productivity. SI with 3cm depth when scheduled on the basis of IW/CPE ratio 1.2 appears to give highest water productivity as compared to other irrigation systems. It implied that one should opt SI with irrigation depth 3cm scheduled on the basis of 1.2 IW/CPE ratio among the tried various depths and frequencies in sprinkler as well as border strip irrigation to obtain higher water productivity (WP). Similarly, one should opt BSI with COD 85% and scheduled on the basis of 1.2 IW/CPE ratio to obtain higher water productivity (WP).

Table 2.13 Water expense (WE), yield and water productivity (WP) under different irrigation system

Name of system	Irrigation	Depth of irrigation	Water expense	Yield,	Water productivity
	Nos.	cm	cm	kg/ha	kg/ha-cm
BSI with COD 65%	9	5.76	51.84	1941	37.4
BSI with COD 75%	7	6.88	48.16	2006	41.7
BSI with COD 85%	6	8.16	48.96	2228	45.5
SI with irrigation depth 2cm	20	2	40	2650	66.3
SI with irrigation depth 3cm	13	3	39	2869	73.6
SI with irrigation depth 5cm	8	5	40	2391	59.8

The soil samples were collected from 0-15 cm depth before sowing of the crop under various irrigation systems and were analyzed for chemical properties. The same are shown in Table 2.14.The chemical properties pH, EC and ESP ranges in-between 7.9 to 8.33, 0.81 to 1.51 dSm-1 and 33.4 to

34.3, respectively recorded after 4 years of experiment i.e. in the year 2016-17. Data indicated no change in chemical properties of soil of the experimental area.

Table 2.14 Chemical properties of soils under different irrigation systems (2016-17)

Irrigation system	pHs	ECe	Cation				Anion			ESP
			Ca	Mg	Na	K	CO3	HCO3	Cl	
		dSm-1	me/ l				me/ l			%
BSI with COD 65%	7.96	1.51	3.0	1.0	9.7	0.48	1	4	5	34.3
BSI with COD 75%	8.13	1.42	3.0	0.5	9.8	0.84	1	5	4	34.2
BSI with COD 85%	8.30	1.31	2.5	1.5	8.2	0.52	0	4	4	33.4
SI with irrigation depth 2cm	8.21	0.86	2.5	0.5	4.6	0.2	0	4	5	33.7
SI with irrigation depth 3cm	8.33	0.81	3.0	0.5	3.5	0.42	0	4	5	33.8
SI with irrigation depth 5cm	7.90	1.15	3.5	1.5	5.8	0.62	0	5	3	33.6

- **Evaluating performance of drip irrigation under different discharge rate and schedules for growing vegetable crop in sodic black soils (Indore)**

Crops grown in sodic black soils require light and frequent irrigation. Drip irrigation may prove effective for providing light and frequent irrigation. Basic infiltration in sodic black soils decreases with increase in ESP. Therefore correct irrigation scheduling is important to meet out variable irrigation requirement of crops in these soils. The study was initiated during the year 2016-17 in sodic black soils of Salinity Research Station, Barwaha at ESP level 40±2. The Cauliflower crop (Ojas) was sown on 12th of November 2016 and harvested on 11th of March 2017. The various details of drip irrigation methods worked out and used in experiment are shown in Table 2.15.

- Water requirement - PE. Pc. Kc. Cc. A
  Where PE is pan evaporation, (8 mm/ day)
  Pc is pan coefficient (0.8)
  Kc is crop coefficient (Average seasonal value - 0.5)
  Cc is canopy factor as (1)
  A is wetted area/ plant (0.3 m2)
    - Volume of water /day/ plant = 0.96 L/ day
- Crop – Cabbage/ Cauliflower
- Plot size - 6.0 x 5.0 m
- Treatments - (i) Discharge rates (Three - 1.3, 2.4 and 4.0 LPH) - Q1, Q2 and Q3
  (ii) Schedule of irrigation (Three – Daily, alternate and every 3rd day) – S1, S2 and S3

Volume of irrigation water applied was kept uniform irrespective of the discharge rates of drippers as well as different schedules.

Table 2.15 Details of drip irrigation systems used in experiment

Particulars	Irrigation schedules								
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Discharge rate of drippers, LPH	1.30	1.30	1.30	2.40	2.40	2.40	4.00	4.00	4.00
Average evaporation, mm/ day	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Pan coefficient	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Maximum crop coefficient	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Wetted area, sq, m	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Water requirement per plant, (L/day)	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Number of plants/ plot	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
Volume of water/ plot/ L/ irrigation	148.5	297.0	445.5	148.5	297.0	445.5	148.5	297.0	445.5

Size of plot, m	6 x 5	6 x 5	6 x 5	6 x 5	6 x 5	6 x 5	6 x 5	6 x 5	6 x 5
Depth of irrigation, cm	0.50	0.99	1.49	0.50	0.99	1.49	0.50	0.99	1.49
Time of irrigation, Minutes	52.73	105.45	158.18	28.56	57.12	85.68	17.14	34.27	51.41
Plant spacing, cm	60x50	60x50	60x50	60x50	60x50	60x50	60x50	60x50	60x50

Water expense, yield and water productivity

The details of Nos. of irrigation, water expense yield and water productivity are given in Table 2.16. The total water expense was estimated around 53 cm in case of daily, alternate and third day irrigation schedules respectively. The depth of irrigation applied were 0.50, 1.00 and 1.50 cm in case of daily, alternate and third day irrigation schedules respectively. The highest curd yield 20976 kg/ha was obtained in case of drip irrigation system scheduled daily with 1.3 LPH dripper discharge rate followed by the lowest 10588 kg/ha in case of drip irrigation system scheduled every third day with 4.0 LPH dripper discharge rate. However, the water productivity was observed highest 395.77 kg/ha-cm in case of drip irrigation system scheduled every day with 1.3 LPH dripper discharge rate followed by 365.75 kg/ha-cm in case of drip irrigation system scheduled every alternate day with 1.3 LPH dripper discharge rate. The lowest WP was observed 197.40 kg/ha-cm in case of drip irrigation system scheduled every third day with 4.0 LPH dripper discharge rate followed by 228.44 kg/ha-cm in case of drip irrigation system scheduled alternate day with 4.0 LPH dripper discharge rate.

Table 2.16 Water expense, yield and water productivity under different drip systems

Treatments	irrigation	Depth of irrigation	Water expense	Curd yield	Curd yield	WP
	Nos.	cm	cm	kg/plot	(kg/ha)	kg/ha-cm
Q1 S1	106	00.50	53.00	62.93	20976	395.77
Q1 S2	53	01.00	53.00	57.57	19191	365.75
Q1 S3	36	01.50	53.00	51.80	17267	321.90
Q2 S1	106	00.50	53.00	51.94	17313	326.67
Q2 S2	53	01.00	53.00	50.39	16796	320.10
Q2 S3	36	01.50	53.00	47.51	15837	295.24
Q3 S1	106	00.50	53.00	36.33	12110	228.49
Q3 S2	53	01.00	53.00	35.96	11986	228.44
Q3 S3	36	01.50	53.00	31.77	10588	197.40

Soil moisture contribution

The soil moisture from 0-15 cm depth was also estimated before sowing and after harvesting of the crop under various drip irrigation systems of the study and the same are shown in Table 2.17. Soil moisture contribution estimated ranges in-between 3.16 to 3.97 cm/ m soil depth in different treatments.

Table 2.17 Soil moisture contribution under different drip irrigation systems

Treatments	Soil moisture BS	Soil moisture AH	Profile contribution	Profile contribution
	%			cm/ m
Q1 S1	24.28	21.87	2.41	3.66
Q1 S2	23.37	21.14	2..23	3.39
Q1 S3	22.19	19.88	2.31	3.51
Q2 S1	20.80	18.19	2.61	3.97

Q2 S2	21.48	19.13	2.35	3.57
Q2 S3	20.12	17.78	2.34	3.56
Q3 S1	19.21	17.13	2.08	3.16
Q3 S2	21.34	19.15	2.19	3.33
Q3 S3	21.11	18.95	2.16	3.28

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

The purpose of experiment was to find out the suitable combination of organic and inorganic inputs for sustainable crop production and to study changes of physico-chemical properties of soil. Details of treatments are as below.

T1- 50%GR; T2- 25%GR + rice straw @5 t/ha; T3- 25%GR + GM @5 t/ha; T4- 25%GR + GM @5 t/ha + Microbial culture; T5- 25%GR + Poultry manure @3t/ha; T6- 25%GR + City Waste Manure @5 t/ha
T7 - Control.

Experimental details are as below.

Sr. No.	Item	Details
1	Crop	Rice and Wheat
2	Varieties	CSR-36, KRL-210
3	No. of treatments	7
4	No. of replication	4
5	Design	RBD
6	Plot size	20 sqm
7	Year of start	2016
8	Location	Crop Research Station, Dalipnagar, Kanpur
9	Initial soil status	pH (9.50); EC (0.94 dSm-1); ESP 48.20; O.C. (%) 0.21

The grain and straw yield of rice varied from 23.82- 40.68 q/ha, 28.44- 49.65 q/ha and wheat from 19.12-35.34 q/ha and 23.33-43.11 q/ha, respectively in different treatments (Table 2.18). The highest yield of rice and wheat was obtained from 25%GR + Poultry manure @3t/ha; followed by 25%GR + GM @5 t/ha + Microbial culture and lowest yield was received from control plot.

Table 2.18 Effect of treatments on grain yield of rice (q/ha)

Treatments	Rice 2016		Wheat 2016-17	
	Grain	Straw	Grain	Straw
T1- 50% GR.	35.38	41.57	30.54	37.25
T2- 25% GR + rice straw @5 t/ha	33.45	39.94	28.72	35.04
T3- 25% GR + GM @5 t/ha	37.72	45.48	29.46	31.54
T4- 25% GR + GM @5 t/ha + Microbial culture	39.27	47.53	32.27	39.52
T5- 25% GR + Poultry manure @3t/ha.	40.68	49.65	35.34	43.11
T6- 25% GR + City West Manure @5 t/ha	38.15	45.95	33.83	40.82

T7 - Control.	23.82	28.44	19.12	23.33
CD=0.05	1.87	2.01	1.92	2.11

Physico chemical Properties of Soil

The data presented in Table 2.19 indicated that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in all treatments excluding control, maximum decrease was observed in 50%GR treatment. The organic carbon was noticed improved in all treatments. The maximum increment of organic carbon was recorded with the application of 25%GR + Poultry manure @3t/ha; followed by 25%GR + GM @5 t/ha + Microbial culture and 25%GR + City Waste Manure @5 t/ha treatment.

Table 2.19 Effect of treatments on physico- chemical properties of soil after one year

Treatments	pH	EC	ESP	OC%
T1- 50%GR.	8.8	0.91	31.8	0.23
T2- 25%GR + rice straw @5 t/ha	9.1	0.92	39.3	0.25
T3- 25%GR + GM @5 t/ha	9.0	0.94	38.8	0.26
T4- 25%GR + GM @5 t/ha + Microbial culture	8.9	0.91	37.5	0.30
T5- 25%GR + Poultry manure @3t/ha.	8.9	0.92	35.2	0.32
T6- 25%GR + City Waste Manure @5 t/ha	9.0	0.93	38.1	0.28
T7 - Control.	9.4	0.95	46.4	0.22
Initial Soil Status	9.50	0.94	48.2	0.21

- **Integrated Farming System (IFS) suitable for problem soil areas of Tamil Nadu (Tiruchirapalli)**

The purpose of the experiment was to evolve a suitable integrated farming system for sustainable income in sodic environment of Tamil Nadu. The main components were agricultural crop (rice), vegetables, fish and poultry. The green manuring was also adopted for nutrient recycling. The green manure crop reached 50 percent flowering on 22-07-2016 which is around 51 days from sowing. The yield of green bio mass was about 7050 kg for 0.3 ha. The moisture content of green biomass was 76 per cent. The green manure was ploughed in-situ using tractor drawn motivator. Crop component during Rabi 2016, the rice variety TRY was sown in nursery on 20-09-2016 and transplanting was done on 18-10-2016. Regular crop management practices recommended for the rice crop was followed. The crop was harvested on 07-02-2017 with a grain yield of 5280 kg ha^{-1}. Under fisheries component, fingerlings were released on 08-09-2016 under poly culture system five fish species viz., 1) Catla-250 nos, 2) Rohu-100 nos, 3) Mrigal-250 nos, 4) Silvercarp-250 nos and 5) Grass carp-250 numbers were released. The total numbers of fishes released were 1100 nos. The harvesting of fish was done in a staggered manner on 2nd, 3rd and 4th week (31-05-2017). A total quantity of 285 kg of fish was harvested. The poultry birds were maintained to ensure its droppings for fish ponds. The birds were marketed in a staggered manner with an average weight of 1.49 kg per bird, from the first week of February 2017 to First week of May 2017. The space available around the bunds of fish pond was used for cultivation of vegetables and greens. Permanent crops viz., coconut and moringa were maintained with an objective of long term yield perspective. The economic value of all bund crop components is Rs. 2500 per year, for an investment of Rs. 800 with a net income of Rs. 1700. The economics of complete system is provided in Table 2.20. The B:C ratio for IFS was 2.54 compared to sole rice crop with B:C ratio as 2.16.

Table 2.20 Economic analysis of Integrated farming system

S. N.	Component	Total cost (Rs)	Gross Income (Rs)	Net Income (Rs)	B:C ratio	Income share (%) for 0.4 ha	Annual net income (Rs)	Additional income by IFS over cropping alone (Rs)	B:C ratio
1	**Rice cropping alone (0.4ha)**								
a	Rice (alone)	17400	37632	20232	2.16	100	20232	-	2.16
2	**Integrated Farming system (0.4 ha)**								
a.	Rice (0.3 ha)	13350	29454	16104	2.21	29	56154	35922	2.54
b.	Fish Pond (1000 m^{-2})	12350	39900	27550	3.23	49			
c.	Poultry (10'x7') 70 sq ft over fish pond	18050	28850	10800	1.60	19			
d.	Bund crops (Around fish pond bund)	800	2500	1700	3.13	3			

2.2 Management of Saline and Saline Waterlogged Soils

- **Influence of silicon on alleviation of salinity effect on rice (Bapatla)**

The experiment was initiated to study the effect of silica nutrition through different sources on alleviation of salinity effect in case of rice. Details of experiment are as below.

T1- Control T2- Potassium silicate (40–60 kg ha-1) T3- Calcium silicate (120–200 kg ha-1) T4- Paddy straw 1 t ha^{-1} T5- Paddy husk 1 t ha^{-1}	Design : Randomized block design Replications :Three Variety : BPT 5204 Spacing :20cm X 15cm

A pot culture experiment was conducted to study the influence of silicon on alleviation of salinity effect on rice at SWS, Agricultural College Farm, Bapatla during rabi 2015-16. In this study using soils of similar characteristics but variable salinity (2, 5 and 10 dS m^{-1} of ECe) collected from Nizampatnam was tested along with four different sources of silica and one control (no silica) treatment in a split plot design replicated thrice. Silicon application through different sources showed significant differences in growth parameters of paddy. Maximum plant height (83.6 cm) was recorded with potassium silicate application which was significantly superior to control and on par with all other sources of silica. More number of tillers was observed with potassium silicate application treatment and the lowest number of tillers was recorded in control treatment. Among different sources of silicon, potassium silicate recorded the highest dry matter (6937 kg ha^{-1}) when compared to all other treatments. The lowest dry matter accumulation was recorded in control treatment (5893 kg ha^{-1}). Among different sources of silicon nutrient, potassium silicate treatment recorded significantly higher grain yield (5686 kg ha^{-1}) and straw yield (6237 kg ha^{-1}) when compared to control treatment in grain (4631 kg ha^{-1}) and straw yields (5118 kg ha^{-1}) and it was on par with calcium silicate application treatment in both grain and straw of paddy (Table 2.21).

Table 2.21 Influence of sources of silica on yield of rice

Silica sources	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)
T1- Control	4631	5118	47.5
T2-Potassium silicate	5686	6237	47.6
T3-Calcium silicate	5456	6002	47.6
T4- Paddy straw	5058	5469	48.0
T5-Paddy husk	4974	5347	48.1
SEm+	184	223	
CD(0.05)	555	672	
CV (%)	7	8	

In case of different source of silicon application, potassium silicate application recorded the lowest sodium uptake in grain (13.07 kg ha-1) and straw (16.37 kg ha-1) when compared to all other treatments. Sodium uptake was high in control (16.49 and 27.69 kg ha-1) treatment both in grain and straw of paddy crop. Among different sources of silicon application, potassium silicate application recorded the highest K/Na ratio followed by calcium silicate (Table 2.22).

Table 2.22 Influence of sources of silica on potassium/sodium ratio

Treatments	K/Na ratio in rice grain	K/Na ratio in rice straw
T1- Control	1.06	2.43
T2- Potassium silicate	2.58	8.05
T3-Calcium silicate	1.74	5.78
T4- Paddy straw	1.42	4.74
T5-Paddy husk	1.27	3.72

Application of potassium silicate source of silicon recorded the highest growth, yield attributes and yield of rice, which was significant over the remaining silica sources and it was on par with calcium silicate application source.

- **Investigation, design, installation and evaluation of mole drainage systems in black soils of Andhra Pradesh for control of waterlogging (Bapatla)**

The purpose of study was to design and install mole drain to control surface waterlogging in black soils of Andhra Pradesh and to understand its performance. Details of the system are given below.

- ✓ Location and situation: Guntur District and East Godavari district Vertisols
- ✓ Design Type: Double Split Plot
- ✓ Main Factors: 2 (Mole depths: 0.4 m and 0.5 m)
- ✓ Sub-factors: 5 (Spacing: T1- 2 m, T2-3 m, T3-4 m, T4-5 m and T5-Control/Check).
- ✓ Sub-sub factors: 2 (Soils Oxygenation and Without Soil Oxygenation)
- ✓ Replications: 4
- ✓ Total experimental area: 2.0 acres.
- ✓ Average plot size: 102.0 sqm
- ✓ Crop : Sugarcane (Saccharum officinarum);
- ✓ Variety: Co 86032
- ✓ Depth of soil oxygenation: 15 cm midway at 15 cm depth in the root zone

Mole drains are unlined channels formed in clay subsoil. Mole drains are used when natural drainage needs improving due to lack of slope or heavy clay subsoil prevents downward drainage. They are a more sophisticated drainage system than open drains. Mole drains do not drain groundwater but only water that enters from above.Two sites were selected in Bapatla, Guntur District and Kapileswarapuram of East Godavari district, A.P. The relation between amount of rainfall and rainy days is given in Fig. 2.3 while drainage coefficient value in mm/day for different return periods is shown in Fig. 2.4.

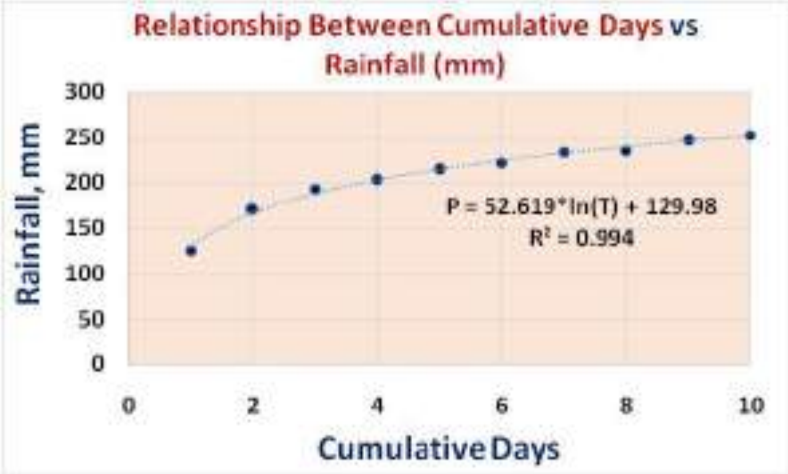


Fig. 2.3 Relationship between Cumulative days and Rainfall, mm

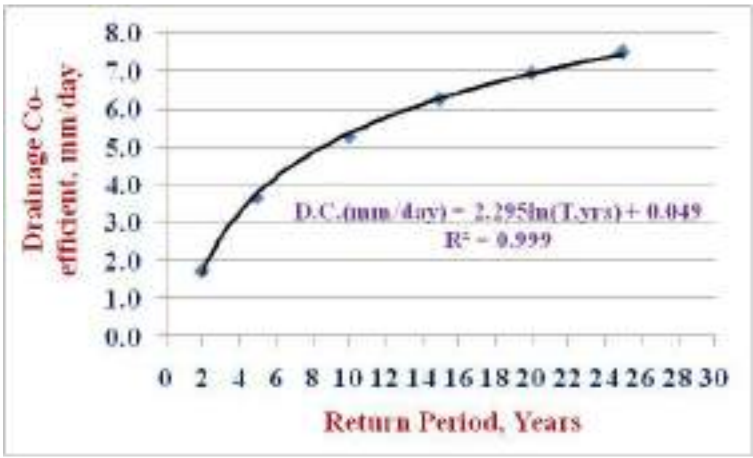


Fig. 2.4 Drainage co-efficient for different return periods in Bapatla region

The Kapileswarapuram site was selected for conducting the mole drainage experiment as per the split plot design envisaged. The rainfall analysis was conducted and found that a maximum probable one day rainfall with a 5-yr return period is 157.0 mm. Soil Physical and chemical investigations at Kapileswarapuram are given Table 2.23.

Table 2.23 Soil Physical and chemical investigations at Kapileswarapuram

Sl.No.	Parameter/ Variable	Value	Units	Remarks/Procedure followed
A.	**Hydro-geological Investigations**			
1.	Drainage Co-efficient (5 Year return Period)	17.78	mm/day	Rainfall Analysis
2.	Depth to relatively Impervious Layer	2.1	m	Augering and Physical Analysis
3.	Avg. Minimum Water table depth (Pre-Drainage and Post-Monsoon)	0.3	m	Observation wells network
4.	Avg. Saturated hydraulic conductivity	0.31	m/day	Auger hole method (Ejkel Kemp test kit).

B.	Surveying and Levelling			
5.	Land slope	0.03	%	Surveying and Levelling
6.	Lateral Mole Slope	0.03	%	Surveying and Levelling
7.	Collector line Slope	0.05	%	Surveying and Levelling
8.	Area	2.11	Acres	Surveying and Levelling

Sl.No.	Parameter/ Variable	Value	Units	Remarks/Procedure followed
C	**Soil Physical Investigations**			
9.	Bulk density	1.537	g/cc	Cylindrical method
10.	Total Porosity	0.42	Fraction	TP=(1-(B.D/P.D)*100
11.	Clay Content	42	%	Bouycos Hydrometer
12.	Field Capacity	0.36	Fraction	PPA method
13.	Eff. Porosity	0.06	Fraction	Eff.P = TP-FC
14.	Permanent Wilting Point	0.225	Fraction	F.C/1.6
D	**Soil Chemical Investigations**			
15.	Avg. E.Ce	3.8	dS m-1	E.C. meter
16.	Avg.pH	7.7		pH meter
17.	ODR	0.12-0.17	μg/cm2/ min	ORP meter
18.	CO3	0.9	meq/L	Titration
19.	HCO3	3.21	meq/L	Titration

Based on the above investigations, the input parameters were used for calculating the drain spacing for the moles using Hooghoudt’s equation as follows:

Design of Mole Drain Spacing using online calculator:

The design input parameters were fed to the system calculator in which in-built Hooghoud’ts equation is programmed for solving for drain spacing as shown below in Fig. 2.5.

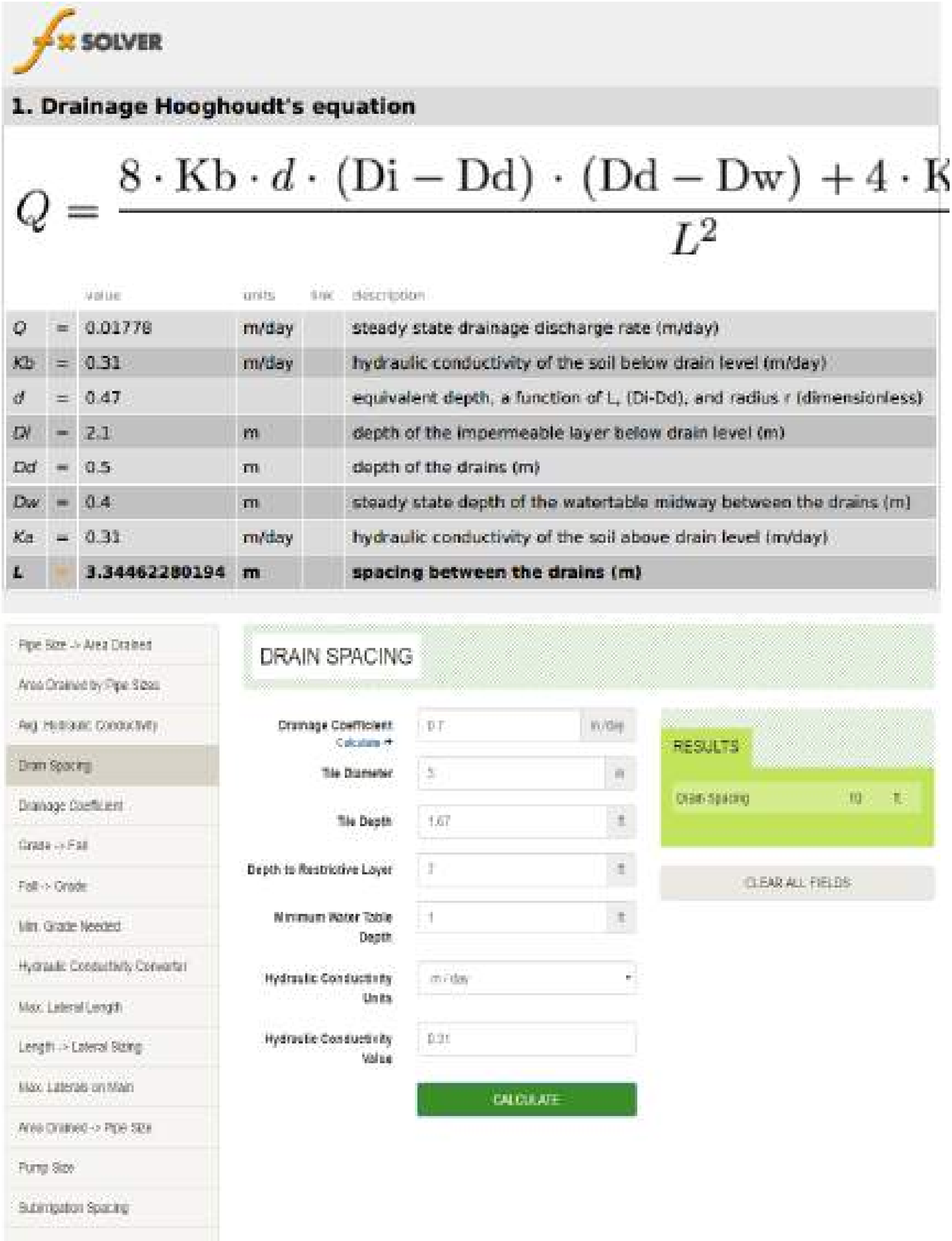


Fig. 2.5 Screenshot of the software used for calculating the mole drain spacing

Thus, the designed spacing of the moles is found to be 10 ft i.e. 3.0 m. Hence, to test the effect of other closed spacings and to conduct the sensitivity analysis, 2, 4 and 5 m spacings were also selected for conducting the experiment at two different depths 0.4m and 0.5m. The following step by step procedure was followed for installing the mole drains. The field was divided into two equal halves of 1.0 acre each in which 0.4m and 0.5m depth drains as shown below Fig. 2.6.

- ✓ Main drain was dug across the longitudinal section of mole lines for facilitating collection of drain water.
- ✓ Marking of mole drain lines of 2, 3, 4 and 5 m spacing in both the plots were carried out with lime powder and a rope in the longitudinal section of the drain.
- ✓ Acquired a 65 h.p. tractor and hitched the mole plough at its highest hitch point.
- ✓ Drawn a line mark with chalk piece on the mole plough at 0.4m and 0.5m to assure the depth of plough into the soil.
- ✓ Lowering the plough to the designated depth into the main drain at the point of intersection of main drain and lateral mole drain for drawing the mole channel.
- ✓ Instructions the driver to maintain the slope towards main drain and begin the channeling with mole plough at a speed of 5-7.5 kmph speed.
- ✓ As it reaches the other end of mole line, the plough has to be lifted up using hydraulic lift of the tractor to bring out from the mole channel.
- ✓ Fitting the mouth of the mole channel in the main drain with L bend of suitable size PVC pipe for facilitating easy draining of water as shown in figure
- ✓ Again introducing the mole plough in the next line and continuing the same procedure from 5 to 8 for every line to complete the installation of mole drains in the field.

The network of observation wells were installed for monitoring the groundwater levels. The situation of the study area is shown below through Fig. 2.6.

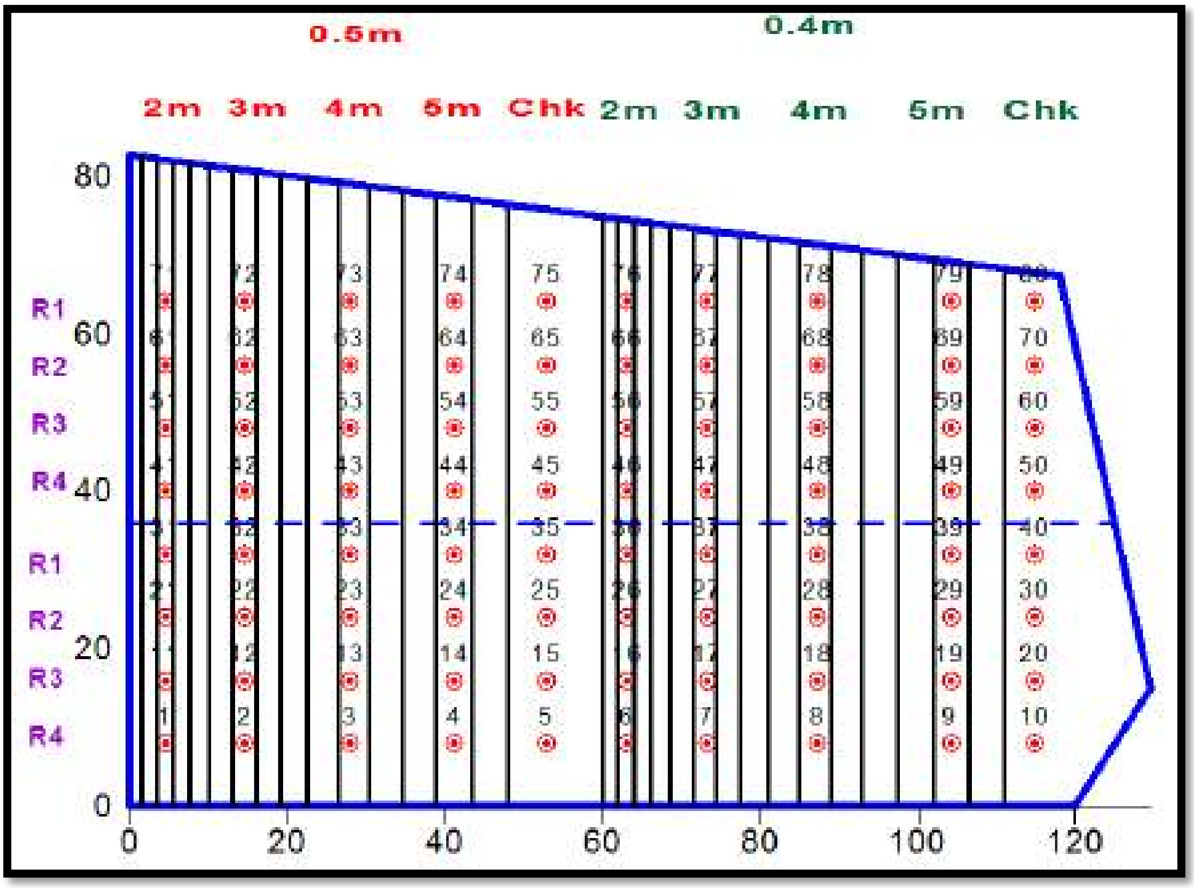


Fig. 2.6 The distribution of treatments and replications in Kapileswarapuram field

The sugarcane seedlings of Co 86032 variety was transplanted in the mole drain field as per the experimental design with a zigzag pattern in two lines with a plant to plant spacing of 30 cm and line to line spacing of 150 cm. The ability of mole drain in controlling surface waterlogging is shown in Plate 2.3.

Plate 2.3 Effect of mole drainage in waterlogged condition of the sugarcane field

Mole drainage systems were designed for Vertisols of East Godavari district for sugarcane crop and were installed. The drains laid at 3 m spacing with 0.4 m & 0.5 m depths found performing better when compared other spacings. The results obtained in one year study revealed that, the temporarily surface waterlogged soils can be reclaimed with low cost mole drainage systems in heavy soils of East Godavari district and addition of soil oxygenation agents (placement of Calcium peroxide granular powder @2 g/plant at 15 cm deep and 15 cm away from the plant) during monsoon season will ensure good aeration. The combined effect of mole drainage and soil oxygenation resulted in 25-38% increase in the sugarcane yields of Co 86032 variety.

- **Response of cotton to drip irrigation in saline soils under conservation agricultural practices (Gangavathi)**

The present study aimed to utilize the fertilizer more efficiently and to find out the best dose of fertilizer for Bt. cotton under saline condition and utilize the paddy straw as mulch which is abundantly available but often is burned by the farmers in the command area. The experiment was initiated during kharif 2013 and continued in Kharif 2016 on response of cotton to fertigation in saline soils under conservation agriculture practices at Agricultural Research Station, Gangavati. The initial soil salinity of the experimental plot was ranging from 5.3 dS/m to 7.0 dS/m and 5.27 dS/m to 9.24 dS/m at 0-15 and 15-30 cm depths respectively and initial pH of the block was ranging from 8.38 to 8.62 and 8.15 to 8.44 at 0-15 and 15-30 cm depths respectively. From the eight observation wells the water table depths of different treatment are being monitored. The Bt. Cotton verity viz, Ajit was sown in paired row (0.60x1.20x0.60 m) system with 0.6 m plant to plant distance. The 4 LPH emitters were punched for every two plants on 12mm lateral and soluble fertilizers were supplied with venturi though drippers. The recommended dose of fertilizers for cotton (100%) is 120:60:60 (Package of practice) and the treatments consist of:

- Main treatment: i) With mulch, ii) Without mulch
- Sub treatment: i) 50 %, ii) 75%, iii) 100% and iv) 125% RDF

Other details of the experiment during 2016-17 are as below (Table 2.24).

Table 2.24 Other details of experiment during 2016-17

S.N.	Parameter	Details	S.N.	Parameter	Details
1	Crop	Bt.Cotton	9	Residue	Paddy straw @ 6.85 t/ha
2	Variety/Hybrid	Ajit	10	Date of sowing	15.07.2016
3	No. of treatments	8	11	Sowing method	Paired row
4	No. of replications	3	12	Row spacing	0.6 x 1.2 x 0.6 m
5	Design	Split plot	13	Plant spacing	60 cm
6	Plot size	6m x 6m	14	Dripper discharge	4 lph
7	Treatment size	10.2m x 10 m	15	Dripper spacing	0.6 m
8	Fertilizer	120:60:60 kg NPK/ha RDF	16	Plants per dripper	2

The soil moisture content on dry weight basis at mid season and at harvest of cotton at different depth (0-15 and 15-30 cm) revealed that significantly higher soil moisture was retained in mulch compared to no mulch treatments (Table 2.25). Among fertilizer level, there was no significant difference was observed.

Table.2.25 Effect of mulching on soil moisture content at different depths of soil (cm) and growth stages of cotton

Treatment		Soil moisture at 30 DAS		Soil moisture at 120 DAS		Soil moisture at Harvest	
Conservation Practice (CA)		0-15	15-30	0-15	15-30	0-15	15-30
	Without	20.24	20.22	25.83	25.21	16.84	15.54
	With mulch	27.26	24.36	31.09	30.36	21.29	20.28
	CD (0.05)	2.92	1.97	1.14	4.89	3.66	2.75
	SE m +/-	0.68	0.46	0.26	1.13	0.85	0.64
Fertigation (F)							
	50 % RDF	23.12	22.38	28.5	28.37	19.05	16.82
	75% RDF	23.82	22.17	28.48	26.15	18.43	18.32
	100% RDF	23.88	21.67	28.87	27.93	20.37	18.55
	125% RDF	24.19	22.94	28	28.70	18.40	17.96

	CD (0.05)	NS	NS	NS	NS	NS	NS
	SE m +/-	1.85	0.8	0.6	1.65	1.03	1.23
Interaction (CA x F)	CD (0.05)	NS	NS	NS	NS	NS	NS
	SE m +/-	2.62	1.07	0.87	2.33	1.45	1.73

Data on vegetative parameter such as germination percentage, plant height, number of monopodial and sympodial branches, bolls per plant and boll weight are given in Table-2. There was no significant difference between mulch and no mulch treatment and also in fertilizer level treatments with respect to germination percentage. In general, nearly 92 % germination was observed in all the plots. Significant difference in plant height was observed under without mulch (121.5 cm) and with mulch (125.6 cm) treatments. Similarly, in case of fertilizer levels, significantly higher plant height (125.8 cm) was observed in 125 % RDF compared with 50 % RDF (120.0 cm). No significant difference in monopodial branches per plant was observed either due to mulch, fertilizer levels or interaction. Significantly higher sympodial branches were observed in mulch treatment as compared to no mulch treatment. In case of fertilizer levels, significantly more sympodial branches were observed in 125 % RDF level treatments as compared to furrow irrigated treatment (Table 2.26).

Table 2.26 Growth attributes of cotton as influenced by different fertigation level and conservation practices.

Treatments		Germi-nation %	Plant height (cm)	Monopod-ial branches	Sympodial branches	Bolls per plant	Boll weight (g/bowl)
Conservati-on Practice (CP)	WTM	92.50	121.5	3.30	29.2	30.00	5.31
	WM	94.4	125.6	3.6	31.4	33.2	5.74
	SE m +/-	0.65	0.36	0.15	0.29	0.82	0.05
	CD (0.05)	NS	1.56	NS	1.25	2.69	0.32
Fertilizer level (FL)	50 % RDF	92.40	120.0	3.2	28.3	29.3	5.03
	75 % RDF	93.60	123.8	3.3	30.0	31.3	5.53
	100 % RDF	94.60	124.0	3.8	31.3	32.0	5.54
	125 % RDF	93.10	125.8	3.7	31.8	34.0	6.00
	SE m +/-	0.91	1.62	0.32	0.79	1.11	0.21
	CD (0.05)	NS	3.53	NS	1.70	2.42	0.54
Interaction (CA x FL)	SE m +/-	1.30	2.29	0.45	1.12	1.58	0.30
	CD (0.05)	NS	NS	NS	NS	NS	NS
WTM-without mulch: WM-with mulch							

It was recorded that, among mulch and no mulch treatments, significantly more numbers of bolls per plant and higher single boll weight was obtained in case of mulch treatment (33.2 and 5.74 g/boll) respectively. In case of fertilizer level treatments, significantly more number of bolls per plant was recorded in 125 % RDF level (34.0 and 6.0 g/boll) which was on par with 100 % RDF (32.0 and 5.54 g/boll), followed by 75 % RDF (31.3 and 5.53 g/boll) and least in case of 50 % RDF (29.3 and 5.03

g/boll) treatment respectively. The third year study revealed that seed cotton yield was significantly higher in 125% RDF (27.3 q/ha) compared to 50 % RDF (24.13 q/ha) but was on par with 75% (25.37 q/ha) and 100% RDF (26.0 q/ha). In case of conservation practices, significantly higher seed cotton yield was recorded in mulch treatment (27.9 q/ha) compared to no mulch treatments (23.5 q/ha) (Table 2.27). The interaction effects between main and sub plots were non-significant. This experiment was concluded.

Table 2.27.Seed cotton yield as influenced by different fertigation levels and Mulching.

Fertilizer level	Cotton Yield (q/ha)		Mean
	Without mulch	With mulch	
	M1	M2	
S1	22.5	25.8	24.13
S2	22.7	28.0	25.37
S3	23.7	28.3	26.00
S4	25.3	29.3	27.30
Mean	23.5	27.9	
	SE m +	CD (0.05)	
M	0.23	1.01	
S	0.95	2.08	
M x S	1.35	NS	

(a) (b)

Plate 2.4 View of cotton experimental plot with mulch (a) and without mulch (b) treatment.

- **Evaluation of subsurface drip irrigation on soil physico-chemical properties, growth and yield of salt tolerant sugarcane in saline Vertisols of Tungabhadra command area (Gangavathi)**

Rice-rice cultivation in the upper reach of the Tungabhadra irrigation project has seriously affected the equitable distribution of water among the farmers and hence the degradation of soils due to water logging and salinity especially at tail end of the command. Change in cropping pattern and improving irrigation water use efficiency could be one solution for minimizing the area becoming waterlogged and saline. Further, evaporation losses may be minimized and leaching of salt from the root zone may be maximized, if Subsurface Drip Irrigation (SSDI) is adopted. The objectives of the experiment are to study the effect of subsurface drip irrigation vs conventional furrow irrigation method on soil physical and chemical properties in saline vertisols of command area and to compare yield, water use efficiency and economics of subsurface drip irrigation vs conventional furrow method of irrigation in saline soil. Details of the experiment are given below.

SN	Variable	Details	SN	Variable	Details
1	Crop	Sugarcane	9	Date of harvest	23-03-2016
2	Variety/Hybrid	Co -91010 (Dhanush)	10	Sowing method	Paired row
3	Number of treatments	9	11	Row spacing	0.6 x 1.2 x 0.6 m
4	Number of replications	3	12	Plant spacing	30 cm
5	Design	Split	13	Dripper discharge	1.6 lph
6	Treatment size	5.4 m (w) x 9 m (L)	14	Dripper spacing	0.4 m
7	Fertilizer	250:75:190 kg NPK/ha	15	Drip line (Anti siphon)	DNPC 2016x0.4x1.6 lph
8	Date of sowing	05-02-2014			

The experiment on evaluation of subsurface drip irrigation on soil physico-chemical properties, growth and yield of salt tolerant sugarcane in saline Vertisols was initiated during summer 2013-14 at Agricultural Research Station, Gangavati and continued during 2016-17. The experiment was laid out in three replications with main treatments such as surface drip (M1), subsurface drip (M2) and furrow irrigation (control) (M3) and sub treatments such as 0.8 (S1), 1.0 (S2) and 1.2 (S3) ET treatments (Fig. 2.7). The sugarcane salt tolerant variety viz, Co-91010 (Dhanush) procured from Mudhol was sown during Feb-2014 in paired row system (0.6x1.20x0.6 m). The 16 mm inline pressure compensated (PC) anti siphon drippers (dripnet) with emitter spacing of 0.4 m and discharge 1.6 LPH were selected and installed. For subsurface drip treatment, the inline lateral was buried in soil at a depth of 0.15 m facing emitters upward and collecting sub mains for flushing of laterals were given with vacuum breakers. The nine observation wells were installed at each treatment to know the effect of different methods of irrigation technique on water table. The soil samples were collected before sowing to know the initial soil ECe, pH and N, P, K distribution. According to the fertigation schedule, the soluble fertilizers were given through venturi. The soil samples were collected at regular interval for soil moisture analysis.

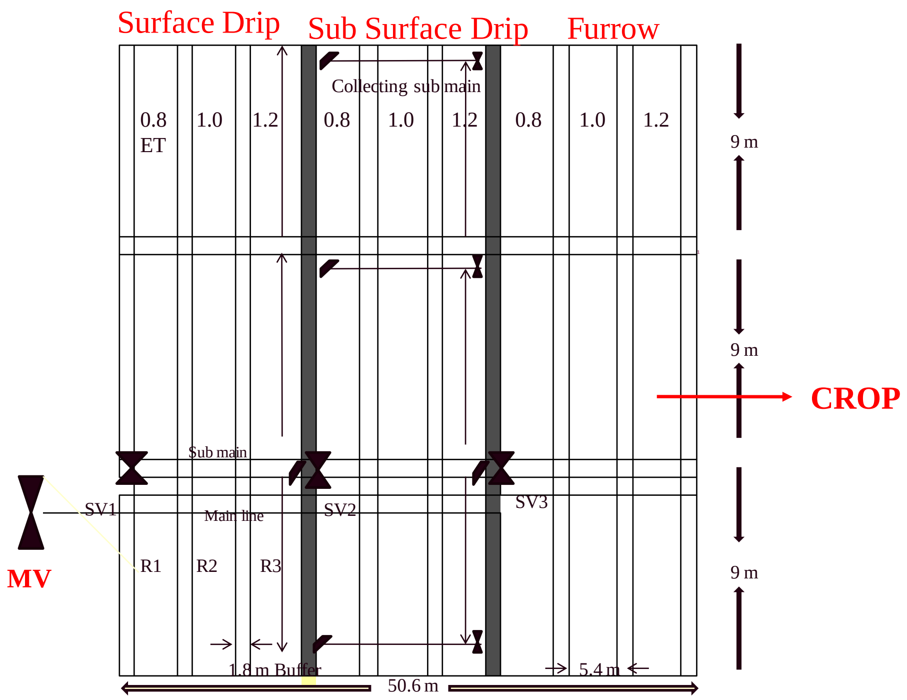


Fig. 2.7 Schematic diagram of sugarcane experimental plot

The initial surface (0-15 cm) soil pH and EC varied from 8.20 to 8.52 and 4.18 to 6.0 dS/m. The mean bulk density and soil porosity of the experimental site ranged between 1.46 to 1.61 gm/cc and 42.8% to 47.2% respectively. The average hydraulic conductivity of the experiment block was 0.23 m/day. The water table depth measured through observation wells weekly for twelve months in all the treatment blocks and the data revealed that, the mean depth of water below ground level (bgl) varied 1.13 (M2S2) to 0.76 m (M3S3) during summer season (March to July) i.e. in canal off period and the mean depth of water bgl varied from 0.99 (M2S1) to 0.56 m (M3S3) during the monsoon (August to December) i.e. in canal on period.

Soil moisture content

Among surface, subsurface drip irrigation methods, at the end of irrigation, the higher soil moisture content (29.5 %) was observed in surface drip with 1.2 ET at 0-15 cm depth at Z-direction (Vertical depth of soil) as given in Table 2.28. In case of 15-30, 30-45 and 45-60 cm depth of soil, the highest soil moisture content (34.2, 30.5 and 22.4 %) was observed in subsurface drip with 1.2 ET.

Table 2.28 Percentage of moisture stored in soil profile at different depths and distances from emitter in surface and subsurface drip irrigation system

Distance from lateral emitter (cm)	Depth (cm)	Treatments					
		M1S1	M1S2	M1S3	M2S1	M2S2	M2S3
		Z-direction (vertical depth)					
0	0-15	25.1	26.6	28.0	22.1	24.3	26.0
	15-30	22.1	21.4	25.4	31.7	32.4	34.2
	30-45	17.1	17.5	21.0	26.4	30.2	30.5
	45-60	15.8	16.2	17.8	22.1	20.1	22.4
10		X-direction (perpendicular to drip lateral)					
	0-15	36.2	35.1	37.6	35.4	38.0	40.5
	15-30	32.4	30.4	34.8	39.9	40.8	41.3
20	0-15	28.3	30.4	33.0	30.4	31.7	33.5
	15-30	22.0	26.4	27.1	38.2	38.7	40.2
10		Y-direction (along the drip lateral)					
	0-15	42.3	47.8	48.2	40.5	42.8	45.4
	15-30	40.5	41.0	44.3	43.8	49.8	51.7
20	0-15	40.0	41.5	42.0	44.2	45.6	46.4
	15-30	31.4	36.4	37.8	42.1	46.6	49.5

In case of X-direction (perpendicular to drip lateral) from 10 cm distance from emitter at 0-15 cm and 15-30 depths, the higher soil moisture content (40.5 and 41.3 %) was observed in subsurface drip at 1.2 ET respectively. In case of 20 cm distance from emitter at 0-15 cm and 15-30 depths, the higher soil moisture content (33.5 and 40.2 %) was observed in subsurface drip at 1.2 ET respectively. In case of Y-direction (along the drip lateral) from 10 cm distance from emitter at 0-15 cm and 15-30 depths, the higher soil moisture content (45.4 and 51.7 %) was observed in subsurface drip with 1.2 ET respectively. In case of 20 cm distance from emitter at 0-15 cm and 15-30 depths, the higher soil moisture content (46.4 and 49.5 %) was observed in subsurface drip with 1.2 ET respectively. From the above data it can be summarized that, in case of 0-15 cm soil depth, more moisture was retained in surface drip irrigation method compared to subsurface drip irrigation. However, at 15-30, 30-45 and 45-60 cm depth of soil, more moisture was retained in subsurface drip compared to surface drip irrigation method. This is due to less evaporation. It was also observed that higher soil moisture content was observed in Y-direction compared to X-direction because of strip wetting pattern. In case of vertical (Z-direction) soil profiles, lower soil moisture was observed compared to lateral directions (X & Y direction) in both the methods of drip irrigation.

Sugarcane growth attributes

The plant height, number of tillers, cane height, internodes per cane and Cane girth were recorded. In case of plant height during 90 days after planting (DAP), 210 DAP and at harvesting time in irrigation methods, significantly higher plant heights were recorded (157.0, 287.8 and 444.0 cm) in subsurface drip irrigation method compared to furrow irrigation and significantly higher plant height was recorded in 1.2 ET irrigation level during 90 DAP. However, no significant difference in plant height was observed in irrigation levels during 210 DAP and at harvesting stage. In irrigation methods and level treatments, significantly higher number of tillers were recorded in subsurface drip and 1.2 ET irrigation level during 90 DAP (1,27,100 and 1,23,000/ha) and 180 DAP (2,29,000 and 2,17,100/ha) respectively (Plate-3). The interaction effect between the treatments was non-significant. In case of cane height, significantly higher height was observed in subsurface drip method among methods of irrigation and no significant difference in cane height was observed in irrigation levels. In case of internodes per cane, significantly higher nodes were recorded in subsurface drip method (22.3) compared to furrow method (19.1). No significant difference was observed in irrigation levels and in interaction effect. Subsurface drip irrigation method registered significant higher cane girth (3.16 cm) as compared to furrow irrigation method in main treatment but no significant difference was observed in irrigation level treatments and in the interaction effect.

Single cane weight and Cane yield

Significantly higher cane weight was recorded in subsurface drip (1584 g) compared to furrow irrigation (1397 g) among irrigation methods and significantly higher weight was recorded at 1.2 ET (1457 g) compared to 0.8 ET (1333 g) in irrigation levels. Among irrigation methods, significantly higher cane yield (129.7 t/ha) was recorded in subsurface drip compared to surface drip (123.3 t/ha) and furrow irrigation (103.2 t/ha) methods (Table H-3). Among irrigation levels, significantly higher yield (122.6 t/ha) was recorded at 1.2 ET irrigation level followed by 1.0 ET (120.4 t/ha) and least in case of 0.8 ET (113.3 t/ha). The interaction effect between irrigation methods and levels was found non-significant (Table -3).

Water use efficiency, Brix percentage and Sugar water use efficiency

Among irrigation methods, significantly higher water use efficiency (WUE) of 85.1 kg/ha/mm was recorded in subsurface drip irrigation compared to surface drip (80.6 kg/ha/mm) and furrow irrigation (67.6 kg/ha/mm) methods. Among irrigation levels, significantly higher WUE (86.4 kg/ha/mm) was recorded at 0.8 ET followed by 1.0 ET (77.9 kg/ha/mm) and least in case of 1.2 ET (68.9 kg/ha/mm). The interaction effect between irrigation methods and levels was found non-significant (Table 3).

The brix percentage did not affect by different irrigation methods and irrigation levels and interaction between irrigation methods and levels was found non-significant. Normally the brix percentage was ranging 20 to 21 in all the treatments. The sugar water use efficiency (S-WUE) was calculated based on brix percentage, yield and total water applied. In case of irrigation methods, significantly higher S-WUE was recorded in subsurface drip irrigation (1.79 kg/m3) followed by surface drip irrigation (1.62 kg/m3) and least in furrow irrigation (1.37 kg/m3) method. Among irrigation levels, significantly higher S-WUE was recorded at 0.8 ET (1.74 kg/m3) followed by 1.0 ET

(1.62 kg/m3) and least in case of 1.2 ET (1.43 kg/m3) irrigation level (Table 2.29). The experiment will continue for 2017-18.

Table 2.29 Sugarcane yield, sugar percentage and water use efficiency as influence different irrigation methods and irrigation levels

Treatments		Single Cane weight (g)	Cane Yield (t/ha)	WUE (kg/ha/mm)	Brix (%)	Sugar water use efficiency (kg/m3)
Irrigation methods (IM)	Surface drip	1426	123.3	80.60	20.19	1.62
	Subsurface drip	1493	129.7	85.10	21.09	1.79
	Furrow	1286	103.2	67.6	20.39	1.37
	SE m +/-	29.79	1.44	1.41	0.20	0.03
	CD (0.05)	117.0	5.69	5.55	NS	0.123
Irrigation levels (IL)	0.8 ET	1333	113.3	86.4	20.10	1.74
	1.0 ET	1417	120.4	77.9	20.70	1.62
	1.2 ET	1457	122.6	68.9	20.80	1.43
	SE m +/-	24.52	1.56	2.21	0.32	0.05
	CD (0.05)	75.56	4.82	6.83	NS	0.144
Interaction (IM x IL)	SE m +/-	42.47	2.71	3.84	0.55	0.08
	CD (0.05)	NS	NS	NS	NS	NS

View of overall growth under subsurface drip, and in furrow irrigation method in sugarcane is shown in Plate 2.5.

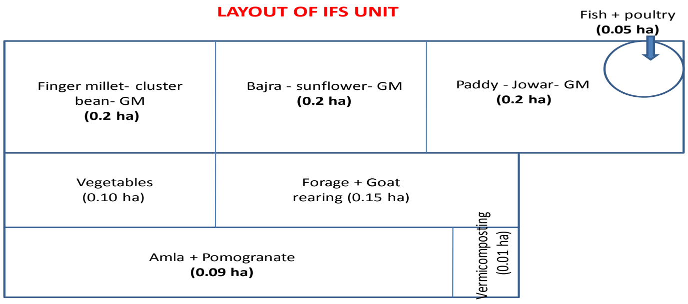
Plate 2.5 View of overall growth under subsurface drip, and in furrow irrigation method in sugarcane.

- **Development of profitable Integrated Farming System (IFS) module for saline vertisols of Thungabhadra Project (TBP) command area of Karnataka (Gangavathi)**

Agriculture in Tungabhadra Project command area of Karnataka is dominated by rice-rice mono cropping system. Out of 3.62 lakh ha, rice occupies an area more than 2.5 lakh ha. Water logging and soil salinity problems are continuously affecting the productivity of the command due to violation of cropping pattern and unscientific irrigation practices. It is estimated that about 96,215 ha area which accounts for over 32 per cent of the total command area (3.62 lakh ha) is salt affected. It has become an uneconomical enterprise especially for the tail-end farmers of the command who lack adequate supply of water and or facing the problem of salinity/sodicity. There is a need for generating farm income through diversification of agriculture in saline soils where the present rice-

rice mono cropping system is subjected to high degree of uncertainty and thus uneconomical. IFS modules are being developed for normal soils however little or no efforts are made to develop IFS module for salt affected soils in TBP command which is rather a more challenging. The components of IFS module are usually complimentary to each other and hence a given piece of land is utilized more economically without any adverse effects on the environment. To augment farm income and create enterprise to make farmers especially of the tail-end to be self-reliant, this project was initiated to develop a suitable IFS module for salt affected soils in TBP command. The IFS components are given below.

I. Cropping systems	
Rice - Sorghum – GM	0.20 ha
Bajra – Sunflower - GM	0.20 ha
Finger millet – Cluster bean – GM	0.20 ha
II. Fodder + Goat rearing (Jamnapari/Shirohi-5+1)	0.15 ha
III. Fishery (six species of common carps) in pond	0.05 ha
IV. Poultry on the pond (Giriraja and Girirani)	Not yet
V. Vermi composting	0.01 ha
VI. Vegetables (Okra, Beet root and cabbage)	0.10 ha
VII. Horticulture (Pomegranate, Amla, drum stick)	0.09 ha
Total	1.00 ha
Conventional cropping system (control) (Rice- Rice - Fallow)	1.00 ha



During the year 2016-17 finger millet, bajra and paddy grown in cropping components. The yield data indicated that 450 kg of grain yield of finger millet and 170 kg paddy grain yields were obtained. Paddy grain yield was very low yield due to low crop stand because of high soil salinity in that area. Five hundred fingerlings were released to the pond and harvested 50 kg of fish in the pond component. Under vegetable components, 130 kg of brinjal and 120 kg of beet root and 15 kg of drum stick were harvested during Kharif and Rabi respectively.

In horticulture component, 50 kg of first bearing fruits of pomegranate was recorded. Under Vermi-composting, about 1000 kg of vermicompost was produced during the year. Among all the components of IFS (as shown in Plate 2.6), poultry on the pond is yet to be established. Cage has been procured for poultry raising on the pond. Benefit cost ratio of all the components of IFS was averaged and compared with conventional farming system of rice- rice monoculture. It was noticed that average B:C ratio (2.74) of all components in IFS was higher than the conventional farming system (1.52) as given in Table 2.30.

Table 2.30 Yield and economics of different components of IFS under saline soils during 2016-17.

Components	Area (ha)	2016-17						
		Yield (kg)			COC	GR	NR	B:C
		K	R	S				
Rice - Jowar-GM	0.20	270	-	-	4960	4590	-370	0.93
Bajra – SF- GM	0.20	-	-	-	-	-	-	-
FM- CB-GM	0.20	450	-	-	4950	13500	8550	2.73
Dairy + fodder	0.15	-	96	-	100	480	380	4.80
Fish pond	0.05			85	1000	6800	5800	6.80
Poultry	-	Yet to be implemented						
Vegetables	0.10	130	120	15	2500	8500	6000	3.40
Horticulture	0.09	-	-	50	1000	2500	1500	2.50
Vermicompost	0.01	-	1000	-	1000	6000	5000	6.00
					15510	42370	26860	2.74
Comparison								
Rice-rice –fallow	1.00	4865	-	-	51230	77840	26610	1.52

Note: FM- finger millet CB- Cluster bean GM- green manure
Market price: FM @ Rs. 30/kg, beetroot @ Rs. 20/kg, paddy @ Rs. 16/kg, fish @ Rs. 80/kg and Pomegranate @ Rs. 50/kg. Urea, DAP and MOP @ Rs. 6, 24 and 16 per kg respectively.


Finger Millet


Pomogranate


Vermicompost unit (with shade)


Pond

Plate 2.6 Different components of IFS under saline soils

- **Modification of waterlogged saline area of south-west Punjab for cultivation (Bathinda)**

The centre was advised to undertake the execution of land modification study for waterlogged saline area of south-west Punjab. Earlier it was proposed to demonstrate at farmer's field, but not possible to executed due to many reasons. In this concern, team from Project Coordinating Unit, ICAR-CSSRI, Karnal, visited the RRS, Bathinda on 27.04.2016 to discuss the matter. The Joint Committee of ICAR-CSSRI and RRS, PAU, Bathinda visited different sites and suggested demonstration of technology may be undertaken on land allotted to PAU in village Ratta Khera, Shri Muktsar Sahib. Movement of machinery was difficult on site due to shallow water table and the contractor stopped the work.

- **Utilization of saline tolerant microbes (Port Blair)**

Growth promotion

Twenty salinity tolerant microbes have been isolated from the rhizosphere soils of selected plants growing in saline condition, characterized and maintained by sub-culturing. After laboratory testing for salinity tolerance, five most promising isolates were used as consortia for further evaluation. A field study was conducted to evaluate the effectiveness bioconsortia on Okra. Saline tolerant bio-consortia were inoculated by seed priming and application to soil through compost in order to assess its effectiveness in promoting plant growth and nutrient uptake.

The results showed that bioconsortia treatments had significant effect on the plant growth at 51st days after sowing as compared to the control. Maximum plant height of 135.6 cm was recorded in NFB3+ SM4 followed by 109.8 cm in NFB3 while control recorded 94.8 cm only. Number of fruits per plant was highest in NFB3+ SM4 (32) which were 45% higher than the control. Similarly fruit dry biomass was highest for NFB3+ SM4 (278.4 gm) followed by NFB3 (277.2 gm). The maximum plant dry biomass was recorded for TA1+ NFB3 (150 gm) which was 60% higher than the control followed by NFB3+ SM4 (144 gm). The results highlighted the usefulness of salinity tolerant bioconsortia (NFB3+ SM4) in promoting plant growth and yield.

Nutrient mobilization

Fifteen salinity tolerant microbes were isolated from the rhizosphere soils of selected plants growing in saline environment and characterised for hydrolytic properties. Out of which four most promising isolates (SM2, 1D, CHI, NW1) were further characterized for *in-vitro* zinc solubilizing ability and maintained by sub-culturing. These isolates were inoculated and incubated for 7 days with tris minimal agar medium supplemented with zinc oxide and zinc phosphate. The clearing zone around the colony was recorded. All the four isolates produced halo around the colony which was due to the solubilizing effect of the isolates (Plate 2.7). The maximum solubilization of 2.3 cm was observed for CHI followed by SM2 (1.8 cm), NW1 (1.5 cm) and ID (1.2 cm). These isolates can be used as a potential biofertilizer for Zn solubilization under moderate saline conditions (5 dSm^{-1}).

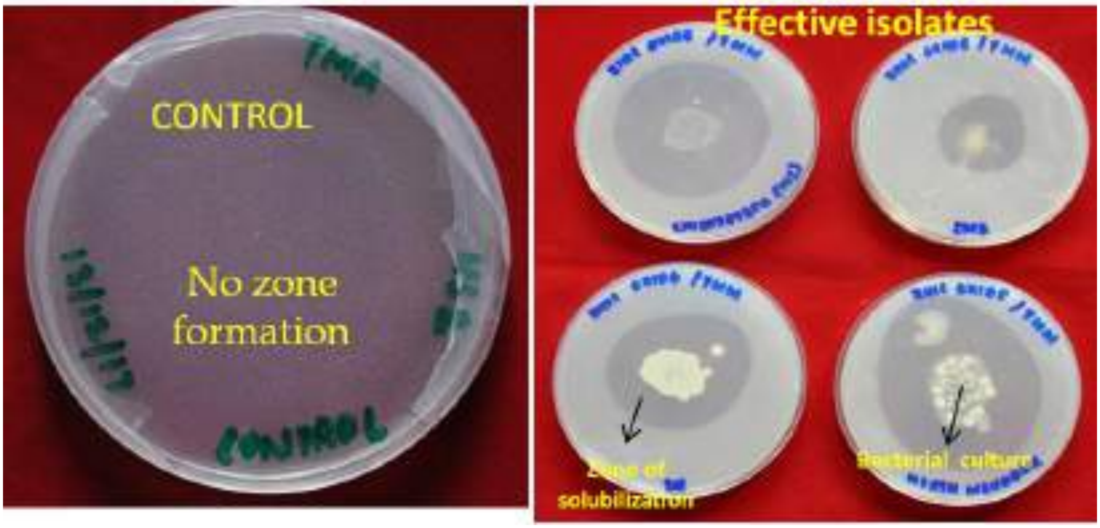


Plate 2.7 Zn solubilization by the salinity tolerant bacterial isolates

Alternate practices

In order to identify and utilize the salinity tolerant wild or land races of different crops which are adapted to the saline conditions are documented. Some of the potential plants are found in its natural habitats (Table 2.31). Soil samples were also collected and analysed for the salinity status.

Table 2.31 Salinity tolerant crops / varieties suitable for island conditions

Underutilized species/Wild plants	Botanical name	Salinity tolerance level (dSm^{-1})	Average yield	Desirable traits
Khaari phal	*Ardisia solanaceae* Roxb., A. *andamanica* Kurz.	2-5	2 kg / tree	Salinity tolerant, grows even in waterlogged soils
Khaari khajoor	*Phoenix paludosa*	2-5	2 kg / tree	Salinity tolerant
Pond apple	*Annona glabra*	2-4	15 kg /tree	Salinity tolerant, can be used as root stock
Noni- rakshak	*Morinda citrifolia*	2-4	15 kg/tree	Salinity tolerant and adapted to hot, humid conditions
Wild nutmeg	*Knema andamanica*	2-5		Can be used as salt tolerant root stock for nutmeg
Jamun (local collection)	*Syzygium claviflorum*	2-3	40-60 kg/tree	Successfully grows near sea shores
Seashore mangosteen	*Garcinia hombroniana*	2-4		Could be used as salt tolerant rootstock for other Garcinia species
Rice land race	*Oryza sativa indica*	2-4	2.5 – 3.5 t/ha	Suitable for lowlying saline areas
Pandanus- orange and yellow	*Pandanus tectorius*	2-8	40-50 kg/tree	Grows well in the coastal, saline soils, act as a bioshield

2.3 Management of Saline–acidic soils

- **Integrated farming system for sustainable land use in Pokkali lands (Vytilla)**

Rice – prawn integration in *Pokkali*

The experiment was planned to evaluate the rice-fish/prawn integration in *Pokkali* lands for maximum productivity as well as benefits and to analyze the changes in soil properties. *Pokkali* field of Kumbalangi, farmer from Ernakulam was selected for the experiment. The water from pokkali field was drained out, field was ploughed and levelled for rice cultivation, ridges and furrows were taken for transplanting of germinated seeds on ridges on 28.06.2016. Harvesting was done manually on 25th October 2016. Only panicles were harvested and straw was kept in the field. The harvested bundles of panicles were brought to the bund using a small boat by farmer. Details are provided in Plate 2.8.


a) Rice cultivation during kharif season


b) Harvesting and collection of harvested panicles using a small boat

c) Capturing fish using portable net from sluice

d) Harvested tiger prawn

Plate 2.8 Rice – prawn integration in *Pokkali*

Data analysis of water samples (Table 2.32), revealed that pH of the rice field decreased during initial stages of plant growth and there after increased by tillering stage. Electrical conductivity of the water samples decreased initially and later increased by the time of harvest.

Table 2.32 Chemical properties of water samples of Pokkali rice field, during different stages of Rice

Crop stage	**pH**		**EC (dSm^{-1})**	
	Soil	**Water**	**Soil**	**Water**
Transplanting	7.69	7.34	2.6	8.2
Dismantling	7.3	7.1	2.6	5.3
Tillering	7.98	8.27	1.2	6.2
Harvesting	7.3	7.21	8.6	8.5

The analysis of soil samples (Table 2.33), data revealed that soil pH from rice field decreased during initial stages of plant growth and there after increased and again decreased by the harvesting period. Electrical conductivity of the samples was constant during transplanting and dismantling stages. But the EC reduced during active tillering and steep hike was observed by the time of harvest. The organic carbon per cent showed a decreasing trend from transplanting to harvesting stage. On observing the available phosphorus content of soil, there was not a much significant difference among the four stages. Available potassium content decreased during dismantling stage and later increased by harvesting time. Sodium, sulphur and iron content were found to increase whereas, calcium and magnesium content showed a decreasing trend. On observing the micronutrient status of soil, the content showed a decreasing trend.

Table 2.33 Chemical properties of soil samples of Pokkali rice field, during different stages of Rice

Crop stages	pH	EC	OC	P	K	Na	Ca	Mg	S	Fe	Cu	Mn	Zn
		dS m^{-1}	%	kg ha^{-1}			mg kg^{-1}						
Transplanting	7.7	2.6	2.34	31.7	811.8	1568.6	555	23.9	30	227.8	0.79	0.98	1.95
Dismantling	7.3	2.6	2.32	29.5	465.3	1931.6	355	21.5	32.5	335.5	0.74	0.7	2.43
Active tillering	7.9	1.2	2.2	31.2	932.3	115	304.2	20.6	45.6	350.3	0.52	0.78	1.54
Harvesting	7.3	8.6	1.89	31.2	885.4	5665.4	382.5	20.7	49.6	445.1	0.45	0.8	0.64

The traditional practice of rice prawn integration was indeed economical and eco-friendly. Analysis of Benefit-Cost ratio (Table 2.34) is also approving the same.

Table 2.34 Cost of Cultivation, returns and benefit cost ratio of rice-prawn integration

Sl. No.	Rice		Prawn	
	Component	Cost (Rs.)	Component	Cost (Rs.)
1	Land preparation, ploughing, ridges and furrow preparation	7000	Prawn seedlings	8000
2	Weeding (8 women)	3200	Transportation charge	5000
3	Transplanting (20 women)	8000	Field preparation, labour charge	10000
4	Harvesting (17 women + 4 men)	16000	Feed	8500
5	Threshing (3 women + 3 men)	3200	-	-

6	Drying (2 men + 2 women)		4000	-	-
Total			41400		31500
Benefit Cost Ratio					
Crop	Cost (Rs)	Yield	Price (Rs/kg)	Returns (Rs)	BC Ratio
Rice	41400	2.38 (t/ha)	40	95200	2.29
Prawn	31500	375(kk/ha)	350	131250	4.16

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. In this system the growth of both the components are interrelated and is one of the proven technology which is very cost effective. During the year 2016-17, grain yield recorded was 2.38 t ha^{-1} and total of 375 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 2.29. 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 fertilisers. This 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 initited 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 (Kharif season crop)

Germination and plant height: Effect of irrigation water quality on germination was found non-significant. The plant height of toria did not differ significantly at 30, 60 and 90 DAS. The maximum plant height increased at 90 DAS.

Dry matter accumulation: The dry matter accumulation per plant at different crop stages showed that dry matter accumulation increased up to 90 DAS. The minimum and maximum dry matter production was obtained during 30 DAS and 60-90 DAS respectively. The treatments were statistically non-significant during whole crop growth period (Table 3.1).

Table 3.1 Effect of alkali and canal water irrigation on toria (2016-17)

Treatments	Germination (%)	Plant height (cm)			Dry matter accumulation (g)		
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
CW	79.00	11.33	79.33	107.67	8.50	32.90	70.83
1CW:1AW	77.67	11.33	79.67	105.33	8.10	32.27	70.40
2CW:2AW	77.65	11.00	77.33	105.33	9.33	32.23	68.37
2AW:2CW	76.00	11.67	76.00	105.33	8.63	31.30	67.50
Mix.(1:2)	77.33	11.67	76.33	106.00	9.10	31.97	67.80
Mix. (2:1)	77.50	11.67	77.00	106.00	9.33	33.20	68.17
AW	76.00	10.67	74.67	102.33	7.90	30.90	64.63
CD (5%)	NS	NS	NS	NS	NS	NS	NS

Plant growth and yield attributing characters: Number of primary and secondary branch was recorded at harvest were found non-significant in all the treatments. The perusal of the data showed that yield attributing characters viz. length of siliqua, no. of seed per siliqua and 1000 seed weight (g) were did not differ significantly, except number of siliqua per plant. The maximum number of siliqua was found in canal water and minimum in all alkali water irrigation (Table 3.2).

Table 3.2 Effect of alkali and canal water irrigation on yield attributing characters of Toria (2016-17)

Treatments	No. of primary branches	No. of secondary branches	No. of siliqua/plant	Length of siliqua (cm)	No. of seed per siliqua	1000 seed weight (g)
CW	12.10	22.07	560.00	4.47	12.40	3.60
1CW:1AW	11.83	20.27	540.67	4.27	12.10	3.47

2CW:2AW	11.57	20.20	537.33	4.37	12.13	3.40
2AW:2CW	11.60	19.77	545.00	4.37	11.67	3.40
Mix.(1:2)	11.47	19.60	528.67	4.40	11.97	3.33
Mix. (2:1)	11.87	19.63	533.67	4.43	12.13	3.50
AW	11.17	18.97	521.00	4.37	10.43	3.17
CD (5%)	NS	NS	25.8	NS	NS	NS

Toria yield, Net profit and B: C ratio: The grain and stover yield differ significantly. The higher grain and stover yield was recorded in canal irrigation (15.48 q/ha and 28.78 q/ha) and lowest in all alkali water (12.10 q/ha and 24.18 q/ha). The biological yield and harvest index differ significantly. The value of biological yield and harvest index was the maximum in all canal water and minimum in all alkali water irrigation. The maximum net profit was produced in canal water irrigation (Rs. 35,839) and lowest in alkali water irrigation (Rs. 23,469). In case of benefit cost ratio the maximum (1.72) was analysed in canal water and lowest (1.12) in alkali water irrigation (Table 3.3).

Table 3.3 Effect of alkali and canal water irrigation on yield, net profit and B:C ratio of Toria (2016-17)

Treatments	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	Net profit (Rs/ha)	B:C ratio
CW	15.48	28.78	44.26	34.97	35,839	1.72
1CW:1AW	14.91	27.30	42.21	35.30	33,753	1.62
2CW:2AW	14.89	26.60	41.49	35.88	33,680	1.61
2AW:2CW	13.10	25.70	38.80	33.74	27,129	1.30
Mix.(1:2)	14.24	25.45	39.69	35.87	31,301	1.50
Mix. (2:1)	14.90	26.33	41.23	36.14	33,717	1.62
AW	12.10	24.18	36.31	33.34	23,469	1.12
CD (5%)	2.6	2.1	2.9	2.7	-	-

Chikory (Rabi season crop)

Germination and plant height: After harvest of toria crop, the chikori was grown during *rabi* season with different alkali: canal irrigation modes.The germination per cent differ non-significantly in all the treatments. The plant height of chicory at 30, 60, 90, 120 and 150 DAS showed that plant height did not differ significantly. However, the plant height increased with the age of the crop. The maximum plant height increased during 120 to 150 days crop growth period (Table 3.4).

Table 3.4 Effect of alkali and canal water irrigation on germination and plant height of Chicory

Treatments	Germination (%)	Plant height (cm)				
		30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
CW	78.54	4.27	8.67	14.93	16.37	18.80
1CW:1AW	78.35	4.20	8.47	14.13	15.77	18.13
2CW:2AW	77.97	4.20	8.60	14.82	15.63	18.43
2AW:2CW	77.87	4.10	8.40	14.33	15.33	18.27
Mix.(1:2)	73.93	4.13	8.23	14.55	15.00	17.90
Mix. (2:1)	78.45	4.23	8.33	14.73	15.47	18.47
AW	77.15	3.83	8.20	12.87	13.73	16.85
CD (5%)	NS	NS	NS	NS	NS	NS

Diameter and length of roots: The diameter of chicory root (cm) and length of chicory root (cm) was recorded and found that diameter of chicory root was significantly higher in CW (12.74 cm) and lowest in AW (9.96 cm). The chicory root length (cm) was significantly higher (23.66 cm) in CW and lowest (18.63 cm) in AW irrigation (Table 3.5).

Chikory yield, net profit and B:C ratio: The chicory root yields differ significantly amongst the different mode of canal and alkali water irrigations. The maximum chicory root yield was found in CW (253.70 q/ha) and lowest in alkali water (178.36 q/ha). The irrigation water mode 1CW:1AW, 2CW:2AW and mixing (2 CW:1AW) were significantly at par to canal water treatment (Table 3.5) The highest net profit of Rs. 74,417.5 was observed in canal water irrigation and lowest of Rs. 42,398 in alkali water irrigation. In case of benefit: cost ratio the maximum was 2.23 in canal water irrigation and lowest 1.27 in alkali water irrigation (Table 3.5).

Table 3.5 Effect of alkali and canal water irrigation on yield, net profit and B:C ratio

Treatments	Diameter of chicory root(cm)	Length of chicory root (cm)	Yield of chicory root (q/ha)	Net profit (Rs/ha)	B:C ratio
CW	12.74	23.66	253.70	74,417.50	2.23
1CW:1AW	11.63	21.71	246.44	71,332.00	2.14
2CW:2AW	11.47	21.20	246.06	71,170.50	2.13
2AW:2CW	10.37	20.25	229.02	63,928.50	1.91
Mix.(1:2)	11.30	21.20	235.61	66,729.25	1.99
Mix. (2:1)	11.57	21.85	246.04	71,162.00	2.13
AW	9.96	18.63	178.36	42,398.00	1.27
CD (5%)	0.92	1.8	18.6	-	-

Rotational net profit and B:C ratio: The maximum net profit (Rs. 1, 10,257), from two crops grown in one year rotation, was recorded in canal water irrigation and lowest (Rs. 65,867) in alkali water irrigation. The benefit cost ratio was maximum (1.98) in canal irrigation and minimum (1.20) in alkali irrigation (Table3. 6).

Table 3.6 Effect of alkali and canal irrigation on net profit and B:C ratio of toria and chicory

Treatments	Net profit (Rs/ha)			B:C ratio		
	Toria	Chicory	Total	Toria	Chicory	Average
CW	35,839.8	74,417.5	1,10,257.3	1.72	2.23	1.98
1CW:1AW	33,753.6	71,332.0	1,05,085.6	1.62	2.14	1.88
2CW:2AW	33,680.4	71,170.5	1,04,850.9	1.61	2.13	1.87
2AW:2CW	27,129.0	63,928.5	91,057.5	1.30	1.91	1.61
Mix.(1:2)	31,301.4	66,729.2	98,030.6	1.50	1.99	1.75
Mix. (2:1)	33,717.0	71,162.0	1,04,879.0	1.62	2.13	1.88
AW	23,469.0	42,398.0	65,867.0	1.12	1.27	1.20

Cropping System productivity: The maximum system yield (268.50 q/ha) was observed in all canal water (CW) irrigation and minimum (190.46 q/ha) in all alkali water irrigation. The other best treatments for system productivity were 1CW:1AW, 2CW:2AW and cyclic 2CW:1AW (Table 3.7).

Table 3.7 Effect of modes of irrigation on system productivity

Treatments	Toria yield (q/ha)	Chicory yield (q/ha)	Cropping system yield (q/ha)
CW	15.48	253.70	268.58
1CW:1AW	14.91	246.44	261.35
2CW:2AW	14.89	246.06	260.95
2AW:2CW	13.10	229.02	242.12
Mix.(1:2)	14.24	235.61	249.85
Mix. (2:1)	14.90	246.04	260.94
AW	12.10	178.36	190.46

- **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. Initially pH, ECe, ESP and Organic Carbon of soil were 9.10, 093 dS/m, 42.2 and 0.28%, respectively.

Mode Irrigation water application	
• Best Available Water (BAW)	
• RSC groundwater	
• BAW followed by all irrigations by RSC water	
• RSC water followed by all irrigation by BAW	
• 1 BAW and 1RSCW (Alternately)	
• BAW + RSC water after mixing	
Other details	
Crop rotation:	Rice, wheat and pearl millet
Varieties:	CSR-36, KRL-211 and ICTP-8203
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	7.5	8.82
EC(dSm-1)	0.7	1.11
Anions (meq l-1)		
CO3	Nil	NIL
HCO3	4.11	8.42

Cl	3.31	1.88
SO4	0.1	0.73
Cations (meq l-1)		
Ca+Mg	6.41	2.63
Na+K	1	8.49
RSC (meql-1)	Nil	5.79

Results indicated that average yield varied from23.51-38.85 and 17.10-.34.49 q/ha for rice and wheat, respectively in rice- wheat cropping system (Table 3.9). Highest yield was obtained from best available water (BAW) followed by BAW + RSCW (mixing) and lowest yield was received from residual sodium carbonate water (RSC Water) treatment.

Table 3.9 Effect of treatments on grain yield of crops (q/ha)

Treatments	Rice-wheat							
	Rice			Mean	Wheat			Mean
	2014	2015	2016		2014-15	2015-16	2016-17	
BAW	37.18	39.25	40.12	38.85	32.73	34.95	35.78	34.49
RSCW	24.25	23.77	22.50	23.51	17.45	17.12	16.72	17.10
BAW - (Rest irrigation with RSCW)	28.77	28.46	27.88	28.37	22.04	23.10	21.94	22.36
RSCW - (Rest irrigation with BAW)	33.26	34.43	36.75	34.81	27.14	28.88	30.22	28.75
1 BAW-1 RSCW (Alternate)	31.65	32.36	32.47	32.16	26.00	27.65	27.42	27.02
BAW + RSCW	34.61	36.11	33.52	34.75	28.11	29.46	28.71	26.43
CD = 0.05	1.57	1.64	1.67	--	1.23	1.46	1.49	--

The average yield varied from 08.44-15.35 and 17.97-33.32 q/ha of pearl millet and wheat respectively in pearl millet - wheat cropping system, (Table 3.10). The highest yield was obtained from best available water (BAW) followed by RSCW - (Rest irrigation with BAW) and lowest yield was received from residual sodium carbonate water (RSCW) treatment.

Table 3.10 Effect of treatments on grain yield of crops (q/ha)

Treatments	Pearl millet-wheat							
	Pearl Millet			Mean	Wheat			Mean
	2014	2015	2016		2014-15	2015-16	2016-17	
BAW	14.52	15.55	15.97	15.35	33.27	35.37	36.28	33.32
RSCW	08.41	08.12	08.78	08.44	18.08	17.85	16.74	17.97
BAW (Rest irrigation with RSCW)	10.58	10.05	09.62	10.08	20.55	20.82	19.96	20.65
RSCW (Rest irrigation with BAW)	12.24	12.83	13.36	12.81	27.95	29.05	31.15	29.38

1 BAW-1 RSCW (Alternate)	10.98	11.27	10.64	10.96	26.78	28.00	28.25	27.39
BAW + RSCW	12.75	12.35	11.42	12.17	28.35	28.16	27.62	28.04
CD = 0.05	1.17	1.29	1.27	--	1.21	1.37	1.35	--

Physico-chemical properties:

Changes in pH, electrical conductivity, exchangeable sodium percentage (ESP) and organic carbon (OC) indicate 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 RSCW. Related data are given in Table 3.11

Table 3.11 Effect of treatments on physico-chemical properties of soil after three years

Treatments	Rice-wheat				Pearl millet-wheat			
	pH	EC	ESP	OC	pH	EC	ESP	OC
BAW	8.5	0.84	31.3	0.36	8.6	0.86	32.5	0.34
RSCW	9.4	0.95	46.7	0.25	9.5	0.96	47.3	0.26
BAW - (Rest irrigation with RSCW)	9.1	0.94	42.4	0.29	9.2	0.95	43.2	0.30
RSCW - (Rest irrigation with BAW)	8.6	0.87	33.3	0.33	8.7	0.90	32.4	0.32
1 BAW-1 RSCW (Alternate)	8.8	0.93	36.0	0.31	8.9	0.92	37.2	0.30
BAW + RSCW	8.7	0.90	35.8	0.32	8.7	0.89	36.0	0.31
Initial values	pH-9.10		EC-0.93		ESP-42.2		OC-0.28	

- **Pressurized irrigation methods for vegetable crops in sodic soils (Tiruchirapalli)**

An experiment was conducted to identify suitable pressurized irrigation methods for different crops and its effect in terms of growth, yield and economics under sodic soil with alkali water. An experiment was initiated during 2016 at research farm of Trichirappalli centre. The pH and EC of the initial experimental field soil were 9.0 and 0.87 dSm^{-1}, respectively. The N, P and K content of the initial soil is 237 kg/ha, 18.6 kg/ha and 254 kg/ha, respectively. The experiment consisted of various irrigation methods in main plots *viz.,* drip, sprinkler and farmer's practice (Furrow irrigation) and four vegetable crops in sub plots viz., cluster bean (var: PUSA Naubahar), bhendi (COBhH-4), vegetable cowpea (var: PKM 1) and onion (CO-5). The drip irrigation system was installed with in-line drippers of 4 lit hr^{-1} at a spacing of 60 cm. The sprinkler irrigation system was installed with a spacing of 6 m along the lateral.

The yield of vegetable crops also showed that drip and sprinkler irrigation were more effective and efficient than furrow irrigation for increasing the yield of vegetable crops under sodic environment. Vegetable cowpea yield was highest among the vegetable crops and recorded an yield of 9264 kg/ha under drip irrigation compared to 7910 kg/ha under sprinkler irrigation and followed by 5426 kg/ha in furrow irrigation (Table 3.12). The yield increase in vegetable cowpea crop under drip irrigation technique was 71% higher than the furrow irrigation. The yield of cluster bean, bhendi and onion was 4120, 5160 and 4019 kg/ha in drip irrigation treatment and the yield increase over control was 43%, 34% and 49%, respectively. The results showed that sprinkler and drip irrigation methods are more suitable than furrow irrigation method. Further, limited surface and ground water resources, drip irrigation method is highly recommended for sodic soil environment for sustainable use of water resources with improved efficiency and more agricultural productivity. Slight build up in sodicity was observed in soil with flood irrigation compared to drip and sprinkler irrigation methods.

Table 3.12. Effect of irrigation methods on yield of vegetables (kg ha^{-1})

Treatments	Cluster bean	Bhendi	Vegetable cowpea	Onion
Drip irrigation	4120	5160	9264	4019
Sprinkler irrigation	3715	4582	7910	3490
Flood irrigation	2880	3856	5426	2692
Mean	3572	4533	7533	3400
CD (P=0.05)	I	C	I at C	C at I
	120	333	511	580

- **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 compared with soil application of gypsum.

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
M_2	Drip with spent wash treated water	S_2	One time application of DSW @ 5 lakh liters ha^{-1}	Crop	: Cotton
				Hybrid	: RCH 20
M_3	Drip with untreated alkali water	S_3	No amendments	Spacing	: 90 x 60 cm

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. The layout plan of the experimental field is depicted in Fig.1. 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 during last week of September 2016. 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 3.13). Gypsum bed treatment reduced the RSC to 3.4.

Table 3.13. Changes in quality of ameliorated alkali water

Sl. 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

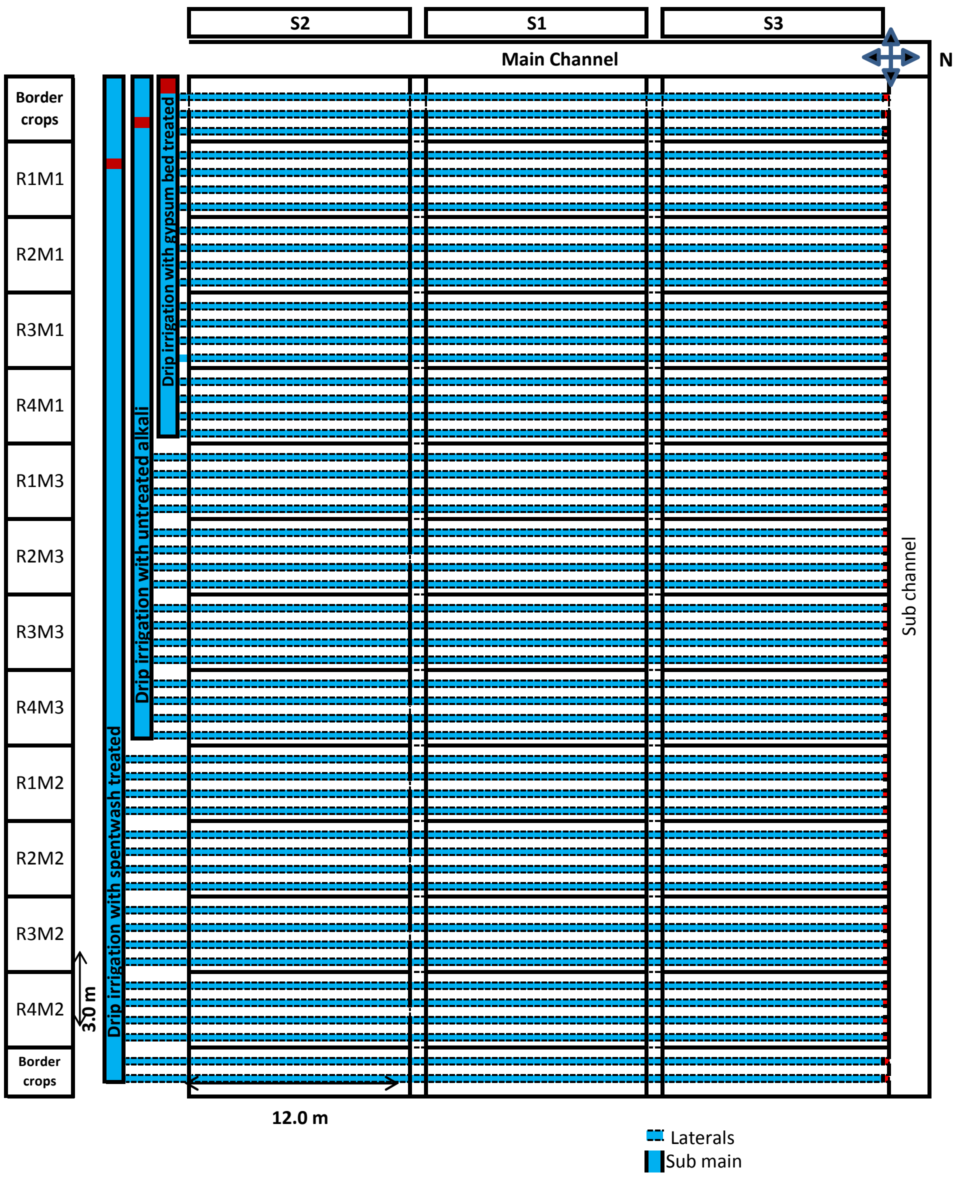


Fig.3. 1 Layout plan of cotton experimental field

Effect of ameliorated alkali water on cotton yield

The results revealed that irrigation with gypsum bed treated alkali water with reclamation of soil through one time application of DSW @ 5 lakh liters ha^{-1} recorded the highest seed cotton yield of 3014 kg/ha and the lowest was recorded in the untreated alkali water irrigated through drip system at un-amended soil (1410 kg/ha). Ameliorating alkali water through gypsum bed recorded the highest seed cotton yield of 2581 kg/ha followed by the treatment of irrigation water with DSW which is 2423 kg/ha (Table 3.14). Drip irrigation with alkali water recorded the lowest seed cotton yield of 1880 kg/ha.

Table 3.14 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	15.4	17.8	10.2	14.5	37.1	42.0	19.2	32.8	2780	3014	1948	2581
M2	15.0	15.6	9.8	13.5	35.7	38.6	18.1	30.8	2608	2882	1780	2423
M3	11.5	12.0	8.3	10.6	19.9	20.6	17.6	19.4	2070	2160	1410	1880
Mean	14.0	15.1	9.4	12.8	30.9	33.7	18.3	27.6	2486	2685	1713	2295
CD	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
(p= 0.05)	1.02	1.23	2.05	2.15	2.08	2.51	4.19	4.39	156.0	188.0	313.9	329.6

Effect of ameliorated alkali water on soil properties

The effect of ameliorated alkali water and soil application of gypsum and distillery spentwash on soil properties viz., pH, EC and ESP are given in Table 3.15. The analysis of soil samples taken after the harvest of crops indicated that the increase in the EC from 0.44 dSm^{-1} to 0.72 dSm^{-1} but slight decrease in soil pH from 8.9 to 8.02 was recorded. The increase of soil ESP from 16.2 to upto 17.4 was noticed which is significant indication of buildup of soil ESP, particularly in the plot irrigated with untreated alkali water and un-amended sodic soil. The soil available nutrients viz., N, P and K content at post harvest stage ranged from 167 to 351, 15.4 to 21.5 and 158 to 928 kg/ha, respectively (Table 3.16 and 3.17). The application of amendments showed significant increase in the available N, P and K content of soil. Highest available N, P and K (260, 18.2 and425 kg/ha respectively) were observed in the treatment of irrigation with DSW treated water with reclamation of soil through one time application of DSW @ 5 lakh liters ha^{-1}.

Table 3.15 Effect of drip irrigation using ameliorated alkali water on pH, EC and ESP of post harvest soil

Treat-ments	pH				EC ($dS\ m^{-1}$)				ESP			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
M1	7.78	7.50	8.75	8.01	0.60	1.04	0.48	0.71	14.8	12.7	23.2	16.9
M2	7.65	7.40	8.70	7.92	0.76	1.09	0.54	0.80	14.2	11.8	22.6	16.2
M3	7.90	7.65	8.84	8.13	0.52	0.96	0.45	0.64	15.5	13.3	23.5	17.4

Mean	7.78	7.52	8.76	8.02	0.63	1.03	0.49	0.72	14.8	12.6	23.1	16.8
CD	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
(p= 0.05)	0.09	0.11	NS	NS	0.04	0.05	NS	NS	0.32	0.39	0.64	0.68

Table 3.16 Effect of drip irrigation using ameliorated alkali water on organic carbon and available nitrogen content of post harvest soil

Treatments	Organic carbon (%)				Available nitrogen (kg/ha)			
	S1	S2	S3	Mean	S1	S2	S3	Mean
M1	0.62	0.92	0.42	0.65	248	340	170	253
M2	0.77	0.94	0.44	0.72	256	351	174	260
M3	0.54	0.87	0.39	0.60	240	337	167	248
Mean	0.64	0.91	0.42	0.66	248	343	170	254
CD	M	S	M at S	S at M	M	S	M at S	S at M
(p= 0.05)	0.05	0.06	0.10	0.11	7.86	9.47	15.81	16.61

Table 3.17 Effect of drip irrigation using ameliorated alkali water on available phosphorus and potassium content of post harvest soil

Treatments	Available phosphorus (kg/ha)				Available potassium (kg/ha)			
	S1	S2	S3	Mean	S1	S2	S3	Mean
M1	16.8	20.4	15.6	17.6	175	905	161	414
M2	17.2	21.5	15.9	18.2	182	928	165	425
M3	16.5	19.8	15.4	17.2	167	891	158	405
Mean	16.8	20.6	15.6	17.7	175	908	161	415
CD	M	S	M at S	S at M	M	S	M at S	S at M
(p= 0.05)	0.71	0.86	1.43	1.50	5.86	7.06	11.79	12.38

Plate 3.1 View of the experimental field

3.2 Management of Saline Water

- **Micro (Drip) Irrigation system with saline water for different vegetable crops in coastal sandy soils (Bapatla)**

This experiment was initiated to study responses of different vegetable crops to variable levels of irrigation water salinity. The vegetable crops like tomato, bhendi, brinjal, radish, capsicum, clusterbean and palak were tested under different levels of irrigation water salinity viz., BAW (0.6), 2, 4, 6 and 8 dS m^{-1}. The results obtained during 2008-09 to 2015-16 were reported in respective biennial reports. Experimentation on 3 new vegetables has been started during 2016 as per details given below.

Main Treatments	**Other details**	
T_1 – Best available water	Experimental Design	RBD
T_2 – EC_{iw} – 2 dS m^{-1}	Replications	4
T_3 – EC_{iw} – 4 dS m^{-1}	Fertilizer	RDF
T_4 – EC_{iw} – 6 dS m^{-1}		
T_5 - EC_{iw} – 8 dS m^{-1}	**Spacing**	
Sub-treatments	a) Moringa	2.5 m x 2.5 m
C_1 – Drumstick (Moringa)	b)Cabbage	60 cm x 60 cm
C_2 – Cabbage	c) Cauliflower	60 cm x 60 cm
C_3 – Cauliflower		

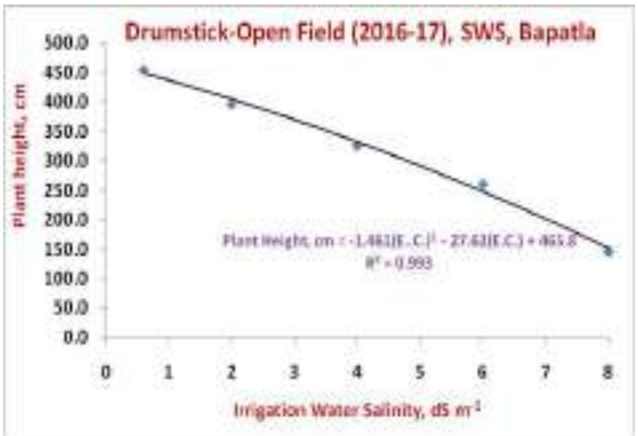
The moringa yields were found significantly decreasing from the best available water (BAW-0.6 dS m-1) to 8 dS m-1. However, difference in the yield was not significant for 6 and 8 dS m^{-1} irrigation water salinity as the P-value is 0.01 which is greater than 0.005. It is also found that the plant heights were not significantly different till 4.0 dS m-1, but after that the plant heights decreased significantly. The chlorophyll_a content is found to be not significantly differing between BAW (0.6dS m-1) and 2.0 dS m-1., but is found to be significantly differing with 4.0, 6.0 and 8.0 dS m^{-1}. The chlorophyll_b content is found to be significantly differing between BAW (0.6dS m-1) and 2.0, 4.0, 6.0 and 8.0 dS m^{-1}. The yields of cabbage, cauliflower and drumstick, t ha^{-1} at different levels of salinity of irrigation water are given Table 3.18 and Table 3.19. Effect of irrigation water salinity on plant height and crop yield for drumstick is shown in Fig.3.2 while production functions are given in Table 3.20.

Table 3.18 Yields of cabbage, cauliflower and drumstick, t ha^{-1} at different levels of salinity of irrigation water

Yield, t ha^{-1}	Cabbage	Cauliflower	Drumstick
0.6	39.76	18.03	33.63
2	32.26	17.70	25.96
4	22.13	10.68	13.30
6	18.39	8.01	5.25
8	11.35	6.02	4.14

Table 3.19 The yield levels of cabbage, cauliflower and drumstick vs EC of irrigation water

Yield Level (%)	Cabbage	Cauliflower	Drumstick
	Irrigation water salinity (EC, dS m^{-1}) at particular yield level		
100	0.7	1.1	0.8
90	1.3	1.7	1.2
80	2.1	2.5	1.6
75	2.5	2.9	1.8
70	2.9	3.3	2.0
60	3.9	4.3	2.5
50	5.0	5.4	3.1
40	6.4	6.8	3.9
30	8.2	8.6	4.8
20	10.7	11.1	6.2
10	15.1	15.4	8.5



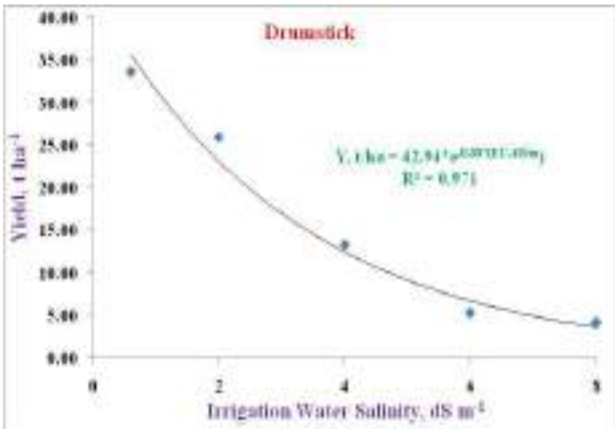
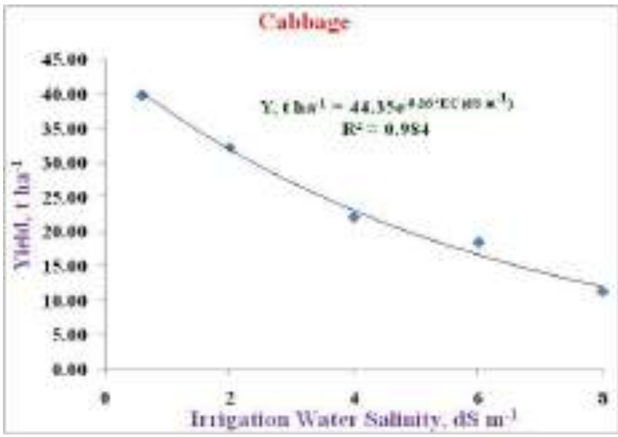


Fig. 3.2 The Scattered plots of the Plant height and yield of Drumstick

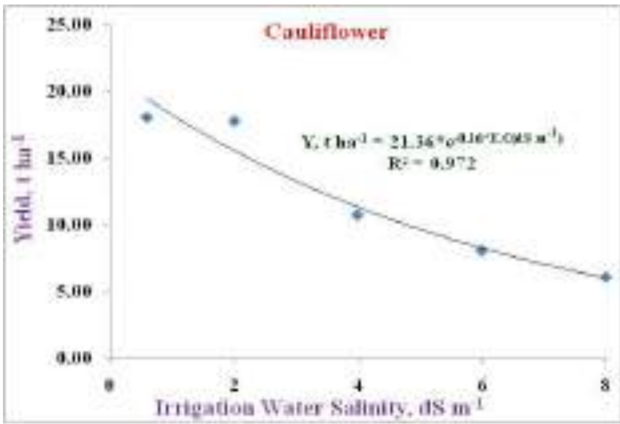
Table 3.20 The production functions of Moringa (Drumstick) Plant height and Yield

Sl.No.	Production Functions	R2 Value	Remarks
1.	Plant height, cm = -1.461*(E.C.)2 - 27.62(E.C.) + 465.8	0.993	Linear Equation
2.	Yield, t ha-1 = 42.94*e-0.30*(EC,dS m-1)	0.971	Exponential Equation

Yield response of cabbage and cauliflower crops under varying irrigation water salinity (BAW, 2, 4, 6 and 8 dS m^{-1}) is shown in Fig. 3.3 while production functions all three crops are given in Table 3.21.



(a) Cabbage



(b) Cauliflower

Fig. 3.3 Yield response of cabbage and cauliflower crops under varying irrigation water salinity

Table 3.21 Production functions of vegetable crops under saline water irrigation

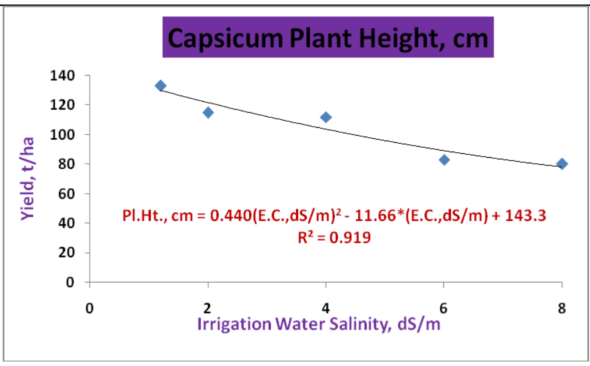
Sl.No.	Crop	Production Functions	R2 Value	Remarks
1.	Cabbage	Yield, t ha-1 = 44.35e-0.16*EC (dS/m)	0.984	Exponential Equation
2.	Cauliflower	Yield, t ha-1 = 21.36e-0.16*EC (dS/m)	0.972	Exponential Equation
3.	Drumstick	Yield, t ha-1 = 42.94*e-0.30*(EC,dS/m)	0.971	Exponential Equation

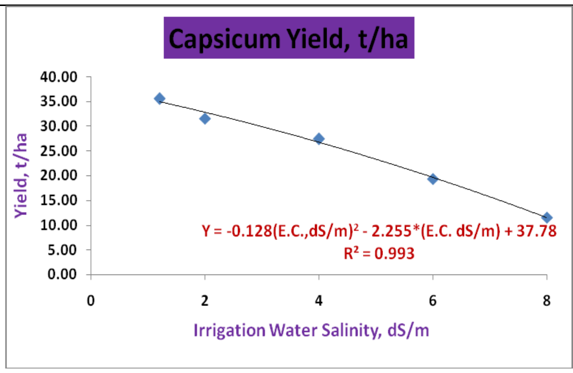
The yield of cabbage, cauliflower and drumstick crops is found to be 39.76, 18.03 and 33.63 t ha^{-1} when irrigated with best available water (BAW) whose EC is 0.6 dS m^{-1}. The yield levels of 90, 75 and 50 per cent of cabbage, cauliflower and drumstick crops were achieved at 1.3, 2.5 and 5.0; 1.7, 2.9 and 5.4 and 1.2, 1.8 and 3.1, respectively, in sandy loam soils. Three crops got damaged physiologically when irrigation water salinity crossed 4.0 dS m^{-1}. The salinity buildup in the soil took place, which was leached during regular rainfall events. Build up of salinity and its vectors are limited to 30 cm either way from the emitter. There is no observed deposition of salts in the drip lateral pipe.

- **Use of saline water in shadenets for different vegetable crops in Krishna Western Delta (Bapatla)**

This experiment was initiated to study responses of different vegetable crops to variable levels of irrigation water salinity under shadenet. The experimentation under shadenets using different levels of salinity of irrigation water was initiated during 2013-14. Initially, Capsicum was tested for 3 years during 2013-14, 2014-15 and 2015-16. The plant height and yield as affected by irrigation water salinity are shown in Fig. 1.

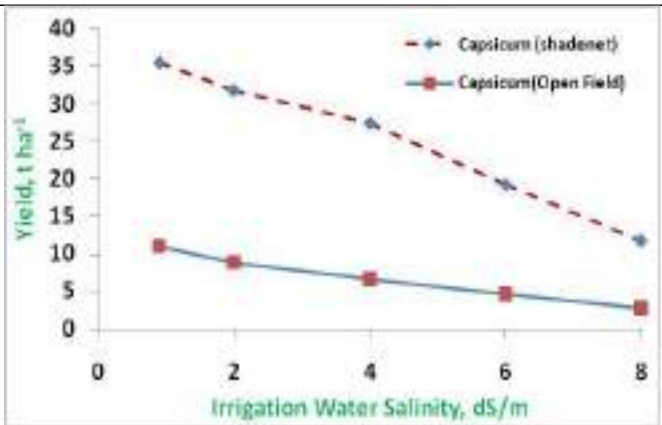
Performance of capsicum crop under open and shadenet as influenced by irrigation water salinity and fruit size as influenced by irrigation water salinity under shadenet are shown in Fig. 3.4.





(a) (b)

Effect of irrigation water salinity on a) plant height and b) crop yield for Capsicum



(a) (b)

Fig. 3.4. Performance of capsicum crop under a) open and shadenet as influenced by irrigation water salinity b) fruit size as influenced by irrigation water salinity under shadenet

The important observations based on experiment are listed below.

- ✓ The mean yield of capsicum grown in shadenets (50% shade) harvested is found to follow the inverse linear equation with the salinity of irrigation.
- ✓ Under shadenets, capsicum yield levels, 90%, 75% and 50% can be realized at 2.3, 4.7, 8.7 dS m-1 irrigation water salinity respectively, when compared with the open field cultivation of capsicum which has a threshold limits of 1.2,2.7 and 5.2 dS m-1 respectively.
- ✓ Capsicum is profitable till 6.0 dS m-1 (@ yield 17.25 t ha-1) under shadenets with drip irrigation and humidifiers, provided the beds are prepared with coco pit+FYM+ soil mix @ 1/3 each and decomposed for 3 months spraying bio-agents. Good surface drainage is a pre requisite for the bedding system.
- ✓ Addition of FYM, foliar application of 19:19:19 and Micronutrients (Iron & Zinc Sulphate) @ 2.0 g L-1 enhanced the yields and disease & pest resistance under drip irrigation with saline water.
- ✓ In shadenets, capsicum suffered from thrips and mites in the initial stages upto 30 DAS, but could be controlled with pesticide containing the active ingredient fipronil @ 2.5 mL L-1 and yellow sticky traps.

The present study was taken up on cabbage and cauliflower crops in shadenets under BAW (0.6), 2, 4, 6 and 8 dS m-1 irrigation water salinity in M/s. Sri Veeranjaneya Vegetable Nursery & Chillies, Bobbepalli, Prakasam district, A.P. during 2016-17. The beds prepared on black soils well mixed with the decomposed cocopeat were considered for laying the experiment. Details of experimentation are provided below.

Main Treatments	**Sub-treatments**	
T_1 – Best available water	C_1 – Cabbage	
T_2 – EC_{iw} – 2 dS m^{-1}	C_2 – Cauliflower	
T_3 – EC_{iw} – 4 dS m^{-1}	**Other details**	
T_4 – EC_{iw} – 6 dS m^{-1}	Experimental Design	RBD
T_5 - EC_{iw} – 8 dS m^{-1}	Replications	4

Yield parameters and yield of cabbage as influenced by irrigation water salinity under shadenet during rabi, 2016-17 are given Table 3.22.

Table. 3.22 Yield and yield parameters of cabbage with different EC levels of irrigation water under shadenet during rabi, 2016-17

Irrigation water Salinity Levels (dS m-1)	Plant height (cm)	Root length cm	LAI	Head Diameter, cm	Weight of individual head, kg	Biomass g	Chlorophyll_a, mg g-1	Chlorophyll_b, mg g-1	Yield (t ha-1)
BAW	43.2	17.55	0.34	22.25	2.55	340.25	36.5	35.83	52.79
2EC	40.2	12.14	0.28	18.83	2.27	265.75	33.5	32.68	47.08
4EC	31.9	10.96	0.24	15.59	1.58	185.80	27.8	30.40	32.82
6EC	27.9	9.61	0.23	13.70	1.28	86.95	23.4	23.95	26.45
8EC	21.9	6.40	0.22	11.45	0.75	32.50	19.7	19.83	15.56

Yield response of Cabbage under shadenets at different levels of irrigation water salinity is shown in Fig. 3.5

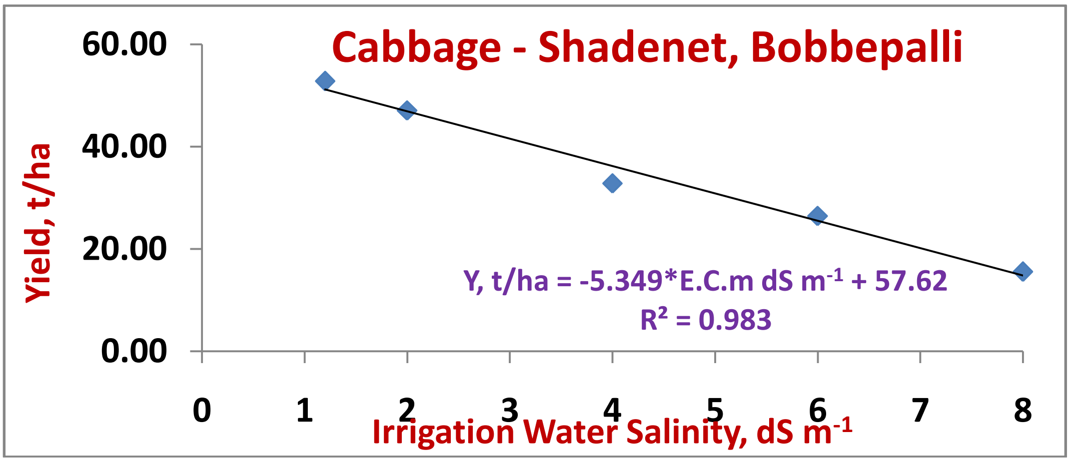


Fig. 3.5 Yield response of Cabbage under shadenets at different levels of irrigation water salinity

Yield parameters and yield of cauliflower as influenced by irrigation water salinity under shadenet during rabi, 2016-17 are given Table 3.23. The initial and final soil salinity along with N, P and K status and organic carbon are given Table 3.24.

Table. 3.23 Yield and yield parameters of cauliflower with different EC levels of irrigation water under shadenet during rabi, 2016-17

Irrigation water Salinity Levels (dSm-1)	Plnt.ht (cm)	Root length, cm	LAI	Curd Diameter cm	Weight of individual curd, kg	Dry Biomass g	Chlorophyll_a, mg g-1	Chlorophyll_b, mg g-1	Yield t ha^{-1}
BAW	81.8	23.48	0.16	25.60	863.25	547.50	29.8	46.06	23.87
2EC	74.0	20.93	0.15	18.77	778.88	478.50	28.6	33.33	21.54
4EC	63.4	14.22	0.08	15.54	594.13	238.50	21.4	42.34	17.20
6EC	59.1	11.00	0.08	11.66	341.53	197.88	15.5	26.54	11.50
8EC	41.4	6.77	0.07	9.29	233.60	74.00	15.4	22.21	9.20

Table 3.24 The initial soil sample analysis of Bobbepalli farm shade net beds

S.No.	Parameter	2 dS m-1			4 dS m-1		
		Initial	Final	Diff. %	Initial	Final	Diff. %
1.	EC dS m-1	0.35	0.50	48.00	0.70	1.10	57.0
2.	pH	7.50	7.8	4.00	7.60	7.70	1.3
3.	Available N, kg ha-1	110.0	121.0	-10.00	118.0	132.0	-11.86
4.	Available P2O5, kg ha-1	38.0	37.0	-2.60	36.5	35.50	-2.74
5.	Available K2O, kg ha-1	615.0	632.0	2.80	610.5	617.0	2.10
6.	OC (%)	0.38	0.34	-10.53	0.34	0.31	-8.82

The mean yield of cabbage and cauliflower grown in shadenets (50% shade) followed the inverse linear equation with the salinity of irrigation. The yield levels of yield levels of 90%, 75% and 50% were realized at 1.9, 3.4 and 5.8 and 1.8, 3.5 and 6.4 dS m^{-1} irrigation water salinity, respectively. There was a depletion in available N, P and also OC per cent while available K showed an increase when water having EC of 2 and 4 dS m-1 was used for irrigation. The production functions of cabbage and cauliflower in shadenets under saline irrigation water given through drip system are given in Table 3.25.

Table 3.25 Production functions of vegetable (cabbage and cauliflower) crops under saline water irrigation in shadenets

Sl.No.	Crop	Production Functions	R2 Value	Remarks
1.	Cabbage	Yield, t ha-1 = -5.349*E.C.m dS m-1 + 57.62	0.983	Linear Equation
2.	Cauliflower	Yield, t ha-1 = -2.097x*E.C., dS m-1+ 25.30	0.985	Linear Equation

The production functions of cabbage and cauliflower were found to follow linear relationship in shadenets where as the same in open field cultivation followed exponential relationship, which presents a possibility of better control over irrigation water salinity stress in shadenets cultivation over open field cultivation. As coastal agricultural belts are potential in adopting the shadenets cultivation for raising nurseries, vegetable cultivation, etc. as the groundwater in coastal aquifers is found to be poor. This study helps in identifying a technological intervention to reduce the ill effects of the poor quality water both on crop and soil as well. The mean yield of cabbage and cauliflower grown in shadenets (50% shade) followed the inverse linear equation with the salinity of irrigation. The yield levels of yield levels of 90%, 75% and 50% were realized at 1.9, 3.4 and 5.8 and 1.8, 3.5 and 6.4 dS m_{-1} irrigation water salinity respectively. The N, P and OC got decreased and K got increased after applying saline irrigation water of 2 and 4 dS m^{-1} . The production functions of cabbage and cauliflower were found to be following linear relationship in shadenets where as the same in open field cultivation followed exponential relationship, which presents a possibility of better control over irrigation water salinity stress in shadenets cultivation over open field cultivation.

- **Optimization of water requirement of groundnut-wheat cropping sequence using saline water under drip irrigation (Bikaner)**

This experiment was initiated to study the impact of irrigation water salinity on groundnut-wheat sequence; to work out the optimum drip geometry for saline irrigation water and to work out optimum water requirement for groundnut and wheat. The main plot treatments comprised of four saline water irrigation (BAW, 4, 8, 12 dS/m) and two drip geometry (60x30 cm, 90x30 cm) and sub-plot treatments of three levels of water requirement IW:CPE ratio (0.6, 0.8, 1.0) in groundnut (var. HNG-10) - wheat (Raj – 3077) crop rotation during 2016-17.

Groundnut: Pooled analysis of data indicated that different treatments had significant effect on pod yield of groundnut. Increase in ECiw beyond 4 dS/m caused significant reduction in pod yield. As compared to BAW, ECiw of 8 dS/m and 12 dS/m caused significant reduction of 61.7 and 78.9 per cent, respectively. Drip laterals spaced at 60 cm resulted in 30% higher pod yield as compared to laterals at 90 cm. So far water requirement is concerned, in comparison to 1.0 PE and 0.6 PE showed significant reduction of 29.4 and 27.6 per cent, respectively, in pod and straw yield. Volume 1.0 PE and 0.8 PE, however, did not differ significantly to each other in this respect. Increase in the salinity of irrigation water beyond 4 dS/m significantly decreased the pod yield under both the drip geometries i.e. 60 cm x 30 cm and 90 cm x 30 cm. Under both the drip geometries, 0.6 PE resulted in significant reduction in pod yield as compared to 1.0 and 0.8 PE (Table 3.26).

Table 3.26 Effect of saline water, drip geometry and ET on pod yield and straw yield of groundnut

Particular	Pod yield (q ha-1)				Straw yield (q ha-1)			
	2014	2015	2016	Pooled	2014	2015	2016	Pooled
ECiw								
BAW	35.34	26.00	33.42	31.58	56.02	45.33	55.35	52.23
4 dS/m	34.19	25.33	33.41	30.98	58.47	43.78	54.27	52.17
8 dS/m	10.39	8.34	17.54	12.09	46.65	23.31	31.47	33.81
12 dS/m	7.69	5.59	6.75	6.67	37.19	17.45	10.33	21.66
S.Em.±	0.63	0.25	0.69	0.33	3.93	0.61	0.95	1.38
CD (5%)	1.86	0.73	2.02	0.93	11.57	1.81	2.78	3.89
Drip Geometry								
60 x 30	24.18	18.95	25.81	22.98	54.44	36.21	42.45	44.36
90 x 30	19.62	13.68	19.75	17.68	44.72	28.73	33.26	35.57
S.Em.±	0.45	0.17	0.48	0.23	2.78	0.43	0.67	0.97
CD (5%)	1.32	0.51	1.43	0.66	8.18	1.28	1.97	2.75
P E								
0.6 V	16.70	12.48	19.01	16.06	35.07	24.53	30.80	30.13
0.8 V	24.36	18.03	24.18	22.19	54.04	35.88	41.00	43.64
1 V	24.64	18.43	25.15	22.74	59.64	36.99	41.76	46.13
S.Em.±	0.40	0.27	0.36	0.20	2.16	0.62	1.49	0.89
CD (5%)	1.15	0.77	1.02	0.55	6.15	1.76	4.24	2.50

Combined effect of treatments (drip geometry x ECiw) on pod yield (q/ha) with pooled data is given in Table 3.27. Further, combined effect of treatments (PE x ECiw); (PE x drip geometry); (PE x drip geometry) on pod yield (q/ha) with pooled data is given in Table 3.28, Table 3.29 and Table 3.30, respectively.

Table 3.27. Combined effect of treatments (drip geometry x ECiw) on pod yield (q/ha) (pooled)

Drip geometry	ECiw levels			
	BAW	4 dS/m	8 dS/m	12 dS/m
60 x 30 cm	36.04	34.98	13.18	7.72
90 x 30cm	27.13	26.97	11.00	5.62
S.Em.±	0.46			
C.D.	1.31			

Table 3.28 Combined effect of treatments (PE x ECiw) on pod yield (q/ha) (pooled)

PE levels	ECiw levels			
	BAW	4 dS/m	8 dS/m	12 dS/m
PE 0.6	24.91	24.54	9.76	5.04
PE 0.8	34.36	33.95	13.05	7.39
PE 1.0	35.48	34.44	13.47	7.59
			S.Em.±	CD (P = 0.05)
ECiw means at same level of PE			0.40	1.11
PE means at same level of ECiw			0.46	1.29

Table 3.29 Combined effect of treatments (PE x drip geometry) on pod yield (q/ha) (pooled)

PE levels	Drip geometry	
	60 x 30 cm	90 x 30cm
PE 0.6	17.81	14.32
PE 0.8	25.05	19.33
PE 1.0	26.09	19.39
	S.Em.±	CD (P = 0.05)
Drip geometry means at same level of PE	0.28	0.78
PE means at same level of Drip geometry	0.33	0.92

Table 3.30 Combined effect of treatments (PE x drip geometry) on straw yield (q/ha) (pooled)

PE levels	Drip geometry	
	60 x 30 cm	90 x 30cm
PE 0.6	39.37	20.90
PE 0.8	46.22	41.06
PE 1.0	47.50	44.76
	S.Em.±	CD (P = 0.05)
Drip geometry means at same level of PE	1.26	3.53
PE means at same level of Drip geometry	1.42	3.98

Wheat: An experiment was initiated during Rabi 2014-15 to optimize water requirement of groundnut – wheat cropping sequence using saline water under drip irrigation. The treatments comprised of four levels of ECiw (BAW, 4 dS/m, 8 dS/m and 12 dS/m), two drip geometries (60 cm x 30 cm and 90 x 30 cm) and 3 levels of water requirement (0.6, 0.8 and 1.0 PE). On the basis of pooled data, results of Rabi component of experiment (Table 3.31) indicated that different treatments had significant effect on seed yield of wheat. Increase in ECiw beyond 8 dS/m caused significant reduction in seed yield. As compared to ECiw of 4 dS/m and ECiw of 8, 12 dS/m caused significant reduction of 3.0 and 58.5 per cent, respectively. Drip laterals spaced at 60 cm resulted in 28.1 % higher seed yield as compared to laterals spaced at 90 cm, a uniform distance of 30 cm, was, however, kept between emitter to emitter under both the drip geometries tested. So far water requirement is concerned, in comparison to 1.0 PE and 0.8 PE, volume 0.6 PE showed significant reduction of 17.3 and 15.6 per cent, respectively, in seed and straw yield. Volume 1.0 PE and 0.8 PE did not differ significantly to each other in this respect.

Combined effects of treatments were also found significant. Increase in the salinity of irrigation water beyond 8 dS/m significantly decreased the seed yield under both the drip geometries i.e. 60 cm x 30 cm and 90 cm x 30 cm. As compared to BAW (Table 3.32 and Table 3.33), reduction in seed yield due to ECiw of 8 dS/m was statistically significant under both the drip geometries (60 cm x 30 cm and 90 cm x 30 cm). It is worth noting that as compared to BAW, ECiw of 8 dS/m caused significant reduction of only 5.1 and 4.1 per cent under drip geometry of 60 cm x 30 cm and 90 cm x 30 m, respectively, but with ECiw of 12 dS/m drastic reduction was noticed. Drip geometry of 90 cm x 30 cm proved to be inferior to 60 cm x 30 cm in this respect of all the levels of ECiw. Similar trends were noticed in almost all the parameters studied.

Table 3.31. Effect of saline water, drip geometry and ET on seed and straw yield of wheat

Particular	Seed yield (q ha-1)			Straw yield (q ha-1)		
	2014-15	2016-17	Pooled	2014-15	2016-17	Pooled
ECiw						
BAW	25.77	28.88	27.32	31.75	35.31	33.53
4 dS/m	25.22	28.52	26.87	30.94	35.19	33.06
8 dS/m	24.49	27.64	26.06	30.02	34.18	32.10
12 dS/m	10.24	12.09	11.16	13.00	15.67	14.33
S.Em.±	0.26	0.34	0.21	0.35	0.38	0.26
C.D. (0.05)	0.76	1.00	0.61	1.02	1.10	0.73
Drip Geometry						
60 x 30	24.18	27.16	25.67	29.15	33.40	31.27
90 x 30	18.67	21.41	20.04	23.71	26.77	25.24
S.Em.±	0.18	0.24	0.15	0.24	0.27	0.18
C.D. (0.05)	0.54	0.71	0.43	0.72	0.78	0.51
P E						
0.6 V	18.83	21.57	20.20	23.99	27.13	25.56
0.8 V	22.41	25.43	23.92	27.53	31.43	29.48
1 V	23.04	25.84	24.44	27.76	31.69	29.73
S.Em.±	0.31	0.38	0.25	0.36	0.46	0.29
C.D. (0.05)	0.87	1.09	0.69	1.04	1.30	0.82

Table 3.32 Combined effect of treatments on seed yield on pooled basis (q/ha)

Drip Geometry	BAW	4 dS/m	8 dS/m	12 dS/m
60 x 30 cm	30.65	30.08	29.10	12.85
90 x 30cm	24.00	23.66	23.02	9.47
S.Em.±	0.30			
C.D.	0.86			

Table 3.33 Combined effect of treatments on straw yield on pooled basis (q/ha)

Drip Geometry	BAW	4 dS/m	8 dS/m	12 dS/m
60 x 30 cm	37.57	36.99	34.39	16.14
90 x 30cm	29.48	29.14	29.81	12.53
S.Em.±	0.36			
C.D.	1.03			

- **Effect of fertility levels on isabgol- pearlmillet crop sequence under drip irrigation using saline water (Bikaner)**

Pearlmillet: An experiment was initiated during Kharif 2015 to optimize water requirement of pearl millet – isabgol cropping sequence using saline water under drip irrigation. The treatments comprised of three levels of ECiw (BAW, 4 and 8 dS/m), and 3 fertility levels (75%; 100 % and 125 %

RD of NPK). Pooled analysis of two years' data (kharif component only) indicated that different treatments had significant effect on grain yield of pearl millet. Increase in the ECiw beyond 4 dS/m caused significant reduction in the grain yield. ECiw 8 dS/m showed significant reduction of 21.9 and 18.0 per cent as compared to BAW and ECiw of 4 dS/m, respectively. Application of 100% and 125% recommended dose of NPK registered significant increased grain yield of pearl millet by 27.9 and 31.9 per cent over 75% RD, respectively. However, levels 100 % RD and 125 % RD were statistically at par. Saline water irrigation of ECiw 8 dS/m showed significant reduction of 16.8 and 14.3 per cent in straw yield as compared to BAW and ECiw 4 dS/m, respectively. Application of 100 % and 125% recommended dose of NPK registered significant increase of 21.6 and 26.1 per cent in straw yield of pearl millet, respectively, over 75 % RD (Table 3.34).

Table 3.34 Effect of different treatments on yield and yield attributes of pearl millet

Treatments	Test weight (g)			Grain yield (q/ha)			Straw Yield (q/ha)		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
ECiw									
BAW	6.58	7.37	6.98	13.33	14.18	13.75	21.65	22.09	21.87
4 dS/m	6.41	7.20	6.81	12.82	13.37	13.10	20.47	21.98	21.23
8 dS/m	5.68	5.85	5.76	10.67	10.82	10.74	17.72	18.66	18.19
SEm+	0.10	0.12	0.08	0.29	0.43	0.26	0.57	0.65	0.43
CD (5%)	0.30	0.34	0.22	0.83	1.24	0.73	1.66	1.90	1.23
Fertility levels									
75 % RD	5.80	6.38	6.09	10.48	10.41	10.45	17.50	17.76	17.63
100 % RD	6.37	6.97	6.67	12.90	13.83	13.37	20.64	22.21	21.43
125 % RD	6.49	7.07	6.78	13.44	14.12	13.78	21.69	22.77	22.23
SEm+	0.10	0.12	0.08	0.29	0.43	0.26	0.57	0.65	0.43
CD (5%)	0.30	0.34	0.22	0.83	1.24	0.73	1.66	1.90	1.23

Combined effect of treatment showed that application of 100% RDF resulted in significant improvement the yield over 75% RDF at all the levels of ECiw but remained at par with that recorded with 125% RDF. Application of 125% RDF at ECiw 4 dS/m recorded yield of 14.59 q/ha which was at par with the yield recorded with 100% RDF at same level of ECiw 4 dS/m and was also at BAW with the application of 100% and 125% of RDF. Increase in ECiw beyond ECiw 4 dS/m caused significant reduction with all the levels of fertilizer application (Table 3.35).

Table 3.35 Combined effect of treatments on grain yield of pearl millet

Treatments	Pearl millet grain yield (q/ha)		
	75 % RDF	**100 %** RDF	**125 %** RDF
BAW	11.04	14.99	15.23
4 dS/m	10.48	14.22	14.59
8 dS/m	9.82	10.89	11.53
SEm+	0.44	-	-
CD (5%)	1.26	-	-

Isabgol

An experiment was conducted during Rabi 2014-15 and 2015-16 to optimize water requirement of pearl millet – isabgol cropping sequence using saline water under drip irrigation. The treatments comprised of three levels of ECiw (BAW, 4 dS/m and 8 dS/m), and 3 fertility levels (75 & RD; 100 % RD and 125 % RD of NPK). The experiment was laid out but wind storms experienced during the season 2014-15 caused severe damage to the crop and left with no harvest, hence considered as failed. During 2015-16 also, crop of isabgol was failed due to hail storm.

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

The experiment was initiated during 2015-16 to evaluate the effect of various combinations of organic manures, bio-fertilizer on pearl millet-wheat cropping system with saline water irrigation and to assess the effect of various organic manures and bio-fertilizers on soil properties. The 12 treatments comprised of T1: 75% RDF; T2: RDF; T3: 75% RDF + ST-3; T4: RDF + ST-3; T5: 75% RDF + 2.5 t/ha biogas slurry + ST-3; T6: RDF + 2.5 t/ha biogas slurry + ST-3; T7: 75% RDF + 2.5 t/ha Vermicompost + ST-3; T8: RDF + 2.5 t/ha Vermicompost + ST-3; T9: 75% RDF + 10 t/ha FYM + Biomix; T10: RDF + 10 t/ha FYM + Biomix; T11: 75% RDF + 2.5 t/ha Vermicompost + Biomix; T12: RDF + 2.5 t/ha Vermicompost + Biomix were replicated thrice in RBD.

The study was conducted at CCS HAU, Hisar to work out the performance of microbial culture on the pearl-millet (var. HHB 223) and wheat (var. WH 1105) 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.

Pearl millet: The maximum grain yield (32.54 q/ha) of pearl millet (HHB-226) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (31.97 q/ha). The minimum grain yield (26.10 q/ha) was recorded with 75% RDF alone (Table 3.36). The yield attributes and yield of pearl millet were at par with the application of RDF alone and RDF + ST-3 with the treatments receiving 75% RDF + 2.5t/ha BGS + ST-3, 75% RDF + 2.5t/ha VC + ST-3, 75% RDF + 10t/ha FYM + Biomix and 75% RDF + 2.5t/ha vermicompost + Biomix, respectively. Integration of chemical fertilizers (75% RDF and RDF) with organic manures (10t/ha FYM, 2.5t/ha biogas slurry, 2.5t/ha vermicompost) and biofertilizer (Biomix) resulted into 16 to 19% higher grain yield over 75% RDF and 9 to 11% higher grain yield over sole application of RDF.

Wheat: The maximum grain yield (50.01q/ha) of wheat (WH-1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (49.40 q /ha).The minimum grain yield (39.57 q/ha) was recorded with 75% RDF alone (Table 3.37). Wheat (WH-1105) under saline water application (8-10 dS/m) showed maximum values of plant height (101.70 cm), test weight (40.27 g) and straw yield (70.75) in the treatment receiving RDF + 10t FYM/ha + Biomix application, which was statistically at par with the treatments receiving 100% RDF + 2.5t/ha vermicompost + Biomix , 100% RDF + 2.5t/ha vermicompost + ST-3 and 100% RDF + 2.5t/ha biogas slurry + ST-3. Grain and straw yield were positively increased with increase in the level of fertilization (75%RDF to RDF) and application of organic manures and biofertilizers with inorganic fertilizers.

Table 3.36 Effect of various treatments on grain yield and yield attributes of pearl millet

Treatments	Plant height (cm)	Effective tillers/mrl	Ear head length (cm)	Test weight (g)	Grain yield (q/ha)
T1	186.34	20.41	19.14	7.10	26.10
T2	200.93	25.65	20.86	7.66	29.03
T3	186.38	20.42	19.24	7.14	26.77
T4	201.23	25.84	20.97	7.68	29.24
T5	197.33	21.79	21.31	7.64	29.33
T6	207.51	26.52	22.33	8.01	31.65
T7	198.23	21.87	21.40	7.66	29.53
T8	208.49	26.55	22.53	8.02	31.58
T9	198.83	23.02	21.83	7.81	30.08
T10	211.77	27.44	22.80	8.05	32.54
T11	198.62	22.31	21.77	7.72	29.67
T12	209.74	26.97	22.63	8.03	31.97
CD (5%)	9.02	4.56	1.40	0.52	2.25

Table 3.37 Effect of various treatments on grain yield and yield attributes of wheat

Treatments	Plant height (cm)	Test weight (g)	Grain yield (q/ha)	Straw yield (q/ha)
T1	91.23	38.29	39.57	59.18
T2	93.20	39.73	43.91	64.64
T3	92.87	38.73	40.73	59.33
T4	93.25	39.60	44.64	64.85
T5	97.27	39.30	44.91	65.21
T6	97.73	40.11	49.00	69.09
T7	97.40	39.40	44.87	65.44
T8	97.79	40.17	48.79	69.31
T9	98.40	39.62	46.38	66.56
T10	101.70	40.53	50.01	70.75
T11	98.37	39.57	46.20	65.96
T12	99.20	40.27	49.40	69.96
CD (5%)	4.79	N/A	4.15	4.21

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

This experiment was initiated during rabi 2013-14 with three irrigation water quality (canal, 8 and 10 dS/m) in main plots and four sewage-sludge applications (SS @ 5 t/ha; SS @ 5 t/ha + 50% RDF; SS @ 5 t/ha + 75% RDF and 100% RDF in sub-plots in pearl millet –wheat crop rotation. During *rabi* season wheat was grown in micro-plots of size 4.5 m x 4.5 m. Treatments were replicated thrice in the split plot design.

Pearl millet: The grain yield of pearl millet (HHB-226) decreased by 22.9 and 30.6% in all saline irrigation of 8 and 10 dS/m as compared to canal irrigation. A reduction of 20.0, 10.2 and 2.8% in grain yield of pearl millet was observed in application of sewage sludge @ 5 t/ha (alone), sewage sludge @ 5t/ha + 50% RDF and sewage sludge @ 5t/ha + 75% RDF as compared to RDF (Table 3.38).

Wheat: The grain yield of wheat (WH- 1105) decreased by 9.8 and 20.5% in all saline irrigation 8 and 10 dS/m as compared to canal irrigation. Reduction of 31.1, 9.8 and 2.7 % in grain yield of wheat was observed in treatments sewage sludge @ 5 t/ha (alone), sewage sludge @ 5 t/ha + 50% RDF and sewage sludge @ 5 t/ha + 75% RDF as compared to RDF (Table 3.39). The mean salinity in the soil profile (0-30cm) at the time of harvest of wheat was varying from 2.88 (0-15cm) to 10.44(15-30cm) dS/m in canal water to the highest EC irrigating water plot (Table 3.40).

Table 3.38 Effect of sewage sludge on grain yield (q/ha) of pearl millet irrigated with saline water of different salinity

	Grain yield (q/ha)			
Treatment	Canal (0.3)	EC_{iw} 8.0 dS/m	EC_{iw} 10 dS/m	Mean
Sewage sludge @ 5 t/ha	25.57	19.17	17.50	20.74
Sewage sludge @ 5 t/ha+50% RDF	28.56	21.83	19.47	23.29
Sewage sludge @ 5 t/ha+75% RDF	30.70	23.70	21.20	25.20
RDF	31.02	24.60	22.20	25.94
Mean	28.96	22.33	20.08	
CD (5%) Treatment (T) = 3.54, Salinity (S)= 3.06, T x S = NS				

Table 3.39 Effect of sewage sludge on grain yield of wheat under different saline waters

	Grain yield (q/ha)			
Treatment	Canal (0.3)	EC_{iw} 8.0 dS/m	EC_{iw} 10 dS/m	Mean
Sewage sludge @ 5 t/ha	33.51	30.03	26.58	30.04
Sewage sludge @ 5 t/ha+50% RDF	43.84	39.81	34.29	39.31
Sewage sludge @ 5 t/ha+75% RDF	47.17	42.58	37.47	42.40
RDF	48.33	43.45	39.03	43.60
Mean	43.21	38.97	34.34	
CD (5%): Treatment (T) = 4.05, Salinity (S)= 3.51 T x S = NS				

Table 3.40 Soil EC_e at different depths after harvest of wheat under different treatments

Treatment	Soil EC_e (dS/m)					
	Canal		EC_{iw} 8.0 dS/m		EC_{iw} 10 dS/m	
	0-15	**15-30**	**0-15**	**15-30**	**0-15**	**15-30**
Sewage sludge @ 5 t/ha	3.10	3.20	10.18	10.78	10.72	10.84
Sewage sludge @ 5 t/ha+50% RDF	3.18	336	9.00	10.30	10.18	10.80
Sewage sludge @ 5 t/ha+75% RDF	2.94	3.16	8.40	8.54	9.86	10.48
RDF	2.30	2.62	7.70	8.00	9.14	9.66
Mean	2.88	3.08	8.82	9.40	9.97	10.44

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

This experiment was initiated during 2013-14 to study the response of different levels of nitrogen application on tomato and to work out suitable nitrogen fertigation dose for tomato crop. There were four irrigation water qualities (Canal (0.3, 2.5, 5.0, 7.5 dS/m) and three nitrogen fertigation levels (75% RDN, 100% and 125%RDN). The experiment was laid out in 2.0 x 2.0 m plot and spacing between plant to plant and row to row was kept as 45 cm.

The fruit yield of tomato under different N and salinity levels under drip irrigation (Table 3.41) revealed that under drip irrigation in 75% RDN of nitrogen application, the relative fruit yields of tomato were obtained 96.90, 88.7 and 76.60% when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in RDN application, the relative fruit yields of tomato were obtained 99.60, 87.50 and 77.00% when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in 125% recommended dose of nitrogen application, the relative fruit yields of tomato were obtained 98.90, 87.50 and 76.70% when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Significant reductions in tomato fruit yield were recorded at ECiw 5.0 and 7.5 dS/m as compared to canal water irrigation. Application of RDN increased the tomato fruit yield significantly over 75% RDN. However, the differences in RDN and 125% RDN were statistically non -significant.

Table 3.41 Effect of nitrogen fertigation under drip saline water irrigation on tomato yield

N Levels	Tomato yield (q/ha)				
	Canal (0.3)	2.5 dS/m	5.0 dS/m	7.5 dS/m	Mean
75% RDN	390.2	378.0	345.9	298.8	353.2
100% RDN	423.0	421.1	370.2	325.6	385.0
125% RDN	430.2	425.3	376.5	330.0	390.5
Mean	414.5	408.1	364.2	318.1	
CD (5%) : Nitrogen (N)=12.2, Salinity level (S) = 19.2, N x S = NS					

- **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 study was to find out the tolerance level of leafy vegetables and to study the changes in soil properties. The experiment was conducted during *rabi* 2016-17 for Radish, Dill and Spinach. The intial pH and EC of experimental soil were 6.82 and 2.35 dS/m, respectively. . The experimental soil was clay loam in texture, neutral in reaction, medium in available nitrogen and phosphorus and very high in potassium. The details of the treatments are provided in Table 3.42.

Table 3.42 Treatments Details

A) Crop	B) Salinity of irrigation water
Spinach (C_1)	1) Pond water (T_1)
Dill (C_2)	2) 2 dSm^{-1}(T_2)
Radish (C_3)	3) 4 dSm^{-1}(T_3)
	4) 6 dSm^{-1}(T_4)
	5) 8 dSm^{-1}(T_5)

Data about influence of irrigation water salinity on crop yield are provided in Table 3.43 and Fig. 3.6. Application of pond water T_1 (13.50 t ha^{-1}) showed significantly higher vegetable yield over rest of all treatments except T_2 (12.01t ha^{-1}) which was found to be at par with T_1. The crop C_3 *i.e.* radish (15.81 t ha^{-1}) produced significantly higher yield over C_1 and C_2. In case of interaction effect, T_1C3 *i.e.* irrigation of radish crop with pond water recorded significantly higher yield over rest of all the interactions.

Table 3.43 Influence of irrigation water salinity on crop yield (t/ha)

Treatments	C_1	C_2	C_3	MEAN	
T_1	9.47	10.89	20.15	13.50	
T_2	9.71	9.99	16.34	12.01	
T_3	7.28	10.40	10.48	9.39	
T_4	9.87	7.83	15.96	11.22	
T_5	8.84	3.21	16.09	9.38	
MEAN	9.03	8.46	15.81		
SE± m for salinity levels	0.61	SE± m for crop	0.47	SE± m for interaction	1.06
CD @5%	1.76	CD @5%	1.37	CD @5%	3.06

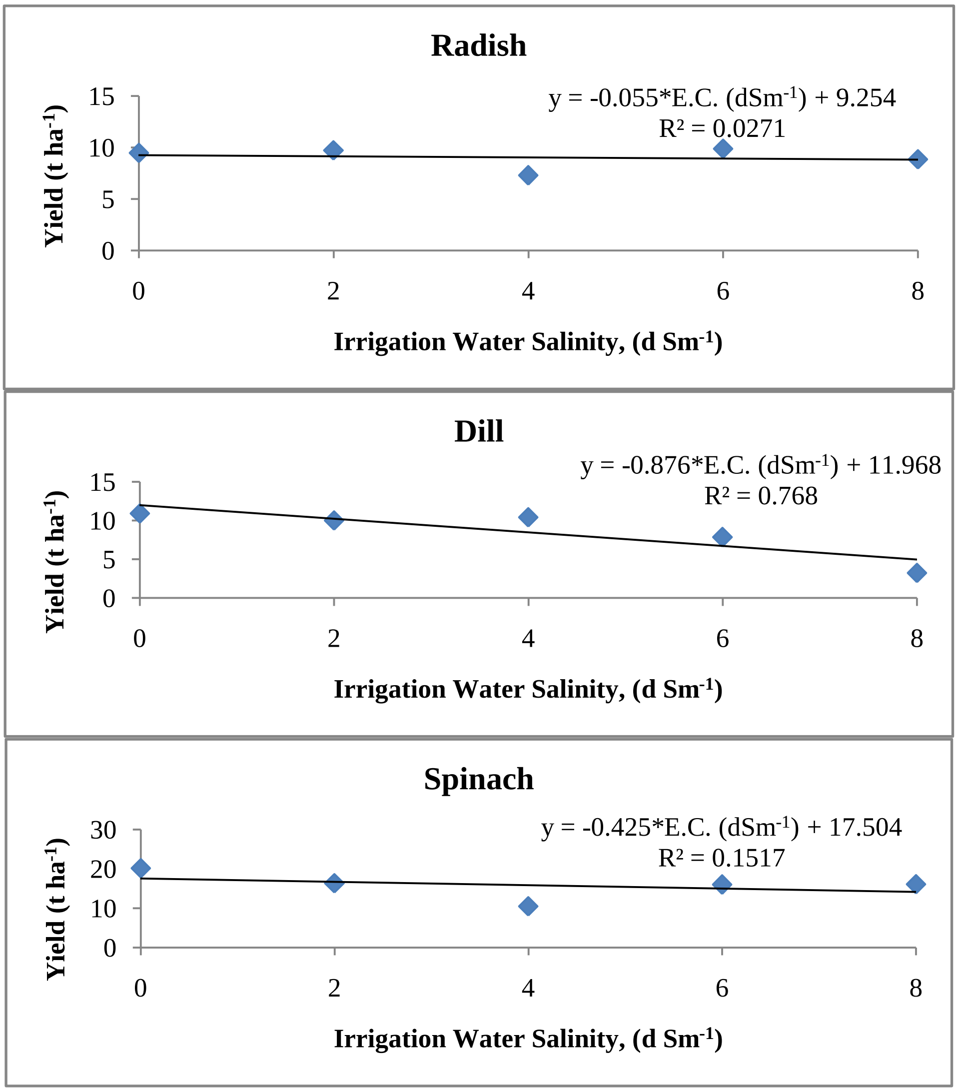


Fig. 3.6 Yield response of crops under varying irrigation water salinity

3.3 Management of Waste Water

- **Management of sewage water as a source of irrigation and nutrients for okra (*summer*)-cluster bean (*kharif*)-cauliflower (*rabi*) crop rotation (Agra)**

This experiment was initiated during 2015-16 with cluster bean-cauliflower-okra crop rotation with for assessing the sewage water and tubewell water quality; to assess the impact of sewage water, tube well water and mixed water and to find out the net economics returns in different treatments. In this experiment okra (summer)-cluster bean (kharif)-cauliflower (rabi) crop rotation during 2016-17 was followed.

Clusterbean (Kharif season crop)

Germination and plant height: The data revealed that there was no significant difference in germination percent as result of irrigation water quality as well as recommended dose of fertilizer. The plant height of cluster bean differ significantly at 60 and 90 DAS in recommended dose of fertilizer, the maximum plant height was recorded in 100% RDF and smaller in 50% RDF. The plant height at 30 DAS was not significant but it was significant at 60 and 90 DAS under application of sewage water irrigation over tube well water irrigation.The maximum plant height was observed in sewage water irrigation and minimum was in tube well water irrigation (Table 3.44).

Dry matter accumulation: The dry matter accumulation of plant (g) of cluster bean crop has significant difference in all the stages of crop growth in recommended dose of fertilizer, the significantly maximum dry matter was recorded in 100% RDF and lowest in 50% RDF. The application of sewage water irrigation over tube well water irrigation, the dry matter accumulation of cluster bean plant in 30 days of sowing was not significant but latter stages 60 and 90 days after sowing the dry matter accumulation of plant (g) shows significant results. The significantly maximum dry matter accumulation was observed in sewage water irrigation and minimum was in tube well water irrigation (Table 3.44).

Table 3.44 Effect of different treatments on germination, plant height and dry matter accumulation (g) of cluster bean

Treatments	Germination (%)	Plant height (cm)			Dry matter accumulation (g)		
		30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
Irrigation water							
SW	89.9	18.99	90.84	137.64	21.42	62.62	103.37
TW	88.5	18.32	84.11	129.00	19.23	54.79	95.91
1 SW:1TW	88.8	18.78	87.03	131.53	19.71	57.62	99.16
CD (5%)	NS	NS	2.23	1.98	0.33	2.63	2.89
Recommended dose of fertilizer							
50%	87.9	18.47	83.64	129.49	19.59	50.83	93.68
75%	88.7	18.70	87.59	132.51	20.18	57.78	98.69
100%	89.2	18.92	90.76	136.15	20.60	66.42	106.07
CD (5%)	NS	NS	2.23	1.98	0.33	2.63	2.89
IW X F	NS	NS	NS	NS	NS	NS	NS

Yield and yield attributes: The data showed that application of sewage water irrigation in cluster bean produced highest pod length (11.03 cm) and lowest in tubewell water irrigation (10.0 cm) but tubewell water and 1SW:1TW water irrigation produced at par pod length. The pod yield per plant was significantly maximum in sewage water irrigation (340.30 g) and lowest in tube well water irrigation (330.9 g), but tube well water and 1SW:1TW water irrigation gave at par per plant pod yield (Table 3.45).

Application of sewage water irrigation gave significantly highest pods yield (117.67 q/ha) and minimum in tube well water irrigation (109.24 q/ha) but non-significant in tube well and 1SW:1TW water irrigation. Application of 75% RDF and 100% RDF results in non significant differences in pod yield. The application of 50% RDF produced significantly lowest pod yield as compared to 75% and 100% RDF (Table 3.45 and Fig 3.7).

Economics and B:C ratio: The cluster bean results in maximum net profit (Rs 72494/ha) and B:C ratio (1.60) in sewage water irrigation and minimum (Rs. 64,070 and 1.42) in tubewell water irrigation. The use of 100% RDF gave maximum net profit (Rs 73802 /ha) and B:C ratio (1.56) and minimum (Rs. 59,599 and 1.39) in tube well water irrigation (Table 3.45).

Table 3.45 Effect of different treatments on yield attributes and yields of cluster bean

Treatments	Pod length (cm)	Pod yield / plant (g)	Pod yield q/ha	Net profit (Rs./ha)	B: C ratio
Irrigation water					
SW	11.03	340.3	117.67	72,494	1.60
TW	10.00	316.7	109.24	64,070	1.42
1 SW:1TW	10.90	330.9	112.36	67,184	1.48
CD (5%)	0.26	7.6	3.32	-	-
Recommended dose of fertilizer					
50%	9.90	321.0	102.46	59,599	1.39
75%	10.31	329.3	115.52	70,347	1.56
100%	11.12	337.7	121.29	73,802	1.56
CD (5%)	0.26	7.6	3.32	-	-
IW X F	NS	NS	5.76	-	-

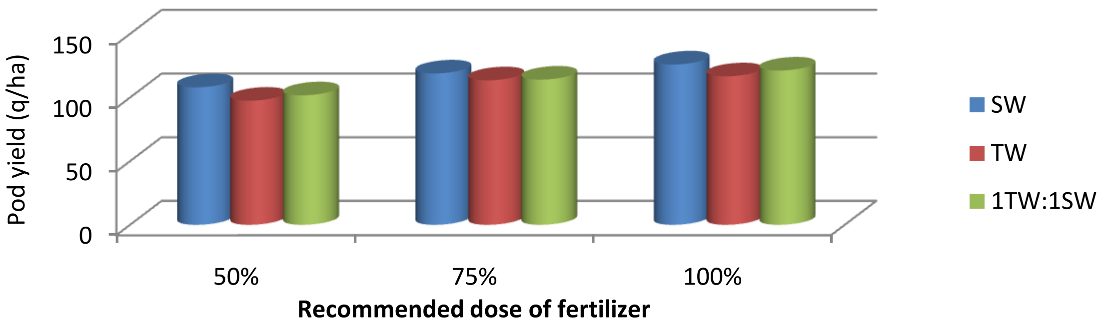


Fig. 3.7. Pod yield of cluster bean (q/ha) in different treatments

Interaction: The interaction effect of irrigation water and recommended dose of fertilizer on pod yield of cluster bean was found to be significant. The data revealed that irrigation water exhibited differential response to RDF. The irrigation water use in cluster bean crop increases the pod yield with every increase in the rate of fertilizer up to 100% RDF. However, pod yield per hectare increased marginally as RDF was increased from 75% to 100%. The maximum pod yield was obtained with the use of sewage water and 100% RDF which was significantly higher than that of other combinations (Table 3.46).

Table 3.46 Interaction effect of irrigation water x fertilizer dose

Irrigation water	Fertilizer dose ((%)			Total	Av.
	50%	75%	100%		
SW	108.07	118.93	126.00	353.00	117.67
TW	97.53	113.53	116.67	327.73	109.24
1SW:1TW	101.76	114.10	121.20	337.06	112.36
Total	307.36	346.56	363.87	-	-
Av	102.46	115.52	121.29	-	-
CD (5%)	8.54				

Cauliflower (Rabi season crop)

After harvest of cluster bean, cauliflower was grown during *rabi* with different irrigation water and recommended dose of fertilizer. The application of irrigation water and dose of fertilizer resulted in significant difference in no. of leaves per plant, circumference of head (cm) and weight of head (g). The all attributes were at maximum in sewage irrigation while minimum in tube well irrigation. Similarly, all attributes were at maximum in 100% RDF while minimum in 50% RDF. The use of sewage water irrigation in cauliflower resulted in significantly maximum flower yield (230.22 q/ha) and minimum yield (187.29 q/ha) in tube well water irrigation. The application of recommended dose of fertilizer significantly produced higher flower yield (231.59 q/ha) in 100% RDF and lowest yield in 176.97 q/ha in 50% RDF (Table 3.47, Fig. 3.8).

Economics and B:C ratio: The maximum net profit (Rs. 82479 /ha) and B:C ratio (1.47) were observed in sewage water irrigation and minimum (Rs. 56719/ha and 1.01) in tube well water irrigation The use of recommended dose of fertilizer 100% RDF gave maximum net profit (Rs. 80741/ha) and B:C ratio (1.41) and minimum (Rs. 53208/ha and 1.00) was in 50% RDF (Table 3.47).

Table 3.47 Effect of different treatments on yield attributes and yields of cauliflower

Treatments	No. of green leaves	Flower diameter (cm)	Flower weight (g)	Yield (q/ha)	Net profit (RS/ha)	B:C ratio
Irrigation water						
SW	19.44	52.67	541.11	230.22	82,479	1.47
TW	15.11	41.93	424.81	187.29	56,719	1.01
1 SW:1TW	17.11	45.51	466.67	214.81	73,231	1.33
CD (5%)	1.92	2.32	6.75	7.94		-
Recommended dose of fertilizer						
50%	16.11	42.94	466.80	176.97	53,208	1.00
75%	17.00	46.96	476.60	223.77	78,480	1.41
100%	18.56	50.21	489.19	231.59	80,741	1.41
CD (5%)	1.92	2.32	6.75	7.94	-	-
IW X F	NS	NS	NS	13.76	-	-

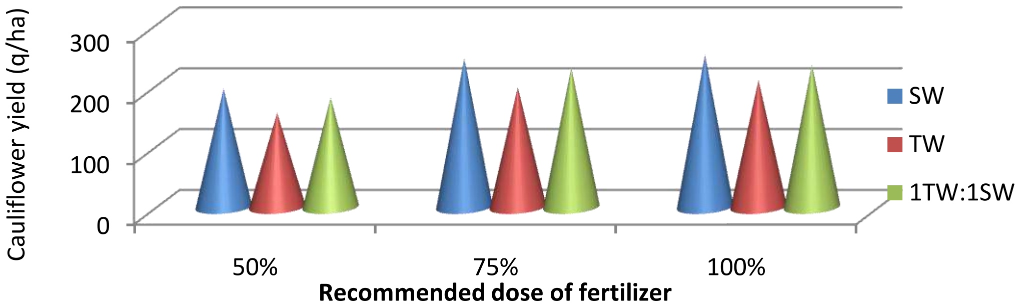


Fig. 3.8 Yield of cauliflower (q/ha) in different treatments

Interaction: The interaction effect of irrigation water and recommended dose of fertilizer on head yield of cauliflower was found significant. The irrigation water use in cauliflower results in increased head yield with every increase in the rate of RDF up to 100%. Where the rate of RDF was increased from 75% to 100% RDF the head yield per hectare marginally increased. The maximum head yield was obtained with the use of sewage water and 100% RDF which was significantly higher than other treatment combinations (Table 3.48).

Table 3.48 Interaction effect of irrigation water x fertilizer on head yield of cauliflower (q/ha)

Irrigation water	Fertilizer dose ((%)			Total	Av.
	50%	75%	100%		
SW	194.93	244.97	250.77	690.67	230.22
TW	155.17	197.40	209.30	561.87	187.29
1SW:1TW	180.80	228.93	234.70	644.43	214.81
Total	530.89	671.30	694.77	-	-
Av	176.96	223.76	231.59	-	-
CD (5%)	13.76				

Okra (Summer season crop)

After harvest of cauliflower crop, the okra crop was grown during summer season with different irrigation water and recommended dose of fertilizer.

Germination and plant height: The germination of okra crop was non significant with use of irrigation water and recommended dose of fertilizer. The plant height of okra crop was recorded at 30, 60 and 90 DAS. The taller plant was produced in sewage water irrigation in all the crop growth stages and lowest in tube well water irrigation. The application of recommended dose of fertilizer gave the significantly highr plant height. The application of higher dose of fertilizer (100% RDF) produced taller plants and lower dose of fertilizer (50% RDF) results in lowest plant height of okra (Table 3.49).

Dry matter accumulation: Significantly higher dry matter accumulation of okra plant was obtained with recommended dose of fertilizer and application of sewage water irrigation over tube well water irrigation. The significantly maximum dry matter accumulation was observed in sewage water irrigation and minimum was in tube well water irrigation The application of 100% RDF produced significantly maximum dry matter per plant and 50% RDF produced minimum dry matter per plant in all the stages of crop growth (Table 3.49).

Table 3.49 Effect of different treatments on germination and plant height of okra

Treatments	Germination (%)	Plant height (cm)			Drymatter accumulation (g)		
		30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
Irrigation water							
SW	75.40	11.18	33.28	48.32	10.90	32.56	77.02
TW	73.80	8.64	28.91	39.24	8.55	24.57	45.71
1 SW:1TW	74.92	9.91	32.71	43.11	10.18	28.89	73.27
CD (5%)	NS	0.63	2.54	2.60	0.63	3.27	6.34
Recommended dose of fertilizer							
50%	74.21	7.91	22.96	33.54.	8.19	24.32	61.99
75%	74.30	10.08	33.33	45.22	9.87	28.67	65.37
100%	74.62	11.74	38.61	47.21	11.56	32.83	68.65
CD (5%)	NS	0.63	2.54	2.60	0.63	3.27	6.34
IW X F	NS	NS	NS	NS	NS	NS	NS

Application of sewage irrigation water and recommended dose of fertilizer clearly indicated that significant higher pod length and pod yield per plant (g) was obtained under sewage water irrigation and minimum in tube well water irrigation. Application of 100% RDF produced highest pod length and pod yield per plant and lowest in 50% RDF (Table 3.50).

The application of sewage water irrigation produced significantly maximum pod yield (199.35 q/ha) as compared to pod yield (102.57 q/ha) obtained with tube well water irrigation. The application of 100% RDF significantly produced higher pod yield (170.86 q/ha) and lowest pod yield (127.35 q/ha) in 50% RDF (Table 3.50 and Fig 3.9).

Economics and B:C ratio: Maximum net profit (Rs. 120382/ha) and B: C ratio (1.52) was obtained in sewage water irrigation and minimum (22309 and 0.30) was in tubewell water irrigation. Application of 100% RDF gave maximum net profit (Rs. 88684/ha) and B:C ratio (1.08) and minimum (51300 and 0.68) was in 50% RDF treatments (Table 3.50).

Table 3.50 Effect of different treatments on yield and economics of okra crop

Treatments	Pod length (cm)	Pod yield per plant (g)	Pod Yield (q/ha)	Net profit (RS/ha)	B:C ratio
Irrigation water					
SW	11.59	332.00	199.35	1,20,382	1.52
TW	8.89	285.67	102.57	22,309	0.30
1 SW:1TW	10.72	300.69	158.69	79,719	0.80
CD (5%)	1.58	6.83	7.63	-	-
Recommended dose of fertilizer					
50%	8.84	293.33	127.35	51,300	0.68
75%	10.48	307.00	162.39	83,429	1.06
100%	11.87	318.00	170.86	88,684	1.08
CD (5%)	1.58	6.83	7.63	-	-
IW X F	NS	NS	13.22	-	-

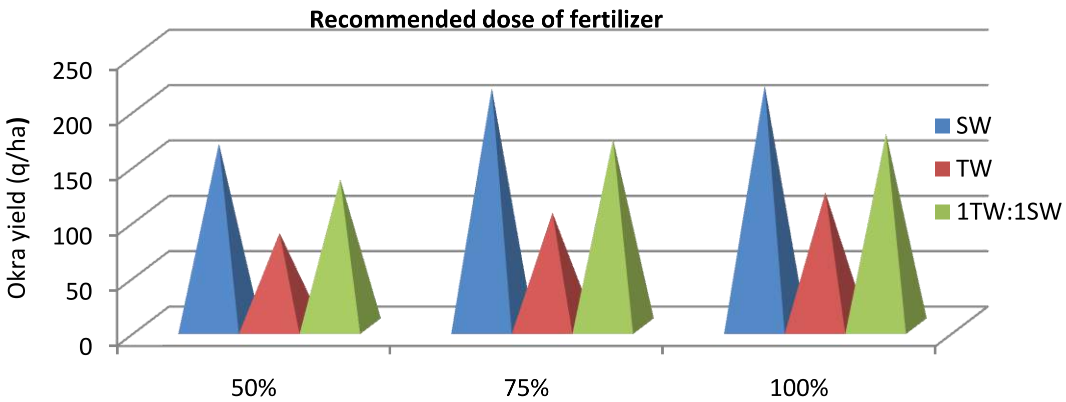


Fig. 3.9 Yield of okra (q/ha) in different treatments.

Interaction: The pod yield of okra was increased with every increase in the rate of RDF up to 100%. Where the rate of RDF was increased from 75% to 100% RDF the pod yield per hectare marginally increased. The maximum pod yield was obtained with the use of sewage water and 100% RDF which was significantly higher than other combinations (Table 3.51).

Table 3.51 Interaction effect of irrigation water x fertilizer dose

Irrigation water	Fertilizer dose (%)			Total	Average
	50%	75%	100%		
SW	165.06	215.36	217.62	598.04	199.35
TW	84.24	102.54	120.94	307.72	102.57
1SW:1TW	132.75	169.27	174.03	476.05	158.69
Total	382.05	487.17	512.59	-	-
Average	127.35	162.39	170.86	-	-
CD (5%)	13.22				

Rotational net profit and B:C ratio: The annually net profit for rotation cluster bean-cauliflower-okra was calculated. The maximum net profit of the three crops grown in one year rotation in sewage water irrigation was Rs. 277355/ha and lowest in tube well water irrigated (Rs. 1 43098/ha). The benefit: cost ratio in this rotation was the maximum in sewage water irrigation (1.53) and minimum (0.91) in tube well water irrigation. The application of 100% recommended dose of fertilizer produced maximum net profit and B:C ratio (Rs. 243227/ha and 1.35) and minimum (Rs. 164507/ha and 1.02) with 50% RDF (Table 3.52).

Table 3.52 Effect of different treatments on net profit and benefit cost ratio of cluster bean, cauliflower and okra crop sequence (2016-17)

Treatments	Net profit (Rs./ha)				B:C ratio			
	Cluster bean	Cauliflower	Okra	Total	Cluster bean	Cauliflower	Okra	Average
Irrigation water								
SW	74,494	82,479	1,20,382	2,77,355	1.60	1.47	1.52	1.52
TW	64,070	56.719	22,309	1,43,098	1.42	1.01	0.30	0.91
1 SW:1TW	67,184	73,231	79,719	2,20,134	1.48	1.33	0.80	1.20
Recommended dose of fertilizer								
50%	59,599	53,208	51,300	1,64,507	1.39	1.00	0.68	1.02
75%	70,347	78,480	83,427	2,32,254	1.56	1.41	1.06	1.34
100%	73,802	80,741	88,684	2,43,227	1.56	1.41	1.08	1.35

Initial and final soil fertility status for crop rotation:

Initial status: Soil fertility was analysed at the initiation of the experiment and clearly indicated that the organic carbon, organic matter, available nitrogen, available P and available K was higher in surface layer (0-15 cm) at the sowing of cluster bean (Table 3.53).

Table 3.53 ECe, Organic carbon and available nutrients in the soil (Initial status)

Treat.	Soil Depth (cm)	ECe dS/m	O.C. (%)	O.M. (%)	Av.N (kg/ha)	Av.P_2O_5 (kg/ha)	Av.K_2O (kg/ha)
SW 50%RDF	0-15	2.2	0.28	0.48	281.5	13.4	195.2
	15-30	2.1	0.25	0.43	272.9	12.2	178.3
	30-60	2.1	0.23	0.40	211.7	9.5	156.2
	60-90	2.0	0.23	0.40	168.3	7.5	84.4
SW 75%RDF	0-15	2.1	0.28	0.48	288.3	12.8	197.5
	15-30	2.0	0.27	0.50	262.7	12.5	187.2
	30-60	2.0	0.25	0.45	202.4	9.8	156.4
	60-90	2.1	0.20	0.34	163.3	7.3	86.8
SW 100%RDF	0-15	2.3	0.28	0.48	289.3	12.5	201.2
	15-30	2.2	0.26	0.45	262.7	11.8	191.4
	30-60	2.1	0.23	0.40	207.2	10.4	158.4
	60-90	2.0	0.19	0.33	161.4	7.7	88.7
TW 50%RDF	0-15	3.1	0.27	0.46	255.4	12.2	187.2
	15-30	2.8	0.24	0.41	245.6	11.1	175.2
	30-60	2.5	0.22	0.38	191.3	9.5	151.4
	60-90	2.3	0.18	0.31	158.4	6.3	82.4
TW 75%RDF	0-15	3.2	0.26	0.45	260.8	12.5	191.4
	15-30	2.7	0.24	0.41	242.7	11.8	178.3
	30-60	2.6	0.21	0.36	191.6	9.5	145.2
	60-90	2.4	0.20	0.34	145.7	6.3	68.7
TW 100%RDF	0-15	3.2	0.26	0.45	262.7	12.7	197.3
	15-30	2.7	0.24	0.41	243.3	11.3	168.4
	30-60	2.5	0.23	0.40	189.7	9.5	152.4
	60-90	2.5	0.19	0.33	145.3	7.0	81.7
1SW:1TW 50%RDF	0-15	2.6	0.27	0.46	265.6	12.2	201.2
	15-30	2.3	0.25	0.43	256.8	11.7	181.7
	30-60	2.2	0.22	0.38	195.3	9.6	157.4
	60-90	2.2	0.20	0.34	155.8	7.5	89.2
1SW:1TW 75%RDF	0-15	2.8	0.27	0.46	272.7	12.5	201.3
	15-30	2.3	0.24	0.41	261.3	11.6	185.4
	30-60	2.4	0.23	0.40	193.6	9.8	160.2
	60-90	2.2	0.18	0.31	157.8	7.6	91.2
1SW:1TW 100%RDF	0-15	2.9	0.27	0.46	275.3	12.2	198.3
	15-30	2.6	0.23	0.40	260.8	10.8	182.7
	30-60	2.5	0.22	0.38	196.2	9.3	160.4
	60-90	2.3	0.20	0.31	161.7	6.5	91.7

Final status (at harvest of okra crop): The pH was observed normal in all the treatments at harvesting of last crop of okra. The sodium range was in the range of 24.2-36.2 meq/l in all the treatments, and was slightly higher. The Ca+Mg present in all the soil samples but this value was higher as compared with initial sowing time. In all soil samples CO_3 was not found but HCO_3 was detected in all the samples. The chloride and sulphate was present in all the samples collected at harvest of okra crop. The SAR was observed in all the collected soil samples but RSC was absent in all samples. The organic carbon was increased in all the soil samples at all depths as compared with initial values. Available nitrogen and potassium was found in medium range while available phosphorus was in lower range, these values increases at the completion of the crop rotation (Table 3.54).

Table 3.54 EC_e, Organic carbon and available nutrients in the soil (at harvest of last crop)

Treatments	Soil Depth (cm)	ECe dS/m	O.C. (%)	O.M. (%)	Av.N (kg/ha)	Av.P_2O_5 (kg/ha)	Av.K_2O (kg/ha)
SW 50%RDF	0-15	3.5	0.28	0.48	274.2	13.1	188.2
	15-30	3.3	0.26	0.45	260.3	12.3	162.5
	30-60	3.4	0.25	0.43	156.3	10.4	151.3
	60-90	3.2	0.22	0.38	142.3	7.5	87.5
SW 75%RDF	0-15	3.5	0.28	0.48	275.7	13.2	188.9
	15-30	3.5	0.26	0.45	250.2	12.5	172.3
	30-60	3.3	0.25	0.43	178.4	10.2	145.6
	60-90	3.2	0.23	0.40	148.4	7.2	87.8
SW 100%RDF	0-15	3.5	0.28	0.48	276.2	13.2	188.9
	15-30	3.4	0.26	0.45	252.8	12.2	172.5
	30-60	3.3	0.25	0.43	178.6	10.0	141.3
	60-90	3.3	0.24	0.41	148.9	8.1	82.8
TW 50%RDF	0-15	4.2	0.25	0.43	232.7	11.2	168.7
	15-30	3.8	0.24	0.43	203.6	10.8	158.2
	30-60	3.6	0.22	0.38	162.7	9.2	132.3
	60-90	3.5	0.18	0.21	128.2	6.3	71.8
TW 75%RDF	0-15	4.3	0.25	0.43	233.8	12.2	170.5
	15-30	4.0	0.24	0.43	209.9	11.5	159.2
	30-60	3.6	0.21	0.36	163.8	9.2	133.3
	60-90	3.6	0.21	0.36	130.5	6.5	70.3
TW 100%RDF	0-15	4.3	0.26	0.45	235.7	12.2	172.2
	15-30	4.0	0.25	0.43	211.5	11.7	152.4
	30-60	3.5	0.22	0.38	165.2	9.5	128.6
	60-90	3.4	0.20	0.34	131.8	7.2	71.2
1SW:1TW 50%RDF	0-15	3.7	0.27	0.4	238.2	12.1	173.3
	15-30	3.4	0.25	0.43	211.9	11.5	158.6
	30-60	3.4	0.24	0.45	166.7	10.2	138.7
	60-90	3.3	0.24	0.42	132.5	7.8	79.2
1SW:1TW 75%RDF	0-15	3.8	0.27	0.46	259.8	12.8	190.2
	15-30	3.4	0.25	0.43	145.4	11.7	157.8
	30-60	3.3	0.24	0.41	173.9	10.9	133.3
	60-90	3.3	0.23	0.36	143.2	7.1	71.7
1SW:1TW 100%RDF	0-15	3.8	0.27	0.46	259.7	12.9	191.3
	15-30	3.6	0.26	0.45	245.2	11.8	158.2
	30-60	3.5	0.24	0.41	184.7	11.1	135.6
	60-90	3.4	0.22	0.38	144.2	7.2	72.2

Cropping System Productivity: The maximum system productivity in cluster bean-cauliflower-okra cropping sequence was observed in treated sewage water irrigation i.e. 547.24 q/ha and minimum (399.10q/ha) in tube well water irrigation. The use of 100% recommended dose of fertilizer produced maximum system productivity of 523.74 q/ha and lowest of 406.78 q/ha in 50% RDF (Table 3.55; Fig. 3.10).

Table 3.55 Effect of different treatments on system productivity

Treatments	Cluster bean yield (q/ha)	Cauliflower yield (q/ha)	Okra Yield (q/ha)	Cropping system yield (q/ha)
Irrigation water				
SW	117.67	230.22	199.35	547.24
TW	109.24	187.29	102.57	399.10
1SW:1TW	112.36	214.81	158.69	485.86
Recommended dose of fertilizer				
50%	102.46	176.97	127.35	406.78
75%	115.52	223.77	162.39	501.68
100%	121.29	231.59	170.86	523.74.

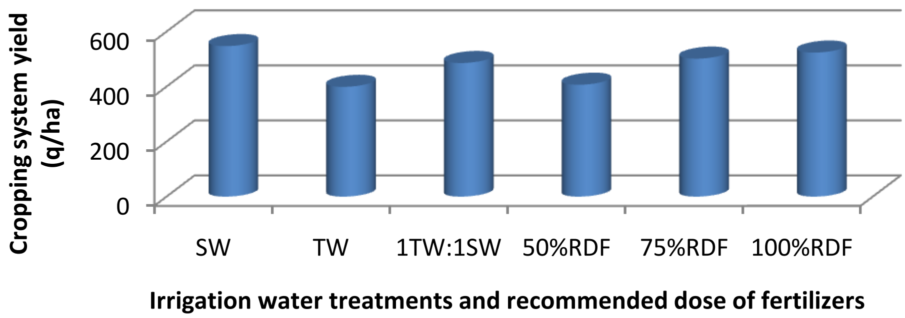


Fig. 3.10 Cropping system productivity for different treatments

4. ALTERNATE LAND MANAGEMENT

- **Evaluation of Silvi-horticultural crops in Saline/alkali soils under rainfed conditions (Bapatla)**

This evaluation was conducted in Sri. P Yedukondala Reddy's field (soil pH and EC were 8.6 and 2.1 dS m-1) of Panduranga Puram village and Sri. G. Apparao's field (soil pH and EC were 7.8 of 4.5 dS m-1) of Peda Vodarevu village. In the sites casuraina, eucalyptus, guava/sapota, pomegranate and custard apple saplings were planted as per the recommended spacing. All the saplings of casurina, eucalyptus and sapota planted on 25.6.2016 at Panduranga Puram site established well. The plant height of casurina, eucalyptus and sapota increased up to 106, 98 and 76.4 cm, respectively. At Pedavodarevu site all the saplings of sapota, guava and pomegranate planted on 18.06.2016 established well with 12, 8 and 21 branches, respectively. Pomegranate established well and reached a height of 89 cm. In case of sapota and guava, plants reached height of 115 and 137 cm, respectively.

5. SCREENING OF CROP CULTIVARS AND GENOTYPES

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

The IVT experiment was conducted in micro-plots and each plot was separated by polythene sheet up to 90 cm depth. The saline water was synthesized for irrigation. The mustard cultivars CSCN-16-1 to CSCN-16-12 (IVT) and CSCN-16-11 to CSCN-16-19(AVT) were irrigated using saline water of ECiw 12 dS/m.

IVT

Growth, yield and yield attributing characters: The different yield attributing characters i.e. plant height, primary branches, secondary branches, days to 50% flowering and siliqua per plant were recorded and found non- significant except plant height and no. of siliqua per plant. The significantly maximum plant height was recorded in CSCN-16-1, CSCN-16-2 and CSCN-16-10 and other genotype has lowest plant height. The no. of siliqua per plant was heighest in CSCN-16-3 (261) and lowest in CSCN-16-8 and CSCN 16-12 (218). The yield of genotypes was significantly affected by saline water irrigation. Significantly higher yield was produced in genotype CSCN-16-10 (25.48 q/ha) and lowest was recorded in genotype CSCN-16-6 (20.04 q/ha). (Table 5.1). Soil salinity data are given in Table 5.2.

Table 5.1 Effect of saline water on yield and yield attributes of mustard genotypes (2016-17)

Genotype	Germination (%)	Days to 50% Flowering	Plant height (cm)	No. of primary Branches	No. of Secondary Branches	Main Shoot Length (cm)	No. of siliqua /plant	Grain yield (q/ha)
CSCN-16-1	82.1	63	188	6.1	6.4	188	225	21.84
CSCN-16-2	82.2	63	185	6.3	63.	185	223	21.93
CSCN-16-3	83.4	62	178	6.9	7.7	178	261	25.30
CSCN-16-4	81.4	62	177	6.3	6.8	177	235	23.89
CSCN-16-5	82.9	62	176	5.9	6.1	176	220	20.71
CSCN-16-6	82.1	62	176	5.8	6.2	176	221	20.04
CSCN-16-7	81.3	63	179	5.7	6.2	179	222	20.63
CSCN-16-8	81.8	62	178	5.7	6.2	178	218	20.44
CSCN-16-9	83.1	62	175	5.8	6.3	175	219	20.07
CSCN-16-10	81.1	63	180	6.9	7.4	180	250	25.48
CSCN-16-11	81.7	63	175	6.0	6.2	175	219	20.33
CSCN-16-12	80.6	62	174	6.1	6.1	174	218	20.14
CD (5%)	NS	NS	4.2	0.8	0.5	4.2	20.5	3.51

Table 5.2 Soil salinity build-up at sowing and at harvest of mustard (2016-17)

ECiw (dS/m)	Soil depth(cm)	ECe (dS/m)	
		At sowing	At harvest
ECiw 12 dS/m	0-15	6.8	10.8
	15-30	5.5	7.8
	30-60	4.5	6.9
	60-90	4.3	5.8

AVT

Growth, yield and yield attributing characters: The yield attributing characters i.e. plant height, primary branches, secondary branches, days to 50% flowering and siliqua per plant were recorded and found non-significant execpt plant height and siliqua per plant. The significantly maximum plant height was recorded in CSCN-16-11, CSCN-16-17, CSCN-16-19, CSCN-16-16 and CSCN-16-15 and other genotype gave lowest plant height. The siliqua per plant was highest in CSCN-16-11 and lowest in CSCN-16-15 & CSCN-16-18. The grain yield of genotypes was significantly affected in saline water irrigation. The significantly higher yield was produced in genotype CSCN-16-19 & CSCN-16-11 (26.56 and 26.47 q/ha) and lowest was recorded in genotype CSCN-16-13 (19.98 q/ha) (Table 5.3; Fig. 5.1).

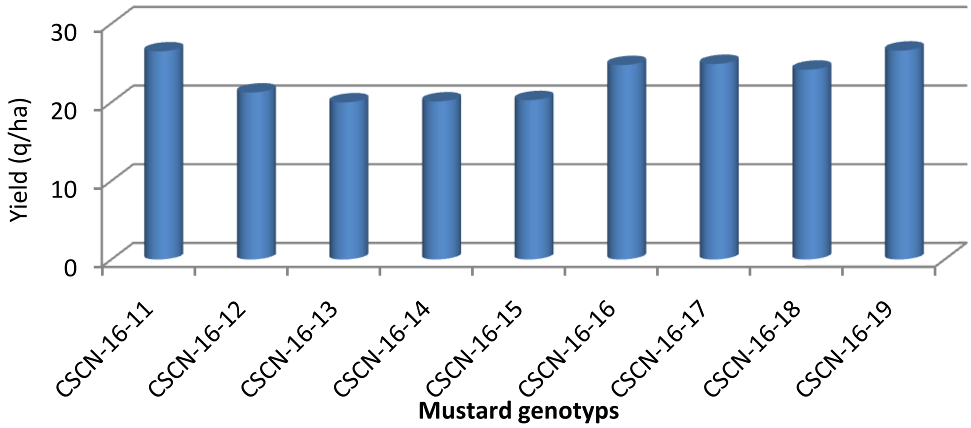


Fig. 5.1 Grain yield (q/ha) of different genotype of mustard

Table 5.3 Effect of saline water on yield and yield attributes of mustard genotypes (2016-17)

Genotype	Germination (%)	Days to 50% Flowering	Plant height (cm)	No. of primary Branches /plant	No. of Secondary Branches/ plant	Main Shoot Length (cm)	No. of siliqua /plant	Grain yield (q/ha)
CSCN-16-11	82.5	63	184.7	7.3	7.7	184.7	320.0	26.47
CSCN-16-12	81.1	62	176.4	5.6	6.3	176.4	225.0	21.23
CSCN-16-13	81.2	62	175.2	5.5	6.1	175.2	216.0	19.98
CSCN-16-14	82.7	62	176.0	5.9	6.3	176.0	220.0	20.10
CSCN-16-15	83.3	63	182.4	6.3	6.3	182.4	219.0	20.26
CSCN-16-16	81.4	62	183.3	6.2	6.9	183.3	255.0	24.73
CSCN-16-17	82.7	63	184.1	6.7	6.6	184.1	255.0	24.86
CSCN-16-18	83.3	63	176.1	6.0	6.3	176.1	216.0	20.14
CSCN-16-19	82.3	62	184.2	7.3	6.9	184.2	219.0	26.56
CD (5%)	NS	NS	2.5	0.7	0.8	2.5	14.2	2.27

The salinity was higher in upper layers at sowing as well as at harvest time. At the time of sowing the ECe of surface layer (0-15 cm) was 6.2 dS/m and in lower depth (60-90 cm) was 4.2 dS/m. whereas, at harvest it increases to 11.3 and 5.8 dS/m, respectively (Table 5.4).

Table 5.4 Soil salinity build-up at sowing and at harvest of mustard (2016-17)

ECiw (dS/m)	Soil depth (cm)	EC_e (dS/m)	
		At sowing	At harvest
ECiw 12 dS/m	0-15	6.2	11.3
	15-30	5.5	8.2
	30-60	4.5	6.9
	60-90	4.2	5.8

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

Plant height: The maximum plant height was observed in Ag-17 and lowest in Ag-20. The levels of fertility were significant in mustard plant height. The tallest plant was observed in 150% RDF and smallest in 100% RDF (Table 5.5).

Table 5.5 Effect of different treatments on plant height (cm) of mustard (2016-17)

Entries	Fertility levels			
	100% RDF	125% RDF	150% RDF	Mean
Ag-17	190.1	197.3	200.6	196.3
Ag-18	188.8	193.3	195.2	192.4
Ag-19	188.0	193.2	191.9	191.0
Ag-20	183.6	188.9	187.8	186.7
Mean	187.6	193.1	193.8	-
CD (5%): Entries (E)=5.33; Fertility (F)=4.21; E X F=NS				

Branches: The entries of mustard shown significant difference in primary and secondary branches per plant. The entries Ag-17 gave significantly maximum primary and secondary branches per plant and Ag-20 minimum primary branches per plant, while in secondary branches/plant gave minimum in Ag-18 (Table 5.6). The application of 150% RDF produced significantly maximum primary and secondary branches and lowest in application of 100% RDF.

Table 5.6 Effect of different treatments on no. of primary /secondary branches/plant of mustard (2016-17)

Entries	Primary branches				Secondary branches			
	100% RDF	125% RDF	150% RDF	Mean	100% RDF	125% RDF	150% RDF	Mean
Ag-17	6.1	6.6	6.8	6.5	9.4	10.2	11.0	10.2
Ag-18	5.8	6.2	6.8	6.3	8.6	9.1	9.9	09.2
Ag-19	6.3	6.4	7.9	6.9	10.9	11.5	11.8	11.4
Ag-20	6.0	6.2	6.4	6.2	9.1	9.4	10.3	9.6
Mean	6.1	6.4	6.9	-	9.5	10.1	10.8	-
CD (5%): Entries (E)=0.20; Fertility (F)=0.23; E X F=NS					CD (5%): Entries (E)=0.58; Fertility(F)=0.39; E X F=NS			

Siliqua: Number of siliqua per plant was found significant in mustard entries and doses of fertilizer. The significantly maximum siliqua per plant was produced in Ag-19 and lowest in Ag-18. Siliqua per plant was significantly maximum under application of 150% RDF while 100% RDF produced minimum siliqua per plant. Entries of mustard significantly differ in number of seeds per siliqua. The entry Ag-19 produced significantly maximum (15.9) seeds per siliqa and Ag-18 gave minimum (14.1) seeds per siliqua. The application of 150% RDF produced significantly maximum (15.3) seeds per siliqua and 100% RDF produced lowest (14.2) seeds per siliqua (Table 5.7).

Table 5.7 Effect of different treatments on siliqua of mustard (2016-17)

Entries	Siliqua/plant				Seeds/siliqua			
	100% RDF	125% RDF	150% RDF	Mean	100% RDF	125% RDF	150% RDF	Mean
Ag-17	249.6	253.5	262.4	255.2	13.7	14.2	15.8	14.6
Ag-18	226.4	228.7	230.4	228.5	13.8	14.1	14.4	14.1
Ag-19	332.9	337.5	339.7	336.7	15.6	15.9	16.1	15.9
Ag-20	246.8	249.4	249.8	248.7	13.7	14.1	14.8	14.2
Mean	263.9	267.3	270.6	-	14.2	14.6	15.3	-
CD (5%) : Entries(E)=28.3; ertility(F)=23.8; E X F=NS					CD (5%): Entries(E)=0.58; Fertility(F)=0.43; ExF=NS			

Seed yield: The data of mustard grain yield (qha^{-1}) clearly indicated that grain yield of entries of mustard differ significantly. The highest grain yield of 28.04q/ha) was found in Ag-19 and lowest grain yield of 21.83 q/ha) in Ag-17 but grain yield of Ag-18 and Ag-20 was at par. The grain yield of mustard increased significantly by 100%, 125% and 150% RDF. The 150% RDF increases the grain yield of mustard by 9.43% and 125% RDF by 7.7per cent over 100 per cent RDF (Table 5.8; Fig. 5.2).

Table 5.8 Effect of different treatments on grain yield (q/ha) of mustard (2046-17)

Entries	Grain yield (q/ha)			
	100% RDF	125% RDF	150% RDF	Mean
Ag-17	20.33	22.44	22.70	21.83
Ag-18	21.78	23.18	23.70	22.89
Ag-19	26.96	28.33	28.81	28.04
Ag-20	20.85	22.89	23.18	22.31
Mean	22.48	24.21	24.60	
CD (5%): Entries(E)=8.56; Fertility(F)=4.18; E X F=NS				

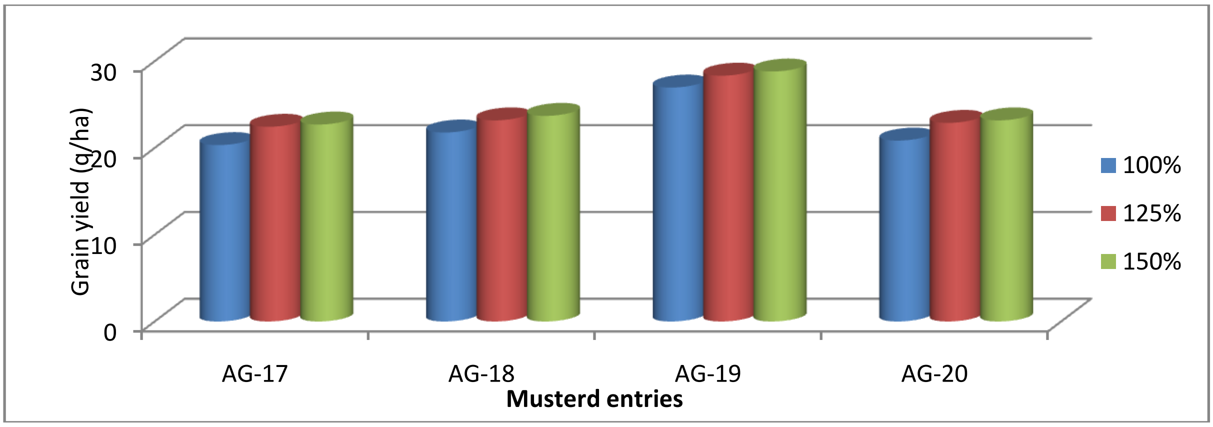


Fig. 5.2 Grain yield (q/ha) different entries of mustard

- **Evaluation trial of lentil germplasm in salinity/sodicity (Agra)**

The experiment was conducted in micro-plots of 4.5 m x 4.0 m size (Plate 5.1). The irrigation water was prepared synthetically for water salinity. The yield of lentil germplasm was significantly affected under saline water irrigation. The highest yield (514.32 kg/ha) was produced in lentil germplasm LSL 16-3 and lowest (200.00 kg/ha) was recorded in germplasm LSL 16-6. The yield of lentil germplasm was significantly differed in sodic water irrigation. The germplasm LSD 16-7 gave highest grain yield (739.38 kg/ha) and lowest grain yield (293.46 kg/ha) was observed in LSD 16-6 (Table 5.9).

Table 5.9 Effect of saline/sodic water irrigation on yield of lentil (2016-17)

Germplasm/Code	Saline water irrigation (EC_{iw} 6 dS/m)		Sodic water irrigation (RSC 6 meq/l)	
	Grain yield/plot (gm)	Grain yield (kg/ha)	Grain yield/plot (gm)	Grain yield (kg/ha)
LSL 16-1	79.10	292.96	145.13	537.53
LSL 16-2	81.73	302.72	100.83	373.46
LSL 16-3	138.87	514.32	80.20	297.04
LSL 16-4	73.63	272.72	102.53	379.75
LSL 16-5	110.67	409.88	159.13	589.38
LSL 16-6	54.00	200.00	79.23	293.46
LSL 16-7	130.10	481.85	199.63	739.38
LSL 16-8	74.73	276.79	104.00	385.18
LSL 16-9	127.57	472.47	168.60	624.44
LSL 16-10	86.87	321.73	123.97	459.14
LSL 16-11	89.60	331.85	108.33	401.23
LSL 16-12	78.63	291.23	130.57	483.58
LSL 16-13	90.30	334.44	118.98	440.68
LSL 16-14	92.20	341.48	124.53	461.23
LSL 16-15	86.57	320.62	102.40	379.26
S Em+	16.1	59.6	8.2	30.3
CD (5%)	33.0	122.1	16.8	62.1

Plate 5.1 Screening of Lentil Germplasm for salinity

The ECe of soil is higher in upper layer at sowing and harvest. At harvest ECe increase in whole profile. The ESP of soil at sowing and at harvest of lentil crop was higher at the time of harvesting (Table 5.10).

Table 5.10 Soil salinity and ESP build-up at sowing and at harvest of lentil

Saline water	Soil depth (cm)	EC_e (dS/m)		Sodic water	Soil depth (cm)	ESP	
		At sowing	At harvest			At sowing	At harvest
EC_{iw} 6 dS/m	0-15	2.4	5.3	RSCiw 6 (meq/l)	0-15	8.6	11.3
	15-30	2.2	4.9		15-30	8.4	10.9
	30-60	2.1	3.5				
	60-90	2.0	3.0				

- **Screening of newly released rice varieties for salinity tolerance (Bapatla)**

To know tolerance level of salinity for newly released rice cultures in Andhra Pradesh, this study was undertaken. The details of study are given below.

a. Design : RBD
b. Replications : Three
c. Crop : Rice
d. Treatments :7
e. Treatments / varieties : 7 (MCM-103; BPT-4455; MCM-101; MCM-110; ; CSR-27; CSR-36 and BPT-5204

NPK fertilizers were applied as per recommendation. Different rice varieties were screened for salinity tolerance in farmers' fields of Bhavanamvari Palem (B V Palem), Guntur district (CSR -36, CSR-27, MCM-100, MCM-101, MCM- 102, MCM-103, MTU-1010 and MTU-1061) and in Pedanindrakolanu (P N Kolanu) during earlier years. At Bhavanamvari Palem, the highest paddy yield (4500 kg ha^{-1}) was recorded with MCM -100 and MTU-1061 followed by CSR -36 and MTU -1010 (4313 kg ha^{-1}). At P N Kolanu, West Godavari district, the varieties viz., CSR-36, CSR-27 and Local check were screened during kharif, 2015 in soils having ECe 5.3 and 6.4 dS m^{-1}, respectively. The highest paddy yield was recorded with MTU-1010 (5813 kg ha^{-1}) followed by CSR-36 (5625 kg ha-1) and CSR-27 (5063 kg/ ha).

The experiment was conducted at Bhavanamvaripalem village, Guntur district during kharif, 2016. Among the varieties tested (MCM-103, BPT-4455, MCM-101, MCM-110, CSR-27, CSR-36 and BPT-5204), the highest grain yield was recorded with CSR 27 (6017 kg ha-1) followed by MCM-110 (5850 kg ha-1). The straw yield was found to be maximum with the variety CSR 36 (6150 kg ha-1) followed by MCM 110 (5500 kg ha-1). Details are given in Table 5.11. Available nutrients were significantly lower (184, 19.8 and 637.3 kg N-P2O5- K2O ha-1) when MCM 101 was the test variety as against the corresponding test values of 250.9, 28 and 704.6 kg ha^{-1} with BPT 5204. Per cent depletion in available N,P and K against initial were 2.23, 42 and 22 with MCM 101, however a depletion of 18.6 and 13 per cent in available P and K while a built up of 33 % in available N happened with BPT 5204. Similarly, in case of the highest yielder CSR 27, a built up in available N to the tune of 23 % and depletion in available P and K to the extent of 39.5 and 14.4 % were observed (Table 5.12).

Table 5.11 Biometric observations and yield of rice varieties tested at Bhavanamvaripalem village

Varieties	Plant height (cm)		No. of tillers per hill		Yield (kg ha^{-1})	
	Tillering stage	Panicle initiation stage	Tillering stage	Panicle initiation stage	Grain	Straw
1. MCM 103	45.6	76.5	19.1	11.0	1133	1000
2. BPT4455	57.5	97.9	20.3	15.0	5533	5383
3. MCM - 101	60.3	117.3	21.1	13.5	5400	5517
4. MCM-110	59.1	109.3	21.1	12.7	5850	5533
5. CSR 27	60.8	116.9	18.1	12.0	6017	5267
6. CSR-36	61.7	110.9	17.9	13.8	6100	6150
7. BPT-5204	56.7	99.9	19.3	13.3	5347	5667
SEm±	1.1	1.8	0.8	0.4	147	247
CD	3.8	6.1	2.8	1.2	490	827

Table 5.12 Fertility status of soil after harvest of rice crop at Bhavanavaripalem village

Varieties	pH(1:2)	ECe (dS m-1)	Available Nutrients (kg ha-1)		
			N	P2O5	K2O
1. MCM 103	8.3	5.0	230.0	26.7	743.0
2. BPT4455	8.1	3.1	238.3	23.6	721.1
3. MCM - 101	8.1	4.6	184.0	19.8	637.3
4. MCM-110	8.1	4.1	221.6	23.6	667.5
5. CSR 27	8.2	4.4	230.0	20.8	695.6
6. CSR-36	7.9	5.3	238.3	22.3	746.4
7. BPT-5204	8.4	4.9	250.9	28.0	704.6
Initial	8.6	5.2	188.2	34.4	812.4
SEm±	0.03	0.5	9.1	1.3	18.27
CD	0.11	1.8	30.4	4.4	61.09

- **Screening of different crop varieties under drip with saline water irrigation (Bikaner)**

This experiment was initiated during kharif 2015 on screening of cluster bean varieties for salt tolerance under four saline water irrigations (BAW, 4, 8, 12 dS/m). Cluster bean varieties (RGC 1066, RGC 936, RGC 1014, RGC 1003) were screened during 2015-17. Pooled results for two years showed that up to ECiw of 4 dS/m there was no significant reduction in the grain yield of cluster bean, however, ECiw of 8 dS/m caused significant reduction of 37.9 and 34.9 per cent in grain yield over BAW and ECiw of 4 dS/m, respectively. Straw yield, however, reduced significantly with every increase in salinity of irrigation water. ECiw of 4 dS/m and 8 dS/m caused significant reduction of 5.6 and 40.4 per cent in straw yield of cluster bean as compared to BAW (Table 5.13).

Table 5.13 Evaluation of cluster bean varieties under saline water drip irrigation (2015-17)

Treatments	Plant height (cm)			Number of pods per plant		
	2015	2016	Pooled	2015	2016	Pooled
Salinity levels						
BAW	109.48	110.33	109.90	107.50	114.75	111.13
4 dS/m	105.52	107.74	106.63	104.75	109.88	107.32
8 dS/m	84.65	85.84	85.24	74.63	78.66	76.64
SEm	2.26	1.10	1.26	3.31	2.55	2.09
CD (5%)	7.83	3.82	3.88	11.46	8.84	6.44
Varieties						
RGC 1066	125.42	128.05	126.73	119.11	127.75	123.43
RGC 936	74.08	75.42	74.75	70.42	73.67	72.04
RGC 1017	106.78	107.93	107.35	100.86	106.55	103.71
RGC 1003	93.25	93.82	93.54	92.11	96.41	94.26
SEm	1.84	1.82	1.29	3.71	2.64	2.28
CD (5%)	5.33	5.28	3.66	10.77	7.66	6.46

Variety RGC 1066 established its superiority by a margin of 47.0, 14.9 and 46.5 per cent grain yield over RGC 936, RGC 1017 and RGC 1003, respectively. Similarly, straw yield of variety RGC 1066 recorded significant increase of 64.1, 12.8 and 68.4 per cent over RGC 936, RGC 1017 and RGC 1003, respectively Table 5.14.

Table 5.14. Evaluation of cluster bean varieties under saline water drip irrigation (2015-17)

Treatments	Grain Yield (q/ha)			Straw yield (q/ha)		
	2015	2016	Pooled	2015	2016	Pooled
Salinity levels						
BAW	10.27	12.87	11.57	12.60	14.81	13.70
4 dS/m	9.79	12.30	11.04	11.91	13.96	12.93
8 dS/m	6.62	7.76	7.19	7.42	8.92	8.17
SEm	0.187	0.296	0.175	0.26	0.28	0.19
CD (5%)	0.648	1.024	0.54	0.91	0.97	0.59
Varieties						
RGC 1066	10.89	13.69	12.29	13.85	16.19	15.02
RGC 936	7.41	9.31	8.36	8.34	9.96	9.15
RGC 1017	9.95	11.45	10.70	12.29	14.35	13.32
RGC 1003	7.33	9.44	8.39	8.08	9.76	8.92
SEm	0.214	0.239	0.160	0.29	0.31	0.21
CD (5%)	0.620	0.694	0.45	0.85	0.91	0.61

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

The experiments on screening of crop cultivars were initiated to evaluate the performance of different varieties of crops under saline water irrigations and to study the effects of different qualities of saline water on the salt build up in the soil profile. 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 tolerance of seven genotypes of cotton, fourteen genotypes of wheat, seven genotype of pearl millet and nineteen genotypes of mustard were tested under different saline water irrigation treatments i.e. canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m.

Cotton: Increasing salinity results in a gradual decrease in seed cotton yield. Among the seven genotypes, H-1472 gave the highest (174.60 g/m^2) seed cotton yield and H-1465 resulted in lowest seed cotton yield (131.73 g/m^2) at EC_{iw} 7.5 dS/m. The mean seed cotton yield reduced by 25.60% at EC_{iw} 7.5 dS/m as compared to canal irrigation. Overall mean yield (210.81 g/m^2) of H-1472 was significantly higher than other genotypes followed by H-1098i (199.25 g/m^2) and H-1465 was the lowest yielder (157.44 g/m^2). The overall mean reduction in seed cotton yield at 2.5, 5.0 and 7.5 dS/m was 4.55, 15.99 and 25.98%, respectively as compared to canal irrigation (Table 5.15).

Wheat: The data showed that the grain yield of different genotypes of wheat decreased with an increase in EC of the irrigation water (Table 5.16). Wheat genotype P-12908 performed the best at EC_{iw} (7.5 dS/m) and gave 31.67% higher grain yield as compared with KRL 210 (check). It was followed by P-9142 which gave 29.54 % higher grain yield than KRL 210 whereas; the performance of Kh-65 was the poorest. On the basis of overall mean grain yield P-13339 gave maximum grain yield (499.39 g/m^2) which was 27.71% higher than KRL-210 followed by P-12908(495.18 g/m^2) which was 27.10% higher than KRL-210. The overall mean reduction in wheat yield at 2.5, 5.0 and 7.5 dS/m was 2.19, 10.52 and 24.69%, respectively as compared to canal irrigation. Physiological observations for Normalized Difference Vegetation Index (NDVI), Chlorophyll content (SPAD units) and Chlorophyll fluorescence (Fv/Fm ratio) were recorded at heading and anthesis (Table 5.17, 5.18 and 5.19). Percent reduction in NDVI at 7.5 dS/m was least in P-12908 (17.1%), P- 12334 (18.9%), P-13348 (18.9%) and P-13339 (20.5%), percent reduction in Fv/Fm ratio was least in P- 12334(7.6%), P-13348(8.8%), P-12908 (9.1%) and P-12953(9.7%) and in Chlorophyll content (SPAD units) percent reduction was least in P-9134 (11.0%), P-9143 (16.9%), P 9132 (18.2%), and P-13348 (18.7%).

Table 5.15 Effect of saline waters on seed cotton yield (g/m^2) of cotton genotypes

Genotype	ECiw (dS/m)				Mean
	Canal (0.3)	2.5	5.0	7.5	
H-1098i	223.20	216.45	190.40	166.97	199.25
H-1316	179.50	172.50	151.13	136.30	159.86
H-1353	213.30	202.30	184.27	157.33	189.30
H-1465	178.80	171.30	147.93	131.73	157.44
H-1472	242.43	229.42	196.80	174.60	210.81
H-1489	191.35	180.93	168.07	138.63	169.74
H-1508	196.05	186.87	158.27	148.87	172.53
Mean	203.52	194.25	170.98	150.63	
CD (5%) Variety (V) = 12.97, Salinity (S) = 9.81 V x S = NS					

Table 5.16 Grain yield (g/m^2) of wheat genotypes as affected by different saline waters

Genotype	Grain yield (g/m^2)				Mean
	Canal (0.3)	2.5	5.0	7.5	
P- 9132	429.43	421.30	393.93	336.67	395.33
P-9134	480.37	473.53	426.33	374.10	438.58
P-9135	416.23	405.43	376.43	319.17	379.32
P- 9137	453.00	441.87	408.03	318.63	405.38
P-9142	520.37	509.50	472.77	411.27	478.48
P-9143	464.30	453.63	420.57	358.03	424.13
P-12334	511.93	500.27	472.53	376.23	465.24
P-12883	439.93	428.57	391.40	319.27	394.79
P-12908	542.20	533.00	481.40	424.10	495.18

P-12953	391.63	384.60	358.83	306.67	360.43
P-13339	556.83	548.83	483.67	408.23	499.39
P-13348	507.57	493.03	439.10	369.50	452.30
Kh-65	330.83	319.10	288.93	244.87	295.93
KRL-210	403.93	394.03	356.20	289.77	360.98
Mean	460.61	450.48	412.15	346.89	
CD (5%)	Variety (V) = 21.92, Salinity (S)= 11.72, V x S = NS				

Table 5.17 Normalized Difference Vegetation Index (NDVI) of wheat genotypes at salinity waters

Genotypes	NDVI at heading				NDVI at anthesis			
	Canal (0.3)	2.5	5.0	7.5	Canal (0.3)	2.5	5.0	7.5
P- 9132	0.80	0.71	0.70	0.48	0.65	0.55	0.34	0.32
P-9134	0.81	0.76	0.73	0.50	0.69	0.68	0.44	0.35
P-9135	0.85	0.78	0.78	0.61	0.71	0.70	0.58	0.52
P- 9137	0.86	0.71	0.69	0.64	0.77	0.70	0.47	0.37
P-9142	0.86	0.80	0.78	0.70	0.72	0.83	0.56	0.39
P-9143	0.86	0.82	0.80	0.73	0.74	0.73	0.62	0.46
P-12334	0.86	0.83	0.79	0.78	0.74	0.74	0.65	0.60
P-12883	0.86	0.83	0.75	0.65	0.74	0.70	0.59	0.51
P-12908	0.84	0.80	0.72	0.68	0.76	0.73	0.64	0.63
P-12953	0.83	0.82	0.82	0.67	0.81	0.73	0.65	0.52
P-13339	0.85	0.81	0.81	0.77	0.78	0.75	0.74	0.62
P-13348	0.84	0.84	0.76	0.75	0.79	0.74	0.70	0.64
Kh-65	0.86	0.84	0.83	0.81	0.85	0.77	0.76	0.74
KRL-210	0.85	0.82	0.80	0.78	0.82	0.76	0.71	0.67

Table 5.18 Chlorophyll content (SPAD units) of wheat genotypes at different salinity waters

Genotypes	Chlorophyll content at heading				Chlorophyll content at anthesis			
	Canal (0.3)	2.5	5.0	7.5	Canal (0.3)	2.5	5.0	7.5
P- 9132	33.3	32.0	28.6	28.2	32.4	27.9	26.8	26.5
P-9134	39.5	37.9	26.2	26.0	27.2	26.8	25.7	24.2
P-9135	35.6	32.4	27.2	25.5	32.4	24.4	24.3	22.4
P- 9137	35.7	34.1	31.7	27.2	32.8	29.7	27.2	25.8
P-9142	34.3	34.2	28.1	24.4	32.2	24.5	22.4	19.7
P-9143	33.1	28.0	27.3	26.0	28.3	25.8	25.5	23.5
P- 12334	33.5	33.2	27.9	25.9	29.1	26.8	23.8	23.2
P-12883	30.0	28.5	26.5	25.8	27.5	26.8	24.6	21.6
P-12908	32.3	27.0	26.3	24.2	26.9	23.6	22.4	21.6
P-12953	33.3	32.4	30.7	30.4	29.6	28.0	27.5	23.0
P-13339	40.4	38.2	33.1	30.1	32.8	32.8	30.6	23.6
P-13348	37.8	31.3	28.0	26.7	29.8	27.6	26.5	24.2
Kh-65	40.1	37.8	31.3	26.0	28.9	28.4	27.8	23.7
KRL-210	30.9	29.4	28.1	21.5	25.5	24.5	21.5	19.6

Table 5.19 Chlorophyll fluorescence (Fv/Fm ratio) of wheat genotypes at different salinity waters

Genotypes	Chlorophyll content at heading				Chlorophyll content at anthesis			
	Canal (0.3)	2.5	5.0	7.5	Canal (0.3)	2.5	5.0	7.5
P- 9132	33.3	32.0	28.6	28.2	32.4	27.9	26.8	26.5
P-9134	39.5	37.9	26.2	26.0	27.2	26.8	25.7	24.2
P-9135	35.6	32.4	27.2	25.5	32.4	24.4	24.3	22.4
P- 9137	35.7	34.1	31.7	27.2	32.8	29.7	27.2	25.8
P-9142	34.3	34.2	28.1	24.4	32.2	24.5	22.4	19.7
P-9143	33.1	28.0	27.3	26.0	28.3	25.8	25.5	23.5
P-12334	33.5	33.2	27.9	25.9	29.1	26.8	23.8	23.2
P-12883	30.0	28.5	26.5	25.8	27.5	26.8	24.6	21.6
P-12908	32.3	27.0	26.3	24.2	26.9	23.6	22.4	21.6
P-12953	33.3	32.4	30.7	30.4	29.6	28.0	27.5	23.0
P-13339	40.4	38.2	33.1	30.1	32.8	32.8	30.6	23.6
P-13348	37.8	31.3	28.0	26.7	29.8	27.6	26.5	24.2
Kh-65	40.1	37.8	31.3	26.0	28.9	28.4	27.8	23.7
KRL-210	30.9	29.4	28.1	21.5	25.5	24.5	21.5	19.6

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 5.20). Pearl millet variety HHB-226 performed best at ECiw (7.5 dS/m) followed by HHB-223 whereas the performance of ICMB-843-22 was the poorest. The mean grain yield (309.64 g/m^2) of HHB-226 was higher than other genotypes followed by HHB-223 (289.10 g/m^2) and HHB-272 (244.00 g/m^2). The genotype ICMB-843-22 was the lowest yielder with mean grain yield of 82.50 g/m^2 at ECiw 7.5 dS/m, overall mean grain yield reduced by 23.69% as compared to canal treatment. The overall mean reduction in pearl millet yield at 2.5, 5.0 and 7.5 dS/m was 4.90, 12.63 and 23.79%, respectively as compared to canal.

Table 5.20 Grain yield (g/m^2) of pearl millet genotypes as affected by different saline waters

Genotype	Grain yield (g/m^2)				Mean
	Canal (0.3)	EC_{iw} 2.5	EC_{iw} 5.0	EC_{iw} 7.5	
HHB-226	343.83	326.17	302.57	266.00	309.64
HHB-223	321.40	309.00	279.30	246.50	289.10
HHB-272	273.00	259.00	240.00	205.00	244.00
ICMB-843-22	180.10	102.40	94.47	82.50	96.87
ICMB-94555	157.70	151.70	135.40	116.80	140.40
HBL-11	111.27	104.57	96.70	87.77	100.07
HMS-47B	120.23	113.20	106.40	89.50	107.33
Mean	205.14	195.08	179.22	156.32	
CD (5%)	Variety (V) = 7.70, Salinity (S) = 5.82, V x S =15.41				

Mustard: Ten genotypes of IVT and nine 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 5.21 and 5.22). In IVT, the mustard genotypes CSCN-16-3 gave the highest seed yield (241.90 g/m^2) followed by CSCN-16-9 (239.30 g/m^2) at ECiw 7.5 dS/m and the lowest seed yield (172.67g/m^2) was obtained in CSCN-16 -5.

The Na^+/K^+ ratio increased with increasing salinity levels and the values varied from 0.66 to 3.30. Salinity susceptibility index (SSI) also followed the same trend. The mean values less than one was recorded in most of the mustard genotypes even at 7.5 dS m^{-1} of salinity (Table 5.22 and Table 5.23).

In AVT, the mustard genotypes CSCN-16-13 gave the highest seed yield (250.44 g/m^2) followed by CSCN-16-12 (233.87 g/m^2) at ECiw 7.5 dS/m and the lowest seed yield (167.48 g/m^2) was obtained in CSCN-16-14 (Table 5.24). The Na^+/K^+ ratio increased with increasing salinity levels and the values varied from 0.71 to 2.68 . Salinity susceptibility index (SSI) also followed the same trend. The mean values less than one was recorded in CSCN-16-12, CSCN-16-13, CSCN-16-14, CSCN-16-16 and CSCN-16-18 mustard genotypes at 7.5 dS m^{-1} of salinity (Table 5.25 and Table 5.26).

Table 5.21 Seed yield (g/m^2) of mustard genotypes (IVT) as affected by salinity waters

Genotype	Seed yield (g/m^2)				Mean
	Canal (0.3)	EC_{iw} 2.5	EC_{iw} 5.0	EC_{iw} 7.5	
CSCN-16-1	276.17	263.70	245.67	207.70	248.31
CSCN-16-2	306.50	259.17	275.23	227.60	276.13
CSCN-16-3	313.00	301.30	280.20	241.90	284.10
CSCN-16-4	284.47	268.47	252.20	210.47	253.90
CSCN-16-5	218.70	202.27	185.87	172.67	195.87
CSCN-16-6	269.23	253.33	233.53	206.17	240.57
CSCN-16-7	302.73	288.43	272.23	220.93	271.08
CSCN-16-8	250.60	233.87	207.53	191.60	220.90
CSCN-16-9	308.13	269.10	276.60	239.30	280.03
CSCN-16-10	283.50	264.53	253.20	214.80	254.00
Mean	281.31	267.11	248.23	213.31	
CD (5%)	V=17.30 S = 10.94 SxV= NS				

Table 5.22 Effect of saline waters on Na^+/K^+ ratio of mustard genotypes under IVT

Genotype	Na^+/K^+ ratio			
	Canal (0.3)	EC_{iw} 2.5	EC_{iw} 5.0	EC_{iw} 7.5
CSCN-16-1	0.75	1.45	1.92	2.46
CSCN-16-2	0.73	1.30	1.76	4.25
CSCN-16-3	0.71	1.24	1.65	2.63
CSCN-16-4	0.61	1.54	1.57	3.31
CSCN-16-5	0.86	1.31	1.61	2.06
CSCN-16-6	0.45	0.98	2.24	4.02
CSCN-16-7	0.65	1.23	1.77	3.99
CSCN-16-8	0.77	0.85	2.18	3.66
CSCN-16-9	0.46	1.19	1.71	3.43
CSCN-16-10	0.57	0.99	1.44	3.18
Mean	0.66	1.21	1.79	3.30

Table 5.23 Salinity susceptibility index (SSI) of mustard genotypes under IVT as affected by waters of different salinities

Genotype	Salinity susceptibility index			
	EC_{iw} 2.5	EC_{iw} 5.0	EC_{iw} 7.5	Mean
CSCN-16-1	0.75	0.85	0.95	0.85
CSCN-16-2	0.21	0.12	0.27	0.20
CSCN-16-3	0.18	0.87	0.84	0.63
CSCN-16-4	0.31	0.13	0.31	0.25
CSCN-16-5	0.24	1.15	0.68	0.69
CSCN-16-6	0.24	0.11	0.34	0.23
CSCN-16-7	0.19	0.88	0.79	0.62
CSCN-16-8	0.34	0.20	0.30	0.28
CSCN-16-9	0.37	0.52	0.75	0.55
CSCN-16-10	0.18	0.20	0.33	0.24

Table 5.24 Seed yield of mustard genotypes under AVT as affected by different salinity waters

Genotype	Seed yield (g/m^2)				Mean
	Canal (0.3)	EC_{iw} 2.5	EC_{iw} 5.0	EC_{iw} 7.5	
CSCN-16-11	272.83	255.60	231.93	186.81	236.79
CSCN-16-12	328.58	311.33	279.03	233.87	288.20
CSCN-16-13	332.37	319.77	285.77	250.44	297.08
CSCN-16-14	195.50	186.37	173.27	167.48	180.65
CSCN-16-15	220.31	214.03	201.37	178.44	203.54
CSCN-16-16	317.88	297.83	264.70	216.74	274.29
CSCN-16-17	309.12	290.53	260.80	211.40	267.96
CSCN-16-18	283.52	269.50	244.97	190.17	247.08
CSCN-16-19	291.98	281.30	250.47	202.00	256.43
Mean	283.57	269.58	243.59	204.15	
CD (5%)	V=18.04 S = 12.02 SxV= NS				

Table 5.25 Effect of different saline waters on Na^+/K^+ ratio of mustard genotypes under initial variety trial (AVT)

Genotype	Na^+/K^+ ratio			
	Canal (0.3)	2.5	5.0	7.5
CSCN-16-11	0.54	1.33	1.82	3.05
CSCN-16-12	0.78	0.98	1.93	2.58
CSCN-16-13	0.62	1.17	1.23	1.69
CSCN-16-14	0.82	1.17	1.49	2.88
CSCN-16-15	0.72	1.05	1.43	2.17
CSCN-16-16	0.42	1.29	1.57	3.77
CSCN-16-17	0.64	1.37	1.70	2.68
CSCN-16-18	0.86	1.37	1.38	2.55
CSCN-16-19	0.98	1.25	1.72	2.75
Mean	0.71	1.22	1.59	2.68

Table 5.26 Salinity susceptibility index (SSI) of mustard genotypes under AVT as affected by different salinity waters

Genotype	Salinity susceptibility index			
	2.5	5.0	7.5	Mean
CSCN-16-11	0.35	0.73	0.97	0.68
CSCN-16-12	0.15	0.21	0.30	0.22
CSCN-16-13	0.25	0.68	0.83	0.59
CSCN-16-14	0.19	0.17	0.17	0.18
CSCN-16-15	0.15	0.52	1.10	0.59
CSCN-16-16	0.41	0.32	0.29	0.34
CSCN-16-17	0.15	0.48	1.09	0.57
CSCN-16-18	0.34	0.28	0.30	0.31
CSCN-16-19	0.11	0.50	1.02	0.54

- **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 5.27.

Table 5.27 Varieties of rice, wheat and mustard used for screening

Rice	Wheat	Mustard	Other Expt. Details	
CSR-23	KRL-210	CS-52	No of replication:	Three in each crop
CSR-27	KRL-213	CS-54	Design:	RBD
CSR-30	PBW-343	CS-56	Plot size:	20 m2
CSR-36	PBW-502	Varuna	Year of start	2015
CSR-43	WH-147	Pitamvari	Location:	Crop Research Farm, Dalipnagar, Kanpur
Pant-12	K-307	Rohini	Initial soil status:	
NDR-359	K-8434	Urvashi	pH	9.30
Kranti	DBW-17	Kanti	EC (dSm-1)	0.89
			ESP	45.3
			O.C. (%)	0.23

The average grain and straw yield of different varieties of rice varied from 21.89-43.08 q/ha and 26.84-52.02 q/ha respectively. The maximum yield 43.08 q/ha of rice was recorded from variety CSR-36 followed by CSR-23 and CSR-27 (Table 5.28). The minimum yield 21.89 q/ha was obtained from CSR-30.

Table 5.28 Yield of rice (q/ha) in sodic soil conditions

Varieties	Grain (2015)	Grain (2016)	Mean	Straw (2015)	Straw (2016)	Mean
CSR-23	39.82	41.57	40.69	48.77	51.12	49.95
CSR-27	37.65	38.24	37.94	45.68	46.65	46.16
CSR-30	21.27	22.52	21.89	26.22	27.46	26.84
CSR-43	36.38	38.85	37.61	43.38	44.89	44.14
CSR-36	43.52	42.64	43.08	52.57	52.02	52.29
Pant-12	28.69	27.83	28.26	34.86	35.53	35.20
NDR-359	35.12	36.33	35.72	42.92	44.11	43.52
Kranti	33.41	32.54	32.97	39.43	40.22	39.83

The average grain and straw yield of different varieties of wheat varied from 26.89-35.38 q/ha and 32.31-43.34 q/ha respectively. The maximum yield 35.38 q/ha of wheat was recorded from variety KRL-210 followed by KRL-213 and PBW-343 (Table 5.29). The minimum yield 26.89 q/ha was obtained from WH-147.

Table 5.29 Yield of wheat (q/ha) in sodic soil conditions

Varieties	Grain (2015-16)	Grain (2016-17)	Mean	Straw (2015-16)	Straw (2016-17)	Mean
KRL-210	34.55	36.22	35.38	42.15	44.53	43.34
KRL-213	33.84	34.87	34.35	40.94	42.12	41.53
PBW-343	32.42	33.15	32.78	39.87	40.53	40.20
PBW-502	31.27	30.20	30.73	36.89	35.86	36.37
WH-147	26.10	27.68	26.89	31.84	32.78	32.31
K-307	28.77	29.12	28.94	34.25	35.65	34.95
K-8434	29.52	28.76	29.19	36.72	36.62	36.67
DBW-17	27.33	28.44	27.88	32.54	33.74	33.14

The average grain yield of different varieties of mustard varied from 10.46-16.18 q/ha and stalk yield from 26.30-40.75 q/ha. The maximum yield 16.18 q/ha of mustard was recorded from variety CS-56 followed by CS-54 and CS-52 (Table 5.30). The minimum yield 10.46 q/ha was obtained from Urvasi.

Table 5.30 Yield of mustard (q/ha) in sodic soil conditions

Varieties	Grain (2015-16)	Grain (2016-17)	Mean	Stalk (2016-17)	Stalk (2016-17)	Mean
CS-52	13.25	13.34	13.29	32.92	34.10	33.51
CS-54	14.78	14.42	14.60	37.82	37.00	37.41
CS-56	16.12	16.25	16.18	40.27	41.24	40.75
Varuna	12.97	12.25	12.66	34.25	33.72	33.98
Pitambri	11.55	11.22	11.38	29.45	28.04	28.74
Rohini	12.32	11.67	11.99	33.74	34.52	34.13
Urvasi	10.63	10.29	10.46	26.73	25.88	26.30
Kranti	12.14	12.10	12.12	30.35	29.48	29.91

- **Evaluation of chilly hybrid and varieties for their tolerance to sodicity levels (Tiruchirapalli)**

This experiment is being continued in the same experimental plot with six ESP gradients with different chilly hybrids and varieties during 2015-16. Treatment details are as below.

Main plots	• Different Gradient of ESP (8, 16, 24, 32, 40 and 48)
Strip plots	• Different Chilli varieties viz., Kovilpatti - 1 (K-1), Ramanathapuram-Mundu(local), Manaparai local and TNAU Hybrid Chilli CO-1
Others	• Replication: 3; Design: Strip Plot Design • Spacing: 60 x 45 cm; Date of sowing: 28.09.2016

Nursery was raised with various varieties viz., Kovilpatti - 1 (K-1), Ramanathapuram-Mundu local, Manaparai local and TNAU Hybrid Chilly CO-1 at sodic soil during January 2016. Due to sodicity, the seeds were not germinated and thus the trial was abandoned during that season and thus the trial was initiated during August, 2016. Nursery was again raised during second week of August, 2016 with normal soil with good quality water. The existing main field also prepared in A6b farm of ADAC&RI, Tiruchirapalli. In experimental field, based on the ESP existed in the different main plots, the sodium bicarbonate was applied to main plots and mixed thoroughly with the soil to create different gradient ESP levels viz., 8, 16, 24, 32, 40 and 48 were artificially. Further, the ESP 8 was created through application of gypsum and leaching with good quality water. Then the experimental plot was thoroughly ploughed individually to bring optimum soil tilt and the ridges and furrows were formed with a spacing of 60 cm. Thereafter the chilly seedlings were transplanted along the ridges with a spacing of 60 cm between rows and 45 cm between plants during last week of September 2016. The seedling vigour was good as it was raised under normal soil with good quality water. Other management practices like gap filling weeding and other inter cultivation practices were carried out according to the recommended package of practices. The experiment was maintained using bore well water with the RSC of 7.2 due to the non-availability of canal water. The crop could not be well established in the main field after transplanting. The crops were dried upon irrigation with bore well water even in the ESP of 8. It could be concluded that chilly will not be suitable crop for raising in the sodic soil further, the use of alkali water even under the normal ESP the performance was very poor.

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

Screening for salt tolerance was undertaken to identify the suitable cultivar of clusterbean (*Cyamopsis tetragonoloba* L.) for saline water, total twenty germplasm of Clusterbean were shown on 5th July, 2016. The crop was harvested on 11 November, 2016. In the preliminary experiment, the data on effect of poor quality water on plant height, number of primary branches and number of secondary branches of cluster bean was collected. 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. It was observed that poor quality water significantly affect the number of cluster per plant and number of pods per plant, where as no significantly effect was reported on number of pods per cluster. The maximum cluster per plant was recorded in germplasm IC 41202 followed by IC 40235 > IC 40417 > IC 113578 > IC40752 under poor quality water. Whereas, maximum number of pods per plant was observed in germplasm IC 40235 followed by IC40417 > IC 41202 and IC 40752. Data presented in Table 5.31 revealed that pod length, number of grains per pod and seed index does not affect significantly by poor quality water. Whereas, grain yield per plant significantly influenced by poor quality water. It was also reported that maximum grain yield was observed in IC 40235 germplasm followed by IC 40417 > IC 40752 and IC 40266.

Table 5.31 Effect of poor quality water on pod length, number of grains, grain yield and seed index of different cluster bean (*Cyamopsis tetragonoloba* L.) Germplasm

S.N.	Cultivars	Number of grains/ pods			Grain yield /plant			Seed Index		
		CW	TW	Mean	CW	TW	Mean	CW	TW	Mean
1	IC 39418	9.00	8.19	8.60	14.93	7.00	10.97	2.79	2.75	2.77
2	IC 39980	8.50	8.25	8.38	11.82	5.55	8.68	2.83	2.76	2.79
3	IC40004	8.17	7.50	7.83	7.08	5.57	6.32	2.48	2.41	2.44
4	IC40230	8.67	8.23	8.45	13.16	8.84	11.00	2.86	2.65	2.75
5	IC40235	8.33	8.00	8.17	19.42	14.61	17.01	3.10	2.99	3.04
6	IC40249	9.01	8.33	8.67	10.66	7.16	8.91	2.94	2.73	2.84
7	IC40256	9.23	8.50	8.87	13.95	5.70	9.83	2.92	2.74	2.83
8	IC40417	9.00	8.50	8.75	15.53	11.98	13.75	2.94	2.84	2.89
9	IC40458	8.82	8.55	8.68	11.52	7.82	9.67	2.66	2.55	2.60

10	IC40741	8.00	7.68	7.84	12.84	7.58	10.21	2.71	2.52	2.61
11	IC40752	9.00	7.80	8.40	14.68	10.11	12.39	2.99	2.82	2.91
12	IC40162	9.00	7.33	8.17	16.23	4.24	10.24	2.89	2.60	2.74
13	IC40266	8.67	8.55	8.61	15.77	9.42	12.60	2.94	2.81	2.87
14	IC40682	8.83	8.43	8.63	12.58	6.81	9.69	2.98	2.94	2.96
15	IC40763	9.00	8.21	8.60	14.27	8.54	11.41	2.82	2.61	2.71
16	IC40998	9.15	9.08	9.12	8.23	5.37	6.80	2.93	2.74	2.84
17	IC41189	9.40	9.17	9.28	10.05	4.91	7.48	2.51	2.46	2.48
18	IC41202	8.33	8.08	8.21	13.01	8.49	10.75	2.88	2.13	2.50
19	IC113578	8.15	8.00	8.08	11.42	7.71	9.56	2.39	2.16	2.27
20	IC329038	8.67	8.00	8.33	11.27	5.70	8.49	2.88	2.66	2.77
Mean		8.75	8.22		12.92	7.65		2.82	2.64	
CD (5%) WQ		NS			1.89			NS		
Germplasm		NS			1.98			0.20		
Interaction		NS			2.79			NS		

- **Screening of salinity tolerance Chickpea (*Cicer arietinum* L.) Germplasm (Bathinda)**

Screening for salt tolerance was undertaken to identify suitable cultivar of Chickpea (*Cicer arietinum* L.) for saline water. Total twenty cultivars were shown on 26th November, 2016, using split plot design with five rows (2.5 meter) of each cultivar with 2 replications. The following observation namely, plant height (cm), number of primary branches per plant, number of secondary branches per plant and grain yield per plant were recorded. The crop was harvested on 6th May, 2017. The effect of poor quality water on different growth parameters and yield of chickpea was presented in Table 5.32. The data showed that poor quality water significantly effect on all growth parameters and yield of chickpea. The maximum plant height was reported in germplasm PDG 4 followed by PDG 5 > L 552 > JG62 and Karnal Channa-1. Lowest number of primary branches was reported in germplasm GLK 14311 followed by GLK-07-042 > L-556 > PDG 3 and L552. The germplasm karnal channa-1 showed maximum number of secondary branches followed by L-552 > PDG-3 > PBG7 and PDG 4. The use of poor quality water adversely affects the yield of chickpea. Maximum grain yield was reported in Karnal channa-1 followed by PBG7 > PDG4 and PBG5.

Table 5.32Effect of poor quality water on different growth parameters and yield of Chickpea (*Cicer arietinum* L.) germplassm

S. N	Cultivars	Plant height (cm)			Yield/plant		
		CW	TW	Mean	CW	TW	Mean
1	GL-12021	45.31	21.10	33.21	10.42	4.38	7.40
2	GL-13042	44.38	17.73	31.05	11.27	4.35	7.81
3	GL-29078	42.06	17.60	29.83	8.75	4.86	6.81
4	GL-14015	48.88	19.38	34.13	11.89	6.78	9.33
5	GNG-2171	42.25	17.50	29.88	23.87	5.57	14.72
6	GL-29095	39.25	21.00	30.13	13.45	6.73	10.09
7	GLK-07-042	40.94	14.50	27.72	12.00	2.10	7.05
8	GLK-14311	38.69	11.56	25.13	8.83	2.49	5.66
9	PBG-1	44.50	18.50	31.50	14.54	4.15	9.35
10	GL-13037	44.50	21.88	33.19	20.45	6.67	13.56
11	JG-62	36.94	26.25	31.59	8.13	4.52	6.33
12	GPF-2	35.13	20.13	27.63	9.96	5.25	7.60
13	PDG-3	43.00	24.31	33.66	15.82	7.65	11.74

14	L-556	41.25	24.69	32.97	10.75	5.19	7.97
15	L-552	49.00	27.06	38.03	14.00	7.21	10.60
16	PBG-5	44.63	27.38	36.00	16.84	8.03	12.44
17	PDG-4	43.38	28.06	35.72	13.43	8.97	11.20
18	ICCU-10508	39.13	25.38	32.25	11.10	7.79	9.44
19	PBG-7	42.44	25.31	33.88	15.02	10.91	12.96
20	Karnal Channa-1	37.38	25.63	31.50	19.70	15.39	17.54
Mean		42.15	21.75		13.51	6.45	
CD (5%) WQ		14.66			3.37		
Germplasm		2.80			0.83		
Interaction		3.96			1.17		

6. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

- **ORP for the use of underground saline water at farmer's field (Agra)**

The field demonstrations under ORP for the use of poor quality water were initiated during kharif 1993 in Karanpur village of Mathura district. During 2016-17, eleven farmers were selected for saline water use (ECiw 7.1 to 13.0 dS/m) of different villages i.e. Deen Dayal Dham (Nagla Chandra Bhan), Dhana Khema, Nagla Jalal, Garhi Pachauri and Dalatpur in district Mathura (UP) and Odara in Bhratpur district (Rajasthan). The water quality parameters pertaining to tubewell water of the selected farmers are given in Table 6.1. During the year 2016-17, the salinity of RSC waters varied from 3.0-5.1 dS/m, RSC 6.2 – 8.8 meq/l and SAR 17.0 – 24.7 $(mmol/l)^{1/2}$. In saline waters, EC_{iw} varied from 10.0 to 23.5 dS/m, RSC Nil and SAR 11.0 – 24.9 $(mmol/l)^{1/2}$.

Table 6.1 Water quality of farmer's tube well water

Name of the farmer	EC_{iw}	RSC (meq/l)	SAR $(mmol/l)^{1/2}$
RSC water			
Mr. Harvans Kumar	3.0	8.8	17.0
Mr. Om Prakash	4.4	7.6	23.9
Mr. Hakim Singh	5.1	6.2	24.7
Saline Water			
Mr. Subhash Chand	10.0	-	11.0
Mr. Ram Bharosee	15.0	-	19.0
Mr. Hari Prasad	13.5	-	12.5
Mr. Lal Hans	10.9	-	16.2
Mr. Dinesh Chand	11.0	-	17.0
Mr. Mukesh Kumar	13.8	-	24.0
Mr. Roop Singh	23.5	-	24.9
Mr. Birendra Singh	19.9	-	23.5
Mr. Jagan Singh	12.6	-	15.5

Kharif season

The demonstrations during kharif season were conducted at 12 farmers' fields. Out of 12 farmers, pearl millet (var. Super boss) was grown on 6 fields (3 with alkali water + 3 with saline water), Sorghum fodder (var. Poorbi white) was grown on 4 fields. The NPK fertilizers were applied @ 120:60:30 kg/ha for pearl millet and 90:30:30 kg/ha for sorghum fodder.

In alkali water irrigation, pearl millet was grown at three farmers' fields. The yield was varied from 1.80 to 2.35 t/ha in residual effect of gypsum and 1.60 to 2.10 t/ha without gypsum treated fields. Whereas the per cent increase was recorded from 11.7 to 12.5 in gypsum added fields compared to without gypsum fields (Table 6.2).

In high SAR saline water, the pearl millet crop was grown on three farmer's field, sorghum fodder on four farmers fields (Table 6.3). The pearl millet grain yield varied from 1.90 to 2.40 t/ha in ORP demonstration field. The pearl millet yield was increased by 11.1 to 11.8 per cent as compared to traditional farming. Sorghum fodder grown on four farmers' fields, the sorghum fodder yield varied from 37.0 to 40.5 t/ha in ORP demonstration fields. In ORP field the Sorghum fodder increased by 15 per cent over conventional method.

Table 6.2 Pearl millet grain yield and soil characteristics (0-30cm) at crop harvest with and without gypsum in alkali water irrigation during 2016

Name of farmer	Treatments	Variety	ORP yield (t/ha)	% increase	EC_e (dS/m)	pH2	SAR $(mmol/l)^{1/2}$	ESP
Mr. Harvans Kumar	Gypsum	Poineer 86M86	1.80	12.5	3.8	7.7	16.1	15.5
	No Gypsum	,,	1.60	-	3.8	7.7	16.5	18.3
Mr Om Prakash	Gypsum	Supper Boss	2.35	11.9	8.2	7.9	17.3	19.2
	No Gypsum	,,	2.10	-	6.6	7.9	15.0	20.8
Mr. Hakim Singh	Gypsum	Poineer 86M86P	1.90	11.7	3.8	7.8	14.4	20.7
	No Gypsum	,,	1.70	-	3.6	7.7	11.4	22.1

Table 6.3 Pearl millet and sorghum fodder yield and soil characteristics (0-30cm) at crop harvest in high SAR saline water irrigation during 2016

Name of farmer	Crop/ Variety	ORP yield (t/ha)	Farmers Yield (t/ha)	% increase over farmers yield	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
Mr.Lal Hans	Sorghum/ Poorbi white	38.25	33.50	14.17	4.1	7.2	11.2
Mr. Birendra Singh	Pearl millet/ Supper Boss	2.33	2.1	11.1	4.9	7.3	16.5
Mr. Roop Singh	Sorghum/ Poorbi white	37.00	32.50	13.84	5.5	7.1	17.0
Mr. Subhash Chand	Pearl millet/ Supper Boss	2.40	2.15	11.6	3.1	7.2	6.9
Mr. Mukesh Kumar	Sorghum GF/ Poorbi white	40.50	35.00	15.71	2.4	7.1	11.0
Mr. Hari Prasad	Sorghum/ Poorbi white	37.50	33.00	13.63	5.8	7.3	13.4
Mr. Dinesh Chand	Pearl millet/ Supper Boss	1.90	1.70	11.8	2.5	7.1	8.7

GF- Green Fodder

Rabi Season

A total of 19 farmers were selected for sowing the rabi season crops. In alkali water (Savai village, Agra district), wheat (var. Raj 4238) was sown on 3 farmer's field. Irrigation with saline water using rain water harvesting through recharge structures at Odara village, Bharatpur district Rajasthan, wheat (var. Raj 4120 , Raj 4238) was sown on eight farmer's fields and at one farmers field mustard (var. Rohini) was sown. Other 7 farmers were also selected in saline water irrigation condition, and wheat (var. KRL 210) was sown. The recommended dose of NPK fertilizers @ 120:60:60 kg/ha in wheat and mustard along with 12.5 kg/ha Forate and 12.5 kg/ha zinc were applied.

Wheat crop was sown at 3 farmers' field in Savai village, of district Agra. The yield and yield attributing characteristics increased in Residual effect of gypsum treated fields over control (without gypsum). The average wheat yield increased about 12.2 per cent in residual effect of gypsum treated fields over control (without gypsum). The soil pH, SAR and ESP decreased in gypsum treated fields over control. The maximum yield (4.67 t/ha) was recorded in the field of Mr. Om Prakash in alkali water irrigation (Table 6.4 and 6.5).

Table 6.4 Residual effect of gypsum on yield attributes of wheat in alkali water (2016-17)

Name of farmer	Treatments	Germination/ running meter at 21 days	Plant height (cm) at 55 days	Shoots/ running meter at 55 days	Shoots/ running meter at harvest	Plant height (cm)	Ear length (cm)
Mr.Harivans	Gypsum	62.0	34.5	100.5	91.0	90.5	9.0
	No Gypsum	51.5	31.0	89.5	83.0	86.5	8.7
Mr. Om Prakash	Gypsum	58.5	35.0	101.5	97.0	99.5	10.5
	No Gypsum	53.5	32.0	97.5	92.0	93.5	9.8
Mr Hakim Singh	Gypsum	60.0	34.0	93.5	91.5	91.0	8.8
	No Gypsum	54.0	31.0	90.0	88.0	88.5	8.4

Table 6.5 Residual effect of gypsum on wheat yield (t/ha) and soil characters (0-30 cm) at harvest (2016-17)

Name of farmer	Treatment	ORP yield (t/ha)	% increase over control	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$	ESP
Mr. Harvans	Gypsum	4.17	13.6	5.6	7.7	18.4	19.4
	No Gypsum	3.67	-	3.7	7.8	15.2	20.2
Mr. Om Prakash	Gypsum	4.67	11.2	4.9	7.8	16.2	17.8
	No Gypsum	4.20	-	6.8	8.0	22.9	19.5
Mr. Hakim Singh	Gypsum	4.33	11.9	5.0	7.9	17.7	19.1
	No Gypsum	3.87	-	5.2	7.8	16.6	22.8

Only one farmer Mr.Hari Parsad sown mustard during rabi season 2016-17. The seed yield of mustard was recorded 2.37 t/ha, it increased by 12.8 per cent as compared to traditional farming. At harvest of mustard the ECe 7.9 (dS/m), pH 7.2 and SARe 16.2 $(mmol/l)^{1/2}$ were recorded (Table 6.6).

Table 6.6 Effect of saline water on grain yield of mustard (var. Rohini) at water recharge sites of Odara village during 2016-17

Farmers Name	ECiw (dS/m)	ORP Yield (t/ha)	Farmers yield (t/ha)	% Increase	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
Mr Hari Prasad	8.1	2.37	2.10	12.8	7.9	7.2	16.2

The wheat crop was sown at 8 farmers' field in rain water recharge site and other seven farmer's fields. The yield attributing characters are presented in Table 6.7. The average of eight farmer's field, wheat yield was increased by 11.3 per cent in rain water recharge site and other seven farmer's yield increased by 10.2 per cent. The EC_e ranges 4.7 to 10.9 dS/m, pH ranges from 7.0 to 7.5 and SAR ranges from 11.4 to 23.5 $(mmol.l)^{1/2}$ at all fields. The EC_e and SAR increases with increasing EC of tubewell waters on farmer's field (Table 6.8).

Table 6.7 Yield attributes of wheat in saline water at farmers field (2016-17)

Name of farmer	Germination/ running meter at 21 days	Plant height (cm) at 55 days	Shoots/ running meter at 55 days	Shoots/ running meter at harvest	Plant height (cm)	Ear length (cm)
Recharge Site						
Mr.Dinesh Chand	45.5	37.0	97.0	93.5	90.5	9.6
Mr Ram Bharose	50.5	39.5	99.0	94.5	91.0	9.3
Mr. Mukesh Kumar	53.5	36.0	105.5	99.0	104.5	10.8
Mr. Lal Hans	53.0	38.0	96.0	91.0	91.5	10.0
Mr.Birendra Singh	49.5	37.5	99.5	92.5	89.0	9.2
Mr.Roop Singh	48.0	38.5	95.5	92.0	87.0	8.6
Mr.Subhas Chand	56.5	38.0	101.0	96.5	95.1	9.8
Mr.Jagan Singh	52.0	42.5	103.5	97.0	93.5	10.0
Other farmers						
Mr.Bhanwar Singh	53.5	36.5	98.0	91.5	94.0	9.7
Mr.Kishan Singh	53.5	39.0	107.5	97.5	98.0	9.8
Mr.R.M.Pathak	63.5	37.0	108.5	98.5	91.5	9.6
Mr.Mahendra Pratap	60.5	36.5	104.0	96.0	98.5	9.8
Mr.Ram Babu	54.5	39.5	95.5	91.5	99.5	9.4
Mr.Chandan lal	64.5	36.0	106.0	96.5	97.5	9.8
Mr.Babu lal	56.5	35.5	101.0	97.8	91.5	9.6

Table 6.8 Grain yield of wheat and soil characters at recharge sites and farmer's fields during 2016-17

Name of farmer	ECiw (dS/m)	Variety	ORP Yield (t/ha)	Farmers Yield (t/ha)	% Increase	EC_e (dS/m)	pH2	SAR $(mmol/l)^{1/2}$
Recharge site								
Mr.Lal Hans	10.9	Raj.4120	4.75	4.30	10.5	8.1	7.1	20.2
Mr.MukeshKumar	13.8	,,	4.37	3.90	12.0	8.8	7.1	14.3
Mr. Ram Bharose	15.0	,,	4.25	3.75	13.3	9.8	7.2	11.4
Mr.Birendra Singh	11.0	,,	4.00	3.60	11.1	9.6	7.1	15.4
Mr.Roop Singh	23.5	Raj.4120	3.75	3.40	10.3	10.9	7.1	23.5
Mr.Subhas Chand	8.2	Raj.4238	5.00	4.45	12.3	7.7	7.2	11.6
Mr.Jagan Singh	7.1	,,	4.87	4.40	10.7	8.6	7.0	14.9
Mr. Dinesh Chand	11.0	,,	4.62	4.20	10.0	6.6	7.2	23.6
Other farmers								
Mr.Bhanwar Singh	7.1	KRL-210	4.20	3.80	10.5	7.1	7.5	-
Mr.Kishan Singh	6.4	,,	4.33	2.90	11.0	6.3	7.3	-
Mr.R.M.Pathak	6.7	,,	4.50	4.05	11.1	6.7	7.2	-
Mr.Mahendra Pratap	6.3	,,	4.67	4.20	11.2	6.0	7.2	-
Mr.Ram Babu	4.7	,,	4.35	4.00	8.7	4.7	7.2	-
Mr.Chandan lal	7.3	Raj.4238	4.63	4.20	10.2	7.3	7.1	-
Mr.Babu lal	5.8	KRL-210	4.50	4.15	8.4	5.2	7.2	-

At recharge sites farmers tubewell water initial EC_{iw} ranges from 10.9 to 23.5 dS/m it decreased with rain water recharge. The EC_{iw} lowest was determine of first irrigation i.e. 4.5 to 5.9 (dS/m) in first irrigation, second irrigation 5.8 to 7.6 (dS/m), third irrigation is 7.5 to 11.5 (dS/m), forth irrigation 9.0

to 14.4(dS/m) and fifth irrigation 10.0 to 12.5 (dS/m). The ECiw of farmers tube well water decreased due to dilution of underground water with rain water recharge (Table 6.9).

Table 6.9 EC_{iw} (dS/m) during irrigations at rain water recharge sites (2016-17)

Name of farmer	Initial ECiw (dS/m)	I^{st} irrigation (pre-sowing)	II^{nd} irrigation	III^{rd} irrigation	IVth irrigation	Vth irrigation
Mr. Lal Hans	10.9	4.7	5.9	7.6	9.2	10.1
Mr.RamBhari	15.0	4.5	7.4	9.2	10.9	12.5
Mr.JaganSingh	12.6	5.6	6.4	8.5	10.2	11.3
Mr Mukesh Kum.	13.8	4.8	6.0	7.6	9.1	10.6
Mr.DineshChand	11.0	5.9	5.8	7.5	9.0	-
Mr.BirendraSingh	19.9	4.7	7.6	9.8	12.5	-
Mr.Roop Singh	23.5	5.8	8.7	11.5	14.4	-
Mr.Subhash Chand	10.0	5.7	7.0	8.7	9.6	10.0

In saline and alkali water, the soil salinity decreased at harvest of kharif season crop, pH also decreased in gypsum treated fields over control (no gypsum). At harvest of Rabi season, the EC_e was higher in surface layer (0-30 cm) as compared to the lower depth (60-90 cm). Under saline water irrigation, the soil salinity was increased with increased number and EC of irrigations applied at farmer's fields (Table 6.10).

Table 6.10 Status of soil salinity (dS/m) and pH at harvest of kharif and rabi crops (2016-17)

Name	Soil depth (cm)	Kharif at harvest		Rabi at harvest	
		EC_e (dS/m)	pH_2	EC_e (dS/m)	pH_2
Alkali water					
Mr Harvans kumar (Pearl millet - Wheat)					
Gypsum	0-15	3.5	7.6	8.6	7.7
	15-30	4.1	7.8	7.6	7.8
	30-60	4.6	7.7	6.6	7.7
	60-90	5.8	7.9	5.3	7.7
No gypsum	0-15	3.7	7.5	8.2	7.8
	15-30	4.0	7.9	6.7	7.8
	30-60	5.4	7.9	6.0	7.7
	60-90	6.7	7.8	6.5	7.7
Mr .Om Prakash (Pearl millet-wheat)					
Gypsum	0-15	3.6	7.9	8.6	8.0
	15-30	4.4	8.0	7.8	7.8
	30-60	6.1	7.8	7.6	7.5
	60-90	7.7	8.1	6.9	7.8
No gypsum	0-15	3.8	7.9	8.9	7.9
	15-30	4.9	7.9	8.0	8.1
	30-60	6.0	7.8	7.3	7.7
	60-90	9.3	8.1	6.7	8.0
Mr .Hakim Singh (Pearl millet-wheat)					
Gypsum	0-15	5.6	7.8	9.9	7.9
	15-30	4.4	7.8	7.3	8.0
	30-60	5.4	8.0	6.0	7.7
	60-90	5.8	8.1	5.6	7.6

No gypsum	0-15	4.3	7.6	9.1	7.9
	15-30	5.1	7.9	8.0	7.8
	30-60	5.7	7.7	8.3	7.8
	60-90	7.0	7.8	7.1	7.9
High SAR Saline water					
Mr. Jagan Singh (fellow-wheat)	0-15	4.3	7.3	8.7	7.0
	15-30	3.5	7.2	8.6	7.0
	30-60	3.4	7.1	7.8	7.0
	60-90	3.3	7.1	7.0	7.0
Mr Hari Prasad (fellow-wheat)	0-15	5.7	7.1	8.4	7.2
	15-30	6.0	7.5	7.5	7.2
	30-60	6.3	7.7	6.9	7.2
	60-90	7.0	7.6	6.2	7.1
Mr Mukesh Kumar (Sorghum-wheat)	0-15	2.5	7.1	9.4	7.1
	15-30	2.3	7.2	8.2	7.2
	30-60	5.4	7.2	6.5	7.1
	60-90	5.9	7.2	4.6	7.1
Mr Ram Bharose (fellow-Wheat)	0-15	2.6	7.3	10.3	7.2
	15-30	2.7	7.3	9.3	7.2
	30-60	2.7	7.2	9.3	7.0
	60-90	3.3	7.1	8.4	7.1
Mr Dinesh Chand (Pearl millet-wheat)	0-15	2.4	7.1	6.9	7.1
	15-30	2.6	7.2	6.3	7.1
	30-60	3.4	7.3	6.2	7.1
	60-90	5.1	7.3	6.0	7.3
Mr Lal Hans (Sorghum-wheat)	0-15	3.8	7.2	8.5	7.1
	15-30	4.3	7.3	7.7	7.4
	30-60	4.7	7.2	7.5	7.1
	60-90	6.0	7.3	7.6	7.2
Mr Subhash Chand (Pearlmillet-wheat)	0-15	2.8	7.2	8.6	7.2
	15-30	3.5	7.3	6.8	7.2
	30-60	3.8	7.3	6.0	7.0
	60-90	6.7	7.4	6.0	7.0
Mr. Birendra Singh (Pearl millet-wheat)	0-15	4.8	7.4	10.3	7.1
	15-30	5.8	7.3	8.9	7.2
	30-60	6.9	7.4	8.8	7.1
	60-90	9.7	7.3	8.5	7.2
Mr. Roop Singh (Sorghum-wheat)	0-15	4.3	7.1	11.4	7.1
	15-30	6.8	7.1	10.5	7.2
	30-60	8.7	7.3	9.5	7.1
	60-90	11.2	7.3	8.4	7.1

- **Survey and investigations for planning conjunctive use of Nallamada drain water with Kommamuru canal for augmenting irrigation (Bapatla)**

The Nallamada drain is carrying flood flows ranging from 20-49 TMC every year with the E.C. of water ranging from 0.6-1.7 dS m-1 during the floods. As it flows across the Kommamuru canal, it offers a natural advantage of conjunctive use of Nallamada drain water with Kommamuru canal water during peak flows, storage of flood water by constructing balancing reservoirs, a series checkdams at every 3 km spacing facilitates rejuvenation of existing lift irrigation schemes and groundwater recharge in the region, in addition to controlling the sea water intrusion. The back water flows coming into Nallamada drain are being utilized by the farmers whose quality is not suitable for irrigation (>10 dS m-1), due to which the crops are failing. This can be solved by constructing a free over fall dam well ahead of the estuary point. In addition to these, the other nearby drain like Nakkavagu, Perali drain, Thungabhadra drain can be interlinked with a series of storage or diversion structures so as to utilize them for irrigation. The same has been developed into a Nallamada Modernization Plan for implementation by the scientists of SWS, Bapatla.

- **Effect of Lagoon Sludge/Spent Wash and Lagoon Sludge application on crop production and soil chemical environment on farmers' fields (Indore)**

The demonstrations on the field of Mr. Hariram Malviya (Village Bapalgaon) were conducted during kharif 2016-17 with paddy (CSR-30) as a test crop. One time application of lagoon sludge (LS) and raw spent wash (RSW) was done 30 days prior to transplanting of rice seedlings. Wheat crop was not raised in the same area during rabi season due to ponding of water from canal over flow in the area at the time of field preparation and sowing. The initial ESP, CEC and ECe of the soil were 42.3, 38.0 cmol (p+) /kg & 1.38 dSm-1. Necessary plant protection and inter-culture operations were adopted as per package of practices. The data in Table 6.11 revealed that application of Lagoon Sludge @ 2.5 t ha-1 along with Raw Spent Wash @ 2.5 lakh L ha-1 increased grain and straw yield of paddy by 96 & 127 % over control respectively. Application of Lagoon Sludge @ 5.0 t ha-1 + RSW @ 2.5 lakh L ha-1 decreased the ESP to 29.3 after harvest of wheat as compared to its initial level of 42.3.

Table 6.11 Effect of lagoon sludge and spent wash applications on grain yield (t ha-1) of paddy and wheat on farmer's field

Treatments	Yield (t ha-1)		% increase in yield over control		ESP after harvest of crop
	Grain	Straw	Grain	Straw	
Paddy					
Control	0.94	1.95	-	-	40.6
Lagoon Sludge @ 5 t ha-1 Raw Spent Wash @ 2.5 lakh L ha-1	1.85	4.43	97	127	29.3

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

The purpose of experiment was to to find out the suitable application method of CSR-Bio for vegetable production and to determine the physico-chemical changes in soil. Treatments were T1-Control, T2- CSR-Bio (soil application) and T3- CSR-Bio (soil application + foliar spray).

Sr. No.	Item	Details
1	Crop	Tomato and cabbage
2	Varieties	Azad T-5 and Golden acre
3	No. of treatments	3
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

The maximum survival percentage, fruit/plant, diameter of fruit and yield of tomato was recorded 56.7%, 22.12, 3.24 cm and 117.98 q/ha and minimum in control plot (Table 6.12).The increment of yield was recorded 24.78% more treated with CSR-Bio (soil application + foliar spray) and 19.85% with CSR-Bio (soil application) over control.

Table 6.12 Effect of CSR-Bio on yield and yield attributes of tomato (mean of two year)

Treatments	Survival (%)	Fruit/plant	Diameter of fruit (cm)	Yield (q/ha)	Inc. (%)
Control	45.4	18.75	2.78	94.55	--
CSR-Bio (soil application)	55.2	21.43	3.21	113.32	19.85
CSR-Bio (soil application + foliar spray)	56.7	22.12	3.24	117.98	24.78

Physico chemical properties of soil

The data presented in Table 6.13 indicate that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in both the treatments including control. However, maximum decrease, was observed in CSR-Bio (soil application + foliar spray) treated plot. The organic carbon improved with the application of CSR-Bio treated plots.

Table 6.13 Effect of CSR-Bio on physico chemical properties of experimental soil after two year

Treatments	pH	EC	ESP	OC
Control	8.9	0.91	38.2	0.34
CSR-Bio (soil application)	8.7	0.89	34.5	0.38
CSR-Bio (soil application + foliar spray)	8.7	0.88	33.8	0.40
Initial soil status	9.1	0.96	43.6	0.29

The maximum survival percentage, no of leaves, head weight and yield was recorded 67.5%, 10.45, 0.89 kg and 141.50 q/ha and minimum in control plot (Table 6.14). The increment of yield was recorded 26.06% more treated with CSR-Bio (soil application + foliar spray) and 21.90% with CSR-Bio (soil application) over control.

Table 6.14 Effect of CSR-Bio on yield and yield attributes of cabbage (mean of two year)

Treatments	Survival (%)	No. of leaves	Head wt (kg)	Yield (q/ha)	Inc. (%)
Control	55.0	8.92	0.75	112.25	--
CSR-Bio (soil application)	65.6	9.71	0.86	136.83	21.90
CSR-Bio (soil application + foliar spray)	67.5	10.45	0.89	141.50	26.06

Physico chemical Properties of Soil:

The data presented in Table 6.15 indicate 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 (Plate 6.1 and 6.2). The organic carbon improved with the application of CSR-Bio treated plots.

Table 6.15 Effect of CSR-Bio on physico chemical properties of experimental soil after two year

Treatments	pH	EC	ESP	OC
Control	8.9	0.91	37.9	0.32
CSR-Bio (soil application)	8.8	0.89	33.7	0.37
CSR-Bio (soil application + foliar spray)	8.7	0.89	32.9	0.38
Initial soil status	9.1	0.96	43.6	0.29

Plate 6.1 View of tomato at farmer's field, Vinovanagar

Plate 6.2 View of cabbage at farmer's field, Vinovanagar

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

Two ponds having stored rain water from farmers field i) Shri. Roshan Vinayak Mhatre, from village Koproli and ii) Shri. Chintaman Mahadev Mhatre, from village Koproliare were selected. 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 and salinity (EC) of the soil samples, taken from farmers' fields are presented in Table 1 and 2. The samples were analysed for the soil electrical conductivity and pH by following standard procedure.

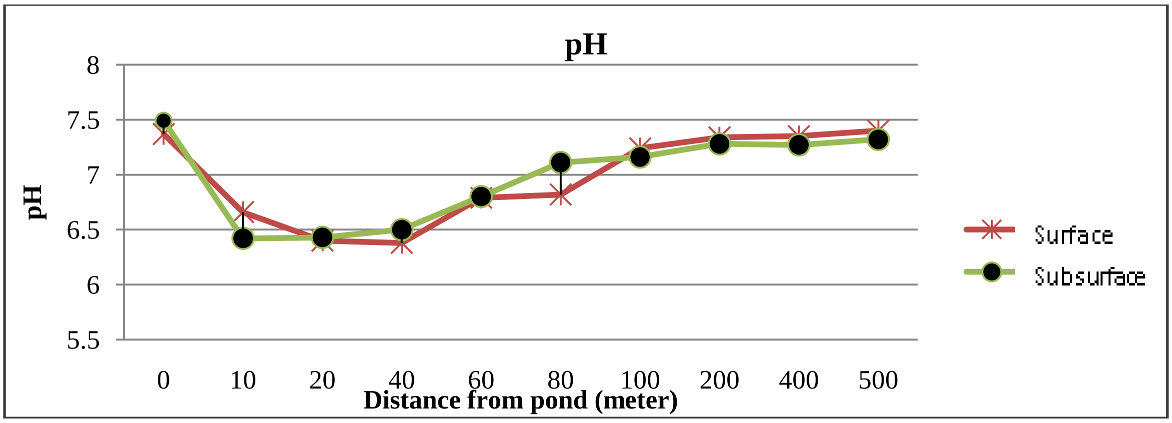
A) Farmer 1: Shri. Roshan Vinayak Mhatre

- **Surface pH and EC (0 to 22.5 cms):** The overall average values of pH and EC for surface soil samples collected from the distance of 0, 10, 20, 30, 40, 60, 80, 100, 200, 400 and 500 meters were 5.06, 4.14, 3.31, 3.21, 3.29, 7.15, 7.88, 11.07, 11.02, 12.83 and 7.37, 6.66, 6.40, 6.38, 6.79, 6.82, 7.24, 7.34, 7.35 d Sm^{-1}, respectively for the October, November, December, January, February, March and April (Fig. 6.1).
- **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 meters were 7.49, 6.42, 6.43, 6.50, 6.80, 7.11, 7.16, 7.28,7.27, 7.32 and 5.19, 4.39, 3.63, 4.04, 4.87, 8.05, 11.25, 11.24, 13.01 d Sm^{-1}, respectively for the October, November, December, January, February, March and April (Fig. 6.1).

B) Farmer 2: Shri. Chintaman Mahadev Mhatre

- **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 meters were 6.67, 7.43, 7.04, 7.35, 6.61, 6.88, 7.78, 7.54, 7.23, 7.25 and 3.60, 3.44, 3.28, 3.83, 1.96, 2.80, 3.16, 2.97, 8.96, 9.79 dSm^{-1}, respectively for the October, November, December, January, February, March and April (Fig. 6.2).
- **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 meters were 6.52, 7.48, 7.09, 7.40, 6.74, 6.87, 7.59, 7.23, 7.29 and 3.79, 3.50, 3.67, 4.30, 2.42, 3.17, 3.28, 3.09, 9.11, 9.90 dSm^{-1}, respectively for the October, November, December, January, February, March and April (Fig. 6.2).

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 meter and maximum at 500 meters. It may be attributed due to dilution and leaching of salts due to percolation of harvested rainwater from fish pond



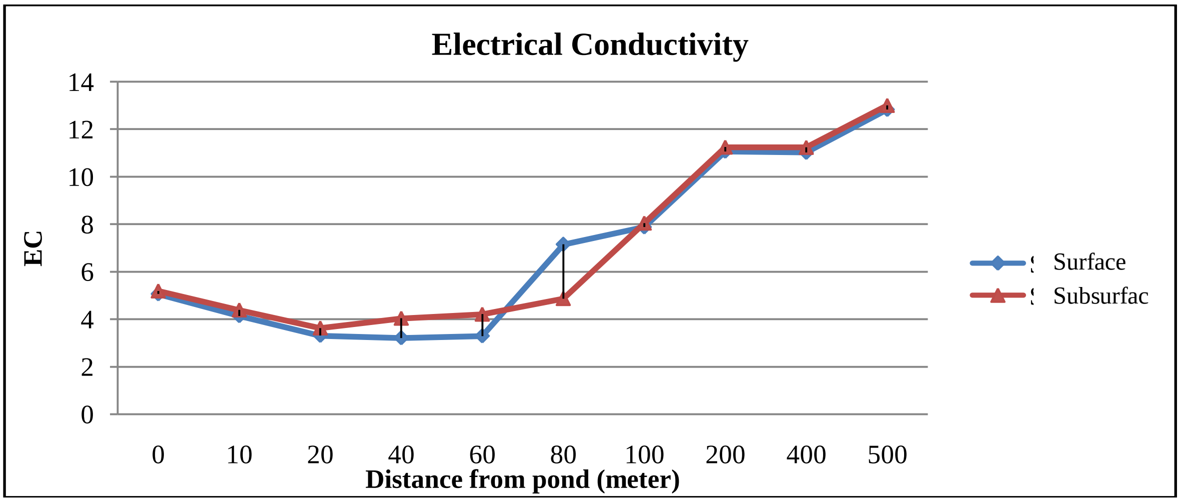
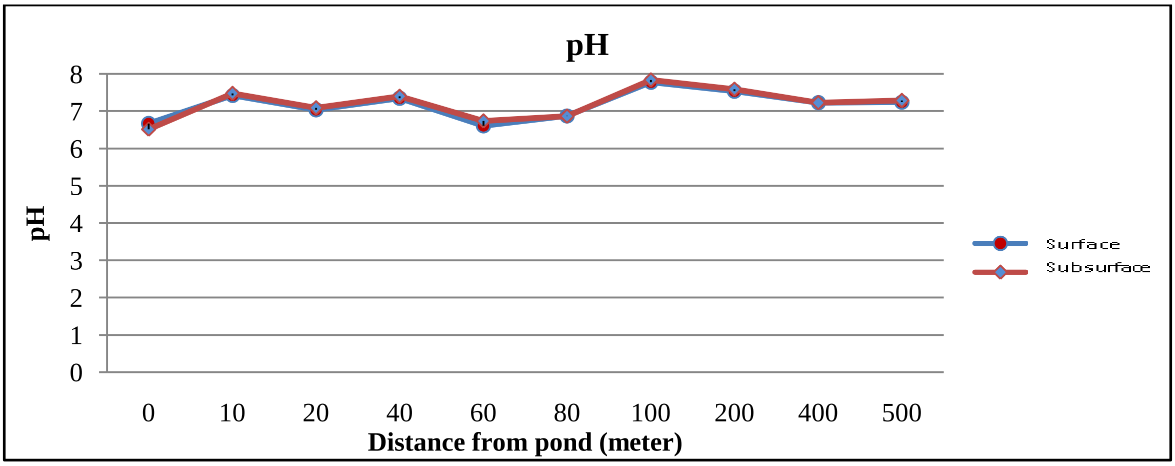


Fig 6.1 Soil pH and EC of the farmers field (Farmer 1)



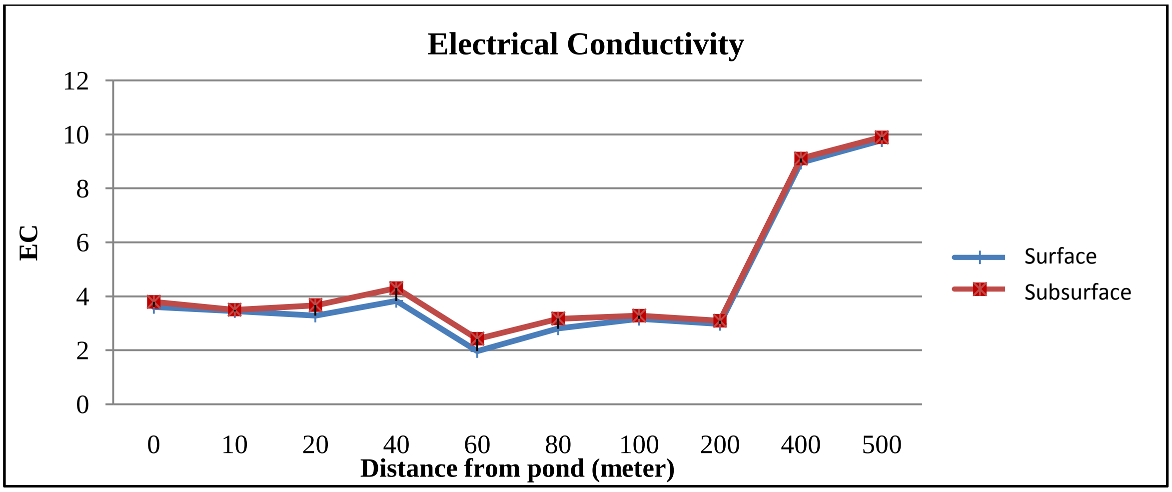


Fig 6.2. pH and EC of the farmers field (Farmer 2)

The 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. This can be priority area of the centre.

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 re designated 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 XI Plan, Project continued with an outlay of Rs. 2125.15 lakh at these centres with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The total outlay of the XII plan is fixed at Rs. 4638.67 lakh including the state share of Rs. 963.67 lakh. The centre wise mandate of the project is as follows:

7.2 MANDATE FOR COOPERATING CENTRES

Main Centre	Mandate
Agra	1. Water quality limits in relation to cropping system 2. Develop strategies for conjunctive use of saline and canal water 3. Improving the nutrient use efficiency in saline environment 4. Improved irrigation techniques and salt water management 5. Rain water management for salinity control 6. Alternate land use through agro-forestry and horticulture 7. Operational research for saline water use
Bapatla	1. Water quality and soil surveys and monitoring of benchmark sites 2. Crop-water production functions with saline water in coastal sands 3. Water quality limits with improved irrigation technologies 4. Improved Dorouv technology 5. Upconing problems of sea water in coastal sandy soils 6. Fertility management of saline coastal sandy soils. 7. Operational research on dorouv technology/saline water use 8. Reclamation of abandoned aqua ponds
Bikaner	1. Water quality surveys 2. Salt and water balance in gypsiferous soils of the IGNP Command 3. Irrigation management for saline water use 4. Drainage for control of salinity and water logging 5. Develop practices for use of nitrate and fluoride rich waters 6. Nutrient management of saline gypsiferous soils
Gangavati	1. Ground water quality surveys 2. Performance evaluation of drainage system in T.B.P. command

	3. Reuse of drainage effluents/conjunctive use 4. Drainage requirement of crops in saline black soils 5. Performance of tree species in saline black soils including bio-drainage 6. Organic materials for improving productivity of saline soils 7. Tolerance of medicinal and aromatic plants to soil salinity 8. Reclamation of rain fed alkali lands
Hisar	1. Ground water quality surveys 2. Conjunctive use of canal and saline ground/drainage waters 3. Water production functions under salt stress conditions 4. Water quality guidelines for sprinklers/drip systems 5. Modelling crop yields under salt stress and strategies for mitigation 6. Management of alkali water for vegetable production
Indore	1. Ground water and soil surveys 2. Management of heavy textured alkali soils 3. Crop-water production functions for alkali black soils 4. Develop parameters for incorporating the effect of Cl/SO_4, Mg/Ca and SAR on sodification and soil permeability 5. Hydrosalinity modelling in Omkeshwar Command 6. Alternate land use of alkali black soils for agro-forestry 7. Tilerance of medicinal and aromatic plants to soil alkali stress 8. Management of wastewaters
Kanpur	1. Water treatment techniques for use of alkali water 2. Conjunctive use of alkali and canal water 3. Performance of tree species in alkali soils 4. Fertility management under conditions of alkali water use 5. Soil/ land/ water resource inventories in Ramganga/Sharda Sahayak Command 6. Resource conservation technologies for alkali soils 7. Salt tolerance studies on crop cultivars
Tiruchirappalli	1. Ground water quality surveys of Tamil Nadu 2. Mitigation strategies for adverse effects of salts on soil and crops 3. Conjunctive use of poor quality ground and canal waters 4. Survey of poor quality ground waters and salt affected soils 5. Alternate land use of salt-affected soils through agro-forestry 6. Multi-enterprise agriculture for higher income 7. Use of Distillery Spent wash for alkali land and water reclamation
Network trials	1. Identification of appropriate cultivars of crops for saline/alkali environments in different agro-ecological regions 2. Water quality/salt affected soil resource inventories/mapping
Coordinating Unit	1. Developing guidelines on use of saline water 2. Use of saline water in agro-forestry 3. Modeling salt and water transport and crop response in saline environment 4. Generating chemical/physical parameters for computers models 5. Management of domestic and industrial wastewaters 6. Bio-drainage and wastewater disposal strategies 7. Management of adhoc projects approved by the council
Volunteer Centre	**Mandate**
Bathinda	1. Monitoring of ground water quality for irrigation purpose 2. Exploring land-water management options for crop cultivation in water logged salt affected areas
Panvel	1. Assessment of soil properties of coastal region

	2. Development of IFS model 3. Assessment of ground water qualities 4. Suitability of saline water for irrigation
Port Blair	1. Assessment of ground water quality and soil salinity status of A& N Islands 2. Isolation and characterization of microbes to enhance crop performance under saline environment 3. Evaluation of alternate land management options
Vyttila	1. Survey, characterization and mapping of ground water quality in the coastal areas of Kerala 2. Delineation and mapping of salt affected soils in the coastal areas of Kerala 3. Integrated farming system for sustainable land use in Pokkali lands

7.3 STAFF POSITION (2016-17)

STAFF POSITION AT THE COOPERATING CENTRES

XI plan	Agra	Bapatla	Bikaner	Gangavathi	Hisar	Indore	Kanpur	Trichy	Total
Scientific	4	6	5	5	4	5	4	4	37
Technical	6	6	5	5	4	6	6	4	42
Administrative	1	1	1	1	1	1	1	1	08
Supporting	2	2	2	2	2	2	2	2	16
Total	**13**	**15**	**13**	**13**	**11**	**14**	**13**	**11**	**103**

POST WISE STAFF POSITION AS ON 31.03.2017

Name of the post	Coordinating Unit, Karnal	Centres							
		Indore	Kanpur	Bikaner	Agra	Bapatla	Gangavati	Trichy	Hisar
Project Coordinator	1	–	–	–	–	–	–	–	–
Soil Scientist	1	–	–	1	–	2	2(1)	–	–
Soil Chemist	-	1	1	1(1)	1(1)	–	–	1	1
Agronomist	1	–	–	–	–	–	–	–	–
Drainage Engineer	–	1	–	–	–	–	–	–	–
Soil Physicist	1(1)	–	1	–	–	–	–	–	–
Jr. Soil Chemist	1(1)	1(1)	–	1(1)	1(1)	1	–	1	1
Jr. Soil Physicist	–	1(1)	–	–	1	–	–	–	–
Jr. Drainage Eng.	–	–	–	1	–	1 (1)	1	–	–
Soil Water Eng.	–	–	–	–	–	1	1	1	1
Jr. Plant Physio.	–	–	1	–	–	–	–	–	–
Jr. Agronomist	-	–	–	1	1	1	1	1	1
Jr. Soil Survey	–	1	1	–	–	–	–	–	–
Tech. Officer	2(1)	–	–	–	–	–	–	–	–
STA	–	2(1)	1	2	2	1	1	2	2(2)
Overseer	–	–	1(1)	–	–	–	–	–	–
Lab. Tech.	1	–	–	–	–	–	–	–	–
Tracer	--	–	–	–	–	–	–	–	–
Field Asstt.	–	1	1	1	2(1)	1	2	1	1
Fieldman	–	1	1	–	–	1	–	–	–
Lab. Asstt.	1(1)	1	1	1	1	2	1	1	1
UDC	1(1)	1	1	1	1	1	1	1	1(1)
Jr. Steno.	1(1)	–	–	–	–	–	–	–	–
Jeep Driver	–	1	1	1(1)	1	1(1)	1	–	–
Lab. Attendant	3(2)	1	1	1(1)	1	1	1	1 (1)	1
Messenger	-	1(1)	1	1	1(1)	1	1	1	1(1)

( ) Vacant position

STAFF POSITION AS ON 31. 03. 2017

Coordinating Unit, CSSRI Karnal

Sr. No.	Position Sanctioned	No.	Name of Incumbent	Period	
				From	To
1.	Project Coordinator	1	Dr. M. J. Kaledjonkar	28.03.2016	Contd.
2.	Sr. Agronomist	1	Dr. R. L. Meena	18.07.2007	Contd.
3.	Soil Scientist	1	Dr. B. L. Meena	30.01.2013	Contd.
4.	Environmental Scientist	1	Dr. R. K. Fagodiya	13.16.2016	Contd.
5.	Technical Officer	2	Vacant	01.02.2014	
			Sh. Anil Sharma	12.10.2011	Contd.
6.	Technical Assistant	1	Vacant	23.03.2016	
7.	Sr. Technician	1	Sh. Mohinder Singh	03.07.2014	Contd.
8.	Personal Assistant	1	Vacant	-	-
9.	Lab. Attendant	1	Sh. Raj Kumar	17.09.2013	Contd

Cooperating Centres

AGRA

Sr. No.	Name of the post	No.	Name of incumbent	Periods	
				From	To
1	Soil Chemist	1	Vacant-Charge taken over by Dr RB Singh)	01.01.2012	Contd…
2	Jr. Soil Physicist	1	Dr. RB Singh	30.11.1987	Contd…
3	Jr. Agronomist	1	Dr SK Chauhan	15.03.1996	Contd…
4	Jr. Soil Chemist	1	Vacant	-	-
5	S.T.A. (Soils)	2	Dr RS Chauhan	01.08.1991	Contd…
6			DR PK Shishodia	11.07.1994	Contd…
7	U.D.C	1	Mr. Rajeev Chauhan	04.09.1991	Contd…
8	Field Assistants	2	Mr NP Pachauri is working against the field Assistant		
			Vacant	-	-
9	Lab Assistants	1	Mr. Sarnam Singh	18.12.1989	Contd…
10	Jeep Driver	1	Mr Ram Sewak working against the Jeep driver post		
11	Lab Attended	1	Mr. Devi Singh working against Lab Attendant		
12	Messenger	1	Vacant	-	-

BAPATLA

Sr. No.	Name of the post	No.	Name of incumbent	Periods	
				From	From
1.	Principal Scientist (SS) & Head	1	Dr. D. Balaguravaiah	04-01-2016	25-04-2016
			Dr. P. Prasuna Ran	22-06-2016	29-08-2017
2	Senior Scientist (SS)	1	Dr. P. Mohana Rao*	10-02-2016	Contd…
3	Scientist (SS)	1	Dr. Y. Sudha Rani	21-02-2014	Contd…
4	Scientist (SWE-1)	1	Sri A. Sambaiah	06-02-2013	Contd…
5	Scientist (Agronomy)	1	Mrs. K. Anny Mrudhula	10-12-2013	Contd…
6	Sr. Assistant	1	Sri D. Bullaiah	02-09-2013	Contd…
7	Lab Assistant	2	Sri S. Baba Vali	04-09-1990	Contd…

			Vacant		
8	Field Assistant	2	Sri M Venkata Rao	02-01-2012	Contd…
			Sri Y. Kiran Kumar	25-04-2015	Contd…
9	UDC	1	Sri. S K Mastan Vali	01-03-2011	Contd…
10	Lab Attendant	1	Sri D.V.Siva Rao	16-07-1992	Contd…
11	Driver	1	Vacant	-	-
12	Messenger	1	Sri A. Babu Rao	16-11-2016	Contd…

BIKANER

Sr. No.	Position Sanctioned	No.	Name of Incumbent	Period	
				From	To
1.	Chief Scientist & O/I	1	Dr. I.J. Gulati	24.07.12	Contd.
2.	Soil Chemist	1	Vacant	-	30.04.09
3.	Jr. Soil Chemist)	1	Vacant	-	30.07.14
4.	Jr. Agronomist	1	Dr. N.S.Yadava	08.07.11	Contd.
5.	Jr. Drainage Engg.	1	Er. A. K. Singh	10.09.01	Contd.
6.	Technical Assistant	2	Dr. Deepak Gupta	04.08.10	Contd.
			Sh. R.L. Sharma	23.07.14	Contd.
7.	Ag. Supervisor	1	Mr. G. S. Pareek	01.06.13	Contd.
8.	Lab. Assistant	1	Mr. S.K. Bazad	14.02.94	Contd.
9.	L.D.C.	1	Mr. Manohar Singh	02.04.11	Contd.
10.	Driver	1	Vacant	01.06.13	-
11.	Lab. Attendant	1	Vacant	30.09.14	-
12.	Messanger	1	Mr. Ganesh Ram	25.03.94	Contd.

GANGAVATI

Sr. No.	Position Sanctioned	No.	Name of Incumbent	Period	
				From	To
1.	Principal Scientist and OIC	1	Dr. Vishwanath J.	04.01.12	Contd.
2.	Scientist (Drainage Engg.)	1	Er. A.V. Karegoudar	12.12.09	Contd.
3.	Scientist (SWE)	1	Er. Rajkumar R. H.	27.05.11	Contd.
4.	Scientist (Soil Science)	1	Vacant	-	-
5.	Scientist (Agronomy)	1	Dr. Anand S.R.	07.11.12	Contd.
6.	Lab Assistant	1	Mr. Prakash Banakar	21.04.11	Contd.
7.	Field Assistant	2	Mr. Ramappa Talwar	09.07.12	Contd.
			Mr. P. Balasaheb	19.11.01	Contd.
8.	Sr. Field Assistant	1	Mr. K. Veeranna	02.04.98	Contd.
9.	U.D.C.	1	Smt. Renuka R.B.	21.12.09	Contd.
10.	Driver	1	Mr. B. D. Golasangi	13.08.10	31.07.16
			Mr. Doddahussain sab	01.08.16	Contd.
11.	Lab Attendant	1	Mr. Veeresh S. Akki	06.06.15	15.07.16
			Mr. G.S. Manjunath	16.07.16	Contd.
12.	Messenger	1	Doddabaappa S	01.02.92	27.11.16
			Mr.Sameer Hejib	28.11.16	Contd.

HISAR

Sr. No.	Position Sanctioned	No.	Name of Incumbent	Period	
				From	To
1.	Agronomist & OIC	1	Dr. Satyavan-taken charge of OIC on 01.02.2016 by	11.03.1997	Contd.
2.	Soil Scientist	1	vacant	01.02.2016	
3.	Soil Scientist	1	Dr. Ram Prakash	24.05.2011	Contd.
4.	Asstt. Soil water Engg.	1	Er. Krishan Kumar	18.05.2013	29.09.2016
5.	Field assistant	1	Sh. Jagdish Chander	03.02.2001	06.02.2017
			Sh. Umed Singh	07.02.2017	Contd.
6.	Lab. Assistant	1	Mr. Dhan Singh	02.03.2009	28.02.2017
7.	LDC	Vacant	-	12.09.2013	
8.	Lab Attendant	1	Sh. Surat Singh	25.05.2010	Contd.
9.	Messenger	Vacant	-	01.05.2012	

INDORE

Sr. No.	Position Sanctioned	No.	Name of Incumbent	Period	
				From	To
1	Soil Chemist & OIC	1	Dr. U. R. Khandkar	02.09.2008	Contd.
2	Drainage Engineer	1	Er. R. K. Sharma	09.05.2000	Contd.
3	Jr. Soil Survey Officer	1	Sh. B. B. Parmar	02.09.2009	Contd.
4	Jr. Soil Physicist	1	Dr. (Mrs) S.P.K.Unni	15.09.2003	28.02.2017
			Vacant	01.03.2017	-
5	Jr. Soil Chemist	1	Vacant	-	
6	Technical Assistant	2	Dr. S.C.Tiwari	04.03.1989	Contd.
			Vacant	-	-
7	U.D.C.	1	Sh. Anil Vijayvargiya	01.10.2014	Contd.
8	Lab. Technician	1	Ms. R. Ansari	16.11.1995	Contd.
9	Field Asstt.	1	Sh. N.S.Tomar	04.04.1996	Contd.
10	Field man cum Tractor Driver	1	Sh. S. R.Hirve	25.08.2003	Contd.
11	Jeep Driver	1	Jageshwar Vishkarma	27.03.2017	Contd.
12	Lab. Attendant	1	Sh. D. S. Baghel	01.04.2011	Contd.
13	Messenger	1	Vacant	28.08.2003	-

KANPUR

Sr. No.	Position Sanctioned	No.	Name of Incumbent	Period	
				From	To
1.	Soil Chemist & OIC	1	Dr Ravindra Kumar	09.05.2008	Contd.
2.	Soil Physicist	1	Dr Devendra Singh	01.07.2014	Contd.
3.	Asstt. Agronomist	1	Sri S.N.Pandey	01.07.2009	Contd.
4.	Asstt. Soil Survey Officer	1	Sri Vinod Kumar	29.12.2011	Contd.
5.	Sr. Technical Asstt.	1	Sri G.S.Tripathi	01.08.2004	Contd.
6.	Field Asstt.	1	Sri Ved Prakash	16.08.2014	Contd.
7.	Field Asstt.	1	Sri Vinay Kumar	03.07.2014	Contd.
8.	Lab. Assistant	1	Sri P.S. Katiyar	01.08.2004	Contd.
9.	U.D.C.	1	Sri Neeraj Kumar	10.05.2016	Contd.
10.	Driver	1	Sri Madan Mohan	01.01.2016	Contd.

11.	Lab. Attendant	1	Sri Gaya Prasad	01.05.1988	Contd.
12.	Messenger	1	Sri Ram Moorat	01.01.2010	Contd.

TIRUCHIRAPPALLI

Sr. No.	Position Sanctioned	No.	Name of Incumbent	Period	
				From	To
1.	Soil Chemist & OIC	1	Dr. P. Balasubramaniam	02.03.2016	Contd.
2.	Jr. Soil Chemist	1	Dr. M. Baskar	09.05.2008	Contd.
3.	Jr. Agronomist	1	Dr. A.Alagesan	07.04.2015	Contd.
4.	Jr. Soil Water Engineer	1	Dr. M. Selvamurugan	08.04.2015	Contd.
5.	Sr. Technical Asst.	2	Mr. K. Karikalan	09.06.2014	Contd.
			Mr. R. Mutharasan	09.06.2011	Contd.
6.	Field Asst	1	Mr. U. Jossephraj	01.04.2011	Contd.
7.	U.D.C.	1	Mr.Muhammod Ali	01.03.2016	Contd.
8.	Lab. Assistant	1	Mr. A Palanivel	06.05.2013	31.05.2016
			Mr. P. Sakthivel	01.07.2016	Contd.
9.	Messenger	1	Mr. V. Palaniyandi	01.04.1995	Contd.

Volunteer Centres

BATHINDA

Sr. No.	Name of the post	Number	Name of incumbent	Periods	
				From	To
1.	Soil Chemist & Nodal officer	1	Dr. Brijesh K. Yadav	16.05.2014	Contd.
2.	Assist. Agril. Engg.	1	Dr. Sudhir Thaman	16.05.2014	Contd.
3.	SRF	1	Deepak Kumar	07.08.2015	31.03.2017

PANVEL

Sr. No.	Name of the post	Number	Name of incumbent	Periods	
				From	To
1.	Soil Scientist & Nodal Officer	1	Dr. K. D. Patil	05.05.2014	30.05.2017
2.	SRF	1	Miss. S. S. Khobragade	22.08.2016	31.03.2017

PORT BLAIR

Sr. No.	Name of the post	Number	Name of incumbent	Periods	
				From	To
1.	Soil Scientist & Nodal Officer		Dr. A Velmurugan	-	-
2.	SRF	1	Dr. Waseem Iqbal	-	-

VYTTILA

Sr. No.	Name of the post	Number	Name of incumbent	Periods	
				From	To
1.	Soil Scientist & Nodal Officer	1	Dr. Sreelatha, A. K.	3.07.2014	Contd.
2.	SRF	1	Manju Roshni K	12.05.2015	31.03.2017
3.	SRF		Anila T. Sasi	01.08.2016	31.03.2017

7.4 WEATHER DATA (2016-17)

Main Centre

AGRA

Latitude - 27020' N Longitude - 77090' E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	22.8	40.1	51.3	-	5.3
May	26.6	41.5	67.6	40.0	7.3
June	28.8	40.3	78.0	62.9	7.6
July	27.5	37.1	67.2	634.9	6.2
August	26.3	32.8	93.8	175.3	6.0
September	25.4	34.7	87.6	27.8	5.7
October	19.6	34.5	90.6	7.0	5.4
November	11.5	29.5	86.6	-	5.6
December	8.9	23.5	87.1	-	5.6
January 2017	7.6	21.0	94.9	26.5	5.3
February	10.3	26.7	84.9	-	5.4
March	14.9	31.6	71.7	21.8	6.1

BAPATLA

Latitude - 15° 54' N Longitude - 80° 28' E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	-	-	-	-	-
May	-	-	-	-	-
June	-	-	-	-	-
July	-	-	-	-	-
August	-	-	-	-	-
September	-	-	-	-	-
October	-	-	-	-	-
November	-	-	-	-	-
December	-	-	-	-	-
January 2017	-	-	-	-	-
February	-	-	-	-	-
March	-	-	-	-	-

BIKANER

Latitude – 28° 01’ N   Longitude – 73° 35’ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	38.9	28.4	62.6	107.8	9
May	34.8	26	74.5	152.3	6.2
June	38	24.4	57.7	4.4	9.8
July	36.2	20.5	53.9	28.4	9.2
August	32	12	51.75	0	5.5
September	29.1	9	58.6	0	3.4
October	20.7	6.4	71.4	2.2	2.1
November	28.3	9.3	49.5	0	5
December	33.7	15.6	21	0.8	7.2
January 2017	40.6	22.9	43.4	18.8	11.7
February	42.9	26.8	40.95	19.2	11.9
March	39.8	27.5	54.1	123	9.3

GANGAVATHI

Latitude – 15° 00’N   Longitude – 76° 00’ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	40.41	26.03	28.9	0	-
May	37.84	26.06	40.7	46.2	-
June	32.33	23.53	56.6	134.9	-
July	30.41	23.32	61.0	68.3	-
August	30.74	22.96	59.2	48	-
September	29.53	22.53	65.6	72.4	-
October	31.97	20.16	46.1	1	-
November	31.13	15.79	42.5	0	-
December	30.61	15	40.8	2.3	-
January 2017	31.22	14.77	36.6	0	-
February	37.95	14.84	26.2	0	-
March	37.09	20.09	23.1	6.3	-

HISAR

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

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	37.9	18.4	43.0	0	6.8
May	41	24.8	49.0	44.3	9.1
June	39.6	27.6	57.5	91.1	7.2
July	35.1	26.1	81.0	244.8	4.8
August	34	25.6	79.5	80.4	4.2
September	35.2	24.2	70.0	2.8	4.8
October	34.6	18.4	63.0	12	3.9
November	29.4	11.1	70.0	0	1.9
December	25.9	7.8	73.0	0	1.5
January 2017	18.6	6.9	85.0	41.2	1.1
February	24.3	7.8	69.0	0	2.1
March	29	11.3	64.0	0	3.6

INDORE

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

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	-	-	-	0.0	13.2
May	-	-	-	0.0	16.9
June	-	-	-	51.5	12.5
July	-	-	-	236.2	4.8
August	-	-	-	167.3	3.0
September	-	-	-	134.5	3.9
October	-	-	-	37.6	3.6
November	-	-	-	0.0	3.0
December	-	-	-	0.0	2.9
January 2017	-	-	-	0.0	3.2
February	-	-	-	0.0	4.9
March	-	-	-	0.0	9.4

KANPUR

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

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	22.2	40	45.5	0	4.6
May	25.5	39	52.5	49.6	7
June	27.3	37.8	65.5	113.4	6.9
July	25.7	32.2	84.5	309.3	4.2
August	25.9	32.7	80.0	137.1	3.6
September	25.2	33.1	78.5	23.6	4.3
October	19.3	33.7	64.0	34	3.9
November	12.6	29.3	63.5	0	2.8
December	9.3	22.5	78.5	0	1.5
January 2017	8.1	21.1	71.0	28.2	1.2
February	10.5	25.8	68.0	0	2.1
March	14.8	31.4	60.0	0.6	3.2

TIRUCHIRAPPALLI

Latitude – 29° 43' N Longitude – 76° 58' E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
June 2016	36.6	26.5	61.1	30.7	8.2
July	36.1	26.3	66.6	162.2	7.8
August	36.7	26.5	56.3	16.8	8.8
September	36.7	25.9	56.5	61.2	7.2
October	36	25.3	60.5	66.8	6.1
November	33	23.5	66.8	0	5
December	31.7	21.6	70.2	65.6	4.1
January 2017	25.7	17.3	52.0	18.8	3.5
February	31.7	20.6	62.7	0	6.1
March	36.7	24.3	63.7	41.4	7.2
April	40.5	27.1	53.4	0	8.7
May	39	27.8	55.6	92.4	8.7

Coordinating Unit

KARNAL

Latitude – 29° 43′ N Longitude – 76° 58′ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	37.6	18.6	34.5	0	6.1
May	38.4	23.6	46.5	48.6	8.7
June	37.7	26.6	59.5	42.4	7.8
July	33.3	26.4	80	185	4.6
August	32.4	25.4	82.5	283.7	3.3
September	33.2	24.1	76	21.6	3.4
October	33.1	17.8	65	0	2.9
November	28.7	11.1	62	0	2.6
December	22	8.3	77.5	0	1.2
January 2017	19.1	6.8	81.5	85.8	0.9
February	23.1	8.4	71.5	0	2
March	28	11.6	61.5	7.8	2.9

Volunteer Centre

BATHINDA

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

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	37.3	19.5	51.4	0	5.6
May	40.9	25.1	45.7	34.6	6.6
June	40.3	27.9	57.4	33.5	8.2
July	35.2	27.3	73.5	128.6	6.2
August	33.6	26	78.3	361.7	4.9
September	34.5	24.1	73.4	0	3.2
October	34.2	18.3	61.5	0	2.1
November	28.5	10.8	63.3	0	2.2
December	23.1	7.8	73.6	0	2.3
January 2017	18.5	6.4	32.1	9.5	2.2
February	24.1	7.8	25.4	0	2.7
March	28.9	11.8	24.1	0	3.5

PANVEL

Latitude – 18° 59′ N Longitude – 73° 06′ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	40.0	22.0	84.0	0.0	1.6
May	38.6	24.2	86.0	0.0	1.9
June	35.6	22.5	90.0	440.8	1.2
July	30.2	22.8	94.0	1160.6	0.8
August	30.8	22.7	94.0	718.8	0.9
September	31.2	22.3	91.0	630.6	0.8
October	35.0	17.8	86.0	57.4	1.0
November	37.0	15.3	78.8	0.0	1.0
December	36.5	13.3	79.0	0.0	1.4
January 2017	36.0	12.2	79.0	0.0	0.9
February	31.1	14.8	80.0	0.0	1.2
March	42.0	17.2	76.0	0.0	2.2

PORT BLAIR

Latitude – 11° 36′ N　　　　Longitude – 92° 42′ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	33.4	25.6	44	7	-
May	33.3	26.5	73	271	-
June	30	25	87	495.9	-
July	30.6	25.2	86	425.3	-
August	31	25.2	84	325.3	-
September	29.5	24.0	89	956.1	-
October	31.0	24.3	82	358.8	-
November	31.0	25.1	78	167	-
December	29.3	24.1	78	444.7	-
January 2017	27.2	21.3	70	94.7	-
February	30.7	24.2	68	0.6	-
March	31.9	24.1	65	6.8	-

VYTTILLA

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

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Average		
April 2016	-	-	-	-	-
May	-	-	-	-	-
June	30.8	23.6	-	431.0	-
July	31.4	24.6	-	544.7	-
August	31.2	24.3	-	178.8	-
September	30.5	24.3	-	30.5	-
October	32.3	22.4	-	131.6	-
November	-	-	-	115.1	-
December	-	-	-	19.5	-
January 2017	34.0	21.3	-	16.8	-
February	34.8	21.3	-	0	-
March	34.4	24.3	-	97.9	-

7.5 List of publication

AGRA

Research papers

Chauhan S.K. (2016). Effect of alkali and canal waters in cyclic and blended mode on potato (*Solanum tuberosum L.*)- Sunflower (*Helianthus annuus L.*)- Sesbania (*Sesbania sesban*) cropping sequence. Accepted for publication Indian Journal of Agronomy, IARI, New Delhi.

Chauhan, S.K. (2016). Effect of saline water irrigation in fennel (f*oeniculum valgare mell.)* growing in semi-arid condition. Under publication TECHNOFAME-A journal of Multidisciplinary Advance Research. December issue.

Chauhan, S.K. (2016). Effect of spacing and salinity of irrigation water on growth and flower yield of marigold in semi-arid condition. Ann. Agric. Res. New Series Vol. 37 (4) 1-4.

Dharmendra Singh, Chandan Kumar Singh, Shanti Kumari, Ram Sewak Singh Tomar, Sourabh Karwa, Rajendra Singh, Raja Bahadur Singh, Susheel Kumar Sarkar, Madan Pal (2017). Discerning morpho-anatomical, physiological and molecular multiformity in cultivated and wild genotypes of lentil with reconciliation to salinity stress. PLOS ONE 12(5): e0177465.https://doi.org/10.1371/journal.pone.0177465.

Singh S B and Chauhan S K (2016). Effect of integrated nutrient management in pearl millet crop grown in semi-arid condition. Under publication TECHNOFAME-A journal of Multidisciplinary Advance Research. December issue.

Singh S B and Chauhan S K (2016). Effect of Integrated Nutrient Management on barley (*Hordeum vulgare L.*) under semi-arid conditions of Western Uttar Pradesh. TECHNOFAME-A Journal of Multidisciplinary Advance Research Vol. 5 (1): 20-23.

Seminar/Symposia Papers

Shroti, S. K. and Chauhan S. K. (2016). Integrated Nutrient Management in Sunflower crop (*Helianthus annus*). National Seminar on Waste Management and its control Measures, held at Deptt of Botany R.B.S. College, Agra, 27-28 Februry,2016.

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R. Kumar, S.N. Pandey and D. Singh (2017) Participated in National conference on organic farming for sustainable agriculture and livelihood security under changing climatic conditions organized by C. S. Azad University of Agriculture and Technology, Kanpur during December 12-13.

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Mahendran, P. P., R. Velmurugan and P. Balasubramaniam. 2016. Identifying critical limit in soil and plant for determining response of groundnut to boron application in Madurai soils of Tamil Nadu, India, Journal of Plant Nutrition. Vol.39:2,163-171, DOI.10.1080/01.904167.2015.1086793.

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KARNAL

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Meena B.L., Kumar P., Kumar A., Meena R.L. and Kaledhonkar M.J. 2016.Effect of Rate and Methods of Zinc and Iron Application on Mustard in Salt Affected Soil. In: *81st Annual Convention: 2016 conducted by Indian Society of Soil Science* held at RVSKV, Gwalior during 20-23 October, 2016.

Meena B.L., Meena R.L., Velmurugan A. and Sharma D.K. 2016. Study Impact Assessment of Broad Bed and Furrow System in Tsunami Affected Water Logged Saline Areas for Agrobiodiversity in Island Agro-Ecosystem of India: A Case *In: 1st International Agrobiodiversity Congress* conducted by Indian Council of Agricultural Research at New Delhi, India during November 6-9, 2016.

Meena B.L., Pandey C.B., Zamir Ahmed S.K., Dam Roy S., Meena R.L. and Kaledhonkar M.J. 2016. Nitrogen Management through *Gliricidia* in Its Alley Cropping System. In: *81st Annual Convention: 2016 conducted by Indian Society of Soil Science* held at Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya, Gwalior during 20-23 October, 2016.

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RL Meena, Anil R Chinchmalatpure, SK Ambast, MJ Kaledhonkar and BL Meena (2016). Mitigating adverse impact of saline water irrigation on fennel (*Foeniculum vulgare Mill.*) seed spice through organic inputs in semi-arid conditions. Poster presented in 4th International Agronomy Congress held at IARI, New Delhi during 22 – 26 November 2016.

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Dotaniya M.L., Rajendiran S., Meena B.P., Meena A.L., Dotaniya C.K., Meena B.L., Jat R.L., and Saha J. K. 2016. Elevated Carbon Dioxide (CO_2) and Temperature *vis-a-vis* Carbon Sequestration Potential of Global Terrestrial Ecosystem Conservation Agriculture. *In:* Conservation Agriculture (Eds. J.K. Bisht *et al.*), pp.225-256.

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Yadav B K, Sidhu A S and Thaman Sudhir (2016). Soil fertility status of Punjab Agricultural University seed farm, Chak Ruldu Singh Wala, Sangat, Bathinda, Punjab.Annals of Plant and Soil Research 18 (3):226.231.

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Sekhon K S, Kaur Anureet, Thaman S, Sidhu A S, Garg N and Choudhary O P (2016). Influence of irrigation water quality and mulching on fruit yield and soil properties in okra. Research paper presented and abstract published in the proceedings of 81st Annual Convention of Indian Society of Soil Science held at RVSKVV, Gwalior from October 20-23, 2016.

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irrigation?" Research paper presented (oral) in the 5th National Seminar of Indian Society of Soil Salinity and Water Quality on "Climate Resilient Saline Agriculture: Sustaining Livelihood Security" held at SKRAU, Bikaner from January 21-23, 2017.

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Yadav B K, Thaman, Sudhir (2017). Participated in the XXV biennial workshop of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture held at SKRAU, Bikaner, Rajasthan during January 19-20, 2017.

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Yadav, B K and Singh, P (2016). MittiParakh Lai Namunaylan de wakh- wakh Tarikay. March/ 2016/ 4 pages. (In Punjabi).

PANVEL

Research paper

D. K. Borse, K. D. Patil, L. S. Chavan, S. A. Chavan and U. V. Mahadkar (2016) "Performance of different Rice varieties along with various nutrient levels under direct seeded method of cultivation on coastal saline soil condition of north konkan" (Paper published in Journal of Indian Society of Coastal Agricultural Research during July 2016)

Seinar paper/abstract

J. J. Palkar, K. D. Patil, S. S. Khobragade and M. J. Kaledhonkar (2017). Monitoring Ground Water Quality for Irrigation in Coastal Districts of Konkan region (Abstract published at 5th National Seminar- Climate Resilient Saline Agriculture: Sustaining Livelihood Security, 2017 held at Bikaner).

J. J. Palkar, K. D. Patil, S. S. Khobragade and P. R. Parte (2016) "Studies on Quality of Irrigation Water from Sea or Creek Side to Land Side in Coastal Region of Konkan" (Abstract published in State Level Seminar Dr. BSKKV, Dapoli, 22 September 2016)

J. J. Palkar, K. D. Patil, S. S. Khobragade, P. B. Vanve and M. J. Kaledhonkar (2016). Quality of Irrigation Water in Coastal Districts of Konkan Region of Maharashtra. Jornal of Soil Salinity and Water Quality., 8(2): 221-223. (Full lenght research paper published in journal at 5th National Seminar- Climate Resilient Saline Agriculture: Sustaining Livelihood Security, 2017 held at Bikaner).

K. D. Patil, J. J. Palkar, S. S. Khobragade and M. J. Kaledhonkar (2017) Exploring Land and Water Management Options for Farming in low-lying areas in Coastal Region of Maharashtra.

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S. S. Khobragade., K. D. Patil, J. J. Palkar and M. J. Kaledhonkar (2017). Studies on Soil Properties from Sea or Creek Side to Land Side in Coastal Districts of Konkan during pre-monsoon Season. (Abstract published at 5th National Seminar- Climate Resilient Saline Agriculture: Sustaining Livelihood Security, 2017 held at Bikaner).

Book/Technical Bulletins

S. S. Khobragade, K. D. Patil, J. J. Palkar, and P. R. Parte (2016) "Principles of Manures, Fertilizers and Agro-Chemicals" book (September 2016)

Dr. K. D. Patil, (Extn.) (2016) "Micronutrient Research in Konkan Region" Technical Bulletin (September 2016)

PORT BLAIR

Book chapter

Velmurugan, A., Ambast, S.K., Swarnam, T.P., Burman, D., Subhasis Mandal,and Subramani, T. (2018). Land shaping methods for climate change adaptation in coastal and island region. In: Biodiversity and climate change in tropical islands. Sivaperuman et al., (Eds.). Elsevier Publishers.

Folder

Bioconsortia for enhancing crop productivity in the coastal areas (Folder)

Land shaping methods for agricultural diversification in waterlogged and saline areas (Folder)

VYTTILA

Seminars/Symposium paper

Aditya Mohan and Sreelatha A. K. 2016 Nutrient Dynamics in Pokkali Soils. International Journal of Applied and Pure Science and Agriculture. 2(9):119-123

Aditya Mohan and Sreelatha A.K. 2016. Microbial Biomass Carbon and Dehydrogenase activity in Pokkali Soils, Proceedings of 26th Swadeshi Science Congress, (7-9 November2016) Kochi.

Anila T. Sasi, Sreelatha, A. K, Manju Roshni, K. and Arya Lekshmi, V.2017.Survey, characterization and mapping of ground water quality in coastal areas of Alappuzha, Ernakulam and Thrissur districts of Kerala Proceedings of National Seminar on Biodiversity Conservation and farming systems Wetland ecology (22-23 Feb 2017)

M. Roshni K., Sreelatha A. K., A. Lekshmi V. and A. T. Sasi.2017. Vegetable cultivation in bunds for sustainable land use in Pokkali lands. Proceedings of National Seminar on Biodiversity Conservation and farming systems Wetland ecology (22-23 Feb 2017)

Manju Roshni, K, SreelathaA. K., Arya Lekshmi, V. and Anila T. Sasi. 2016. Evaluation of Soil Properties before and after rice cultivation in Pokkali lands, Proceedings of 26th Swadeshi Science Congress, (7-9 November2016), Kochi.

Sreelatha, A. K and Shylaraj, K. S 2017. Pokkali rice cultivation in India: A technique for multistress management. In Soil salinity management in agriculture-Technological advances and applications Gupta, S. K and Goel, M. R (eds), Apple Academic Press, p 317-336

Sreelatha, A. K, Manju Roshni, K., Arya Lekshmi, V. and Anil. T. Sasi. 2017. Temporal variations in soil nutrient dynamics of rice-prawn integration in Pokkali soils. Abstracts of 5th National seminar on Climate Resilient Saline Agriculture: Sustaining Livelihood Security (21-23 Jan 2017) pp 46

Surya Surendran and Sreelatha, A. K.2016.Distribution of available soil micronutrients in selected Panchayaths of Ernakulam district, (7-9 November2016), Proceedings of 26th Swadeshi Science Congress, Kochi.

7.6 FINANCE (2016-17)

The Twelfth Five Year Plan (2012–2017) was sanctioned by the Council vide letter No. NRM-24-4/2013-I-II dated 28-02-2014 with an outlay of Rs 4638.67 lakhs (ICAR Share Rs 3675.00 lakh). The budget head and Centre wise statement of expenditure for 2016–17 is given below:

MAIN CENTRE

AGRA

Budget head	2016-17	
	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	6200000	7084127
TA & POL	100000	61260
Contingencies		0
Recurring	350000	349383
Non-recurring	0	0
Works	0	0
Total	6650000	7494770
ORP		
TA	100000	72336
Rec. contingencies	250000	248970
Total	350000	321306
Grand Total	**7000000**	**7816076**

BAPATLA

Budget head	2016-17	
	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5000000	7349355
TA & POL	130000	129878
Contingencies		
Recurring	300000	349603
Non-recurring	0	0
Works	0	0
Total	5430000	7828836
ORP		
TA	100000	99736
Rec. contingencies	200000	249268
Total	300000	349004
Grand Total	**5730000**	**8177840**

BIKANER

Budget head	2016-17	
	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5700000	7612103
TA & POL	75000	74360
Contingencies		
Recurring	401000	378288
Non-recurring	0	0
Total	**6176000**	**8064751**

GANGAVATI

Budget head	2016-17	
	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	3800000	4934513
TA & POL	150000	135664
Contingencies		
Recurring	500000	496305
Non-recurring	0	0
Total	**4450000**	**5566482**

HISAR

Budget head	2016-17	
	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	2850000	3422384
TA & POL	75000	26862
Contingencies		
Recurring	500000	518048
Non-recurring	0	0
Total	**3425000**	**3967294**

INDORE

Budget head	2016-17	
	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	6450000	
TA & POL	100000	
Contingencies		
Recurring	450000	
Non-recurring	0	
Total	**7000000**	**9182006**

KANPUR

Budget head	2016-17	
	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5000000	6836412
TA & POL	100000	99463
Contingencies		
Recurring	400000	396937
Non-recurring	0	0
Total	**5500000**	**7332812**

TIRUCHIRAPPALLI

Budget head	**2016-17**	
	Released ICAR share (75%)	Expenditure ICAR share (75%)
Pay & Allowances	5000000	6152731
TA & POL	130000	129683
Contingencies		
Recurring	590000	589995
Non-recurring	0	0
Total	**5720000**	**6872409**

KARNAL

Budget head	2016-17	
	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0
TA & POL	30000	30000
Contingencies		
Recurring	1319000	1318000
Non-recurring	0	
Total	**1349000**	**1348000**

VOLUNTEER CENTRE

BATHINDA

Budget head	2016-17	
	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0
TA & POL	75000	
Contingencies		
Recurring	675000	
Non-recurring	0	
Total	**750000**	**1212009**

PANVEL

Budget head	2016-17	
	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0
TA & POL	100000	88354
Contingencies		
Recurring	700000	788782
Non-recurring	0	0
Total	**800000**	**877136**

PORT BLAIR

Budget head	2016-17	
	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0
TA & POL	100000	78430
Contingencies		
Recurring	700000	830247
Non-recurring	0	0
Total	**800000**	**908677**

VYTTILA

Budget head	2016-17	
	Released ICAR share (100%)	Expenditure ICAR share (100%)
Pay & Allowances	0	0
TA & POL	100000	
Contingencies		
Recurring	700000	
Non-recurring	0	
Total	**800000**	**831351**

*The unspent balances of previous FY 2015-16 were utilized by the Volunteer centres during FY 2016-17. Hence, there is an excess expenditure compared to fund released.

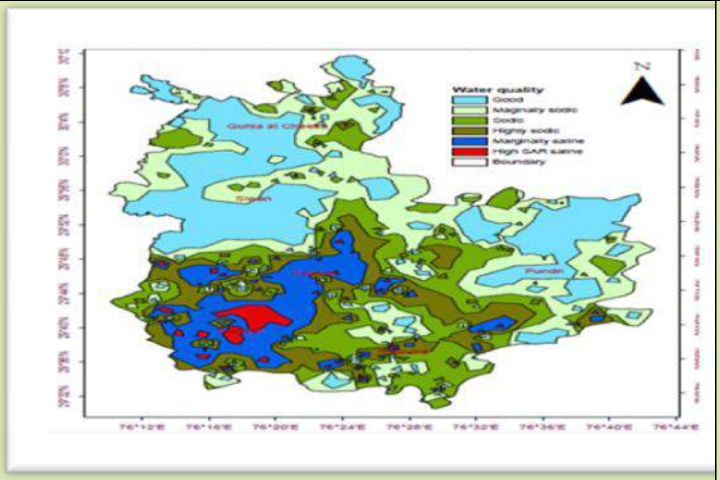

25वीं द्विवार्षिक कार्यशाला
25th BIENNIAL WORKSHOP
Welcome

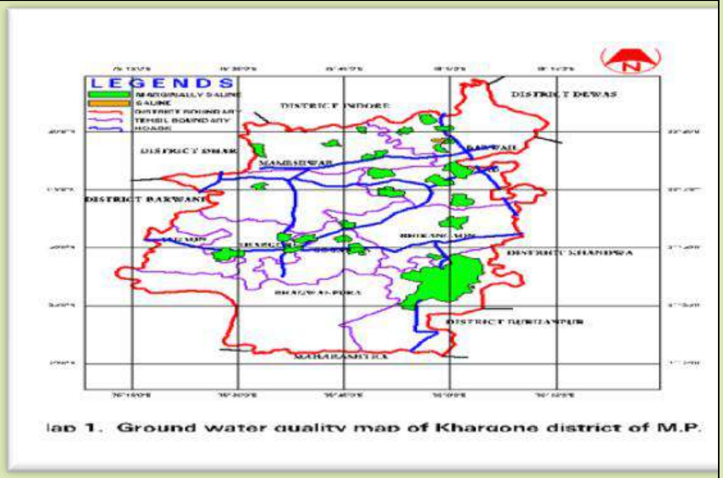

25वीं द्विवार्षिक कार्यशाला
25th BIENNIAL WORKSHOP
All India Coordinated Research Project
"Management of Salt Affected Soils and Use of Saline Water in Agriculture"
19-20 जनवरी 2017

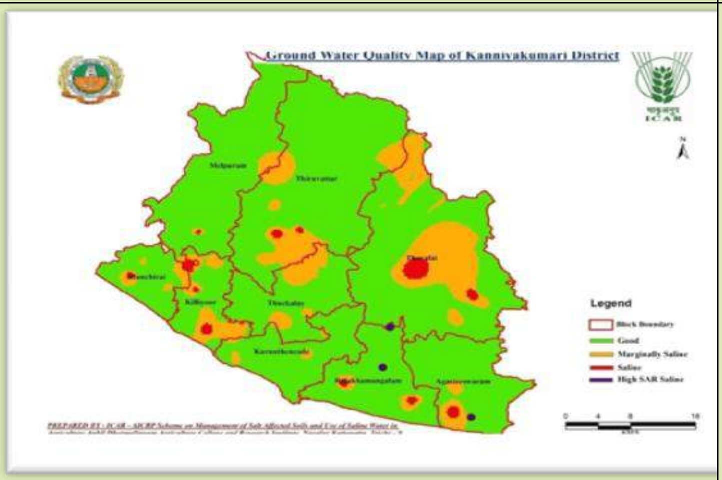
भाकृअनुप
ICAR

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

Agrisearch with a human touch







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