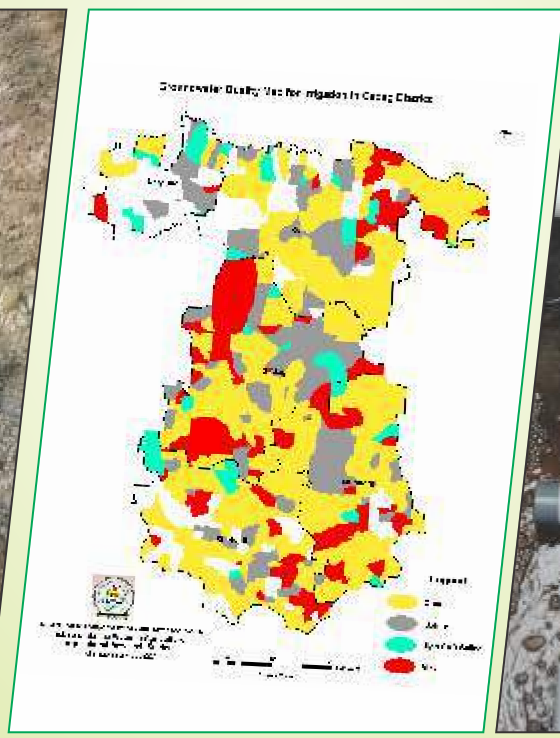
अखिल भारतीय समन्वित अनुसंधान परियोजना
लवणग्रस्त मृदाओं का प्रबंधन एवं खारे जल का कृषि में उपयोग

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

# द्विवार्षिक प्रतिवेदन
# Biennial Report
(2016-18)



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

भाकृअनुप
ICAR

**Project Coordinating Unit**
**ICAR-Central Soil Salinity Research Institute**
**Karnal - 132 001, Haryana (India)**

**Citation:**

Biennial Report (2016-18). All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture, ICAR-Central Soil Salinity Research Institute, Karnal, 282p.

**Edited by:**

MJ Kaledhonkar, RL Meena and BL Meena

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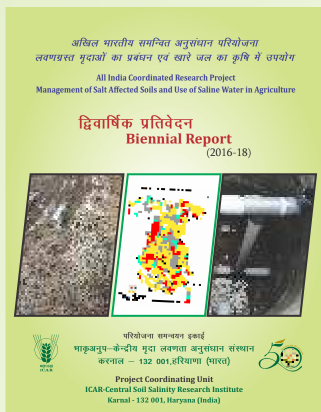


**Published by**

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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

द्विवार्षिक प्रतिवेदन

## Biennial Report

## 2016-18

**Cooperating Centres**

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

**Volunteer Centres**

1. Regional Research Station, Punjab Agril University, Bathinda (Punjab)
2. Khar Land Research Station, Panvel (Maharashtra)
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
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**ICAR-Central Soil Salinity Research Institute**
**Karnal - 132 001 (India)**

**FOREWORD**

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. Crop production losses due to salinity at the national level are tune of 5.66 million tonnes (M t), accounting for the annual monetary losses of ₹ 8,000 Crores, at prevailing Minimum Support Prices (MSP) of different crops during 2015. To address salinity and sodicity issues, the ICAR-CSSRI was established at Karnal (Haryana) in 1969. It is my pleasure that institute is celebrating **Golden Jubilee Year** of its establishment. The introspection of 50 years of journey gives immense happiness as Institute has made significant contributions towards crop production in saline and alkali environments. At present, institute has three regional research stations at Canning Town in West Bengal, Bharuch in Gujarat and Lucknow in Uttar Pradesh. Besides, AICRP on Salt Affected Soils and Use Saline Water in Agriculture, established 1972, contribute towards vision of ICAR-CSSRI. 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 and salt tolerant varieties of rice, wheat and mustard are important mile stones. Use of microbial consortia for salinity and sodicity management is recent development. It is has been proved that investments on reclamation of salt affected soils are justified as farmers get better economic returns compared to other degraded soils. Integration of different reclamation and resource conversation technologies, with synergetic effects, appears to be a probable solution for climate change challenges and institute is taking lead on this aspect at national level. Certainly, it will increase farmers' incomes by reducing salinity/ sodicity stress as well as input costs.

The twelve centres of AICRP located in various agro-ecological regions work to find solutions to location specific water and salt problems and to provide technologies suiting to those environments. The centres basically contribute towards soil and ground water characterization in respective states, standardization of the use of chemical amendments (gypsum, distillery spent wash, etc) and organic manures for reclamation of sodic soils, effective agronomic and irrigation management interventions (including drip and sprinklers) for saline/sodic waters, resource conservation technologies in sodic soils in Gangetic plains, subsurface drainage with controlled option for waterlogged saline Vertisols of Karnataka, low cost groundwater recharge in semi-arid regions of Uttar Pradesh, skimming of fresh water in coastal aquifers, use of protected structures, land shaping and integrated farming system models in coastal lands. Technologies developed by centres are successfully demonstrated through field trials/ operational research programmes and are well accepted under development schemes. I believe that the site-specific technologies developed under this AICRP have the potential of application not only within limits of state of jurisdiction but beyond the state. This biennial report contains the research results for 2016-18 at twelve research centres including 4 volunteer centres covering arid, semiarid, irrigated, rainfed and coastal eco-systems.

At the end, an excellent cooperation received from Dr MJ Kaledhonkar, Project Coordinator and Dr RL Meena, Sr. Scientist and Dr BL Meena, Scientist (Sr. Scale) in smooth running of the project is placed on the record. Concerted efforts in compilation and editing of the biennial report and for organization of biennial workshop deserve appreciation. The help of PC unit staff for project operations is worth mentioning. It would be my pleasure to extend all support to the project for solving farmers' problems.

(PC Sharma)
Director, ICAR-CSSRI

# PREFACE

The soil sodicity and soil salinity are considered as land degradation processes in agricultural lands and both affect crop yields adversely on 6.73 m ha. Management of such lands comprises reclamation including salt leaching, improved agronomic, irrigation water and nutrient practices, alternate land uses and use of salt tolerant varieties. The ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) along with three regional stations and AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture with network of twelve centres have made significant contributions towards 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 as well as reclamation and management of salt affected soils and poor quality waters considering prevalent agro-climatic conditions in the regions. All these efforts have helped in creating greater awareness about sodicity and salinity issues in the country. The reclamation and management of salt affected soils, whether sodic or saline, require special skills and multi-disciplinary team is always desired to find optimal solution. Very interestingly, these soils were of good quality before degradation. If land degradation processes of such lands are reversed, the soils can be very productive after reclamation. Therefore, benefit cost ratio remains always favourable in case of reclamation activities of sodic and saline soils. The large scale reclamation programmes in various states created employment, improved crop productivity and production, enhanced land value, promoted other allied activities and increased incomes of farmers and their social status.

There are reports that groundwater availability and quality are declining and issues of specific ion toxicity are arising. Availability of gypsum and its quality for continuing sodic soil reclamation, repeat application of amendments in sodic groundwater areas, higher cost of subsurface drainage system in waterlogged saline soils, sea water intrusion through creeks and groundwater in coastal areas, dry land salinity/ sodicity in groundwater irrigated areas are impeding factors in pushing reclamation activities in forward direction. Alternate options to existing amendments including organic/ green manuring, distillery spent wash, etc. need to be tried and standardized. Different drainage methods such as surface, subsurface, and bio-drainage are to be used to their potential capacities. Crop diversification options and new crop varieties tolerant to salinity/ sodicity are required to be tested for making best use of available resources. It is important to note that global warming and climate change are making farming activities on salt affected soils more vulnerable than earlier. With the collective wisdom of invited experts, CSSRI scientific staff and scientists of AICRP centres during Biennial Workshop 2016-18 in **Golden Jubilee Year of ICAR-CSSRI**, it would be possible to develop innovative programmes that would be able to address the current challenges associated with soil quality, ground water depletion and pollution particularly by fluoride and nitrate, dry land salinity, wastewater use, reclamation activities, mapping of salt affected soils and poor quality waters, environmental degradation and climatic change.

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 Alagusundram and DDG (Agril. Engg) and 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 and cooperation in all spheres. I wish to extend my sincere thanks to Chief Scientists at cooperating centres; Dr RB Singh, Dr Prasuna Rani, Dr IJ Gulati/ 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. Full support and coordination from Dr RL Meena, Pr. Scientist and Dr BL Meena, Sr. Scientist in PC unit functioning and compilation of biennial report 2016-18 is appreciated. I also thank other PC Unit staff members such as Shri AK Sharma, Smt Dinesh Gugnani, Shri Sukhbir Singh for their cooperation in day to day activities.

(M J Kaledhonkar)
Project Coordinator

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SUMMARY OF RESEARCH ACCOMPLISHMENTS (2016-18)

# RESOURCE INVENTORIES OF SALT AFFECTED SOILS AND POOR QUALITY WATERS

## RESOURCE INVENTORIES OF SALT AFFECTED SOILS

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

Ground truth survey was carried out in salt affected areas of Kurnool district, identified from LISS-III data, representative surface and subsurface soil samples were collected from 53 locations along with GPS coordinates during March, 2017.The pH, EC and SAR values in surface soils varied from 5.5 to 10.30, 0.30 to 33.00 $dSm^{-1}$ and 0.25 to 79.8 whereas the same parameters in subsurface soils varied from 4.8 to 10.20, 0.20 to 19.00 $dSm^{-1}$ and 0.19 to 57.50 respectively. However 32% surface soils and 23 % subsurface soils have SAR >10.The mean ionic composition ($HCO^{3-}$, $Cl^-$, $SO_4^{-2}$-, $Ca^2$, $Mg^{2+}$, $K^+$ and $Na^+$) of surface soils was higher than subsurface soils.

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

Soil salinity and water logging are the twin problems of TBP command due to unscientific land and water management and violation of cropping pattern over the years. Majority of the reports vary in their estimates on the extent of soil salinity. A proper delineation of the area through intensive ground truth is thus look imperative in arriving at a close approximate of salt affected area. No such delineation of salt affected soils in TBP command is available. With the aid of GPS and toposheet, soil samples were collected on a grid basis (5' x 5' = 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 during. 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. In Hospet taluk, Bellary district a total of 121 samples were collected for soil salinity appraisal.

In Raichur district, at surface soil (0-15 cm) $pH_{(1:2.5)}$, pHs, $EC_{(1:2.5)}$ and $EC_e$ 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, 1.27, 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 $HCO_3^-$ followed by $SO_4^{2-}$. Nearly 13 per cent of surface samples had $EC_e$ >4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 $(CO_3+HCO_3)/(Cl+SO_4)$ and $(Na/(Cl+SO_4)$ ratios were to the extent of nearly 6 and 39 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 $EC_e$ 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 $EC_e$ of these samples was >4.0 dS/m. The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas $Na/(Cl+SO_4)$ 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 $EC_e$ 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 per cent of samples were found to be saline as their $EC_e$ was >4.0 dS/m.–The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas $Na/(Cl+SO_4)$ ratio was >1. However, about 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 $EC_e$ 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 $EC_e$ was >4.0 dS/m.–The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas $Na/(Cl+SO_4)$ ratio was >1. However, about 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 $EC_e$ varied from 10.76 to 7.82, 10.23 to 7.45, 31.0 to 0.19 (dS/m) and 75.0 to 0.64 (dS/m) respectively with an average of 8.55, 8.11, 5.39, and 13.2 dS/m respectively. Among cations, average Na content was more than Ca+Mg followed by K. In case of anions, average $Cl^-$ content was more than $HCO_3^-$ followed $SO_4^{2-}$. Nearly 40 per cent of surface samples had $EC_e$ >4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 $(CO_3+HCO_3)/(Cl+SO_4)$ 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 $EC_e$ varying from 10.55 to 7.43, 10.33 to 7.55, 19.9 to 0.12 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. Similar to surface soils, average Na content was more than Ca+Mg followed by K. In case of anions, average $Cl^-$ content was more than $HCO_3^-$ followed by $SO_4^{2-}$.Nearly 40 per cent of sub surface samples were considered to be saline as the $EC_e$ of these samples was >4.0 dS/m. The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas Na/(Cl+SO4) was >1. However, about 4 and 58 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 48 per cent of samples analyzed had SAR >13. At 30-60 and 60+ cm depths, 42 to 46 per cent of samples had ECe >4, 64 to 84 per cent of samples with Na/(Cl+SO4) >1 and 51.1 to 61.1 per cent of samples had SAR >13 at these depths respectively.

In Hospet taluk (Bellary district), at surface soil (0-15 cm) $pH_{(1:2.5)}$, pHs, EC $_{(1:2.5)}$ and $EC_e$ varied from 8.74 to 5.72, 8.26 to 5.88, 19.0 to 0.15 (dS/m) and 43.0 to 0.39 (dS/m) respectively with an average of 7.51, 7.25, 1.28, and 2.96 dS/m respectively. Among cations, average Na content was more than Ca+Mg followed by K. In case of anions, average $Cl^-$ content was more than $HCO_3^-$ followed $SO_4^{2-}$. Nearly 15 per cent of surface samples had $EC_e$ >4.0 dS/m reflecting that these soils are saline. However, per cent of samples with >1 $(CO_3+HCO_3)/(Cl+SO_4)$ and $(Na/(Cl+SO_4)$ ratios were to the extent of nearly 42 and 39 respectively. About 19.5 per cent of samples had SAR>13. At 15-30 cm depth, nearly 10 and 7 per cent of samples had $EC_e$ >4 and SAR>13. At 30-60 cm depth, nearly 12.5 and 25 per cent of samples had ECe >4 and SAR>13. At 60+ cm, nearly 20 and 60 per cent of samples had ECe >4 and SAR>13 respectively. At lower depths, per cent of samples with $(CO_3+HCO_3)/(Cl+SO_4)$ and Na/(Cl+SO4) ratios >1 varied from 20 (60+ cm) to 31.7 (15-30 cm) and 19.5 (15-30 cm) to 62.5 (30-60 cm) respectively.

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

The soil survey of Khargone, Khandwa and Dewas districts was carried out by the centre during 2016-18. 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 districts, respectively. The maps showing salt affected soils in Khargone and Khandwa districts were prepared using Remote Sensing and GIS techniques. Samples (164) were collected from Dewas district. The samples from remaining part of the district will be collected during the year 2018-19 and map of the area covering salt affected soils will be generated on the basis of district as a whole.

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

**RESOURCE INVENTORIES OF POOR QUALITY GROUNDWATER WATERS**

**Survey and characterization of underground waters of Agra and Mathura districts (Agra)**

The ground water survey of Agra district in Uttar Pradesh was repeated after 40 years and completed in 2017. Fifteen blocks viz Fatehpur Sikri, Akola, Achhnera, Bichpuri, Jagner, Sainya, Kheragarh, Barauli Ahir , Khandauli, Shamsabad, Bah, Pinahat, Fatehabad, Etmadpur and Jaitpur Kalan were surveyed and total 951 samples were collected mostly from December to March, when the maximum number of tube wells were under use for irrigation purpose and analyzed for different water constituents for its quality. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions ($CO_3$, $HCO_3$, Cl and $SO_4$). Quality parameters like SAR and RSC were calculated. The classification of water quality was done on the basis of EC, SAR and RSC values as suggested by CSSRI, Karnal.

Comparing the water quality of recent survey of Agra district with 35 years ago, it was found that the good quality waters in the different blocks have been reduced sharply except Jagner, Sainya, Barauli Ahir, Khandauli and Kheragarh blocks. The major number of samples falls in high SAR saline water quality category in both the surveyed periods. Except the Jagner, Sainya, Barauli Ahir and Kheragarh blocks, the High SAR Saline water quality area has increased in seven blocks. The saline water quality (marginally saline and saline) area decreased in Fatehpur Sikri, Bichpuri Jagner, Sainya,Kheragarh, Barauli Ahir, Shamsabad, Bah and slight increase trend was observed in Alkali water area whereas the water quality of three blocks i.e. Jagner, Sainya and Kheragarh mostly remained unchanged even after three decades of time interval. In four surveyed blocks of Mathura district, it was observed that good quality water area increased in Farah and reduced in Goverdhan and Mathura blocks, while in Baldev block, the water was found almost same as compared to previous survey.

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

In the year 2016, a total of about 228 ground water samples were collected from 46 mandals of West Godavari along with GPS locations and were characterized for their quality. The results revealed that the number of samples under good quality declined from 81.9 percent in the year 1989-90 to 58.3 percent in 2016 whereas percent alkali water increased from 0.1% (1989) to 8.8% (2016). Similarly, in the year 2017, a total of about 313 ground water samples were collected covering all the mandals of East Godavari district. The results of revisiting sites indicated that, the percent of good quality water declined to 61.7 percent in the year 2017 as compared to 83.7 percent in the year1989. However, the alkali and highly alkali waters increased from 0.0-3.8 per cent from the year 1989 to 2017. However, the quality of water was deteriorated as compared to earlier studies.

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

Pre and post monsoon ground water samples (120 in each season) were collected up to 50 km from sea coast with GPS coordinates along four routes (Machilipatnam, Kanaparthi, Nizampatnam and Suryalanka).The pH and EC values of ground water samples (Pre and post monsoons) were neutral to alkaline and non-saline to highly saline. The data of water samples collected during pre-monsoon-2017 indicated that the pH values increased in Kanaparthi, Suryalanka and Nizampatnam routes and remain same in Machilipatnam route as compared to pre-monsoon-2016. The data of water samples collected during post-monsoon -2017 indicated that the pH values increased in Machilipatnam and Kanaparthi routes, decreased in Nizampatnam route and remained same in Bapatla route as compared to post-monsoon-2016. EC values were higher in pre-monsoon -2016 and 2017 in all routes as compared to EC values of post –monsoon 2016 and 2017. However, Suryalanka and Nizampatnam routes recorded higher EC values as compared to other routes in Pre and Post-monsoon of 2016 and 2017. Machilipatnam route recorded the highest EC value of 19.30. 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)**

In Rajasthan, majority of the ground waters contains high salt concentrations and their use for irrigation adversely affects the crop production. Water samples of 104 tube wells distributed in 73 villages *i.e* 20 villages of Bilara, 24 villages of Pipar city and 29 villages of Bhopalgarh tehsils of Jodhpur district were collected and analyzed for various chemical characteristics. The data on range of EC and pH of water samples in these tehsils ranged from 2.47 to 10.52 dS/m, 0.56 to 19.50 dS/m, 0.93 to 5.81 dS/m and 7.33 to 8.42, 7.10 to 9.13 and 7.22 to 8.45, respectively. The concentration of calcium varied from 3.36 to 27.40, 0.80 to 4.00 and 0.80 to 9.40 me/L and magnesium varied from 3.54 to 28.00, 1.20 to 11.60 and 1.20 to9.00me/L in Bilara, Pipar city and Bhopalgarh tehsils, respectively. Sodium concentration ranged from 16.80 to 55.13 me/L in Bilara, 2.48 to 183.22 me/L in Pipar city and 5.08 to 45.36 me/L in Bhopalgarh tehsils whereas concentration of potassium ion for these tehsils varied from 0.06 to 0.32, 0.07 to 0.70 and 0.07 to 0.88 me/L, respectively. Soluble carbonates varied from 0.20 to 0.80 me/L in Bilara, 0.00 to 4.20 me/L in Pipar city and 0.40 to1.50 me/L in Bhopalgarh tehsil while bicarbonates varied from 6.80 to 17.60 me/L in Bilara, 2.60 to 12.80 me/L in Pipar city and 3.60 to10.00 me/L in Bhopalgarh tehsil of Jodhpur district. The concentration of chloride varied from 11.25 to 80.15, 1.60 to 152.42 and 3.50 to 45.00 me/L while sulphate varied from 0.53 to 8.09, 0.50 to 29.48 and 0.37 to 9.85 me/L for Bilara, Pipar city and Bhopalgarh tehsils, respectively. Chloride and sodium was the dominant anion and cation, respectively. The SAR of water samples ranged from 8.22 to 20.68, 2.10 to 76.08 and 3.18 to 23.79, whereas Adj. SAR of water sample ranged from 24.10 to 59.96, 3.98 to 220.6 and 7.32 to 59.09, respectively for Bilara, Pipar city and Bhopalgarh tehsils of Jodhpur district.

As far as RSC of these water samples is concerned, it ranged from 0.00 to 4.00, 0.00 to 4.20 and 0.00 to 4.50 me/L in Bilara, Pipar city and Bhopalgarh tehsils, respectively. About 90 and 87.50 and 81.66 per cent water samples in Bilara, Pipar city and Bhopalgarh tehsils, respectively had RSC less than 2.5 me/L. As regards salinity 7.50, 10.00 and 82.50 per cent water samples in Bilara tehsil showed EC in the range of 2 to 3, 3 to 4 and > 4 dS/m, while in Pipar city tehsil 5.0, 5.0, 15.0, 12.5 and 62.50 per cent water samples had EC in the range of < 1, 1 to 2, 3 to 4 and > 4 dS/m and 13.33, 35.0 and 20.0 per cent water samples of Bhopalgarh tehsil showed EC in the range of 2 to 3 , 3 to 4 and > 4 dS/m.

About 15, 70 and 15 per cent water samples in Bilara, were under saline, high SAR saline and marginally alkali, respectively. In Pipar city tehsil about 10.00, 17.50, 60.00 and 12.50 per cent water samples were under good, marginally saline, high SAR saline and highly alkali category, respectively. About 21.67, 15.00, 48.34, 8.33, 3.33 and 3.33 per cent water samples of Bhopalgarh tehsil fall under good marginally saline, high SAR saline, marginally alkali, alkali and highly alkali, respectively.

The range of chemical characteristics of soil samples in these tehsils indicated that $pH_2$ of soil samples in Bilara tehsil varied from 8.00 to 9.49, in Pipar city tehsil 8.03 to 9.53 and Bhopalgarh tehsil from 7.90 to 9.43, whereas, the corresponding $EC_2$ ranged from 0.74 to 3.12, 0.12 to 4.53 and 0.16 to 9.69 dS/m in Bilara, Pipar city and Bhopalgarh tehsils, respectively. Since approximately 50 per cent ground waters have shown saline-sodic characteristics and soils of corresponding fields have also shown dominance of sodium ion, therefore, use of gypsum either for neutralization of RSC of waters or application in field is recommended.

**Survey and characterization of ground waters of Kaithal and Mewat districts for irrigation (Hisar**)

The survey and characterization of underground irrigation water of namely Kaithal, Guhla, Kalayat, Pundari, Rajound and Siwan blocks of Kaithal district was undertaken during 2016-17. and Nuh, Nagina, Punahana and Ferozepur Jhirka blocks of Mewat district was undertaken during 2017-18. In Kaithal district, total 530 groundwater samples were collected with the spatial points through GPS for all the blocks. The samples were collected uniformly from all the blocks. In Kaithal district, total 530 groundwater samples were collected with the spatial points through GPS for all the blocks. The samples were collected uniformly throughout from all the blocks. In Kaithal, Guhla, Kalayat, Pundari, Rajound and Siwan blocks of Kaithal district, Marginally saline water were found 25.5, 2.7, 21.6,6.1,13.6 and 1.3 percent where as high SAR Saline water were to tune of 8.0, 11.1, 13.7,11.2,11.9 and 13.7 per cent, respectively. Among the six blocks of Kaithal district, Guhla and Pundri blocks has best groundwater quality in which 63.2 and 60.3 per cent samples were found in good quality category. Overall in the 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. In Mewat district, total 307 groundwater samples were collected with the spatial points through GPS for all the blocks. Among the Four blocks of Mewat district, Nuh and Nagina blocks has best groundwater quality in which 35.4 and 55.0 per cent samples were found in good quality category.Overall in Mewat district, 30.5, 26.1, 2.3, 31.6, 4.6, 0.7 and 4.2 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, Khandwa and Dewas district of Madhya Pradesh (Indore)**

Ground water survey of the Khargone, Khandwa and Dewas districts was conducted by Salt Affected Soils Project, College of Agriculture, Indore. 253, 180 and 164 ground water samples were collected from different villages of different tehsils of the districts. Out of 253 samples collected from Khargone, 208 (82.2 %) belongs to Good category “Good (A)”, 44 (17.4 %) belong to category “Marginally Saline ($B_1$)” and 1 (0.4 %) belong to category “Saline ($B_2$)”. In Khandwa district, out of 180 samples collected, 158 (87.8 %) belongs to category “Good (A)” and 22 (12.2 %) belong to category “Marginally Saline ($B_1$)”. Out of 164 samples collected from Dewas, 138 (84.2%) belongs to category “Good (A)”, 22 (13.4%) belong to category “Marginally Saline ($B_1$)” and 4 (2.4 %) belong to category “Saline ($B_2$)”. The samples from remaining part of the district will be collected during the year 2018-19 and the final report and map will be generated on the basis of district as a whole.

**Survey and Characterization of underground irrigation water of Kanpur dehat and Auraiya 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 (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.

Further, underground irrigation water samples were collected from different villages of Auraiya district. Out of 88 samples, 65 (73.86 %) were categorized as good, 17 (19.32 %) marginally saline, 02 (2.27 %) saline, 01 (1.14 %) highly saline, 02 (2.27 %) alkali and 01 (1.14 %) were highly alkaline water.

**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 done by collecting and 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 as suggested by Central Soil Salinity Research Institute (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 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.

Out of the total ground water samples collected from Cuddalore district, 69.9 per cent is coming under good quality, 16.27 per cent is marginally saline, 9 per cent is saline water, 0.8 per cent is marginally alkali and 3.4 per cent is under high alkali categories. Hence, around 70 percent of the ground water resources can only be made available for irrigation purpose, the remaining are under threat. The results and interpretation of hydro chemical analysis of ground water revealed the dominance of cations ($Na^+$>$Ca^{2+}$>$Mg^{2+}$>$K^+$) over anions ($HCO_3^-$> $Cl^-$> $CO_3^{2-}$ > $SO_4^{2-}$) in ground water samples of study area and their occurance was also in the above said order. The maximum EC, SAR and RSC was recorded in Kumaratchi block followed by in Parangipettai block of Cuddalore district since these blocks are situated nearby coastal areas (10 km from sea shore). The nitrate content of the ground water samples of coastal blocks were all in safer side (<2.5meq/l) except in few places exceeding 2.5meq/l. The fluoride content in all blocks of Cuddalore district was found to be safe.

**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 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. It is reported that 79, 85, 47 and 56% water samples have RSC less than 2.5 $meqL^{-1}$; 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 $meqL^{-1}$) and 4% water is unsuitable for irrigation (RSC, > 5.0 $meqL^{-1}$).

The EC of majority of the cases i.e. 15 % in Sangat, 11 % in Talwandi Sabo, 16 % in Bathinda, 9% in Maur and 39 % in Nathana block was less than 2 dS $m^{-1}$. Whereas, 43 % in Sangat, 49 % in Talwandi Sabo, 61 % in Bathinda, 65% in Maur and 49 % in Nathana blocks were observed between 2 to 4 $dSm^{-1}$ and rests was more than 4 $dSm^{-1}$. It is reported that based on electrical conductivity only 22 % water could be used without any possible risk of soil salinization. Further, 54% water was rated as marginal (EC, 2 to 4 $dSm^{-1}$) for irrigation and 24% water was not suitable for irrigation due to their higher electrical (>4 $dSm^{-1}$) conductivity.

It is observed that 71%, 68%, 76% and 66 % water samples have RSC < 2.5 me $L^{-1,}$ in the blocks Sangat, Talwandi Sabi and Bathinda, Maur and Nathana, respectively. While 15%, 21%, 19%, 17% and 21 % of water samples showed RSC between 2.5-5.0 me $L^{-1}$ in the blocks Sangat, Talwandi Sabi, Bathinda, Maur and Nathana, respectively. Further, it is reported that on the basis of RSC 69% water is safe (RSC, <2.5 $meL^{-1}$), 19% water is marginal (RSC, 2.5 to 5.0 $meL^{-1}$) and 12% water is unsuitable for irrigation (RSC, > 5.0 $meL^{-1}$).

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

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).

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

Analysis of the ground water samples from Thiruvananthapuram, Kottayam, Kollam Pathanamthitta,Kannur, Kasargod, Malappuram and Kozhikode districts revealed some of the general observations. 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 per cent samples were of good quality and 2.6 per cent samples belonged to marginally saline category. In Kottayam district 82.35 per centsamples wereunder good quality and 11.76 per cent water samples were marginally saline. Ground water sample from Murinjapuzha was saline in nature. In Kollam, 95.23 per cent of the samples belonged to good in category whereasground water sample collected from Azeekal belonged to marginally saline. All the ground water sample collected from Pathanamthitta district were good in quality.Almost 73.07 percent of ground water samples collected from Kasargod district were grouped under good quality and 23.07 per cent samples were marginally alkaline.Water samples collected from Kannankai was marginally saline. In Kannur districts 46.66 per cent of ground water samples were grouped under good quality and 26.66 percent of the samples were marginally alkaline. Wide variation in ground water quality was found in Kaipad areas. 13.33 per cent of water samples were high alkaline as well as high SAR saline water each. In Kozhikode and Malappuram districts 73.68 and 40 per cent samples each were of good quality and 26.31 and 60 per cent samples each were marginally alkaline respectively.Tthe ground water data of Idukki, Palakkad and

Wayanad districts obtained from Central ground water board revealed that all the water samples of the three districts were grouped under good quality for irrigation. Absence of sea shore might be the one of the reasons for this. Ground water pH varied from strongly acid to strongly alkaline.

## MANAGEMENT OF SALT AFFECTED SOILS

### MANAGEMENT OF ALKALI SOILS

#### Reclamation of abandoned aqua ponds (Bapatla)

The experiment was carried out in Nizampatnam, Guntur district during Kharif-2016-17. In reclaimed fields, rice variety MTU-1010 was grown by application of recommended fertilizers [180:40:40 N: $P_2O_5$:$K_2O$ with basal application of $ZnSO_4$@50 kg $ha^{-1}$].The yields recorded in the fields of Sri P. Babu and Sri M.Veerraju were 5231 and 5269 kg $ha^{-1}$ respectively. Adoption of reclamation technology resulted in reduction in salinity of the soil in both the farmer's fields after harvest of rice crop. Due to adoption of same reclamation technology in Kharif- 2017-18 in three farmers' fields resulted in 27.7, 23.6 and 26.3 per cent yield enhancement over check yield of 4800 kg $ha^{-1}$. Further, the ECe of soils declined to 4.2, 3.4 and 3.1dS$m^{-1}$, respectively.

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

A field experiment was conducted in Narravaripalem during Kharif-2016 with four treatments viz., Gysum@50% GR, Bicompost@4t $ha^{-1}$,Gypsum@50%GR+ Bicompost@4t $ha^{-1}$ and farmers practice. The results revealed that, application of Gypsum@50%GR+ Bicompost@4t $ha^{-1}$ resulted in higher yields (5000kg $ha^{-1}$) over farmer's practice (3600 kg $ha^{-1}$). Besides the soil pH declined from 8.6 to 8.4 due to application of Bicompost@4t $ha^{-1}$ and to 8.2 when Bicompost@4t $ha^{-1}$ was applied along with Gypsum@50% GR. During Kharif-2017 conducted in sandy clay loam soil ( with pH of 9, EC of 1.3 dS$m^{-1}$ and ESP >15) with low OC and available N, medium available P and high available K. Gypsum was applied to the field before onset of monsoons to leach the salts. Pressmud compost@4t $ha^{-1}$ was applied 15 days before the transplanting of BPT-5204 rice variety and followed by application of recommended dose of fertilizers. Among the treatments, pressmud compost 4 t $ha^{-1}$+ Gypsum @50%GR treatment recorded the higher grain yield (6220 kg $ha^{-1}$) over pressmud compost treatment (5680 kg $ha^{-1}$). The application of pressmud compost along with Gypsum (being rich source of Ca and organic carbon) decreased the pH , reduced the ESP by replacing Na by Ca and increased the CEC of soil

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

The experiment was conducted in Randomised block design with three replications and five treatments in alkali soils to study the effect of treatments on the performance of safflower crop. The results indicated that application of FYM along with gypsum and 25% extra recommended dose of nitrogen recorded the highest plant height (63.7 and 95.3 cm) , number of heads per plant (18.5 and 21.3) and seed yield (1114 and 1439 kg $ha^{-1}$) followed by application of gypsum + 25% extra nitrogen during 2016 and 2017 respectively. However, farmer's practice recorded significantly lower plant height (45.9 and 70.8 cm) no. of heads per plant (5.1 and 5.0) and seed yield (530 and 477 kg $ha^{-1}$) as compared to all other treatments during both the years.

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

The long-term experiment was initiated to observe the effect of organic/green manuring on soil properties and crop yield in an alkali soil. 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 during the year. The maximum yield of paddy (3.71 & 3.96 t $ha^{-1}$) and wheat (3.47 & 3.68 t $ha^{-1}$) was recorded at soil ESP of 25, however, the lowest yields were recorded 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 experiment was initiated in *rabi* 2013-14. The minimum water expense (WE) was obtained of 39 cm in case of sprinkler irrigation (SI) with irrigation depth 3 cm followed by 40 cm in SI with irrigation depth 2 cm and maximum WE was 51.84 cm in case of BSI with COD 65 % followed by 48.96 cm in BSI with COD 85 %. The highest yield of 2869 & 2567 kg $ha^{-1}$ in 2016-17 and the lowest yield of 1941 & 1673 kg $ha^{-1}$ in 2017-18 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 values with 73.6 & 54.2 in 2016-17 and 37.4 & 32.3 kg/ha-cm. It implied that one should opt SI with irrigation depth 3cm scheduled on the basis of 1.2 IW/CPE ratio.

**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 during 2016-17. 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. The soil moisture from 0-15 cm depth was also estimated before sowing and after harvesting of the crop under various drip irrigation systems. Soil moisture contribution estimated ranges in-between 3.16 to 3.97 cm/ m soil depth in drip irrigation systems, respectively.

The total water expense was estimated around 54 cm in case of daily, alternate and third day irrigation schedules in 2017-18. 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 16223 kg/ha was obtained in case of drip irrigation system scheduled daily with 1.3 LPH dripper discharge rate followed by the lowest 9076 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 297.68 kg/ha-cm in case of drip irrigation system scheduled every day with 1.3 LPH dripper discharge rate followed by 281.50 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 164.62 kg/ha-cm in case of drip irrigation system scheduled every third day with 4.0 LPH dripper discharge rate followed by 182.59 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 average grain and straw yield of rice varied from 24.20-41.43 and 29.09-50.34 q/ha respectively. The maximum yield of grain (41.43 q/ha) and straw (50.34 q/ha) was obtained from 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 while minimum yield was received from control plot. The average grain and straw yield of wheat varied from 19.34-36.04 and 23.80-43.97 q/ha respectively. The maximum yield of grain (36.04 q/ha) and straw (43.97 q/ha) was obtained from 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 while minimum yield was received from control plot. The maximum changes in pH, EC, ESP and OC was analyzed in 50%GR followed by 25%GR + poultry manure @3t/ha and 25%GR + GM @5 t/ha + microbial culture as compared to other treatments.

**Management of sodic soil under different irrigation scenarios in rice based cropping system in the Cauvery Delta Zone of Tamil Nadu (Tiruchirapalli)**

The reporting field experiment pertaining to Rabi 2017 was started during October 2017. This is the second rice crop in the rice-pulse cropping system. The treatments viz., Factor A : Irrigation scenarios (4) $I_1$: Canal water alone, $I_2$: Canal water: Alkali water (1:1 cyclic mode), $I_3$: Canal+Alkali water combined (50+50 %) per irrigation, $I_4$: Alkali water alone and Factor B: Soil amendments (4) $S_1$: Control, $S_2$: Green / green leaf manuring @ 6.25 t/ha, $S_3$: Distillery spent wash @ 5 lakh litres / ha, $S_4$: Gypsum 50 % GR + Green manuring with Daincha @ 6.25 t/ha were imposed as per the treatment schedule. During this rice season only irrigation treatments (Factor-A) imposed and factor B is the residual effect of the onetime application of soil amendments during the start of the cropping system experiment. The rice (Variety- TRY-3) nursery was raised on 16.10.2017, transplanted on 17.11.2017 and harvested on 26-03-2018. Among the irrigation treatments, the results reveals that, the treatments viz., $I_3$; $I_2$ and $I_1$; recorded with a grain yield of 4815, 4948 and 5318 kg $ha^{-1}$ respectively. Application of alkali water alone ($I_4$) recorded a lowest grain yield of 4536 kg $ha^{-1}$. Among the soil amendments, the treatment $S_3$, recorded a significant highest yield of 5473 kg $ha^{-1}$ followed by $S_4$, $S_2$, and $S_1$ with a respective grain yield of 5091, 4866 and 4187 kg $ha^{-1}$. There does not exist any interaction between irrigation methods and residual effect of soil amendments. The percent yield increase over irrigation of alkali water alone over rest of the treatments reveals that the irrigation treatment $I_1$ Canal water irrigation recorded with highest yield increase of 38.2 % followed by $I_2$ and $I_3$ with the corresponding value of 28.6 and 25.1 respectively. Among the different soil amendments $S_3$ recorded with 42.2 % yield increase followed by $S_4$, $S_2$ and $S_1$. Among the irrigation treatments $I_1$ had a highest gross income of Rs. 92078 $ha^{-1}$ followed by $I_2$, $I_3$ and $I_4$. Among the soil amendments $S_3$ recorded highest gross income of 94782 followed by $S_4$, $S_2$ and $S_{1.}$

The net income was calculated and it is found that , among the irrigation scenarios $I_1$ recorded with highest net income of Rs. 49078 followed by $I_2$, $I_3$ and $I_4$. Among the different soil amendments $S_3$ recorded with highest net income of Rs. 51782 followed by $S_4$, $S_2$ and $S_1$. The BCR was calculated for different treatments and found that, among the irrigation treatments $I_1$ recorded with highest BCR of 2.14 followed by $I_2$ , $I_3$ and $I_4$. Among the different soil amendments $S_3$ recorded with highest BCR of 2.20 followed by $S_4$, $S_2$ and $S_1$.

**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.

**MANAGEMENT OF SALINE AND SALINE WATERLOGGED SOILS**

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

The experiment was conducted in randomized block design with four replications and five treatments in saline soils to study the influence of different sources of silicon on alleviation of salinity effect on rice. Application of silicon through different sources showed significant difference in growth and yield parameters of paddy. Among different sources, application of potassium silicate recorded the maximum plant height (75.7 and 92.0 cm), number of tillers per plant (15.4 and 27.0), panicle length (18.8 and 22.2 cm), filled grains per panicle (127 and 214), test weight (19.0 and 17.4), grain (4631 and 5125 kg $ha^{-1}$) and straw yield (6237 and 7346 kg $ha^{-1}$) during both the years i.e., 2016 and 2017. This treatment was on par with calcium silicate in terms of paddy grain and straw yields. In treatment receiving no silicon recorded the lowest plant height (75.7 and 92.0 cm), number of tillers per plant (10.2 and 21.0), panicle length (15.9 and 20.3 cm), number of filled grains per panicle (93 and 199), grain yield (4631 and 5125 kg $ha^{-1}$) and straw yield (5118 and 6284 kg $ha^{-1}$) during 2016 and 2017.

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

To the existing 50 m lateral spacing (2.8 ha) SSD experiment, additional 40 (2.62 ha) and 60 m (4.0 ha) lateral spacing SSD systems were initiated at Agricultural Research Station, Gangavati during *Rabi-Summer* 2013-14. Over six seasons, the mean surface (0-15 cm) soil salinity (ECe) reduced from 8.05 to 4.0, 4.3 to 1.41, 7.69 to 3.96 dS/m and 7.33 to 2.64, 6.28 to 3.93 and 5.99 to 5.71 dS/m under conventional and controlled SSD at 40 m and 50 m and 60 m spacing respectively. The average drain discharge during *Kharif* 2017 was 0.44 vs. 0.16, 1.27 vs. 0.18 and 0.61 vs. 0.36 mm/d under conventional and controlled SSD at 40, 50 and 60 m spacing respectively. The average over five seasons it was 0.67 vs. 0.32, 2.05 vs. 0.50 and 1.0 vs. 0.67 mm/day under conventional and controlled SSD respectively. The salinity of drainage water over five seasons was 3.93 vs. 3.23, 2.22 vs. 2.36 and 3.12 vs. 2.12 dS/m and salt removal was 0.65 vs. 0.26, 1.03 vs. 0.40 and 0.73 vs. 0.27 t/ha under conventional and controlled SSD at 40, 50 and 60 m spacing respectively. Similarly, the loss of N was 1.87 vs. 0.63, 5.95 vs.2.64 and 4.30 vs. 2.68 kg/ha with the paddy grain yield varying from 39.3 vs. 37.3, 51.2 vs. 46.7, and 46.3 to 44.8 q/ha under conventional and controlled SSD at 40, 50 and 60 m spacing respectively.

**Evaluation of variable lateral out let head of controlled drainage system in saline Vertisols of TBP command (Gangavathi)**

A field experiment was laid out at Thimmapur village (Farmers' field) in an area of 2 ha block by taking three treatments i.e., Controlled SSD with 50 m spacing each with a raise of lateral head up to root zone,0.3 m and 0.6 m, including conventional, fixed and variable outlet heads during *Kharif* 2015. The topography of the area was about 0.165% sloping towards east direction. Considering the topography, the main collector line of the sub surface drainage was planned west to east direction with provision of outlet in east end.

The experimental site was divided into eight blocks based on soil salinity so as to accommodate the treatments. As there was no water available for irrigation, the plot was left fallow during *Kharif* 2015 and 2016. During *Kharif* 2017, as per the suggestions of QRT, only the conventional SSD system was considered so as to attain faster reclamation. After the crop harvest, soil salinity declined at all the block and at all the depths. In the coming seasons, depending on the availability of water the actual variable outlet head concept will be considered.

**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 found performing better when compared other spacings. The results obtained in 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.
To study the performance, mole drains of 5 m spacing were installed and Maize crop was sown in an area of 2.0 acres at spacing 60x20 cm spacing. As the crop was sown in late rabi, rainfall events equivalent depth of water is given to the field and the mole drains are kept in open position. To facilitate the disposal of drainage water, a concept of drain water harvesting was introduced and a small farm pond to accommodate the drainage water was also created in the study area. Mole drainage systems were designed for Vertisols for maize crop and were installed at SWS fields, Bapatla. Highest plant height and yield of 291.3 cm and 3.86 t $ha^{-1}$of maize were observed with installation of mole drains at 5 m spacing. The results obtained in one year study revealed that, the temporarily waterlogged soils can be reclaimed with low cost mole drainage systems.

**Evaluation of mole drains on reclamation of saline Vertisols in TBP Command (Gangavathi)**

**A) Agricultural Research Station, Gangavathi**

Prior to paddy transplanting during *Kharif*-2016, soil samples were drawn again to a depth of 60 cm and mole drains were laid out. The soil pH varied from 7.91 (0-15 cm) to 8.1 (30-60 cm) and soil salinity was 3.33, 4.29 and 4.30 at 0-15, 15-30 and 30-60 cm respectively. During puddling operation (land preparation), mole drains appear to be collapsed after puddling operation by cage wheel, hence it was not possible to monitor the experiment. During Kharif-2017, instead of cage wheel, power tiller was used to facilitate shallow puddling operation which did not affect mole drain and paddy transplanting was taken up successfully.The average drain discharge during *Kharif*-

2017observed was 0.39 mm/d, salinity of the drainage effluent was 0.70 dS/m and removal of salts of about 0.023 t/ha through drainage effluent. Loss of nitrogen over the sampling period during Kharif-2017 was 0.36 kg/ha. There was slight improvement in paddy grain yield (38.1 q/ha) to the extent of 8 to 10 per cent over previous years' yield. Soil samples drawn after crop harvest are being analyzed.

**B) Farmers' field (Thimmapur village)**

The same project work was initiated at Thimmapur village in farmer's field. A total of 81 soil samples to a depth of 60 cm with 15 cm increment were collected using GPS during May-2017 and analyzed for soil pH and ECe. The initial soil pH of the experimental area was 7.73 at 0-15 cm and 7.78 at lower depths. The initial mean soil salinity (ECe) of the experimental area was 36.61, 22.70 and 11.64 dS/m at 0-15 cm, 15-30 cm and 30-60 cm respectively. The soil texture at 0 to 60 cm was found to be clay with clay content varying from 50 to 65 % in the study area. The experimental site was divided into three blocks based on the levels of soil salinity. The average soil pH and ECe of the block- I was 7.6, 7.7, 7.8 and 29.8, 15.6 and 8.42 dS/m at 0-15, 15-30 and 30-60 cm respectively. The average soil pH and ECe of the block- II was 8.1, 7.9, 7.8 and 36.0, 25.2 and 11.1 dS/m at 0-15, 15-30 and 30-60 cm respectively. Similarly, The average soil pH and ECe of the block- III was 7.5, 7.6, 7.8 and 44.1, 27.2 and 15.4 dS/m at 0-15, 15-30 and 30-60 cm respectively. Due to higher soil salinity levels in block-II and III, the spacing of mole drain followed was 3 m while it was 5 m in block-I. Cotton (Kaveri-Jadhu) was raised in polythene bags and transplanted on to the experimental plot on August 18, 2017 at 90 x 60 cm spacing. Though the crop was established, due to consistent rainfall, crop suffered due to waterlogging and yield was about 1.2 qt for whole block. The drainage water salinity was measured over three times and it varied from 4.58 to 25.7 dS/m, 8.74 to 39.7 dS/m and 5.31 to 7.75 dS/m in block-I, II and III respectively.

**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 2017-18 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 (0.6 x1.20 x 0.6 m). To monitor depth to water table, nine observation wells were installed. 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 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 pooled data of four years of experiment revealed that, among irrigation methods, significantly higher cane yield (131.0 t/ha) was recorded in subsurface drip compared to surface drip (124.4 t/ha) and furrow irrigation (105.0 t/ha) methods. Among irrigation levels, significantly higher yield (124.7 t/ha) was recorded at 1.2 ET irrigation level followed by 1.0 ET (121.0 t/ha) and least in case of 0.8 ET (114.7 t/ha). Significantly higher water use efficiency (WUE) of 83.0 kg/ha/mm was recorded in subsurface drip irrigation compared to surface drip (78.6 kg/ha/mm) and furrow irrigation (66.4 kg/ha/mm) methods. Among irrigation levels, significantly higher WUE (83.2 kg/ha/mm) was recorded at 0.8 ET followed by 1.0 ET (75.9 kg/ha/mm) and least in case of 1.2 ET (68.9 kg/ha/m).

Among irrigation methods, the brix percentage was significantly higher in case of subsurface drip (20.80%) compared to surface drip and furrow irrigation methods. The sugar water use efficiency (S-WUE) was significantly higher in subsurface drip irrigation (1.72 kg/$m^3$) followed by surface drip irrigation (1.59 kg/$m^3$) and least in furrow irrigation (1.34 kg/$m^3$) method. Among irrigation levels, significantly higher S-WUE was recorded at 0.8 ET (1.66 kg/$m^3$) followed by 1.0 ET (1.57 kg/$m^3$) and least in case of 1.2 ET (1.43 kg/$m^3$) irrigation level. The experiment was concluded.

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

Influence of saline water and different micro-irrigation techniques on soil properties, yield and water use efficiency of tomato *(Solanum lycopersicum)* & simulation modeling (HYDRUS) in Tungabhadra Command area was initiated during late Rabi -2018 at Agricultural Research Station, Gangavathi. The experiment consisted of irrigation methods as main treatments (surface drip irrigation, subsurface drip irrigation and furrow irrigation (control) and quality of irrigation water as sub-treatments (BAW, ECiw-2 dS/m, 3 dS/m, 4 dS/m and 5 dS/m. The irrigation water applied based on soil moisture tension and yield parameters of tomato are being collected at regular interval. The experiment is under progress.

**Evaluation of performance of sweet sorghum varieties/hybrids for bio-ethanol production under saline soils of TBP command area of Karnataka (Gangavathi)**

This experiment was initiated during *Rabi*-2017 on a saline vertisols (ECe 8-10 dS/m) at Agricultural Research Station, Gangvathi. The treatments consisted of fourteen (14) sweet sorghum genotypes procured from IIMR, Hyderabad and sown in November 2017 in RCBD design with three replications each. The results indicated that, among the fourteen (14) genotypes plant height and no. of internodes per plant was significantly higher with SPV-2023 (163.1 cm and 7.8 respectively) as compared to other genotypes but was on par with SPV-2025, RSSV-138-1, SSV-74, SSV-84, CSV-19SS and CSV-24SS. Whereas, brix reading was significantly superior with SPV-2325 (14.33) as compared to other genotypes, but was on par with SPV-2024, SPV-2023, RSSV-138-1, SSV-74, SSV-84, CSV-19SS and CSV-24SS. Due to stray animals and birds problem, yield data was not satisfactory and hence not considered.

**Yield maximization through permanent bed planting (PBP) with different furrow irrigation modes in cotton under saline Vertisols of TBP command area of Karnataka (Gangavathi)**

A field experiment laid out in a split plot design with nine treatments and three replications each was conducted during *Kharif* 2017at Agricultural Research Station, Gangavathi. Percent soil moisture content and soil pH and ECe were monitored before and after every irrigation. Both at surface and subsurface, percent soil moisture content was higher under Farmers' practice compared to Permanent Raised Bed (PRB)+Mulch and PRB+No-mulch. Among irrigation modes, EFI (Every Furrow Irrigation) had higher percent soil moisture over ASFI (Alternate Skip Furrow Irrigation) and PSFI (Permanent Skip Furrow Irrigation) respectively. Similarly, at both the depths, PRB+Mulch maintained lower soil ECe compared to PRB+No-mulch and Farmer's practice. Among irrigation modes, PSFI method maintained lower ECe over ASFI and EFI. Overall, the seed cotton yield under PRB+Mulch (2685 kg $ha^{-1}$) was significantly higher compared PRB+No mulch (2495 kg $ha^{-1}$) and Farmers' practice (2280 kg $ha^{-1}$). Among different irrigation modes, the seed cotton yield under PSFI (2580 kg $ha^{-1}$) was significantly higher compared to ASFI (2485 kg $ha^{-1}$) and EFI (2396 kg $ha^{-1}$). Furthermore, significantly higher net return and B:C ratio was obtained under PRB+Mulch (₹ 78770 $ha^{-1}$ and 2.76, respectively) compared PRB+No mulch and Farmers' practice respectively. The treatment PSFI (₹ 70856 $ha^{-1}$ and 2.50, respectively) had significantly higher net return and B:C ratio over EFI and ASFI respectively.

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

During 2016-17, economics of all the components of IFS was worked out and compared with conventional farming system of rice-rice monoculture. The data indicates that gross returns, net returns and B:C ratio was higher with IFS (Rs. 42,370/-, Rs. 26,860/- and 2.74, respectively) as compared to conventional farming system (Rs. 77,840/- Rs. 26,610 and 1.52, respectively). However, during 2017-18, it was observed that in IFS components gross and net returns (Rs.28,356 and Rs.10,396, respectively) were lower than conventional farming system (Rs. 70,000 and Rs. 20,150, respectively). However, the average B:C ratio (1.39) of all components in IFS was similar to that of conventional farming system (1.40). The lower net return in IFS components was mainly due to low yield in vegetable components and no yield in horticulture and fish components.

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

Land modification work was completed during peak summer. Experiment on integration of fish and crop/ vegetable cultivation are proposed in land modification model and will be undertaken soon. The crop/ vegetables will be grown on raised bunds. Soil samples were collected from 9 different locations on raised bund to know the fertility status. It is reported that pH of the soil varied from 7.87 to 8.13, having very high electrical conductivity (1:2; soil: water) ranged from 5.15 to 10.13, very low to organic carbon (0.08 - 0.13%) content and available phosphorus. However, it contains sufficient amount of available potassium. The soils of the site were deficient in all four micronutrients (Fe, Cu, Zn and Mn).

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

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

**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.

## MANAGEMENT OF SALINE–ACIDIC SOILS

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

#### A. Integrated farming system for sustainable land use in Pokkali lands – vegetable cultivation

Experimental data showed that mulching with polythene sheet was having a significant effect on crop growth and yield of vegetables viz. cauliflower, cabbage, cowpea and bhendi. The effect of mulching and drip fertigation was evident from the higher yields in case of bhendi and cowpea. Treatments with mulch were found to have significantly higher yields than treatments without mulch. Hence vegetable cultivation with mulch and drip fertigation is more effective vegetable cultivation on Pokkali bunds. It was also observed that yields obtained from cabbage and cauliflowers were very low and hence not suitable for cultivation.

#### B. Rice – prawn integration in Pokkali on farmer's field

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-1and total of 375 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 3.22. This is mainly because of the fact that the residues of prawn cultivation become manure for rice cultivation, thereby reducing the additional requirements of any external means of fertilisers. A multilevel integrated farming system model suitable for Pokkali lands which involve paddy-prawn-crab in low lands vegetables and other crops in the midlands with duck and goat farming is being tried. This is also having good benefit cost ratio of 2.06 along with improved economic status, livelihood opportunities and human nutrition. Integrating aquaculture with agriculture was found to be judicial management and ideal utilization of farm resources. Thus integrated farming is found to improve soil quality and it is cost effective as input requirement is less.

## MANAGEMENT OF POOR QUALITY WATERS

## MANAGEMENT OF ALKALI WATER

### Use of Alkali water to supplement Canal waters in Toria–chikori crop rotation (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 average of two years annually net profit for toria-chikori rotation was calculated. The maximum net profit with canal irrigated treatment was Rs. 1, 06,788 while lowest in alkali irrigated treatment Rs. 56,456. The benefit cost ratio in this rotation was calculated and found maximum in canal- irrigated treatment (3.62) and minimum in alkali water- irrigated treatment (1.95).

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

The plant height of safflower, blackgram, greengram and chickpea was 75.2, 39.8, 55.4, and 13.8 cm with 15, 9, 7 and 10 branches, respectively with gypsum treated water while 62.3, 26.2, 39.4 and 12.4 cm with 10, 7, 6 and 8 branches respectively when irrigated using untreated water. The highest yields were recorded with gypsum treated water in different crops like safflower (900 kg $ha^{-1}$), blackgram (700 kg $ha^{-1}$), greengram (575 kg $ha^{-1}$) and chickpea (1500 kg $ha^{-1}$) as against 825, 625, 450 and 1125 kg $ha^{-1}$, respectively with RSC water.

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

The average yield of rice varied from 23.16-39.45 in rice-wheat cropping system. The highest grain yield of 39.45 q/ha was obtained under best available water followed by 35.40 q/ha under RSCW - (Rest irrigation with BAW) and BAW + RSCW (23.16 q/ha) while lowest yield was obtained under RSCW treatment. The average grain yield of wheat varied from 16.92-34.87 q/ha in rice- wheat cropping system. The maximum grain yield of 34.87 q/ha was obtained under best available water (BAW) followed 29.51 q/ha under RSCW - (Rest irrigation with BAW) and 29.10 q/ha under BAW + RSCW while lowest grain yield was observed under RSCW treatment. The average grain yield of pearl-millet varied from 08.32-15.52 q/ha in pearl millet - wheat cropping system. The highest grain yield of 15.52 q/ha was obtained under BAW followed 13.07 q/ha obtained under RSCW - (Rest irrigation with BAW) and 12.14 q/ha under BAW + RSCW while lowest grain yield was recorded under RSCW treatment. The average grain yield of wheat varied from 17.28-35.11 q/ha in pearl millet- wheat cropping system. Changes in pH, EC, ESP and OC indicated overall improvement in soil properties in treated plots excluding RSCW plots. The soil pH, EC and ESP decreased in BAW irrigated plot and increased with 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 during 2016. 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.

The results of 2017 showed that drip and sprinkle irrigation were more effective and efficient than furrow irrigation for increasing the yield of vegetable crops cultivated under sodic soil condition. The maximum yield of 3895, 4820, 7980 and 3785 kg $ha^{-1}$ was recorded in cluster bean, bhendi, vegetable cowpea and onion, respectively under drip irrigation system. The yield increase in vegetables under drip irrigation over furrow irrigation was 38% in cluster bean, 28% in bhendi, 40% in vegetable cowpea and 28% in onion. 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.

Sowing of second crop of Cotton BG II hybrid RCH 20 was done along the ridges with a spacing of 90 cm between rows and 60 cm between plants during first week of March 2018.Other management practices like gap filling and weeding were carried out according to the recommended package of practices. Further observations are under progress.

**MANAGEMENT OF SALINE WATER**

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

Salt tolerance of crops and threshold EC levels were tested in a field experiment during 2016 and 2017 with three crops viz., cabbage, cauliflower and moringa grown with micro irrigation of waters having different salinity levels of BAW, 2, 4, 6 and 8 dS $m^{-1}$. Yield of cabbage showed a reduction from 40.08 to 11.78 t $ha^{-1}$ when salinity rose from 0.6 to 8 dS $m^{-1}$, resulting in an increase in the per cent yield reduction from 7.61 to 18.19. Similarly, the yields of cauliflower decreased from 18.67 to 6.12 t $ha^{-1}$ with yield reduction being 2.14 to 67.22 per cent. While, the yield reduction was higher in case of moringa realizing 95.87 per cent reduced yields at 8 dS $m^{-1}$, and 75% yield reduction was observed even at 4 dS $m^{-1}$.

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

Salt tolerance of crops and threshold EC levels were tested in a field experiment under shadenets with two crops viz., cabbage and cauliflower grown with micro irrigation of waters having different salinity levels of BAW, 2, 4, 6 and 8 dS $m^{-1}$. The 90%, 75% and 50% yield levels of cabbage and cauliflower in shadenets is found to be at 1.71, 3.23 and 5.76 dS $m^{-1}$ and 2.01, 3.56 and 6.13 dS $m^{-1}$ respectively. The yield of cabbage and cauliflower grown in shadenet is found to be 37 % and 35% more than the yields obtained in open field at all the salinity levels. The intervention of shadenets is offsetting the ill effects of irrigation water salinity to 37 and 35% in cabbage and cauliflower. The rest of the plant parameters are also showing clear differences in growth of the plant under salinity stress in open field and shadenets.

Any specified yield level of the crops could be achieved even at a higher EC level of irrigation water when the crop is grown in shadenets than in the open field. A 100% yield level could be attained at a salinity level of 0.2 and 0.7 dS $m^{-1}$ respectively in open field and shadenet for cabbage, while it was 0.8 and 1.0 dS $m^{-1}$ for cauliflower. Similarly, 75% and 50% yield levels could be achieved at 2.8 and 3.2 dS $m^{-1}$; 5.5 and 5.8 dS $m^{-1}$ respectively for cabbage with corresponding threshold EC levels of 3.3 and 3.6 dS $m^{-1}$ and 5.8 and 6.1 dS $m^{-1}$ for cauliflower. This could be due to reduced evaporation in shadenets and low crop water demand that might have led to low amount of irrigation water use and thus low additions of salts to the soil and lower capillary rise of salts along with water.

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

A study on Optimization of water requirement of groundnut-wheat cropping sequence using saline water under drip irrigation was conducted during 2016-17 and 2017-18. Salinity of irrigation water, irrigation volume and drip geometries brought about significant variations in yields of groundnut and wheat in both the years. Increase in salinity of irrigation water beyond 4 dS/ms caused drastic reduction in the pod yield of groundnut, whereas, wheat yield showed sharp decline beyond ECiw of 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 the crops. So far water requirement, 0.8 PE found to be at par with 1.0 PE, using 0.6 PE resulted in significant reduction in the yields of both the crops i.e. groundnut and wheat.

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

Another study on effect of fertility levels on isabgol – pearl millet crop sequence under drip irrigation using saline water was conducted during 2016-17 and 2017-18. Salinity of irrigation water and fertility levels had significant effect on grain yield of pearl millet. Increase in the ECiw beyond 4 dS/m caused significant reduction in the grain yield of both the crops. In respect of fertility levels, it is noted that application of 100% and 125% of recommended doses of NPK registered significant increase in grain yield of pearl millet and isabgol over 75% of RDF. In terms of straw yield also similar trend was observed.

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

During 2016-2017, 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 2). 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.

During 2017-18, the maximum plant height (215 cm), yield attributes viz., effective tillers/plant, earhead length (cm) and grain yield (36.33 q/ha) of pearl millet was obtained with RDF + FYM 10 t/ha + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (36.08 q/ha). The minimum grain yield (29.21 q/ha) was recorded with 75% RDF alone. The maximum grain yield (52.51 q/ha) of wheat (WH 1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (52.06 q /ha).The minimum grain yield (41.91 q/ha) was recorded with 75% RDF alone.

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

During 2016-17, 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 treatment sewage sludge 5 t/ha (alone), sewage sludge 5t/ha + 50% RDF and sewage sludge 5t/ha + 75% RDF as compared with RDF.

The grain yield of wheat (WH- 1105) decreased by 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.

During 2017-18, The grain yield of pearl millet (HHB 226) decreased by 23.03 and 31.08 % in all saline irrigation of 8 and 10 dS/m as compared to canal irrigation. A reduction of 20.56, 11.14 and 4.89% in grain yield of pearl millet was observed in treatment sewage sludge 5 t/ha (alone), sewage sludge 5t/ha + 50% RDF and sewage sludge 5t/ha + 75% RDF as compared with RDF.

The grain yield of wheat (WH 1105) decreased by 23.1 and 36.25% in all saline irrigation 8 and 10 dS/m as compared to canal irrigation. Reduction of 31.98, 12.33 and 5.98 % 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 vegetable crops (Hisar)**

During 2016-17, tomato crop 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.

During 2017-18, onion crops under drip irrigation in 75% RDN of nitrogen application, the relative yields of onion were obtained 94.50 and 65.74 % when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in RDN application, the relative yields of onion were obtained 95.41 and 69.67% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. Under drip irrigation in 125% recommended dose of nitrogen application, the relative yields of onion were obtained 94.51 and 68.79% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in 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)**

Response of leafy vegetables (Radish, Dill and Spinach) to five levels of saline water irrigation (i.e. pond water, water of EC 2,4,5 and 8 $dSm^{-1}$) and consequent changes in soil properties were studied under experiment conducted during *rabi* 2016-17 and rabi 2017-18. At all levels of irrigation water salinity radish performed better, it was followed by Spinach and Dill. However, yields of by Spinach and Dill were not significantly different. The irrigation water salinity-yield relations were developed for three crops.

**MANAGEMENT OF WASTE WATER**

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

A field experiment was conducted on cluster bean- cauliflower – okra crop rotation in sandy loam soil with a treatment combination having three irrigation water i.e. sewage water, tube well water and 1 sewage water: 1 tube well water and three levels of fertilizer i.e. 50, 75 and 100% recommended dose of fertilizer. The cluster bean was sown as a *kharif* crop while cauliflower was sown in winter season and okra crop was sown in summer season. It was observed that the crops irrigated with sewage water gave the highest yield compared with tube well water and 1 sewage water: 1 tube well water irrigation. The maximum net profit on basis of two years' data was for sewage water irrigation treatment (Rs. 3,02,415) and lowest in tube well water irrigated treatment (Rs. 1,38,337). The benefit cost ratio in this rotation was calculated and maximum was for sewage water irrigation treatment (4.80) and minimum in tube well irrigated treatment (2.48). The application of 100% RDF gave significantly higher yield of cluster bean, cauliflower and okra compared to 50 and 75% RDF.

**ALTERNATE LAND MANAGEMENT**

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

The experiment was laid out at Pedavodarevu village using Casuarina, Neem, sapota, Custard apple, Guava and Pomegranate plants. The initial soil pH and EC were 7.8 and 4.5 $dSm^{-1}$, respectively. All the crops were established well. The plant height recorded by casuarina (224.0, 483 cm), Neem (104.8, 345 cm), Sapota (115, 170 cm) Custard apple (41.3, 86 cm), guava (137.0, 360 cm) and Pomegranate (89.0, 252 cm) during 2017 and 2018, respectively.

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

Marigold, chrysanthemum and tulasi seedlings are grown under drip irrigation with BAW, 2, 4, 6 and 8 EC water. The plant height recorded by chrysanthemum, marigold and tulasi was (40.2, 37.8 cm), (62, 65 cm) and (57.2 and 37.8 cm), respectively with best available water while the plant height at 8 EC water was (32.0, 30.6 cm), (39, 49.2 cm) and (42.8, 33.0 cm), respectively for chrysanthemum, marigold and tulasi during 2016 and 2017. The number of flowers per plant recorded by chrysanthemum were (175, 175) and marigold (190, 246) with best available water while using 8 EC water the chrysanthemum recorded (70, 148) and marigold (75, 157), respectively during 2016 and 2017.

## SCREENING OF CROP CULTIVARS AND GENOTYPES

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

**Lentil :** Lentil entries were tested under saline and sodic waters during 206-17. The yield of lentil germplasm was significantly affected in saline water irrigation. The highest yield was produced by lentil germplasm LSL 16-3 (514.32 kg/ha) and lowest was recorded for germplasm LSL 16-6 (200.00 kg/ha). The yield of lentil germplasm was significantly affected by sodic water. The germplasm LSD 16-7 gave highest grain yield (739.38 kg/ha) and lowest yield was for LSD 16-6 (293.46 kg/ha).

**Mustard:** Screening of mustard cultivars (IVT and AVT) supplied by DRM, Bharatpur was carried out 2016-17 and 2017-18. The yield of genotype was significantly affected due to saline water irrigation. The significantly higher yield was produced by genotype CSCN-16-10 (25.48 q/ha) and lowest was recorded in genotype CSCN-16-6 (20.04 q/ha) during 2016-17. In 2017-18, genotype CSCN 17-10 gave higher grain yield (20.80 q/ha) and lowest was in case of CSCN 17-3 and CSCN 17-5 (15.86 q/ha). In case of AVT, CSCN 16-19 genotype gave highest yield (26.56 q/ha) while lowest was in of CSCN16-13 (19.98 q/ha) in 2016-17. During 2017-18, highest grain yield was recorded in CSCN 17-13 (20.23q/ha) and lowest was for CSCN 17-11 (15.82 q/ha).

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

The four mustard entries were supplied by ICAR-DRMR, Sewar, Bharatpur (Raj.) in the year 2016-17. The experiment was planned with three fertility levels i.e., 100, 125 and 150% of recommended dose of fertilizers. The highest grain yield was found for AG-19 (2803.70 kg/ha) and lowest for AG-17 (2182.72 kg/ha) but AG-18 and AG-20 were at par. The grain yield of mustard increased significantly with fertilizer dose i.e. 100%, 125% and 150% RDF. Increase in grain yield of mustard in case of 150% RDF was 9.43% over 100% RDF and 1.6% over 125% RDF. The application of 125% RDF significantly increased the grain yield of mustard by 7.7 % compared with 100% RDF.

In the year 2017-18, ICAR-DRMR supplied seven entries of mustard with three doses of fertilizer i.e. 100%, 125% and 150% of recommended dose of fertilizers and two plant spacing i.e. 30 cm x 10 cm and 45 cm x 15 cm. The highest grain yield was found for AG-17 (2129.49 kg/ha) in case of plant spacing of 30 x10 cm and (2206.72 kg/ha) in case of plant spacing of 45 x 15 cm and it was lowest in case of AG-14 (1682.01 kg/ha and 1720.76 kg/ha) for spacing 30 x 10 cm and 45x 15 cm. The grain yield of mustard entries increased significantly with fertility dose. In case of 30x10 cm spacing, increase in grain yield of mustard for 150% RDF and 125% RDF was 8.68 and 1.23% over control (100% RDF), respectively. In case of 45 x 15 cm plant spacing, increase in grain yield of mustard was 14.28 and 6.45% for 150 and 125% RDF, respectively.

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

The experiment was conducted at Bhavanamvaripalem village, Guntur district during Kharif-2016. Among the varieties tested (MCM-101, MCM-103, MCM-110, BPT-4455, BPT5204 , CSR-27 and CSR-36) , 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 BPT 5204 (5667 kg $ha^{-1}$). Among the varieties tested for salt tolerance during 2017, CSR 36 was significantly superior to other varieties, the grain and straw yields being 6400 and 7460 kg $ha^{-1}$, while, BPT 2615 realized a significantly lower corresponding yields of 5267 and 6325 kg $ha^{-1}$.

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

Another study on evaluation of cluster bean varieties (RGC-1066, RGC-936, RGC-1017 and RGC-1003) under saline irrigation water through drip was conducted during 2016 and 2017. Results showed that up to ECiw of 4 dS/m there was no significant reduction in the grain and straw yield of cluster bean, however, ECiw of 8 dS/m caused significant reduction in grain and straw yield of cluster bean over ECiw of 4 dS/m. Variety RGC 1066 established its superiority in grain and straw yield over RGC 936, RGC 1017 and RGC 1003.

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

**2016-2017**

The tolerance of cotton, wheat, pearl millet and mustard under saline water irrigation treatments was evaluated during 2016-2017 lined micro-plots of 2 m x 2 m in size.The tolerance of seven genotypes of cotton (H-1098i, H-1316, H-1353, H-1465, H-1472, H-1498 and H-1508), fourteen genotypes of wheat (P-9132, P-9134, P-9135, P-9137, P-9142, P-9143, P-12334, P-12883, P-12908, P-12953, P-13339, P-13348, Kh-65 and KRL-210), seven genotype of pearl millet (HHB-226, HHB-223, HHB-272, ICMB-834-22, ICMB-94555, HBL-11and HMS-47B) and ninteen genotypes of mustard IVT: CSCN-16-1, CSCN-16-2, CSCN-16-3, CSCN-16-4, CSCN-16-5, CSCN-16-6, CSCN-16-7, CSCN-16-8, CSCN-16-9 and CSCN-16-10. AVT-1: CSCN-16-11, CSCN-16-12, CSCN-16-13, CSCN-16-14, CSCN-16-15, CSCN-16-16, CSCN-16-17, CSCN-16-18 and CSCN-16-19) were tested under different saline water irrigation treatments i.e. canal water, $EC_{iw}$ 2.5, 5.0 and 7.5 dS/m.Uniform fertilizer applications were made in all the treatments using urea, DAP and $ZnSO_4$. The soil samples were collected before sowing and after the harvesting of the crops. The soil samples were air dried, ground to pass through a 2 mm sieve and analyzed for electrical conductivity. Among the seven cotton genotypes H-1472 gave maximum seed cotton yield (174.6 g/$m^2$) followed by H-1098i (199.25 g/$m^2$) with saline water (7.5 dS/m) irrigation whereas the performance of H-1465 was the poorest. Among the fourteen genotypes of wheat, 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. Among the pearl millet hybrids, HHB 226 performed best at ECiw (7.5 dS/m) followed by HHB 223 whereas the performance of HHB 272 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/$m^2$). Among the parents of pearl millet hybrids, ICMB-94555 was the highest yielder with mean grain yield of 116.80 g/$m^2$ whereas ICMB-843-22 was the poorest yielder with mean grain yield of 82.50 g/$m^2$ at ECiw 7.5 dS/m.

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. The mean salinity in the soil profile (0-30cm) at the time of sowing was varying from 1.68 to 8.54 dS/m in canal water to the highest EC irrigating water plot.

**2017-18**

During 2017-2018, the tolerance of seven genotypes of cotton (H 1098i, H 1316, H 1353, H 1465, H 1472, H 1489 and H 1508), fourteen genotypes of wheat (WH 1218, WH 1235, WH 1240, WH 1241,

WH 1242, WH 1243, WH 1244, WH 1246, WH 1247, WH 1248, WH 1249, WH 1250, KRL 19 and KRL 210), seven genotype of pearl millet (HHB 146, HHB 226, HHB 272, HBL 11, HMS-47B, AC-04/13 and ICMB-843-22B) and twenty two genotypes of mustard (IVT: CSCN-17-1, CSCN-17-2, CSCN-17-3, CSCN-17-4, CSCN-17-5, CSCN-17-6, CSCN-17-7, CSCN-17-8, CSCN-17-9 and CSCN-17-10.AVT-1: CSCN-17-11, CSCN-17-12, CSCN-17-13, CSCN-17-14, CSCN-17-15, CSCN-17-16, CSCN-17-17, CSCN-17-18, CSCN-17-19, CSCN-17-20, CSCN-17-21, CSCN-17-22) were tested under different saline water irrigation treatments i.e. canal water, $EC_{iw}$ 2.5, 5.0 and 7.5 dS/m for cotton and pearl millet and $EC_{iw}$ 5.0,7.5 and 10.0 dS/m.

Among the seven genotypes, H-1472 gave the highest (220.63 $g/m^2$) seed cotton yield and H-1465 resulted in the lowest seed cotton yield (166.09 $g/m^2$) at $EC_{iw}$ 7.5 dS/m.

In wheat genotype WH 1250 performed the best at $EC_{iw}$ 10.0 dS/m and gave 21.64% higher grain yield compared with KRL 210 (check). It was followed by WH 1247 which gave 15.97 % higher grain yield than KRL 210 whereas the performance of KRL 19 was the least. On the basis of overall mean, WH 1250 gave maximum grain yield (495.72 $g/m^2$) which was 27.74% higher than KRL 210 followed by WH 1247 (476.49 $g/m^2$) which was 22.78% higher than KRL 210.

Among the pearl millet hybrids, HHB 226 performed best at ECiw (7.5 dS/m) followed by HHB 272 whereas the performance of HHB 146 was the poorest. The mean grain yield (271.96 $g/m^2$) of HHB 226 was higher than other genotypes followed by HHB 272 (233.95 $g/m^2$) and HHB 146 (205.76 $g/m^2$). Among the parents of pearl millet hybrids, ICMB-843-22B was the highest yielder with mean grain yield of 85.47 $g/m^2$ whereas AC-04/13 was the poorest yielder with grain yield of 68.81 $g/m^2$ at ECiw 7.5 dS/m.

In IVT, the mustard genotypes CSCN-17-10 gave the highest seed yield (221.62 $g/m^2$) followed by CSCN-17-1 (200.08 $g/m^2$) at ECiw 10.0 dS/m and the lowest seed yield (172.67$g/m^2$) was obtained in CSCN-16 -5. In AVT, the mustard genotypes CSCN-17-13 gave the highest seed yield (221.90 $g/m^2$) followed by CSCN-17-22 (218.38 $g/m^2$) at ECiw 10.0 dS/m and the lowest seed yield (181.70 $g/m^2$) was obtained in CSCN-17-11. The mean salinity in the soil profile (0-30cm) at the time of sowing was varying from 1.62 to 10.29 dS/m in canal water to the highest EC irrigating water plot.

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

The average grain yield of rice varied from 22.30-43.43 q/ha in different varieties. The highest grain yield of 43.43 q/ha of rice was obtained in variety CSR 36 followed by 41.15 q/ha from CSR 23 and 38.49 q/ha from CSR 43. The lowest grain yield of 22.30 q/ha was obtained from CSR 30. The average grain yield of wheat varied from 27.37-36.21 q/ha in different varieties. The highest grain yield of 36.21 q/ha of wheat was recorded from variety KRL 210 followed by 34.82 q/ha from KRL 213 and 33.41 q/ha from PBW-343. The minimum grain yield of 27.37 q/ha was obtained from WH 147. The average grain yield of mustard varied from 10.69-16.47 q/ha in different varieties. The highest grain yield of 16.47 q/ha of mustard was recorded from variety CS 56 followed by 14.77 q/ha from CS 54 and 13.56 q/ha from CS 52 whereas variety Varuna, Rohini and Kranti yielded at par grain yield. The lowest grain yield of 10.69 q/ha was obtained from variety Urvasi.

**Evaluation of chilly and onion for 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. Further, a field experiment was conducted to assess the effect of different Exchangeable Sodium Percentage (ESP) levels of soil on growth and yield of onion and to fix optimum sodicity tolerance limits of onion based on the performance under different soil sodicity levels. The results revealed that among the different levels of ESP, the bulb yield was declined with increased ESP levels from 8. However, more than 50 per cent yield could be achieved up to 24 ESP level. Among the varieties Co 5 (seed) and local (Bulb), the performance of Co 5 was superior over local. The highest onion bulb yield of 14206 and 16213kg per hectare was recorded in local (onion bulb) and Co5 (seed) varieties respectively. Similar trend with respect to the individual bulb weight per plant was also recorded. Hence, it is concluded that the onion can be grown in sodic soil up to the ESP level of 24 where the 50 per cent of yield.

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

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. The maximum cluster per plant was recorded in germplasm IC 41202 followed by IC 40235 > IC 40417 > IC 113578 > IC40752 under poor quality water. The grain yield per plant significantly got 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.

**Screening of wheat cultivars for salt tolerance (Bathinda)**

The seven verities namely HD 3086, HD 2967, KR L 213, Unnat PBW 550, PBW 725, KRL210 and Unnat PBW343 were grown under two quality water ( canal water and Tubewell water) having different chemical compositions. Maximum grain yield was reported in variety HD 3086 followed by Unnat PBW 550 and PBW 725 under the both conditions.

**ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS**

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

The technology transfer program for saline water use was based on the technology developed by center. It was implemented on farmers' fields for different types of poor quality waters i.e. saline, high SAR-saline and alkali water at village Odara in Bharatpur district and Savai village in Agra district. The year of 2016-17, 19 farmers were selected from Odara village(District Bharatpur, Rajasthan), 8 farmers (with high SAR saline water) from Savai village (District Agra) 3 farmers (with alkali water) and 7 farmers (with saline water) were selected from Deen Dayal Dham (Nagla Chandra Bhan), Dhana Khema, Nagla Jalal, Garhi Pachauri and Dalatpur in district Mathura (U.P.) EC of irrigation water ranged from 7.1 to 13.0 dS/m.

During 2017-18, the total 11 farmers selected from different villages such as Deen Dayal Dham (Nagla Chandra Bhan), Dhana Khema, Nagla Jalal, Garhi Pachauri and Dalatpur in district Mathura (U.P.) and Odara in Bhratpur district (Rajasthan) for saline water use demonstrations. ECiw ranged from 7.1 to 13.0 dS/m. The type of technology demonstration (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) changed according to nature of water problem. It was observed that adoption of improved technologies helped to increase crop yield over non-adopters. The use of forate and zinc also gave fruitful results by controlling the effect of termite and zinc deficiencies.

In alkali water, three farmers grew wheat, gypsum application increased yield by 12.2 per cent. At recharge sites, wheat yield ranged (3.75 to 4.87 t/ha) and yield increase was 11.3 per cent over traditional farmers. In case of saline water increase in yield was 10.2 per cent. In case of mustard yield increase was 12.8 per cent in rain water recharge site.

In the year 2017-18, five farmers grew mustard crop. The ORP farmers' mustard grain yield ranged from 21.2 to 25.8 q/ha and other farmers' yield ranged from 19.2 to 22.7 q/ha. The net profit of ORP farmers in case of mustard crop ranged from Rs. 58,103 to 75,646 and B: C ratio ranged from 3.3 to 4.5 and it ranged from Rs. 50,098 to 57,911 and B:C ratio from 2.6 to 2.9 for other farmers.

At ORP site, six farmers grew wheat crop under conjunctive use. The ORP farmers' wheat yield ranged from 42.7 to 44.9 q/ha and other farmers yield ranged from 38.9 to 40.5 q/ha. The net profit of ORP farmers for wheat crop ranged from Rs. 58,980 to 64,338 and B: C ratio ranged from 1.8 to 2.0. In case of other farmers, it ranged from Rs. 41,935 to 48,000 and B:C ratio from 1.1 to 1.4. At ORP site, one farmer who adopted organic wheat cultivation produced 47.2 q/ha compared with traditional farming system 41.8 q/ha. The net profit and B:C ratio of this farmer was found Rs. 1,08,105 & 4.1 compared with traditional farmer Rs. 49,815 & 1.4.

**Evaluation of microbial formulations for crop productivity and soil health under different agro-ecosystem (Agra)**

Effect of microbial formulation on yield of sorghum crop was studied during 2017-18. The yield and yield attributing characters were significantly affected in different treatments. The highest grain yield (28.5 q/ha) of sorghum was recorded with microbial formulation T5 (Halo Azo + Halo PSB inoculation + FYM/VC/ Compost @2.5t/ha +75% RDF) treatment and it was lowest (24.0 q/ha) in T2 (Un-inoculated + FYM/VC/ Compost @2.5t/ha +75% RDF). After harvest of crop, the organic carbon, available N, available P and available K in soil profile (0- 30cm) were higher in T5 treatments as compared to other treatments

**Survey and investigations for planning conjunctive use of Nallamada drain water with Kommamuru canal for augmenting irrigation (Bapatla).**

The analysis of water samples collected revealed that in a given water year, the quality of water is changing enormously and it is found to be the recent trend since 2015. The quality of water flowing in the drain during rabi season/NE is much poor and is not fit for agricultural or domestic use. The study needs to be conducted as per the tidal calendars instead of monthly sampling. The range of salinity is very high as 32.5 $dSm^{-1}$ near the estuary, it is 13.7 and 3.9 $dSm^{-1}$ in the middle and at the upstream again, it is shooting up to 26.5 $dS\ m^{-1}$. This is very alarming and farmers are to be strictly advised to go for testing of these waters before using it for any crop. Nallamada drain water can be used for crop production if it is conjunctively used along with Kommamuru canal in scientifically rationed proportions.

**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 was 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 as 59.6 %, 23.72, 3.27 cm and 124.48 q/ha. The yield enhancement of 24.07% was observed with CSR-Bio (soil application + foliar spray) and 19.43 % with CSR-Bio (soil application) over control. The maximum survival percentage, no. of leaves, head weight and yield of cabbage was recorded 69.5, 11.45, 0.92 kg and 151.57 q/ha. The yield enhancement of 25.30% was obtained with CSR-Bio (soil application + foliar spray) and 20.71% with CSR-Bio (soil application) over control. The data indicated that there was reduction in pH, EC and ESP in both treatments including control, maximum decrease, however was observed in CSR-Bio (soil application + foliar spray) treated plots. The organic carbon improved with the application of CSR-Bio treated plots.

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

Data showed that variety KRL210 showed higher plant height, whereas HD 2967 perform higher number of tillers/$m^2$ and ear length among the varieties tested. The variety KRL-213 showed higher number of seed/ear followed by HD 2967, whereas, higher grain yield was observed in variety HD2976 followed by KRL 210 and KRL213.

## INTRODUCTION

The All India Coordinated Project for Research on Use of Saline Water in Agriculture was first sanctioned during the Fourth Five Year Plan under the aegis of Indian Council of Agricultural Research, New Delhi at four research centres namely Agra, Bapatla, Dharwad and Nagpur to undertake researches on saline water use for semi-arid areas with light textured soils, arid areas of black soils region, coastal areas and on the utilization of sewage water, respectively. During the Fifth Five Year Plan the work of the project continued at the above four centres. In the Sixth Five Year Plan, four centres namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water and Soil Salinity Management were transferred to this Project whereas the Nagpur Centre was dissociated. As the mandate of the Kanpur and Indore centres included reclamation and management of heavy textured alkali soils of alluvial and black soil regions, the Project was redesigned as All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture. Two of its centres located at Dharwad and Jobner were shifted to Gangavati (w.e.f. 1.4.1989) amd Bikaner (w.e.f. 1.4.1990), respectively, to work right at the locations having large chunks of land afflicted with salinity problems. During the Seventh Plan, the project continued at the above locations. During Eighth Five Year Plan, Two new centres at Hisar and Tirruchirapalli were added. These centres started functioning from I$^{st}$ 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 Agri. Univ. Tiruchirappalli (Tamil Nadu)

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

**Volunteer Centres**

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

**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 three Year Plan (2017–2020) 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 and 2017-18 are given in the Section 7.6.

## RESEARCH ACCOMPLISHMENTS

# 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 and Kurnool district Andhra Pradesh (Bapatla)

Soil survey was conducted in salt affected soils of ten districts in Andhra Pradesh from the selected points and analyzed for various soil properties. Mapping and digitization of surveyed area is done based on satellite imageries of 2010 and classification of salt affected soils as per CSSRI is completed in eight districts viz., Chittor, Vizayanagaram, Vizakhapatnam, Srikakulam, Nellore, East Godavari, Krishna and West Godavari and for the remaining districts is under progress (NRSA 2008).

The results of the survey conducted during 2015-16 in Ananthapur district 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 $m^{-1}$) with low to high organic carbon, available phosphorous (19.3 to 62.3 kg $ha^{-1}$) and available potassium (120 to779 kg $ha^{-1}$) and low to medium 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 53 locations along with GPS coordinates with 1: 50,000 toposheet during March, 2017. Sandy clay loam, clay and sandy loam were dominant textural groups of the surface soils with the corresponding proportions of 32, 26 and 15 per cent followed by clay loam (9.4%), loamy sand (9.4%) and sandy clay (7.6%). While, the sandy clay loam dominated the sub surface comprising of 51 per cent of the samples followed by clay (21%), loamy sand (15.1%), sandy clay (5.7%) and clay (5.7%). The CEC of surface and sub surface soils ranged from 2-39.1 and 3.3-38.15 c mol (p+) kg-1 soil respectively.

The pH of the surface soils ranged from 5.5 to 10.3, while EC from 0.3 to 33 dS m-1 with a mean of 4.42 dS $m^{-1}$; SAR was from 0.25 to 79.8 with a mean of 10.4. When SAR is considered, 32% of surface soils and 23% of sub surface soils were having SAR>10 (Table 1.1).The mean ionic composition of surface soils is higher than sub surface soils with $HCO_3^-$, $Cl^-$, $SO_4^{2-}$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$ contents of 11.8, 23.5, 5.36, 7.73, 3.67, 29.6 and 0.82 me $L^{-1}$ respectively as against the corresponding mean contents of 0.8, 16.2, 4.34, 4.4, 2.93, 21.1 and 0.72 me $L^{-1}$ at 25.50 cm depth (Table 1.2).

Table 1.1 Physico chemical properties of soils collected from salt affected areas of Kurnool (2017)

| Depth (cm) | pH | | $EC_e$ ($dSm^{-1}$) | | SAR | |
|---|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | Range | Mean |
| 0-25 | 5.5 to 10.3 | - | 0.3 to 33.0 | 4.42 | 0.25 to 79.8 | 10.4 |
| 25-50 | 4.8 to 10.2 | - | 0.2 to 19.0 | 7.27 | 0.19 to 57.5 | 9.64 |

The organic carbon content of surface soil ranged from 0.01 to 0.91 per cent (av. 0.3%) against 0.01 to 0.52 (av. 0.19%) per cent in the sub soil. Clay, sand and silt fractions of surface soils ranged from 2-62.4, 1.6-78.8 and 2.8-36.4 per cent with CEC ranging from 2-39.1 c mol (p+) $kg^{-1}$ soil. While in the sub surface the particle size fractions were 8.4-60.8, 9.2-88 and 0.4-36 per cent with the CEC of 3.3 – 41.21 c mol (p+) $kg^{-1}$ soil (Table 1.3).

Table 1.2 Soluble ion content in salt affected soils of Kurnool district

| Parameter ($meqL^{-1}$) | Surface | | Subsurface | |
|---|---|---|---|---|
| | Range | Mean | Range | Mean |
| $CO_3^{2-}$ | - | - | - | - |
| $HCO_3^-$ | 0.6 to 72.8 | 11.8 | 6.8 to 56.4 | 0.8 |
| Cl- | 0.4 to 181.6 | 23.5 | 0.4 to 108.8 | 16.2 |
| $SO_4^{2-}$ | 0.12 to 61.6 | 5.36 | 0.1 to 31.6 | 4.34 |
| $Ca^{2+}$ | 0.8 to 58.8 | 7.73 | 0.4 to 20.0 | 4.4 |
| $Mg^{2+}$ | 0.4 to 26.8 | 3.67 | 0.4 to 16.0 | 2.93 |
| $Na^+$ | 0.032 to 276 | 29.6 | 0.027 to 162.5 | 21.1 |
| $K^+$ | 0.15 to18.8 | 0.82 | 0.04 to 17.1 | 0.72 |

Table 1.3 Soil fertility in surface and subsurface soils of Kurnool district

| Parameter | Surface | | Subsurface | |
|---|---|---|---|---|
| | Range | Mean | Range | Mean |
| Available N (kg $ha^{-1}$) | 37.6 to 363 | 121 | 37.6 to 175 | 107 |
| Available $P_2O_5$ (kg $ha^{-1}$) | 7.4 to 66.5 | 26.9 | 7.0 to 84 | 28.1 |
| Available $K_2O$ (kg $ha^{-1}$) | 100 to 964 | 308 | 66.9 to 762 | 229.7 |
| OC % | 0.01 to 0.91 | 0.3 | 0.01 to 0.52 | 0.19 |
| Zn (ppm) | 0.1 to 2.2 | 0.4 | 0.02 to 1.97 | 0.33 |
| Mn (ppm) | 1.2 to 31.8 | 6.0 | 1.24 to 24.3 | 4.9 |
| Fe (ppm) | 0.2 to 18.7 | 1.5 | 0.2 to 7.1 | 1.1 |
| Cu (ppm) | 0.1 to 5.6 | 0.7 | 0.3 to 1.6 | 0.6 |

**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. In Hospet taluk, Bellary district a total of 121 samples were collected for soil salinity appraisal.

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, $SO_4$, $CO_3$, $HCO_3$). With the available data, SAR, ($CO_3$+$HCO_3$)/ (Cl+$SO_4$) and (Na/(Cl+$SO_4$) ratios were calculated.

**Raichur district**

In Raichur district (Table 1.4 and 1.5), 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 ($dSm^{-1}$) and 47 to 0.14 ($dSm^{-1}$) respectively with an average of 8.09, 7.56, 1.27, 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 13 per cent of surface samples had ECe > 4.0 $dSm^{-1}$ reflecting that these soils are saline. However, per cent of samples with >1 ($CO_3$+$HCO_3$)/ (Cl+$SO_4$)and (Na/(Cl+$SO_4$) ratios were to the extent of nearly 6 and 39 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 varied from 9.66 to 6.14, 8.42 to 6.66, 12.5 to 0.11 ($dSm^{-1}$), and 24 to 0.28 ($dSm^{-1}$) with an average of 8.33, 7.75, 1.08 $dSm^{-1}$ and 2.25 $dSm^{-1}$ respectively. Nearly 10 per cent of samples were considered to be saline as the $EC_e$ of these samples was >4.0 $dSm^{-1}$. The overall mean of the ($CO_3$+$HCO_3$)/ (Cl+$SO_4$)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 $dSm^{-1}$ and 14.0 to 0.38 $dSm^{-1}$ with an average of 8.38, 7.66, 1.32 $dSm^{-1}$ and 2.70 $dSm^{-1}$ respectively. Similar to above depths, Na+ and Cl- were the dominant cation and anion respectively. Nearly 15 per cent of samples were found to be saline as their ECe was >4.0 $dSm^{-1}$. The overall mean of ($CO_3$+$HCO_3$)/ (Cl+$SO_4$) was less than 1 whereas (Na/(Cl+$SO_4$) 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.

Table 1.4 Characterization of soil samples 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) | 9.00 | 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 | 1.27 | 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 ($dSm^{-1}$) | 47.0 | 0.14 | 2.68 | 24.0 | 0.28 | 2.25 | 14.00 | 0.38 | 2.70 | 11.60 | 0.52 | 2.51 |
| Cations/Anions (meq/L) | | | | | | | | | | | | |
| Ca+Mg | 154.8 | 1.20 | 9.54 | 49.2 | 2.10 | 7.44 | 31.50 | 1.90 | 7.16 | 25.80 | 2.20 | 6.93 |
| $Na^+$ | 81.7 | 0.46 | 16.9 | 110.9 | 1.39 | 15.12 | 117.0 | 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 |
| $HCO_3^-$ | 144.0 | 4.00 | 9.8 | 18.0 | 3.50 | 7.79 | 14.00 | 3.00 | 7.69 | 19.0 | 4.00 | 9.28 |
| $Cl^-$ | 139.0 | 7.00 | 17.84 | 115.0 | 5.00 | 14.35 | 76.00 | 5.50 | 14.6 | 53.0 | 7.00 | 14.1 |
| $SO_4^{2-}$ | 2.50 | Tr | 0.46 | 2.08 | Tr | 0.32 | 2.40 | 0.02 | 0.46 | 1.96 | 0.04 | 0.59 |
| SAR | 26.8 | 0.24 | 8.50 | 57.07 | 1.02 | 8.42 | 33.18 | 1.23 | 9.78 | 36.86 | 2.79 | 11.8 |
| ($CO_3$+$HCO_3$)/ (Cl+$SO_4$) | 1.25 | 0.07 | 0.61 | 1.51 | 0.12 | 0.72 | 1.40 | 0.06 | 0.72 | 1.72 | 0.16 | 0.75 |
| Na/(Cl+$SO_4$) | 3.34 | 0.05 | 0.96 | 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.*

At 60+ cm, the pH(1:2.5), pHs, EC(1:2.5), and $EC_e$ varied from 9.58 to 7.87, 9.03 to 7.48,5.4 to 0.30 $dSm^{-1}$ and 11.6 to 0.52 $dSm^{-1}$ with an average of 8.67, 8.14, 1.26 $dSm^{-1}$ and 2.51 $dSm^{-1}$ 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 $EC_e$ was >4.0 $dSm^{-1}$. The overall mean of the $(CO_3+HCO_3)$/ $(Cl+SO_4)$ was less than 1 whereas $(Na/(Cl+SO_4)$ ratio was >1. However, about 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.

Table 1.5 Distribution of soil samples (%) from Raichur district, Karnataka for soil salinity appraisal

| Soil Depth (Cm) | pHs | | | $EC_e$ ($dSm^{-1}$ ) | | | $(CO_3+HCO_3)$/ $(Cl+SO_4)$ | | $(Na/(Cl+SO_4)$ | | SAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <7.5 | 7.5-8.5 | >8.5 | <2.0 | 2-4 | >4 | <1 | >1 | <1 | >1 | <13 | >13 |
| 0-15 | 31.8 (34) | 68.2 (73) | 0 | 64.5 (69) | 22.4 (24) | 13.1 (14) | 94.4 (101) | 5.60 (6) | 60.7 (65) | 39.3 (42) | 84.1 (90) | 15.9 (17) |
| 15-30 | 15.7 (16) | 84.3 (86) | 0 | 66.64 (68) | 23.52 (24) | 9.80 (10) | 87.2 (89) | 12.7 (13) | 51.9 (53) | 48.0 (49) | 88.2 (90) | 11.8 (12) |
| 30-60 | 32.4 (23) | 67.6 (48) | 0 | 62.0 (44) | 22.6 (16) | 15.4 (11) | 84.5 (60) | 15.5 (11) | 40.84 (29) | 59.16 (42) | 73.24 (52) | 26.76 (19) |
| 60 + | 2.33 (1) | 97.67 (42) | 0 | 48.84 (21) | 34.88 (15) | 16.28 (7) | 79.07 (34) | 20.93 (9) | 46.51 (20) | 53.49 (23) | 65.11 (28) | 34.89 (15) |

No. of samples: 107 (0-15 cm), 102 (15-30 cm), 71 (30-60 cm) and 43 (60 + cm)

**Sindhanur, Manvi, Devdurga and Raichur Taluks**

Characterization of soil samples collected from Sindhanur, Manvi, Devdurga and Raichur taluks of Raichur district for soil salinity appraisal as well as percent distribution of soil properties of samples were done and are presented below in Table 1.6 to Table 1.11.

Table 1.6 Characterization of soil samples collected from Sindhanur taluk, Raichur, 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 | 9.0 | 7.6 | 8.3 | 9.00 | 7.87 | 8.54 |
| EC (1:2.5) | 21.0 | 0.20 | 1.90 | 12.5 | 0.30 | 1.43 | 6.9 | 0.3 | 1.5 | 3.30 | 0.30 | 1.17 |
| pHs | 8.10 | 6.80 | 7.60 | 8.34 | 7.00 | 7.86 | 8.2 | 7.3 | 7.7 | 8.59 | 7.48 | 7.99 |
| ECe ($dSm^{-1}$) | 47.0 | 0.50 | 4.40 | 24.0 | 0.47 | 3.04 | 14.0 | 0.4 | 3.0 | 6.40 | 0.52 | 2.35 |
| Cations/Anions (meq/L) | | | | | | | | | | | | |
| Ca+Mg | 154.8 | 2.30 | 14.0 | 49.20 | 3.10 | 9.29 | 29.0 | 1.9 | 7.4 | 25.8 | 2.20 | 6.10 |
| $Na^+$ | 81.7 | 1.91 | 21.1 | 49.26 | 2.17 | 15.15 | 44.6 | 2.1 | 15.5 | 50.00 | 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 |
| $HCO_3^-$ | 144.0 | 4.50 | 12.4 | 18.00 | 3.50 | 7.70 | 12.0 | 3.0 | 7.3 | 10.50 | 4.00 | 6.93 |
| $Cl^-$ | 139.0 | 7.00 | 22.20 | 115.0 | 5.00 | 18.20 | 76.0 | 5.50 | 17.1 | 53.00 | 7.00 | 12.9 |
| $SO_4^{2-}$ | 2.29 | 0.09 | 0.61 | 2.10 | Tr | 0.40 | 2.08 | 0.02 | 0.47 | 1.64 | 0.04 | 0.55 |
| SAR | 26.76 | 1.43 | 8.83 | 22.08 | 1.56 | 7.45 | 19.77 | 1.80 | 9.26 | 21.26 | 2.79 | 11.8 |
| $(CO_3+HCO_3)$/ $(Cl+SO_4)$ | 0.97 | 0.20 | 0.54 | 1.13 | 0.12 | 0.63 | 1.40 | 0.06 | 0.67 | 1.09 | 0.16 | 0.65 |
| $Na/(Cl+SO_4)$ | 2.26 | 0.22 | 0.98 | 2.79 | 0.12 | 0.98 | 2.59 | 0.21 | 1.14 | 2.76 | 0.43 | 1.52 |

Table 1.7 Distribution of soil samples (%) from Sindhanur taluk, Raichur district, Karnataka

| Soil Depth (Cm) | pHs | | | $EC_e$ ($dSm^{-1}$) | | | $(CO_3+HCO_3)/(Cl+SO_4)$ | | $(Na/(Cl+SO_4)$ | | SAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <7.5 | 7.5-8.5 | >8.5 | <2.0 | 2-4 | >4 | <1 | >1 | <1 | >1 | <13 | >13 |
| 0-15 | 31.7 (13) | 68.3 (28) | 0 | 58.5 (24) | 19.5 (8) | 22.0 (9) | 100 (42) | 0 | 63.4 (26) | 36.6 (15) | 85.4 (35) | 14.6 (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) | 90.48 (38) | 9.52 (4) |
| 30-60 | 25.0 (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) |

*No. of samples: 42 (0-15 cm), 42 (15-30 cm), 36 (30-60 cm) and 21 (60 + cm)*

Table 1.8 Characterization of soil samples collected from Manvi taluk, Raichur district, Karnataka

| 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 |
| $EC_e$ ($dSm^{-1}$) | 6.60 | 0.14 | 1.79 | 6.60 | 0.28 | 1.64 | 9.90 | 0.48 | 2.23 | 11.60 | 0.68 | 2.67 |
| Cations/Anions (meq/L) | | | | | | | | | | | | |
| Ca+Mg | 45.7 | 1.20 | 6.73 | 31.40 | 2.10 | 5.77 | 29.50 | 2.40 | 6.47 | 22.60 | 2.60 | 7.56 |
| $Na^+$ | 69.6 | 0.46 | 15.81 | 69.60 | 1.39 | 14.10 | 99.00 | 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 |
| $HCO_3^-$ | 12.0 | 4.00 | 8.00 | 13.50 | 4.50 | 7.63 | 10.5 | 5.50 | 7.87 | 13.50 | 6.50 | 11.4 |
| $Cl^-$ | 61.00 | 7.00 | 14.69 | 46.50 | 6.50 | 11.70 | 27.0 | 6.50 | 11.0 | 49.50 | 9.50 | 16.0 |
| $SO_4^{2-}$ | 1.67 | Tr | 0.39 | 1.48 | 0.02 | 0.25 | 1.02 | 0.04 | 0.40 | 1.96 | 0.05 | 0.66 |
| SAR | 23.20 | 0.44 | 8.72 | 57.07 | 1.02 | 9.03 | 33.18 | 1.23 | 10.4 | 36.86 | 3.95 | 11.8 |
| $(CO_3+HCO_3)/(Cl+SO_4)$ | 1.25 | 0.14 | 0.62 | 1.51 | 0.19 | 0.74 | 1.26 | 0.27 | 0.77 | 1.41 | 0.24 | 0.81 |
| $Na/(Cl+SO_4)$ | 3.34 | 0.05 | 0.99 | 7.67 | 0.17 | 1.19 | 7.33 | 0.26 | 1.55 | 2.89 | 0.41 | 1.24 |

Table 1.9 Percent distribution of soil samples from Manvi taluk, Raichur district, Karnataka

| Soil Depth (Cm) | pHs | | | $EC_e$ ($dSm^{-1}$) | | | $(CO_3+HCO_3)/(Cl+SO_4)$ | | $(Na/(Cl+SO_4)$ | | SAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <7.5 | 7.5-8.5 | >8.5 | <2.0 | 2-4 | >4 | <1 | >1 | <1 | >1 | <13 | >13 |
| 0-15 | 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) | 84.78 (39) | 0 | 67.39 (31) | 28.26 (13) | 4.35 (2) | 86.96 (40) | 13.0 (6) | 50.0 (23) | 50.0 (23) | 91.30 (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 | 100.0 (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) |

*No. of samples: 50 (0-15 cm), 46 (15-30 cm), 30 (30-60 cm) and 18 (60 + cm)*

Table 1.10 Characterization of soil samples from Devdurga and Raichur taluks, Raichur, Karnataka

| 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) | 8.94 | 7.53 | 8.10 | 9.46 | 7.70 | 8.47 | 8.72 | 8.18 | 8.37 | 9.58 | 8.00 | 8.74 |
| EC (1:2.5) | 9.90 | 0.13 | 1.07 | 6.70 | 0.15 | 0.97 | 5.00 | 0.24 | 2.07 | 2.70 | 0.69 | 1.32 |
| pHs | 8.08 | 7.16 | 7.62 | 8.42 | 7.36 | 7.70 | 8.12 | 7.25 | 7.66 | 8.65 | 7.76 | 8.27 |
| ECe ($dSm^{-1}$) | 16.6 | 0.44 | 2.04 | 13.4 | 0.36 | 1.86 | 12.20 | 1.28 | 5.14 | 7.60 | 1.01 | 2.68 |
| Cations/Anions (meq/L) | | | | | | | | | | | | |
| Ca+Mg | 44.20 | 2.40 | 6.98 | 40.40 | 2.20 | 7.41 | 31.50 | 2.20 | 13.1 | 18.40 | 4.70 | 8.28 |
| $Na^+$ | 23.91 | 0.52 | 9.56 | 110.9 | 2.87 | 18.3 | 117.0 | 5.00 | 44.6 | 73.91 | 9.13 | 26.4 |
| $K^+$ | 0.48 | 0.05 | 0.15 | 0.15 | 0.04 | 0.07 | 0.15 | 0.05 | 0.09 | 0.09 | 0.03 | 0.05 |
| $HCO_3^-$ | 12.00 | 6.00 | 8.50 | 13.50 | 5.00 | 8.46 | 14.00 | 7.00 | 9.50 | 19.00 | 8.00 | 12.1 |
| $Cl^-$ | 97.5 | 7.50 | 16.66 | 51.00 | 6.00 | 11.54 | 55.50 | 5.50 | 22.8 | 26.50 | 10.0 | 15.0 |
| $SO_4^{2-}$ | 2.50 | 0.01 | 0.31 | 1.93 | 0.01 | 030 | 2.40 | 0.28 | 1.08 | 1.71 | 0.05 | 0.53 |
| SAR | 17.9 | 0.23 | 6.81 | 25.50 | 1.63 | 9.31 | 29.48 | 2.96 | 14.5 | 24.37 | 5.89 | 11.1 |
| $(CO_3+HCO_3)/(Cl+SO_4)$ | 1.10 | 0.07 | 0.74 | 1.48 | 0.17 | 0.93 | 1.15 | 0.24 | 0.79 | 1.72 | 0.28 | 0.98 |
| $Na/(Cl+SO_4)$ | 1.88 | 0.04 | 0.83 | 5.41 | 0.24 | 1.45 | 2.02 | 0.82 | 1.45 | 2.62 | 0.72 | 1.36 |

Table 1.11 Distribution (%) of soil samples from Raichur and Devdurga taluks, Raichur Karnataka

| Soil Depth (Cm) | pHs | | | $EC_e$ ($dSm^{-1}$) | | | $(CO_3+HCO_3)/(Cl+SO_4)$ | | $(Na/(Cl+SO_4)$ | | SAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <7.5 | 7.5-8.5 | >8.5 | <2.0 | 2-4 | >4 | <1 | >1 | <1 | >1 | <13 | >13 |
| 0-15 | 31.2 (5) | 68.8 (11) | 0 | 87.5 (14) | 6.25 (1) | 6.25 (1) | 81.2 (13) | 18.8 (3) | 62.5 (10) | 37.5 (6) | 87.5 (14) | 12.5 (2) |
| 15-30 | 35.7 (5) | 64.3 (9) | 0 | 85.7 (12) | 7.10 (1) | 7.10 (1) | 71.4 (10) | 28.6 (4) | 50.0 (7) | 50.0 (7) | 71.4 (10) | 28.6 (4) |
| 30-60 | 20.0 (1) | 80.0 (4) | 0 | 80.0 (4) | 0 | 20.0 (1) | 80.0 (4) | 20.0 (1) | 60.0 (3) | 40.0 (2) | 80.0 (4) | 20.0 (1) |
| 60 + | 0 | 75.0 (3) | 25.0 (1) | 75.0 (3) | 0 | 25.0 (1) | 50.0 (2) | 50.0 (2) | 50.0 (2) | 50.0 (2) | 75.0 (3) | 25.0 (1) |

*No. of samples: 16 (0-15 cm), 14 (15-30 cm), 5 (30-60 cm) and 4 (60 + cm)*

**Bellary Taluk (Bellary district)**

In Bellary taluk (Bellary district), at surface soil (0-15 cm) pH (1:2.5), pHs, EC (1:2.5) and $EC_e$ varied from 10.76 to 7.82, 10.23 to 7.45, 31.0 to 0.19 ($dSm^{-1}$ ) and 75.0 to 0.64 ($dSm^{-1}$ ) respectively with an average of 8.55, 8.11, 5.39, and 13.2 $dSm^{-1}$ respectively (Table 1.12 and 1.13). Among cations, average Na content was more than Ca+Mg followed by K. In case of anions, average Cl- content was more than $HCO_3^-$ followed $SO4_2^-$. Nearly 40 per cent of surface samples had $EC_e$ > 4.0 $dSm^{-1}$ reflecting that these soils are saline. However, per cent of samples with >1 $(CO_3+HCO_3)/(Cl+SO_4)$ were nil whereas $(Na/(Cl+SO_4)$ 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 $EC_e$ varying from 10.55 to 7.43, 10.33 to 7.55, 19.9 to 0.12 and 35.0 to 0.37 ($dSm^{-1}$ ) respectively with an average of 8.34, 8.21, 2.90 $dSm^{-1}$ and 7.18 $dSm^{-1}$ respectively. Similar to surface soils, 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 40 per cent of sub surface samples were considered to be saline as the ECe of these samples was >4.0 dSm-1 . The overall mean of the $(CO_3+HCO_3)/(Cl+SO_4)$ was less than 1 whereas $(Na/(Cl+SO_4)$ was >1. However, about 4 and 58 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 48 per cent of samples analyzed had SAR >13. At 30-60 and 60+ cm depths, 42 to 46 per cent of samples had $EC_e$ >4, 64 to 84 per cent of samples with $Na/(Cl+SO_4)$ >1 and 51.1 to 61.1 per cent of samples had SAR >13 at these depths respectively.

**Hospet Taluk (Bellary district)**

In Hospet taluk (Bellary district), at surface soil (0-15 cm) pH(1:2.5), pHs, EC(1:2.5) and ECe varied from 8.74 to 5.72, 8.26 to 5.88, 19.0 to 0.15 ($dSm^{-1}$) and 43.0 to 0.39 ($dSm^{-1}$ ) respectively with an average of 7.51, 7.25, 1.28, and 2.96 $dSm^{-1}$, respectively (Table 1.14 and 1.15). Among cations, average Na content was more than Ca+Mg followed by K. In case of anions, average Cl- content was more than $HCO_3^-$ followed SO42-. Nearly 15 per cent of surface samples had ECe > 4.0 $dSm^{-1}$ reflecting that these soils are saline. However, per cent of samples with >1 $(CO_3+HCO_3)/ (Cl+SO_4)$and $(Na/(Cl+SO_4)$ ratios were to the extent of nearly 42 and 39 respectively. About 19.5 per cent of samples had SAR>13. At 15-30 cm depth, nearly 10 and 7 per cent of samples had ECe >4 and SAR>13. At 30-60 cm depth, nearly 12.5 and 25 per cent of samples had ECe >4 and SAR>13. At 60+ cm, nearly 20 and 60 per cent of samples had ECe >4 and SAR>13 respectively. At lower depths, per cent of samples with $(CO_3+HCO_3)/ (Cl+SO_4)$ and $(Na/(Cl+SO_4)$ ratios >1 varied from 20 (60+ cm) to 31.7 (15-30 cm) and 19.5 (15-30 cm) to 62.5 (30-60 cm) respectively.

Table 1.12 Characterization of soil samples from Bellary taluk, Bellary district, Karnataka

| Properties | Depth (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-15 cm | | | 15-30 cm | | | 30-60 cm | | | 60+ cm | | |
| | Max | Min | Avg | Max | Min | Avg | Max | Min | Avg | Max | Min | Avg |
| pH (1:2.5) | 10.76 | 7.82 | 8.55 | 10.55 | 7.43 | 8.34 | 10.2 | 7.22 | 8.55 | 10.3 | 8.12 | 8.78 |
| EC (1:2.5) | 31.0 | 0.19 | 5.39 | 19.90 | 0.12 | 2.90 | 9.40 | 0.16 | 2.71 | 8.40 | 0.20 | 2.69 |
| pHs | 10.23 | 7.45 | 8.11 | 10.33 | 7.55 | 8.21 | 10.1 | 7.63 | 8.35 | 9.65 | 7.76 | 8.33 |
| ECe ($dSm^{-1}$ ) | 75.0 | 0.64 | 13.20 | 35.00 | 0.37 | 7.18 | 24.0 | 0.43 | 5.28 | 19.30 | 0.55 | 5.69 |
| Cations/Anions (meq/L) | | | | | | | | | | | | |
| Ca+Mg | 126.0 | 3.20 | 19.27 | 55.20 | 2.70 | 13.06 | 38.0 | 2.30 | 11.4 | 37.10 | 2.40 | 13.8 |
| $Na^+$ | 634.5 | 1.83 | 117.6 | 262.8 | 1.43 | 66.15 | 196.5 | 1.88 | 45.4 | 145.6 | 2.60 | 45.9 |
| $K^+$ | 1.56 | 0.04 | 0.30 | 0.60 | 0.02 | 0.16 | 0.36 | 0.02 | 0.11 | 0.45 | 0.03 | 0.10 |
| $HCO_3^-$ | 259.5 | 5.25 | 24.2 | 54.6 | 2.50 | 13.24 | 41.5 | 2.50 | 15.4 | 35.4 | 2.10 | 16.3 |
| $Cl^-$ | 554.5 | 6.52 | 109.2 | 254.6 | 5.20 | 54.39 | 120.4 | 4.80 | 35.2 | 142.1 | 4.21 | 38.9 |
| $SO_4^{2-}$ | 4.87 | 0.06 | 1.26 | 3.68 | 0.03 | 1.42 | 3.20 | 0.05 | 1.24 | 2.82 | 0.07 | 1.35 |
| SAR | 290.7 | 1.07 | 38.9 | 122.9 | 1.16 | 23.45 | 83.1 | 1.32 | 19.1 | 41.4 | 1.57 | 17.5 |
| $(CO_3+HCO_3)/(Cl+SO_4)$ | 2.80 | 0.04 | 0.50 | 1.23 | 0.07 | 0.46 | 2.24 | 0.15 | 0.53 | 0.76 | 0.10 | 0.50 |
| $Na/(Cl+SO_4)$ | 2.13 | 0.14 | 1.00 | 3.83 | 0.27 | 1.18 | 2.20 | 0.35 | 1.14 | 1.60 | 0.55 | 1.17 |

Table 1.13 Percent distribution of soil samples from Bellary taluk, Bellary district, Karnataka

| Soil Depth (Cm) | pHs | | | $EC_e$ ($dSm^{-1}$) | | | $(CO_3+HCO_3)/(Cl+SO_4)$ | | $(Na/(Cl+SO_4)$ | | SAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <7.5 | 7.5-8.5 | >8.5 | <2.0 | 2-4 | >4 | <1 | >1 | <1 | >1 | <13 | >13 |
| 0-15 | 1.92 (1) | 84.61 (44) | 13.5 (7) | 25.0 (13) | 34.61 (18) | 40.38 (21) | 100.0 (52) | 0.00 | 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) | 96.0 (48) | 4.00 (2) | 42.0 (21) | 58.0 (29) | 52.0 (26) | 48.0 (24) |
| 30-60 | 0.00 | 73.3 (33) | 26.7 (12) | 37.8 (17) | 20.0 (9) | 42.2 (19) | 97.8 (44) | 2.20 (1) | 35.6 (16) | 64.4 (29) | 48.9 (22) | 51.1 (23) |
| 60+ | 0.00 | 76.9 (20) | 23.1 (6) | 30.8 (8) | 23.1 (6) | 46.2 (12) | 100.0 (26) | 0.00 | 15.4 (4) | 84.6 (22) | 38.5 (10) | 61.5 (16) |

*Values in parentheses are no. of samples.*

Table 1.14 Characterization of soil samples from Hospet taluk, Bellary district, Karnataka

| 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) | 8.74 | 5.72 | 7.51 | 8.56 | 4.76 | 7.55 | 8.69 | 6.72 | 7.87 | 8.76 | 7.06 | 7.93 |
| EC (1:2.5) | 19.0 | 0.15 | 1.28 | 12.40 | 0.16 | 1.03 | 8.80 | 0.20 | 1.17 | 6.50 | 0.19 | 1.26 |
| pHs | 8.26 | 5.88 | 7.25 | 8.14 | 6.49 | 7.45 | 8.29 | 6.53 | 7.45 | 8.10 | 6.48 | 7.57 |
| ECe ($dSm^{-1}$) | 43.0 | 0.39 | 2.96 | 17.80 | 0.23 | 1.57 | 12.3 | 0.30 | 1.77 | 8.80 | 0.36 | 2.02 |
| Cation /Anion | | | | | | | | | | | | |
| Ca+Mg | 46.60 | 4.20 | 11.93 | 64.80 | 2.40 | 8.74 | 31.2 | 3.20 | 8.80 | 22.20 | 3.7 | 8.11 |
| $Na^+$ | 153.2 | 1.59 | 21.4 | 62.5 | 1.2 | 10.5 | 168 | 2.0 | 25.1 | 141.7 | 2.72 | 28.8 |
| $K^+$ | 1.24 | 0.08 | 0.37 | 0.58 | 0.23 | 0.33 | 0.35 | 0.03 | 0.12 | 1.05 | 0.05 | 0.19 |
| $HCO_3^-$ | 35.0 | 6.50 | 10.67 | 18.0 | 5.00 | 8.26 | 22.0 | 5.0 | 8.79 | 15.0 | 6.00 | 8.10 |
| $Cl^-$ | 346.0 | 5.50 | 21.24 | 87.5 | 4.50 | 11.41 | 44.5 | 6.50 | 11.9 | 26.0 | 5.00 | 10.7 |
| $SO_4^{2-}$ | 2.71 | Tr | 0.50 | 2.30 | 0.01 | 0.28 | 2.21 | 0.01 | 0.48 | 2.22 | 0.04 | 0.66 |
| SAR | 42.1 | 0.94 | 7.90 | 33.6 | 0.07 | 4.98 | 45.4 | 1.29 | 10.4 | 54.2 | 1.22 | 13.1 |
| $(CO_3+HCO_3)/(Cl+SO_4)$ | 3.21 | 0.04 | 0.92 | 2.33 | 0.10 | 0.94 | 1.28 | 0.12 | 0.82 | 1.59 | 0.30 | 0.81 |
| $Na/(Cl+SO_4)$ | 3.41 | 0.23 | 1.10 | 4.61 | 0.14 | 0.86 | 6.30 | 0.26 | 1.64 | 11.1 | 0.14 | 2.40 |

Table 1.15 Percent distribution of soil samples from Hospet taluk, Bellary district, Karnataka

| Soil Depth (Cm) | pHs | | | $EC_e$ ($dSm^{-1}$) | | | $(CO_3+HCO_3)/(Cl+SO_4)$ | | $(Na/(Cl+SO_4)$ | | SAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <7.5 | 7.5-8.5 | >8.5 | <2.0 | 2-4 | >4 | <1 | >1 | <1 | >1 | <13 | >13 |
| 0-15 | 73.2 (30) | 26.8 (11) | 0 | 70.7 (29) | 14.6 (6) | 14.6 (6) | 58.5 (24) | 41.5 (17) | 61.0 (25) | 39.0 (16) | 80.5 (33) | 19.5 (8) |
| 15-30 | 51.2 (21) | 48.8 (20) | 0 | 85.4 (35) | 4.80 (2) | 9.80 (4) | 68.3 (28) | 31.7 (13) | 80.5 (33) | 19.5 (8) | 92.7 (38) | 7.3 (3) |
| 30-60 | 54.2 (13) | 45.8 (11) | | 79.2 (19) | 8.30 (2) | 12.5 (3) | 75.0 (18) | 25.0 (6) | 37.5 (9) | 62.5 (15) | 75 (18) | 25 (6) |
| 60+ | 40.0 (6) | 60.0 (9) | 0 | 66.7 (10) | 13.3 (2) | 20.0 (3) | 80.0 (12) | 20.0 (3) | 80 (12) | 20 (3) | 40 (6) | 60 (9) |

**Characterization and Delineation of Typical Profiles of Salt Affected Soils using Remotely Sensed Data and Ground Truth of Khargone, Khandwa and Dewas 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. 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). 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 1.16). On the basis of degree of salinity and alkalinity, the soils were classified and map of the district was generated (Fig. 1.1).

Table 1.16 Distribution of salt affected soils in different categories in Khargone district

| Category | Tehsil | Area (ha) | No. of Villages | Name of villages |
|---|---|---|---|---|
| Slightly saline and slightly alkali (EC 4-8 $dSm^{-1}$ 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 $dSm^{-1}$ 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 $dSm^{-1}$ and ESP > 40.0) | Gogawan | 54 | 01 | Randi |
| | Barwaha | 206 | 02 | Agarwada and Nandiya |
| Total | | 2448 | 27 | |

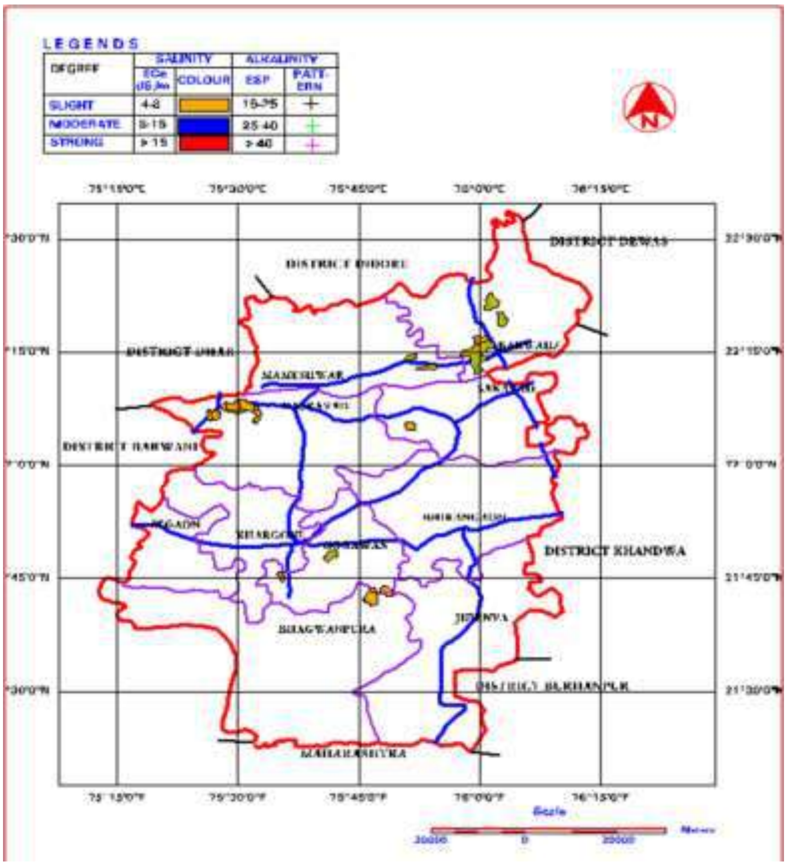



Fig. 1.1 Distribution of salt affected soils in Khargone district of Madhya Pradesh

**Khandwa district**

One hundred eighty surface soil samples were collected from different villages of Khandwa district. 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.

Table 1.17 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 $dSm^{-1}$ and ESP 15-25) | Punasa | 38 | 04 | Beed, Dohad, Mundi and Dharakwadi |
| | Harsud | 22 | 01 | Kherkheda |
| | Pandhana | 16 | 01 | Takli |
| Total | | 76 | 06 | |

All salt affected soils comes under the category of slightly saline and slightly alkali (76 ha). 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 1.17). On the basis of degree of salinity and alkalinity, the soils were classified and map of the district was generated (Fig. 1.2).

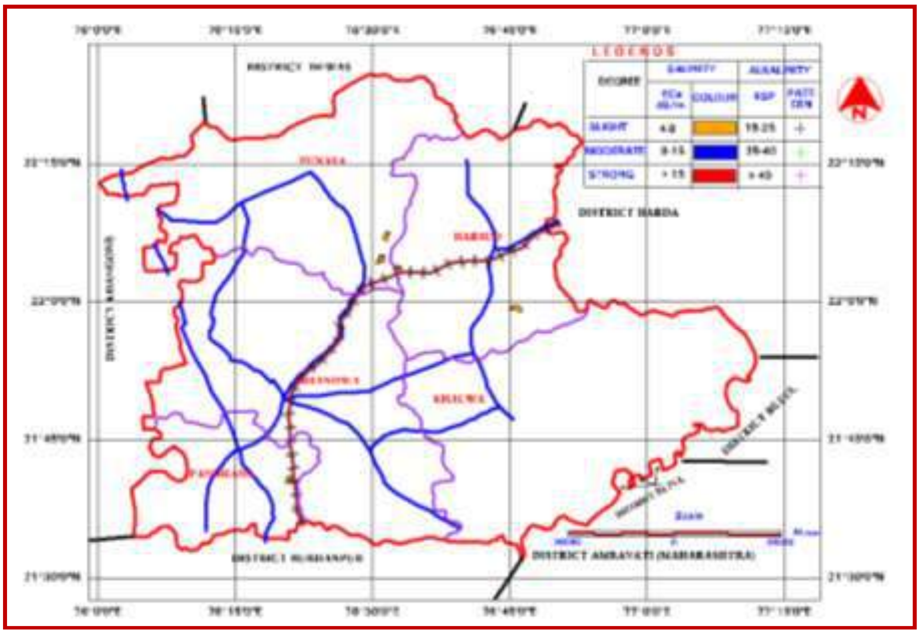


Fig. 1.2 Distribution of salt affected soils in Khandwa district of Madhya Pradesh

**Dewas district**

Detailed reconnaissance soil survey was carried in different tehsils of Dewas district of Madhya Pradesh to find out locations, extent and nature of salt affected soil. On the basis of physiography and geographical regional characteristics, Dewas district lies in between $22^o$ 17' to $23^o$ 20' N & $75^o$ 50" to $77^o$ 10' E. Canal as well as open/tube wells usually irrigate these crops. The Districts has hot sub-humid climate characterized by hot summers and mild winters. The average annual rainfall is about 1067mm. Maximum and minimum temperatures are 45 °C and 5.0 °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 their 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 - $EC_e$ 8 to 15 $dSm^{-1}$ and high - $EC_e$ >15 $dSm^{-1}$) and alkalinity (slight - ESP 15 to 25), moderate - ESP 25 to 40) and high - ESP > 40). 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.

**Analysis of soil samples**

One hundred sixty four surface soil samples were collected from different villages of Dewas district. The reaction of soil (pHs) in the surface layer is alkaline. pHs of the saturation paste ranged from 6.5 to 9.0. The $EC_e$ of saturation extract is an important property to judge the behaviour of soil in respect of salinity/ alkalinity. $EC_e$ values ranged from 0.5 to 14.7 $dSm^{-1}$. Among different cations, Na ranged from 0.1 to 14.0 me $L^{-1}$. The SAR values ranged between 0.07 and 3.19.

The data pertaining to exchangeable cations, CEC and ESP revealed that exchangeable Ca, Mg and Na ranged from 10.0 to 28.60, 5.78 to 21.82 and 0.47 to 22.44 cmol ($p^+$) $kg^{-1}$, respectively. Cation exchange capacity (CEC) ranged from 39.20 to 48.90 cmol ($p^+$) $kg^{-1}$, whereas, exchangeable sodium percentage (ESP) varied from 1.02 to 54.82, respectively.

Soil sampling from complete district is not yet completed. The samples from remaining part of the district will be collected during the year 2018-19 and map of the area covering salt affected soils will be generated on the basis of district as a whole.

**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 1.20). In general, soil salinity was EC was low but in some low lying areas it was as high as 10.1 (dSm-1 ) 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 1.20 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 ($dSm^{-1}$) | 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:** 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. 1.3). Soil and ground water samples from these areas needs to be collected for analysis and monitoring of rise in salinity level.

**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. The whole study area falls under eleven districts of Kerala viz. Thiruvanamthapuram, Kollam, Pathanamthitta, Kottayam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod. Among this, Thiruvanthapuram, Kottayam, Kollam and Pathanamthitta were covered during 2016-17 and Malappuram, Kozhikode, Kannur and Kasaragod during 2017-18. 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.

**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 the pH of soil samples ranged from slightly acidic to slightly alkaline. 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.

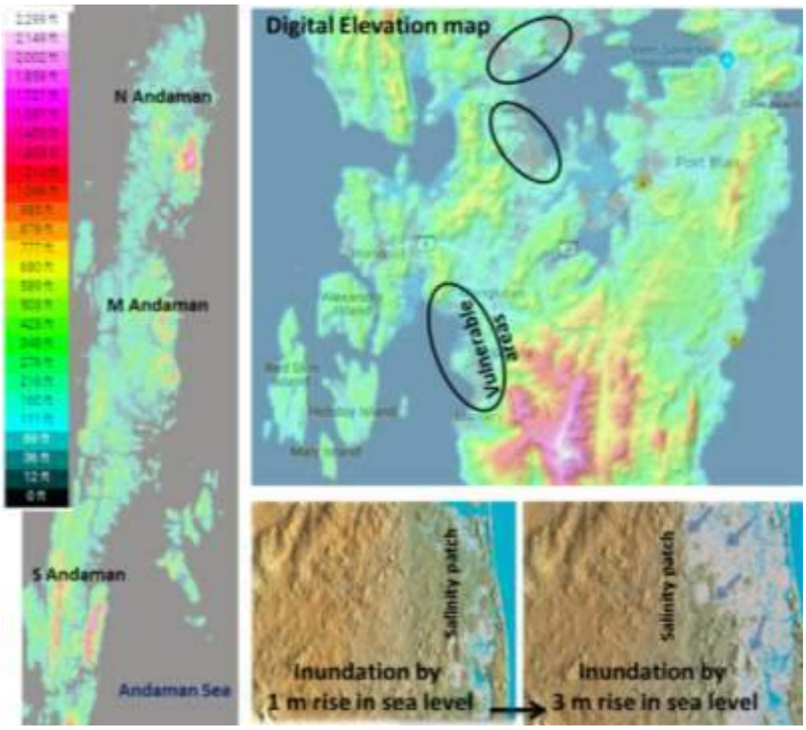



Fig.1.3 Terrain analysis for vulnerability mapping

**Kottayam district**

The soil samples (17 No.) were collected from Kottayam district 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 1.9 dSm$^{-1}$. From the analytical data it was evident that the pH of soil samples ranged 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 data of 21 samples from 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, five 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.

**Kasargode district**

As part of the survey, 26 soil samples were collected from Kasargode district also and the analytical data indicated that soil pH values ranged from 5.08 to 7.67 while electrical conductivity (EC) values ranged from 0.07 to 0.8 dS $m^{-1}$. As per the values the pH of soil samples ranges from strongly acidic to slightly alkaline. The electrical conductivity of soil samples is also within the favorable range for crop growth. Percentage of organic carbon ranged from 0.13 to 2.73 which varied from very low to very high. The sodium content of soils were in general high due to intrusion of saline or brackish water after monsoon and the content ranged from 20.5 to 25 mg $kg^{-1}$. Potassium and Phosphorus values ranged from 11 to 93 and 15.01 to 254.8 kg $ha^{-1}$ respectively. The available potassium was low in all soils and available phosphorus ranged from medium to high The values of calcium, magnesium, sulphur, boron, iron, zinc, copper and manganese ranged from 106.4 to 1797.6, 8.215 to 18.13, 0.087 to 5.13, 0.05 to 0.306, 4.90 to 104.3, 1.654 to 24.73, 0.757 to 10.68 and 2.403 to 50.63 mg $kg^{-1}$ respectively. As per the data, available calcium ranged from 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 high as indicated by the values. The status of available micronutrients in soil samples was in sufficient range except for boron and copper. Copper content varied from deficient to sufficient range.

**Kannur district**

About fourteen soil samples were collected from different locations of Kannur districts and the soil samples were analysed for various chemical parameters. The analytical data indicated that soil pH values ranged from 3.97 to 7.46 while electrical conductivity (EC) values ranged from 0.07 to 16.5 $dSm^{-1}$. Soil samples collected form Kaipad area was saline. This shows that the pH of soil samples ranged from extremely acidic to slightly alkaline. The electrical conductivity of soil samples ranged from non-saline to saline. The organic carbon per cent ranged from 0.57 to 2.87 which shows that organic carbon content falls under low to high category. Sodium content ranged from 13 to 2642 mg $kg^{-1}$. Potassium and Phosphorus values ranged from 37.5 to 242 and 9.67 to 107.67 kg $ha^{-1}$ respectively. The sodium content of soils especially in Kaipad areas was very high due to intrusion of saline or brackish water after monsoon. The available potassium and phosphorus contents of soils were in low to high range in majority of the soils. The values of calcium, magnesium and sulphur ranged from 572.5 to 1142, 13.56 to 20.1 and 0.93 to 22.49 mg $kg^{-1}$. In all the soil samples, available calcium content was in adequate and magnesium content was in the lower range. The available sulphur content of the soils was ranged from low to adequate. On analysis, it was found that available boron, iron, zinc, copper and manganese content ranged from 0.076 to 1.128, 27.84 to 291.1, 1.018 to 106.6, 1.218 to 13.52 and 2.583 to 30.07 mg $kg^{-1}$ respectively. The content of available boron was low in most of the soils and other micronutrients such as zinc, copper, manganese and iron were high in all the soils.

**Kozhikode district**

The analytical data of 19 soil samples indicated that soil pH values ranged from 4.73 to 7.85 while electrical conductivity (EC) values ranged from 0.07 to 0.89 $dSm^{-1}$. The pH of soil samples ranges from very strongly acidic to slightly alkaline group. The electrical conductivity of soil samples were found to be in safe levels. The soils were having low to high organic carbon per cent ranging from 0.49 to 1.76 percent. The sodium content of soils ranged from 14 to 33.5 mg $kg^{-1}$. Available potassium and phosphorus values ranged from 21.5 to 322.5 and 9.93 to 146.87 kg $ha^{-1}$ respectively which implies that the available potassium and available phosphorus contents of soils ranged from low to high. Considering the secondary nutrient status, the available calcium content was high in most of the samples and magnesium content was found to be lower, whereas available sulphur content ranged from low to medium. The values of calcium, magnesium and sulphur ranged from 142.95 to 1264, 6.54 to 13.56, 0.89 to 7.16 mg $kg^{-1}$ respectively. The boron, iron, zinc, copper and manganese content ranged from 0.024 to 0.262, 20.53 to 161.4, 1.521 to 34.82, 0.132 to 5.594 and 2.892 to 42.83 mg $kg^{-1}$ respectively. Among the micronutrients boron was deficient in all the samples and copper content was low in half of the samples and other micronutrients are in sufficiency range.

**Malappuram district**

Analysis of 18 samples showed that soil pH values ranged from 4.39 to 6.94 while electrical conductivity (EC) values ranged from 0.1 to 4.6 $dSm^{-1}$. From the analytical data it was evident that the pH of soil samples ranges from very strongly acidic to neutral range and the soil samples were non saline except the sample from Tanur. Organic carbon content was in general low in the soil samples and the values ranged from 0.1 to 1.99 per cent. Sodium content ranged from 21.5 to 73.5 mg $kg^{-1}$. Potassium and Phosphorus values ranged from 19.5 to 219.5 and 43.02 to 488.98 kg $ha^{-1}$ respectively. The sodium and phosphorus content of soils was high whereas the available potassium content was in low to medium range. Among the secondary nutrients, available calcium content was high in all of the soils whereas the available magnesium and sulphur content of the soils were very low. The values of calcium, magnesium and sulphur ranged from 291.85 to 1242, 11.08 to 16.74 and 0.31 to 1.75 mg $kg^{-1}$ respectively. The boron, iron, zinc, copper and manganese ranged from 0.028 to 0.206, 32.75 to 150.8, 3.269 to 74.29, 1.661 to 17.45 and 25.97 to 26.38 mg $kg^{-1}$ respectively. The contents of available micronutrients such as iron, zinc, copper and manganese content were high in all the soils, but boron was very low in most of the soils.

On basis of analysis of groundwater samples in different districts of Kerala, it is concluded that:

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

## 1.2 Resource Inventories of Poor Quality Ground waters

**Survey and Characterization of Underground Waters of Agra and Mathura Districts (Agra)**

The ground water survey of Agra district in Uttar Pradesh was repeated after 40 years from the year 2012 and completed in 2017. Fifteen blocks viz Fatehpur Sikri, Akola, Achhnera, Bichpuri, Jagner, Sainya, Kheragarh, Barauli Ahir , Khandauli, Shamsabad, Bah, Pinahat, Fatehabad, Etmadpur and Jaitpur Kalan were surveyed and total 951 samples were collected mostly from December to March, when the maximum number of tube wells were under use for irrigation purpose and analyzed for different water constituents for its quality. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions ($CO_3$, $HCO_3$, Cl and $SO_4$). Quality parameters like SAR and RSC were calculated. The classification of water quality was done based on EC, SAR and RSC values as suggested by CSSRI, Karnal (Table 1.21). The range of EC, pH, SAR and RSC characters are presented in Table 1.22.

Table 1.21 Grouping of quality irrigation waters for irrigation in India

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

Table 1.22 Range of different water constituents and its mean

| Blocks | EC ($dSm^{-1}$) | | pH | | RSC (meq/l) | | SAR $(mmol/l)^{1/2}$ | |
|---|---|---|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| 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 |
| 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 |
| 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 maximum EC 26.3 dSm$^{-1}$ was recorded in Fatehpur Sikri followed by 25.4 dSm$^{-1}$ in Achhnera and 23.2 dSm$^{-1}$ in Bichpuri block. The highest RSC value 28.2 me/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.

The distribution of water samples in different EC, SAR and RSC classes are presented in Table 1.23. According to EC classes, more than 50 per cent samples of Fatehpur Sikri, Akola, Achhnera and Bichpuri blocks were found in classes of more than 5.0 dSm$^{-1}$. In EC class < 1.5 dSm$^{-1}$, the maximum samples (i.e. 88.7 per cent) were found in Jaitpur Kalan followed by 84.4 per cent in Bah and 76.0 per cent in Pinahat block. More than 50 per cent samples in most of the blocks were having RSC <2.5 me/l. In category >2.5 me/l RSC more than 30 per cent samples were recorded in all blocks except Fatehpur Sikri, Akola, Achhnera and Bichpuri blocks. In case of SAR classes, the major number of samples were found in 0-10 and 10-20 (mmol/l)$^{1/2}$ 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 1.23 Frequency distribution of water samples in different EC, RSC and SAR classes of different blocks of Agra district

| Parti-culars | Fatehpur Sikri (60) | Akola (40) | Achhnera(58) | Bichpuri (45) | Jagner (50) | Sainya (54) | Khera-garh(59 | Barauli Ahir(69) | Khandaul (70) | Sham-sabad (68) | Bah (64) | Pinaha (50) | Fate-habad (90) | Etmad-pur (73) | Jaitpur Kalan (71) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EC classes (dSm$^{-1}$)** | | | | | | | | | | | | | | | |
| 0- 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 34.0 | 16.7 | 11.9 | 46.4 | 31.4 | 48.5 | 84.4 | 76.0 | 62.2 | 24.7 | 88.7 |
| 1.5- 3.0 | 3.33 | 25.0 | 25.9 | 24.4 | 36.0 | 35.2 | 37.3 | 46.4 | 40.0 | 30.9 | 15.6 | 20.0 | 30.0 | 41.1 | 6.5 |
| 3.0- 5.0 | 30.0 | 22.5 | 24.1 | 22.2 | 20.0 | 22.2 | 27.1 | 5.8 | 18.6 | 17.7 | - | 2.0 | 6.7 | 20.6 | 2.8 |
| 5.0-10.0 | 46.7 | 37.5 | 32.8 | 26.7 | 6.0 | 16.7 | 15.2 | 1.4 | 7.1 | 2.9 | - | 2.0 | 1.1 | 6.8 | - |
| >10.0 | 20.0 | 15.0 | 17.2 | 26.7 | 4.0 | 9.2 | 8.5 | - | 2.9 | - | - | - | - | 6.8 | - |
| **RSC Classes (me/l)** | | | | | | | | | | | | | | | |
| Absent | 80.0 | 60.0 | 65.5 | 75.5 | 40.0 | 51.8 | 55.9 | 39.1 | 38.6 | 39.7 | 6.2 | 16.0 | 18.9 | 23.3 | 8.5 |
| 0-2.5 | 5.0 | 15.0 | 19.0 | 13.3 | 26.0 | 18.5 | 10.2 | 27.6 | 22.9 | 27.9 | 28.1 | 34.0 | 27.8 | 20.5 | 50.7 |
| 2.5- 5.0 | 3.3 | 10.0 | 10.3 | 6.7 | 10.0 | 13.0 | 11.9 | 17.4 | 22.8 | 22.1 | 50.0 | 34.0 | 30.0 | 31.5 | 38.0 |
| 5.0-10.0 | 8.3 | 10.0 | 5.2 | 4.4 | 14.0 | 14.8 | 20.3 | 15.9 | 15.7 | 10.3 | 14.1 | 16.0 | 23.3 | 24.7 | 2.8 |
| >10.0 | 3.3 | 5.0 | - | - | 10.0 | 1.9 | 1.7 | - | - | - | 1.6 | - | - | - | - |
| **SAR Classes (mmol/l)$^{1/2}$** | | | | | | | | | | | | | | | |
| 0-10 | 10.0 | 10.0 | 13.8 | 42.2 | 70.0 | 42.6 | 49.1 | 82.6 | 45.7 | 64.7 | 95.3 | 88.0 | 70.0 | 45.2 | 93.0 |
| 10-20 | 46.7 | 60.0 | 51.7 | 35.5 | 24.0 | 57.4 | 45.8 | 17.4 | 48.6 | 29.4 | 4.7 | 12.0 | 27.8 | 49.3 | 7.00 |
| 20-30 | 23.3 | 22.5 | 27.6 | 20.0 | 4.0 | - | 3.40 | - | 4.30 | 4.40 | - | - | 2.20 | 5.50 | - |
| 30-40 | 18.3 | 7.5 | 5.2 | 2.2 | 2.0 | - | 1.70 | - | 1.40 | - | - | - | - | - | - |
| >40 | 1.7 | - | 1.7 | - | - | - | - | - | - | 1.5 | - | - | - | - | - |

**Nitrate:** The nitrate was detected in only Fatehpur Sikri & Barauli Ahir (15.0 & 4.3 per cent samples ) blocks and fifty per cent samples were found in both 0-2.5 and 2.5-5.0 me/l classes in Fatehpur Sikri block whereas all samples (100%) in Barauli Ahir block were found and in rest of the blocks no sample of nitrate presence was found (Table 1.24).

**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 1.25).

The cationic order Na>Mg>Ca>K was found in all the blocks whereas anionic order Cl>$SO_4$>$HCO_3$>$CO_3$

was also in all the blocks except in Barauli Ahir block ($SO_4$>Cl>$HCO_3$>$CO_3$). The distribution of water samples in different water quality classes as given in Table 1.26.

Table 1.24 Nitrate in different blocks of Agra district.

| Particulars<br>Nitrate (meq/l) | Fatehpur Sikri (60) | Barauli Ahir (69) |
|---|---|---|
| *Nitrate having samples (%) | 15.0 | 4.3 |
| ** Per cent among Nitrate having samples | | |
| 0 - 2.5 | 50.0 | 100.0 |
| 2.5 - 5.0 | 50.0 | - |
| 5.0 – 7.5 | - | - |

*Per cent of collected samples in respective blocks; ** Per cent of nitrate having samples only

Table 1.25 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 | - | - | - | - | - | - | - |

Table 1.26 Distribution of water samples in different water quality ratings (2012 to 2017)

| 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** |

Table 1.26 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, 23.9 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 water quality classes for Agra district is shown in Fig. 1.4

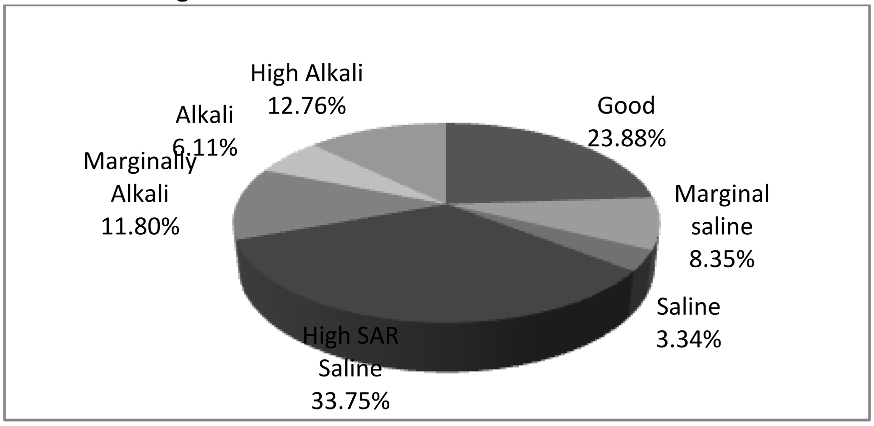



Fig. 1.4 Distribution of water quality classes in Agra district

Comparing the water quality of latest collected samples with 35 years ago collected 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 major number of samples falls in high SAR saline water quality in both the surveyed periods except the Jagner , Sainya, Barauli Ahir and Kheragarh blocks, the High SAR Saline water quality has been increased in seven blocks (Table 1.27). The saline water quality (marginally saline and saline) decreased in Fatehpur Sikri, Bichpuri Jagner, Sainya,Kheragarh, Barauli Ahir, Shamsabad, Bah and slight increase trend was observed in Alkali water whereas the water quality of three blocks i.e. Jagner, Sainya and Kheragarh mostly remained unchanged even after three decades of time interval.

Table 1.27 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** |

The spatial distribution of groundwater quality as per survey during 2012-2017 is shown in Fig. 1.5.

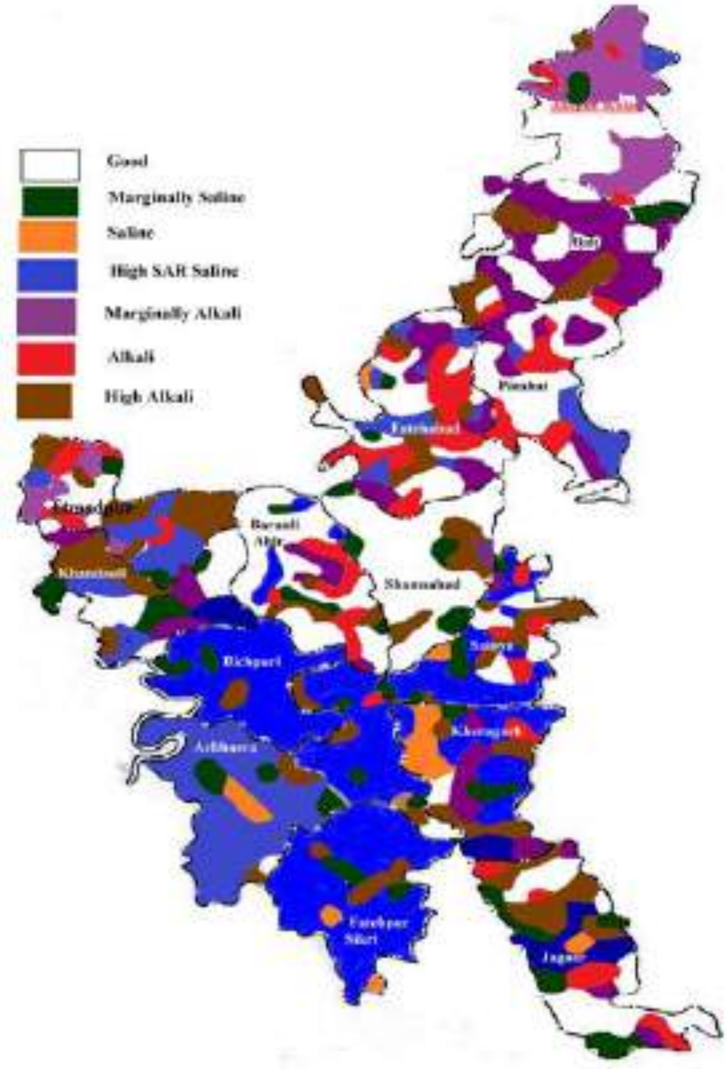



**Fig. 1.5** Water quality map of Agra district (2017)

**Mathura district**

From 2017, the ground water survey of Mathura district in Uttar Pradesh was initiated again and total four blocks viz. Farah, Goverdhan, Mathura and Baldev were surveyed, total 284 samples were collected mostly from December to March, when the maximum number of tube wells were under use for irrigation purpose and analyzed for different water constituents for their quality. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions ($CO_3$, $HCO_3$, Cl and $SO_4$). Quality parameters like SAR and RSC were calculated. Classification of water quality was done based on EC, SAR and RSC values as suggested by CSSRI, Karnal. The range of EC, pH, SAR and RSC characters are presented in Table 1.28. The maximum EC 13.2 $dSm^{-1}$ was recorded in Baldev followed by 12.4 $dSm^{-1}$ in Goverdhan and 12.2 $dSm^{-1}$ in Mathura block. The highest RSC value 16.0 me/l was recorded in Mathura block followed by 15.0 and 10.4 me/l in Baldev and Farah block respectively. Whereas the highest SAR 12.0 $(mmol/l)^{1/2}$ was recorded in Baldev followed by 10.1 and 9.6 $(mmol/l)^{1/2}$ in Farah and Goverdhan block, respectively.

Table 1.28 Minimum and maximum values of different water constituents in Farah, Goverdhan, Mathura and Baldev blocks of Mathura District

| Block | EC ($dSm^{-1}$) | | pH | | RSC (meq/l)* | | SAR $(mmol/l)^{1/2}$ | |
|---|---|---|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Farah | 1.0-9.5 | 3.5 | 7.8-9.1 | 8.5 | Nil-10.4 | | 3.0-24.0 | 10.1 |
| Goverdhan | 1.2-12.4 | 5.6 | 7.7-9.0 | 8.3 | Nil-3.4 | | Nil-27.1 | 9.6 |
| Mathura | 0.8-12.2 | 4.4 | 7.7-9.5 | 8.3 | Nil-16.0 | | 0.9-31.8 | 8.6 |
| Baldev | 1.0-13.2 | 4.1 | 8.2-9.5 | 8.8 | Nil-15.0 | | 0.4-32.4 | 12.0 |

**Mean RSC of positive value.*

The distribution of water samples in different EC, SAR and RSC classes are presented in Table 1.29. According to EC classes 40.3, 14.5, 34.7 & 21.7 per cent samples of were found in 1.5-3.0 $dSm^{-1}$ category, 23.9, 30.6, 23.6 & 31.3 per cent in 3.0-5.0, while 25.4, 45.2, 20.8 & 28.9 per cent samples in 5.0-10.0 $dSm^{-1}$ category in Farah, Goverdhan, Mathura and Baldev blocks were found, respectively. More than 84 per cent samples in surveyed blocks were having RSC <2.5 me/l except Farah block (71.7 per cent). In category >10.0 me/l RSC only 1.5, 2.8 and 1.2 per cent samples in Farah, Mathura and Baldev were recorded, respectively. In case of SAR classes, the major number of samples were found in 0-10 and 10-20 $(mmol/l)^{1/2}$ classes. In class 20-30 $(mmol/l)^{1/2}$ only 4.5, 3.2, 4.2 & 6.0 per cent samples of Farah, Goverdhan, Mathura and Baldev were recorded.

Table 1.29 Frequency distribution of water samples in different EC, RSC and SAR classes of Farah, Goverdhan, Mathura and Baldev blocks of Mathura district

| Particulars | Farah (67) | Goverdhan (62) | Mathura (72) | Baldev (83) |
|---|---|---|---|---|
| **EC Classes** | | | | |
| 0- 1.5 | 10.4 | 1.6 | 11.2 | 14.5 |
| 1.5- 3.0 | 40.3 | 14.5 | 34.7 | 21.7 |
| 3.0- 5.0 | 23.9 | 30.6 | 23.6 | 31.3 |
| 5.0-10.0 | 25.4 | 45.2 | 20.8 | 28.9 |
| >10.0 | - | 8.1 | 9.7 | 3.6 |
| **RSC Classes** | | | | |
| Absent | 65.7 | 93.5 | 84.7 | 73.5 |
| 0-2.5 | 6.0 | 6.5 | 5.6 | 10.8 |
| 2.5- 5.0 | 17.9 | - | 6.9 | 7.2 |
| 5.0-10.0 | 8.9 | - | - | 7.2 |
| >10.0 | 1.5 | - | 2.8 | 1.2 |
| **SAR Classes** | | | | |
| 0-10 | 62.7 | 56.5 | 65.2 | 36.1 |
| 10-20 | 32.8 | 40.3 | 29.2 | 56.6 |
| 20-30 | 4.5 | 3.2 | 4.2 | 6.0 |
| 30-40 | - | - | 1.4 | 1.2 |
| >40 | - | - | - | - |

**Nitrate:** The nitrate was detected in only Fatehpur Sikri & Barauli Ahir (15.0 & 4.3 per cent samples) blocks and fifty and fifty per cent samples were found in 0-2.5 and 2.5-5.0 me/l classes respectively in Fatehpur Sikri block whereas all samples (100%) in Barauli Ahir block were found and in rest of the blocks no sample of nitrate presence was found (Table 1.30).

Table 1.30 Nitrate in Farah, Goverdhan, Mathura and Baldev blocks of Mathura District

| Particulars<br>Nitrate (me/l) : | | |
|---|---|---|
| *Nitrate having samples (%) | 15.0 | 4.3 |
| ** Per cent among Nitrate having samples | | |
| 0 - 2.5 | 50.0 | 100.0 |
| 2.5 - 5.0 | 50.0 | - |
| 5.0 – 7.5 | - | - |
| 7.5 –10.0 | - | - |
| >10.0 | - | - |

**Per cent of collected samples in respective blocks*
*** Per cent of nitrate having samples only.*

**Fluoride:** It is clear from Table 1.31 that the most of the samples(>65%) in all surveyed blocks came into class 0-1.5 ppm F category, whereas in 1.5-3.0 (ppm) category 22.4, 8.1, 15.3, 10.8 and 10.4, 3.2, 9.7, 7.3 per cent samples found in 3.0-5.0 ppm category, respectively.

Table 1.31 Fluoride in Farah, Goverdhan, Mathura and Baldev blocks of Mathura District

| Blocks | Fluoride classes (ppm) | | | | |
|---|---|---|---|---|---|
| Name | 0-1.5 | 1.5-3.0 | 3.0-5.0 | 5.0-10.0 | >10.0 |
| Farah | 67.2 | 22.4 | 10.4 | - | - |
| Goverdhan | 88.7 | 8.1 | 3.2 | - | - |
| Mathura | 75.0 | 15.3 | 9.7 | - | - |
| Baldev | 81.9 | 10.8 | 7.3 | - | - |

Cationic pattern was Na>Mg>Ca>K while anionic pattern was $Cl>SO_4>HCO_3>CO_3$ in different blocks of Mathura district. The distribution of water samples in different water quality classes (Table 1.32) reveals that 17.9, 6.5, 22.2, 18.1 per cent sample of good quality underground irrigation water were found in Farah, Goverdhan, Mathura and Baldev blocks. 52.3, 88.7, 69.4, 68.7 per cent samples of Farah, Goverdhan, Mathura and Baldev blocks came under Saline class (Marginally saline, Saline and High SAR saline) while, rest 29.8, 4.8, 8.4, 13.2 per cent samples came in Alkali class (Marginally Alkali and High Alkali only) respectively.

Table 1.32 Distribution of water samples in different water quality ratings (2017-18)

| S. No. | Blocks | No. of Samples | Good | Marginally Saline | Saline | High SAR Saline | Marginally Alkali | Alkali | High Alkali |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Farah | 67 | 17.9 | 19.4 | 6.0 | 26.9 | 16.4 | - | 13.4 |
| 2 | Goverdhan | 62 | 6.5 | 25.8 | 29.0 | 33.9 | - | - | 4.8 |
| 3 | Mathura | 72 | 22.2 | 29.1 | 11.1 | 29.2 | 4.2 | - | 4.2 |
| 4 | Baldev | 83 | 18.1 | 19.3 | 2.4 | 47.0 | 3.6 | - | 9.6 |

Comparing the water quality of latest collected samples with 40 years ago collected samples of surveyed blocks of Mathura district, it can be explained that the good quality water area increased in Farah block and reduced in Goverdhan and Mathura block while in Badev it was found at par. The major number of samples was in Saline water quality in the surveyed periods. The High SAR Saline water quality area increased in Goverdhan, Mathura and Baldev blocks (Table 1.33). The saline water quality (marginally saline and saline) decreased in Farah block and Alkali water area found decreasing in Goverdhan, Mathura and Baldev blocks, whereas, minor changes were recorded in Farah block in respect of Alkali classes.

Table 1.33: Distribution of water samples in different water quality ratings (1978-89)

| S.No. | Blocks | No. of Samples | Good | Marginally Saline | Saline | High SAR Saline | Marginally Alkali | Alkali | High Alkali |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Farah | 97 | 9.3 | 10.3 | 15.5 | 35.0 | 11.3 | 5.1 | 13.5 |
| 2 | Goverdhan | 104 | 20.2 | 20.2 | 19.2 | 26.9 | 9.6 | 3.0 | 0.9 |
| 3 | Mathura | 94 | 28.7 | 20.2 | 17.0 | 14.9 | 6.4 | 5.4 | 7.4 |
| 4 | Baldev | 76 | 19.7 | 25.0 | 7.9 | 23.4 | 7.9 | 13.5 | 2.6 |

Spatial distribution of Mathura district is shown in Fig. 1.6.

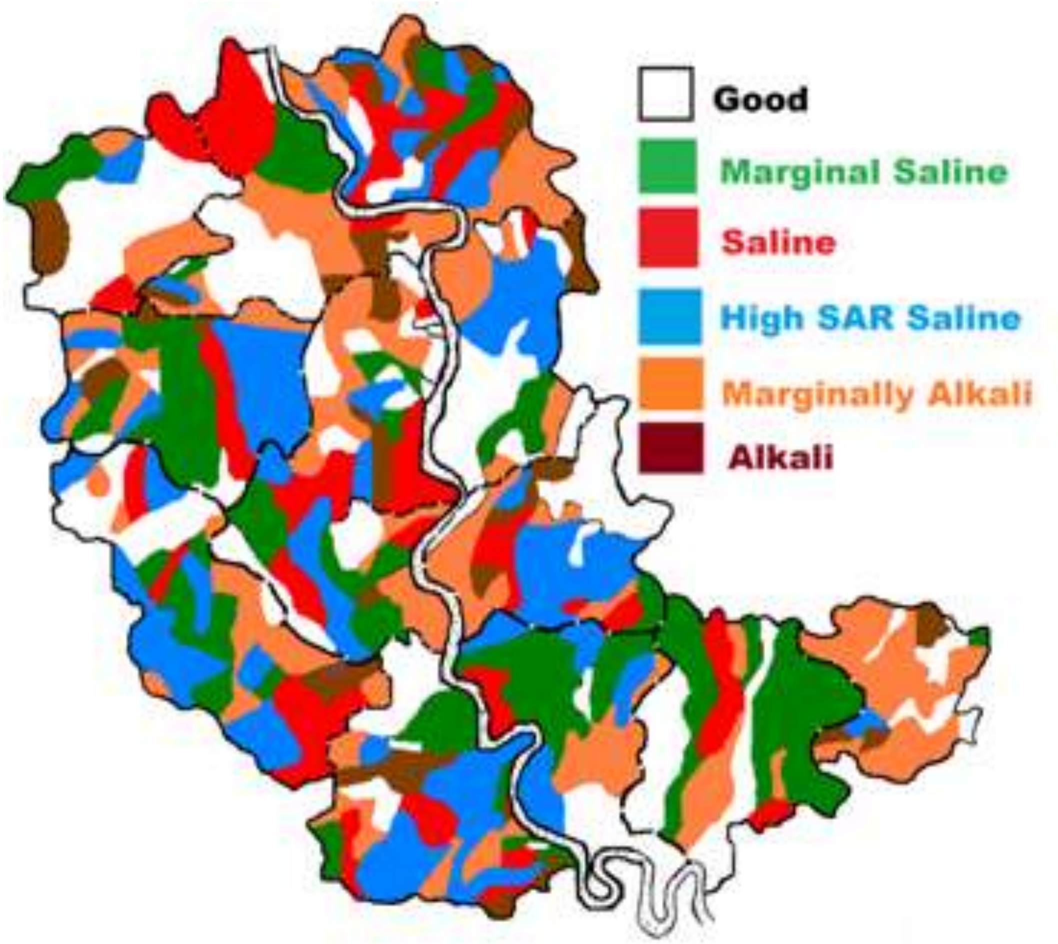



Fig. 1.6 Water quality map of Mathura comprising Farah, Mathura, Goverdhan and Baldev blocks

**Survey and Characterization of Underground Waters in West Godavari and East Godavari Districts-Revisiting Sites (Bapatla)**

**West Godavari**

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 dS $m^{-1}$, respectively. The SAR ranged from 0.02 to 63.1 with a mean value of 4.7 during pre monsoon period, while it ranged from 0.25 to 29.2 with a mean value of 4.2 during post monsoon period. The residual sodium carbonate values of water samples ranged from -69.0 to 13.2 me $L^{-1}$ during pre monsoon period and from -65.0 to 11.8 during post monsoon period (Table 1.34).

Table 1.34 Physico-chemical and chemical properties of groundwater samples of West Godavari district

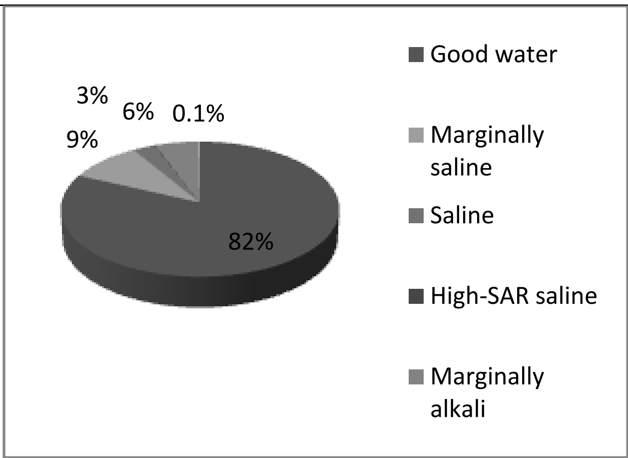
| Parameters | Pre monsoon (2016) | | Post monsoon (2016) | |
|---|---|---|---|---|
| | Range | Mean | Range | Mean |
| pH | 6.5 to 8.6 | - | 6.2 to 8.8 | - |
| EC (dS $m^{-1}$) | 0.3 to 26 | 2.0 | 0.3 to 26 | 1.9 |
| $CO_3^{2-}$ ($meqL^{-1}$) | - | - | - | - |
| $HCO_3^-$ ($meqL^{-1}$) | 0.4 to 23.4 | 7.3 | 0.6 to 23.4 | 7.6 |
| $Cl^-$ ($meqL^{-1}$) | 0.4 to 235.2 | 12.4 | -0.4 to 245.2 | 11.0 |
| $SO_4^{2-}$ ($meqL^{-1}$) | 0.001 to 0.75 | 0.031 | 0.01 to 0.81 | 0.116 |
| $Ca^{2+}$ ($meqL^{-1}$) | 0.4 to 41.4 | 4.7 | 0.8-41.4 | 4.7 |
| $Mg^{2+}$ ($meqL^{-1}$) | 0.4 to 52.1 | 3.7 | 0.4 to 52.1 | 4.0 |
| $Na^+$ ($meqL^{-1}$) | 0.03 to 229.3 | 10.7 | 0.36 to 179.6 | 9.5 |
| $K^+$ ($meqL^{-1}$) | 0.003 to 15.5 | 0.8 | 0.01 to 14.5 | 0.9 |
| RSC ($meqL^{-1}$) | -69.0 to 13.2 | | -65.0 to 11.8 | |
| SAR | 0.02 to 63.1 | 4.7 | 0.25 to 29.2 | 4.2 |

The pre monsoon water samples were classified based on rating chart of CSSRI, Karnal. In 1989-90, 81.9% samples were of good quality while in 2016-17 pre-monsoon, 58.3% samples of good quality. There is reduction in good quality ground water area and increase in other quality categories as given in Table 1.35.

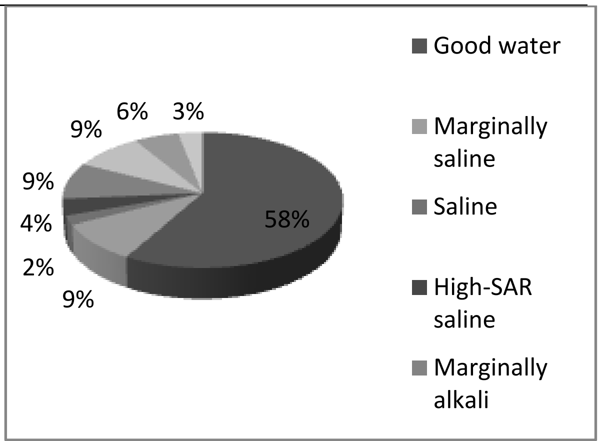
Quality of irrigation water was found to be deteriorated as compared to earlier studies. Per cent good quality water came down to 58.3 per cent as compared to 81.9 per cent recorded during 1989-90. On the other side, the per cent alkali water increased to 8.8 as compared to 0.1 in 1989-90 (Fig. 1.7).

Table 1.35 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 alkali | 44 | 20 | 13 | 5.6 | 8.8 | 5.7 |
| 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 |




(a) Groundwater quality during 1989-90




(b) Groundwater quality during pre monsoon (2016-17)

Fig. 1.7 Temporal changes in Groundwater quality in West Godavari District

**East Godavari**

Total 313 ground water samples were collected both during pre monsoon and post monsoon seasons of 2017-18 from 59 mandals of East Godavari District. The district has seven revenue divisions viz., Amalapuram, Elapaka, Kakinada Pedddapuram, Rajahmundry, Ramachandrapuram and Rampachodavaram.

All the waters from Maredumilli, Gagavaram, Ramavaram, Rajavommangi, Kadiam, Ravulapalem, Kothapeta, Ambajipeta, Mallikapuram, Uppalaguptam, Pedapudi, Peddapuram and Gandapalli were of good quality. Among the water of Rajahmundry, 50 % showed EC > 2 $dSm^{-1}$ and were dominated by sodium (0.49-11.6 with mean as 5.79 me $L^{-1}$) and $Cl^-$ (0.90 to 15.2 with mean as 7.65 me $L^{-1}$). RSC was not present in all the samples. Boron content ranged between 0.05 – 0.08 ppm. While, Sitanagaram waters had EC ranged from 0.70 to 3.70 $dSm^{-1}$ with average of 2.03 $dSm^{-1}$. Devipatnam waters are safe with respect to RSC having low sodium hazard. Out of 9 samples analyzed, one was having EC of 2.20 $dSm^{-1}$. One of 10 waters of Rampachodavaram was moderately saline having EC >

3 dSm$^{-1}$. Waters were dominated by $Ca^{2+}$ (mean 4.11 me $L^{-1}$) and $HCO_3^-$ (5.47 me $L^{-1}$). Only one sample was found high RSC of 7.2 me $L^{-1}$ dominated by $Na^+$ and $HCO_3^-$ contents of 12.52 and 13.2 me $L^{-1}$ showing sodicity hazard. Out of total 12 samples collected from Addatheegala, two were showing EC > 2 dSm$^{-1}$. One sample had EC as 2.60 dSm$^{-1}$ and RSC as 11.0 me $L^{-1}$. One water sample of 5 in Yeleswaram, had RSC of 5.4 me $L^{-1}$ and E.C of 2.0 dSm$^{-1}$ but low sodium hazard. In Alamuru mandal, one sample had RSC of 3.60 me $L^{-1}$ with $Na^+$ and $HCO_3^-$ contents of 9.54 and 8.4 me $L^{-1}$. The 37.5 % samples from Athreyapuram had EC > 2 dSm$^{-1}$ . The ranges for different chemical properties are given in Table 1.36. Further samples were classified into different water quality groups. During pre monsoon season, 62.3, 20.77, 3.51, 4.15, 5.43, 1.28 and 2.56 per cent of waters were falling under good, marginally saline, saline, marginally alkali, alkali, highly alkali and high SAR saline categories, with corresponding per cent of 71.57, 10.86, 2.24, 3.51, 5.11, 4.79 and 1.92 during post monsoon season (Fig.1.8).

Table 1.36 Physico-chemical and chemical properties of groundwater samples of East Godavari district

| Parameter | Range | Mean | Parameter | Range | Mean |
|---|---|---|---|---|---|
| pH | 6.4 to 8.1 | - | $Ca^{2+}$ (meq$L^{-1}$) | 0.6 to 34.8 | 4.3 |
| EC (dS $m^{-1}$) | 0.2 to 49 | 2.0 | $Mg^{2+}$ (meq$L^{-1}$) | 0.2 to 105.2 | 3.8 |
| $CO_3^{2-}$ (meq $L^{-1}$) | - | - | $Na^+$ (meq$L^{-1}$) | 0.07 to 368.2 | 8.3 |
| $HCO_3^-$ (meq$L^{-1}$) | 0.6 to 18 | 6.7 | $K^+$ (meq$L^{-1}$) | 0.04 to 9.7 | 0.6 |
| $Cl^-$ (meq$L^{-1}$) | 0.4 to 446 | 7.2 | RSC (meq$L^{-1}$) | -133.4 to 13.8 | -1.4 |
| $SO_4^{2-}$ (meq$L^{-1}$) | 0.012 to 10.43 | 1.2 | SAR | 0.07 to 44.01 | 3.6 |

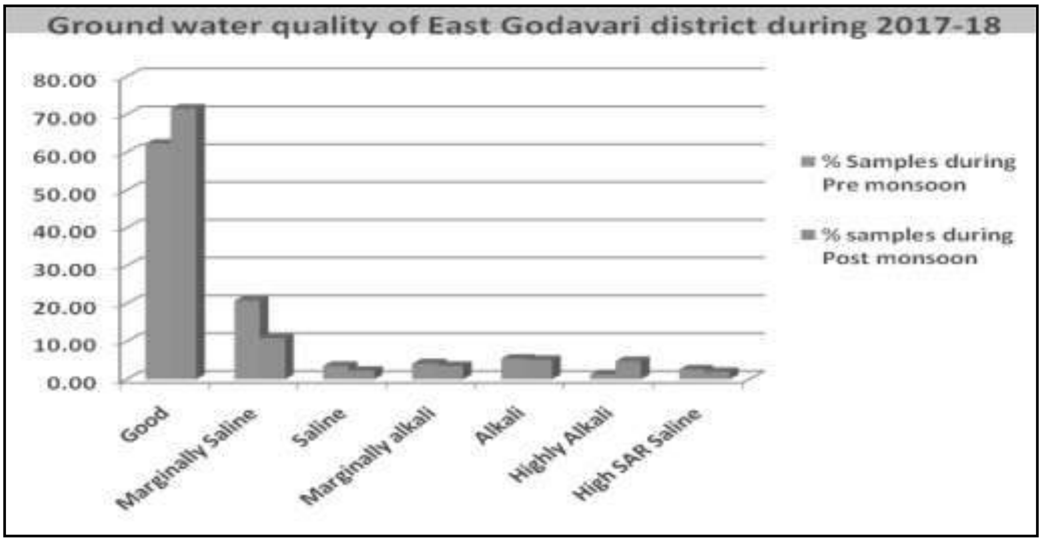



Fig.1.8 Pre monsoon and post monsoon variation in groundwater quality of East Godavari

The changes in percent of samples in different quality categories with time (i.e. 1989-90 and 2017-18) are shown in Table 1.37 It is observed that there is deterioration in groundwater quality over the years. The same is shown in Fig. 1.9.

Table 1.37 Comparison of ground water quality of East Godavari district with previous year

| S.No. | Quality | Percent of samples | | No. of samples | |
|---|---|---|---|---|---|
| | | Previous (1989-90) | Present (2017-18) | Previous (1989-90) | Present (2017-18) |
| 1 | Good water | 83.7 | 61.7 | 108 | 193 |
| 2 | Marginally saline | 14.7 | 19.5 | 19 | 61 |
| 3 | Saline | 0.8 | 3.2 | 1 | 10 |
| 4 | High-SAR saline | 0.0 | 3.5 | 0 | 11 |
| 5 | Marginally alkali | 0.8 | 4.2 | 1 | 13 |
| 6 | Alkali | 0.0 | 3.8 | 0 | 12 |
| 7 | Highly alkali | 0.0 | 3.8 | 0 | 12 |
| 8 | NA | 0.0 | 0.3 | 0 | 1 |
| Total | | 100 | 100 | 129 | 313 |

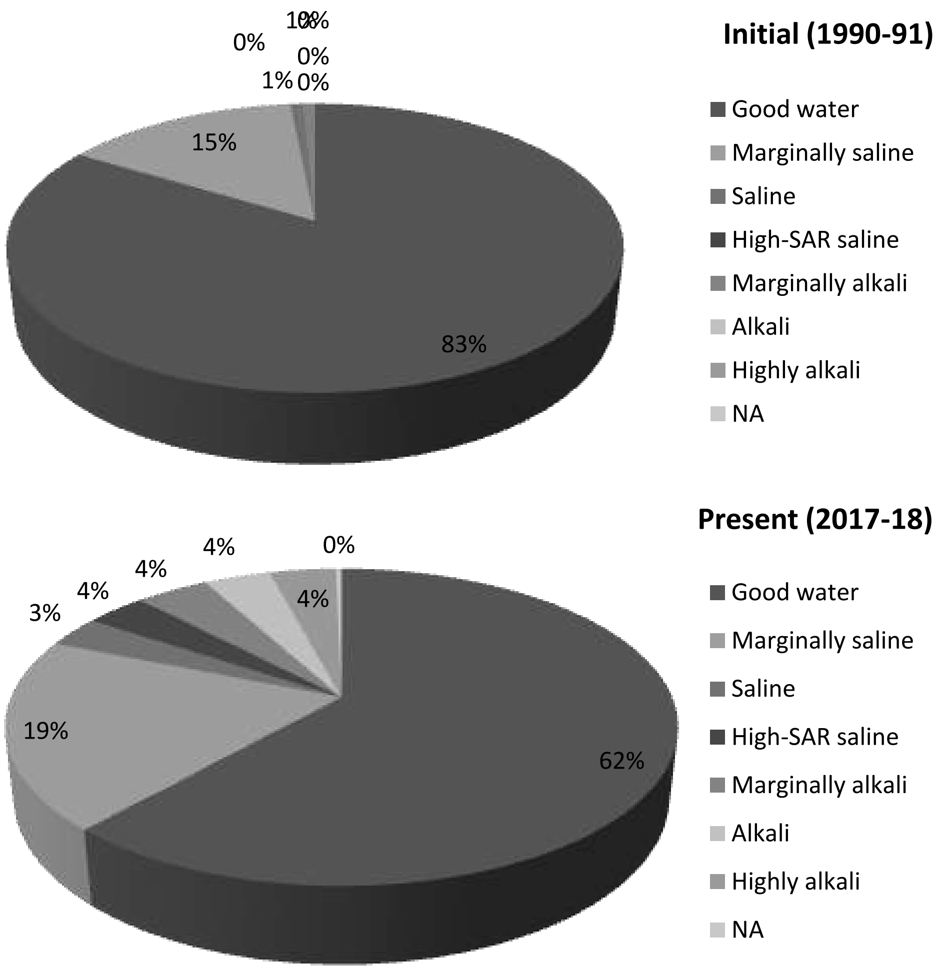



Fig. 1.9 Changes in ground water quality of East Godavari over a period from 1990-91 to 2017-18

The management options as per groundwater quality class are provided below in Table 1.38.

Table 1.38 Classification of ground water and their management practices

| Rating | EC ($dSm^{-1}$) | SAR | RSC ($m e L^{-1}$) | % samples | Recommended management practices |
|---|---|---|---|---|---|
| Good | <2 | <10 | <2.5 | 49.3 | Can be used for all types of soils and crops |
| Marginally saline | 2-4 | <10 | <2.5 | 28.4 | Can be used with slight salt tolerant crops and periodic monitoring salts |
| Saline | >4 | <10 | <2.5 | 4.9 | Unsuitable for irrigation can be used with slight salt tolerant crops and periodic monitoring salts |
| High SAR saline | >4 | >10 | <2.5 | 12.0 | Unsuitable for irrigation but good quality of irrigation is required. |
| Marginally alkaline | <4 | <10 | 2.5-4.0 | 0.9 | Can be used periodic monitoring of gypsum |
| Highly alkaline | <4 | <10 | >4.0 | 4.4 | Unsuitable for irrigation |

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

The study area, an uniform strip of 50 km wide along the sea coast covering the three districts, *viz.,* Krishna, Guntur and Prakasam, was selected and four routes (Machilipatnam, Kanaparthy, Suryalanka and Nizampatnam) perpendicular to sea coast were identified with objectives i) to study the chemical composition of groundwater as influenced by seawater intrusion and ii) to find out the relationship between soil salinity and distance from seashore. Groundwater sampling points for different routes are given in Table 1.39. In each route six villages were identified and five samples were collected in each village. Thus a total of 120 points were selected by choosing thirty from each stratum considering the ingress of salinity along the coastal line.

Table 1.39 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<br>Guduru | Nidumolu<br>Challapalli | Vuyyuru<br>Bhattiprolu |
| II | Kanaparthi | Uppugunduru<br>Kadavakuduru | Inkollu<br>J. Panguluru | Addanki<br>Parchuru |
| III | Suryalanka | Bapatla<br>Appikatla | Kakumanu<br>Pedanandipadu | Prattipadu<br>Etukuru |
| IV | Nizampatnam | Chandavolu<br>Cherukupalli | Govada<br>Ponnuru | Chebrolu<br>Tenali |

The route wise pH, EC, RSC and SAR values for pre-monsoon and post monsoon period for 2016 and 2017 are given from Table 1.40 to Table 1.43. As per pre monsoon data 2016, higher EC values were observed along Suryalanka route (0.30 to 10.70 $dSm^{-1}$) followed by Nizampatnam route (0.9 to 8.6 $dSm^{-1}$), Machilipatnam route (1.00 to 5.10 $dSm^{-1}$) and Kanaparthi route (0.50 to 4.60 $dSm^{-1}$). Data related to post-monsoon 2016 period indicated slight reduction in all the parameters studied compared to pre-monsoon period in majority of samples. Higher EC values were observed along Suryalanka route (0.6-9.4 $dS\ m^{-1}$) followed by Nizampatnam route (0.7-7.9 $dS\ m^{-1}$), Machilipatnam route (0.4 – 5.4 $dSm^{-1}$) and Kanaparthi route (0.5 – 4.2 $dSm^{-1}$).

During pre-monsoon period, 2016 the highest EC (5.10 $dSm^{-1}$) and SAR (19.15) values were recorded at Machilipatnam, which is 7.3 km away from sea in Machilipatnam route whereas, in Nizampatnam route Govada, which is 21 km away from sea recorded the highest EC (8.60 $dSm^{-1}$) and SAR (19.94) values. Along Suryalanka route, the highest pH (8.0) and SAR (22.66) values were recorded at Appikatla, which is 14.2 km away from sea whereas, the highest EC (10.7 $dSm^{-1}$) was recorded at Pattipadu, which is 42 km away from sea. In Kanaparthi route the highest pH (8.0) value was recorded at J Panguluru which is 28.3 km away from sea whereas, the highest EC (4.6 $dSm^{-1}$) and SAR (19.8) values were recorded at Parchuru, which is 42 km away from sea. Pre monsoon and post monsoon data for 2017 followed similar trend except highest EC of 19.30 $dSm^{-1}$was recorded on Machilipatnam during Dec. 2017.

Table 1.40 Route wise pH, EC, RSC and SAR values during pre monsoon period (Jun. 2016)

| S. No. | Route | pH | EC ($dSm^{-1}$) | 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 1.41 Route wise ranges of pH and EC values during post monsoon period (Dec. 2016)

| S. No. | Route | pH | EC ($dSm^{-1}$) | 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 |

Table 1.42 Route wise pH, EC, RSC and SAR values during pre monsoon period (Jun. 2017)

| S. No. | Route | pH | EC (dS $m^{-1}$) | RSC (me $L^{-1}$) | SAR |
|---|---|---|---|---|---|
| 1 | Machilipatnam | 7.1 to 8.3 | 0.70 to 5.80 | 0 to 3.4 | 1.03 to 3.26 |
| 2 | Kanaparthi | 7.0 to 8.5 | 0.40 to 5.0 | 0 to 6.6 | 0.59 to 23.85 |
| 3 | Suryalanka | 7.0 to 8.3 | 0.80 to 11.0 | 0 to 5.6 | 2.05 to 25.73 |
| 4 | Nizampatnam | 7.1 to 8.3 | 0.90 to 9.80 | 0 to 8.8 | 2.60 to 17.03 |

Table 1.43 Route wise ranges of pH and EC values during post monsoon period (Dec. 2017)

| S. No. | Route | pH | EC ($dSm^{-1}$) | RSC (me $L^{-1}$) | SAR |
|---|---|---|---|---|---|
| 1 | Machilipatnam | 6.9 to 7.9 | 0.50 to 19.30 | 0 to 14.04 | 1.44 to 36.4 |
| 2 | Kanaparthi | 6.7 to 7.9 | 0.40 to 5.0 | 0 to 14.20 | 0.66 to 42.5 |
| 3 | Suryalanka | 6.9 to 8.1 | 0.40 to 9.70 | 0 to 10.44 | 0.64 to 49.22 |
| 4 | Nizampatnam | 7.2 to 7.7 | 1.6 to 8.30 | 0 to 11.60 | 2.82 to 10.76 |

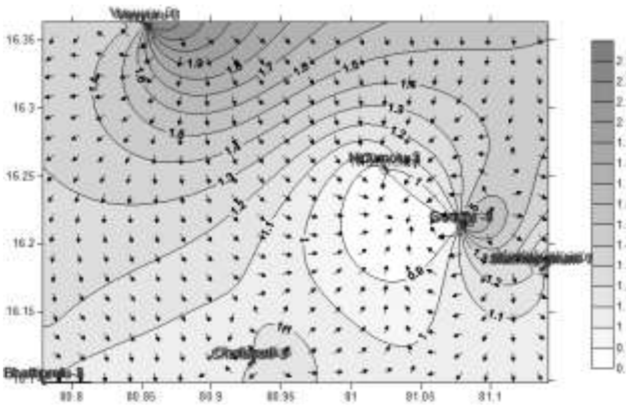
The ground water samples for pre and –post monsoon periods for 2016 were analyzed for different ions and ionic ratios (Todd, 1959) and the following observations were made about sea water intrusion.

- 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

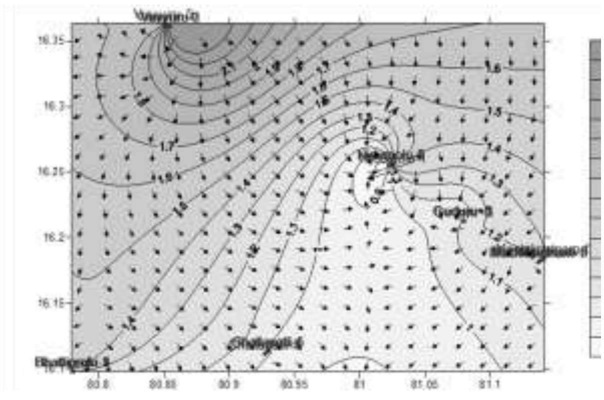
Nizampatnam routes indicating seawater intrusion, while around 13, 6, 33 and 3 per cent samples respectively are injuriously contaminated.

- 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.

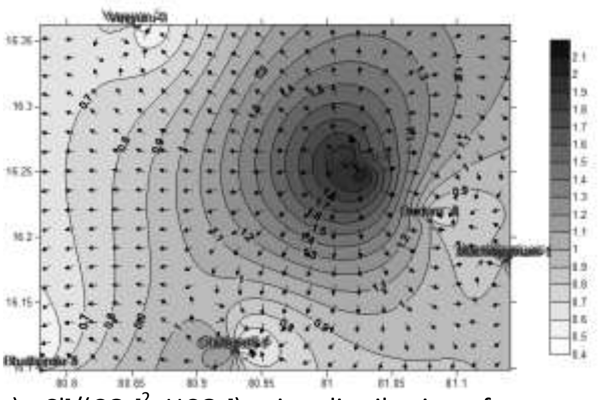
The $Na^{+}/Cl^{-}$ and $Cl^{-}/(CO_3^{-2}+HCO_3^{-})$ ratio values of groundwater from sea towards inland during pre and post monsoon periods along different routes are presented in Fig. 1.10. Lower $Na^{+}/Cl^{-}$ and higher $Cl^{-}/(CO_3^{-2}+HCO_3^{-}$ ratios were observed at Nidumolu (20 km), Inkollu (27 km), Kakumanu (27 km) and Chebrolu (39 km) 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.



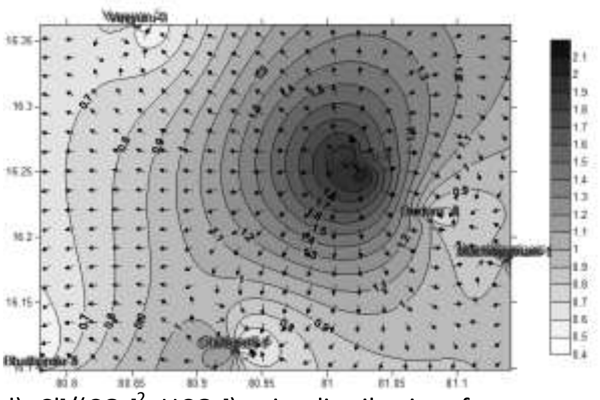
a) $Na^{+}/Cl^{-}$ ratio distribution from sea during pre monsoon period in Machili patnam route



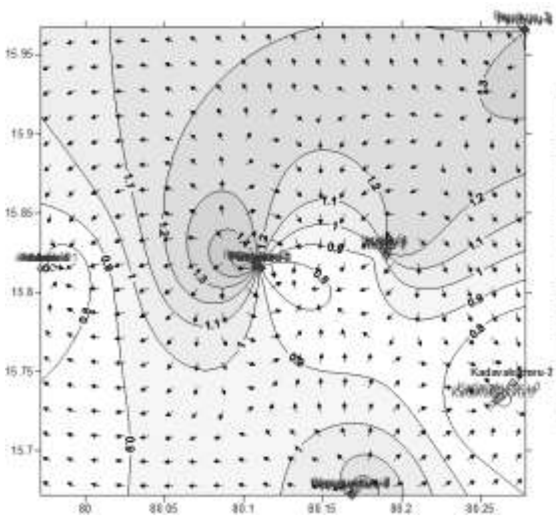
b) $Na^{+}/Cl^{-}$ ratio distribution from sea during post monsoon period in Machili patnam route



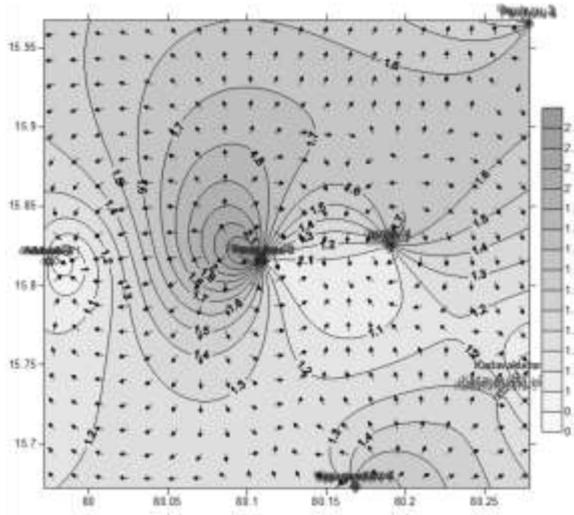
c) $Cl^{-}/(CO_3^{-2}+HCO_3^{-})$ratio distribution from sea during pre monsoon period in Machili patnam route



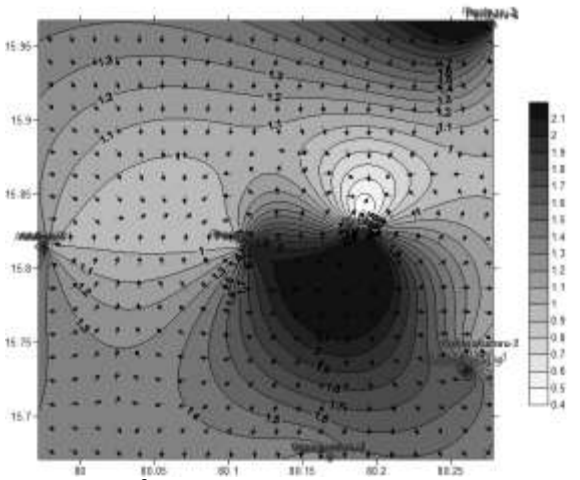
d) $Cl^{-}/(CO_3^{-2}+HCO_3^{-})$ratio distribution from sea during post monsoon period in Machili patnam route



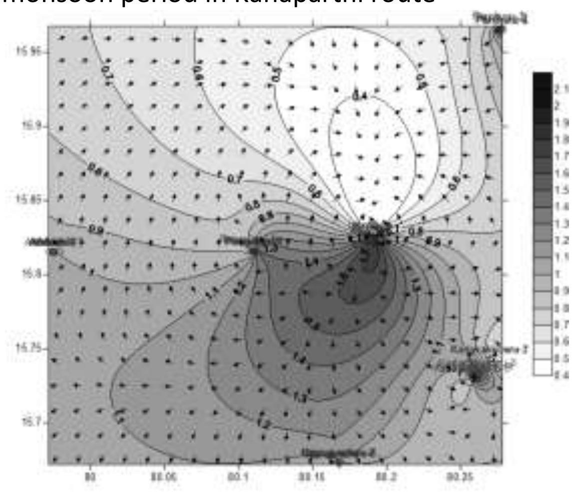
e) $Na^+/Cl^-$ ratio distribution from sea during pre monsoon period in Kanaparthi route



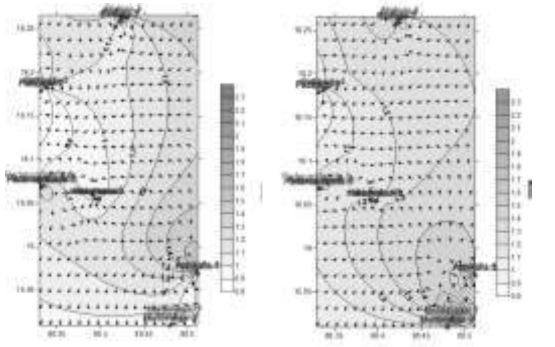
f) $Na^+/Cl^-$ ratio distribution from sea during post monsoon period in Kanaparthi route



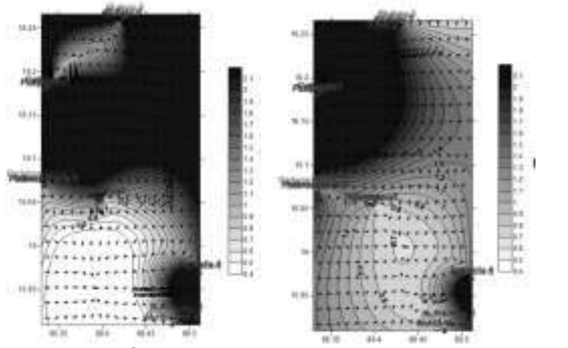
g) $Cl^-/(CO_3^{-2}+HCO_3^-)$ ratio distribution from sea during pre monsoon period in Kanaparthi route



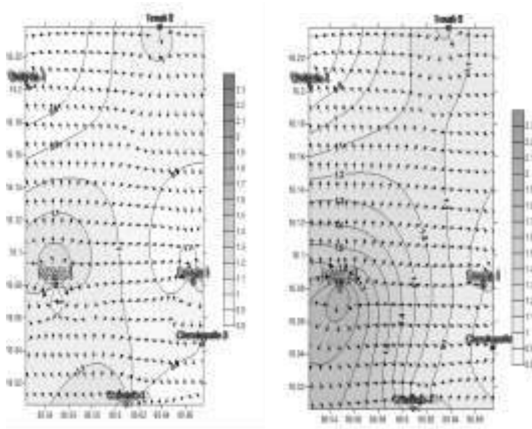
h) $Cl^-/(CO_3^{-2}+HCO_3^-)$ ratio distribution from sea during post monsoon period in Kanaparthi route



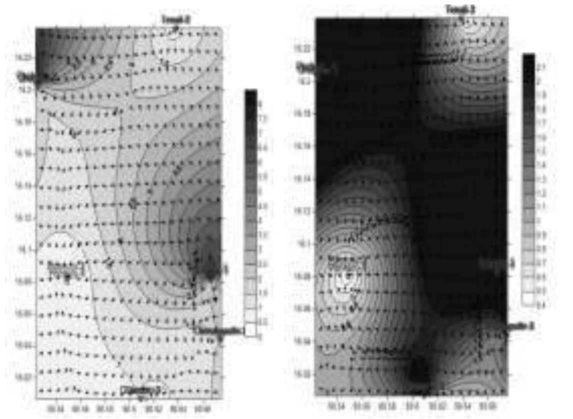
i) $Na^+/Cl^-$ ratio distribution from sea during pre and post monsoon periods, respectively in Suryalanka route



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. 1.10 Distribution of ionic ratios in groundwater in coastal region in Andhra Pradesh

**Survey and Characterization of Underground Waters for Irrigation (Bikaner)**

Survey of Jodhpur district was initiated during 2016-17. Jodhpur district is centrally situated in the western region of the Rajasthan state. It lies between between $26^0$ 00' and $27^o$ 37' N latitude and $72^o$ 55' and $73^o$ 52' E longitude. This district is situated at a height of 250-300 meters above sea level. The district is divided into 15 tehsils *viz* Jodhpur, Luni, Osian, Phalodi, Shergarh, Bilara, Pipar city, Bhopalgarh, Bapini, Tinwari, bavadi, Bap, Lohawat, Denchu and Balesar tehsils.

During 2016-18, survey of three tehsils, viz., Bilara, Pipar City and Bhopalgarh of Jodhpur were completed. Water samples from tube wells distributed in 73 villages *i.e* 20 villages of Bilara, 24 villages of Pipar city and 29 villages Bhopalgarh 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.

The data of water samples from Bilara, Pipar City and Bhopalgarh tehsils showed that EC ranged from 2.47 to 10.52 $dSm^{-1}$, 0.56 to 19.50 $dSm^{-1}$, and 0.93 to 5.81 $dSm^{-1}$, whereas, pH ranged from 7.33 to 8.42, 7.10 to 9.13 and 7.22 to 8.45, respectively. The concentration of calcium varied from 3.36 to 27.40, 0.80 to 4.00 and 0.80 to 9.40meq/L and magnesium varied from 3.54 to 28.00, 1.20 to 11.60 and 1.20 to 9.00 meq/L in Bilara, Pipar city and Bhopalgarh tehsils of Jodhpur district, respectively. Sodium concentration ranged from 16.80 to 55.13 meq/L in Bilara tehsil, 2.48 to 183.22 meq/L in Pipar city tehsil and 5.08 to 4.36 meq/L in Bhopalgarh tehsil, whereas, concentration of potassium ion for Bilara, Pipar city and Bhoplagarh tehsils varied from 0.06 to 0.32, 0.07 to 0.70 and 0.07 to 0.88 meq/L, respectively. Soluble carbonates varied from 0.20 to 0.80 meq/L in Bilara, 0 to 4.20 meq/L in Pipar city and 0.40 to 1.40 meq/L in Bhopalgarh tehsils while, bicarbonates varied from 6.80 to 17.60 meq/L in Bilara, 2.60 to 12.80 meq/L in Pipar city and 3.60 to 10.00 meq/L in Bhopalgarh tehsils of Jodhpur district. The concentration of chloride varied from 11.25 to 80.15, 1.60 to 152.42 and 3.50 to 45.00 meq/L while, sulphate varied from 0.53 to 8.09, 0.50 to 29.48 and 0.37 to 9.85 meq/L for Bilara, Pipar city and Bhopalgarh tehsils, respectively. Chloride and sodium was the dominant anion and cation, respectively. The SAR of water samples ranged from 8.22 to 20.68, 2.10 to 76.08 and 3.18 to 23.79, whereas, soluble sodium percentage (SSP) of water samples ranged from 47.03 to 80.39, 42.97 to 95.49 and 49.22 to 89.11, respectively for Bilara, Pipar city and Bhopalgarh tehsils of Jodhpur district (Table 1.44)

Table 1.44 Range of chemical characteristics of tube well waters and soils of Bilara, Pipar city and Bhopalgarh tehsils of Jodhpur district

| Characteristics | Bilara Tehsil | | Pipar city Tehsil | | Bhopalgarh Tehsil | |
|---|---|---|---|---|---|---|
| | Water (40)* | Soil (40)* | Water (40 )* | Soil (40)* | Water (60 )* | Soil (60)* |
| 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) | 7.22 - 8.45 (7.81) | 7.90 - 9.43 (8.90) |
| EC ($dSm^{-1}$) | 2.47 - 10.52 (5.78) | 0.74 - 3.12 (1.50) | 0.56 - 19.5 (5.27) | 0.12 - 4.53 (0.68) | 0.93 - 5.81 (2.97) | 0.16 - 9.69 (0.93) |
| 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) | 0.80 - 9.40 (3.54) | 0.1 - 34 (2.03) |
| 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) | 1.20 - 9.00 (3.18) | 0.1 - 30.5 (1.52) |
| 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) | 5.08 - 45.36 (22.44) | 1.30 – 30.6 (5.56) |
| K (me/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) | 0.07 - 0.88 (0.16) | 0.02 – 1.25 (0.19) |
| $CO_3$ (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) | 0.40 - 1.50 (0.65) | 0.20 - 0.80 (0.63) |
| $HCO_3$ (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) | 3.60 - 10.0 (6.35) | 0.40 - 4.0 (1.31) |
| 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) | 3.50 - 45.0 (19.51) | 0.80 - 80.0 (6.68) |
| $SO_4$ (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) | 0.37 - 9.85 (3.47) | 0.01 - 12.10 (0.67) |
| RSC (meq/L) | 0.00 - 4.00 (0.56) | - | 0.00 - 4.20 (1.34) | - | 0.0 4.50 (0.27) | - |
| 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) | 3.18 - 23.79 (12.29) | 2.82 - 8.50 (4.93) |
| Potential salinity (meq/L) | 12.08 - 83.54 (45.78) | - | 2.25 - 167.16 (41.59) | - | 3.98 - 47. 51 (21.25) | - |
| Adj. SAR | 24.10 - 59.96 (36.87) | - | 3.98 - 220.63 (62.57) | - | 7.3 - 59.09 (29.13) | - |
| 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) | 49.22-89.11 (74.89) | 31.75- 83.33 (69.80) |
| Water table (ft) | 100 - 550 (354) | - | 60 - 700 (320) | - | 300 - 1200 (750) | - |

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

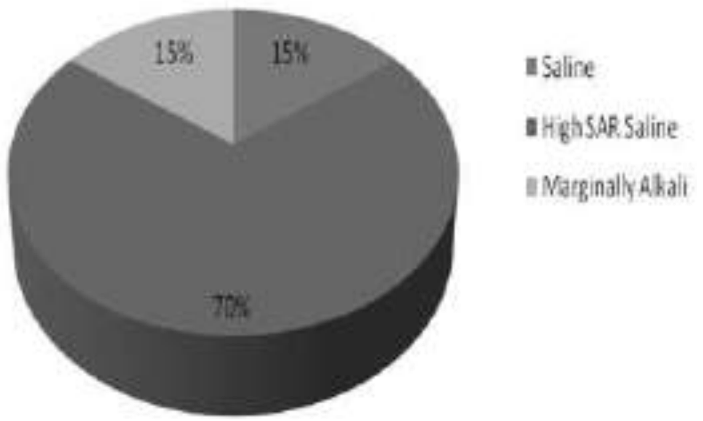
The distribution of water samples in different ranges of EC and RSC showed that RSC of water samples ranged from 0.0 to 4.0, 0.0 to 4.2 and 0.0 to 4.5 meq/L in Bilara, Pipar city and Bhopalgarh tehsils, respectively. About 90, 87.50 and 81.66 percent water samples in Bilara, Pipar city and Bhopalgarh tehsils, had RSC value of <2.5, meq/L, respectively, whereas, about 10, 12.50 and 18.34 percent waters have shown RSC value of in range of 2.5 to 5.0 meq/L (i.e. > 2.5 meq/L) in Bilara, Pipar city and Bhopalgarh tehsils. As regard to salinity 7.50, 10 and 82.50 per cent water samples in Bilara tehsil showed EC in the range of 2 to 3, 3 to 4 and >4 dS/m, whereas in Pipar city tehsil 5, 5, 15, 12.50 and 62.50 per cent water samples had EC in the range of <1, 1 to 2, 2 to 3, 3 to 4 and > 4 dS/m and Bhopalgarh tehsil 5, 26.67, 13.33, 35 and 20 per cent water samples had EC in the range of <1, 1 to 2, 2 to 3, 3 to 4 and > 4 dS/m, respectively. Cationic composition showed that $Na^+$ was the dominant cation but the degree of dominance was more in Pipar city tehsil as compared to Bilara and Bhopalgarh tehsils, similar was the case with chloride.

About 15, 70 and 15 per cent water samples in Bilara was saline, high SAR saline and marginally alkali, respectively. In Pipar city tehsil about 10, 17.50, 60 and 12.50 per cent water samples were good, marginally saline, high SAR saline and highly alkali category and in Bhopalgarh tehsil about 21.67, 15, 48.33, 8.33, 3.33 and 3.34 percent water samples were good, marginally saline, high SAR saline, marginally alkali, alkali and highly alkali category, respectively (Table 1.45 and Fig.1.11).

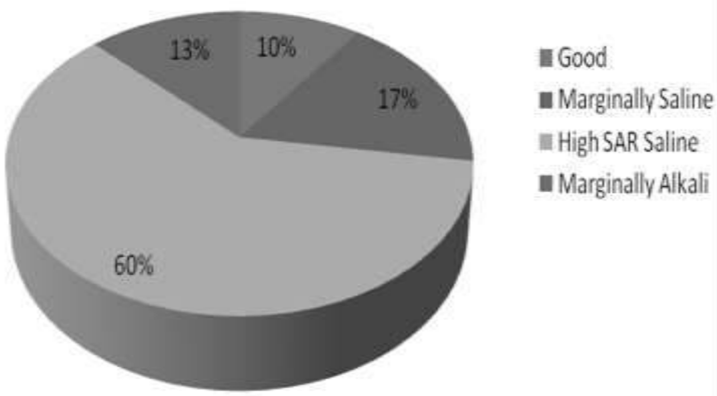
Table 1.45 Groundwater quality in Bilara Pipar city and Bhopalgarh tehsils of Jodhpur district

| Water quality | Name of villages in tehsils | | |
|---|---|---|---|
| | Bilara | Pipar city | Bhopalgarh |
| Good<br>EC <2 $dSm^{-1}$<br>SAR <10 and<br>RSC <2.5 $meqL^{-1}$ | --- | Sindhipura, Nanan-3, Khudecha-1, Gadsuriya | Basni Cholawatan (2), Basni Theda (2), Bagoria(2), Bholaram Nagar (2), Ram Nagar (1), Basni Budha (2), Shiv Nagar (1), Nadsar (1) |
| Marginally saline<br>EC 2-4 $dSm^{-1}$<br>SAR <10<br>RSC <2.5 $meqL^{-1}$ | --- | Siyara, Basani Khariya-1, Basani Khariya-2, Sargiya, Malawas-1, Madaliya-2, Madaliya-3, | Rajlani (2), Nadsar (1), Barani Kalan (2), Barani Khurd (2), Gopal Nagar (1), Dev Naryanpur (1) |
| Saline<br>EC >4$dSm^{-1}$<br>SAR <10<br>RSC <2.5 $meqL^{-1}$ | Jhurli-1, Jhurli-2, Udaliyawas-2, Birawas-1, Birawas-2, Birawas-3 | --- | --- |
| High SAR saline<br>(EC >4 $dSm^{-1}$<br>SAR >10<br>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 | 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 | Todiyana (1), Nagalwas (2), Paldi Ranwat (3), Surpura khurd (2), Khumbhara (2), Khiradesar (1), Bhopal garh (1), Bholaram Nagar (1), Dadni (2), Garsani (2), Asop (2), Rampura (2),Radod (2),Gopalnagar (2), Lawari (2), Gagsingpur (2), Dev Naryanpur (1) |
| Marginally alkali<br>(EC <4 $dSm^{-1}$<br>SAR <10<br>RSC 2-4 $mqeL^{-1}$ | Sindhi Nagar-1, Olvi-1, Olvi-2, Khariya-1, Jhak-1, Khejarla | --- | Todiyana (1), Bhopal garh (1), Ram nagar (1) Shivnath Nagar(1), Shiv Nagar(1) |
| Alkali<br>(EC <4 $dSm^{-1}$<br>SAR <10<br>RSC >4.0 $meqL^{-1}$ | --- | --- | Chapla (2) |

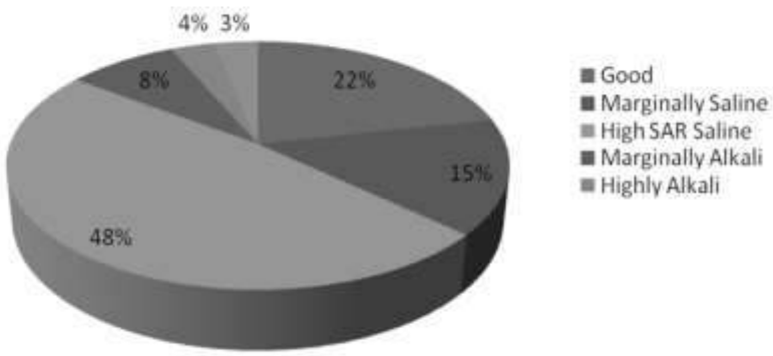
| | | | |
|---|---|---|---|
| Highly alkali<br>EC <4 $dSm^{-1}$<br>SAR >10<br>RSC >4.0 $meqL^{-1}$ | --- | Pipar Road, Riyan Seta Ri-1, Riyan Seta Ri-2, Jalka-2, Borunda-1 | Hiradesar (1), Shivnath Nagar (1) |




a. **Bilara Tehsil**




b. **Pipar City**




c. **Bhopalgarh Tehsil**

Fig. 1.11 Distribution (%) of water quality in Bilara, Pipar City and Bhopalgarh tehsil of Jodhapur district

This clearly indicated that approx. 50 per cent waters in the studied area were saline-sodic type, the prolonged use of such type of waters being high in carbonate and bicarbonates may immobilizes soluble calcium and magnesium in soil precipitating them as carbonates, consequently the concentration of sodium in soil solution and exchange complex might increase, which ultimately might lead to formation of alkali soils.

About 10, 62.5 and 27.5 per cent water samples in Bilara, 37.5, 42.5, 15 and 5 per cent in Pipar city and 16.67, 60 and 23.3 per cent in Bhopalgarh showed pH in the range of 7-7.50, 7.50-8.0, 8.0 – 8.5 and >8.5, respectively, Table 1.46.

Table 1.46 Per cent distribution of water samples in relation to pH, EC, SAR, SSP and RSC of Bilara Pipar city and Bhopalgarh tehsils of Jodhpur district

| Characteristics | Bilara (%) | Pipar city (%) | Bhopalgarh (%) |
|---|---|---|---|
| **pH** | | | |
| 7.0-7.5 | 10.00 | 37.50 | 16.67 |
| 7.5-8.0 | 62.50 | 42.50 | 60.00 |
| 8.0-8.5 | 27.50 | 15.00 | 23.33 |
| > 8.5 | - | 5.00 | - |
| **EC ($dSm^{-1}$)** | | | |
| <2 | - | 10.00 | 31.67 |
| 2-4 | 17.50 | 27.50 | 48.33 |
| 4-6 | 42.50 | 27.50 | 20.00 |
| >6 | 40.00 | 35.00 | - |
| **SAR** | | | |
| 0-10 | 30.00 | 25.00 | 33.33 |
| 10-20 | 67.50 | 7.50 | 61.67 |
| 20-30 | 2.50 | 27.50 | 5.00 |
| > 30 | - | 40.00 | - |
| **SSP** | | | |
| < 50 | 10.00 | 5.00 | 1.67 |
| 50-60 | 2.50 | 0.00 | 6.67 |
| 60-70 | 47.50 | 2.50 | 15.00 |
| 70-80 | 37.50 | 20.00 | 38.33 |
| > 80 | 2.50 | 72.50 | 38.33 |
| **RSC ($meqL^{-1}$)** | | | |
| <1.25 | 82.50 | 62.5 | 61.67 |
| 1.25-2.50 | 7.50 | 25.00 | 20.00 |
| >2.50 | 10.00 | 12.50 | 18.33 |

In Bilara tehsil 17.5, 42.5 and 40 per cent water samples had EC in the range of 2-4, 4-6 and >6 $dSm^{-1}$ while, in Pipar city 10, 27.50, 27.50 and 35 per cent water samples had EC in the range of <2, 2-4, 4-6 and >6 dS/m and in Bhopalgarh tehsil 31.67, 48.33 and 20 percent water samples had EC in the range of <2, 2-4 and 4-6 dS/m, respectively. Nearly 97.50 and 95 per cent water samples of Bilara and Bhopalgarh had SAR <20, respectively while, Pipar city had only 32.5 percent water sample had SAR <20 and rest having SAR >20. About 78 per cent water samples the Bilara tehsil, had SSP 60-80, in Pipar city 72.50 percent samples having SSP >80 and in Bhopalgarh tehsil majority of (91.66 per cent) samples having SSP >60.

Farmers are mostly growing wheat and mustard in rabi with sprinkler irrigation, whereas, pearl millet and cluster bean are being grown in kharif season as rain fed crops with supplement irrigation whenever needed. Some farmers are also growing vegetables in rabi season near the vicinity of townships. Soils are light to medium in texture and farmers are using more than the recommended doses of fertilizers especially in rabi season crops.

The detailed chemical characteristics of soil samples irrigated with corresponding tube well water in the tehsils of Bilara Pipar city and Bhopalgarh of Jodhpur district indicate that $pH_2$ of soil samples in Bilara tehsil varied from 8.0 to 9.49, in Pipar city varied from 8.03 to 9.53 and in Bhopalgarh from 7.90 to 9.43 whereas, the corresponding $EC_2$ ranged from 0.74 to 3.12 and 0.12 to 4.53 and 0.16 to 9.69 $dSm^{-1}$, respectively. $Na^+$ being prominent cation ranged from 4.30 to 21.09 meq/L with an average of 9.03 me/L in Bilara tehsil, in Pipar city tehsil it ranged from 0.50 to 38.12 meq/KL with and average value 4.38 meq/l and in Bhopalgarh tehsil $Na^+$ ranged from 1.3 to 30.60 meq/L, with an average value of 5.56 meq/L. As compared to $Na^+$ content in all three tehsils the $Ca^{++}$ + $Mg^{++}$ content was approximately half. Like groundwater, in soil also chloride was observed dominant anion with an average value of 4.55, 3.42 and 6.68 meq/L in Bilara, Pipar city and Bhopalgarh of Jodhpur district, respectively.

Since >50 per cent of ground waters of all the three tehsils have shown high SAR saline characteristics and soils of corresponding fields have also shown dominance of sodium, therefore, use of gypsum either for neutralization of RSC of waters or application in field is recommended.

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

**Survey and Characterization of Ground Waters of Kaithal and Mewat Districts for Irrigation (Hisar**)

The survey and characterization of ground water for irrigation was undertaken during 2016-17 in Kaithal, Guhla, Kalayat, Pundari, Rajound and Siwan blocks of Kaithal district and during 2017-18 in Nuh, Nagina, Punahana and Ferozepur Jhirka blocks of Mewat district of Haryana.

**Kaithal District**

Kaithal is the north eastern district of Haryana State. It has a total geographical area of 2317 sqkm and is located between 29°31’- 30°12’ N latitudes and 76°10’- 76°42’ E longitudes. The district has been divided into six blocks namely Kaithal, Guhla, Kalayat, Pundari, Rajound and Siwan. The climate of study area has been characterized as tropical steppe, semiarid and hot (above 40° C in May & June) which is mainly dry with very hot summer and cold winter in January except during monsoon season when moist air of oceanic origin penetrates into the district. Annual rainfall of district is 563 mm which is unevenly distributed over the area. Nearly 85 per cent of annual rainfall occurred during south west monsoon.

The district has two types of soils, viz., sierozem and desert soils. Major parts of the district mainly comprise sierozem soil while desert soils are comparatively found in smaller part of the district especially in northern part. Sierozem soils are found in the areas where the normal annual rainfall varies from 300 to 500 mm. These soils vary from sandy loam to loamy sands in texture and are marginally fertile. These soils are highly vulnerable to salinity and alkali hazard, though salinity is major hazard.

Rice-wheat is the main cropping system in the region and jowar, bajra, sugarcane, cotton are also grown the area. Due to fertile nature of soils multiple cropping systems are followed in the district resulting in higher crop production and economic returns, thereby, increasing the socio-economic condition of the farmers. However, secondary salinization problem is increasing due to injudicious use of poor quality water for irrigation. Total 530 water samples were collected from six blocks of Kaithal district from running tube wells and latitudes and longitudes angles recorded using GPS and anlysed in laboratory.

In the Kaithal district, electrical conductivity (EC) ranged from 0.30 to 8.25 $dSm^{-1}$ with a mean of 1.80 $dSm^{-1}$ (Table 1.47). The lowest EC 0.30 dS/m was observed in village Azimgarh in Guhla block and the highest EC 8.25 $dSm^{-1}$was observed in village Kachana of Guhla block. To study the spatial distribution of EC in the district, a spatial variable map was prepared by using ArcGIS through the interpolation of the available data at 530 sampling points (Fig. 1.12). The variation of EC in Kaithal district is grouped into 3 classes with a class interval of 2 $dSm^{-1}$. The most dominating range of EC is 0-2 $dSm^{-1}$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 area of the district. The pH ranged from 7.01 to 9.80 with a mean of 8.20 (Table 1.47). The sodium adsorption ratio (SAR) were found to be ranged between from 2.51 to 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 found to be ranged between 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 given in Table 1.48. Percentage of samples in different EC classes is different, its highest percentage (76.60) was found in EC class of 0-2 $dSm^{-1}$ and its lowest percentage (7.73) was found in EC class ≥ 4 $dSm^{-1}$.

In case of anions, chloride was the dominant anion with maximum concentration of chlorides in groundwater samples varied from 0.40 to 48.00 $meqL^{-1}$ with the mean value of 8.30 $meqL^{-1}$. The concentration of bicarbonates in groundwater samples varied from 0.0 to 10.50 $meqL^{-1}$ with a mean of 3.64 $meqL^{-1}$. 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 1.47). It was analysed that anions the $Cl^-$ was the highest and its value increased with the increase in EC (Table 1.48 and Fig. 1.13).

Table 1.47 Range and mean of different water quality parameters for Kaithal district

| Quality Parameter | Range | Mean |
|---|---|---|
| pH | 7.01 - 9.80 | 8.20 |
| EC ($dSm^{-1}$) | 0.30 - 8.25 | 1.80 |
| RSC ($meqL^{-1}$) | 0.00 - 6.90 | 1.60 |
| SAR $(mmolL^{-1})^{1/2}$ | 2.51 - 27.67 | 2.55 |
| $Ca^{2+}$ ($meqL^{-1}$) | 0.20 - 5.30 | 1.18 |
| $Mg^{2+}$ ($meqL^{-1}$) | 0.80 - 14.84 | 3.45 |
| $Na^+$ ($meqL^{-1}$) | 1.80 - 61.10 | 12.89 |
| $K^+$ ($meqL^{-1}$) | 0.04 - 3.20 | 0.20 |
| $CO_3^{2-}$ ($meqL^{-1}$) | 0.00 - 5.30 | 1.21 |
| $HCO_3^-$ ($meqL^{-1}$) | 0.00 - 10.50 | 3.64 |
| $Cl^-$ ($meqL^{-1}$) | 0.40 - 48.00 | 8.30 |
| $SO_4^{2-}$ ($meqL^{-1}$) | 0.00 - 40.10 | 4.10 |

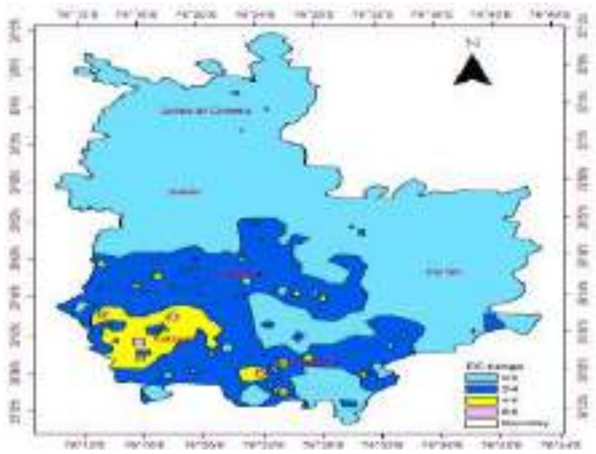


Fig. 1.12 Spatial variability of EC of groundwater used for irrigation in Kaithal district

Table 1.48 Chemical composition of groundwater samples 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 ($(mmoll^{-1})^{1/2}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ($meqL^{-1}$) | | | | | |
| 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 |

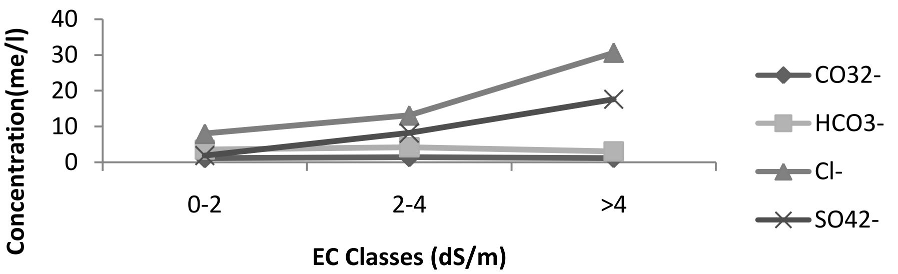



Fig.1.13. Anions ($CO_3$, $HCO_3$, Cl, $SO_4$) concentration ($meqL^{-1}$) in different EC classes of Kaithal district

The concentration of sodium in groundwater samples varied from 1.80 to 61.10 $meqL^{-1}$ with an average value of 12.89 $meqL^{-1}$ (Table 1.47), followed by magnesium (0.80 to 14.84 $meqL^{-1}$) and calcium (0.20 to 5.30 $meqL^{-1}$). Mean values for $Na^+$, $Mg^{2+}$, $Ca^{2+}$ and $K^+$ were 12.89, 3.45, 1.18 and 0.22 $meqL^{-1}$, respectively. The mean of cation $Na^+$ was the highest and its value increased with the increase in EC (Table 1.48 Fig. 1.14). Its lowest mean (8.73 $meqL^{-1}$) was found in the class 0-2, and highest mean (39.98 $meqL^{-1}$) was laid in the EC class of ≥ 4 $dSm^{-1}$.

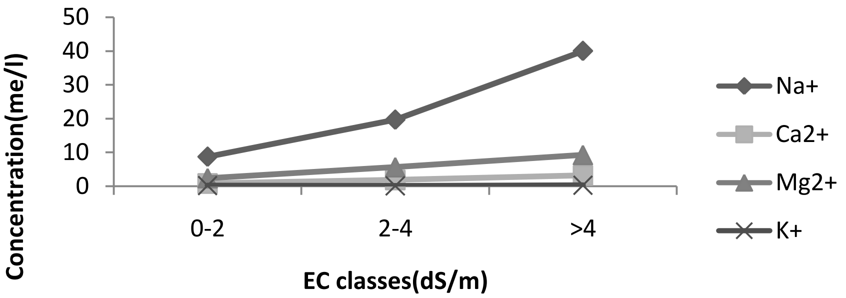



Fig. 1.14. Cations (Ca, Mg, Na, K) concentration (meq$L^{-1}$) in different EC classes of Kaithal district

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 marginally saline and high SAR saline, respectively. In alkali group 11.3, 13 and 8.7percent 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 category.

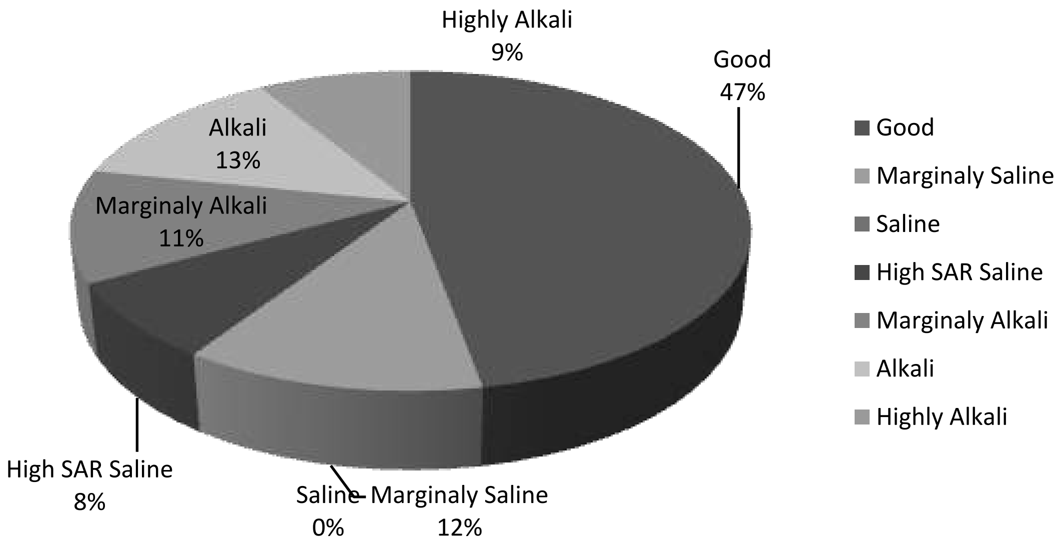



Fig. 1.15 Quality of groundwater (percent) in Kaithal district

Groundwater quality map for Kaithal district 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 tubewells 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 falls under good quality category but among these area where SAR <10 and RSC ≥ 2.5 falls under marginally alkali and alkali. Groundwater quality map for Kaithal district according to AICRP criteria is depicted in Fig.1.15.

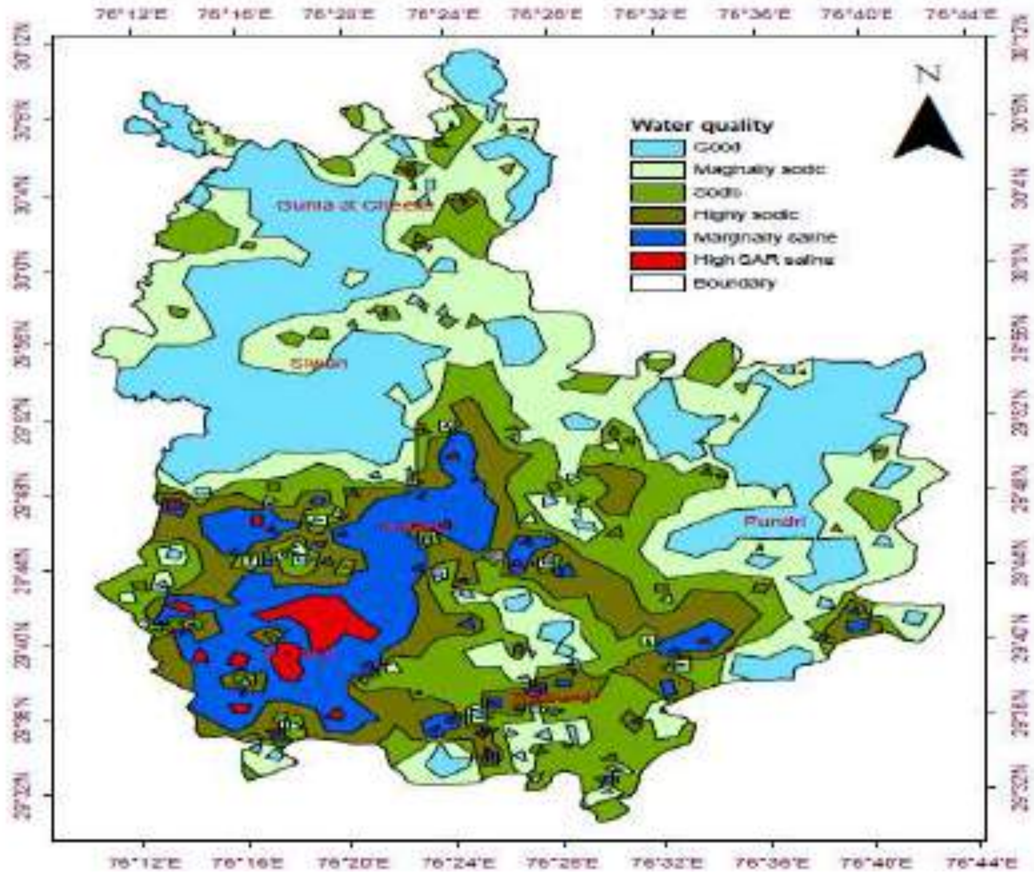



Fig. 1.16 Groundwater quality map for Kaithal district according to AICRP criteria

**Mewat District**

The Mewat district of Haryana located between 27°30'11 to 28°21'01 N latitude and 76°54'46 to 77°'16'01 E longitude. The geographical area of Mewat is 1859.61 $km^2$ and is comprised of four developmental blocks Nuh, Nagina, Ferozepur Jhirka and Punahana. The Mewat district falls under the sub-tropical, semi-arid climatic zone with extremely hot temperature in summer. Dryness of air is standard feature in Mewat except during the monsoon season. The normal annual rainfall in Mewat district is about 594 mm spread over 31 days. The soils of the Mewat represent a typical alluvial profile of Yamuna origin and are mostly salt affected.. The soils of the district are light in texture, particularly sandy, sandy- loam and clay loam.

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 307 sampling points (Fig. 1.17). The variation of EC in Palwal district is grouped into 6 classes with a class interval of 2 $dSm^{-1}$. The most dominating range of EC is 0-2 $dSm^{-1}$ which occupied maximum area in the district and covering all the blocks of the district. The next dominating range was 2-4 $dSm^{-1}$ which is covering a large portion. EC ranging from 10-12 $dSm^{-1}$ is observed in small patches in the district.

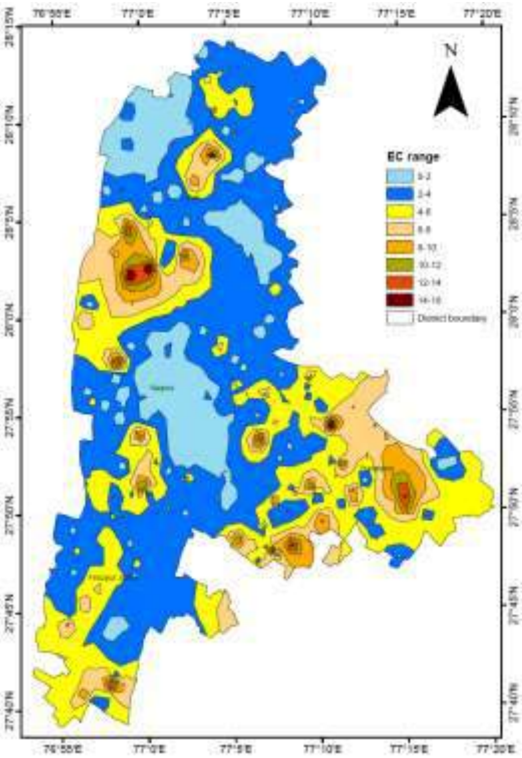



Fig. 1.17 Spatial variability of EC of groundwater used for irrigation in Mewat district

In Mewat district, electrical conductivity (EC) ranged from 0.59 to 15.90 $dSm^{-1}$ with mean 4.01 $dSm^{-1}$ (Table 1.49). The lowest EC of 0.59 $dSm^{-1}$ in water samples was observed in village Biwan in Nuh block and the highest EC of 15.90 $dSm^{-1}$ was observed in village Kurthala of Nuh block. To visualize its variability in different samples of the district, it was observed that in Mewat district, 203 samples had EC 0-4 $dSm^{-1}$, 77 samples had EC 4 to 10 $dSm^{-1}$, 27 samples had EC ≥10 $dSm^{-1}$. (Fig. 1.18).

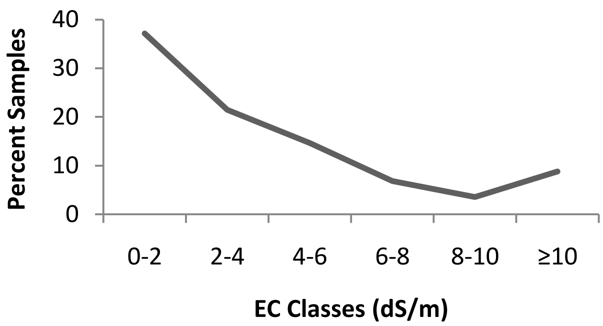



Fig. 1.18 Percent samples in EC classes in Mewat district

The pH ranged from 7.00 to 9.60 with a mean of 8.07 (Table 1.49). The sodium adsorption ratio (SAR) were found to be ranged between from 2.35 to 52.91 $(mmol\ l^{-1})^{1/2}$ with a mean value of 13.33 $(mmol\ l^{-1})^{1/2}$. The residual sodium carbonate (RSC) was found between 0.0 - 5.80 $meqL^{-1}$ with mean of 0.43

$meqL^{-1}$. EC classes were grouped into 6 different classes with an interval of two units. The percent distribution of sample in different EC classes is shown in Table 1.50 and Fig. 1.17. Percentage of samples in different EC classes is different, its highest percentage (37.13) was found in EC class of 0-2 $dSm^{-1}$ and its lowest percentage (3.58) was found in EC class 8-10 $dSm^{-1}$. In EC range of 2-4 $dSm^{-1}$, there is a 21.50 percent sample which is nearly an indication of good quality groundwater according to AICRP criteria on the basis of EC only.

Table 1.49 Range and mean of different water quality parameters for Mewat district

| Quality Parameter | Range | Mean |
|---|---|---|
| pH | 7.00 - 9.60 | 8.07 |
| EC ($dSm^{-1}$) | 0.59 - 15.90 | 4.01 |
| RSC ($meqL^{-1}$) | 0.00 - 5.80 | 0.43 |
| SAR $(mmolL^{-1})^{1/2}$ | 2.35 - 52.91 | 13.33 |
| $Ca^{2+}$ ($meqL^{-1}$) | 0.25 - 11.20 | 2.22 |
| $Mg^{2+}$ ($meqL^{-1}$) | 0.80 - 32.60 | 6.64 |
| $Na^{+}$ ($meqL^{-1}$) | 3.20 - 137.10 | 29.99 |
| $K^{+}$ ($meqL^{-1}$) | 0.05 - 6.91 | 0.39 |
| $CO_3^{2-}$ ($meqL^{-1}$) | 0.00 - 5.10 | 0.53 |
| $HCO_3^{-}$ ($meqL^{-1}$) | 0.20 - 12.30 | 3.15 |
| $Cl^{-}$ ($meqL^{-1}$) | 1.80 - 134.50 | 27.50 |
| $SO_4^{2-}$ ($meqL^{-1}$) | 0.10 - 39.10 | 7.63 |

Table 1.50 Chemical composition of groundwater samples of Mewat 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 $(mmol\ l^{1})^{1/2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ($meqL^{-1}$) | | | | | | | | | |
| 0-2 | 37.13 | 9.64 | 0.93 | 2.78 | 0.18 | 0.46 | 2.12 | 8.25 | 2.45 | 0.60 | 6.97 |
| 2-4 | 21.50 | 18.70 | 2.13 | 6.38 | 0.44 | 0.65 | 3.25 | 18.2 | 5.28 | 0.60 | 9.40 |
| 4-6 | 14.66 | 36.21 | 2.62 | 7.94 | 0.32 | 0.50 | 3.32 | 32.9 | 9.62 | 0.11 | 16.70 |
| 6-8 | 6.84 | 53.57 | 4.03 | 11.81 | 0.53 | 0.36 | 3.64 | 49.9 | 15.2 | 0.19 | 21.26 |
| 8-10 | 3.58 | 71.41 | 3.77 | 11.36 | 0.59 | 0.77 | 3.72 | 64.2 | 17.6 | 0 | 27.83 |
| ≥10 | 8.79 | 107.46 | 5.23 | 15.66 | 1.04 | 0.47 | 6.12 | 97.6 | 24.0 | 0 | 35.55 |

In case of anions, chloride was the dominant anion with maximum the concentration of chlorides in groundwater samples varied from 1.80 to 134.50 $meqL^{-1}$ with mean of 27.50 $meqL^{-1}$. The concentration of bicarbonates in groundwater samples varied from 0.020 to 12.30 $meqL^{-1}$ with mean of 3.15 $meqL^{-1}$. The mean values for $CO_3^{2-}$, $HCO_3^{-}$, $Cl^{-}$ and $SO_4^{2-}$ were 0.53, 3.15, 27.50 and 7.63 $meqL^{-1}$, respectively (Table 1.49). The mean of anion $Cl^{-}$ was the highest and its value increased with the increase in EC (Table 1.50; Fig. 1.19).

The concentration of sodium in groundwater samples varied from 3.20 to 137.10 $meqL^{-1}$ with mean 29.99 $meqL^{-1}$ (Table 1.49), followed by magnesium (0.80 to 32.60 $meqL^{-1}$) and calcium (0.25 to 11.20 $meqL^{-1}$). Mean for $Na^{+}$, $Mg^{2+}$, $Ca^{2+}$ and $K^{+}$ were 29.99, 6.64, 2.22 and 0.39 $meqL^{-1}$, respectively. The mean of cation $Na^{+}$ was the highest and its value increased with the increase in EC (Table 1.50 and Fig. 1.20). Its lowest mean value (9.64 $meqL^{-1}$) was found in the class 0-2, the highest mean value (107.46 $meqL^{-1}$) was laid in the EC class of ≥ 10 dS/m.

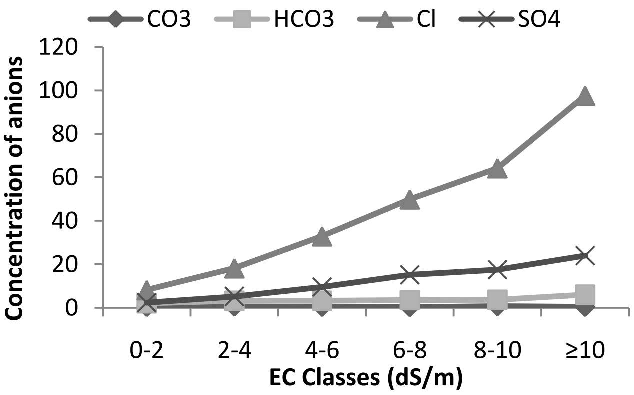



Fig. 1.19 Anions ($CO_3$, $HCO_3$, Cl, $SO_4$) concentration ($meqL^{-1}$) in EC classes of Mewat district

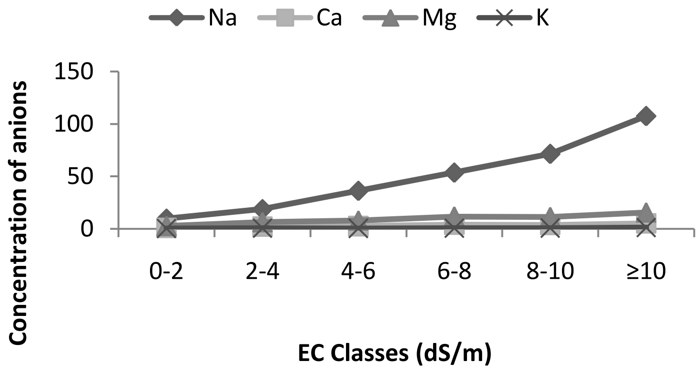



Fig.1.20 Cations (Ca, Mg, Na, K) concentration ($meqL^{-1}$) in EC classes of Mewat district

According to AICRP classification, it was found that 30.5 percent samples were of good quality, 60 percent saline and 9.5 percent alkali (Fig. 1.21). Out of the saline water, 26.1, 2.3 and 31.6 percent were marginally saline, saline and high SAR saline, respectively. In alkali group 4.6, 0.7 and 4.2 percent were marginally alkali, alkali and highly alkali, respectively. Out of seven categories of water, maximum 30.35 percent samples were good quality followed by marginally saline (26.1 percent) and minimum 0.7 percent were alkali category.

Groundwater quality map for Mewat district was prepared to study its spatial variability in the district (Fig. 1.22). In the district, 30.5 percent samples are under good category but spatial variable map of block indicates less area under good quality. Good category groundwater is mostly lying in Nagina, Nuh and Ferozepur Jhirka blocks of the district and highly scattered in other blocks. Area of the district having EC <2 falls under good quality category but among these area where SAR <10 and RSC ≥ 2.5 falls under marginally alkali and alkali. Most of the area where EC is >4 dS/m falls under high SAR saline in comparison to saline condition, whereas, in both condition EC is >4 dS/m. With this fact area under high SAR saline increased and area under saline reduced. There is a little problem of alkalinity in groundwater of the district because marginally alkali and alkali categories were observed very scattered with small polygons.

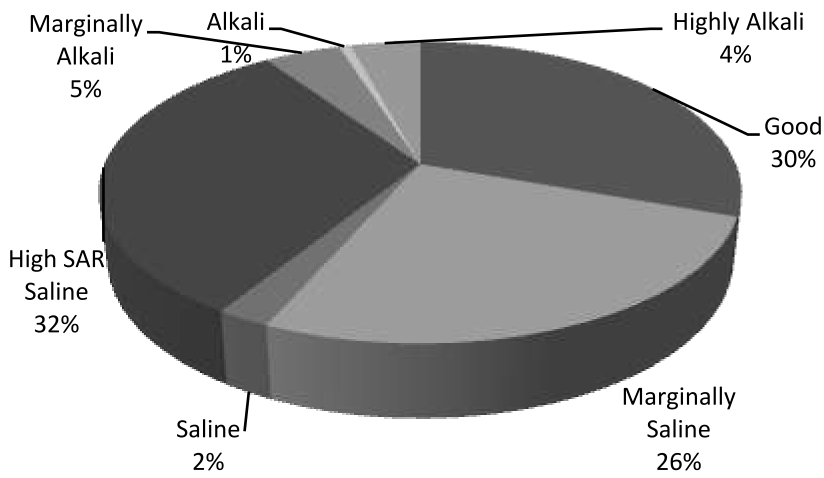



Fig.1.21 Quality of groundwater (percent) in Mewat district

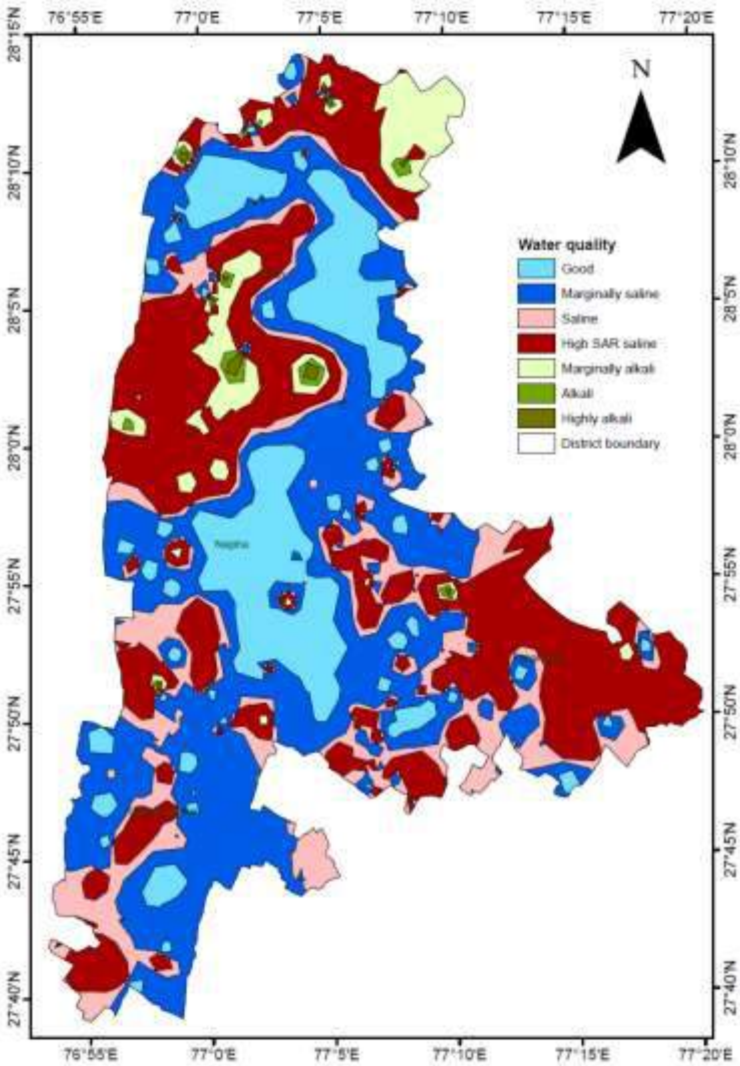



Fig. 1.22 Groundwater quality map for Mewat district according to AICRP criteria

**Survey and Characterization of Ground Water for Irrigation; Salinity Associated Problems of Khargone, Khandwa and Dewas District 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.

The survey and characterization of underground irrigation water of Dewas district of Madhya Pradesh was undertaken during 2017-18. The district is situated in the southern part of the state. It lies in between $22^o$ 17' to $23^o$ 20' N & $75^o$ 50" to $77^o$ 10' E. A variety of crops like soybean, cotton, maize, sorghum wheat, gram and vegetables etc. are the main crops grown in the districts. Canal as well as open/tube wells usually irrigate these crops. The Districts has hot sub-humid climate characterized by hot summers and mild winters. The average annual rainfall is about 1067 mm. Maximum and minimum temperatures are 45 °C and 5.0 °C respectively. One hundred sixty four water samples were collected from different tehsils of Dewas district. The wells/tube wells vary in depth from 8 to 183 m depth in Dewas district.

**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 1.52). 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 $Ca^{2+}$ , $Mg^{2+,}$ $Na^+$ 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 1.51).

**Bhikangaon Tehsil**: The quality of groundwater of Bhikangaon tehsil indicates that pH, EC, SAR and RSC ranged from 7.0 to 7.7, 0.35 to 2.58 $dSm^{-1}$, 0.81 to 8.82 and nil me $L^{-1}$ respectively (Table 1.52). 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 1.51).

**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 1.52). 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 1.51).

**Bhagwanpura Tehsil**: The pH, EC SAR and RSC ranged from 7.2 to 7.9, 0.24 to 0.40 $dSm^{-1}$, 1.00 to 2.16 and nil me $L^{-1}$ respectively (Table 1.52). 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 1.52). Similarly the cations like $Ca^{2+}$ , $Mg^{2+}$, $Na^+$ 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 1.51).

**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 1.52). 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 1.51).

**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 1.52). 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 (Table 1.51).

**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 1.52). 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 1.51).

**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 1.52). 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 1.51).

**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 1.52). 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 $Ca^{2+}$, $Mg^{2+}$, $Na^+$ 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 1.51).

Table 1.51 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

**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 1.52). All 18 ground water samples belong to category "A" (Table 1.51).

### 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 1.51 while salient features of ground water samples of Khargone district are provided in Table 1.52. Similarly spatial distribution is provided in Fig. 1.23.

Table 1.52 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) |
| $CO_3^{2-}$ | 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) |
| $HCO_3^-$ | 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) |
| $SO_4^{2-}$ | 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) |
| $Ca^{2+}$ | 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) |
| $Mg^{2+}$ | 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

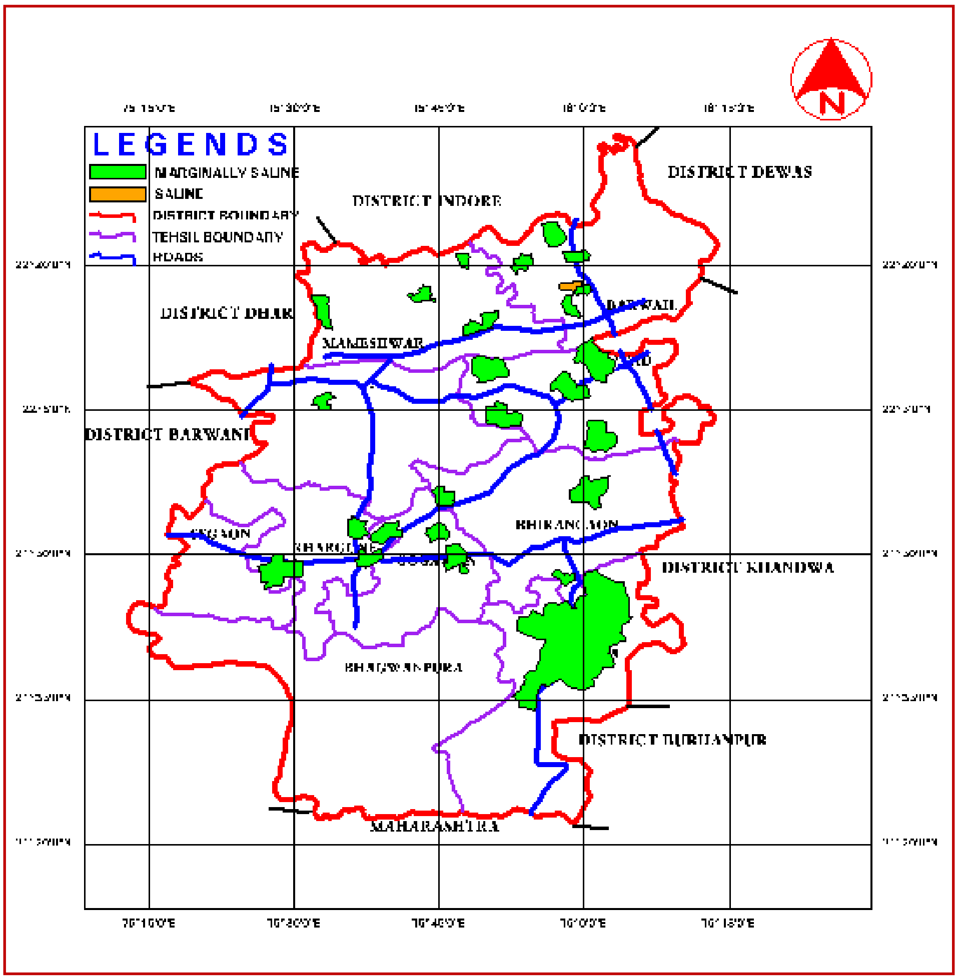



Fig. 1.23 Groundwater quality map of Khargone district

**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 1.54). 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 $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ 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 1.53).

**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 1.54). 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 1.53).

**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 1.54). 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 1.53).

**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 1.54). 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 $Ca^{2+}$ , $Mg^{2+}$, $Na^{+}$ 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 1.53).

**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 1.54). 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 1.53).

**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 1.53) while salient features of ground water samples of Khandwa district are provided in Table 1.54. Similarly spatial distribution is provided in Fig. 1.24.

Table 1.53 Frequency distribution of water in water quality categories of 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 1.54 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 |
| $CO_3^{2-}$ | 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) |
| $HCO_3^-$ | 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) |
| $SO_4^{2-}$ | 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) |
| $Ca^{2+}$ | 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) |
| $Mg^{2+}$ | 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

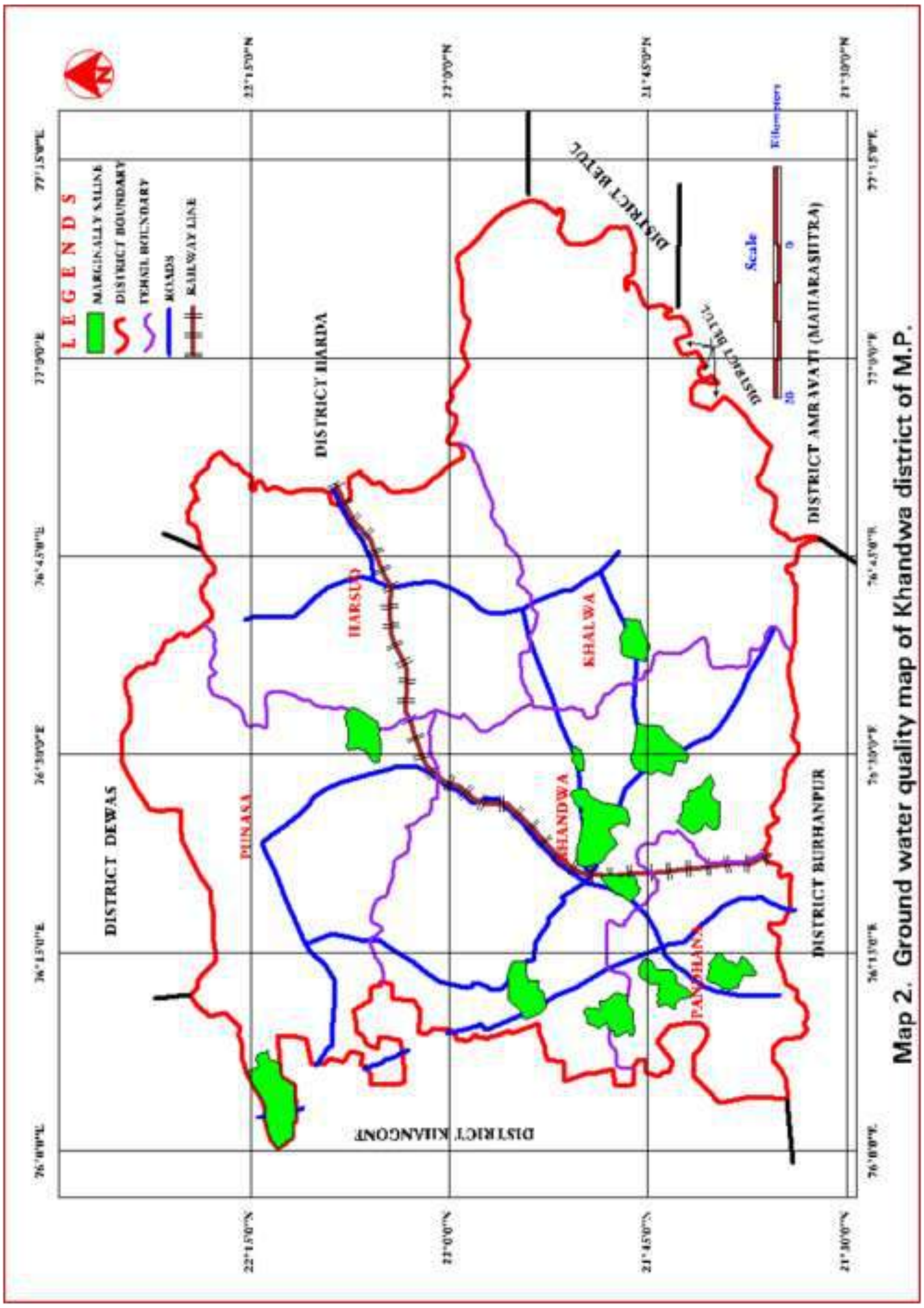



Fig. 1.24 Spatial distribution of groundwater quality of Khandwa district

**Quality of Groundwater in Dewas district**

**Dewas Tehsil:** The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 7.1 to 8.3, 0.59 to 4.15 dSm$^{-1}$, 0.60 to 9.45 and Nil me L$^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 8.6, 2.0 to 22.4 and 0.6 to 52.0 me L$^{-}$

1, respectively. Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 1.8 to 18.0, 0.0 to 12.8, 1.18 to 17.67 and 0.01 to 10.30, respectively. Out of thirty two samples, 27 (84.4 %) water samples come under good water category "A". However, 4 (12.5 %) and 1 (3.1 %) samples fall under marginally saline water ($B_1$) and saline ($B_2$) categories respectively (Table 1.55).

**Bagali Tehsil:** The quality of groundwater of Bagali tehsil indicate that pH, EC, SAR and RSC ranged from 7.50 to 8.14, 0.62 to 1.40 $dSm^{-1}$, 0.63 to 2.28 and Nil me $L^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.00 to 3.00, 2.20 to 8.80 and 0.80 to 4.40 me $L^{-1}$, respectively. Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 2.00 to 7.80, 0.40 to 3.40, 1.01 to 4.45 and 0.00 to 0.30, respectively. Out of 14 samples, 14 (100.0 %) water samples come under good water category "A" (Table 1.55).

**Kannod Tehsil:** The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 7.7 to 7.90, 0.59 to 0.89 $dSm^{-1}$, 0.03 to 2.34 and Nil me $L^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.6 to 2.8, 3.0 to 5.0 and 0.4 to 2.0 me $L^{-1}$, respectively. Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 2.2 to 4.8, 1.20 to 4.40, 0.07 to 3.77 and 0.01 to 0.10, respectively. Out of thirty two samples, 5 (100%) water samples come under good water category "A" (Table 1.55).

**Khategaon Tehsil:** The quality of groundwater of Khategaon tehsil indicate that pH, EC, SAR and RSC ranged from 7.40 to 8.0, 0.65 to 1.19 $dSm^{-1}$, 1.17 to 1.99 and Nil me $L^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 2.0 to 3.00, 2.60 to 4.20 and 1.80 to 5.60 me $L^{-1}$, respectively. Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 3.80 to 6.40, 0.40 to 2.20, 1.73 to 3.27 and 0.03 to 0.22, respectively. Out of 3 samples, 14 (100.0 %) water samples come under good water category "A" (Table 1.55).

**Hatpipaliya Tehsil:** The quality of groundwater of Hatpuipliya tehsil indicate that pH, EC, SAR and RSC ranged from 7.40 to 8.3, 0.57 to 1.76 $dSm^{-1}$, 0.42 to 1.67 and Nil me $L^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 4.80, 2.0 to 7.0 and 1.0 to 9.6 me $L^{-1}$, respectively. Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 2.6 to 9.40, 1.20 to 6.20, 0.7 to 3.27 and 0.03 to 0.21, respectively. Out of 12 samples, 14 (100.0 %) water samples come under good water category "A" (Table 1.55).

**Sonkatch Tehsil:** The quality of groundwater of Sonkatch tehsil indicate that pH, EC, SAR and RSC ranged from 7.20 to 9.3, 0.48 to 3.98 $dSm^{-1}$, 0.52 to 5.58 and Nil me $L^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 5.40, 2.0 to 21.4 and 0.2 to 21.4 me $L^{-1}$, respectively. Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 1.60 to 17.0, 0.00 to 13.0, 0.82 to 8.85 and 0.00 to 1.08, respectively. Out of thirty four samples, 34 (97.1 %) water samples come under good water category "A". However, 1 (2.9 %) and 1 (3.1 %) samples fall under marginally saline water ($B_1$) categories respectively (Table 1.55).

**Udaygarh Tehsil:** The quality of groundwater of Udaygarh tehsil indicate that pH, EC, SAR and RSC ranged from 7.5 to 8.5, 0.35 to 1.27 $dSm^{-1}$, 0.29 to 3.50 and Nil me $L^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 1.0 to 3.0, 1.4 to 8.2 and 2.0 to 4.8 me $L^{-1}$, respectively. Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 1.20 to 5.20, 0.00 to 5.20, 0.38 to 6.07 and 0.00 to 0.60, respectively. Out of 24 samples, 24 (100.0 %) water samples come under good water category "A" (Table 1.55).

**Tonkkhurd Tehsil:** The quality of groundwater samples indicate that pH, EC SAR and RSC ranged from 6.9 to 9.3, 0.52 to 4.58 $dSm^{-1}$, 0.20 to 10.99 and Nil me $L^{-1}$ respectively (Table 1.56). Carbonate, bicarbonate, chloride and sulphate ions ranged from Nil, 2.0 to 8.06, 1.20 to 31.0 and 0.6 to 28.60 me $L^{-1}$, respectively.

Similarly the cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$ varied from 2.0 to 26.0, 1.0 to 13.4, 0.42 to 17.37 and 0.01 to 1.18, respectively. Out of forty samples, 20 (50%) water samples come under good water category "A". However, 17 (42.5%) and 3 (7.5%) samples fall under marginally saline water ($B_1$) and saline ($B_2$) categories respectively (Table 1.55).

**Frequency distribution of water samples:** A ground water survey of the Dewas district was conducted by Salt Affected Soils Project, College of Agriculture, Indore. 164 ground water samples were collected from different villages from different tehsils of the district. Out of these 164 samples, 138 (84.2%) belongs to category "A", 22 (13.4%) belong to category "$B_1$" and 4 (2.4 %) belong to category "$B_2$" (Table 1.56). The samples from remaining part of the district will be collected during the year 2018-19 and the final report and map will be generated on the basis of district as a whole.

Table 1.55 Frequency distribution of water samples into categories of water quality in Dewas district

| Category | Tehsils | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dewas | Bagali | Kannod | Khategaon | Hatpipaliya | Sonkatch | Udaygarh | Tonkkhurd | Satvas | |
| A | 27 (84.4) | 14 (100) | 5 (100) | 3 (100) | 12 (100) | 33 (97.1) | 24 (100) | 20 (50) | 0 | 138 (84.2) |
| B1 | 4 (12.5) | 0 | 0 | 0 | 0 | 1 (2.9) | 0 | 17 (42.5) | 0 | 22 (13.4) |
| B2 | 1 (3.1) | 0 | 0 | 0 | 0 | 0 | 0 | 3 (7.5) | 0 | 4 (2.4) |
| B3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 32 | 14 | 5 | 3 | 12 | 34 | 24 | 40 | 0 | 164 |

Figures in parenthesis are percentage of the samples

Table 1.56. Salient Features of ground water samples of Dewas district

| Parameter | Dewas | Bagali | Kannod | Khategaon | Hatpipaliya | Sonkatch | Udaygarh | Tonkkhurd |
|---|---|---|---|---|---|---|---|---|
| pH | 7.10-8.25 (7.80) | 7.50-8.14 (7.83) | 7.70-7.90 (7.80) | 7.40-8.0 (7.80) | 7.40-8.30 (7.90) | 7.20-9.30 (8.30) | 7.50-8.50 (8.10) | 6.90-9.30 (8.40) |
| EC ($dSm^{-1}$) | 0.59-4.15 (1.30) | 0.62-1.40 (0.87) | 0.59-0.89 (0.72) | 0.65-1.19 (0.89) | 0.57-1.76 (0.93) | 0.48-3.98 (1.12) | 0.35-1.27 (0.75) | 0.52-4.58 (2.15) |
| $Ca^{2+}$ | 1.80-18.00 (5.41) | 2.00-7.80 (4.57) | 2.20-4.80 (3.40) | 3.80-6.40 (4.73) | 2.60-9.40 (4.27) | 1.60-17.00 (4.59) | 1.20-5.20 (3.27) | 2.00-26.00 (11.17) |
| $Mg^{2+}$ | 0.00-12.8 (3.21) | 0.40-3.40 (1.94) | 1.20-4.40 (2.52) | 0.40-2.20 (1.40) | 1.20-6.20 (3.17) | 0.00-13.00 (3.04) | 0.00-5.20 (2.50) | 1.00-13.40 (3.43) |
| $Na^{+}$ | 1.18-17.67 (4.08) | 1.01-4.45 (2.08) | 0.07-3.77 (1.18) | 1.73-3.27 (2.65) | 0.70-3.27 (1.58) | 0.82-8.85 (3.22) | 0.38-6.07 (1.65) | 0.42-17.37 (6.15) |
| $K^{+}$ | 0.01-10.30 (0.44) | 0.00-0.30 (0.07) | 0.01-0.10 (0.04) | 0.03-0.22 (0.09) | 0.03-0.21 (0.12) | 0.00-1.08 (0.20) | 0.00-0.60 (0.14) | 0.01-1.18 (0.23) |
| $CO_3^{2-}$ | Nil | Nil | Nil | Nil | Nil | Nil | Nil | Nil |
| $HCO_3^{-}$ | 1.00-8.60 (2.53) | 1.00-3.00 (1.66) | 1.60-2.80 (2.28) | 2.00-3.00 (2.47) | 1.00-4.80 (2.13) | 1.00-5.40 (3.22) | 1.00-3.00 (2.00) | 2.00-8.00 (3.03) |
| $Cl^{-}$ | 2.00-22.40 (6.49) | 2.20-8.80 (4.30) | 3.00-5.00 (3.64) | 2.60-4.20 (3.20) | 2.00-7.00 (3.68) | 2.00-21.40 (5.19) | 1.40-8.20 (3.16) | 1.20-31.00 (9.95) |
| $SO_4^{2-}$ | 0.60-52.00 (5.39) | 0.80-4.40 (2.69) | 0.40-2.00 (1.30) | 1.80-5.60 (3.27) | 1.00-9.60 (3.38) | 0.20-21.40 (5.19) | 0.20-4.80 (2.32) | 0.60-28.60 (8.54) |
| SAR | 0.60-9.45 (2.15) | 0.63-2.28 (1.15) | 0.03-2.34 (0.72) | 1.17-1.99 (1.53) | 0.42-1.67 (0.80) | 0.52-5.58 (1.75) | 0.29-3.50 (0.97) | 0.20-10.99 (2.28) |
| RSC ($meL^{-1}$) | Nil | Nil | Nil | Nil | Nil | Nil | Nil | Nil |

*Data in parenthesis are mean values of the parameters*

**Survey and Characterization of Underground Irrigation Water of Kanpur Dehat and Auraiya District Of Uttar Pradesh (Kanpur)**

**2016-17**

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 1.57.

**Block-Akbarpur**

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 1.57 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 1.58).

Table 1.58 frequency of different categories of groundwater quality of Kanpur Dehat district

| Block | Samples | Good | Marginal Saline | Saline | High Saline | Marginal Alkali | Alkali | High 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 |

**2017-18**

**Auriya district**

Survey work was initiated in Auriya district of UP. The area of each block is classified into three water quality aquifer zones (good, marginal and poor) by adopting the criteria, district soil/water testing lab and the local farmers. Water samples were also collected randomly from tube wells covering entire area of the each aquifer zone. Underground water samples were analyzed for pH, EC, ESP, SAR and ionic composition. 88 ground irrigation water samples were collected from different villages of Auraiya district. Out of total samples 32, 29 and 27 samples were collected from Ajitmal, Bidhuna, and Erwakatra blocks respectively.

The analysis of ground irrigation water samples of Ajitmal block indicated that pH, EC, SAR and RSC ranges from 7.2 to 8.4, 0.38 to 3.28 $dSm^{-1}$, 0.7 to 10.2 and 0.0 to 7.2 $meqL^{-1}$, respectively. Most of the water samples belong to good (24 samples). Out of 32 samples, only 7 samples marginally saline and 01 of alkali water category. Chloride was dominant anion whereas calcium was dominant cation followed by sodium.

The analysis of ground irrigation water samples of the Bidhuna block indicated that pH, EC, SAR and RSC ranges from 7.4 to 8.2, 0.32 to 3.21 $dSm^{-1}$, 0.6 to 9.3 and 0.0 to 2.7 $meqL^{-1}$, respectively. Most of the water belongs to good (21 samples). Out of 29 samples, only 05 samples were marginally saline water, 01 of saline, 01 alkaline and 01 highly alkaline category.

The analysis of ground irrigation water samples of Erwakatra block indicated that pH, EC, SAR and RSC ranges from 7.3 to 8.6, 0.35 to 3.25 $dSm^{-1}$, 0.4 to 9.5 and 0.0 to 2.5 $meqL^{-1}$, respectively. Out of 27 groundwater samples, 20 samples are good, 05 samples were marginally saline, 01 saline and one highly saline water category.

**Frequency distribution of water samples:** Out of 88 samples, 65 (73.86 %) belongs to good, 17 (19.32 %) belongs to marginally saline, 02 (2.27 %) belongs to saline, 01 (1.14 %) belongs to highly saline, 02 (2.27 %) belongs to alkali and 01 (1.14 %) belongs to highly alkaline category (Table 1.59).

Table 1.59 Frequency of different categories of groundwater quality of Auraiya district

| Category | Ajitmal | Bidhuna | Erwakatra | Total | Percent |
|---|---|---|---|---|---|
| Good | 24 | 21 | 20 | 65 | 73.86 |
| Marginally saline | 07 | 05 | 05 | 17 | 19.32 |
| Saline | -- | 01 | 01 | 02 | 2.27 |
| Highly saline | -- | -- | 01 | 01 | 1.14 |
| Marginally alkali | -- | -- | -- | -- | -- |
| Alkali | 01 | 01 | -- | 02 | 2.27 |
| Highly alkali | -- | 01 | -- | 01 | 1.14 |
| **Total samples** | **32** | **29** | **27** | **88** | **--** |

**Survey and Characterization of Ground Water of Coastal Districts of Tamil Nadu for Irrigation (Tiruchirapalli)**

**Kanyakumari District (2016-17)**

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 ($CO_3$, $HCO_3$, Cl and $SO_4$). Quality parameters like SAR and RSC were calculated. Classification of water quality is done on the basis of EC, SAR and RSC values as suggested by CSSRI, Karnal. 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 1.60). 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.

The range of pH, EC, SAR and RSC characters are presented in Table 1.The maximum EC 6.83 $dSm^{-1}$ was recorded in Killiyur block followed by 5.91 $dSm^{-1}$ in Rajakamangalam block and 5.71 $dSm^{-1}$ 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. 1.25, 1.26, and 1.27, respectively.

The distribution of water samples in different water quality classes (Table 1.61) 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 1.60 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 |

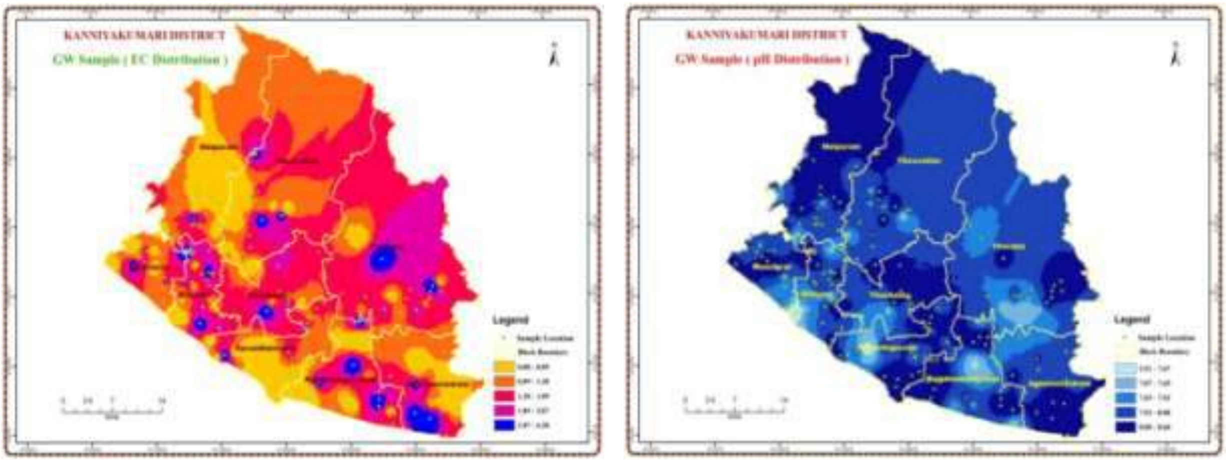



Fig. 1.25 Spatial distribution of a) Ground water EC and
b) Groundwater pH in Kanyakumari district (TN)


Fig.1.26 Spatial Distribution of groundwater SAR in Kanyakumari district (TN)

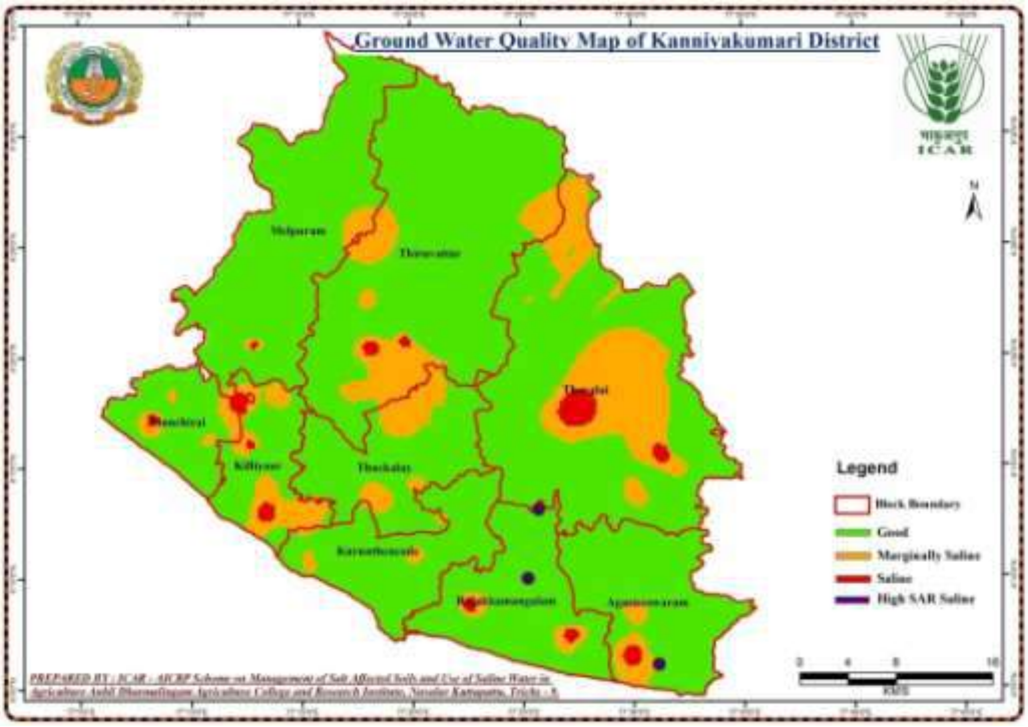



Fig. 1.27 Spatial distribution of Groundwater quality in Kanyakumari district (TN)

Table 1.61 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 1.62).

Table 1.62 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 $dSm^{-1}$.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.

**Cuddalore district (2017-18)**

The study area, Cuddalore district in Tamil Nadu lies on the East Coast of Southern India, bound on the north, south and west by Villupuram, Nagapattinam and Perambalur districts and on the east by Bay of Bengal. It lies between 11° 43'north of latitude and 79° 49' East of longitude. It has an average elevation of 1 meter (3 feet). The total geographical area of the district is 3706 km2 with a coast line of about 54 km. Around 161 bore well sample locations were chosen based on grid survey (pre survey) to collect ground water samples in 13 blocks of Cuddalore district during May 2018 which cover the distance of 4 to 80 km from the seashore. Ground water sampling was done through grid surveying having grid size of 10sq.km each so that each grid receives at least one bore well location. Samples were stored in airtight bottles.

The water samples were analyzed for pH, EC, cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$) and anions ($CO_3^{2-}$, $HCO_3^{-}$, $Cl^{-}$, $SO_4^{2-}$) nitrate and Fluoride contents by following the Versanate method (USDA Hand Book 60), Na+ through flame photometry (Jackson, 1958) and anions like $CO_3^{2-}$, $HCO_3^{-}$, $Cl^{-}$, $SO_4^{2-}$ by following the methods of Richards (1954) and Eaton (1950). Quality parameters like SAR and RSC were calculated by using the formulas of (Richards, 1954; Eaton, 1950). The ranges of pH, EC, RSC and SAR for different blocks are provided in Table 1.63.

Table 1.63 Range of different ground water constituents and their mean

| S.No | Block name | pH | | EC (ds/m) | | RSC(m.eq/l) | | SAR(mmol/l)1/2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| 1. | Panruti | 7.21-8.47 | 7.89 | 0.14-2.64 | 1.10 | 0.82-1.81 | 1.37 | 2.46-5.37 | 4.32 |
| 2. | Cuddalore | 6.43-8.58 | 8.09 | 0.35-2.07 | 1.04 | 0.36-2.86 | 1.65 | 1.94-5.21 | 3.55 |
| 3. | Annagramam | 7.73-8.34 | 8.05 | 0.74-1.49 | 1.08 | 0.17-2.36 | 1.39 | 2.02-5.23 | 3.26 |
| 4. | Parangipettai | 7.16-8.12 | 7.78 | 2.14-11.53 | 4.39 | 1.76-3.48 | 2.47 | 1.87-39.94 | 8.83 |
| 5. | Kurinchipadi | 6.52-8.58 | 7.65 | 1.98-3.06 | 2.43 | 0.71-2.48 | 1.88 | 1.77-4.51 | 3.38 |
| 6. | Bhuvanagiri | 7.71-8.32 | 7.99 | 1.34-5.62 | 2.60 | 0.43-2.46 | 1.64 | 2.23-5.72 | 3.84 |
| 7. | Keerapalayam | 7.83-8.35 | 8.08 | 0.63-3.77 | 1.38 | 1.36-2.47 | 2.03 | 1.77-4.71 | 2.99 |
| 8. | Kattumannarkoil | 7.36-8.53 | 7.93 | 0.62-1.42 | 0.96 | 0.14-2.28 | 1.42 | 1.98-5.10 | 3.41 |
| 9. | Kumarachi | 7.02-8.46 | 7.74 | 4.02-17.62 | 7.42 | 1.63-5.77 | 2.96 | 2.87-45.22 | 15.03 |
| 10. | Kammapuram | 6.96-8.64 | 7.77 | 0.46-1.43 | 0.90 | 0.10-2.17 | 1.20 | 2.08-4.66 | 3.19 |
| 11. | Virudhachalam | 6.54-7.96 | 7.18 | 0.38-1.28 | 0.75 | 0.46-2.34 | 1.63 | 1.99-5.022 | 3.12 |
| 12. | Nallur | 7.63-10.83 | 8.42 | 0.46-3.02 | 1.42 | 0.12-2.26 | 1.28 | 1.99-4.88 | 3.14 |
| 13. | Mangaloor | 6.87-9.03 | 8.09 | 0.96-3.15 | 1.45 | 0.26-2.17 | 0.86 | 1.91-5.55 | 3.70 |

The maximum EC 17.62 $dSm^{-1}$ was recorded in Kumaratchi block followed by 11.53 $dSm^{-1}$ in Parangipettai block of Cuddalore district. The highest RSC value of 5.77 m.eq / l was recorded in Kumaratchi block followed by Parangipettai block 3.48 meq/l. The highest SAR of 45.22 was seen in Kumaratchi block followed by 39.94 of Parangipettai block.

The various ionic constituents like cations viz., $Ca^{2+}$,$Mg^{2+}$,$Na^{+}$,$K^{+}$ and anions viz., $CO_3^{2-}$, $HCO_3^{-}Cl^{-}$, $SO4^{2-}$ were analysed and cationic and anionic distribution pattern for various blocks was studied. The total cations and anions dominantly present in kumaratchi block while comparing with other blocks in cuddalore district. The cationic order $Mg^{2+} > Na^{+} > Ca^{2+} > K^{+}$ was found in Panruti, Cuddalore, Annagaramam , Kurinjipadi, Bhuvanagiri, Keerapalayam, Kattumannarkoil, Kammapuram, Virudhachalam, Nallur, Mangaloore blocks and also the another cationic order($Na^{+} > Mg^{2+} > K^{+} > Ca^{2+}$) was found in Kumaratchi and Parangipettai block of cuddalore district. The anionic order $HCO_3^{-} > Cl^{-} > CO_3^{2-} > SO_4^{2-}$ was found in Cuddalore, Annagaramam, Kurinjipadi, Bhuvanagiri, Keerapalayam, Kattumannarkoil, Kammapuram, Virudhachalam, Nallur, Mangaloore blocks except Kumaratchi and Parangipettai and Panruti has $Cl^{-} > HCO3^{-} > CO_3^{2-} > SO_4^{2-}$. Classification of ground water samples for their suitability to irrigation was done on the basis of EC, SAR, RSC values as suggested by AICRP (1989) for different blocks and distribution of samples under different categories is given in Table 1.64 and Fig. 1.29. The thematic map pertaining to ground water quality was prepared using RS – Arc GIS software is shown in Fig. 1.30.

Table 1.64 Percentage distribution of ground water samples under different quality classes for different blocks of Cuddalore district

| S.NO | Blocks | No. of samples collected | Good | Marginally saline | Saline | High SAR saline | Marginally alkali | Alkali | High alkali |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Panruti | 11 | 90.9 | 9.1 | - | - | - | - | - |
| 2. | Cuddalore | 25 | 92 | 4 | - | - | 4 | - | - |
| 3. | Annagramam | 12 | 100 | - | - | - | -- | - | - |
| 4. | Parangipettai | 13 | | 39 | 38.5 | - | 7 | - | 15.4 |
| 5. | Kurinchipadi | 16 | 6.3 | 93.7 | - | - | - | - | - |
| 6. | Bhuvanagiri | 14 | 50 | 35.7 | 14.3 | - | | | |
| | | | | | | | - | - | - |
| 7. | Keerapalayam | 10 | 90 | 10 | - | - | - | - | - |
| 8. | Kattumannarkoil | 10 | 100 | - | - | - | - | - | - |
| 9. | chi | 10 | - | - | 70 | - | - | - | 30 |
| 10. | Kammapuram | 10 | 100 | - | - | - | - | - | - |
| 11. | Virudhachalam | 10 | 100 | - | - | - | - | - | - |
| 12. | Nallur | 10 | 90 | 10 | - | - | - | - | - |
| 13. | Mangaloor | 10 | 90 | 10 | - | - | - | - | - |
| | Total | 161 | | | | - | - | - | - |
| | Average | | 69.9% | 16.27% | 9% | - | - | - | 3.4% |

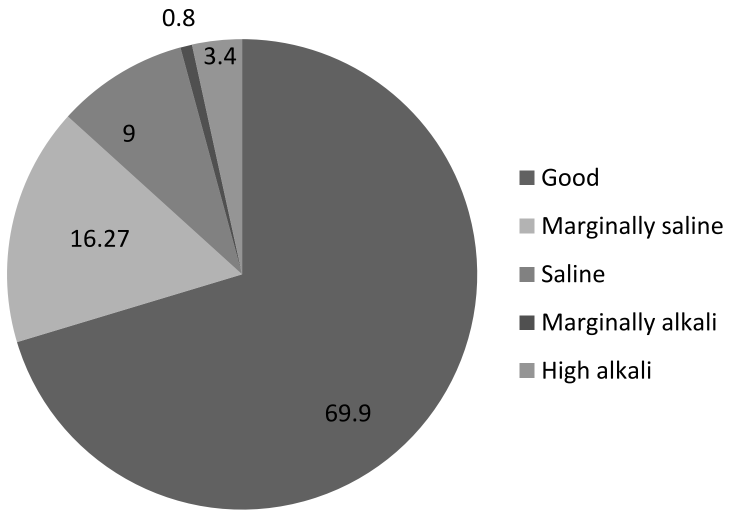



Fig. 1.29 Percentage distribution of quality of ground water samples of Cuddalore district

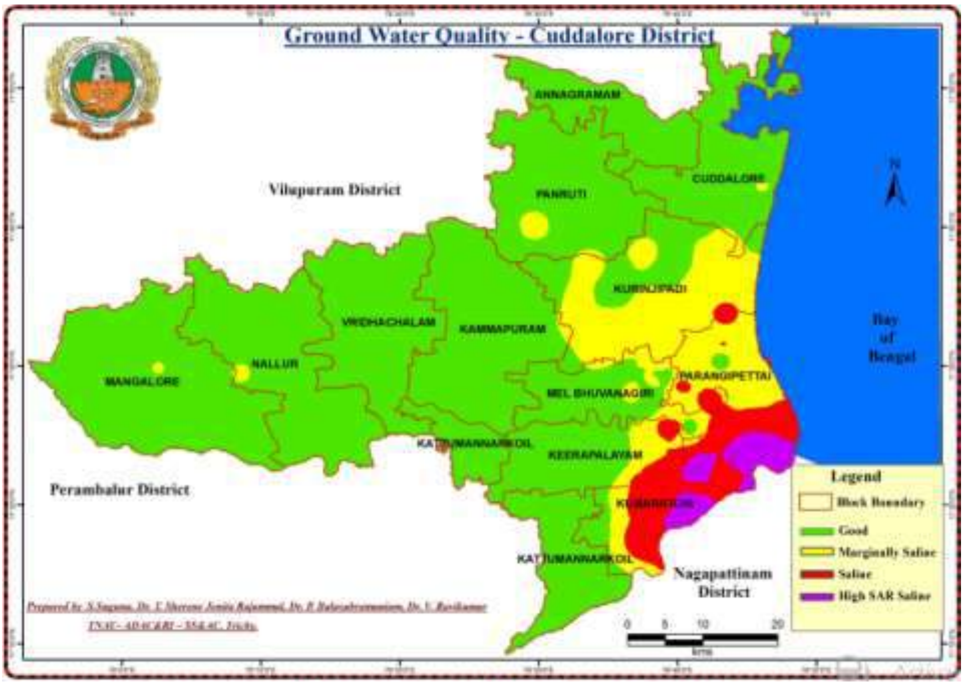



Fig. 1.30 Ground water quality map of Cuddalore district

Table 1.65 Nitrate content (meq/l) in different blocks of Cuddalore district

| S.NO | Block name | Nitrate classes (meq/l) | | | | |
|---|---|---|---|---|---|---|
| | | 0 – 2.5 | 2.5 - 5 | 5 - 7.5 | 7.5 - 10 | >10 |
| 1. | Panruti block | 100 | - | - | - | - |
| 2. | Cuddalore block | 100 | - | - | - | - |
| 3. | Annagramam block | 100 | - | - | - | - |
| 4. | Parangipettai block | 76.9 | 23.1 | - | - | - |
| 5. | Kurinchipadi block | 100 | - | - | - | - |
| 6. | Bhuvanagiri block | 100 | - | - | - | - |
| 7. | Keerapalayam block | 100 | - | - | - | - |
| 8. | Kattumannarkoil block | 100 | - | - | - | - |
| 9. | Kumarachi block | 70 | 30 | - | - | - |
| 10. | Kammapuram block | 100 | - | - | - | - |
| 11. | Virudhachalamblock | 100 | - | - | - | - |
| 12. | Nallur block | 100 | - | - | - | - |
| 13. | Mangaloor block | 100 | - | - | - | - |

All the blocks of Cuddalore district was in safer level regarding fluride level in ground water samples as given in Table 1.66. It can be concluded that out of the total ground water samples collected from Cuddalore district, 69.9 per cent is coming under good quality, 16.27 per cent is marginally saline, 9 per cent is saline water, 0.8 per cent is marginally alkali and 3.4 per cent is under high alkali categories. Hence, around 70 percent of the ground water resources can only be made available for irrigation purpose, the remaining are under threat. The results and interpretation of hydro chemical analysis of ground water revealed the dominance of cations (Na+>Ca2+>Mg2+>K+) over anions (HCO3-> Cl-> CO32- > SO42-) in ground water samples of study area and their occurance was also in the above said order. The maximum EC, SAR and RSC was recorded in Kumaratchi block followed by in Parangipettai block of Cuddalore district since these blocks are situated nearby coastal areas (10 km from sea shore). The nitrate content of the ground water samples of coastal blocks were all in safer side (<2.5meq/l) except in few places exceeding 2.5meq/l. The fluoride content in all blocks of Cuddalore district was found to be safe.

Table 1.66 Fluoride content (ppm) in different blocks of Cuddalore district

| S.NO | Block name | Fluoride classes(ppm) | | | | |
|---|---|---|---|---|---|---|
| | | 0 – 2.5 | 2.5 - 5 | 5 - 7.5 | 7.5 - 10 | >10 |
| 1. | Panruti block | 100 | - | - | - | - |
| 2. | Cuddalore block | 100 | - | - | - | - |
| 3. | Annagramam block | 100 | - | - | - | - |
| 4. | Parangipettai block | 100 | - | - | - | - |
| 5. | Kurinchipadi block | 100 | - | - | - | - |
| 6. | Bhuvanagiri block | 100 | - | - | - | - |
| 7. | Keerapalayam block | 100 | - | - | - | - |
| 8. | Kattumannarkoil block | 100 | - | - | - | - |
| 9. | Kumarachi block | 100 | - | - | - | - |
| 10. | Kammapuram block | 100 | - | | | |
| 11. | Virudhachalam block | 100 | - | - | - | - |
| 12. | Nallur block | 100 | - | - | - | - |
| 13. | Mangaloor block | 100 | - | - | - | - |

**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 1.67. 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 1.67 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 1.68 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 1.68 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 1.69 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 1.69 Block-wise percent distribution of water samples in various categories with respect to residual sodium carbonate (RSC)

| RSC ($meqL^{-1}$) | 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 |

Based on EC and RSC, ground water samples were categorized in three major classes such as suitable, marginal and unsuitable for irrigation purposes. It is reported that out of these only 26% samples were suitable for irrigation in all conditions whereas 64% water is suitable for coarse textured and salt tolerant crop with periodic monitoring of salt accumulation in the soil and rest of 10% water samples were qualified as unsuitable for irrigation.

Data presented in Table 1.70 showed that the range and average value of different chemical constituents present in groundwater samples collected during 2017-18. The electrical conductivity (EC) ranged between 1.1-9.9 $dSm^{-1}$ with mean value 4.0 $dSm^{-1}$ in Sangat, 1.2-8.4 $dSm^{-1}$ with mean value 3.97 $dSm^{-1}$ in Talwandi Sabo, 1.0-8.1 $dSm^{-1}$ with mean value 3.2 $dSm^{-1}$ in Bathinda, 1.3-11.0 $dSm^{-1}$ with mean value 3.6 $dSm^{-1}$ in Maur and 1.1-6.1 $dSm^{-1}$ with mean value 2.5 $dSm^{-1}$ in Nathana block. Sangat block contain higher RSC followed by Talwandi Sabo and Bathinda block , whereas minimum RSC was reported in Maur block among the studied areas. The maximum $Ca^{+2}$ +$Mg^{+2}$ was reported in Sangat block followed by Talwandi Sabo and Maur block and minimum average value was recorded in Nathana block. Among the anions, chloride was dominant ion with values ranging from 0.2 to 58.0 $meL^{-1}$ followed by bicarbonate (2.2-18.0 me $L^{-1}$) and carbonate (0.0 to 0.50 me $L^{-1}$) in the studied areas.

Table 1.70 Distribution of different chemical constituents of ground water in blocks of Bathinda surveyed in 2017-18

| Name of Blocks | | Sangat (65)* | | Talwandi Sabo (75) | | Bathinda (75) | | Maur (75) | | Nathana (61) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. | Range | Ave. |
| Depth | (ft) | 35-550 | 105 | 30-150 | 88 | 35-750 | 250 | 80-850 | 185 | 80-700 | 315 |
| pH | | 7.5-8.7 | 7.6 | 7.2-8.8 | 7.4 | 7.4-8.6 | 7.6 | 7.3-8.8 | 7.7 | 7.1-8.2 | 7.5 |
| EC | $dSm^{-1}$ | 1.1-9.9 | 4.0 | 1.2-8.4 | 3.97 | 1.0-8.1 | 3.2 | 1.3-11.0 | 3.6 | 1.1-6.1 | 2.5 |
| $Ca^{+2}$ +$Mg^{+2}$ | $meL^{-1}$ | 1.5-27.5 | 9.4 | 1.5-28.0 | 8.9 | 1.5-7.5 | 6.6 | 1.5-33.5 | 8.5 | 2-16.5 | 6.0 |
| $Cl^{-1}$ | | 1.0-22.7 | 7.5 | 0.4-58 | 13.9 | 0.4-23 | 6.1 | 2-28.6 | 10.0 | 0.2-5.2 | 2.4 |
| $CO_3^{-2}$ | | 0-0.5 | 0.2 | 0-0.30 | 0.2 | 0-0.4 | 0.2 | 0-0.3 | 0.2 | 0-0.5 | 0.4 |
| $HCO_3^-$ | | 3.0-18.0 | 7.3 | 4.2-14.8 | 8.0 | 2.6-12 | 6.8 | 2.6-13 | 7.2 | 2.2-13.0 | 6.8 |
| RSC | | 0-12.0 | 3.6 | 0-10.1 | 3.4 | 0-9.5 | 3.1 | 0-8.1 | 3.0 | 0-7.2 | 3.1 |

*Values in parenthesis are number of water samples

The distribution of water samples in different ranges of electrical conductivity (EC) are given in Table 1.71. The EC of majority of the cases i.e. 15 % in Sangat, 11 % in Talwandi Sabo, 16 % in Bathinda, 9% in Maur and 39 % in Nathana block was less than 2 dS $m^{-1}$. Whereas, 43 % in Sangat, 49 % in Talwandi Sabo, 61 % in Bathinda, 65% in Maur and 49 % in Nathana blocks were observed between 2 to 4 $dSm^{-1}$ and rests was more than 4 $dSm^{-1}$. It is reported that based on electrical conductivity only 22 % water could be used without any possible risk of soil salinization. Further, 54% water was rated as marginal (EC, 2 to 4 $dSm^{-1}$) for irrigation and 24% water was not suitable for irrigation due to their higher electrical (>4 $dSm^{-1}$) conductivity.

Table 1.71 Percent distribution of water samples in various categories with respect to electrical conductivity.

| EC ($dSm^{-1}$ at 25º C ) | Percent distribution | | | | | |
|---|---|---|---|---|---|---|
| Blocks | Sangat | Talwandi Sabo | Bathinda | Maur | Nathana | Average |
| < 2.0 | 15 | 11 | 16 | 09 | 39 | 22 |
| 2.0-4.0 | 43 | 49 | 61 | 65 | 49 | 54 |
| > 4.0 | 42 | 40 | 23 | 26 | 12 | 24 |

The distribution of water samples in different ranges of residual sodium carbonate (RSC) are given in Table 1.72.

Table 1.72 Percent distribution of water samples in various categories with respect to residual sodium carbonate (RSC)

| RSC ($meL^{-1}$) | Percent distribution | | | | | |
|---|---|---|---|---|---|---|
| Blocks | Sangat | Talwandi Sabo | Bathinda | Maur | Nathana | Average |
| < 2.5 | 71 | 68 | 68 | 76 | 66 | 69 |
| 2.5-5.0 | 15 | 21 | 19 | 17 | 21 | 19 |
| >5.0 | 14 | 11 | 13 | 07 | 13 | 12 |

It is observed that 71%, 68%, 76% and 66 % water samples have RSC < 2.5 me $L^{-1,}$ in the blocks Sangat, Talwandi Sabi and Bathinda, Maur and Nathana, respectively. While 15%, 21%, 19%, 17% and 21 % of water samples showed RSC between 2.5-5.0 me $L^{-1}$ in the blocks Sangat, Talwandi Sabi, Bathinda, Maur and Nathana, respectively. Further, it is reported that on the basis of RSC 69% water is safe (RSC, <2.5 $meL^{-1}$), 19% water is marginal (RSC, 2.5 to 5.0 $meL^{-1}$) and 12% water is unsuitable for irrigation (RSC, > 5.0 $meL^{-1}$).

**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 1.73. 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 1.73 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 waters 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 salinity status of study area, samples were analyzed for pH, electrical conductivity, carbonate, bicarbonate, chloride, sulphate, sodium, potassium, calcium, magnesium, boron, SAR and RSC. Collection of ground water samples of Thiruvananthapuram, Kollam, Kottayam and Pathanamthitta districts were completed in 2016-17 and Kannur, Kasargod, Kozhikode and Malappuram districts were completed in 2017-18. A total of thirty eight ground water samples were collected from Thiruvananthapuram district. There are irrigation water quality indices to classify irrigation water on quality parameters like EC, SAR, RSC, Boron content and Ca/Mg ratio of water samples. Ground water samples of Thiruvananthapuram district were classified into different classes according to these quality indices and are represented in Table 1.74

Table 1.74 Classification of irrigation water based on quality indices

| Categories | EC ($dSm^{-1}$) | SAR | RSC (me $L^{-1}$ ) |
|---|---|---|---|
| Good | <2 | <10 | <2.5 |
| Marginally saline | 2-4 | <10 | <2.5 |
| Saline | >4 | <10 | <2.5 |
| High SAR saline | >4 | >10 | <2.5 |
| Marginally alkaline | <4 | <10 | 2.5 – 4.0 |
| Alkaline | <4 | <10 | >4.0 |
| Highly alkaline | Variable | >10 | >4.0 |

**Thiruvananthapuram district**

The analytical data of 38 samples showed that pH value of water samples ranged from 5.7 to 7.2 while EC value ranged from 0.10 to 4.2 $dSm^{-1}$. About 18.42% of the water samples were slightly acidic in nature. 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 value 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. Sodium content ranged from 25.6 to 95.62 me $L^{-1}$. Potassium content of water samples ranged from 1.32 to 7.7 me $L^{-1}$. 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 to 0.924 me $L^{-1}$.

**Kottayam district**

The analytical data of 17 samples 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 $m^{-1}$. Water samples from Pulikkattussery, Nattakam and Changanassery were slightly acidic in nature. 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. Potassium content of water samples ranged from 1.05 to 2.301 me $L^{-1.}$ 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 of water was nil.

**Kollam district**

The analytical data of 21 samples 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 $m^{-1}$. About 33.33 per cent of the samples were slightly acidic in nature. 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. . Potassium content of water samples ranged from 22.5 to 107.1 ppm.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 to 0.98 me $L^{-1}$.

**Pathanamthitta district**

The survey of Pathanamthitta district was completed by collecting five 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 $dSm^{-1}$. Water samples from Peringara and Thiruvalla were slightly acidic in nature. 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. Potassium content of water samples ranged from 24.42 to 51.24 ppm. Iron and zinc content ranged from 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 to 1.131 me $L^{-1}$.

**Kasargod district**

The analytical data of 26 samples from district showed that pH values of water samples ranged from 6.27 to 8.07 while EC values ranged from 0.040 to 3.8 $dSm^{-1}$. Carbonate and bicarbonate values ranged from 0.0 to 1.92 and 0.16 to 3.68 me $L^{-1}$ respectively. Chloride values ranged from 14.2 to 198.8 me $L^{-1}$.Calcium and magnesium content ranged from 0.06 to 1.54 and 0.01 to 0.20 me $L^{-1}$ respectively.Iron content ranged from 0.263 to 0.418 ppm. Sodium content of the samples ranged from 0.18 to 9.58 me $L^{-1}$. Potassium content of water samples ranged from 1.60 to 20.9 ppm.Mg/Ca ratio ranged from 0.08 to 0.97. The highest value of SAR was 7.268 and lowest value was 0.1945. RSC of water samples ranged from 0 to 4.97 me $L^{-1}$.

**Kannur district**

The analytical data of 15 samples showed that pH values of water samples ranged from 7.47 to 8.55 while EC values ranged from 0.02 to 37 $dSm^{-1}$. Carbonate and bicarbonate values ranged from 0.64 to 6.72 and 0.64 to 13.44 me $L^{-1}$ respectively. Chloride and sulphate values ranged from 21.3 to 2201 and 0.007 to 1.623 me $L^{-1}$respectively. Nitrate values ranged from 0.2 to 2.5 me $L^{-1}$. Calcium and magnesium content ranged from 0.05 to 6.25 and 0.01 to 0.25 me $L^{-1}$ respectively. Iron content ranged from 0.270 to 0.559 ppm. Sodium content of the samples ranged from 0.19 to 122.17 me $L^{-1}$. Potassium content of water samples ranged from 1.7 to 189 ppmMg/Ca ratio ranged from 0.04 to 0.34. The highest value of SAR was 48 and lowest value was 0.2. RSC of water samples ranged from 0 to 15.3 me $L^{-1}$.

**Kozhikode district**

The analytical data of 19 samples showed that pH values of water samples ranged from 7.23 to 8.53 while EC values ranged from 0.08 to 0.83 to $dSm^{-1}$. Carbonate and bicarbonate values ranged from 0.0 to 2.88 and 0.80 to 16 me $L^{-1}$ respectively. Chloride and sulphate values ranged from 14.2 to 49.7 and 0.003 to 0.044 me $L^{-1}$. Nitrate values ranged from 0.10 to 0.60 me $L^{-1}$. Calcium and magnesium content ranged from 0.10 to 1.85 and 0.016 to 0.106 me $L^{-1}$ respectively. Iron content ranged from 0.337 to 0.576 ppm. Sodium content of the samples ranged from 0.12 to 1.17 me $L^{-1}$. Potassium content of water samples ranged from 1.8 to 10.2 ppm. Mg/Ca ratio ranged from 0.05 to 0.35. The highest value of SAR was 0.98 and lowest value was 1.5. RSC of water samples ranged from 0.68 to 16.94 me $L^{-1}$.

**Malappuram district**

The analytical data of 20 samples showed that pH values of water samples ranged from 6.84 to 8.75 while EC values ranged from 0.12 to 1.05 $dSm^{-1}$. Carbonate and bicarbonate values ranged from 0 to 3.52 and 0.80 to 15.84 me $L^{-1}$ respectively. Chloride and sulphate values ranged from 7.1 to 63.9 me $L^{-1}$and 0.008 to 0.044 respectively. Nitrate values ranged from 0.1 to 0.6 me $L^{-1}$. Calcium and magnesium content ranged from 0.11 to 1.32 and 0.040 to 0.125 me $L^{-1}$ respectively. Sodium and iron content ranged from 0.13 to 1.85 and 0.332 to 0.585 ppm respectively. Potassium content of water samples ranged from 1.9 to 16.8 me $L^{-1}$.Mg/Ca ratio ranged from 0.06 to 0.59. The highest value of SAR was 2.51 and lowest value was 0.22. RSC of water samples ranged from 0.64 to 18.82 me $L^{-1}$.

**Palakkad, Wayanad and Idukki districts**

Ground water quality data for Palakkad (34 locations) Wayanad (17 locations) and Idukki (21 locations) district were collected from Central Ground Water Board (CGWB), Thiruvanathapuram and analysed. The interpretation of data of Idukki, Palakkad and Wayanad revealed that all the water samples of the three districts were grouped under good quality for irrigation. Absence of sea shore might be the one of the reasons for it. Ground water pH varied from strongly acid to strongly alkaline.

On basis of analysis of groundwater samples in different districts of Kerala, it is concluded that:

- 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 per cent samples were of good quality and 2.6 per cent samples belonged to marginally saline category.
- In Kottayam district 82.35 per cent samples were under good quality and 11.76 per cent water samples were marginally saline. Ground water sample from Murinjapuzha was saline in nature.
- In Kollam, 95.23 per cent of the samples belonged to good in category where as ground water sample collected from Azeekal belonged to marginally saline.
- In Pathanamthitta district, all ground water samples were good of quality.
- In Kasargod district, almost 73.07 percent of ground water samples were grouped under good quality and 23.07 per cent samples were marginally alkaline. Water samples collected from Kannankai was marginally saline.
- In Kannur districts 46.66 per cent of ground water samples were grouped under good quality and 26.66 percent of the samples were marginally alkaline. Wide variation in ground water quality was found in Kaipad areas. 13.33 per cent of water samples were high alkaline as well as high SAR saline water each.
- In Kozhikode and Malappuram districts 73.68 and 40 per cent samples were of good quality and 26.31 and 60 per cent samples were of marginally alkaline, respectively.
- In Idukki, Palakkad and Wayanad districts all water samples were grouped under good quality for irrigation. Absence of sea shore might be the one of the reasons for it. Ground water pH varied from strongly acid to strongly alkaline.

## 2. MANAGEMENT OF SALT AFFECTED SOILS

### 2.1 Management of Alkali Soils

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

**Kharif 2016-17**

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 taken up at 16 locations i.e. at Gokarnamatham (2 no.), at Adavuladivi (9 no.) and Ganapavaram (5 no.) locations. The land was leveled, salts were leached and *dhaincha* was sown and ploughed *insitu* at 50 % flowering stage. Basal application of $ZnSO_4$ @ 50 kg $ha^{-1}$ was done, N-$P_2O_5$–$K_2O$ were applied @ 180-40-40 kg/ha. Due to the adoption of reclamation measures, there was considerable reduction in pH, electrical conductivity and SAR values of the soils from the initial, realizing better yields of rice.

The initial and final pH of soil in Gokarnamatam varied from 9.00 to 9.77 and from 7.21 to 7.38, respectively. In case of Adavuladeevi and Ganapavaram, initial pH ranged from 8.12 to 9.38 and 8.5 to 9.74, respectively. The final pH ranged from 7.42 to 8.06 for Adavuladeevi and it ranged from 7.46 to 7.76 for Ganapavaram. The decrease in pH may be attributed to the exchange of sodium by calcium applied through gypsum. The reduction in pH could also be due to the organic acids produced during the decomposition of incorporated green manure. The ECe of the initial soils ranged from 18.5 to 22.0, 6.8 to 16.0 and 11.1 to 17.5 in 11.1 to 17.5 dS $m^{-1}$ in Gokarnamatam, Adavuladeevi and Ganapavaram, respectively. Considerable reduction in ECe was also observed. The decrease in ECe could be due to leaching of salts as result of improved physical properties due to addition of gypsum and green manures. The SAR of the soils was found to decline to 3.30 to 5.45, 3.25 to 10.42 and 3.38 to 12.94 from the initial values of 14.37 to 24.02, 14.91 to 20.82 and 17.63 to 27.49 in Gokarnmatam, Adavuladdevi and Ganapavaram, respectively. The mean grain yield of paddy in reclaimed aqua ponds ranged from 4250 to 5380 kg $ha^{-1}$ compared to the non-reclaimed fields (3348 to 4150 kg/ha). The increase in yield was varied from 12 to 43 per cent over the control.

**Kharif 2017-18**

The experiment was conducted in three farmer's fields at Nizampatnam, Guntur district during *kharif*, 2017-18 in sandy clay loam soils having the pH ranging from 8.1 to 8.2 and EC ranging from 3.1 to 4.2 dS $m^{-1}$, low in available N, medium in available P and high in K (Table 2.1). In those farmers' fields reclamation practices viz. leveling, 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 and rice variety, BPT 5204 was grown. The recommended dose of fertilizers (180:40:40 N, $P_2O_5$ and $K_2O$ kg $ha^{-1}$, respectively and basal application of $ZnSO_4$ @ 50 kg $ha^{-1}$) was applied. By adopting the reclamation practices, plant height, number of productive tillers $panicle^{-1}$ and filled grains $panicle^{-1}$ were recorded more in reclaimed filed compared to non reclaimed filed. The grain yields of 5690 to 5877 were recorded in reclaimed fileds compared to non reclaimed filed (4800 kg ha-1) and an increase of 23.6 to 27.7% in grain yields was recorded (Table 2.2). Considerable improvement in pH and salinity and available nutrient status of the soils were observed in fields at harvest of the crop (Table 2.3).

An ORP was carried out in three farmers' fields (abandoned aqua ponds) having a high EC of 10.5, 9.1 and 8.2 dS $m^{-1}$. Due to adoption of reclamation technology, there were 27.7, 23.6 and 26.3 per cent yield enhancement over check yield of 4800 kg $ha^{-1}$. The EC of the soils showed a decline to 4.2, 3.4 and 3.1 dS $m^{-1}$ respectively.

Table 2.1 Initial soil properties of experimental fields at Nizampatnam

| S. No. | Particulars | pH | EC (1:2) (dS $m^{-1}$) | Available Nutrients (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | | | | N | $P_2O_5$ | $K_2O$ |
| 1 | Sri. P.Babu | 8.2 | 10.5 | 167 | 25.9 | 845 |
| 2 | Sri. S.Basavaiah | 8.1 | 9.1 | 175 | 24.4 | 809 |
| 3 | Sri. M.Verraju | 8.2 | 8.2 | 191 | 28.6 | 778 |

Table 2.2 Yield attributes and yields of rice

| Farmer | Pant height (cm) | No of tillers $m^{-2}$ | No of productive tillers $m^{-2}$ | Filled grains $panicle^{-1}$ | Grain (kg $ha^{-1}$) | Straw (kg $ha^{-1}$) | % increase in yield over control |
|---|---|---|---|---|---|---|---|
| Sri. P. Babu | 102.5 | 21 | 267 | 135 | 5877 | 6800 | 27.7 |
| Sri. S.Basavaiah | 100.3 | 20 | 256 | 132 | 5690 | 6733 | 23.6 |
| Sri. M.Verraju | 103.5 | 20 | 270 | 136 | 5813 | 6630 | 26.3 |
| Control (non reclaimed field) | 99.0 | 18 | 212 | 119 | 4800 | 5300 | - |

Table 2.3 Physico-chemical and chemical properties of experimental fields after harvest of crop

| Farmer | pH | EC (1:2) (dS $m^{-1}$) | Available Nutrients (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|
| | | | N | $P_2O_5$ | $K_2O$ |
| P. Babu | 8.16 | 4.2 | 159 | 34.4 | 545 |
| S.Basavaiah | 8.07 | 3.4 | 142 | 32.9 | 631 |
| M.Verraju | 8.02 | 3.1 | 171 | 37.8 | 667 |

**Effect of chemical and organic amendments in reclamation of salt affected 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.

The experiment was carried out at Narravari palem during *kharif* 2017 in the sandy clay loam soil having the pH of 9.0, EC of 1.3 dS $m^{-1}$ and ESP >15. The initial soil is low in organic carbon and available nitrogen, medium in phosphorus and high in potassium (Table 2.4).

| Treatments | Site of experiment | : | Narravari palem |
|---|---|---|---|
| 1.Biocompost @ 4t ha-1 + gypsum @ 50% GR | Season | : | Kharif, 2017 |
| 2. Biocompost @ 4t ha-1. | Crop | : | Paddy (BPT 5204) |
| 3. Gypsum @ 50% GR | Design | : | RBD |
| 4. Farmers practice | Replications | : | 4 |

Table 2.4 Initial soil properties of experimental field

| Parameters | Value | Parameters | Value |
|---|---|---|---|
| pH | 9.0 | $K_2O$ (kg $ha^{-1}$) | 645 |
| EC | 1.3 | OC | 0.30 |
| N (kg $ha^{-1}$) | 209 | CEC | 6.2 |
| $P_2O_5$ (kg $ha^{-1}$) | 29.4 | ESP | 20.7 |

Gypsum was applied to the field before onset of monsoons to leach the salts. Pressmud compost @ 4t $ha^{-1}$ applied 15 days before the transplanting of rice (BPT 5204) recommended dose of fertilizers were applied. Physico-chemical properties of pressmud compost are provided in Table 2.5 Highest number of productive tillers and grains $panicle^{-1}$ were recorded in treatment applied with pressmud along with gypsum (Table 2.6).

Table 2.5 Physico-chemical properties of pressmud compost

| Parameter | Pressmud compost | Parameter | Pressmud compost |
|---|---|---|---|
| pH | 7.1-7.6 | Magnesium (%) | 1.5-2.5 |
| EC (dS $m^{-1}$) | 1.5-2.3 | Sulphur (%) | 2.0-3.0 |
| C:N ratio | 10-11.4 | Organic carbon (%) | 30-40 |
| Nitrogen (%) | 2.7-3.5 | Iron (%) | 1.6-1.8 |
| Phosphorous (%) | 1.5-2.5 | Manganese (%) | 0.21-0.22 |
| Potassium (%) | 3.0-4.0 | Zinc (%) | 0.19-0.42 |
| Calcium (%) | 4.0-7.0 | Copper (%) | 0.72-1.0 |

Table 2.6 Influence of pressmud compost and gypsum on yield attributes of rice

| Treatment | Plant height (cm) | No. of tillers $hill^{-1}$ | No. of productive tillers $hill^{-1}$ | No. of filled grains $panicle^{-1}$ |
|---|---|---|---|---|
| Pressmud compost @4 t $ha^{-1}$ +Gypsum@50% | 105 | 21 | 252 | 201 |
| Pressmud compost@4 t $ha^{-1}$ | 103 | 20 | 260 | 193 |
| Gypsum@50% | 107 | 20 | 280 | 174 |
| Farmers' practice | 99 | 19 | 216 | 144 |

Highest grain yield (6220 kg $ha^{-1}$) was recorded in pressmud compost @4 t $ha^{-1}$ +Gypsum@50% followed by (5880 kg $ha^{-1}$) in case of Gypsum@50%, then 5680 kg $ha^{-1}$ for pressmud compost@4 t $ha^{-1}$. The lowest 4700 kg $ha^{-1}$ was recorded in farmer's practice (Table 2.7).

Table 2.7 Influence of pressmud compost and gypsum on yield of rice

| Treatments | Yield (kg $ha^{-1}$) | |
|---|---|---|
| | Grain | Straw |
| Pressmud compost @4 t $ha^{-1}$ +Gypsum@50% | 6220 | 6974 |
| Pressmud compost@4 t $ha^{-1}$ | 5680 | 6052 |
| Gypsum@50% | 5880 | 6216 |
| Farmers' practice | 4700 | 5356 |
| SE(m) | 68 | 89 |
| CD | 226 | 297 |

Application of pressmud compost and gypsum influenced the soil properties. Pressmud compost had more organic carbon and calcium. Pressmud compost and gypsum application decreased the soil pH by replacing the sodium with calcium and also reduced considerable amount of exchangeable sodium percentage (Table 2.8).

Table 2.8 Influence of pressmud compost and gypsum on soil properties after harvest of crop

| Farmer | pH (1:2) | EC (1:2) (dS $m^{-1}$) | Available Nutrients (kg $ha^{-1}$) | | | CEC | ESP |
|---|---|---|---|---|---|---|---|
| | | | N | $P_2O_5$ | $K_2O$ | | |
| Pressmud compost @4 t $ha^{-1}$ +Gypsum@50% | 8.37 | 4.43 | 138 | 40 | 618 | 11.2 | 10.2 |
| Pressmud compost@4 t $ha^{-1}$ | 8.50 | 4.43 | 113 | 37 | 794 | 9.6 | 13.4 |
| Gypsum@50% | 8.45 | 2.50 | 105 | 33 | 540 | 10.7 | 13.2 |
| Farmers practice | 8.92 | 2.40 | 88 | 25 | 399 | 7.5 | 16.1 |

**Studies on Performance of Safflower in Alkali Soils with different Agronomic Management Practices (Bapatla)**

The experiment was initiated during 2016 and continued during 2017 at Alakapuram. The initial soil was found to have a pH of 9.6 and EC of 5.6 dS $m^{-1}$. The treatments applied were such as i) $T_1$- Farmers practice, ii) $T_2$- Gypsum application, iii) $T_3$- FYM + Gypsum application, iv) $T_4$- Gypsum application + 25% extra recommended dose of nitrogen fertilizer and v) $T_5$- FYM+ Gypsum application +25% extra recommended dose of nitrogen fertilizer. During 2016, 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 2.9). Electrical conductivity also followed the same trend.

Treatment with FYM+ Gypsum application +25% extra nitrogen treatment recorded the highest plant height (63.7cm and 95.3cm) but, it was on par with the treatment of gypsum + 25% extra nitrogen. The lowest plant height of 45.9 and 70.8 cm was recorded by farmers practice during 2016 and 2017. Yield attributing characters *viz.*, the number of branches per plant (10.06 and 10.5), number of heads per plant (18.5 and 21.3) and number of seed per head (8.5 and 10.0) were also followed the similar trend as that of plant height during 2016-17. Application of gypsum + FYM + 25% extra nitrogen to safflower in alkali soils recorded the highest seed yield (1114 and 1434 kg $ha^{-1}$) during 2016 and 2017, respectively. Farmers practice recorded the lowest yield of 530 and 477 kg $ha^{-1}$ during respective years (Table 2.10).

Table 2.9 Influence of different management practices on soil pH and EC of safflower in alkali soils

| Treatments | At Harvest | |
|---|---|---|
| | 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 |
| - Gypsum application + 25% extra recommended dose of nitrogen fertilizer | 8.1 | 7.3 |
| -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 |

Table 2.10 Influence of different management practices on growth and yield attributes of safflower in alkali soils

| Treat-ments | Plant height (cm) | | No. of branches plant$^{-1}$ | | No. of heads plant$^{-1}$ | | No. of seed head$^{-1}$ | | Seed yield ( kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| $T_1$ | 45.9 | 70.8 | 5.6 | 4.3 | 5.1 | 5.0 | 4.3 | 4 | 530 | 477 |
| $T_2$ | 55.6 | 75.8 | 7.9 | 6.5 | 13.3 | 14.5 | 6.4 | 5 | 639 | 648 |
| $T_3$ | 57.3 | 83.3 | 9.9 | 8.0 | 14.2 | 14.8 | 7.3 | 6 | 882 | 732 |
| $T_4$ | 61.3 | 94.3 | 10.4 | 8.3 | 16.3 | 17.5 | 7.9 | 8 | 906 | 1026 |
| $T_5$ | 63.7 | 95.3 | 10.6 | 10.5 | 18.5 | 21.3 | 8.5 | 10 | 1114 | 1434 |
| SEm$\pm$ | 4.5 | 2.9 | 0.5 | 0.7 | 1.1 | 1.0 | 0.5 | 0.5 | 23 | 54 |
| CD(0.05) | 9.5 | 8.8 | 1.4 | 2.2 | 3.2 | 3.1 | 1.4 | 1.4 | 71 | 163 |
| CV (%) | 11.0 | 6.9 | 10.4 | 19.7 | 18.7 | 13.5 | 12.6 | 14.1 | 6 | 12 |

**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 too 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 paddy – wheat crop rotation, recommended for such soils was 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 presented 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/hill (17.58 and 17.69), plant height (115.5 and 111.8 cm) and length of panicle (20.2 and 20.9 cm) were noticed in case of dhaincha treated plots at soil ESP of 25, in both the respective years. However, the lowest values were noticed in control at all the ESP levels.

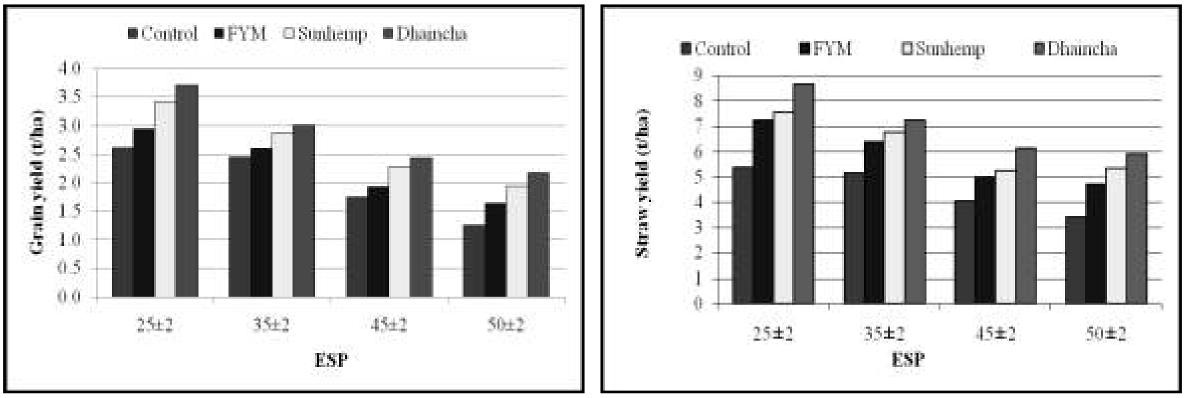
The grain and straw yield of paddy as influenced by application of green manures and FYM at different soil ESP given in Table 2.11 and 2.12 and Fig 1 indicated that grain and straw yield of paddy decreased significantly with increase in soil ESP. Incorporation of green manure significantly enhanced the paddy yield (grain and straw) over control. Maximum grain and straw yield of paddy was recorded in case of dhaincha (3.71, 3.96 and 8.68, 8.23 t $ha^{-1}$) followed by sunhemp (3.42, 3.57 and 7.55, 7.81 t $ha^{-1}$) in 2016-17 and 2017-18, respectively at soil ESP of 25, while, lowest yield was observed in control plots.

Table 2.11 Grain and straw yield (t $ha^{-1}$) of paddy as influenced by application of green manures/ FYM at different ESP levels (2016-17)

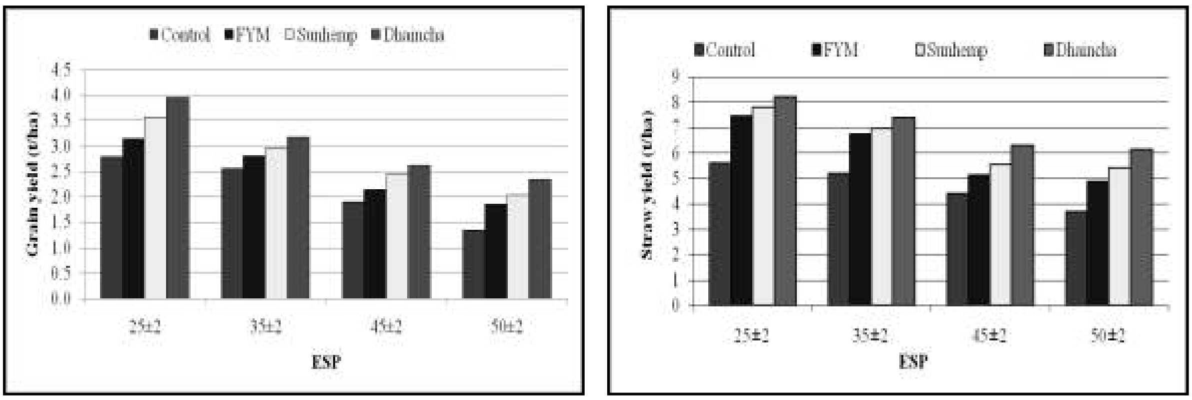
| Green manures | ESP Levels | | | | Mean |
|---|---|---|---|---|---|
| | 25±2 | 35±2 | 45±2 | 50±2 | |
| | | | Grain | | |
| Control | 2.62 | 2.45 | 1.75 | 1.25 | 2.02 |
| FYM @ 10 t $ha^{-1}$ | 2.95 | 2.61 | 1.93 | 1.64 | 2.28 |
| Sunhemp | 3.42 | 2.88 | 2.29 | 1.94 | 2.63 |
| Dhaincha | 3.71 | 3.02 | 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 | |

Table 2.12 Grain and straw yield (t $ha^{-1}$) of paddy as influenced by application of green manures/ FYM at different ESP levels (2017-18)

| Green manures | ESP Levels | | | | Mean |
|---|---|---|---|---|---|
| | 25±2 | 35±2 | 45±2 | 50±2 | |
| | | | Grain | | |
| Control | 2.79 | 2.57 | 1.90 | 1.35 | 2.15 |
| FYM @ 10 t $ha^{-1}$ | 3.16 | 2.81 | 2.14 | 1.86 | 2.49 |
| Sunhemp | 3.57 | 2.96 | 2.44 | 2.03 | 2.75 |
| Dhaincha | 3.96 | 3.18 | 2.62 | 2.35 | 3.02 |
| Mean | 3.37 | 2.88 | 2.28 | 1.90 | |
| | ESP | FYM/GM | ESP x FYM/GM | FYM/GM x ESP | |
| CD 5 % | 0.15 | 0.15 | NS | NS | |
| | | | Straw | | |
| Control | 5.62 | 5.19 | 4.38 | 3.69 | 4.72 |
| FYM @ 10 t $ha^{-1}$ | 7.46 | 6.75 | 5.12 | 4.88 | 6.05 |
| Sunhemp | 7.81 | 6.96 | 5.53 | 5.42 | 6.43 |
| Dhaincha | 8.23 | 7.38 | 6.31 | 6.15 | 7.02 |
| Mean | 7.28 | 6.57 | 5.33 | 5.04 | |
| | ESP | FYM/GM | ESP x FYM/GM | FYM/GM x ESP | |
| CD 5 % | 0.58 | 0.35 | NS | NS | |




**2016-17**




**2017-18**

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 in both the years 2016-17 and 2017-18. Maximum number of effective tillers per meter row length (55.0 and 56.25), plant height (107.4 and 110.80 cm) and length of earhead (8.70 and 8.88 cm) were noticed in case of dhaincha treated plots at soil ESP of 25 in both the respective years. Number of effective tillers per meter row length, plant height and length of earhead 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 2.13 and 2.14 & Fig. 2.1). Highest grain and straw yield of wheat was recorded in case of dhaincha (3.47, 3.68 and 4.71, 4.85 t $ha^{-1}$ in both the respective yesrs) followed by sunhemp (3.21, 3.50 t $ha^{-1}$ in 2016-17 and 4.30, 3.98 t $ha^{-1}$ 2017-18) 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 2.13 Grain and straw yield (t $ha^{-1}$) of wheat as influenced by application of green manures/ FYM at different ESP levels (2016-17)

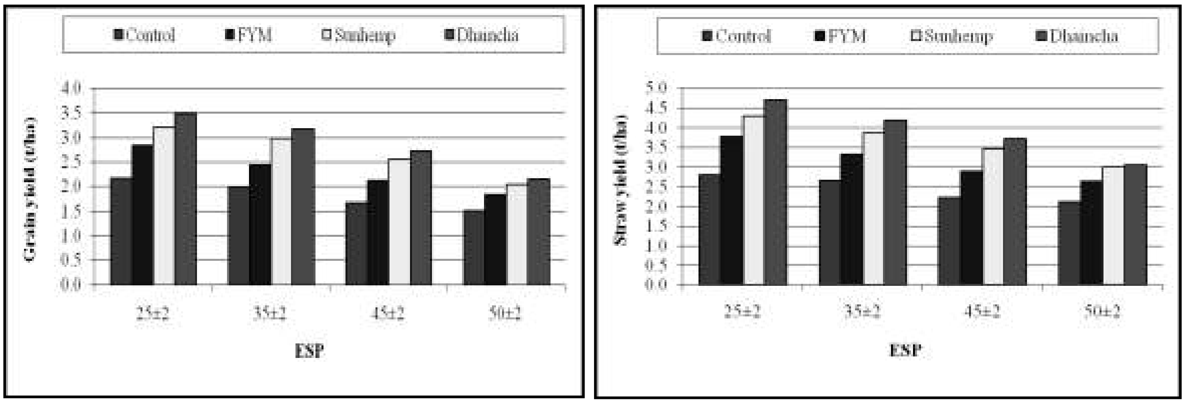
| Green manures | ESP Levels | | | | Mean |
|---|---|---|---|---|---|
| | 25±2 | 35±2 | 45±2 | 50±2 | |
| | | | Grain | | |
| Control | 2.16 | 1.99 | 1.67 | 1.51 | 1.83 |
| FYM @ 10 t $ha^{-1}$ | 2.84 | 2.44 | 2.12 | 1.84 | 2.31 |
| Sunhemp | 3.21 | 2.97 | 2.55 | 2.04 | 2.69 |
| Dhaincha | 3.47 | 3.17 | 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 | |

**Effect of green manures/FYM on soil properties**

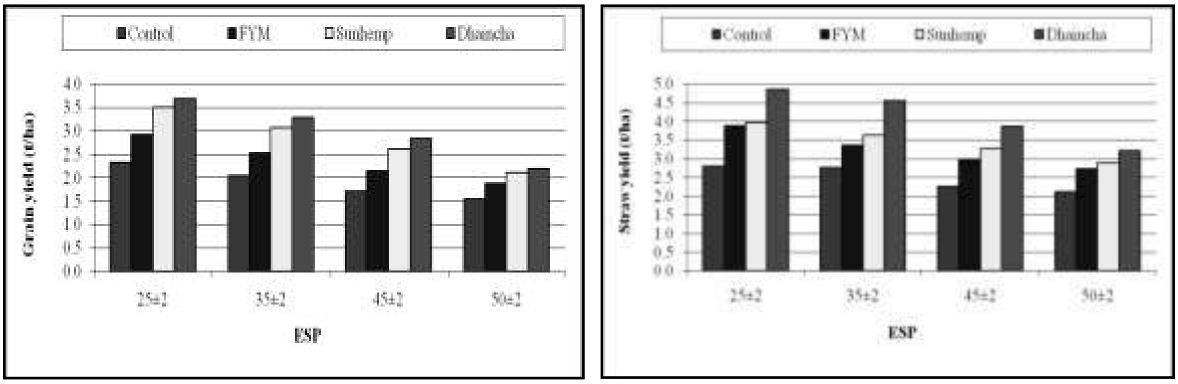
The data presented in Table 2.15 indicated that pHs and ECe of soil did not alter significantly, however, the ESP values were decreased significantly due to incorporation of green manures/FYM. The lowest average ESP (23.54 in 2016-17 and 22.62 in 2017-18) was recorded under incorporation of dhaincha followed by sunhemp (26.70 in 2016-17 and 25.90 in 2017-18).

Table 2.14 Grain and straw yield (t ha$^{-1}$) of wheat as influenced by application of green manures/ FYM at different ESP levels (2017-18)

| Green manures | ESP Levels | | | | Mean |
|---|---|---|---|---|---|
| | 25±2 | 35±2 | 45±2 | 50±2 | |
| | | | Grain | | |
| Control | 2.33 | 2.04 | 1.70 | 1.53 | 1.90 |
| FYM @ 10 t ha$^{-1}$ | 2.92 | 2.53 | 2.15 | 1.88 | 2.37 |
| Sunhemp | 3.50 | 3.06 | 2.62 | 2.10 | 2.82 |
| Dhaincha | 3.68 | 3.29 | 2.82 | 2.20 | 3.00 |
| Mean | 3.11 | 2.73 | 2.32 | 1.93 | |
| | ESP | FYM/GM | ESP x FYM/GM | FYM/GM x ESP | |
| CD 5 % | 0.14 | 0.08 | 0.19 | 0.16 | |
| | | | Straw | | |
| Control | 2.80 | 2.77 | 2.26 | 2.12 | 2.49 |
| FYM @ 10 t ha$^{-1}$ | 3.89 | 3.36 | 2.97 | 2.74 | 3.24 |
| Sunhemp | 3.98 | 3.63 | 3.27 | 2.90 | 3.44 |
| Dhaincha | 4.85 | 4.56 | 3.87 | 3.23 | 4.13 |
| Mean | 3.88 | 3.58 | 3.09 | 2.75 | |
| | ESP | FYM/GM | ESP x FYM/GM | FYM/GM x ESP | |
| CD 5 % | 0.41 | 0.21 | NS | NS | |




**2016-17**




**2017-18**

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

Table 2.15 ESP as influenced by application of green manures/ FYM after harvest of wheat

| Green manures | ESP Levels | | | | Mean |
|---|---|---|---|---|---|
| | 25 | 35 | 45 | 50 | |
| | | | 2016-17 | | |
| 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 | |
| | | | 2017-18 | | |
| Control | 22.55 | 31.05 | 39.20 | 43.07 | 33.97 |
| FYM @ 10 t ha$^{-1}$ | 18.14 | 25.14 | 33.42 | 38.38 | 28.77 |
| Sunhemp | 17.05 | 23.03 | 31.18 | 32.34 | 25.90 |
| Dhaincha | 14.27 | 20.72 | 26.83 | 28.67 | 22.62 |
| Mean | 18.00 | 24.98 | 32.66 | 35.61 | |
| | ESP | FYM/GM | ESP x FYM/GM | FYM/GM x ESP | |
| CD 5 % | 0.80 | 0.62 | 1.33 | 1.25 | |

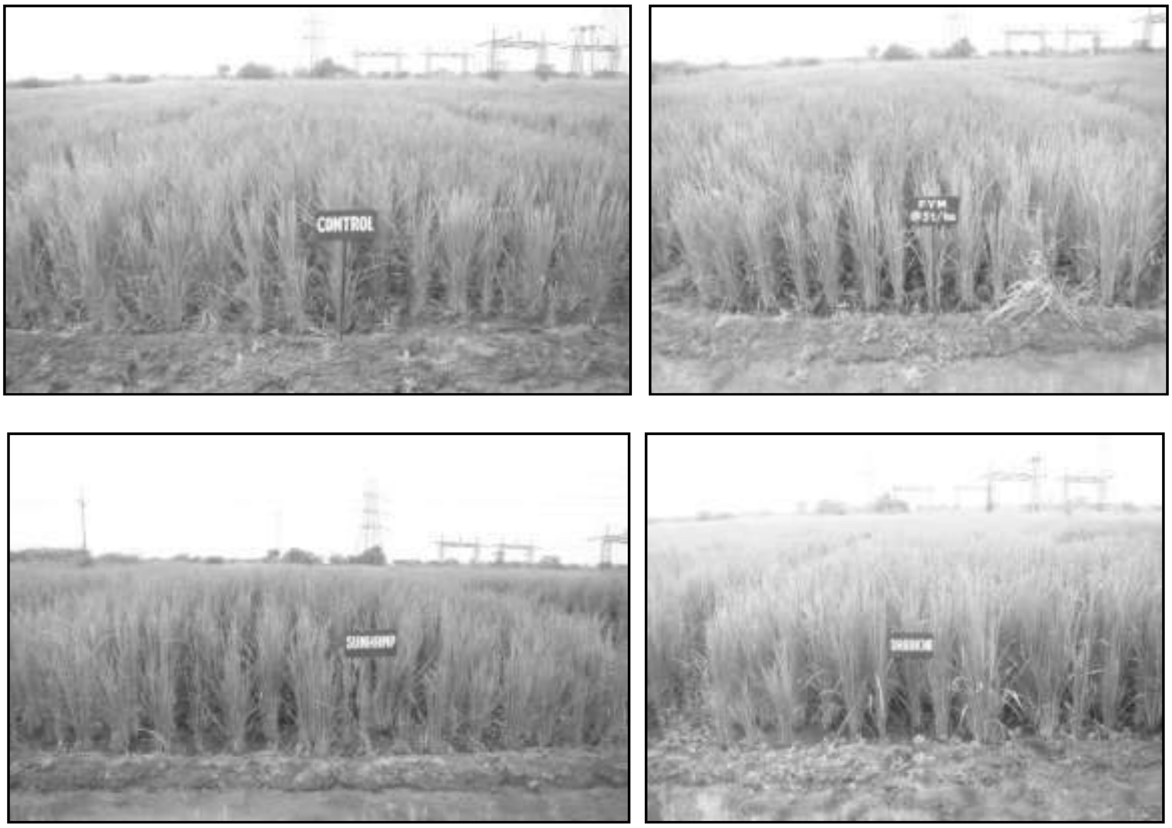



Plate 2.1 Performance of paddy under different treatments in sodic soil condition

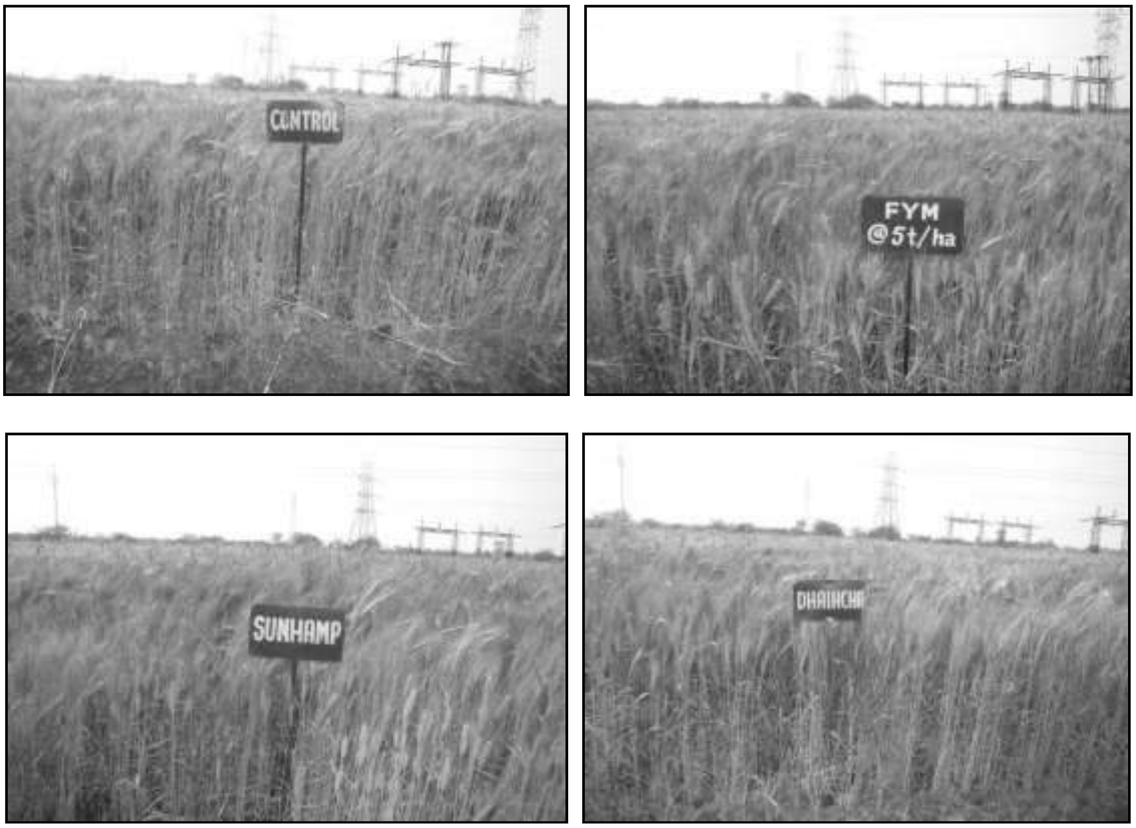



Plate 2.2 Performance of wheat under different treatments in sodic soil condition (2016-17)

**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 6 m 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 details of the yield, total water expense and water productivity obtained were shown in Table 2.16 & 2.17 and discussed as below.

The details of the total water expense, obtained during the year 2016-17 and 2017-18 under different depths and frequencies in case of boarder strip and sprinkler irrigation are shown in Table 2.16 & 2.17. 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 cm during the years 2016-17 respectively. 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 and 2017-18 under different depths and frequencies in case of boarder strip and sprinkler irrigation are shown in Table 2.16 & 2.17. The highest yield of 2869 and 2567 kg/ha in respective years were obtained in case of SI with irrigation depth 3cm and the lowest yield of 1941 and 1673 kg/ha, respectively were obtained in case of BSI with COD 65%. The data clearly indicates that to obtain higher yield of wheat crop in sodic black soils, one should opt SI with irrigation depth 3 cm 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 water productivity (WP) obtained during the year 2016-17 and 2017-18 under different depths and frequencies in case of boarder strip and sprinkler irrigation are shown in Table 2.16 & 2.17. Improved production along with judicious use of water in sodic black soil is necessary which can well be assessed by water productivity. The highest water productivity (WP) of 73.6 and 54.2 kg/ha-cm was obtained in case of SI with depth 3 cm in both the respective years and the lowest water productivity (WP) of 37.4 and 32.3 kg/ha-cm was obtained in case of BSI with COD 65% in 2016-17 and 2017-18, respectively. However, the maximum water productivity (WP) was 45.5 and 39.0 kg/ha-cm in case of BSI with COD 85% followed by 41.7 and 37.0 kg/ha-cm in BSI with COD 75% in 2016-17 and 2017-18, respectively. The data indicates superiority of sprinkler irrigation over BSI in respect of water productivity. SI with 3 cm depth when scheduled on the basis of IW/CPE ratio 1.2 appears to give highest water productivity as compared to tried various irrigation systems. It implies that one should opt SI with irrigation depth 3cm scheduled on the basis of 1.2 I W/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).

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 during 2016-17 only. The same are shown in Table 2.18. 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 2.16 Water expense (WE), yield and water productivity (WP) under different irrigation system (2016-17)

| Name of system | Irrigation Nos. | Depth of fee irrigation cm | Water expense cm | Yield, kg/ha | Water productivity 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 | 40.00 | 2650 | 66.3 |
| SI with irrigation depth 3cm | 13 | 3 | 39.00 | 2869 | 73.6 |
| SI with irrigation depth 5cm | 8 | 5 | 40.00 | 2391 | 59.8 |

Table 2.17. Water expense (WE), yield and water productivity (WP) under different irrigation system (2017-18)

| Name of system | Nos. of irrigation | Depth of fee irrigation cm | Water expense cm | Yield kg/ha | Water productivity kg/ha-cm |
|---|---|---|---|---|---|
| BSI with COD 65% | 09 | 5.76 | 51.84 | 1673 | 32.3 |
| BSI with COD 75% | 07 | 6.88 | 48.16 | 1783 | 37.0 |
| BSI with COD 85% | 06 | 8.16 | 48.96 | 1907 | 39.0 |
| SI with irrigation depth 2cm | 20 | 2.00 | 40.00 | 2114 | 52.9 |
| SI with irrigation depth 3cm | 13 | 3.00 | 39.00 | 2567 | 54.2 |
| SI with irrigation depth 5cm | 08 | 5.00 | 40.00 | 1915 | 47.9 |

Table 2.18. Chemical properties of soils under different irrigation systems (2016-17)

| Irrigation system | pHs | $EC_e$ | 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 2.19.

- 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 2.19 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 2.20 during 2016-17. 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 2.20 Water expense, yield and water productivity under different drip systems (2016-17)

| Treatments | Irrigation | Depth of fee irrigation | Water expense | Curd yield | Curd yield | WP |
|---|---|---|---|---|---|---|
| | Nos. | cm | cm | kg/plot | (kg/ha) | kg/ha-cm |
| $Q_1 S_1$ | 106 | 00.50 | 53.00 | 62.93 | 20976 | 395.77 |
| $Q_1 S_2$ | 53 | 01.00 | 53.00 | 57.57 | 19191 | 365.75 |
| $Q_1 S_3$ | 36 | 01.50 | 53.00 | 51.80 | 17267 | 321.90 |
| $Q_2 S_1$ | 106 | 00.50 | 53.00 | 51.94 | 17313 | 326.67 |
| $Q_2 S_2$ | 53 | 01.00 | 53.00 | 50.39 | 16796 | 320.10 |
| $Q_2 S_3$ | 36 | 01.50 | 53.00 | 47.51 | 15837 | 295.24 |
| $Q_3 S_1$ | 106 | 00.50 | 53.00 | 36.33 | 12110 | 228.49 |
| $Q_3 S_2$ | 53 | 01.00 | 53.00 | 35.96 | 11986 | 228.44 |
| $Q_3 S_3$ | 36 | 01.50 | 53.00 | 31.77 | 10588 | 197.40 |

The details of Nos. of irrigation, water expense, yield and water productivity are given in Table 2.21 during 2017-18. The total water expense was estimated around 54 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 16223 kg/ha was obtained in case of drip irrigation system scheduled daily with 1.3 LPH dripper discharge rate followed by the lowest 9076 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 297.68 kg/ha-cm in case of drip irrigation system scheduled every day with 1.3 LPH dripper discharge rate followed by 281.50 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 164.62 kg/ha-cm in case of drip irrigation system scheduled every third day with 4.0 LPH dripper discharge rate followed by 182.59 kg/ha-cm in case of drip irrigation system scheduled alternate day with 4.0 LPH dripper discharge rate. The results of study during the year 2017-18 indicates that drip irrigation of 3 cm depth with daily frequency basis was found most effective and promising for growing cabbage crop in sodic black soils.

Table 2.21 Water expense, yield and water productivity under different drip systems (2017-18)

| Discharge rates (LPH) | irrigation Nos. | Depth of fee irrigation cm | Water expense cm | Curd yield kg/plot | Curd yield (kg/ha) | WP kg/ha-cm |
|---|---|---|---|---|---|---|
| $Q_1 S_1$ | 109 | 0.5 | 54 | 48.7 | 16223 | 297.68 |
| $Q_1 S_2$ | 54 | 1.0 | 54 | 45.1 | 15049 | 281.50 |
| $Q_1 S_3$ | 36 | 1.5 | 54 | 44.6 | 14854 | 269.44 |
| $Q_2 S_1$ | 109 | 0.5 | 54 | 37.3 | 12444 | 228.34 |
| $Q_2 S_2$ | 54 | 1.0 | 54 | 36.0 | 12008 | 224.61 |
| $Q_2 S_3$ | 36 | 1.5 | 54 | 34.7 | 11574 | 209.95 |
| $Q_3 S_1$ | 109 | 0.5 | 54 | 31.0 | 10323 | 189.42 |
| $Q_3 S_2$ | 54 | 1.0 | 54 | 29.3 | 9761 | 182.59 |
| $Q_3 S_3$ | 36 | 1.5 | 54 | 27.2 | 9076 | 164.62 |

**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 2.22. Soil moisture contribution estimated ranges in-between 3.16 to 3.97 cm/ m soil depth in different treatments during 2016-17 only.

Table 2.22 Soil moisture contributions 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 |

General view of the experimental area (2017-18)

**Assessment of Efficacy of Organic Amendments for Sustainable Crop Production under Rice-Wheat Cropping System in Sodic Soil (Kanpur)**

This experiment was conducted at Research farm, Dalipnagar, Kanpur with the objectives to find out the suitable combination of organic and inorganic inputs for sustainable crop production in sodic conditions during 2016 to 2018. The treatments comprised of $T_1$- 50%GR; $T_2$- 25%GR + rice straw @5 t/ha; $T_3$- 25%GR + GM @5 t/ha; $T_4$- 25%GR + GM @5 t/ha + Microbial culture; $T_5$- 25%GR + Poultry manure @3t/ha; $T_6$- 25%GR + City Waste Manure @5 t/ha and $T_7$ - Control. Rice variety CSR 36 and wheat variety KRL 210 were sown during kharif and rabi season. The initial soil status was pH 9.50, EC ( 0.94 dS/m), ESP 48.20 and OC 0.21%.

The average grain yield of rice varied from 24.20 to 41.43 and straw yield 29.09-50.34 q/ha (Table 2.23). The maximum grain yield (41.43 q/ha) and straw yield (50.34 q/ha) was obtained from 25%GR + Poultry Manure @ 3t/ha treatment followed by 25%GR + GM @5 t/ha + Microbial culture and 25%GR + City Waste Manure @5 t/ha.

Table 2.23 Effect of different treatments on grain and straw yield of rice (q/ha)

| Treatments | Grain yield | | | Straw yield | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Mean | 2016 | 2017 | Mean |
| $T_1$- 50%GR | 35.38 | 36.82 | 36.10 | 41.57 | 43.55 | 42.56 |
| $T_2$- 25%GR + rice straw @5 t/ha | 33.45 | 34.55 | 34.00 | 39.94 | 41.46 | 40.70 |
| $T_3$- 25%GR + GM @5 t/ha | 37.72 | 38.98 | 38.35 | 45.48 | 47.00 | 46.24 |
| $T_4$- 25%GR + GM @5 t/ha + Microbial culture | 39.27 | 40.86 | 40.06 | 47.53 | 49.44 | 48.48 |
| $T_5$- 25%GR + Poultry manure @3t/ha | 40.68 | 42.18 | 41.43 | 49.65 | 51.03 | 50.34 |
| $T_6$- 25%GR + City Waste Manure @5 t/ha | 38.15 | 39.65 | 38.90 | 45.95 | 47.97 | 46.96 |
| $T_7$ - Control | 23.82 | 24.58 | 24.20 | 28.44 | 29.74 | 29.09 |
| CD (0.05) | 1.87 | 1.93 | -- | 2.01 | 2.27 | -- |

The average grain yield of wheat varied between 19.34 - 36.04 and straw yield between 23.80 - 43.97 q/ha (Table 2.24). The maximum grain yield (36.04 q/ha) and straw yield (43.97 q/ha) was obtained from 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.

Table 2.24 Effect of different treatments on grain and straw yield of wheat (q/ha)

| Treatments | Grain yield | | | Straw yield | | |
|---|---|---|---|---|---|---|
| | 2016-17 | 2017-18 | Mean | 2016-17 | 2017-18 | Mean |
| $T_1$- 50%GR | 30.54 | 32.00 | 31.27 | 37.25 | 39.04 | 38.14 |
| $T_2$- 25%GR + rice straw @5 t/ha | 28.72 | 29.68 | 29.20 | 35.04 | 36.21 | 35.62 |
| $T_3$- 25%GR + GM @5 t/ha | 29.46 | 30.35 | 29.90 | 36.54 | 38.10 | 37.32 |
| $T_4$- 25%GR + GM @5 t/ha + Microbial culture | 32.27 | 33.88 | 33.07 | 39.52 | 41.67 | 40.59 |
| $T_5$- 25%GR + Poultry manure @3t/ha | 35.34 | 36.75 | 36.04 | 43.11 | 44.83 | 43.97 |
| $T_6$- 25%GR + City Waste Manure @5 t/ha | 33.83 | 35.16 | 34.49 | 40.82 | 43.24 | 42.03 |
| $T_7$ - Control | 19.12 | 19.56 | 19.34 | 23.33 | 24.27 | 23.80 |
| CD (0.05) | 1.92 | 1.86 | -- | 2.11 | 2.24 | -- |

The soil properties improved with the application of different treatments as compared to control (Table 2.25). The maximum changes in pH, EC, ESP and OC in 50%GR followed by 25%GR + Poultry manure @3t/ha and 25%GR + GM @5 t/ha + Microbial culture as compared to other treatments.

Table 2.25 Effect of treatments on soil properties after two year

| Treatments | pH | EC (dS/m) | ESP | OC % |
|---|---|---|---|---|
| $T_1$- 50%GR | 8.8 | 0.91 | 31.8 | 0.23 |
| $T_2$- 25%GR + rice straw @5 t/ha | 9.1 | 0.92 | 39.3 | 0.25 |
| $T_3$- 25%GR + GM @5 t/ha | 9.0 | 0.94 | 38.8 | 0.26 |
| $T_4$- 25%GR + GM @5 t/ha + Microbial culture | 8.9 | 0.91 | 37.5 | 0.30 |
| $T_5$- 25%GR + Poultry manure @3t/ha | 8.9 | 0.92 | 35.2 | 0.32 |
| $T_6$- 25%GR + City Waste Manure @5 t/ha | 9.0 | 0.93 | 38.1 | 0.28 |
| $T_7$ - Control | 9.4 | 0.95 | 46.4 | 0.22 |
| Initial Soil Status | 9.5 | 0.94 | 48.2 | 0.21 |

**Management of Sodic Soil under different Irrigation Scenarios in Rice Based Cropping System in Cauvery Delta Zone of Tamil Nadu (Tiruchirapalli)**

This study was planned to understand effect of alkali soil management practices under different irrigation scenarios on the productivity of rice based cropping system and to know the lasting effect of different soil amendments in alkali soil under different irrigation scenarios. The treatments viz., Factor A , : Irrigation scenarios (4) $I_1$:Canal water alone, $I_2$: Canal water : Alkali water (1:1 cyclic mode), $I_3$:Canal+Alkali water combined (50+50 %) per irrigation, $I_4$:Alkali water alone and Factor B: Soil amendments (4) $S_1$: Control, $S_2$: Green / green leaf manuring @ 6.25 t/ha, $S_3$: Distillery spent wash @ 5 lakh litres / ha, $S_4$:Gypsum 50 % GR + Green manuring with Daincha @ 6.25 t/ha were imposed as per the treatment schedule. The field experiment was laid out in Factorial Randomized Block Design with 3 replications and plot size of 10 x 4 m =40 $m^2$. The initial soil properties, irrigation water quality parameters and properties of distillery spent wash (DSW) are given in Table 2.26, 2.27 and 2.28, respectively.

Table 2.26 Initial soil properties at experimental field

| Sr. No. | Particulars | Value | Sr. No. | Particulars | Value |
|---|---|---|---|---|---|
| 1 | pH | 9.2 | 6 | Available K, kg $ha^{-1}$ | 215 |
| 2 | EC, dS $m^{-1}$ | 0.45 | 7 | ESP % | 26.2 |
| 3 | Organic Carbon % | 0.48 | 8 | Exchangeable Ca, c mol $(p^+)$ $kg^{-1}$ | 8.6 |
| 4 | Available N , kg $ha^{-1}$ | 215 | 9 | Exchangeable Mg, c mol $(p^+)$ $kg^{-1}$ | 4.6 |
| 5 | Available P, kg $ha^{-1}$ | 12.8 | 10 | Exchangeable Na, c mol $(p^+)$ $kg^{-1}$ | 4.8 |
| | | | 11 | Exchangeable K, c mol $(p^+)$ $kg^{-1}$ | 0.28 |

Table 2.27 Irrigation water quality used for experiment

| Water type | pH | EC, dS $m^{-1}$ | RSC, m eq $lit^{-1}$ | SAR |
|---|---|---|---|---|
| Alkali water | 8.6 | 1.42 | 6.7 | 9.4 |
| Canal water | 7.6 | 0.28 | - | 2.8 |

Table 2.28 Properties of distillery spent wash (DSW)

| SN | Parameter | Value | SN | Parameter | Value | SN | Parameter | Value |
|---|---|---|---|---|---|---|---|---|
| 1 | pH | 4.3 | 7 | Nitrogen | 1,200 | 13 | Calcium | 2,100 |
| 2 | EC ($dSm^{-1}$) | 28 | 8 | Phosphorus | 325 | 14 | Magnesium | 1,700 |
| 3 | BOD | 45,200 | 9 | Potassium | 9,600 | 15 | Zinc | 3.5 |
| 4 | COD | 90,600 | 10 | Chlorides | 10,300 | 16 | Copper | 0.8 |
| 5 | Total dissolved solids | 80,100 | 11 | Sulphates | 3,420 | 17 | Iron | 25 |
| 6 | Suspended solids | 41,900 | 12 | Sodium | 470 | 18 | Manganese | 4 |

(Except pH and EC all values are in mg $L^{-1}$)

This experiment was approved for the year 2015-16 to 2017-18 during the Biennial workshop held during 05th - 07th June 2015 at Agra. During Rabi of 2015-16 experiment was conducted for first time. The data presented in the Table 2.29 indicated that application of amendments resulted in significant decrease in soil pH after 1st year's experiment. The pH declined from 9.16 in control to 8.95, 8.37 and 8.45 due to GM ($M_2$), DSW ($S_3$) and GYP+GM ($S_4$) application respectively. Maximum reduction in soil pH was recorded in DSW applied plots. A decrease in pH of 0.71, 0.79 and 0.21 was observed in the Gypsum+GM, DSW and GM applied plots, respectively, over the control. There were no significant changes in the soil pH due to irrigation. The soil pH changes because of interaction effect of irrigation treatments and soil amendments were also found non-significant.

Table 2.29 Effect of irrigation water and soil amendments on post harvest soil pH (1st year of experiment)

| Treatment (I: Irrigation / S: Soil amendment ) | $S_1$: (Farmers practice) | $S_2$: Green manuring @6.25 t $ha^{-1}$ | $S_3$: Distillery spent wash @ 5 lakh lit $ha^{-1}$ | $S_4$: Gypsum 50%GR+ Green manuring | Mean |
|---|---|---|---|---|---|
| $I_1$: Canal water (CW) | 9.12 | 8.90 | 8.32 | 8.43 | 8.69 |
| $I_2$: 1CW:1AW(Cyclic) | 9.18 | 8.96 | 8.38 | 8.46 | 8.75 |
| $I_3$: CW+AW(50+50) | 9.17 | 8.95 | 8.39 | 8.45 | 8.74 |
| $I_4$: Alkali water (AW) | 9.20 | 8.98 | 8.41 | 8.48 | 8.77 |
| Mean | 9.16 | 8.95 | 8.37 | 8.45 | |
| | | SED | CD (0.05) | | |
| | I | 0.09 | NS | | |
| | S | 0.09 | 0.18 | | |
| | IxS | 0.18 | NS | | |

The EC of after harvest soil varied from 0.45 to 0.91 $dSm^{-1}$. There was no significant difference between control ($S_1$) and GM ($S_2$) applied treatments. An increase of 0.18 and 0.40 dS $m^{-1}$ of electrical conductivity was observed with Gypsum + GM ($S_4$) and DSW ($S_3$) application, respectively, over the control. An increase of 0.03, 0.03 and 0.06 $dSm^{-1}$ was recorded due to irrigation treatments viz., $I_2$, $I_3$ and $I_4$ respectively over canal water irrigation.

The changes in exchangeable sodium percentage of soil due to application of treatments varied from 12.7 to 26.9. Significant reduction in the soil Exchangeable Sodium Percentage (ESP) is noted due to application of amendments. Lowest ESP (13.3) was recorded in the DSW applied treatments and highest (26.3) was recorded in the control. Decrease in the ESP of 4.6, 13.0 and 10.3 was observed on account of application of GM, DSW and Gypsum+GM over the control, respectively. The application of different irrigation did not affect the ESP significantly. The interaction effect of amendments and irrigation were also not significant.

During Rabi of 2016-17, the experiment was not possible due to drought in Cauvery Delta Zone. The experiment was planned for second time during Rabi of 2017-18. This is the second rice crop in the rice-pulse cropping system. During this rice season only irrigation treatments (Factor-A) imposed and factor B is the residual effect of the onetime application of soil amendments during the start of the cropping system experiment. The rice (Variety- TRY-3) nursery was raised on 16.10.2017. The main field was prepared with the previous field layout as intact. Transplanting was done on 17.11.2017. The crop was harvested on 26-03-2018. The results are furnished below.

The effect of various irrigation sources and soil amendments on grain yield of rice is presented in Table 2.30. Among the irrigation management practices, application of alkali water alone ($I_4$) recorded a lowest grain yield of 4536 kg ha$^{-1}$. The other treatments viz., $I_3$;Applicatiion of canal water +Alkali water (50+50), $I_2$; application of canal and alkali water as 1:1 cyclic mode and $I_1$; application of Canal water alone recorded with a grain yield of 4815, 4948 and 5318 kg ha$^{-1}$ respectively. Among the irrigation treatments $I_1$ recorded significantly highest yield followed by $I_2$ and $I_3$ which are statistically on par. $I_4$ recorded with least yield which is statistically has significant difference between $I_1$, $I_2$ and $I_3$. Among the soil amendments, the treatment $S_3$, application of distillery spent wash @ 5 lakh litres ha$^{-1}$ recorded with a significantly highest grain yield of 5473 kg ha$^{-1}$ followed by $S_4$; application of gypsum 50% GR+green manuring @ 6.25 kg ha$^{-1}$, $S_2$; green manuring @ 6.25 t ha$^{-1}$ and $S_1$; control with a respective grain yield of 5091, 4866 and 4187 kg ha$^{-1}$. There does not exist any interaction between irrigation methods and residual effect of soil amendments.

Table 2.30 Effect of irrigation scenario and soil amendments on grain yield of rice (kg ha$^{-1}$)

| Treatment (I: Irrigation / S: Soil amendment | $S_1$: (Farmers practice) | $S_2$: Green manuring @6.25 t ha$^{-1}$ | $S_3$: Distillery spent wash @ 5 lakh lit ha$^{-1}$ | $S_4$: Gypsum 50%GR+ Green manuring | Mean |
|---|---|---|---|---|---|
| $I_1$: Canal water (CW) | 4587 | 5175 | 5959 | 5553 | 5318 |
| $I_2$: 1CW:1AW(Cyclic) | 4170 | 5023 | 5453 | 5145 | 4948 |
| $I_3$: CW+AW(50+50) | 4142 | 4728 | 5347 | 5042 | 4815 |
| $I_4$: Alkali water (AW) | 3848 | 4537 | 5134 | 4623 | 4536 |
| Mean | 4187 | 4866 | 5473 | 5091 | |
| | | SED | CD(0.05) | | |
| | I | 92 | 189 | | |
| | S | 92 | 189 | | |
| | IxS | 185 | NS | | |

The straw yield recorded from the field experiments is presented in Table 2.31. Among the irrigation treatments $I_1$ recorded with significantly highest straw yield of 6982 kg ha$^{-1}$ followed by $I_2$ and $I_3$, both were significantly on par with each other with a corresponding value of 6488 and 6317 kg ha$^{-1}$ respectively. $I_4$ recorded with the lowest straw yield of 5925 kg ha$^{-1}$. Among the soil amendments, $S_3$ recorded with highest straw yield of 7209 kg ha$^{-1}$ followed by $S_4$, $S_2$ and $S_1$ which are significantly different from each other with a corresponding value of 6645, 6373 and 5484 kg ha$^{-1}$. There does not exist any interaction between irrigation methods and residual effect of soil amendments.

Table 2.31 Effect of irrigation scenario and soil amendments on straw yield of rice (kg $ha^{-1}$)

| Treatment (I: Irrigation / S: Soil amendment | $S_1$: (Farmers practice) | $S_2$: Green manuring @6.25 t $ha^{-1}$ | $S_3$: Distillery spent wash @ 5 lakh lit $ha^{-1}$ | $S_4$: Gypsum 50%GR+ Green manuring | Mean |
|---|---|---|---|---|---|
| $I_1$: Canal water (CW) | 6014 | 6785 | 7847 | 7280 | 6982 |
| $I_2$: 1CW:1AW(Cyclic) | 5476 | 6623 | 7179 | 6673 | 6488 |
| $I_3$: CW+AW(50+50) | 5470 | 6191 | 7049 | 6559 | 6317 |
| $I_4$: Alkali water (AW) | 4977 | 5895 | 6759 | 6067 | 5925 |
| Mean | 5484 | 6373 | 7209 | 6645 | |
| | | SED | CD(0.05) | | |
| | I | 121 | 246 | | |
| | S | 121 | 246 | | |
| | IxS | 241 | NS | | |

The percent yield increase of the different treatments and treatment combinations has been worked out over the control treatment combination $I_4S_1$ and presented in Table 2.32. Among the irrigation treatment $I_1$ Canal water irrigation recorded with highest yield increase of 38.2 % followed by $I_2$ and $I_3$ with the corresponding value of 28.6 and 25.1 respectively. Among the different soil amendments $S_3$ recorded with 42.2 % yield increase followed by $S_4$, $S_2$ and $S_1$.

Table 2.32 Effect of irrigation water and soil amendments on % yield increase over control ($I_4S_1$)

| Treatment (I: Irrigation / S: Soil amendment | $S_1$: (Farmers practice) | $S_2$: Green manuring @6.25 t $ha^{-1}$ | $S_3$: Distillery spent wash @ 5 lakh lit $ha^{-1}$ | $S_4$: Gypsum 50%GR+ Green manuring | Mean |
|---|---|---|---|---|---|
| $I_1$: Canal water (CW) | 19.2 | 34.5 | 54.9 | 44.3 | 38.2 |
| $I_2$: 1CW:1AW(Cyclic) | 8.4 | 30.5 | 41.7 | 33.7 | 28.6 |
| $I_3$: CW+AW(50+50) | 7.6 | 22.9 | 38.9 | 31.0 | 25.1 |
| $I_4$: Alkali water (AW) | | 17.9 | 33.4 | 20.1 | 23.8 |
| Mean | 11.7 | 26.4 | 42.2 | 32.3 | |

The calculated gross income for the different treatments is presented in the Table 2.33. Among the irrigation treatments $I_1$ had a highest gross income of 92078 rupees $ha^{-1}$ followed by $I_2$, $I_3$ and $I_4$. Among the soil amendments $S_3$ recorded with highest gross income of 94782 followed by $S_4$, $S_2$ and $S_1$

Table 2.33 Effect of irrigation scenario and soil amendments on gross income (Rs $ha^{-1}$)

| Treatment (I: Irrigation / S: Soil amendment) | $S_1$: (Farmers practice) | $S_2$: Green manuring @6.25 t $ha^{-1}$ | $S_3$: Distillery spent wash @ 5 lakh lit $ha^{-1}$ | $S_4$: Gypsum 50%GR+ Green manuring | Mean |
|---|---|---|---|---|---|
| $I_1$: Canal water (CW) | 79401 | 89590 | 103197 | 96123 | 92078 |
| $I_2$: 1CW:1AW(Cyclic) | 72196 | 86996 | 94433 | 88993 | 85654 |
| $I_3$: CW+AW(50+50) | 71737 | 81839 | 92596 | 87231 | 83351 |
| $I_4$: Alkali water (AW) | 66550 | 78482 | 88903 | 80041 | 78494 |
| Mean | 72471 | 84227 | 94782 | 88097 | |

The net income was calculated and presented in Table 2.34. Among the irrigation scenarios $I_1$ recorded with highest net income of Rs. 49078 followed by $I_2$, $I_3$ and $I_4$. Among the different soil amendments $S_3$ recorded with highest net income of Rs. 51782 followed by $S_4$, $S_2$ and $S_1$.

Table 2.34 Effect of irrigation scenario and soil amendments on net income (Rs $ha^{-1}$)

| Treatment (I: Irrigation / S: Soil amendment) | $S_1$: (Farmers practice) | $S_2$: Green manuring @6.25 t $ha^{-1}$ | $S_3$: Distillery spent wash @ 5 lakh lit $ha^{-1}$ | $S_4$: Gypsum 50%GR+ Green manuring | Mean |
|---|---|---|---|---|---|
| $I_1$: Canal water (CW) | 36401 | 46590 | 60197 | 53123 | 49078 |
| $I_2$: 1CW:1AW(Cyclic) | 29196 | 43996 | 51433 | 45993 | 42654 |
| $I_3$: CW+AW(50+50) | 28737 | 38839 | 49596 | 44231 | 40351 |
| $I_4$: Alkali water (AW) | 23550 | 35482 | 45903 | 37041 | 35494 |
| Mean | 29471 | 41227 | 51782 | 45097 | |

The BCR was calculated for different treatments and presented in Table 2.35. Among the irrigation treatments $I_1$ recorded with highest BCR of 2.14 followed by $I_2$ , $I_3$ and $I_4$. Among the different soil amendments $S_3$ recorded with highest BCR of 2.20 followed by $S_4$, $S_2$ and $S_1$.

Table 2.35 Effect of irrigation scenario and soil amendments on BC ratio

| Treatment (I: Irrigation / S: Soil amendment) | $S_1$: (Farmers practice) | $S_2$: Green manuring @6.25 t $ha^{-1}$ | $S_3$: Distillery spent wash @ 5 lakh lit $ha^{-1}$ | $S_4$: Gypsum 50%GR+ Green manuring | Mean |
|---|---|---|---|---|---|
| $I_1$: Canal water (CW) | 1.85 | 2.08 | 2.40 | 2.24 | 2.14 |
| $I_2$: 1CW:1AW(Cyclic) | 1.68 | 2.02 | 2.20 | 2.07 | 1.99 |
| $I_3$: CW+AW(50+50) | 1.67 | 1.90 | 2.15 | 2.03 | 1.94 |
| $I_4$: Alkali water (AW) | 1.55 | 1.83 | 2.07 | 1.86 | 1.83 |
| Mean | 1.69 | 1.96 | 2.20 | 2.05 | |

On basis of 2nd years' data, it is concluded that among the irrigation treatments, the results reveals that, the treatments viz., $I_3$; $I_2$ and $I_1$; recorded with a grain yield of 4815, 4948 and 5318 kg $ha^{-1}$ respectively. Application of alkali water alone ($I_4$) recorded a lowest grain yield of 4536 kg $ha^{-1}$. Among the soil amendments, the treatment $S_3$, recorded a significant highest yield of 5473 kg $ha^{-1}$ followed by $S_4$, $S_2$, and $S_1$ with a respective grain yield of 5091, 4866 and 4187 kg $ha^{-1}$. There does not exist any interaction between irrigation methods and residual effect of soil amendments. The percent yield increase over irrigation of alkali water alone over rest of the treatments reveals that the irrigation treatment $I_1$ Canal water irrigation recorded with highest yield increase of 38.2 % followed by $I_2$ and $I_3$ with the corresponding value of 28.6 and 25.1 respectively. Among the different soil amendments $S_3$ recorded with 42.2 % yield increase followed by $S_4$, $S_2$ and $S_1$. Among the irrigation treatments $I_1$ had a highest gross income of 92078 rupees $ha^{-1}$ followed by $I_2$, $I_3$ and $I_4$. Among the soil amendments $S_3$ recorded with highest gross income of 94782 followed by $S_4$, $S_2$ and $S_1$. The net income was calculated and it is found that , among the irrigation scenarios $I_1$ recorded with highest net income of Rs. 49078 followed by $I_2$, $I_3$ and $I_4$. Among the different soil amendments $S_3$ recorded with highest net income of Rs. 51782 followed by $S_4$, $S_2$ and $S_1$. The BCR was calculated for different treatments and found that, among the irrigation treatments $I_1$ recorded with highest BCR of 2.14 followed by $I_2$, $I_3$ and $I_4$. Among the different soil amendments $S_3$ recorded with highest BCR of 2.20 followed by $S_4$, $S_2$ and $S_1$.

**Integrated Farming System 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 2.36. The B:C ratio for IFS was 2.54 compared to sole rice crop with B:C ratio as 2.16.

Table 2.36 Economic analysis of Integrated farming system

| Sr. No. | 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)**

Silicon application through different sources showed significant differences in growth parameters of paddy. Maximum plant height of 83.6cm and 1000.8cm during 2016 and 2017, respectively, was recorded with potassium silicate application which was significantly superior to control and on par with all other sources of silica during both the years. More numbers of tillers per plant (15.4 and 27) were observed with potassium silicate application as compared to all other treatments (Table 2.37).

Table 2.37 Influence of sources of silica on growth of rice

| Silica sources | Plant height (cm) | | No. of tillers plant$^{-1}$ | |
|---|---|---|---|---|
| | 2016 | 2017 | 2016 | 2017 |
| $T_1$- Control | 75.7 | 92.0 | 10.2 | 21 |
| $T_2$-Potassium silicate | 83.6 | 100.8 | 15.4 | 27 |
| $T_3$-Calcium silicate | 82.7 | 100.0 | 13.3 | 26 |
| $T_4$- Paddy straw | 81.0 | 98.6 | 12.4 | 25 |
| $T_5$-Paddy husk | 79.5 | 96.6 | 11.2 | 24 |
| SEm$\pm$ | 2.3 | 3.7 | 0.5 | 1.1 |
| CD(0.05) | 6.9 | NS | 1.5 | 3.5 |
| CV (%) | 5.7 | 6.7 | 7.9 | 9.2 |

The numbers of total grains per panicle were significantly influenced by silica sources. The highest number of total grains per panicle 143 and 219 were observed in potassium silicate treatment during 2016 and 2017. It was significantly superior to all other sources. The longer panicle 18.8 during 2016 and 22.2cm during 2017 was observed in potassium silicate application followed by calcium silicate (18.3 and 21.6cm) application, respectively. The test weight was significantly influenced by silica sources. The maximum test weight (19.0 and 17.3g) was observed with potassium silicate application followed by calcium silicate and the lowest test weight (17.9 and 16.3g) was observed by control treatment (Table 2.38).

Table 2.38 Influence of sources of silica on yield attributes of rice

| Silica sources | Total grains panicle$^{-1}$ (No.) | | Panicle length (cm) | | Filled grains panicle$^{-1}$ (No.) | | Test weight (g) | |
|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| $T_1$- Control | 98 | 208 | 15.9 | 20.3 | 93 | 199 | 17.9 | 16.3 |
| $T_2$-Potassium silicate | 143 | 219 | 18.8 | 22.2 | 127 | 214 | 19.0 | 17.3 |
| $T_3$-Calcium silicate | 125 | 218 | 18.3 | 21.6 | 113 | 213 | 18.5 | 17.1 |
| $T_4$- Paddy straw | 108 | 215 | 16.7 | 21.4 | 103 | 207 | 18.4 | 16.9 |
| $T_5$-Paddy husk | 105 | 2111 | 16.6 | 20.6 | 100 | 204 | 18.1 | 16.4 |
| SEm$\pm$ | 5 | 6.3 | 0.6 | 0.6 | 3 | 5.3 | 0.36 | 0.4 |
| CD(0.05) | 15 | NS | 1.9 | 1.7 | 10 | NS | 1.09 | NS |
| CV(%) | 8 | 5.8 | 7.2 | 5.6 | 6 | 5.1 | 5.05 | 4.6 |

Among different sources of silica, potassium silicate treatment recorded significantly higher grain yield (5686 and 6273 kg $ha^{-1}$) and straw yield (6237 and 7346 kg $ha^{-1}$) when compared to grain yield (4631 and 5125 kg $ha^{-1}$) and straw yield (5118 and 6284 kg $ha^{-1}$) of control treatment during 2016 and 2017 (Table 2.39).

Table 2.39 Influence of sources of silica on grain and straw yield of rice

| Silica sources | Grain yield (kg $ha^{-1}$) | | Straw yield (kg $ha^{-1}$) | |
|---|---|---|---|---|
| | 2016 | 2017 | 2016 | 2017 |
| $T_1$- Control | 4631 | 5125 | 5118 | 6284 |
| $T_2$-Potassium silicate | 5686 | 6273 | 6237 | 7346 |
| $T_3$-Calcium silicate | 5456 | 6084 | 6002 | 7195 |
| $T_4$- Paddy straw | 5058 | 5538 | 5469 | 6672 |
| $T_5$-Paddy husk | 4974 | 5342 | 5347 | 6465 |
| SEm$\pm$ | 184 | 153 | 223 | 175 |
| CD(0.05) | 555 | 461 | 672 | 529 |
| CV (%) | 7 | 5.4 | 8 | 5.2 |

Plate 2.3 Field view of rice crop

**Investigation, Design, Installation and Evaluation of Mole Drainage Systems in Black Soils of Andhra Pradesh for Control of Waterlogging (Bapatla)**

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 were installed. The network of observation wells were installed for monitoring the groundwater levels.

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.

Plate 2.4 a Glimpses of sugarcane transplantation and data collection in the mole drained fields in Kapileswarapuram, East Godavari district


Plate 2.4 b Glimpses of sugarcane transplantation and data collection in the mole drained fields in Kapileswarapuram, East Godavari district.

The variations in the brix content and yield of sugarcane are shown in the following tables for the 0.4 m depth mole drainage system under 2, 3, 4 and 5 m spacing.

| 0.4-WSO (Without Soil oxygenation) | | | | | |
|---|---|---|---|---|---|
| Spacing (m) | R1 | R2 | R3 | R4 | Mean |
| 2 | 23.7 | 25.3 | 21.2 | 22.8 | 23.3 |
| 3 | 24.5 | 24.3 | 24.0 | 24.7 | 24.4 |
| 4 | 23.3 | 22.8 | 23.2 | 23.3 | 23.2 |
| 5 | 16.0 | 21.5 | 21.3 | 20.8 | 19.9 |
| Check | 19.5 | 19.0 | 19.8 | 19.8 | 19.5 |

| 0.4-SO (Soil oxygenation) | | | | | |
|---|---|---|---|---|---|
| Spacing (m) | R1 | R2 | R3 | R4 | Mean |
| 2 | 24.3 | 24.0 | 24.0 | 23.3 | 24.0 |
| 3 | 26.3 | 25.3 | 25.3 | 22.0 | 25.0 |
| 4 | 24.0 | 24.3 | 23.2 | 22.3 | 23.4 |
| 5 | 23.2 | 22.5 | 22.8 | 23.3 | 23.1 |
| Check | 19.3 | 20.0 | 21.7 | 22.7 | 20.8 |

| Spacing (m) | 0.4m depth – WSO, t/acre | | | | | Spacing (m) | 0.4m depth – SO, t/acre | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | Mean | | R1 | R2 | R3 | R4 | Mean |
| 2 | 39.02 | 39.26 | 37.41 | 40.43 | 39.03 | 2 | 49.24 | 48.87 | 44.95 | 48.33 | 47.85 |
| 3 | 49.18 | 50.19 | 51.99 | 50.64 | 50.50 | 3 | 59.94 | 58.85 | 56.16 | 58.25 | 58.30 |
| 4 | 42.79 | 43.45 | 44.07 | 41.25 | 42.89 | 4 | 53.14 | 51.83 | 51.68 | 50.92 | 51.89 |
| 5 | 41.45 | 40.00 | 43.35 | 42.05 | 41.71 | 5 | 52.64 | 51.29 | 49.77 | 48.93 | 50.66 |
| check | 26.11 | 24.64 | 27.28 | 26.35 | 26.09 | check | 30.41 | 27.77 | 31.22 | 31.40 | 30.20 |

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 spacing. The results obtained in 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.

**Installation of Mole Drainage Systems (2017-18)**

The experiment was laid in Ag. College Farm, Bapatla fields, where there was chronic water logging problem due to Bheemuni drain flowing just adjacent and more over the land patch is at lowest elevation with respect to the surrounding fields. Hence, it is congested the seepage from drain and the neighboring paddy fields, due to which over a period of time, the land portion immediate adjacent to the Bheemuni Drain has become alkaline and rest is under water logging.

To study the performance of mole drains, the mole drains of 5 m spacing were installed and Maize crop was sown in an area of 2.0 acres at a spacing 60x20 cm spacing. As the crop was sown in late rabi, to study the performance of mole drains, rainfall events equivalent depth of water is given to the field and the mole drains are kept in open position. To facilitate the disposal of drainage water, a concept of drain water harvesting was introduced and a small farm pond to accommodate the drainage water was also created in the study area. Mole drainage systems were designed for Vertisols for maize crop and were installed at SWS fields, Bapatla. Highest plant height and yield of 291.3 cm and 3.86 t $ha^{-1}$of maize were observed with installation of mole drains at 5 m spacing (Table 2.40). The results obtained in one year study revealed that, the temporarily waterlogged soils can be reclaimed with low cost mole drainage systems.

Table 2.40 Plant height and yield of maize var NSL Sandhya NMH 666 variety

| Treatments | Plant height (cm) | Yield (t $ha^{-1}$) |
|---|---|---|
| T1- 5m spacing (Waterlogged soil) with Mole Drainage | 291.3 | 3.86 |
| T2- 5m Spacing (Alkali Waterlogged Soil) With Mole Drainage | 144.5 | 2.20 |
| T3- 5m Spacing (Alkali Waterlogged Soil) With Mole Drainage + Gypsum | 157.5 | 3.00 |
| T4-Check (Water logging) | 123.5 | 2.01 |
| T5-Check (Alkali + Water logging) | 79.75 | 1.24 |
| **Average** | 160.49 | 2.46 |

Plate 2.5 a Digging of Main drain for laying mole drains (The shallow water table resulted in seepage into the main drain). Preparation of pipe bends for mole drains

Plate 2.5 b Standing maize crop in Bapatla Mole drainage fields.

**Evaluation of Spacing and Controlled Subsurface Drainage System on Soil Properties, Water Table, Crop Yield and Nutrient Losses in Rice Fields of TBP Command (Gangavathi)**

A field experiment was laid out at ARS, Gangavathi in an additional area of 6 ha block adjacent to the existing SSD experiment (50 m spacing) initiated during 2012-13 by taking four additional treatments i.e., conventional and controlled SSD with 40 m and 60 m spacing each with a lateral depth of 1.0 m.

**Soil salinity:** The initial mean soil salinity (ECe) of the 40 m and 50 m and 60 m experimental area were 7.69, 9.55, 9.17 and 8.42 dS/m and 6.97, 8.09, 9.43 and 10.45 and 6.65, 8.27, 8.72 and 8.82 dS/m at 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm respectively. At crop harvest during Kharif-16, the soil salinity under 40 m spacing conventional SSD was reduced from 8.05 to 4.01 (0-15 cm), 9.94 to 4.14 (15-30 cm), 9.7 to 5.68 (30-60 cm) and 8.66 to 5.43 dS/m (60-90 cm) respectively. In case of controlled drainage system, the average soil salinity reduced from 7.33 to 2.64 (0-15 cm), 9.18 to 3.79 (15-30 cm), 8.63 to 8.22 (30-60cm) and 8.16 to 10.06 dS/m (60-90 cm) respectively. At crop harvest during Kharif-16, the soil salinity under 50 m spacing conventional SSD was reduced from 4.3 to 1.41 (0-15 cm), 5.1 to 1.97 (15-30 cm), 5.93 to 2.58 (30-60 cm) and 5.25 to 5.14 dS/m(60-90 cm) respectively. In case of controlled drainage system, the average soil salinity reduced from 6.28 to 3.93 (0-15 cm), 8.3 to 3.84 (15-30 cm), 12.01 to 5.59 (30-60 cm) and 13.85 to 6.54 dS/m (60-90 cm) respectively. At crop harvest during kharif 2016, the soil salinity under 60 m spacing conventional SSD was reduced from 7.69 to 3.96 (0-15cm), 10.25 to 5.83 (15-30 cm), 11.01 to 6.44 (30-60 cm) and 11.55 to 6.48 dS/m (60-90 cm) respectively. In case of controlled drainage system, the average soil salinity reduced from 5.99 to 5.71 (0-15 cm) and increased slightly from 6.29 to 7.24 (15-30 cm), 6.43 to 8.64 (30-60cm) and 6.10 to 7.9 dS/m (60-90 cm) respectively. Due to continuous flow in the conventional system removal of dissolved salts through drainage effluent could be faster and deeper than controlled drainage system. Higher soil salinity at lower depth in controlled system (Table 2.41) may also be attributed to their higher levels of salinity observed initially.

Table 2.41 Soil salinity (ECe, dS/m) at different soil depth (cm) as influenced by spacing of SSD and Controlled drainage systems

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

| Season | 50 m spacing | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Conventional drainage | | | | Controlled drainage | | | |
| | 0-15 | 15-30 | 30-60 | 60-90 | 0-15 | 15-30 | 30-60 | 60-90 |
| Initial | 4.30 | 5.10 | 5.93 | 5.25 | 6.28 | 8.30 | 12.01 | 13.85 |
| R/S-2013-14 | 7.79 | 7.79 | 8.03 | 7.95 | 3.72 | 6.22 | 8.33 | 10.91 |
| Kharif-14 | 2.50 | 1.97 | 3.70 | 5.32 | 1.86 | 4.52 | 6.94 | 6.62 |
| R/S-2014-15 | 2.20 | 2.03 | 3.73 | 4.42 | 4.14 | 5.26 | 8.64 | 9.01 |
| Kharif-15 | 2.56 | 3.36 | 3.06 | 2.91 | 4.87 | 7.63 | 9.28 | 6.86 |
| Kharif-2016 | 1.41 | 1.97 | 2.58 | 5.14 | 3.93 | 3.84 | 5.59 | 6.54 |

| Season | 60 m spacing | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Conventional drainage | | | | Controlled drainage | | | |
| | 0-15 | 15-30 | 30-60 | 60-90 | 0-15 | 15-30 | 30-60 | 60-90 |
| Initial | 7.69 | 10.25 | 11.01 | 11.55 | 5.99 | 6.29 | 6.43 | 6.10 |
| R/S-2013-14 | 7.80 | 8.33 | 7.76 | 8.93 | 6.58 | 7.24 | 6.53 | 6.67 |
| Kharif-14 | 6.83 | 7.20 | 7.46 | 7.31 | 5.47 | 6.02 | 7.12 | 7.46 |
| R/S-2014-15 | 5.62 | 7.67 | 8.35 | 9.47 | 4.39 | 5.78 | 5.27 | 5.68 |
| Kharif-15 | 6.51 | 8.15 | 9.33 | 10.03 | 5.34 | 6.48 | 6.93 | 6.75 |
| Kharif-2016 | 3.96 | 5.83 | 6.44 | 6.48 | 5.71 | 7.24 | 8.64 | 7.90 |

**Drainage discharge/drainage salinity/salt removal:** In conventional subsurface drainage system during Kharif-2017, the average drain discharge observed was 0.44, 1.27 and 0.61 mm/d for 40, 50 and 60 m spacing respectively (Table 2.42).

In case of controlled drainage system fitted with water table control PVC pipe set device, the average drain discharge observed was 0.16, 0.18 and 0.36 mm/d 40, 50 and 60 m spacing respectively. Thus, the drain discharge in conventional system at all the spacing was higher over the controlled system. Average of six seasons, drainage discharge under conventional and controlled SSD were 0.67 vs. 0.32, 2.05 vs. 0.50 and 1.0 vs. 0.67 mm/day respectively. Though the trend was similar, conventional had higher discharge than controlled SSD (Fig. 2.3).

Table 2.42 Drainage discharge as influenced by spacing of SSD and Controlled drainage systems

| | Conventional sub surface drainage (mm/day) | | | | | | | Controlled sub surface drainage (mm/day) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (m) | R/S-13-14 | K-14 | R/S-14-15 | K-15 | K-16 | K-17 | Avg | R/S-13-14 | K-14 | R/S 14-15 | K-15 | K-16 | K-17 | Avg |
| 40 | 0.40 (40) | 1.38 (34) | - | 0.58 (25) | 0.55 (21) | 0.44 (24) | 0.67 | 0.10 (40) | 0.93 (34) | - | 0.18 (25) | 0.25 (21) | 0.16 (24) | 0.32 |
| 50 | 2.4 (41) | 1.14 (34) | - | 2.61 (26) | 2.88 (23) | 1.27 (25) | 2.05 | 0.20 (41) | 0.72 (34) | - | 0.81 (26) | 0.62 (23) | 0.18 (25) | 0.50 |
| 60 | 1.85 (29) | 0.97 (34) | 0.81 (31) | 0.86 (19) | 0.93 (26) | 0.61 (24) | 1.00 | 1.25 (29) | 0.60 (34) | 0.72 (31) | 0.56 (19) | 0.51 (26) | 0.36 (24) | 0.67 |

***Note**: During R/S-14-15 and 2015-16, crop was not taken due to shortage of water at 40 and 50 m spacing. Values in parentheses indicate number of events.*

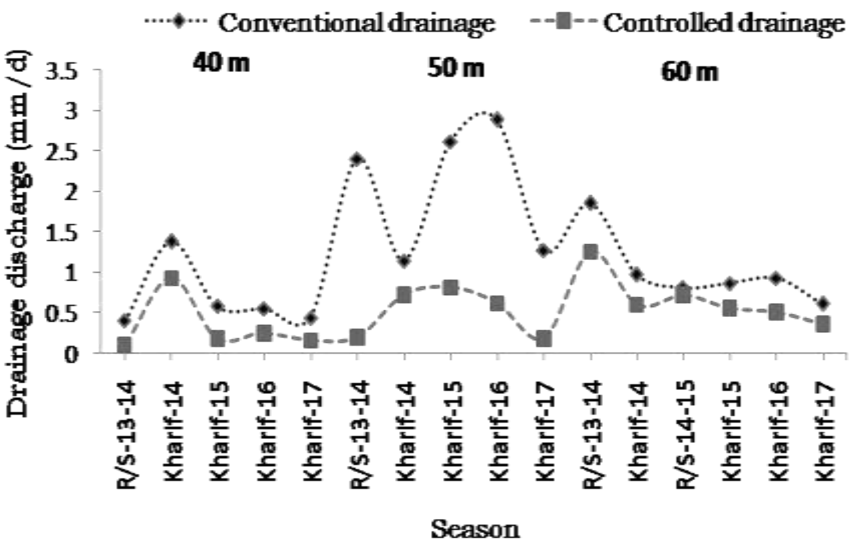



Fig. 2.3 Average drain discharge (drainage events) for conventional and controlled drainage system

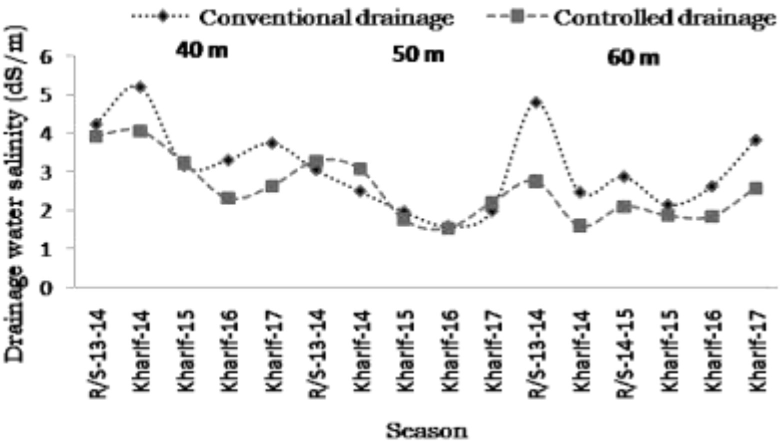



Fig. 2.4 Average drainage water salinity (drainage events) for conventional and controlled drainage system

In conventional system, the average salinity of the drainage effluent (Fig. 2.4) observed during Kharif-2017 was 3.70, 1.98 and 3.84 dS/m, as against 2.62, 2.19 and 2.57 dS/m for 40, 50 and 60 m spacing in controlled sub surface drainage system respectively. Average over six seasons, salinity of drainage effluent under conventional and controlled SSD were 3.93 vs. 3.23, 2.22 vs. 2.36 and 3.12 vs. 2.12 dS/m respectively. Irrespective of SSD, 40 m spacing had higher salinity of the drainage effluent than other spacing evaluated.

This means that in case of conventional system nearly 0.24, 0.38 and 0.34 t/ha of salts was removed (Fig. 2.5) through drainage effluent as against 0.065, 0.054 and 0.14 t/ha under controlled system over the sample period in 40, 50 and 60 m spacing respectively. Average over six seasons, the amount of salts removed under conventional and controlled SSD was 0.65 vs. 0.26, 1.03 vs. 0.40 and 0.73 vs. 0.27 t/ha respectively indicating that higher drainage discharge and salt removal in conventional system over the controlled system in all the three spacing evaluated.

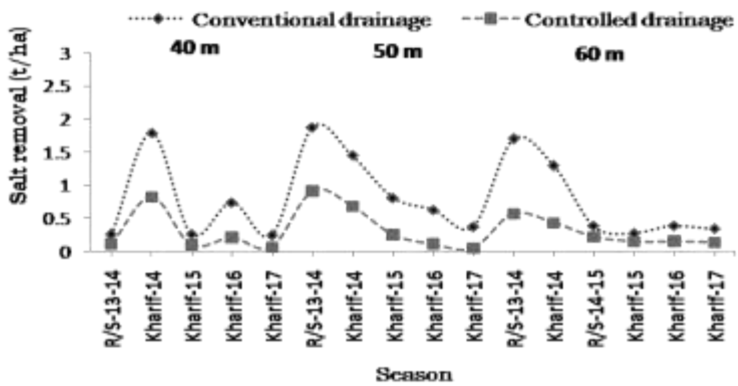



Fig. 2.5 Salt removal (drainage events) for conventional and controlled drainage system

**Nutrient loss through drainage system:** Loss of nitrogen over the sampling period in 40, 50 and 60 m spacing during Kharif-2017 was 1.36 vs. 0.42, 3.34 vs.0.45 and 1.24 vs. 0.73 kg/ha under conventional and controlled SSD systems respectively (Fig. 2.6). Average over six seasons, the loss of nitrogen was 1.87 vs. 0.63, 5.95 vs. 2.64 and 4.30 and 2.68 kg/ha under conventional and controlled

SSD at 40, 50 and 60 m spacing. Due to non-availability of canal water, no crop was taken during R/S 2015-16.

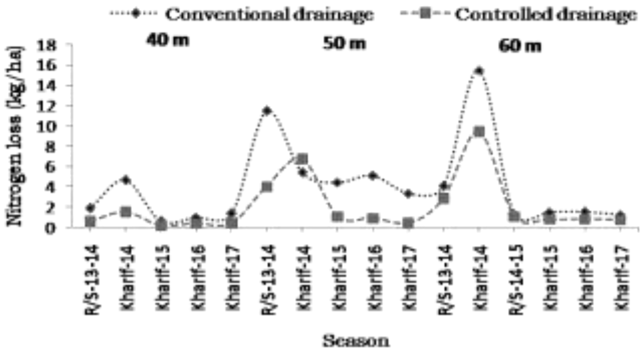



Fig. 2.6 Nitrogen loss (drainage events) for conventional and controlled drainage system

**Grain yield:** During Kharif-17 grain yields were 46.5 vs. 42.0 q/ha, 52.0 vs. 45.3 and 53.4 vs. 49.4 q/ha under conventional and controlled drainage systems at 40, 50 and 60 m SSD spacing respectively (Fig. 2.7). Irrespective of spacing, the average grain yields over six seasons were higher (39.3, 51.2 and 46.3 q/ha) under conventional compared to controlled SSD (37.3, 46.7 and 44.8 q/ha). Further, the higher grain yield levels in both conventional and controlled drainage system at 50 m spacing compared to 40 and 60 m spacing may be attributed to the reason that the 50 m drainage system was installed two years before to other 40 and 60 m spacing.

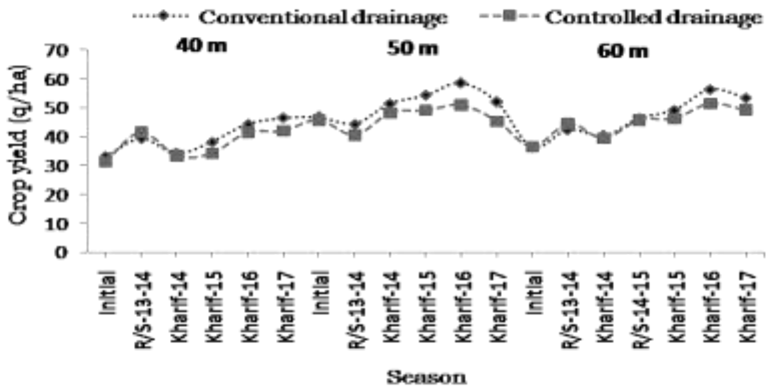



Fig.2.7 Crop yield for conventional and controlled drainage system

**Evaluation of Variable Lateral Out Let Head of Controlled Drainage System in Saline Vertisols of TBP Command (Gangavathi)**

An experiment was planned to study/ compare soil properties, water table and crop yield as influenced by variable depth of controlled drainage system; to assess discharge rate and quantify the nutrient losses through the different variable depth of controlled drainage system and to work out the economics of the controlled drainage system. Treatments were T-1 Controlled Drainage spacing of 50 m and upto root zone depth of paddy(control); T-2 Controlled Drainage spacing of 50 m and outlet depth of 0.3 m and T-3 Controlled Drainage spacing of 50 m and outlet depth of 0.6 m. A field experiment was conducted at Thimmapur village (Farmers field) in an area of 2 ha block by taking three treatments. A total of 17 soil samples from 2.0 ha area to a depth of 90 cm were collected in the field for characterization. Based on the analysis the ECe of experimental area varied from 4.04 to 23.41 dS/m with an average value of 13.48 dS/m, 4.76 to 26.07 dS/m with mean of 14.40 dS/m, 4.39 to 22.88 dS/m with a mean of 12.29 dS/m and 3.06 to 23.41 dS/m with a mean of 11.67 dS/m at 0-15 cm, 15-30 cm, 30-60cm and 60-90 cm respectively.

The experimental site was divided into eight blocks based on soil salinity so as to accommodate the treatments. As there was no water available for irrigation, the plot was left fallow during Kharif 2015 and 2016. During Kharif 2017, as per the suggestions of QRT, only the conventional SSD system was considered so as to attain faster reclamation. After the crop harvest, soil salinity declined in case of all blocks except Block III and IV (Table 2.43). The increase in salinity at few locations might be non-uniform leaching due to improper leveling of the plots. However, there was increase in pH of the soil. With leaching of soluble salts, soil might have developed tendency from salinity to sodicity. After successfully completion of reclamation leaching, variable outlet head concept will be considered.

Table 2.43 Average soil salinity ($EC_e$, dS/m) as influenced by variable lateral head system

| Depth (cm) | Block-I | | Block-II | | Block-III | | Block-IV | | Block-V | | Block-VI | | Block-VII | | Block-VIII | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | R/S-17-18 | Initial | R/S-17-18 | Initial | R/S-17-18 | Initial | R/S-17-18 | Initial | R/S-17-18 | Initial | R/S-17-18 | Initial | R/S-17-18 | Initial | R/S-17-18 |
| 0-15 | 9.43 | 7.5 | 16.2 | 11.1 | 7.54 | 9.19 | 12.0 | 13.8 | 11.0 | 8.4 | 10.7 | 7.06 | 9.17 | 9.15 | 11.2 | 10.5 |
| 15-30 | 13.9 | 13.4 | 18.3 | 16.0 | 10.42 | 10.6 | 12.3 | 13.6 | 13.8 | 8.86 | 14.6 | 10.8 | 12.3 | 10.9 | 16.1 | 14.8 |
| 30-60 | 11.46 | 12.7 | 12.2 | 14.3 | 14.67 | 16.3 | 10.0 | 9.15 | 12.4 | 6.54 | 13.8 | 10.0 | 11.0 | 11.0 | 16.0 | 16.2 |
| 60-90 | 10.4 | 8.78 | 9.4 | - | 12.0 | - | 7.27 | 5.72 | 9.40 | 8.33 | 14.8 | 13.9 | 8.63 | 10.7 | 13.5 | 12.6 |

**Evaluation of Mole Drains on Reclamation of Saline Vertisols in TBP Command (Gangavathi)**

This project work was initiated at A.R.S. Gangavati. Prior to paddy transplanting during Kharif-2016, soil samples were drawn again to a depth of 60 cm and mole drains were laid out. The soil pH varied from 7.91 (0-15 cm) to 8.1 (30-60 cm) and soil salinity was 3.33, 4.29 and 4.30 at 0-15, 15-30 and 30-60 cm respectively. During puddling operation (land preparation), mole drains appear to be collapsed after puddling operation by cage wheel, hence it was not possible to monitor the experiment. During Kharif-2017, instead of cage wheel, power tiller was used to facilitate shallow puddling operation which did not affect mole drain and paddy transplanting was taken up successfully. The average drain discharge during Kharif-2017observed was 0.39 mm/d, salinity of the drainage effluent was 0.70 dS/m and removal of salts of about 0.023 t/ha through drainage effluent. Loss of nitrogen over the sampling period during Kharif-2017 was 0.36 kg/ha. There was slight improvement in paddy grain yield (38.1 q/ha) to the extent of 8 to 10 per cent over previous years' yield. Soil samples drawn after crop harvest are being analyzed.

**Farmer's field (Thimmapur village):** The same project work was initiated at Thimmapur village in farmer's field. A total of 81 soil samples to a depth of 60 cm with 15 cm increment were collected using GPS during May-2017 and analyzed for soil pH and ECe. The initial soil pH of the experimental area was 7.73 at 0-15 cm and 7.78 at lower depths. The initial mean soil salinity (ECe) of the experimental area was 36.61, 22.70 and 11.64 dS/m at 0-15 cm, 15-30 cm and 30-60 cm respectively. The soil texture at 0 to 60 cm was found to be clay with clay content varying from 50 to 65 % in the study area. The experimental site was divided into three blocks based on the levels of soil salinity. The average soil pH and ECe of the block- I was 7.6, 7.7, 7.8 and 29.8, 15.6 and 8.42 dS/m at 0-15, 15-30 and 30-60 cm respectively. The average soil pH and ECe of the block- II was 8.1, 7.9, 7.8 and 36.0, 25.2 and 11.1 dS/m at 0-15, 15-30 and 30-60 cm respectively. Similarly, The average soil pH and ECe of the block- III was 7.5, 7.6, 7.8 and 44.1, 27.2 and 15.4 dS/m at 0-15, 15-30 and 30-60 cm respectively. Due to higher soil salinity levels in block-II and III, the spacing of mole drain followed was 3 m while it was 5 m in block-I. Cotton (Kaveri-Jadhu) was raised in polythene bags and transplanted on to the experimental plot on August 18, 2017 at 90 x 60 cm spacing. Though the crop was established, due to consistent rainfall, crop suffered due to waterlogging and yield was about 1.2 qt for whole block. The drainage water salinity was measured on volume basis over three times and it varied from 4.58 to 25.7 dS/m, 8.74 to 39.7 dS/m and 5.31 to 7.75 dS/m in block-I, II and III respectively.

**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.

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. 2.8). 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.

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 (27.4 %) was observed in surface drip with 1.2 ET at 0-15 cm depth at Z-direction (Vertical depth of soil) (Table 2.45). In case of 15-30, 30-45 and 45-60 cm depth of soil, the highest soil moisture content (34.5, 29.7 and 22.2 %) was observed in subsurface drip with 1.2 ET.

Table 2.45 Percentage of moisture stored in soil profile at different depths and distances from emitter in surface and subsurface drip irrigation system (Pooled data of four years)

| Distance from lateral (cm) | Depth (cm) | Treatments | | | | | |
|---|---|---|---|---|---|---|---|
| | | M1S1 | M1S2 | M1S3 | M2S1 | M2S2 | M2S3 |
| | | Verticle Z-direction (at the end of irrigation) | | | | | |
| | 0-15 | 24.5 | 26.4 | 27.4 | 22.6 | 24.0 | 25.4 |
| | 15-30 | 21.9 | 21.8 | 24.9 | 31.5 | 30.9 | 34.5 |
| | 30-45 | 17.3 | 18.0 | 21.0 | 25.4 | 27.7 | 29.7 |
| | 45-60 | 15.3 | 16.5 | 17.3 | 20.7 | 20.6 | 22.2 |
| 10 | | Lateral X-direction, perpendicular to drip lateral (at the end of irrigation) | | | | | |
| | 0-15 | 32.0 | 32.5 | 34.9 | 29.7 | 31.7 | 34.3 |
| | 15-30 | 28.7 | 28.3 | 31.5 | 35.7 | 36.6 | 37.8 |
| 20 | 0-15 | 26.2 | 27.9 | 30.4 | 26.4 | 27.7 | 30.0 |
| | 15-30 | 20.8 | 23.8 | 24.7 | 34.6 | 35.5 | 36.8 |
| 10 | | Lateral Y-direction, along drip lateral (at the end of irrigation) | | | | | |
| | 0-15 | 40.5 | 44.0 | 45.2 | 40.3 | 43.5 | 45.0 |
| | 15-30 | 36.1 | 38.1 | 40.2 | 44.0 | 47.1 | 49.3 |
| 20 | 0-15 | 38.8 | 41.8 | 44.0 | 41.4 | 43.3 | 43.5 |
| | 15-30 | 30.8 | 35.3 | 37.4 | 43.1 | 46.5 | 48.8 |

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 (34.3 and 37.8 %) 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 (30.4 and 30.0 %) was observed in surface drip at 1.2 ET and 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 (45.2 and 49.3 %) was observed in surface drip with 1.2 ET and 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 (44.0 and 48.8

%) was observed in surface drip with 1.2 ET and 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, the lower moisture was observed compared to perpendicular and along the 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 at 90 days after planting (DAP), 210 DAP and at harvesting time for different irrigation methods, significantly higher plant heights were recorded (156.4, 287.4 and 443.6.0 cm) in subsurface drip irrigation method compared to furrow irrigation and no significant difference was observed between irrigation level treatments in case of plant height at 210 and at harvesting stage. However, significant difference was observed between irrigation levels in case of 90 DAS. The interaction effect between the treatments was non-significant in all the three cases (90 DAP, 210 DAP and at harvest). 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 (1,27,000 and 1,24,000/ha) and 180 DAP (2,30,000 and 2,19,000/ha) respectively. The interaction effect between the treatments was non-significant. In case of cane height, significantly higher height was observed in subsurface drip method and 1.2 ET irrigation level among methods of irrigation and irrigation levels respectively. In case of internodes per cane, significantly higher nodes were recorded in subsurface drip method (21.6) compared to furrow method (18.4) and in case of irrigation levels, significantly higher internodes were observed in 1.2 ET compared to 0.8 ET treatment and no significant difference was observed in in interaction effect. Subsurface drip irrigation method registered significant higher cane girth (3.17 cm) as compared to furrow irrigation method in main treatment but no significant difference was observed in irrigation level treatments and significant difference was observed in the interaction effect.

**Yield attributes and Yield:** Significantly higher cane weight was recorded in subsurface drip (1495 g) compared to furrow irrigation (1248 g) among irrigation methods and significantly higher weight was recorded at 1.2 ET (1425 g) compared to 0.8 ET (1319 g) in irrigation levels. Among irrigation methods, significantly higher cane yield (131.0 t/ha) was recorded in subsurface drip followed by surface drip method (124.4 t/ha) and least in furrow irrigation (105.0 t/ha) method. Among irrigation levels, significantly higher yield (124.7 t/ha) was recorded at 1.2 ET irrigation level followed by 1.0 ET (121.0 t/ha) and least in case of 0.8 ET (114.7 t/ha). The interaction effect between irrigation methods and levels was found non-significant (Table 2.46).

Table 2.46 Sugarcane yield, sugar percentage and water use efficiency as influence by different irrigation methods and irrigation levels (Pooled data of four years)

| Treatments | | Single Cane weight (g) | Cane Yield (t/ha) | WUE (kg/ha/mm) | Brix (%) | SWUE (kg/m3) |
|---|---|---|---|---|---|---|
| Irrigation methods (IM) | Surface drip | 1368 | 124.4 | 78.6 | 20.28 | 1.59 |
| | Subsurface drip | 1495 | 131.0 | 83.0 | 20.8 | 1.72 |
| | Furrow | 1248 | 105.0 | 66.4 | 20.16 | 1.34 |
| | SE m +/- | 5.6 | 0.92 | 0.69 | 0.12 | 0.014 |
| | CD (0.05) | 21.97 | 3.62 | 2.7 | 0.47 | 0.055 |
| Irrigation levels (IL) | 0.8 ET | 1319 | 114.7 | 83.2 | 19.99 | 1.66 |
| | 1.0 ET | 1397 | 121.0 | 75.9 | 20.6 | 1.57 |
| | 1.2 ET | 1425 | 124.7 | 68.9 | 20.66 | 1.43 |
| | SE m +/- | 16.3 | 1.07 | 0.76 | 0.23 | 0.018 |
| | CD (0.05) | 50.2 | 3.29 | 2.3 | NS | 0.057 |
| Interaction (IM x IL) | SE m +/- | 28.23 | 1.85 | 1.31 | 0.39 | 0.032 |
| | CD (0.05) | NS | NS | NS | NS | NS |

**Water use efficiency, Brix percentage and Sugar water use efficiency**

Among irrigation methods, significantly higher water use efficiency (WUE) of 83.0 kg/ha/mm was recorded in subsurface drip irrigation followed by surface drip (78.6 kg/ha/mm) and least in furrow irrigation (66.4 kg/ha/mm) methods. Among irrigation levels, significantly higher WUE (83.2 kg/ha/mm) was recorded at 0.8 ET followed by 1.0 ET (75.9 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 2.46). Among irrigation method, significantly higher brix percentage was recorded in subsurface drip method and least in case of furrow irrigation method and the brix percentage did not affected by irrigation levels and interaction between irrigation methods was found non-significant. Normally the brix percentage was ranging 19 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 (1.72 kg/m3) followed by surface drip irrigation (1.59 kg/m3) and least in furrow irrigation (1.34 kg/m3) method. Among irrigation levels, significantly higher S-WUE was recorded at 0.8 ET (1.66 kg/m3) followed by 1.0 ET (1.57 kg/m3) and least in case of 1.2 ET (1.43 kg/m3) irrigation level.

**Economic analysis:** The sugarcane economic analysis was done for four years (2014-15 to 2017-18) and is presented in Table 2.47.

Table 2.47  Economic analysis of Sugarcane for four years (2014-15 to 2017-18)

| Year | Main Treatments | Sub treatments | Yield (t/ha) | CoC (Rs/ ha) | GR (Rs/ha) | NR (Rs/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|
| 2014-15 | Surface drip | 0.8 ET | 120.2 | 289000 | 323204 | 34204 | 1.12 |
| | | 1.0 ET | 123.2 | 289500 | 331274 | 41774 | 1.14 |
| | | 1.2 ET | 130.0 | 290000 | 349700 | 59700 | 1.21 |
| | Subsurface drip | 0.8 ET | 126.6 | 304050 | 340446 | 36396 | 1.12 |
| | | 1.0 ET | 133.2 | 304550 | 358200 | 53650 | 1.18 |
| | | 1.2 ET | 134.6 | 305050 | 362020 | 56970 | 1.19 |
| | Furrow irrigation | 0.8 ET | 100.2 | 175500 | 269619 | 94119 | 1.54 |
| | | 1.0 ET | 108.5 | 176000 | 291946 | 115946 | 1.66 |
| | | 1.2 ET | 115.8 | 176500 | 311368 | 134868 | 1.76 |
| 2015-16 | Surface drip | 0.8 ET | 123.4 | 174348 | 332027 | 157679 | 1.90 |
| | | 1.0 ET | 131.8 | 174848 | 354596 | 179748 | 2.03 |
| | | 1.2 ET | 140.7 | 175348 | 378402 | 203055 | 2.16 |
| | Subsurface drip | 0.8 ET | 134.4 | 175132 | 361590 | 186458 | 2.06 |
| | | 1.0 ET | 144.8 | 175632 | 389431 | 213800 | 2.22 |
| | | 1.2 ET | 146.9 | 176123 | 395161 | 219039 | 2.24 |
| | Furrow irrigation | 0.8 ET | 101.5 | 161500 | 272954 | 111454 | 1.69 |
| | | 1.0 ET | 111.7 | 162000 | 300392 | 138392 | 1.85 |
| | | 1.2 ET | 114.1 | 162000 | 307037 | 145037 | 1.90 |
| 2016-17 | Surface drip | 0.8 ET | 114.9 | 174348 | 309027 | 134680 | 1.77 |
| | | 1.0 ET | 125.8 | 174848 | 338429 | 163581 | 1.94 |
| | | 1.2 ET | 129.3 | 175348 | 347844 | 172496 | 1.98 |
| | Subsurface drip | 0.8 ET | 126.9 | 175123 | 341442 | 166319 | 1.95 |
| | | 1.0 ET | 130.3 | 175623 | 350453 | 174831 | 2.00 |
| | | 1.2 ET | 131.9 | 176123 | 354865 | 178742 | 2.01 |
| | Furrow irrigation | 0.8 ET | 98.0 | 161500 | 263701 | 102201 | 1.63 |
| | | 1.0 ET | 105.1 | 162000 | 282773 | 120773 | 1.75 |
| | | 1.2 ET | 106.4 | 162500 | 286297 | 123797 | 1.76 |
| | | 1.2 ET | 123.5 | 176123 | 332215 | 156093 | 1.89 |
| | Furrow irrigation | 0.8 ET | 97.0 | 161500 | 260930 | 99430 | 1.62 |
| | | 1.0 ET | 99.0 | 162000 | 266310 | 104310 | 1.64 |
| | | 1.2 ET | 102.6 | 162500 | 275913 | 113413 | 1.70 |

| | | Sub treatments | Yield (t/ha) | CoC (Rs/ ha) | GR (Rs/ha) | NR (Rs/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|
| 2017-18 | Surface drip | 0.8 ET | 115.3 | 174348 | 310238 | 135890 | 1.78 |
| | | 1.0 ET | 117.4 | 174848 | 315914 | 141066 | 1.81 |
| | | 1.2 ET | 120.8 | 175348 | 325033 | 149685 | 1.85 |
| | Subsurface drip | 0.8 ET | 118.0 | 175123 | 317420 | 142298 | 1.81 |
| | | 1.0 ET | 121.3 | 175623 | 326378 | 150755 | 1.86 |

Note: CoC = Cost of Cultivation, GR and NR = Gross returns and Net returns.

During first year of experiment (2014-15) higher net returns (Rs. 134868) and benefit cast ratio (1.76) was recorded in furrow irrigated with 1.2 ET irrigation level and in case of subsurface drip irrigation with 1.2 ET irrigation level the net returns (Rs. 56970) and benefit cost ratio (1.19) was lower. This was mainly because of initial higher investment cost for drip irrigation unit. However, during 2015-16, 2016-17 and 2017-18 onwards the higher net returns and benefit cost ratio was recorded higher in case of subsurface drip irrigation with 1.2 ET irrigation level in all these three years. This is due to nil investment cost during these three years except some maintenance cost for drip irrigation unit. This experiment is concluded.

**Influence of Saline Water and different Micro-Irrigation Techniques on Soil Properties, Yield and Water Use Efficiency of Tomato *(Solanum Lycopersicum)* & Simulation Modeling (HYDRUS) in Tungabhadra Command Area (Gangavathi)**

Tomato *(Solanum Lycopersicum)*, native of Peru-Ecuador-Bolivian area of South-America. It is most widely grown vegetable crop in the world as well as in India. It is one of the most popular and widely grown vegetable in the world ranking second in importance. During the last few years, irrigated tomato has been expanding rapidly in the semi-arid part of Karnataka around shallow to deep wells having a salinity of more than 2 dS/m with normal irrigation methods. It is very much essential to know the salt and water dynamics (Moisture and salt distribution pattern) whenever we use saline water for irrigation purpose especially in vadose zone under micro-irrigation technique. In order to efficiently use and manage micro-irrigation systems, several models (analytical and empirical) have been developed to simulate water flow from an emitting source (a point or line source) in the soil. One of the most complete packages for simulating water, heat, and solute transport in both two and three-dimensional, variably saturated, porous media is the HYDRUS software package. The HYDRUS model enables its users to trace the movement of water and solutes and the wetting patterns in both simple and complex geometries for homogeneous or heterogeneous soils. From this we can simulate water flow and solute transport for a micro-irrigation system. Hence a study was initiated to study the "Influence of saline water and different micro-irrigation techniques on soil properties, yield and water use efficiency of tomato (*Solanum lycopersicum*) & simulation modeling (HYDRUS) in Tungabhadra Command area during late Rabi -2018 at Agricultural Research Station, Gangavathi. The experiment consisted of irrigation methods as main treatments (surface drip irrigation, subsurface drip irrigation and furrow irrigation (control) and quality of irrigation water as sub-treatments (BAW, ECiw-2 dS/m, 3 dS/m, 4 dS/m and 5 dS/m. Also it is proposed to work out economic feasibility of different irrigation techniques under saline water.

The experiment was laid out in three replications with main treatments (Irrigation methods) such as furrow irrigation as control (M0), surface drip (M1), subsurface drip (M2) and sub treatments such as normal water i.e. canal water (S0), ECiw (Electric conductivity of irrigation water)-2 dS $m^{-1}$ (S1), ECiw-3 dS $m^{-1}$(S2), ECiw-4 dS $m^{-1}$(S3) and ECiw-5 dS $m^{-1}$(S4) of saline water treatments.

The tomato variety viz, Lakshmi F1 Hybrid (Nunhems Bayer Seeds Pvt.Ltd) transplanted during January-2018 in single row system (1.2 x 0.4 m). The 16 mm inline pressure compensated (PC) anti siphon drippers (dripnet) with emitter spacing of 0.4 m and discharge 2.0 LPH were selected and installed. For subsurface drip treatment, the inline lateral was buried in soil at a depth of 0.20 m facing emitters upward and collecting sub mains for flushing of laterals were given with vacuum breakers. Soil samples were collected before sowing for physico-chemical properties. Soil samples were collected at regular interval by Time-domine reflectometer (TDR) for soil moisture analysis. The soil moisture data was collected at different depths and at different distance from the later to know the moisture movement and distribution pattern. Soil samples were collected at 'Z' vertical direction to lateral i.e at emitter location (5, 20 and 40 cm depth), 'Y' along the lateral direction (20 cm apart at 5, 20 and 40 cm depth) and 'X' perpendicular to lateral direction (20 cm apart at 5, 20 and 40 cm depth). The experimental setup, irrigation and water quality analysis were explained as below.

- Experimental setup: Consists of all accessories of drip irrigation viz., pump, filters (primary and secondary), fertigation unit (venturi), mainline, sub main, lateral, inline dripper for surface and subsurface drip (emitter to emitter-0.4m and discharge-2 lph).
- 2000 litres water tanks were installed for preparation of five different EC levels of irrigation i.e. Normal, 2, 3, 4 and 5 dS/m respectively. Irrigation: was applied only when soil metric potential at 0.2 m depth (measure with vacuum tensiometer, Irrometers) up to close -30 kPa soil moisture tension (SMT), except at seedling and establishment stage. Quantity of irrigation will be applied at 100% ET level.
- Water quality: pH, EC, SAR and RSC of irrigation water at every time after the filling up of the five tanks are being collected.

**Development of Profitable Integrated Farming System (IFS) Module for Saline Vertisols of Thunga Bhadra 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 monocropping 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. Treatment details are provided below.

| | | |
|---|---|---|
| Components | | |
| 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) | - | |
| 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 and paddy grown in cropping components. The yield data indicated that totally 555 kg of grain yield of finger millet and 600 kg of grain yield paddy was obtained. Paddy grain yield was very low yield due to low crop stand because of high soil salinity in that area. However, in vegetable components brinjal, tomato and beet root were sown but we could able to harvest only 19 kg brinzal, 142 kg tomato and 10 kg beet root due to high salinity. In Horticulture component, though pomegranate fruit bearing was satisfactory, harvesting was poor due to monkey menace. Five hundred fingerlings were released to the pond but here also we could not harvest the fish due to water shortage. Under Vermicomposting, about only 200 kg of vermicompost was harvested during the year. Economics of all the components of IFS was worked out and compared with conventional farming system of rice-rice monoculture. It was observed that in IFS components gross and net returns (Rs.28,356 and Rs.10,396, respectively) was lower as compared to conventional farming system (Rs. 70,000 and Rs. 20,150, respectively). Whereas, average B:C ratio (1.39) of all components in IFS was similar to the conventional farming system (1.40). The lower net return in IFS components was mainly due to low yield in vegetable components and no yield in Horticulture and fish components (Table 2.48).

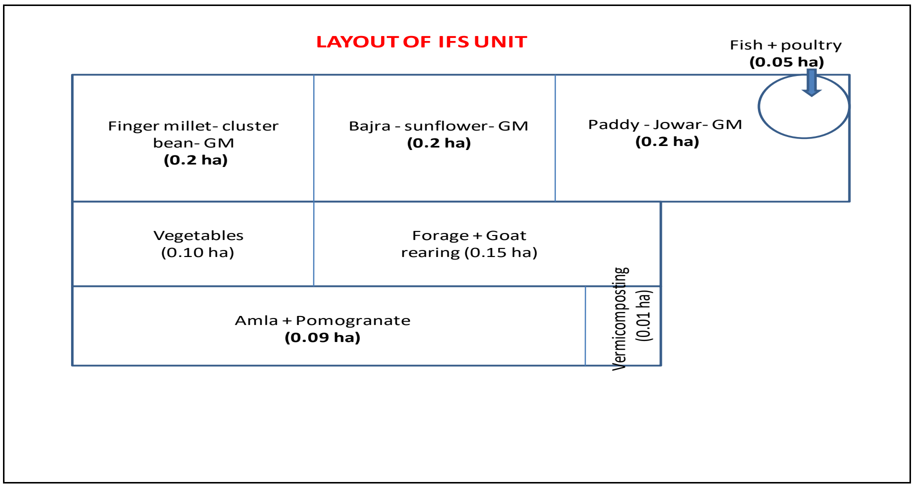



Plate 2.6 Layout of IFS Unit

Table 2.48 Yield and economics of different components of IFS under saline soils during 2017-18

| Components | Area (ha) | 2017-18 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Yield (kg) | | | COC | GR | NR | B:C |
| | | K | R | S | | | | |
| Rice - Jowar-GM | 0.20 | 600 | - | - | 6960 | 9600 | 2640 | 1.37 |
| FM – SF- GM | 0.20 | 155 | - | - | 3500 | 4650 | 1150 | 1.32 |
| FM- CB-GM | 0.20 | 400 | - | - | 5500 | 12000 | 6500 | 2.18 |
| Dairy + fodder | 0.15 | - | - | - | - | - | - | - |
| Fish pond | 0.05 | - | - | - | - | - | - | - |
| Poultry | - | Yet to be implemented | | | | | | |
| Vegetables | 0.10 | 19 | 142 | 10 | 1000 | 906 | -94 | 0.90 |
| Horticulture | 0.09 | - | - | - | - | - | - | - |
| Vermicompost | 0.01 | - | - | 200 | 1000 | 1200 | 200 | 1.20 |
| | | | | | 19960 | 28356 | 10396 | 1.39 |
| Comparison | | | | | | | | |
| Rice-rice -fallow | 1.00 | 4375 | - | - | 49850 | 70000 | 20150 | 1.40 |

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.

**Evaluation of Performance of Sweet Sorghum Varieties/Hybrids for Bio-Ethanol Production under Saline Soils of TBP Command Area of Karnataka (Gangavathi)**

This experiment was initiated during Rabi-2017 on a saline vertisols (ECe 8-10 dS/m) at Agricultural Research Station, Gangvathi. The treatments consisted of fourteen (14) sweet sorghum genotypes procured from IIMR, Hyderabad and sown in November 2017 in RCBD design with three replications each. The results indicated that, among the fourteen (14) genotypes plant height and no. of internodes per plant was significantly higher with SPV-2023 (163.1 cm and 7.8 respectively) as compared to other genotypes but was on par with SPV-2025, RSSV-138-1, SSV-74, SSV-84, CSV-19SS and CSV-24SS. Whereas, brix reading was significantly superior with SPV-2325 (14.33) as compared to other genotypes, but was on par with SPV-2024, SPV-2023, RSSV-138-1, SSV-74, SSV-84, CSV-19SS and CSV-24SS.

**Yield Maximization through Permanent Bed Planting (PBP) with different Furrow Irrigation Modes in Cotton under Saline Vertisols of TBP Command Area of Karnataka (Gangavathi)**

In Tungabhadra project command area, the cotton is grown in an area of 19,735 ha with a production of 69,080 tons and productivity of 2500 kg seed cotton per hectare (Anon. 2012a). The area under cotton is increasing over the years, mainly due to water scarcity for rice cultivation. At the same time cotton productivity is decreasing over the year due to soil degradation. However, soil salinity and the shallow water table are twin problems of the command areas are adversely affecting cotton production. The farmers in the command area are cultivating cotton by dibbling cotton seeds in the flat land. Recent research findings demonstrated that conservation agriculture (CA) practices, i.e., reduced tillage, residue retention and appropriate rotation, can influence the location and accumulation of salts by reducing evaporation and upward salt transport in the soil. Among the CA practices, raised bed planting is gaining importance for row-spaced crops in many parts of the world. Raised beds with residue retention are reportedly saving 25–30% irrigation water, increasing water use efficiency and providing better opportunities to leach salts from the furrows However, under saline conditions, increased salt accumulation on top of the beds has been reported due to the upward movement of salts through capillary rise in response to evaporation gradients. Similarly, when irrigation water is applied to the furrows on every side of the bed, it allows salts to leach down from the furrows. But the evaporation of water during the drying periods results in salt accumulation on the tops and side slopes of the raised beds. Such salt movement to the centre of the bed may damage (young) plants seeded there. With the permanent skip furrow irrigation (PSFI) method, salts are ‘pushed’ across the bed from the irrigated side of the furrow, where plants are located, to the dry side without plants. This management of root zone salinity through raised beds and irrigation could improve emergence, stand establishment and finally crop yields in saline fields. Also surface mulching with crop residue has been identified as a promising management option to combat soil salinity, as it can decrease soil water evaporation, increase infiltration and regulate soil water and salt movement. Since, such information i.e., raised bed planting with mulching and permanent skip irrigation method for cotton is meager or lacking for saline vertisols of TBP command, this experiment is proposed with following objectives such as i) effects of different methods of planting and modes of irrigation on soil moisture content and soil salinity; ii) Growth and yield of cotton under different methods of planting and modes of irrigation and iii) Economics of cotton production.

**Experimental Details:** Analysis of both surface and subsurface soil samples of the experimental site revealed that the soil was alkaline in pH (8.32 and 8.48) and saline (6.45 and 7.82 dS m-1) at the time of sampling respectively. Surface soil organic carbon content was low whereas available NPK were low, medium and high respectively. In surface soil micronutrients (Zn, Fe, Mn and Cu) contents were in medium category. The experiment was laid out in a split plot design with nine treatments and three replications each (plot size of 9 x 6.3 m). The main-plot consisted of method of planting viz., $M_1$: PRB with mulch, $M_2$: PRB without mulch and $M_3$: Farmers’ practice and sub-plot consisted of modes of irrigation viz., $I_1$: Every furrow irrigation (EFI), $I_2$: Alternate skip furrow irrigation (ASFI) and $I_3$: Permanent skip furrow irrigation (PSFI). For mulch treatment paddy straw was applied as surface mulch @ 6.85 t/ha to a thickness 1.25 cm. The land was ploughed once with mould board plough and then harrowed twice to bring the soil to fine tilth. The permanent raised beds of 60 cm wide at the top and 15 cm height were prepared using tractor drawn bed maker prior to sowing. The Bt cotton hybrid (KCH-14-K59) having duration of 175-180 days was sown by hand dibbling on 23rd July

2017 with a spacing of 0.90 x 0.60 m on the middle of each raised bed and gap filling was done 7 days after sowing and one plant per hill was retained after thinning at 15 DAS. Recommended dose of NPK (180:90:90 kg ha-1) was applied to all the treatments. Fifty per cent of recommended dose of N and K and entire dose of P was applied in the form of urea, muriate of potash (MOP) and diammonium phosphate (DAP), respectively at 4 to 5 cm deep and 5 cm away from the plants as basal dose and the remaining half of N and K was applied in two splits at 30 and 60 days after sowing (DAS). The crop was irrigated with canal water irrigation as per the treatments based on 1.2 ET (evapotranspiration) at an interval of 14-16 days and in total 4 irrigations were given. During the 4th irrigation, to study salt leaching efficiency irrigation was given in all the furrows irrespective of different modes of irrigation i.e., EFI, ASFI and PSFI. The plant protection measures were taken for all the treatments as and when required.

**Results**

**Soil moisture**: Among main plots, $M_3$ had significantly higher soil moisture in 0-15 cm i.e., 8.8 to 17.7, 8.6 to 16.4 and 8.4 to 15.9 per cent higher over $M_1$ and $M_2$ at after $1^{st}$, $2^{nd}$ and $3^{rd}$ irrigation. Among sub plots, $I_1$ had 12.9 to 24.4, 8.8 to 17.7, 8.6 to 16.4 and 8.4 to 15.9 per cent higher surface soil moisture content over $I_2$ and $I_3$ at after $1^{st}$, $2^{nd}$, $3^{rd}$ and $4^{th}$ irrigations respectively. The interaction effects due to main and sub-plot treatments showed generally $M_1I_1$ having significantly higher soil moisture content over rest of the treatments except farmers' practice at after $1^{st}$, $2^{nd}$, $3^{rd}$ and $4^{th}$ irrigations. Similar trends were observed in case of subsurface soils (15-30 cm).

**Soil Salinity**: Among main plots, $M_1$ had soil ECe in 0-15 cm i.e., 12.3 to 7.3, 8.1 to 13.4, 15.9 to 19.9 and 11.3 to 19.2 per cent lower than $M_2$ and $M_3$ at before $1^{st}$, $2^{nd}$, $3^{rd}$ and $4^{th}$ irrigations, respectively. Among subplots, $I_3$ had 17.4 to 11.7, 16.4 to 8.2, and 20.1 to 10.0 per cent lower soil ECe than $I_1$ and $I_2$ at before $2^{nd}$, $3^{rd}$ and $4^{th}$ irrigations respectively. The interaction effects due to main and sub-plot treatments revealed that except before 1st irrigation, generally $M_1I_3$ had significantly lower soil ECe over rest of the treatments. Similar trends were observed in case of subsurface soils (15-30 cm).

**Plant height**: Irrespective of main and subplot treatments, plant height increases temporally across different physiological stages of crop viz., 60, 90 DAS and harvest. Among main-plot treatments, $M_1$ (144.2 cm) recorded significantly higher plant height compared to $M_2$ (131.4 cm) and $M_3$ (129.7 cm) at harvest respectively (Table 2.49). Among sub-plot, significantly higher plant height was recorded in $I_3$ (138.8 cm) compared to $I_2$ (136.4 cm) and $I_1$ (130.2) at harvest, respectively. There were no significant differences due to interaction effect of main and sub-plot treatments at all stages of crop growth.

**No. of bolls per plant:** Number of bolls per plant increased temporally across the growth stages irrespective of main and sub-plot treatment. The treatment M1 recorded significantly higher number of bolls per plant (29.1) compared to $M_2$ (27.5) and $M_3$ (24.2) at harvest respectively. Among sub-plots, number of bolls per plant also varied significantly. At harvest, I3 recorded significantly higher number of bolls per plant (27.9) compared to 25.9 ($I_1$) and 27.0 ($I_2$) bolls per plant respectively. Number of bolls per plant was significantly higher in $M_1I_3$ (30.8) compared to other treatments at harvest respectively.

Table 2.49 Plant height, number of bolls plant$^{-1}$, boll weight (g), seed cotton yield (kg ha$^{-1}$) and B:C ratio as influenced by different treatments

| Treatments | Plant ht (cm) | Bolls/plant | Mean boll weight (g) | Seed cotton yield (kg/ha) | B:C ratio |
|---|---|---|---|---|---|
| Main-plot | | | | | |
| $M_1$: PRB+Mulch | 144.2 | 29.1 | 4.95 | 2685 | 2.76 |
| $M_2$: PRB+ No-mulch | 131.4 | 27.5 | 4.37 | 2495 | 2.42 |
| $M_3$:Farmers' practice | 129.7 | 24.2 | 4.14 | 2280 | 2.04 |
| S.Em± | 1.28 | 0.41 | 0.12 | 33.2 | 0.04 |
| CD @ 5% | 5.04 | 1.62 | 0.48 | 130.5 | 0.17 |
| Sub-plot | | | | | |
| $I_1$ : EFI | 130.2 | 25.9 | 4.15 | 2396 | 2.32 |
| $I_2$ : ASFI | 136.4 | 27.0 | 4.46 | 2485 | 2.41 |
| $I_3$ : PSFI | 138.8 | 27.9 | 4.84 | 2580 | 2.50 |
| S.Em± | 1.87 | 0.25 | 0.10 | 27.99 | 0.04 |
| CD @ 5% | 5.76 | 0.77 | 0.30 | 86.3 | 0.12 |
| Interaction (M x S) | | | | | |
| $M_1I_1$ | 136.5 | 27.6 | 4.40 | 2595 | 2.67 |
| $M_1I_2$ | 146.8 | 29.0 | 4.95 | 2719 | 2.80 |
| $M_1I_3$ | 149.2 | 30.8 | 5.50 | 2741 | 2.82 |
| $M_2I_1$ | 127.3 | 26.3 | 4.42 | 2388 | 2.32 |
| $M_2I_2$ | 131.0 | 28.2 | 4.29 | 2408 | 2.34 |
| $M_2I_3$ | 136.0 | 27.9 | 4.40 | 2690 | 2.61 |
| $M_3I_1$ | 126.7 | 23.8 | 3.62 | 2204 | 1.97 |
| $M_3I_1$ | 131.3 | 23.8 | 4.15 | 2328 | 2.09 |
| $M_3I_1$ | 131.1 | 24.9 | 4.63 | 2308 | 2.07 |
| S.Em± | 3.24 | 0.44 | 0.17 | 48.5 | 0.07 |
| CD @ 5% | NS | 1.34 | 0.52 | NS | NS |

**Mean boll weight:** At harvest, $M_1$ (4.95 g) had significantly higher mean boll weight per plant compared to $M_2$ (4.37 g) and $M_3$ (4.14 g) respectively. Among sub-plot, $I_3$ (4.84 g) had significantly higher mean boll weight compared to $I_1$ (4.15 g) and $I_2$ (4.46 g) respectively (Table 2.49). Similar to number of bolls per plant, significant differences were observed due to interaction effect between main and subplot wherein $M_1I_3$ (5.50 g) had significantly mean boll weight over other treatments respectively.

**Seed cotton yield per hectare:** The seed cotton yield per hectare varied significantly and $M_1$ (2685 kg ha$^{-1}$) recorded significantly higher seed cotton yield compared to $M_2$ (2495 kg ha$^{-1}$) and $M_3$ (2280 kg ha$^{-1}$) (Table 2.49). Significant difference in seed cotton yield per hectare was also observed among sub-plots. The treatment I3 (2580 kg ha$^{-1}$) had significantly higher seed cotton yield over I1 (2396 kg ha-1) and I2 (2485 kg ha$^{-1}$) respectively. There was no significant differences due to interaction effect between main and sub-plot and seed cotton yield varied from 2308 (farmers' practice) to 2741($M_1I_3$) kg ha$^{-1}$ respectively.

**B:C ratio:** The treatment $M_1$ (2.76) recorded significantly higher benefit: cost ratio compared to $M_2$ (2.42) and $M_3$ (2.04) and $I_3$ (2.50) compared to $I_1$ (2.32) and $I_2$ (2.41) respectively. There were no significant differences due to interaction effect and it varied from 1.97 (farmers' practice) to 2.82 ($M_1I_3$) respectively (Table 2.49). The results showed that simple techniques such as mulching and permanent skip furrow irrigation can increase benefit: cost ratio from 2.04 to 2.82 and it is appreciable.

**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. Later on land modification work was completed during peak summer. Experiment on integration of fish and crop/ vegetable cultivation are proposed in land modification model and will be undertaken soon. The crop/ vegetables will be grown on raised bunds. Soil samples were collected from 9 different locations on raised bund to know the fertility status. It is reported that pH of the soil varied from 7.87 to 8.13, having very high electrical conductivity (1:2; soil: water) ranged from 5.15 to 10.13, very low to organic carbon (0.08 - 0.13%) content and available phosphorus. However, it contains sufficient amount of available potassium. The soils of the site were deficient in all four micronutrients (Fe, Cu, Zn and Mn).

**Rain Water Storing in Ponds for Desalination of Coastal Saline Soils on Farmers field (Panvel)**

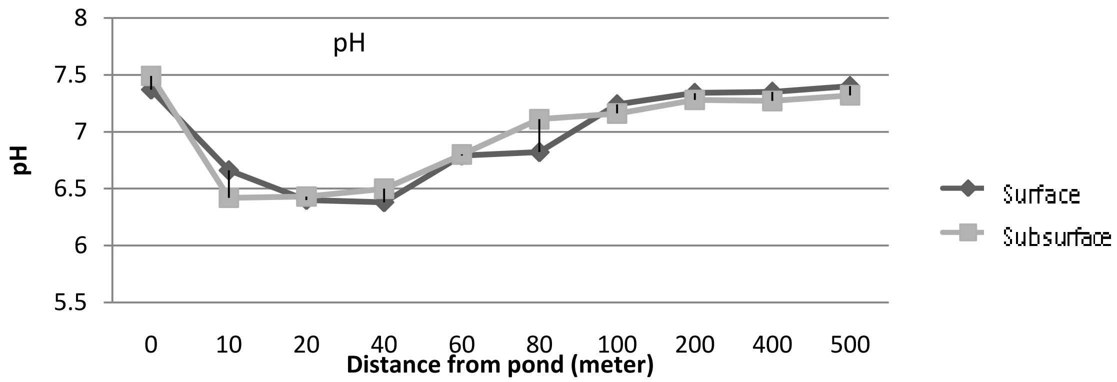
Two ponds having stored rain water from farmers field i) Shri. Roshan Vinayak Mhatre, from village Koproli and ii) Shri. Chintaman Mahadev Mhatre, from village Koproliare were selected. Soil samples from two depths 0-22.5 and 22.5-45 cm, at 0, 10, 20, 40, 60, 80, 100, 200, 400, and 500 m distance from 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. The samples were analyzed 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 2.10).
- **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 2.10).

**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 m 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 2.10).
- **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 m 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 2.10).
-



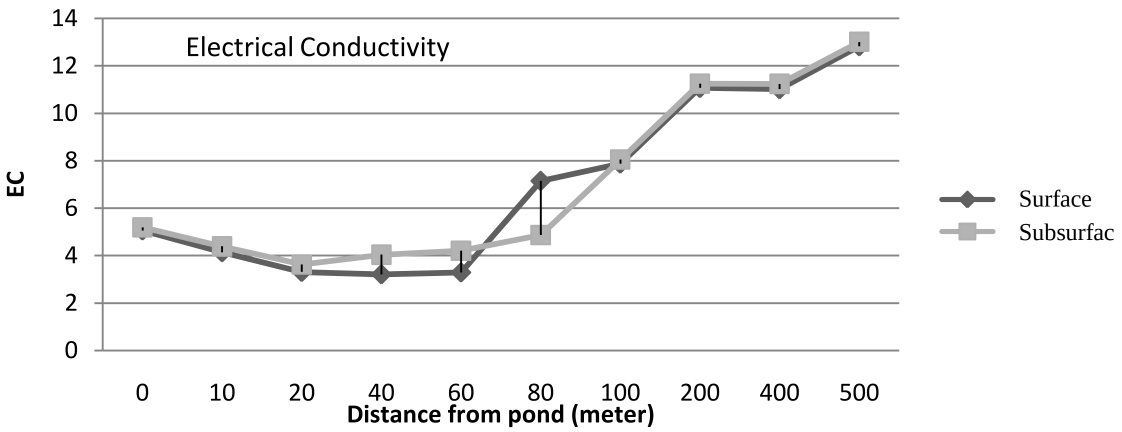
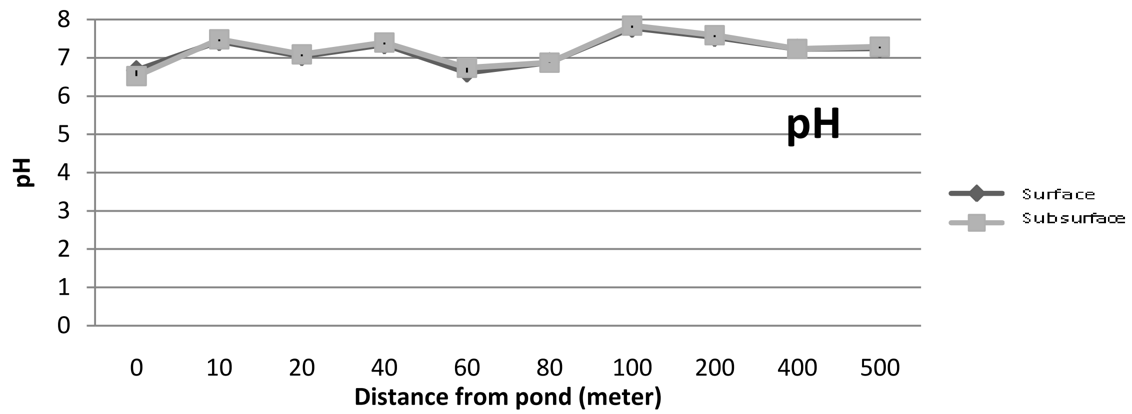




Fig 2.10 a Soil pH and EC of the farmers field (Farmer 1)



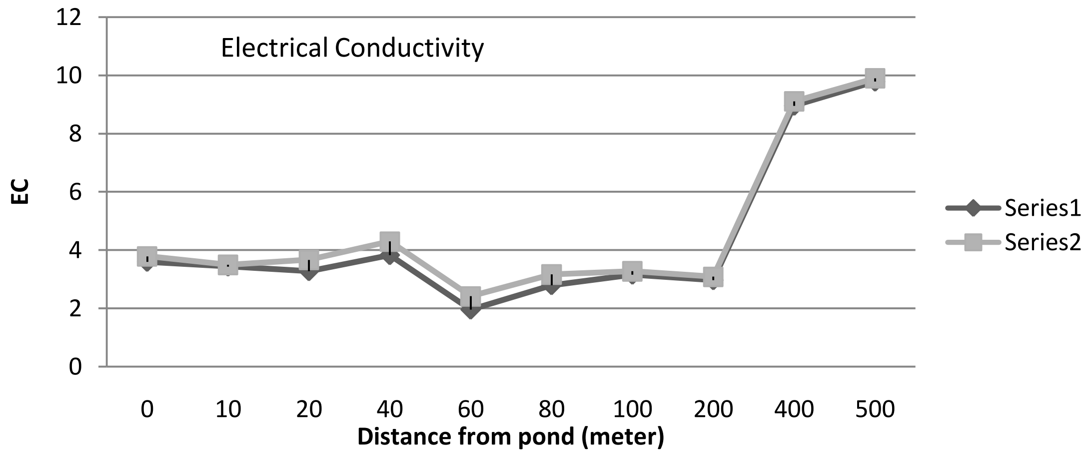




Fig 2.10 b pH and EC of the farmers field (Farmer 2)

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 m and maximum at 500 m. It may be attributed due to dilution and leaching of salts due to percolation of harvested rainwater from fish pond.

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

**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 $51^{st}$ 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. 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 $dSm^{-1}$).

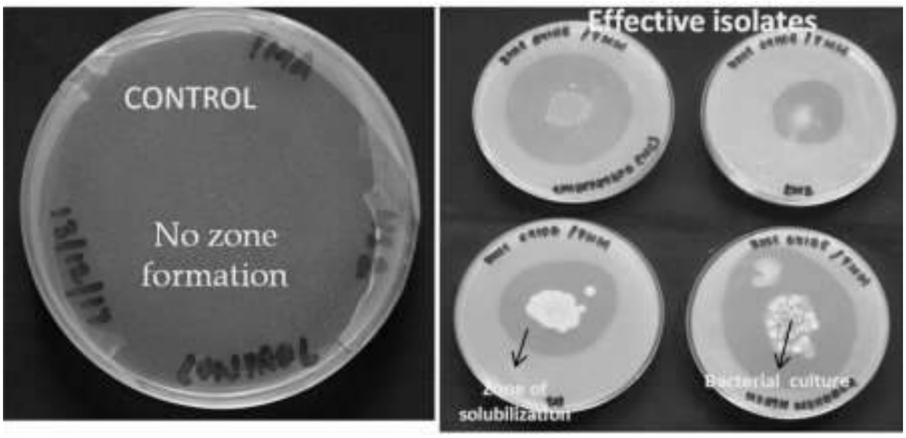



Plate 2.7 Zn solubilization by the salinity tolerant bacterial isolates

**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 2.50). Soil samples were also collected and analysed for the salinity status.

Table 2.50 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)**

**A. Integrated farming system for sustainable land use in Pokkali lands – vegetable cultivation (Vytilla)**

In this experiment was planned to study the effect of plastic mulch on reducing salinity in *Pokkali* lands and to find out best vegetable crop suitable for *Pokkali* lands during summer. To execute the experiment under field condition different activities such as site selection (i.e. bunds of *Pokkali* lands of Rice Research Station, Vyttila), levelling and laying out of the fields, preparation of ridges and furrows in the prepared fields, laying out drip irrigation, spreading of polythene mulches in the fields and agronomic practices as per Package of Practices of Kerala Agricultural University. The experimental details are provided in Table 2.51.

Table 2.51 Experimental details

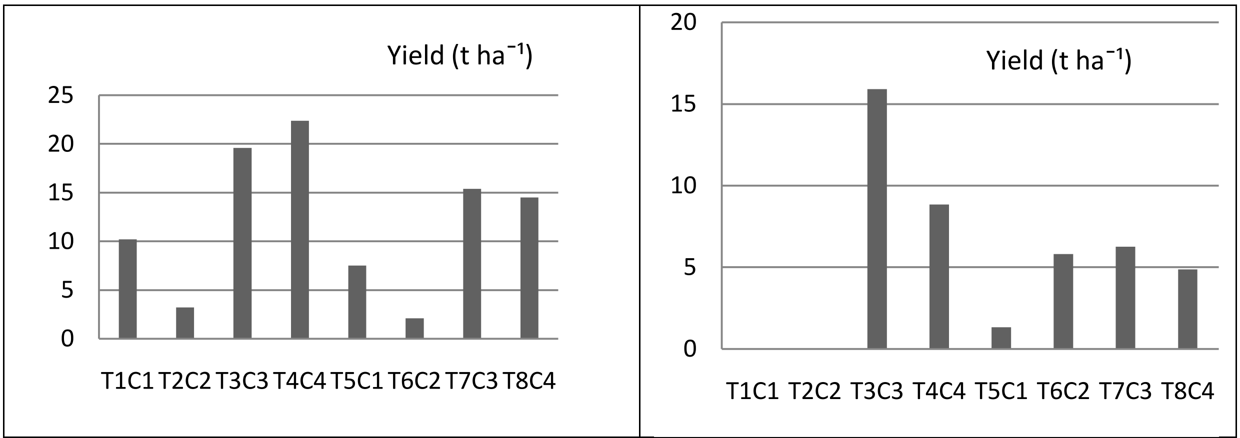
| Sl. No. | Treatments | Crops | Use of mulch | Other details |
|---|---|---|---|---|
| 1 | $T_1C_1$ | Cauliflower | With mulch (WM) | Number of treatments: 8 |
| 2 | $T_2C_2$ | Cabbage | | Design: RBD |
| 3 | $T_3C_3$ | Cowpea | | No. of replications: 3 |
| 4 | $T_4C_4$ | Bhendi | | Plot Size: 3m X 2m |
| 5 | $T_5C_1$ | Cauliflower | Without mulch (WOM) | Vegetables: Cauliflower, cabbage, cowpea and bhendi |
| 6 | $T_6C_2$ | Cabbage | | |
| 7 | $T_7C_3$ | Cowpea | | |
| 8 | $T_8C_4$ | Bhendi | | |

The fourth phase of the experiment was conducted in the research station. Vegetables such as cauliflower, cabbage, cowpea and bhendi were raised to study the adaptability of these vegetables in Pokkali lands. Planting and harvesting dates of crops are given below (Table 2.52).

Table 2.52 Planting and harvesting dates of crops

| Crops | RRS, Vyttila | |
|---|---|---|
| | 2016-2017 | 2017-2018 |
| Bhendi | 15.10.2016 to 3.02.2017 | 15.10.2017 to 3.02.2018 |
| Cowpea | 15.10.2016 to 3.02.2017 | 15.10.2017 to 3.02.2018 |
| Cabbage | 15.10.2016 to 3.02.2017 | 15.10.2017 to 3.02.2018 |
| Cauliflower | 15.10.2016 to 3.02.2017 | 15.10.2017 to 3.02.2018 |

The initial and final soil samples were collected for analyzing pH, EC, OC, available P, K, Na, Ca, Mg, S, B, Fe, Zn, Cu and Mn. As per the analysis data pH of the soil samples of RRS, Vyttila recorded an increase in 2016-2017 and the trend was higher in treatments with mulch as compared to without mulch in case of all the vegetables. But there was no such pattern observed in the year 2017-2018 and the soil pH was decreased from initial value. On observing the electrical conductivity of soil samples in all treatments, it was clear that treatments without mulch were having higher EC values in both years. The organic carbon per cent of the soil samples were very high after the harvest of vegetables in all treatments on comparing it with the initial soil status. On contrast to this, the available phosphorus content in soil was found to decrease in all the treatments with respect to initial soil nutrient status. Though the P content decreased in the treatment plots, available phosphorus content falls under the high category. Available K content was higher in treatment with mulch rather than treatment without mulch in 2016-2017. In the consecutive year, K content of the soil samples was found to be decrease in all the treatments with respect to initial soil nutrient status. The sodium content increased in all treatments compared to initial value in 2016-2017 but in the next year, lower sodium content was reported from all the treatments compared to initial soil status and treatment with mulch reported lower sodium content. Among the secondary nutrients, available calcium content decreased in all the treatments with respect to the initial value whereas, available magnesium content increased in 2016-2017 and a reduction from the initial nutrient status was noticed in the next year. An increment recorded in available sulphur content from the initial soil status. Analytical data revealed that the micronutrient status increased in all the treatments compared to the initial soil nutrient status in the year 2016-2017. But opposite trend was noticed in 2017-2018. Harvesting of crops was started during first week of January. Effect of mulch on the yields of vegetables is shown in Fig. 2.11.




| (a) | (b) |
|---|---|

Fig. 2.11 Yield of (a) vegetables during 2016-2017 and (b) during 2017-2018

The highest yield of crop was obtained in treatment $T_4C_4$, ie. Bhendi with mulch in 2016-2017 and in the next year highest yield was reported in $T_3C_3$, i.e. Cowpea with mulch followed by bhindi with mulch. The performance of bhendi and cowpea was very good compared to other vegetables like cauliflower and cabbage in both treatments with mulch and without mulch. Cauliflower was not able to produce flower bud because of the intense heat exposure in the field. Average maximum temperature was recorded as $33.2^0$C. In addition to this performance of cabbage was also affected resulting in lower yield. The yield data from each treatment plots revealed that higher yield were obtained from treatments with mulch rather than without mulch. On basis of results, it was observed that bhendi (Okra) and cowpea are performing well with provision of drip and mulch under *Pokkali* lands. However, performance of cauliflower and cabbage was not well mainly because unsuitable climatic conditions.

**B. Rice – prawn integration in *Pokkali* on farmer's field**

The basic purpose of this experiment was to evaluate the rice-fish/prawn integration in *Pokkali* lands for maximum productivity and to analyze the changes in soil properties. Site selected was *Pokkali* land at farmer's field, Kumbalangi, Ernakulam.

**Rice cultivation in Pokkali**: Water from *pokkali* field was drained out, field was ploughed and leveled and prepared for rice cultivation. Ridges and furrows were taken and germinated seeds were sown on ridges. Only panicles were harvesting manually on 25$^{th}$ Oct. 2016 and 20$^{th}$ Oct. 2017 in respective years. Straw was kept in the field itself. Harvested bundles of panicles were brought to the bund using a small boat by farmer

Plate 2.8 Land preparation and sowing

Plate 2.9 Harvesting and collection of harvested panicles using a small boat

Soil and water chemical properties for *Pokkali* rice field for both years are provided in Table 2.53.

Table 2.53 Chemical properties of water samples of Pokkali rice field, during different stages of Rice

| Crop stage | pH | | EC ($dSm^{-1}$) | |
|---|---|---|---|---|
| | Soil | Water | Soil | Water |
| | | (2016-17) | | |
| Transplanting | 7.69 | 7.34 | 2.6 | 8.2 |
| Dismantling | 7.3 | 7.10 | 2.6 | 5.3 |
| Tillering | 7.98 | 8.27 | 1.2 | 6.2 |
| Harvesting | 7.3 | 7.21 | 8.6 | 8.5 |
| | | (2017-18) | | |
| Transplanting | 6.77 | 7.24 | 4.31 | 2.9 |
| Dismantling | 6.50 | 7.48 | 2.5 | 2.1 |
| Tillering | 6.96 | 7.02 | 3.5 | 2.9 |
| Harvesting | 6.68 | 7.33 | 2.6 | 3.3 |

On analysis of the water samples, data revealed that in general pH of the samples from 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. Rise of EC and pH was linked with withdrawal of monsoon rains. However, reduction of EC and pH was observed in case of rain events.

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. The details regarding crop and prawn harvest is given below:

- Rice grain yield: 2.38 t $ha^{-1}$ in 2016-17 and 2.00 t $ha^{-1}$ in 2017-18
- Rice field preparation was stared for prawn cultivation during Jan. 2016 and Jan. 2017, respectively
- Tiger prawn seedlings was released during February
- Harvesting took place in the month of May
- Total yield of about 375 kg/ha of prawn were harvested in 2016-17 and 300 kg/ha in 2017-18

**Benefit-Cost Ratio of Rice prawn integration**

The traditional practice of rice prawn integration was indeed economical and eco friendly. Analysis of Benefit-Cost ratio is also approving the same. BC ratio details are in given In Table 2.54, 2.55 and 2.56.

Table 2.54 Cost of Cultivation of Rice/ha

| Sl No. | Components | Cost (Rs.) | |
|---|---|---|---|
| | | **2016-17** | **2017-18** |
| 1. | Seed | 6000 | 6500 |
| 2. | Land preparation, ploughing, ridges and furrow preparation | 15000 | 18000 |
| 3. | Weeding (8 women) | 3200 | 3500 |
| 4. | Transplanting (20 women) | 8000 | 9000 |
| 5. | Harvesting (17women + 4 men) | 16000 | 17000 |
| 6. | Threshing (3 women+ 3 men)- | 3200 | 4000 |
| | Drying ( 2 men+ 2 women) | 4000 | 4500 |
| | Total | 55400 | 62500 |

**Returns:**
Yield –2.38 t $ha^{-1}$ @Rs 60/ kg- = 142800/- (2016-17)
Yield -2.00 t $ha^{-1}$ @60/kg= Rs1,20,000 (2017-18)

Table 2.55 Cost of Cultivation of Prawn/ha

| SN | Components | Cost(Rs.) | |
|---|---|---|---|
| | | **2016-17** | **2017-18** |
| 1. | Field preparation, sluice maintenance, fixing | 9000 | 10000 |
| 2. | Prawn seedlings | 15000 | 15000 |
| 3. | Transportation charge | 5000 | 6000 |
| 4. | Feed | 10000 | 15000 |
| 5. | Harvest (labour charge, pumpset) | 15000 | 18000 |
| | Total | 54000 | 64000 |

**Returns**

Yield -375 kg /ha @Rs.500/- =187500/-(2016-17)

Yield-250 kg/ha@Rs 600/kg= Rs 1,50,000(2017-18)

Table 2.56 BC ratio of Rice and prawn/ha

| Crop | Rice(2016-17) | Rice(2017-18) | Prawn (2016-17) | Prawn 2017-18) |
|---|---|---|---|---|
| Cost of Cultivation (Rs.) | 55400 | 62500 | 54000 | 64000 |
| Returns (Rs) | 142800 | 120000 | 187500 | 150000 |
| BC Ratio | 2.57 | 1.92 | 3.47 | 2.34 |

- Benefit-Cost Ratio of Rice-Prawn integration (2016-17)= 3.01
- Benefit-Cost Ratio of Rice-Prawn integration 2017-18)= 2.13
- Multilevel integrated farming system in Pokkali lands

**C. Integration of rice –prawn-crab-duck- goat on farmer's Pokkali field at Thathappilli**

Farming system involved integration of goat and poultry along with pokkali cultivation. Normally ducks were released after the harvest of paddy cultivation in pokkali fields. Remaining paddy wastes contribute the feed for them. Ducks were also released in standing crop fields so that pest population can be controlled. Goat farming supports farmers by providing a steady income. Fodders and other local feeds like jack leaves were available in plenty and free of cost. Returns from the goat farming were sales of kids and manures. The details of Benefit-Cost analysis are provided in Table 2.57.

Table 2.57 Benefit-Cost Ratio of integrated farming system

| Sl No. | Components | Charges (Rs.) |
|---|---|---|
| **Cost of Cultivation of Rice for 1 ha (2017-18)** | | |
| 1. | Seed cost | 6500 |
| 2. | Land preparation and sowing | 18000 |
| 3. | Weeding (8 women) | 4000 |
| 4. | Transplanting (19 women) | 12000 |
| 5. | Harvesting (17women + 4 men) | 8750 |
| 6. | Threshing (3 women+ 3 men)- | 2800 |
| 7. | Drying ( 2 men+ 2 women) | 3000 |
| | Total | 55,050 |
| | Returns | |
| | Yield –2.00 t $ha^{-1}$ @ Rs 60/ kg | 1,20,000/- |

| **Cost of Cultivation of Prawn+crab/ha** | | |
|---|---|---|
| 1. | Field preparation, sluice maintenance, fixing nets | 10,000 |
| 2. | Prawn seedlings | 40,000 |
| 3. | Prawn feed | 20000 |
| 4. | Crab seedlings | 1,00,000 |
| | Crab feed | 15000 |
| 5. | Harvest (labour charge, pump set etc | 20,000 |
| | Total | 2,05000 |
| | Prawn yield – 300 kg $ha^{-1}$ @ 600/ kg | )00 |
| | Crab yield - 250 no. @1000/kg | )00 |
| | Total returns | 4,30,000 |

| Cost and benefits of goat farming | | |
|---|---|---|
| 1. | Goat 12 nos. | 48000 |
| 2 | Construction of shed | 8,000 |
| 3. | Feed | 2000 |
| | Total | 58000 |
| | Returns / year | |
| 1. | Goat milk | 36720 |
| 2. | Sale of kids (2500/kid) | 50000 |
| 3 | Sale of manure (300g/day for 1 year @5/kg) | 6570 |
| | Total | 93290 |
| **Cost and benefits of poultry (duck) farming** | | |
| 1. | Duck (35 nos.) | 10500 |
| 2 | Feed | 2500 |
| | Total | 13,000 |
| 1 | Returns (Rs. 10/egg) | 30000 |
| 2 | Duck (Rs.300/kg) | 10500 |
| | Total | 40500 |
| | Gross expenditure | 331050 |
| | Gross Returns | 683790 |
| | BC ratio | 2.06 |

On the basis of field results, it was concluded that 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 $tha^{-1}$ and total of 375 kg prawn were harvested. The BC ratio obtained for the rice prawn integration was 3.22. This is mainly because of the fact that the left over's of prawn cultivation become manure for rice cultivation, thereby reducing the additional requirements of any external means of fertilisers. A multilevel integrated farming system model suitable for *Pokkali* lands which involve paddy-prawn-crab in low lands vegetables and other crops in the midlands with duck and goat farming. This is also having good benefit cost ratio of 2.06 along with improved economic status, livelihood opportunities and human nutrition. Integrating aquaculture with agriculture was found to be judicial management and ideal utilization of farm resources. Thus integrated farming is found to enhance the soil properties, cost effective and reducing input requirement.

# 3. MANAGEMENT OF POOR QUALITY WATERS

## 3.1 MANAGEMENT OF ALKALI WATER

### Use of Alkali water to supplement Canal waters in Toria–chikori crop rotation (Agra)

This experiment was initiated during 2015-16 to study the suitable mode of using alkali groundwater for supplemental irrigation where canal supplies are inadequate/ unassured. The experiment was carried out in field plots measuring 4.0 m x 4.0 m in size and each plot was separated by polythene sheet up to 90 cm depth. The alkali water of RSC 10 meq/l was synthesized and applied in Toria-Chikori crop rotation. There were seven treatments viz., T1: All canal; T2: 1CW:1AW; T3: 2CW:2W; T4: 2AW:2CW; T5: Mixing (1 CW+2 AW); T6: Mixing (2 CW+1AW); T7: All Alkali water, in RBD and replicated thrice. Amongst the different canal and alkali water modes the crop yield data for grain yield, harvest index, net profit and B:C ratio are presented in Table 3.1. The grain yield differed significantly amongst the different modes of canal and alkali irrigation. The average higher grain yield recorded in canal irrigated treatments (14.2 q/ha). The maximum net profit and B:C ratio was observed in canal irrigated plots (Rs. 33,637and 1.57) and lowest in all alkali irrigated treatments (Rs. 18,697 and 0.88).

Table 3.1 Effect alkali water irrigation to supplemen canal water irrigation on seed yield, Stover yield, net profit and benefit cost ratio of Toria (Av.2016-17 and 2017-18)

| Treatments | Grain yield(q/ha) | | Mean | Harvest index (%) | Net profit (Rs/ha) | B:C ratio |
|---|---|---|---|---|---|---|
| | 2016-17 | 2017-18 | | | | |
| CW | 14.5 | 13.9 | 14.2 | 35.2 | 33,637 | 1.57 |
| 1CW:1AW | 14.9 | 12.7 | 13.8 | 35.1 | 30,410 | 1.42 |
| 2CW:2AW | 14.9 | 12.6 | 13.8 | 35.6 | 30,141 | 1.41 |
| 2AW:2CW | 13.1 | 11.3 | 12.2 | 33.5 | 24,392 | 1.14 |
| Mix.(1:2) | 14.2 | 12.2 | 13.2 | 35.3 | 28,082 | 1.32 |
| Mix. (2:1) | 14.9 | 12.1 | 13.5 | 35.2 | 29,097 | 1.37 |
| AW | 12.1 | 9.3 | 10.7 | 34.8 | 18,697 | 0.88 |
| CD at 5% | 2.6 | 2.4 | 2.5 | 1.6 | - | - |

After harvest of toria crop, the chikori crop was sown in rabi season with different alkali: canal irrigation modes. The root yield data of chikori crop are presented in Table 3.2. The root yield differed significantly amongst the different modes of canal and alkali irrigation. In average of two years, maximum chikori root yield was found in canal irrigation treatment (258.55 q/ha) while lowest in alkali water irrigated treatment (172.88 q/ha) and other treatments rangeed between them. The maximum net profit and B: C ratio was found in canal irrigated treatment (Rs.73,157 & 2.05) and lowest in all alkali treatments (Rs. 37,759 & 1.07).

### Annually net profit and B:C ratio:

The average of two years annually net profit for toria-chikori rotation was calculated and presented in Table 3.3.The maximum net profit of the two crops grown in one year found with canal irrigated treatment Rs. 1, 06,788 and lowest in alkali irrigated treatment Rs. 56,456. The benefit cost ratio in this rotation was calculated and found maximum in canal- irrigated treatment (3.62) and minimum in alkali water- irrigated treatment (1.95).

Table 3.2: Effect alkali water irrigation to supplement canal water irrigation on yield, net profit and benefit cost ratio of chikori (Av.2016-17 and 2017-18)

| Treatments | Diameter of chikori root(cm) | Length of chikori root (cm) | Yield of chikori root (q/ha) | | Mean | Net profit (Rs/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|
| | | | 2017 | 2018 | | | |
| CW | 12.95 | 24.28 | 253.70 | 263.20 | 258.45 | 73,151 | 2.05 |
| 1CW:1AW | 11.97 | 21.83 | 246.44 | 251.00 | 248.72 | 69,715 | 1.96 |
| 2CW:2AW | 11.72 | 21.69 | 246.06 | 248.93 | 247.50 | 69,295 | 1.95 |
| 2AW:2CW | 10.63 | 20.32 | 229.02 | 225.47 | 227.25 | 60,106 | 1.69 |
| Mix.(1:2) | 11.45 | 21.25 | 235.61 | 240.80 | 238.21 | 65,757 | 1.84 |
| Mix. (2:1) | 11.69 | 21.78 | 246.04 | 249.30 | 247.67 | 69,290 | 1.95 |
| AW | 9.81 | 18.74 | 178.36 | 167.40 | 172.88 | 37,759 | 1.07 |
| CD at 5% | 1.02 | 2.25 | 18.60 | 21.90 | 20.25 | - | - |

Table 3.3: Effect alkali water irrigation to supplemental canal water irrigation on net profit and benefit cost ratio of toria and chicory (Av.2016-17 and 2017-18)

| Treatments | Net profit (Rs/ha) | | | B:C ratio | | |
|---|---|---|---|---|---|---|
| | Toria | Chikori | Total | Toria | Chikori | Total |
| CW | 33,637 | 73,151 | 1,06,788 | 1.57 | 2.05 | 3.62 |
| 1CW:1AW | 30,410 | 69,715 | 1,01,125 | 1.42 | 1.96 | 3.38 |
| 2CW:2AW | 30,141 | 69,295 | 99,436 | 1.41 | 1.95 | 3.36 |
| 2AW:2CW | 24,392 | 60,106 | 84,498 | 1.14 | 1.69 | 2.83 |
| Mix.(1:2) | 28,082 | 65,757 | 93,839 | 1.32 | 1.84 | 3.16 |
| Mix. (2:1) | 29,097 | 69,290 | 98,387 | 1.37 | 1.95 | 3.32 |
| AW | 18,697 | 37,759 | 56,456 | 0.88 | 1.07 | 1.95 |

**Cropping System productivity:**

The average of two years system productivity in toria – chikori cropping sequence is given in Table 3.4. The maximum system yield was observed in all canal water (CW) treatment 273.12 q/ha and minimum in all alkali water treatment (AW) 183.75 q/ha. The other best system treatments for system productivity were 1CW:1AW, 2CW:2AW and cyclic 2CW:1AW. The other treatments gave system productivity yield in between for these treatments.

Table 3.4: Effect of modes of irrigation on system productivity (Av. 2016-17 and 2017-18)

| Treatments | Toria yield (q/ha) | Chikori yield (q/ha) | Cropping System yield (q/ha) |
|---|---|---|---|
| CW | 14.67 | 258.45 | 273.12 |
| 1CW:1AW | 13.82 | 248.72 | 262.54 |
| 2CW:2AW | 13.75 | 247.50 | 261.25 |
| 2AW:2CW | 12.21 | 227.25 | 239.46 |
| Mix.(1:2) | 13.20 | 238.20 | 251.40 |
| Mix. (2:1) | 13.48 | 247.67 | 261.15 |
| AW | 10.71 | 173.04 | 183.75 |

**Soil salinity**

The soil profile ECe, SAR, pH and ESP were determined at sowing & harvest of toria crop and harvest of chikori crop under different treatments and reported in Table 3.5. In general the ECe, pH, SAR and ESP at sowing and harvest of toria crop were normal because number of irrigation was not more and there was some rain falls during crop periods which might have helped in leaching. In case of chikori crop, there was slight increase in values of ECe, SAR, pH and ESP.

Table 3.5: Soil analysis for different canal /alkali irrigated treatments (Av. 2016-17 & 2017-18)

| Treat-ments | Soil Depth (cm) | Toria at sowing | | | | Toria at harvest | | | | Chikori at harvest | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ECe | pH | SAR | ESP | ECe | pH | SAR | ESP | ECe | pH | SAR | ESP |
| T1 | 0-15 | 2.5 | 7.6 | 2.9 | 7.6 | 2.5 | 7.7 | 2.8 | 7.8 | 2.6 | 7.7 | 2.9 | 7.9 |
| | 15-30 | 2.4 | 7.6 | 2.8 | 7.9 | 2.6 | 7.8 | 3.0 | 7.9 | 2.6 | 7.7 | 3.3 | 8.4 |
| | 30-60 | 2.3 | 7.5 | 2.8 | - | 2.4 | 7.7 | 3.1 | - | 2.4 | 7.7 | 3.1 | - |
| | 60-90 | 2.3 | 7.5 | 3.4 | - | 2.4 | 7.5 | 3.5 | - | 2.4 | 7.6 | 3.1 | - |
| T2 | 0-15 | 2.5 | 7.8 | 3.4 | 7.9 | 2.6 | 7.8 | 7.0 | 8.3 | 2.7 | 7.8 | 5.2 | 8.8 |
| | 15-30 | 2.4 | 7.6 | 3.6 | 8.3 | 2.5 | 7.8 | 3.8 | 8.9 | 2.6 | 7.6 | 4.9 | 9.3 |
| | 30-60 | 2.4 | 7.6 | 3.7 | - | 2.5 | 7.7 | 3.9 | - | 2.5 | 7.6 | 4.9 | - |
| | 60-90 | 2.4 | 7.5 | 3.8 | - | 2.3 | 7.5 | 4.2 | - | 2.4 | 7.6 | 4.0 | - |
| T3 | 0-15 | 2.5 | 7.7 | 3.8 | 7.8 | 2.7 | 7.9 | 5.1 | 8.4 | 2.7 | 7.8 | 5.3 | 8.9 |
| | 15-30 | 2.5 | 7.6 | 3.8 | 8.3 | 2.6 | 7.8 | 4.9 | 9.0 | 2.5 | 7.8 | 4.9 | 9.7 |
| | 30-60 | 2.4 | 7.5 | 3.7 | - | 2.5 | 7.7 | 3.7 | - | 2.4 | 7.7 | 4.9 | - |
| | 60-90 | 2.3 | 7.5 | 3.7 | - | 2.4 | 7.6 | 4.1 | - | 2.4 | 7.5 | 4.0 | - |
| T4 | 0-15 | 2.6 | 7.7 | 6.9 | 8.3 | 2.8 | 7.9 | 7.2 | 9.2 | 2.7 | 7.9 | 8.1 | 11.3 |
| | 15-30 | 2.5 | 7.6 | 6.7 | 8.8 | 2.6 | 7.8 | 7.0 | 9.8 | 2.6 | 7.8 | 7.3 | 12.9 |
| | 30-60 | 2.4 | 7.6 | 5.9 | - | 2.5 | 7.7 | 6.1 | - | 2.6 | 7.7 | 6.0 | - |
| | 60-90 | 2.3 | 7.5 | 5.9 | - | 2.4 | 7.6 | 5.9 | - | 2.4 | 7.6 | 5.4 | - |
| T5 | 0-15 | 2.5 | 7.8 | 6.4 | 8.1 | 2.7 | 7.9 | 6.5 | 8.5 | 2.7 | 7.9 | 6.8 | 9.8 |
| | 15-30 | 2.4 | 7.6 | 5.5 | 8.8 | 2.5 | 7.8 | 6.3 | 8.8 | 2.5 | 7.8 | 6.0 | 11.0 |
| | 30-60 | 2.4 | 7.5 | 4.3 | - | 2.6 | 7.7 | 4.8 | - | 2.5 | 7.7 | 4.7 | - |
| | 60-90 | 2.3 | 7.5 | 4.5 | - | 2.4 | 7.7 | 4.6 | - | 2.4 | 7.7 | 4.7 | - |
| T6 | 0-15 | 2.5 | 7.7 | 4.2 | 7.8 | 2.7 | 7.7 | 4.6 | 8.3 | 2.7 | 7.8 | 5.4 | 9.9 |
| | 15-30 | 2.4 | 7.6 | 4.3 | 8.5 | 2.6 | 7.6 | 4.5 | 8.8 | 2.6 | 7.8 | 4.9 | 10.8 |
| | 30-60 | 2.3 | 7.5 | 3.8 | - | 2.5 | 7.5 | 4.3 | - | 2.4 | 7.6 | 4.8 | - |
| | 60-90 | 2.5 | 7.5 | 3.6 | - | 2.4 | 7.5 | 3.7 | - | 2.4 | 7.6 | 4.6 | - |
| T7 | 0-15 | 2.6 | 7.9 | 8.6 | 8.5 | 3.0 | 8.2 | 11.1 | 9.3 | 3.2 | 8.1 | 12.2 | 13.1 |
| | 15-30 | 2.5 | 7.7 | 8.1 | 8.8 | 2.8 | 7.9 | 9.1 | 10.3 | 3.1 | 8.0 | 10.3 | 14.1 |
| | 30-60 | 2.3 | 7.6 | 6.8 | - | 2.6 | 7.7 | 8.0 | - | 3.0 | 7.7 | 8.5 | - |
| | 60-90 | 2.4 | 7.6 | 6.0 | - | 2.5 | 7.7 | 6.0 | - | 2.9 | 7.7 | 6.6 | - |

**Performance of different Crops with Reclaimed Sodic Water through Gypsum Tank (Bapatla)**

In this experiment the existing water tank connected to bore well was modified to suit the gypsum bed. Safflower, chickpea, blackgram and grengram crops established well in plots irrigated with gypsum treated water when compared to irrigated with untreated (high RSC) water. The plant height of safflower, blackgram, greengram and chickpea was 75.2, 39.8, 55.4 and 13.8 cm with 15, 9, 7 and 10 branches, respectively with gypsum treated water while, 62.3, 26.2, 39.4 and 12.4 cm with 10, 7, 6 and 8 branches, respectively (Table 3.6) when irrigated using untreated water. The highest yields were recorded with gypsum treated water in different crops like safflower (900 kg $ha^{-1}$), blackgram (700 kg $ha^{-1}$), greengram (575 kg $ha^{-1}$) and chickpea (1500 kg $ha^{-1}$) during 2016 when compared to irrigated with high RSC water.

Table 3.6 Performance of different crops growth and yield irrigated with sodic water and reclaimed sodic water through gypsum tank

| Crops | Irrigation with gypsum treated water | | | | Irrigation with high RSC water | | | |
|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | No. branches /plant | No. of heads/pods plant | Yield (kg $ha^{-1}$) | Plant height (cm) | No. branches/ plant | No. of heads/pods plant | Yield (kg $ha^{-1}$) |
| Safflower | 75 .2 | 15 | 44 | 900 | 62 .3 | 10 | 29 | 825 |
| Chickpea | 13.8 | 10 | 20 | 1500 | 12.4 | 8 | 17 | 1125 |
| Blackgram | 39.8 | 9 | 8 | 700 | 26.2 | 7 | 7 | 625 |
| Greengram | 55.4 | 7 | 7 | 575 | 39.4 | 6 | 6 | 450 |

**Conjunctive Use of High RSC Water in different Cropping Systems under Sodic Soil Conditions (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. Initially pH, ECe, ESP and Organic Carbon of soil were 9.10, 093 dS/m, 42.2 and 0.28%, respectively. Details of experiment are given below.

**Mode Irrigation water application**

- ✓ T1: Best Available Water (BAW)
- ✓ T2: RSC groundwater
- ✓ T3: BAW followed by all irrigations by RSC water
- ✓ T4: RSC water followed by all irrigations by BAW
- ✓ T5: 1 BAW and 1RSCW (Alternately)
- ✓ T6: BAW + RSC water after mixing

**Other details**

| | |
|---|---|
| Crop rotation: | Rice, wheat and pearl millet |
| Varieties: | CSR-36 (rice), KRL-211 (wheat)and ICTP-8203 (pearl millet) |
| No. : | 6 |
| No of replications: | 3 |
| Design: | Split plot |
| Plot size: | 20 m2 |
| Year of start: | 2014 |
| Location: | Crop Research Farm, Dalipnagar, Kanpur |

Quality parameters of two irrigation waters, namely Best Available Water (BAW) and RSC water are provided in Table 3.7.

Table 3.7 Chemical composition of irrigation waters

| Composition | BAW | RSCW |
|---|---|---|
| pH | 7.5 | 8.82 |
| EC($dSm^{-1}$) | 0.7 | 1.11 |
| Anions (meq $l^{-1}$) | | |
| $CO_3$ | Nil | NIL |
| $HCO_3$ | 4.11 | 8.42 |
| Cl | 3.31 | 1.88 |
| $SO_4$ | 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 |

The average grain yield of rice varied from 23.16 to 39.45 q/ha in rice- wheat cropping system (Table 3.8). The highest grain yield of 39.45 q/ha was obtained under best available water irrigation followed 35.40 q/ha under RSCW - (Rest irrigation with BAW) and 23.16 q/ha under RSCW treatment. The average straw yield of rice varied from 28.36 to 47.67 q/ha in rice- wheat cropping system. The highest yield was obtained with best available water (BAW) 47.67 q/ha followed by 43.38 q/ha with RSCW - (Rest irrigation with BAW) and lowest yield of 28.36 q/ha was obtained with RSCW treatment.

Table 3.8 Effect of treatments on yield of rice in rice-wheat cropping system

| Treatments | Grain yield (q/ha) | | | | | Straw yield (q/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | Mean | 2014 | 2015 | 2016 | 2017 | Mean |
| T1: BAW | 37.18 | 39.25 | 40.12 | 41.25 | 39.45 | 44.98 | 45.68 | 49.34 | 50.70 | 47.67 |
| T2: RSCW | 24.25 | 23.77 | 22.50 | 22.12 | 23.16 | 29.58 | 28.99 | 27.67 | 27.20 | 28.36 |
| T3: BAW - (Rest irrigation with RSCW) | 28.77 | 28.46 | 27.88 | 27.25 | 28.09 | 35.09 | 34.72 | 34.29 | 33.52 | 34.40 |
| T4: RSCW - (Rest irrigation with BAW) | 33.26 | 34.43 | 36.75 | 37.17 | 35.40 | 40.57 | 42.07 | 45.20 | 45.71 | 43.38 |
| T5: 1 BAW-1 RSCW (Alternate) | 31.65 | 32.36 | 32.47 | 33.05 | 32.38 | 38.61 | 39.47 | 39.97 | 40.65 | 39.67 |
| T6: BAW + RSCW | 34.61 | 36.11 | 33.52 | 35.15 | 34.84 | 42.42 | 44.05 | 41.22 | 43.22 | 42.97 |
| CD (0.05) | 1.57 | 1.64 | 1.67 | 1.62 | -- | | | | | |

The average grain yield of wheat varied from 16.92 to 34.87 q/ha in rice-wheat cropping system (Table 3.9). The maximum yield of 34.87 q/ha was obtained under best available water (BAW) followed by 29.51 q/ha with RSCW - (Rest irrigation with BAW) and lowest yield of 16.92 q/ha was obtained with RSCW treatment. The average straw yield of wheat varied from 20.48 to 42.19 q/ha in rice-wheat cropping system (Table 3.9). The maximum yield of 42.19 q/ha was obtained with best available water (BAW) followed by 35.72 q/ha with RSCW - (Rest irrigation with BAW) and lowest yield of 20.48 q/ha was observed with RSCW treatment.

Table 3.9 Effect of treatments on grain yield of wheat in rice-wheat cropping system

| Treatments | Grain yield of wheat (q/ha) | | | | | Straw yield of wheat (q/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2016-17 | 2017-18 | Mean | 2014-15 | 2015-16 | 2016-17 | 2017-18 | Mean |
| T1: BAW | 32.73 | 34.95 | 35.78 | 36.04 | 34.87 | 39.60 | 42.28 | 43.29 | 43.60 | 42.19 |
| T2: RSCW | 17.45 | 17.12 | 16.72 | 16.40 | 16.92 | 21.11 | 20.71 | 20.23 | 19.89 | 20.48 |
| T3: BAW - (Rest irrigation with RSCW) | 22.04 | 23.10 | 21.94 | 22.25 | 22.33 | 26.66 | 27.95 | 26.54 | 27.85 | 27.25 |
| T4: RSCW - (Rest irrigation with BAW) | 27.14 | 28.88 | 30.22 | 31.82 | 29.51 | 32.83 | 34.94 | 36.56 | 38.55 | 35.72 |
| T5: 1 BAW-1 RSCW (Alternate) | 26.00 | 27.65 | 27.42 | 29.07 | 27.53 | 31.46 | 33.45 | 33.17 | 35.17 | 33.31 |
| T6: BAW + RSCW | 28.11 | 29.46 | 28.71 | 30.14 | 29.10 | 34.05 | 35.64 | 34.75 | 36.47 | 35.22 |
| CD (0.05) | 1.23 | 1.46 | 1.49 | 1.52 | -- | 1.46 | 1.42 | 1.52 | 1.49 | -- |

The average grain yield of pearl-millet varied from 08.32 to 15.52 q/ha in pearl millet - wheat cropping system (Table 3.10). The highest yield of 15.52 q/ha was obtained from best available water (BAW) followed by RSCW - (Rest irrigation with BAW) (13.07 q/ha) and BAW + RSCW (12.14 q/ha) while lowest yield of 08.32 q/ha was received from residual sodium carbonate water (RSCW) treatment. The average stover yield of pearl millet varied from 22.32 to 41.92 q/ha in pearl millet-wheat cropping system (Table 3.10). The highest yield was obtained from best available water (BAW) 41.92 q/ha followed by RSCW - (Rest irrigation with BAW) (35.35 q/ha) and BAW + RSCW (33.01 q/ha) while lowest yield of 22.32 q/ha was received from residual sodium carbonate water (RSCW) treatment.

Table 3.10 Effect of treatments on grain yield of pearl millet in pearl millet-wheat cropping system

| Treatments | Grain yield of pearl millet (q/ha) | | | | | Stover yield of pearl millet (q/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | Mean | 2014 | 2015 | 2016 | 2017 | Mean |
| T1: BAW | 14.52 | 15.55 | 15.97 | 16.05 | 15.52 | 2014 | 2015 | 2016 | 2017 | Mean |
| T2: RSCW | 08.41 | 08.12 | 08.78 | 07.98 | 08.32 | 39.20 | 41.98 | 43.17 | 43.34 | 41.92 |
| T3: BAW - (Rest irrigation with RSCW) | 10.58 | 10.05 | 09.62 | 09.42 | 09.91 | 22.07 | 21.92 | 23.72 | 21.57 | 22.32 |
| T4: RSCW - (Rest irrigation with BAW) | 12.24 | 12.83 | 13.36 | 13.88 | 13.07 | 28.56 | 27.14 | 25.97 | 25.45 | 26.78 |
| T5: 1 BAW-1 RSCW (Alternate) | 10.98 | 11.27 | 10.64 | 11.52 | 11.10 | 33.12 | 34.67 | 36.15 | 37.49 | 35.35 |
| T6: BAW + RSCW | 12.75 | 12.35 | 11.42 | 12.05 | 12.14 | 29.64 | 30.45 | 28.75 | 32.10 | 30.23 |
| CD (0.05) | 1.17 | 1.29 | 1.27 | 1.31 | -- | 34.45 | 34.12 | 30.83 | 32.64 | 33.01 |
| | | | | | | 1.47 | 1.52 | 1.57 | 1.55 | -- |

The average grain yield of wheat varied from 17.28 to 35.11 q/ha in pearl millet- wheat cropping system (Table 3.11). The maximum yield was obtained from best available water (BAW) 35.11 q/ha followed by RSCW - (Rest irrigation with BAW) (30.23 q/ha) and BAW + RSCW (28.05 q/ha) while minimum yield of 17.28 q/ha was received from residual sodium carbonate water (RSCW) treatment. The average straw yield of wheat varied from 21.09 to 42.84 q/ha in pearl millet - wheat cropping system (Table 3.11). The maximum yield was obtained from best available water (BAW) 42.84 q/ha followed by RSCW - (Rest irrigation with BAW) (36.90 q/ha) and BAW + RSCW (34.52 q/ha) while minimum yield of 21.09 q/ha was received from residual sodium carbonate water (RSCW) treatment.

Table 3.11 Effect of treatments on grain yield of wheat in pearl millet-wheat cropping system

| Treatments | Grain yield of wheat (q/ha) | | | | | Straw yield of wheat (q/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2016-17 | 2017-18 | Mean | 2014-15 | 2015-16 | 2016-17 | 2017-18 | Mean |
| T1: BAW | 33.27 | 35.37 | 36.28 | 35.52 | 35.11 | 40.58 | 43.15 | 44.32 | 43.33 | 42.84 |
| T2: RSCW | 18.08 | 17.85 | 16.74 | 16.47 | 17.28 | 22.05 | 21.77 | 20.42 | 20.12 | 21.09 |
| T3: BAW - (Rest irrigation with RSCW) | 20.55 | 20.82 | 19.96 | 20.14 | 20.36 | 25.07 | 26.25 | 24.35 | 24.72 | 25.09 |
| T4: RSCW - (Rest irrigation with BAW) | 27.95 | 29.05 | 31.15 | 32.78 | 30.23 | 34.09 | 35.44 | 38.10 | 39.99 | 36.90 |
| T5: 1 BAW-1 RSCW (Alternate) | 26.78 | 28.00 | 28.25 | 28.75 | 17.94 | 32.67 | 34.16 | 34.57 | 35.07 | 34.11 |
| T6: BAW + RSCW | 28.35 | 28.16 | 27.62 | 28.10 | 28.05 | 34.58 | 35.22 | 33.72 | 34.58 | 34.52 |
| CD (0.05) | 1.21 | 1.37 | 1.35 | 1.41 | -- | 1.49 | 1.53 | 1.57 | 1.62 | -- |

Changes in pH, electrical conductivity, exchangeable sodium percentage (ESP) and organic carbon (OC) indicated that although there has been overall improvement in soil properties in every treated plots excluding residual sodium carbonate water (RSCW). The values of soil pH, EC and ESP decreased in BAW irrigated plot and increased with RSCW. There was noted improvement in organic carbon in all the treatments excluding RSCW. Related data are given in Table 3.12

Table 3.12 Effect of treatments on physico-chemical properties of soil after two years

| Treatments | Rice-wheat | | | | Pearl millet-wheat | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | EC | ESP | OC | pH | EC | ESP | OC |
| T1: BAW | 8.7 | 0.88 | 38.7 | 0.32 | 8.7 | 0.89 | 39.2 | 0.31 |
| T2: RSCW | 9.2 | 0.94 | 43.5 | 0.26 | 9.3 | 0.93 | 43.9 | 0.27 |
| T3: BAW - (Rest irrigation with RSCW) | 9.0 | 0.93 | 41.1 | 0.28 | 9.1 | 0.93 | 41.6 | 0.28 |
| T4: RSCW - (Rest irrigation with BAW) | 8.9 | 0.91 | 40.0 | 0.30 | 8.8 | 0.92 | 40.1 | 0.30 |
| T5: 1 BAW-1 RSCW (Alternate) | 8.9 | 0.92 | 40.2 | 0.29 | 9.0 | 0.91 | 40.2 | 0.29 |
| T6: BAW + RSCW | 8.8 | 0.89 | 40.2 | 0.30 | 8.8 | 0.90 | 39.7 | 0.30 |
| Initial values | 9.1 | 0.93 | 42.2 | 0.28 | 9.1 | 0.93 | 42.2 | 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.

**2016-17**

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 3.13). 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 3.13 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 |

**2017-18**

The results of the study showed that the drip irrigation system exhibits significant difference in plant growth parameters of vegetable crops compared to sprinkler irrigation and flooded irrigation under sodic soil environment. The yields of vegetable crops also showed that drip and sprinkle irrigation were more effective and efficient than furrow irrigation for increasing the yield of vegetable crops cultivated under sodic soil condition.

Vegetable cowpea yield was highest among the vegetable crops and recorded an yield of 7980 kg/ha under drip irrigation compared to 6278 kg/ha under sprinkler irrigation and followed by 4786 kg/ha in furrow irrigation (Table 3.14). The yield increase in Vegetable cowpea crop cultivated under drip irrigation technique was 40 % higher than the furrow irrigation.

Table 3.14 Effect of irrigation methods on yield of vegetables (kg $ha^{-1}$)

| Treatments | Cluster bean | Bhendi | Vegetable cowpea | Onion |
|---|---|---|---|---|
| Drip irrigation | 3895 | 4820 | 7980 | 3785 |
| Sprinkler irrigation | 3612 | 4410 | 6278 | 3270 |
| Flood irrigation | 2428 | 3486 | 4786 | 2712 |
| Mean | 3312 | 4239 | 6348 | 3256 |
| CD (P=0.05) | I | C | I at C | C at I |
| | 108 | 300 | 460 | 525 |

The yields of cluster bean, bhendi and onion was 3895, 4820 and 3785 kg/ha respectively in drip irrigation treatment and the yield increase over furrow irrigation was 38%, 28% and 28%, respectively. The EC and pH of experimental soil were not affected due to the different irrigation treatments. The ESP of the soil was significantly increased in furrow irrigation over drip and sprinkler irrigation methods (Table 3.15).

Table 3.15 Effect of irrigation methods on post harvest Soil pH, EC and Exchangeable Sodium Percentage

| Treatments | pH | | | | | EC ($dSm^{-1}$) | | | | | ESP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CB | B | VC | O | Ave | CB | B | VC | O | Ave | CB | B | VC | O | Ave |
| Drip | 8.75 | 8.78 | 8.84 | 8.81 | 8.80 | 0.72 | 0.81 | 0.82 | 0.75 | 0.78 | 25.40 | 25.20 | 25.80 | 25.70 | 25.53 |
| Sprin-kler | 8.95 | 8.87 | 8.91 | 8.90 | 8.91 | 0.78 | 0.85 | 0.94 | 0.84 | 0.85 | 26.60 | 27.00 | 26.80 | 26.20 | 26.65 |
| Flood | 9.10 | 9.11 | 9.17 | 9.06 | 9.11 | 0.92 | 1.06 | 1.03 | 0.99 | 1.00 | 28.10 | 27.70 | 28.40 | 28.60 | 28.20 |
| Mean | 8.93 | 8.92 | 8.97 | 8.92 | 8.94 | 0.81 | 0.91 | 0.93 | 0.86 | 0.88 | 26.70 | 26.63 | 27.00 | 26.83 | 26.79 |
| CD (P=0.05) | I | C | I at C | C at I | | I | C | I at C | C at I | | I | C | I at C | C at I | |
| | NS | NS | NS | NS | | NS | NS | NS | NS | | 0.91 | NS | NS | NS | |

*CB= Cluster bean; B= Bhendi; VC= Vegetable cowpea; O= Onion*

Plate 3.1 View of experimental field on pressurized irrigation for vegetables

The results showed that the practicing of drip irrigation for cultivating all vegetable crops will increase the yield and income of the farmers compared to flood irrigation in sodic environment. Slight buildup in sodicity was observed in soil with flood irrigation compared to drip and sprinkler irrigation methods.

**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.

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. 3.1.

**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<br>Replications | : Strip- plot design<br>: Four |
| $M_2$ | Drip with spent wash treated water | $S_2$ | One time application of DSW @ 5 lakh liters $ha^{-1}$ | Crop<br>Hybrid | : Cotton<br>: RCH 20 |
| $M_3$ | Drip with untreated alkali water | $S_3$ | No amendments | Spacing | : 90 x 60 cm |

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

Table 3.16 Changes in quality of ameliorated alkali water

| Sr. No. | Treatment | pH | EC (dS/m) | RSC |
|---|---|---|---|---|
| 1 | Alkali water (untreated) | 8.96 | 1.62 | 7.6 |
| 2 | Gypsum bed treated water | 8.20 | 1.80 | 3.4 |
| 3 | Distillery spent wash treated water (1:250) | 6.95 | 1.92 | Nil |

**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 3.17). Drip irrigation with alkali water recorded the lowest seed cotton yield of 1880 kg/ha.

Table 3.17 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 3.18. 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 3.19 and 3.20). 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 3.18 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 3.19 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 3.20 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 |

**2017-18**

Sowing of second crop of Cotton BG II hybrid RCH 20 was done along the ridges with a spacing of 90 cm between rows and 60 cm between plants during first week of March 2018.Other management practices like gap filling and weeding were carried out according to the recommended package of practices. Further observations are under progress.

Plate 3.2 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)

The experiment was laid out with four levels of irrigation water *viz.* best available water (BAW) pumped from filter point well (0.6 dS $m^{-1}$) and saline water with 2, 4, 6 and 8 dS $m^{-1}$of electrical conductivity replicated 4 times in each plot of 64.0 $m^2$. The experiment was conducted during *rabi* 2016 and 2017 using the vegetable crops *viz*. cabbage, cauliflower and moringa (drumstick). Moringa (*Moringa oleifera)*, variety PKM-1 was continued for the second year also. The 30 days old seedlings of cabbage (Indam Krishna) and cauliflower (White Gold) were transplanted in both the years during *rabi* season. The experimental soil was neutral in reaction, non saline with medium levels of available nitrogen and phosphorous and high potassium content (Table 3.21).

Table 3.21 Soil fertility status at the start and at harvest of the crops

| Sr. No. | Parameter | 2 dS $m^{-1}$ | | | 4 dS $m^{-1}$ | | |
|---|---|---|---|---|---|---|---|
| | | Initial | Final | Change % | Initial | Final | Change% |
| 1. | E.C. ( dS $m^{-1}$) | 0.5 | 0.7 | 40 | 0.8 | 1.30 | 62.5 |
| 2. | pH | 7.4 | 7.7 | 4 | 7.5 | 7.9 | 2.60 |
| 3. | Avail. N( kg $ha^{-1}$) | 291 | 246 | -15.5 | 272 | 172 | -36.8 |
| 4. | Available $P_2O_5$ (kg $ha^{-1}$) | 30 | 26 | -13.3 | 26.7 | 20.5 | -23.2 |
| 5. | Available $K_2O$ (kg $ha^{-1}$) | 324 | 336 | 3.70 | 312.5 | 330 | 5.60 |

The initial and final soil sample analysis revealed that there is 40-62.5% rise in soil salinity due to application of 2-4 dS $m^{-1}$ irrigation water. But for every season, the available nitrogen is getting reduced by 15.5-36.8 %, i.e. 45.0 kg $ha^{-1}$ to 100 kg $ha^{-1}$ for every increment of irrigation water salinity by 2 dS $m^{-1}$. Similarly available phosphorous got reduced by 13.3-23.2%, i.e. 4.0-6.2 kg $ha^{-1}$ for every increment of irrigation water salinity by 2 dS $m^{-1}$. The available potassium levels are found slightly increased due to irrigation with saline water.

Plate 3.3 Experimental plots of Agricultural Engineering, SWS, Bapatla during 2016-17

### Plant and yield studies of cabbage, cauliflower and moringa (drumstick)

The plant parameters like plant height, root length, Leaf Area Index, Biomass, chlorophyll_a, chlorophyll_b, yield parameters like head/curd/stick diameter/length, head weight, yield were measured and subjected to statistical analysis. Salinity of irrigation water showed significant effect on plant and yield parameters. To develop mathematical models for these ill effects of irrigation water salinity quality on the plant and yield parameters, the following modeling was carried out using Excel. The production functions (i.e. yield level v*s* irrigation water salinity) for three crops cabbage, cauliflower and moringa based on 2 years' (2016-17 and 2017-18) pooled data were developed (Table 3.22 and Fig. 3.2). The yield functions of cabbage and cauliflower followed the linear relationship, where as moringa followed the logarithmic relationship attributing more than 90% cause for the reduction of the yield to irrigation water salinity. The yield levels of 90, 75, 50 and 0 percent were achieved at 1.2, 2.8, 5.5 and 10.8 dS $m^{-1}$ for Cabbage, 1.8, 3.3, 5.8 and 10.8 dS $m^{-1}$ for cauliflower and 0.9, 1.3, 2.5 and 8.7 dS $m^{-1}$ irrigation water salinity for moringa, respectively.

Based on these production functions of three crops, the irrigation water salinity levels were arrived for each yield level (%) as shown in the Table 3.22. The corresponding yields actually realized against each salinity of irrigation water application were mentioned through Table 3.23.

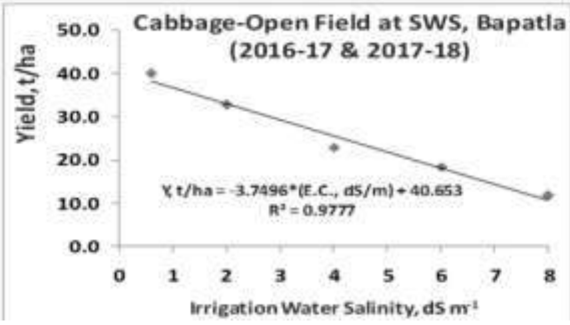
Yield of cabbage showed a reduction from 40.08 to 11.78 t $ha^{-1}$ when salinity rose from 0.6 to 8 dS $m^{-1}$, resulting in an increase in the per cent yield reduction from 18.19 to 7.61. Similarly, the yields of cauliflower decreased from 18.67 to 6.12 t $ha^{-1}$ with yield reduction being 2.14 to 67.22 per cent. While, the yield reduction was higher in case of moringa realizing 95.87 per cent reduced yields at 8 dS $m^{-1}$, and 75% yield reduction was observed even at 4 dS $m^{-1}$.

Table 3.22 Irrigation water salinity and yield relation for pooled yield (2016-17 & 2017-18) levels for crops

| Yield Level % | Irrigation water salinity, E.C., dS $m^{-1}$ | | |
|---|---|---|---|
| | Cabbage | Cauliflower | Moringa |
| 100 | 0.2 | 0.8 | 0.7 |
| 90 | 1.2 | 1.8 | 0.9 |
| 80 | 2.3 | 2.8 | 1.2 |
| 75 | 2.8 | 3.3 | 1.3 |
| 70 | 3.4 | 3.8 | 1.5 |
| 60 | 4.4 | 4.8 | 1.9 |
| 50 | 5.5 | 5.8 | 2.5 |
| 40 | 6.6 | 6.8 | 3.2 |
| 30 | 7.6 | 7.8 | 4.1 |
| 20 | 8.7 | 8.8 | 5.3 |
| 10 | 9.8 | 9.8 | 6.8 |
| 0 | 10.8 | 10.8 | 8.7 |
| Production function | Y, t/ha = -3.749*(E.C., dS/m) + 40.65<br>$R^2$ = 0.977 | Y, t/ha= -1.862*(E.C., dS/m) + 20.11<br>$R^2$ = 0.934 | Y, t $ha^{-1}$= -16.3*ln(E.C., dS $m^{-1}$) + 35.25<br>$R^2$ = 0.944 |

**Irrigation water salinity -yield relation for Cabbage based on pooled data**

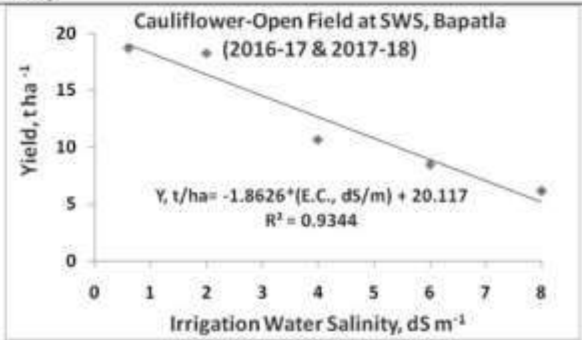
| Yield, t ha-1 | |
|---|---|
| IWS, dS/m | Yield, t/ha |
| 0.6 | 40.1 |
| 2.0 | 32.8 |
| 4.0 | 23.0 |
| 6.0 | 18.4 |
| 8.0 | 11.8 |




**Irrigation water salinity -yield relation for Cauliflower based on pooled data**

A. Cauliflower (2016-17 & 2017-18)

| Yield, t ha-1 | |
|---|---|
| IWS, dS/m | Y, t/ha |
| 0.6 | 18.67 |
| 2.0 | 18.27 |
| 4.0 | 10.68 |
| 6.0 | 8.47 |
| 8.0 | 6.12 |




**Irrigation water salinity -yield relation for drumstick based on pooled data**

B. Moringa (Drumstick) 2016-17

| Salinity, $dS\ m^{-1}$ | Cum. Yield, t/ha |
|---|---|
| 0.6 | 40.7 |
| 2 | 30.9 |
| 4 | 10.4 |
| 6 | 3.8 |
| 8 | 1.7 |

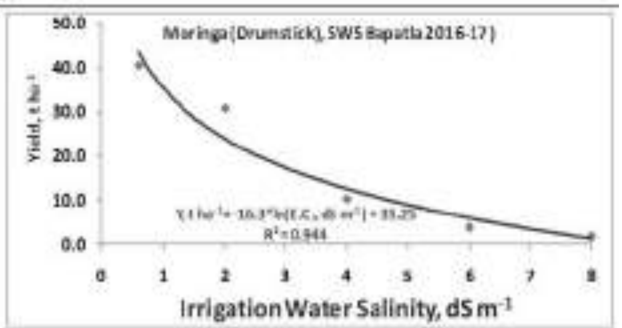



Fig. 3.2 Production functions of yield of Cabbage, Cauliflower, and Moringa

**Use of Saline Water in Shadenets for different Vegetable Crops in Krishna Western Delta (Bapatla)**

The experiment was laid out with four levels of irrigation water in shadenets of Bobbepalli (ORP) farmer's field *viz.* best available water (BAW) pumped from filter point well (0.6 dS $m^{-1}$) and saline water with 2, 4, 6 and 8 dS $m^{-1}$ of electrical conductivity replicated 4 times in each plot of 64 $m^2$. The experiment was conducted during *rabi,* 2016 & 2017 using the vegetable crops *viz*. cabbage, cauliflower (Figure 1). The 30 days old seedlings of cabbage (Indam Krishna @ Indo-American hybrid seeds Pvt.Ltd.) and cauliflower (White Gold) were transplanted in both the years during *rabi* season. The experimental soil was neutral in reaction, non saline with medium levels of available nitrogen and phosphorous and high potassium content (Table 3.24).

Table 3.23 Pooled yield of cabbage, cauliflower and moringa (t $ha^{-1}$) 2016-17 & 2017-18

| EC | Cabbage | | Cauliflower | | Moringa | |
|---|---|---|---|---|---|---|
| (dS $m^{-1}$) | t $ha^{-1}$ | % reduction | t $ha^{-1}$ | % reduction | t $ha^{-1}$ | % reduction |
| 0.6 | 40.08 | -- | 18.67 | -- | 40.72 | -- |
| 2 | 32.79 | 18.19 | 18.27 | 2.14 | 30.89 | 24.14 |
| 4 | 22.98 | 42.66 | 10.68 | 42.80 | 10.39 | 74.48 |
| 6 | 18.40 | 54.09 | 8.47 | 54.63 | 3.76 | 90.77 |
| 8 | 11.78 | 70.61 | 6.12 | 67.22 | 1.68 | 95.87 |

Table 3.24 Soil properties of Bobbepalli farm under shadenet

| Parameter | 2 dS $m^{-1}$ | | | 4 dS $m^{-1}$ | | |
|---|---|---|---|---|---|---|
| | Initial | Final | Change % | Initial | Final | Change % |
| EC (dS $m^{-1}$) | 0.30 | 0.5 | 66.67 | 0.8 | 1.2 | 50 |
| pH | 7.50 | 7.95 | 6.00 | 7.70 | 7.95 | 3.25 |
| Avail. N (kg $ha^{-1}$) | 126 | 118 | -6.34 | 126.0 | 113.0 | -10.31 |
| Avail. $P_2O_5$ (kg $ha^{-1}$) | 46.3 | 41.5 | -10.36 | 36.50 | 31.50 | -13.7 |
| Avail. $K_2O$ (kg $ha^{-1}$) | 632.0 | 648.0 | 2.53 | 617.0 | 623.0 | 1.30 |
| OC (%) | 0.42 | 0.55 | -31.0 | 0.34 | 0.31 | -8.82 |

The initial and final soil sample analysis of the beds in the shadenets of Bobbepalli ORP revealed that the salinity increased by 66.67, pH by 6, available K by 2.53 per cent; while available N, P and organic carbon got reduced by 6.34, 10.36 and 31 per cent respectively in 2 dS $m^{-1}$ plot; while when irrigated with water having 4 dS $m^{-1}$ plot the salinity increased by 50%, pH by 3.25, available K by 1.30. However, available N, P and organic carbon reduced by 10.31, 13.7 and 8.82 per cent respectively.

Plate 3.4 Shadenets experiment with Cabbage and Cauliflower in Bobbepalli during *rabi*, 2017

Irrigation water salinity -yield relations under shadenet for cabbage and cauliflower based on pooled data are shown in Fig. 3.3.

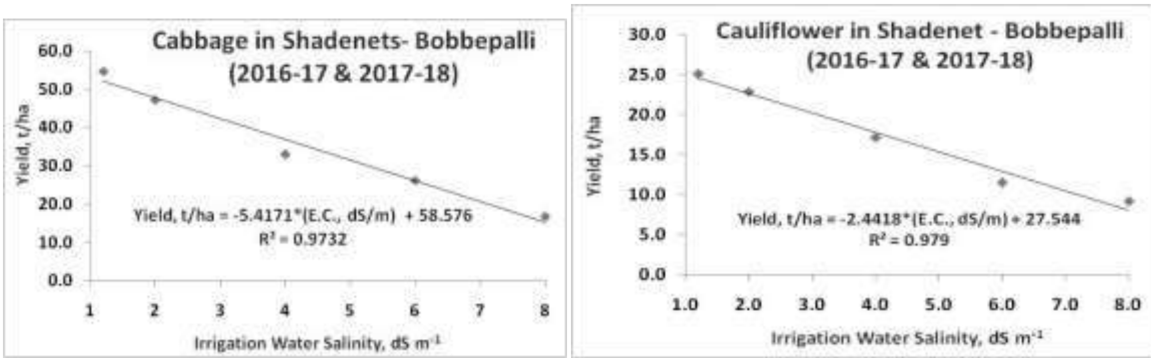



Fig. 3.3 Irrigation water salinity -yield relation under shadenet for cabbage and cauliflower

The 90%, 75% and 50% yield levels of Cabbage and Cauliflower in shadenets is found to be at 1.71, 3.23 and 5.76 dS $m^{-1}$ and 2.01, 3.56 and 6.13 dS $m^{-1}$ respectively (Table 3.25). The yield of cabbage and cauliflower grown in shadenet is found to be 37 % and 35% more than the yields obtained in open field at all the salinity levels (Table 3.26). The intervention of shadenets is offsetting the ill effects of irrigation water salinity to 37 and 35% in cabbage and cauliflower. The rest of the plant parameters are also showing clear differences in growth of the plant under salinity stress in open field and shadenets. At irrigation water salinity of 0.70 and 0.98 dS $m^{-1}$, respectively, for cabbage and cauliflower could produce 100 per cent yield levels. Cauliflower could tolerate a higher EC level for obtaining a specified yield level i.e., 75% and 50% levels of yields could be obtained at 3.23 and 5.76 dS $m^{-1}$ respectively for cabbage while it was 3.56 and 6.13 dS $m^{-1}$ for cauliflower.

Table 3.25 Irrigation water salinity and Yield of Cabbage and Cauliflower in Shadenets at Bobbepalli ORP (2016-17 & 2017-18)

| Yield Level, % | Cabbage | | Cauliflower | |
|---|---|---|---|---|
| | Irrigation water E.C (dS $m^{-1}$) | Yield t $ha^{-1}$ | Irrigation water E.C (dS $m^{-1}$) | Yield t $ha^{-1}$ |
| 100 | 0.70 | 54.76 | 0.98 | 25.14 |
| 90 | 1.71 | 49.29 | 2.01 | 22.63 |
| 80 | 2.73 | 43.81 | 3.04 | 20.11 |
| 75 | 3.23 | 41.07 | 3.56 | 18.86 |
| 70 | 3.74 | 38.33 | 4.07 | 17.60 |
| 60 | 4.75 | 32.86 | 5.10 | 15.09 |
| 50 | 5.76 | 27.38 | 6.13 | 12.57 |
| 40 | 6.77 | 21.91 | 7.16 | 10.06 |
| 30 | 7.78 | 16.43 | 8.19 | 7.54 |
| 20 | 8.79 | 10.95 | 9.22 | 5.03 |
| 10 | 9.80 | 5.48 | 10.25 | 2.51 |
| 0 | 10.81 | 0.00 | 11.28 | 0.00 |

Table 3.26 Comparison of EC (dS $m^{-1}$) for specified yield levels of cabbage and cauliflower in open field and shadenets cultivation

| Yield Level % | Cabbage | | Cauliflower | |
|---|---|---|---|---|
| | Open Field | Shadenet | Open Field | Shadenet |
| 100 | 0.2 | 0.7 | 0.8 | 1.0 |
| 90 | 1.2 | 1.7 | 1.8 | 2.0 |
| 80 | 2.3 | 2.7 | 2.8 | 3.0 |
| 75 | 2.8 | 3.2 | 3.3 | 3.6 |
| 70 | 3.4 | 3.7 | 3.8 | 4.1 |
| 60 | 4.4 | 4.7 | 4.8 | 5.1 |
| 50 | 5.5 | 5.8 | 5.8 | 6.1 |
| 40 | 6.6 | 6.8 | 6.8 | 7.2 |
| 30 | 7.6 | 7.8 | 7.8 | 8.2 |
| 20 | 8.7 | 8.8 | 8.8 | 9.2 |
| 10 | 9.8 | 9.8 | 9.8 | 10.3 |
| 0 | 10.8 | 10.8 | 10.8 | 11.3 |

A perusal of the data indicated that any specified yield level of the crops could be achieved even at a higher EC level of irrigation water when the crop is grown in shadenets than in the open field. A 100% yield level could be attained at a salinity level of 0.2 and 0.7 dS $m^{-1}$ respectively in open field and shadenet for cabbage, while it was 0.8 and 1.0 dS $m^{-1}$ for cauliflower. Similarly, 75% and 50% yield levels could be achieved at 2.8 and 3.2 dS $m^{-1}$; 5.5 and 5.8 dS $m^{-1}$ respectively for cabbage with corresponding EC levels of 3.3 and 3.6 dS $m^{-1}$ and 5.8 and 6.1 dS $m^{-1}$ for cauliflower. This could be due to reduced evaporation in shadenets and low crop water demand that might have led to low amount of irrigation water use and thus low additions of salts to the soil and lower capillary rise of salts along with water.

**Optimization of Water Requirement of Groundnut-wheat Cropping Sequence using Saline Water under Drip Irrigation (Bikaner)**

This experiment was initiated to optimize water requirement of groundnut–wheat cropping sequence using saline water under drip irrigation. The treatments comprised of four levels of $EC_{iw}$ (BAW, 4, 8 and 12 dS/m), two drip geometries (60 cm x 30 cm and 90 x 30 cm) and 3 levels of water requirement IW:CPE ratio (0.6, 0.8 and 1.0 PE).

**Groundnut:** Pooled analysis indicated that different treatments had significant effect on pod yield of groundnut. Increase in $EC_{iw}$ beyond 4 dS/m caused significant reduction in pod yield. Application of irrigation water of $EC_{iw}$ of 8 and 12 dS/m caused significant reduction of 61.09 and 81.49 per cent, respectively as compared to BAW on pooled basis. Drip laterals spaced at 60 cm resulted in 24.03 per cent higher pod yield as compared to laterals spaced at 90 cm. So far water requirement is concerned, in comparison to 1.0 PE, 0.6 PE showed significant reduction of 28.43 per cent in pod yield while in comparison to 0.8 PE, 0.6 PE showed significant reduction of 26.76 per cent (Table 3.27).

The straw yield showed non-significant improvement when $EC_{iw}$ increased to 4 dS/m but further increase in $EC_{iw}$ 8 and 12 dS/m caused significant reduction of 39.63 and 65.71 per cent over $EC_{iw}$ 4 dS/m, respectively (Table 3.27). Drip geometry of 60 cm x 30 cm proved significantly superior to 90 cm x 30 cm by a magnitude of 20.93 per cent in terms of straw yield. Volume 1.0 PE recorded the highest straw yield and differed significantly by a margin of 4.63 and 33.15 per cent to 0.8 and 0.6 PE, respectively.

Table 3.27 Effect of saline water, drip geometry and irrigations on pod yield and straw yield of groundnut

| Particular | Pod yield ($qha^{-1}$) | | | | | Straw yield ($qha^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | Pooled | 2014 | 2015 | 2016 | 2017 | Pooled |
| | | | | | $EC_{iw}$ | | | | | |
| BAW | 35.34 | 26.00 | 33.42 | 30.64 | 31.35 | 56.02 | 45.33 | 55.35 | 52.93 | 52.40 |
| 4 dS/m | 34.19 | 25.33 | 33.41 | 29.68 | 30.65 | 58.47 | 43.78 | 54.27 | 51.41 | 51.98 |
| 8 dS/m | 10.39 | 8.34 | 17.54 | 14.72 | 12.75 | 46.65 | 23.31 | 31.47 | 29.63 | 32.77 |
| 12 dS/m | 7.69 | 5.59 | 6.75 | 5.48 | 6.38 | 37.19 | 17.45 | 10.33 | 9.73 | 18.67 |
| S Em (±) | 0.63 | 0.25 | 0.69 | 0.30 | 0.26 | 3.93 | 0.61 | 0.95 | 0.97 | 1.06 |
| CD (0.05) | 1.86 | 0.73 | 2.02 | 0.87 | 0.73 | 11.57 | 1.81 | 2.78 | 2.87 | 2.99 |
| | | | | | Drip Geometry | | | | | |
| 60 x 30 | 24.18 | 18.95 | 25.81 | 23.27 | 23.05 | 54.44 | 36.21 | 42.45 | 40.44 | 43.38 |
| 90 x 30 | 19.62 | 13.68 | 19.75 | 17.00 | 17.51 | 44.72 | 28.73 | 33.26 | 31.41 | 34.53 |
| S Em (±) | 0.45 | 0.17 | 0.48 | 0.21 | 0.18 | 2.78 | 0.43 | 0.67 | 0.69 | 0.75 |
| CD (0.05) | 1.32 | 0.51 | 1.43 | 0.61 | 0.51 | 8.18 | 1.28 | 1.97 | 2.03 | 2.12 |
| | | | | | PE | | | | | |
| 0.6 V | 16.70 | 12.48 | 19.01 | 16.84 | 16.26 | 35.07 | 24.53 | 30.80 | 29.16 | 29.89 |
| 0.8 V | 24.36 | 18.03 | 24.18 | 21.53 | 22.02 | 54.04 | 35.88 | 41.00 | 38.8 | 42.45 |
| 1 V | 24.64 | 18.43 | 25.15 | 22.02 | 21.91 | 59.64 | 36.99 | 41.76 | 39.73 | 44.53 |
| S Em (±) | 0.40 | 0.27 | 0.36 | 0.64 | 0.22 | 2.16 | 0.62 | 1.49 | 0.78 | 0.70 |
| CD (0.05) | 1.15 | 0.77 | 1.02 | 1.83 | 0.61 | 6.15 | 1.76 | 4.24 | 2.21 | 1.95 |

Plant height at harvest showed significant reduction with increase in $EC_{iw}$ beyond 4 dS/m. Drip geometry of 60 cm x 30 cm proved significantly superior to 90 cm x 30 cm by a magnitude of 10.2 percent. 1.0 PE slightly edged over 0.8 PE while significant increase of 9.2 per cent in plant height as compared to 0.6 PE was recorded (Table 3.28).

It was observed that number of pods per plant was non-significantly affected upto $EC_{iw}$ 4 dS/m but as compared to BAW, $EC_{iw}$ 8 and 12 dS/m caused significant reduction of 34.10 and 58.85 per cent, respectively. Drip geometry of 60 cm x 30 cm found significantly superior to 90 cm x 30 cm by a margin of 15.74 per cent. Volume 1.0 and 0.8 PE being at par with each other and bring about significant increase of 10.35 and 8.36 per cent over 0.6 PE, respectively.

Combined effects of treatments given in Table 3.29, 3.30 and 3.31 and also Fig. 3.4, 3.5,and 3.6 showed that 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. It was also noted that when $EC_{iw}$ increased from 0 to 4 dS/m, difference in yield was not significant, further increase in $EC_{iw}$ caused significant reduction in pod yield at all the levels of PE.

Table 3.28 Effect of saline water, drip geometry and irrigations on plant height and pods per plant of groundnut

| Particular | Plant height (cm) | | | | | Number of pods per plant | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | pooled | 2014 | 2015 | 2016 | 2017 | pooled |
| | | | | | **$EC_{iw}$** | | | | | |
| BAW | 27.25 | 20.11 | 24.24 | 23.26 | 23.72 | 25.55 | 20.52 | 24.45 | 24.16 | 23.67 |
| 4 dS/m | 26.71 | 18.91 | 23.49 | 22.48 | 22.90 | 25.41 | 19.43 | 24.03 | 23.33 | 23.05 |
| 8 dS/m | 21.27 | 14.87 | 16.93 | 16.56 | 17.41 | 19.57 | 15.25 | 17.49 | 17.39 | 17.43 |
| 12 dS/m | 16.56 | 11.44 | 6.17 | 6.23 | 10.10 | 15.06 | 10.02 | 10.54 | 10.29 | 11.48 |
| S Em (±) | 0.36 | 0.45 | 0.67 | 0.55 | 0.27 | 0.36 | 0.39 | 0.27 | 0.69 | 0.23 |
| CD (0.05) | 1.05 | 1.32 | 1.98 | 1.63 | 0.75 | 1.05 | 1.13 | 0.80 | 2.04 | 0.66 |
| | | | | | **Drip Geometry** | | | | | |
| 60 x 30 | 23.91 | 17.27 | 20.82 | 20.07 | 20.52 | 22.36 | 17.30 | 20.30 | 19.94 | 19.98 |
| 90 x 30 | 21.98 | 15.40 | 14.60 | 14.20 | 16.54 | 20.43 | 15.31 | 17.96 | 17.65 | 17.83 |
| S Em (±) | 0.25 | 0.32 | 0.48 | 0.39 | 0.19 | 0.25 | 0.27 | 0.19 | 0.49 | 0.16 |
| CD (0.05) | 0.74 | 0.93 | 1.40 | 1.15 | 0.53 | 0.74 | 0.80 | 0.56 | 1.45 | 0.47 |
| | | | | | **PE** | | | | | |
| 0.6 V | 21.97 | 15.36 | 15.67 | 15.30 | 17.08 | 20.42 | 15.57 | 18.18 | 17.69 | 17.96 |
| 0.8 V | 23.24 | 16.48 | 18.46 | 17.65 | 18.96 | 21.69 | 16.56 | 19.44 | 19.16 | 19.21 |
| 1 V | 23.63 | 17.16 | 18.98 | 18.45 | 19.56 | 22.08 | 16.78 | 19.77 | 19.53 | 19.54 |
| S Em (±) | 0.28 | 0.27 | 0.45 | 0.41 | 0.18 | 0.28 | 0.18 | 0.28 | 0.29 | 0.13 |
| CD (0.05) | 0.78 | 0.78 | 1.28 | 1.17 | 0.50 | 0.78 | 0.50 | 0.80 | 0.83 | 0.36 |

Table 3.29 Combined effect of treatments (drip geometry x $EC_{iw}$) on pod yield and pods/plant of groundnut (pooled)

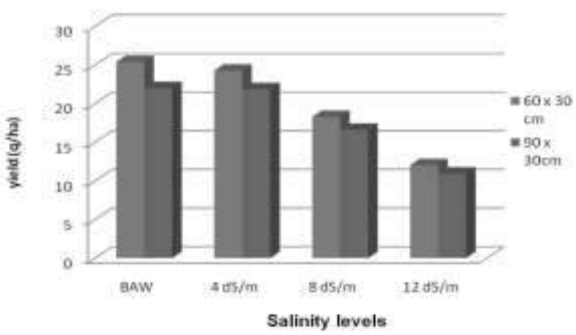
| Drip geometry | Pod yield (q/ha) | | | | Pods/plant | | | |
|---|---|---|---|---|---|---|---|---|
| | BAW | 4 dS/m | 8 dS/m | 12 dS/m | BAW | 4 dS/m | 8 dS/m | 12 dS/m |
| 60 x 30 cm | 35.64 | 34.77 | 14.16 | 7.64 | 25.36 | 24.25 | 18.27 | 12.03 |
| 90 x 30cm | 27.06 | 26.54 | 11.34 | 5.11 | 21.98 | 21.85 | 16.59 | 10.93 |
| S Em (±) | 0.36 | | | | 0.33 | | | |
| CD (0.05) | 1.03 | | | | 0.93 | | | |

Table 3.30 Combined effect of treatments (PE x $EC_{iw}$) on pod yield (q/ha) of groundnut (pooled)

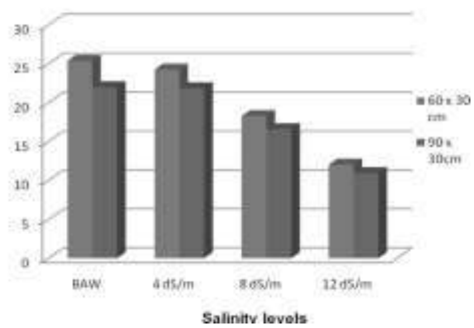
| PE levels | $EC_{iw}$ levels | | | |
|---|---|---|---|---|
| | BAW | 4 dS/m | 8 dS/m | 12 dS/m |
| PE 0.6 | 25.28 | 24.57 | 10.38 | 4.81 |
| PE 0.8 | 33.89 | 33.41 | 13.73 | 7.07 |
| PE 1.0 | 34.88 | 33.98 | 14.14 | 7.25 |
| | | | SEm (±) | CD (0.05) |
| $EC_{iw}$ means at same level of PE | | | 0.44 | 1.22 |
| PE means at same level of $EC_{iw}$ | | | 0.38 | 1.07 |

Table 3.31 Combined effect of treatments (PE x drip geometry) on pod yield and straw yield of groundnut (pooled)

| PE levels | Pod yield (q/ha) | | Straw yield (q/ha) | |
|---|---|---|---|---|
| | 60 x 30 cm | 90 x 30cm | 60 x 30 cm | 90 x 30cm |
| PE 0.6 | 18.21 | 14.30 | 38.00 | 21.78 |
| PE 0.8 | 25.03 | 19.02 | 45.54 | 39.36 |
| PE 1.0 | 25.91 | 19.21 | 46.61 | 42.45 |
| | S Em (±) | CD (0.05) | S Em (±) | CD (0.05) |
| Drip geometry at same level of PE | 0.36 | 1.00 | 1.14 | 3.19 |
| PE at same level of $EC_{iw}$ | 0.31 | 0.87 | 1.10 | 3.08 |




(a)




(b)

Fig. 3.4 Combined effect of treatments (drip geometry x EC iw on **a)** pod yield and **b)** number of pod per plant (polled data)

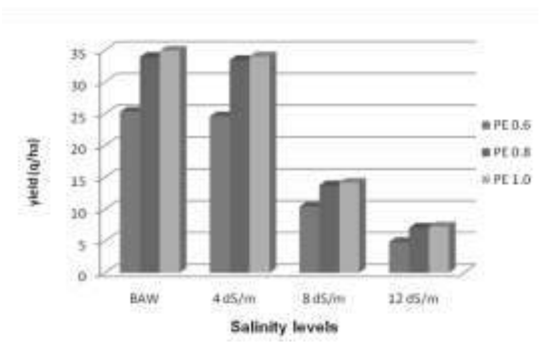



Fig. 3.5 Combined effect of treatments (PE x EC iw on a) pod yield of groundnut (pooled data)

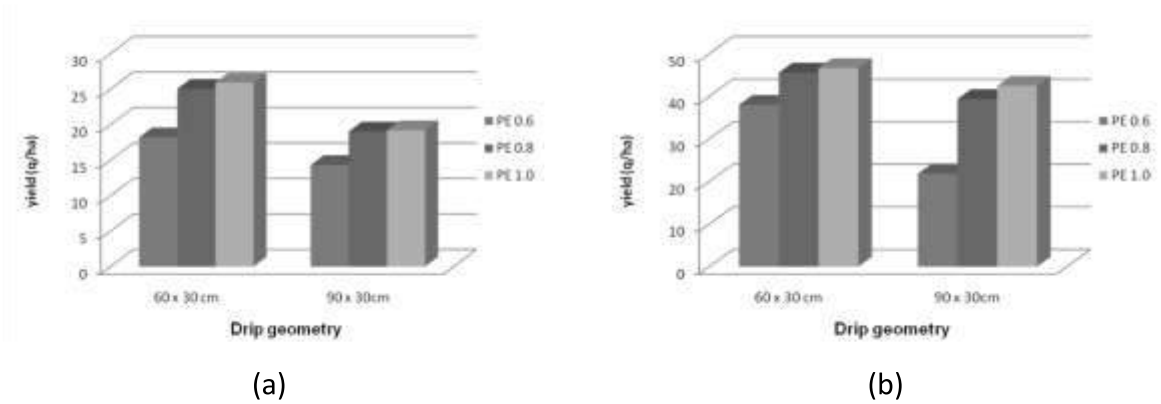



Fig. 3.6 Combined effect of treatments (PEx drip geometry on **a)** pod yield and **b)** straw yield of groundnut (pooled data)

**Wheat:** On the basis of pooled data, results indicated that different treatments had significant effect on yields of wheat (Table 3.32). Increase in $EC_{iw}$ beyond 8 dS/m caused significantly drastic reduction in grain yield. As compared to $EC_{iw}$ 4 dS/m, $EC^{iw}$ 8 and 12 dS/m caused reduction of 3.04 and 56.69 per cent. Drip laterals spaced at 60 cm resulted in 25.25 percent 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 irrigation (PE) requirement is concerned, in comparison to 1.0 PE and 0.8 PE, volume 0.6 PE showed significant reduction of 16.27 and 15.25 per cent, respectively in seed yield.

Table 3.32 Effect of saline water, drip geometry and irrigations on seed and straw yield of wheat

| Particular | Seed yield (q $ha^{-1}$) | | | | Straw yield (q $ha^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2016-17 | 2017-18 | Pooled | 2014-15 | 2016-17 | 2017-18 | Pooled |
| | | | | **$EC_{iw}$** | | | | |
| BAW | 25.77 | 28.88 | 27.17 | 27.27 | 31.75 | 35.31 | 33.68 | 33.58 |
| 4 dS/m | 25.22 | 28.52 | 26.86 | 26.86 | 30.94 | 35.19 | 33.42 | 33.18 |
| 8 dS/m | 24.49 | 27.64 | 25.96 | 26.03 | 30.02 | 34.18 | 32.32 | 32.17 |
| 12 dS/m | 10.24 | 12.09 | 10.88 | 11.07 | 13.00 | 15.67 | 14.44 | 14.37 |
| SEm (±) | 0.26 | 0.34 | 0.31 | 0.09 | 0.35 | 0.38 | 0.52 | 0.15 |
| CD (0.05) | 0.76 | 1.00 | 0.92 | 0.25 | 1.02 | 1.10 | 1.53 | 0.43 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Drip Geometry** | | | | | | | | |
| 60 x 30 | 24.18 | 27.16 | 25.58 | 25.64 | 29.15 | 33.40 | 31.97 | 31.50 |
| 90 x 30 | 18.67 | 21.41 | 19.86 | 19.98 | 23.71 | 26.77 | 24.96 | 25.15 |
| SEm (±) | 0.18 | 0.24 | 0.22 | 0.06 | 0.24 | 0.27 | 0.37 | 0.11 |
| CD (0.05) | 0.54 | 0.71 | 0.65 | 0.18 | 0.72 | 0.78 | 1.08 | 0.30 |
| **PE** | | | | | | | | |
| 0.6 V | 18.83 | 21.57 | 20.12 | 20.17 | 23.99 | 27.13 | 25.78 | 25.63 |
| 0.8 V | 22.41 | 25.43 | 24.02 | 23.95 | 27.53 | 31.43 | 29.66 | 29.54 |
| 1 V | 23.04 | 25.84 | 24.01 | 24.30 | 27.76 | 31.69 | 29.95 | 29.80 |
| SEm (±) | 0.31 | 0.38 | 0.32 | 0.21 | 0.36 | 0.46 | 0.60 | 0.30 |
| CD (0.05) | 0.87 | 1.09 | 0.91 | 0.60 | 1.04 | 1.30 | 1.71 | 0.84 |

Table 3.33 Effect of saline water, drip geometry and irrigations on yield attributes of wheat

| Particular | Plant height (cm) | | | | Tillers/Sqm | | | | Panicles/Sqm | | | | Grains/ear | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2016-17 | 2017-18 | Pooled | 2014-15 | 2016-17 | 2017-18 | Pooled | 2014-15 | 2016-17 | 2017-18 | Pooled | 2014-15 | 2016-17 | 2017-18 | Pooled |
| **$EC_{iw}$** | | | | | | | | | | | | | | | | |
| BAW | 71.87 | 76.90 | 75.49 | 74.75 | 296.59 | 301.93 | 298.78 | 299.10 | 282.29 | 285.79 | 280.54 | 282.87 | 25.32 | 25.63 | 25.42 | 25.46 |
| 4 dS/m | 70.10 | 76.01 | 74.98 | 73.70 | 291.06 | 297.97 | 295.63 | 294.89 | 277.06 | 283.20 | 282.78 | 281.01 | 24.96 | 25.53 | 25.54 | 25.34 |
| 8 dS/m | 59.45 | 74.42 | 73.52 | 69.13 | 254.60 | 285.22 | 282.50 | 274.10 | 233.22 | 269.44 | 252.19 | 251.62 | 21.52 | 24.42 | 24.68 | 23.54 |
| 12 dS/m | 50.75 | 54.61 | 53.34 | 52.90 | 190.44 | 196.93 | 193.85 | 193.74 | 163.89 | 171.37 | 169.82 | 168.36 | 15.76 | 15.87 | 16.86 | 16.16 |
| SEm (±) | 0.60 | 0.78 | 0.93 | 0.53 | 2.96 | 5.21 | 4.11 | 1.58 | 3.30 | 5.46 | 6.26 | 2.43 | 0.22 | 0.41 | 0.65 | 0.34 |
| CD (0.05) | 1.78 | 2.29 | 2.75 | 1.49 | 8.69 | 15.33 | 12.08 | 4.47 | 9.71 | 16.05 | 18.41 | 6.88 | 0.66 | 1.20 | 1.91 | 0.96 |
| **Drip Geometry** | | | | | | | | | | | | | | | | |
| 60 x 30 | 68.21 | 75.39 | 74.27 | 72.63 | 284.35 | 297.20 | 294.64 | 292.07 | 265.70 | 279.64 | 274.39 | 273.25 | 23.64 | 24.74 | 25.06 | 24.48 |
| 90 x 30 | 57.87 | 65.58 | 64.39 | 62.61 | 231.99 | 243.82 | 240.73 | 238.85 | 212.53 | 225.26 | 218.27 | 218.68 | 20.14 | 20.99 | 21.19 | 20.77 |
| SEm (±) | 0.43 | 0.55 | 0.66 | 0.37 | 2.09 | 3.69 | 2.91 | 1.12 | 2.33 | 3.86 | 4.43 | 1.72 | 0.16 | 0.29 | 0.46 | 0.24 |
| CD (0.05) | 1.26 | 1.62 | 1.94 | 1.05 | 6.15 | 10.84 | 8.54 | 3.16 | 6.86 | 11.35 | 13.02 | 4.86 | 0.47 | 0.85 | 1.35 | 0.68 |
| **PE** | | | | | | | | | | | | | | | | |
| 0.6 V | 59.53 | 66.34 | 65.04 | 63.64 | 236.80 | 248.91 | 246.01 | 243.91 | 218.23 | 231.62 | 225.15 | 225.00 | 20.31 | 21.25 | 21.66 | 21.08 |
| 0.8 V | 64.08 | 71.93 | 70.67 | 68.89 | 265.86 | 279.28 | 276.84 | 273.99 | 246.25 | 260.95 | 255.10 | 254.10 | 22.49 | 23.51 | 23.77 | 23.25 |
| 1 V | 65.52 | 73.19 | 72.28 | 70.33 | 271.87 | 283.35 | 280.21 | 278.47 | 252.86 | 264.79 | 258.74 | 258.80 | 22.87 | 23.83 | 23.94 | 23.55 |
| SEm (±) | 0.78 | 1.14 | 0.69 | 0.49 | 3.65 | 4.25 | 5.19 | 2.75 | 3.73 | 4.38 | 5.06 | 2.74 | 0.28 | 0.27 | 0.39 | 0.14 |
| CD (0.05) | 2.22 | 3.24 | 1.97 | 1.37 | 10.38 | 12.09 | 14.76 | 7.70 | 10.62 | 12.45 | 14.39 | 7.65 | 0.79 | 0.78 | 1.10 | 0.38 |

Combined effects of treatments were also found significant. Increase in the salinity of irrigation water beyond 8 dS/m drastically decreased the seed yield under both the drip geometries i.e. 60 cm x 30 cm and 90 cm x 30 cm (Table 3.34). BAW $EC_{iw}$ 4 and 8 dS/m were found at par. It is worth noting that as compared to BAW, $EC_{iw}$ of 8 dS/m caused significant reduction of only 5.19 and 3.77 per cent under drip geometry of 60 cm x 30 cm and 90 cm x 30 m, respectively, but with $EC_{iw}$ of 12 dS/m drastic reduction of 58.54 and 60.53 per cent, respectively, was observed. Drip geometry of 90 cm x 30 cm proved to be inferior to 60 cm x 30 cm at all $EC_{iw}$ levels.

Straw yield results in significant reduction at drip geometry of 90 cm x 30 cm as compared of 60 cm x 30 cm at all the levels of $EC_{iw}$. At drip geometry 60 cm x 30 cm, straw yield was not significant under BAW and $EC_{iw}$ of 4 dS/m. However, further increase in $EC_{iw}$ 8 and 12 dS/m caused significant reduction in straw yield. In case of drip geometry of 90 cm x 30 cm, reduction was not significant up to $EC_{iw}$ 8 dS/m but further increase in $EC_{iw}$ 12 dS/m caused drastic reduction (Table 3.34).

Table 3.34 Combined effect of treatments (drip geometry x $EC_{iw}$) on seed and straw yield (q/ha) of wheat (Pooled)

| Drip geometry | Seed yield (q/ha) | | | | Straw yield (q/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | BAW | 4 dS/m | 8 dS/m | 12 dS/m | BAW | 4 dS/m | 8 dS/m | 12 dS/m |
| 60 x 30 cm | 30.66 | 30.13 | 29.07 | 12.71 | 37.88 | 37.40 | 34.50 | 16.24 |
| 90 x 30cm | 23.89 | 23.60 | 22.99 | 9.43 | 29.28 | 28.96 | 29.85 | 12.50 |
| SEm (±) | 0.13 | | | | 0.21 | | | |
| CD (0.05) | 0.36 | | | | 0.60 | | | |

Combined effect of PE x drip geometry on grain yield (q/ha) of wheat (Pooled) is shown in Table 3.35. The PE 1.0 and PE 0.8 were at par while there was significant yield reduction in case of PE 0.6. The drip geometry 60x30 cm was superior to 90 x30 cm.

Table 3.35 Combined effect of treatments (PE x drip geometry) on grain yield (q/ha) of wheat (Pooled)

| PE levels | Drip geometry | |
|---|---|---|
| | 60 x 30 cm | 90 x 30cm |
| PE 0.6 | 23.51 | 16.83 |
| PE 0.8 | 26.44 | 21.47 |
| PE 1.0 | 26.96 | 21.63 |
| | S Em (±) | CD (0.05) |
| Drip geometry at same level of PE | 0.30 | 0.85 |
| PE at same level of Drip geometry | 0.26 | 0.71 |

**Effect of Fertility Levels on Isabgol-Pearlmillet Crop Sequence under Drip Irrigation using Saline Water (Bikaner)**

**Isabgol:** This experiment was initiated during rabi 2014-15 to optimize water requirement of isabgol – pearl millet cropping sequence using saline water under drip irrigation. The treatments comprised of three levels of $EC_{iw}$ (BAW, 4 and 8 dS/m) and 3 fertility levels (75, 100 and 125 % RDF NPK). The experiment was damaged and left with no harvest, during rabi 2014-15 and 2015-16, the crop (Isabgol) was failed due to heavy hail storm in month of March, 2016. During 2016-17 and 2017-18, the crop data presented in Table 3.36 indicated that different treatments had significant effect on seed yield of isabgol. Increase in the $EC_{iw}$ beyond 4 dS/m caused significant reduction in the seed yield. As compared to BAW and $EC_{iw}$ 4 dS/m, $EC_{iw}$ 8 ds/m showed significant reduction of 3.76 and 41.34 per cent, respectively. In case of fertility levels, application of 100% and 125% RDF of NPK registered significant increase of 26.19 and 29.05 per cent in seed yield of isabgol, respectively, over 75 per cent RDF. However, 100% RDF and 125% RDF were statistically at par. Increase in the $EC_{iw}$ beyond 4 dS/m caused significant reduction in the biological yield. As compared to BAW, $EC_{iw}$ 4 dS/m and $EC_{iw}$ 8 dS/m showed significant reduction of 3.33 and 46.68 per cent in biological yield, respectively. In case of fertility levels, application of 100% and 125% RDF registered significant increase of 29.91 and 33.87 per cent in biological yield of isabgol, respectively, over 75% RDF.

Combined effect of treatment showed (Table 3.37 and Fig. 3.7 and 3.8) 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 125% RDF. Application of 125% RDF at 4 dS/m recorded yield of 9.08 q/ha which was at par with that recorded with 100% RDF at same level of ECiw i.e. 4 dS/m. Further, it was also recorded that yields at BAW with the application of 100% and 125% of RDF were not significantly different than yields at 4 dS/m at 100% and 125% RDF. Increase in ECiw beyond 4 dS/m caused significant reduction with all the levels of fertilizer application. Similar trends were noticed in respect of yield attributing characteristics.

Table 3.36 Effect of saline water and different fertility levels on yield and yield attributes of Isabgol

| Particular | Seed yield (q/ha) | | | Biological yield (q/ha) | | | Plant height (cm) | | | Tillers/plant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016-17 | 2017-18 | Pooled | 2016-17 | 2017-18 | Pooled | 2016-17 | 2017-18 | Pooled | 2016-17 | 2017-18 | Pooled |
| $EC_{iw}$ | | | | | | | | | | | | |
| BAW | 9.00 | 8.57 | 8.78 | 28.27 | 26.23 | 27.25 | 30.31 | 26.09 | 28.20 | 11.34 | 10.95 | 11.14 |
| 4 dS/m | 8.57 | 8.34 | 8.45 | 26.74 | 25.90 | 26.32 | 29.68 | 25.98 | 27.83 | 11.05 | 10.77 | 10.91 |
| 8 dS/m | 5.52 | 4.78 | 5.15 | 16.25 | 12.81 | 14.53 | 22.73 | 22.66 | 22.69 | 5.77 | 4.85 | 5.31 |
| S Em (±) | 0.17 | 0.13 | 0.106 | 0.58 | 0.43 | 0.361 | 0.51 | 0.65 | 0.413 | 0.17 | 0.16 | 0.118 |
| CD (0.05) | 0.50 | 0.37 | 0.303 | 1.69 | 1.26 | 1.027 | 1.48 | 1.90 | 1.175 | 0.50 | 0.48 | 0.336 |
| Fertility levels (% RDF) | | | | | | | | | | | | |
| 75 | 6.44 | 6.16 | 6.30 | 19.33 | 18.12 | 18.72 | 25.54 | 21.76 | 23.65 | 7.55 | 6.93 | 7.24 |
| 100 | 8.22 | 7.69 | 7.95 | 25.50 | 23.13 | 24.32 | 28.37 | 26.21 | 27.29 | 10.09 | 9.65 | 9.87 |
| 125 | 8.43 | 7.84 | 8.13 | 26.42 | 23.69 | 25.06 | 28.81 | 26.77 | 27.79 | 10.53 | 9.98 | 10.26 |
| S Em (±) | 0.17 | 0.13 | 0.106 | 0.58 | 0.43 | 0.361 | 0.51 | 0.65 | 0.413 | 0.17 | 0.16 | 0.118 |
| CD (0.05) | 0.50 | 0.37 | 0.303 | 1.69 | 1.26 | 1.027 | 1.48 | 1.90 | 1.175 | 0.50 | 0.48 | 0.336 |

Table 3.37 Combined effect of treatments ($EC_{iw}$ x fertility levels) on seed yield and tillers of isabgol

| Treatments | Seed yield (q/ha) | | | Tillers/plant | | |
|---|---|---|---|---|---|---|
| | 75 % RDF | 100 % RDF | 125 % RDF | 75 % RDF | 100 % RDF | 125 % RDF |
| BAW | 8.14 | 9.04 | 9.18 | 8.96 | 11.95 | 12.53 |
| **4** dS/m | 7.37 | 8.91 | 9.08 | 8.54 | 11.86 | 12.33 |
| **8** dS/m | 3.40 | 5.92 | 6.14 | 4.22 | 5.79 | 5.92 |
| S Em (±) | | 0.18 | | | 0.21 | |
| CD (0.05) | | 0.52 | | | 0.58 | |

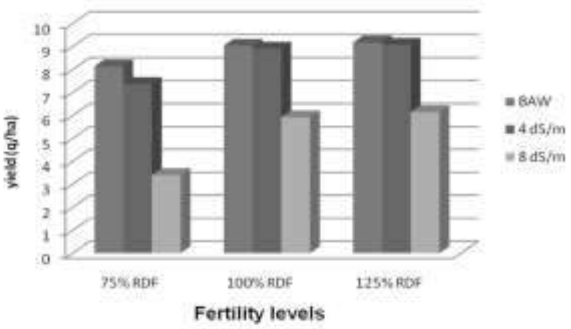



Fig. 3.7 Combined effect of treatments (ECiw x fertility levels) on seed yield (q/ha) of isabgol

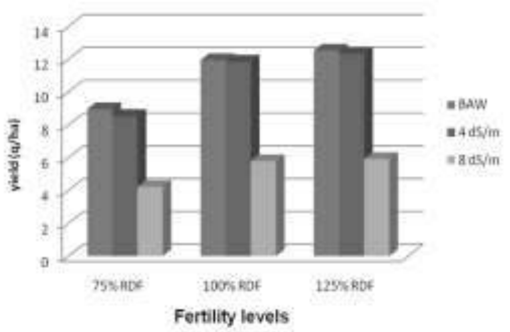



Fig. 3.8 Combined effect of treatments (ECiw x fertility levels) on tillers per plant of isabgol

Plate 3.6 Field view of Isabgol experiment

**Pearl millet:** The experiment was initiated during Kharif 2015. The treatments comprised of three levels of $EC_{iw}$ (BAW, 4 and 8 dS/m) and 3 fertility levels (75, 100 and 125 % RDF) of NPK. Results of kharif crop (Table 3.38) indicated that Increase in the $EC_{iw}$ beyond 4 dS/m caused significant reduction in the grain yield. As compared to BAW and $EC_{iw}$ 4 dS/m, saline water of $EC_{iw}$ 8 dS/m results in significant reduction of 29.31 and 22.94 per cent respectively. In case of fertility levels, it was observed that application of 100 % and 125 % RDF of NPK registered significant increase of 25.45 and 28.54 per cent in grain yield of pearl millet, respectively over 75 % RDF. In terms of straw yield also, similar trend was observed and increase in the $EC_{iw}$ beyond 4 dS/m caused significant reduction in the straw yield. As compared to BAW and $EC_{iw}$ of 4 dS/m, application of saline water of $EC_{iw}$ of 8 dS/m showed significant reduction of 20.23 and 16.71 per cent, respectively. In case of fertility levels, it was observed that application of 100 % and 125 % RDF of NPK registered significant increase of 21.55 and 26.09 per cent in straw yield of pearl millet, respectively over 75 % RDF.

The yield attributes showed significant reduction when $EC_{iw}$ increased from 4 dS/m to 8 dS/m, however, BAW and $EC_{iw}$ of 4 dS/m were at par. Application of 100% RDF of fertilizers found significantly superior over 75% RDF in respect of all yield attributes and remained at par with 125% RDF of fertilizers.

Combined effect of treatment (Table 3.39 and Fig. 3.9) showed that application of 100% RDF resulted in significant improvement in the yield over 75% RDF at all the levels of $EC_{iw}$ but remained at par with 125% RDF. Application of 125% RDF at 4 dS/m recorded yield of 14.05 q/ha which was at par with 100% RDF at same level of $EC_{iw}$ i.e. 4 dS/m. Increase in $EC_{iw}$ beyond 4 dS/m caused significant reduction with all the levels of fertilizer application.


Plate 3.7 Field view of pearl millet experiment

Table 3.38 Effect of saline waters and fertility level on yields and yield attributes of pearl millet

| Treatments | Plant height (cm) | | | | Ear head length (cm) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | Pooled | 2015 | 2016 | 2017 | Pooled |
| | | | | $EC_{iw}$ | | | | |
| BAW | 158.28 | 161.36 | 149.50 | 159.82 | 20.90 | 21.54 | 19.85 | 21.22 |
| 4 dS./m | 153.58 | 157.38 | 144.42 | 155.48 | 19.70 | 20.21 | 18.73 | 19.96 |
| 8 dS/m | 126.50 | 124.42 | 93.92 | 125.46 | 14.63 | 14.31 | 10.63 | 14.47 |
| S Em (+) | 2.96 | 3.36 | 3.57 | 2.241 | 0.52 | 0.35 | 0.47 | 0.32 |
| CD (0.05) | 8.64 | 9.82 | 10.41 | 6.372 | 1.53 | 1.02 | 1.37 | 0.90 |
| | | | | Fertility levels (% RDF) | | | | |
| 75 | 133.25 | 135.11 | 108.33 | 134.18 | 15.20 | 15.79 | 13.45 | 15.50 |
| 100 | 151.12 | 152.32 | 137.00 | 151.72 | 19.68 | 19.88 | 17.43 | 19.78 |
| 125 | 154.00 | 155.73 | 142.50 | 154.86 | 20.35 | 20.39 | 18.33 | 20.37 |
| S Em (+) | 2.96 | 3.36 | 3.57 | 2.241 | 0.52 | 0.35 | 0.47 | 0.32 |
| CD (0.05) | 8.64 | 9.82 | 10.41 | 6.372 | 1.53 | 1.02 | 1.37 | 0.90 |

| Treatments | Grain yield (q/ha) | | | | Straw Yield (q/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | Pooled | 2015 | 2016 | 2017 | Pooled |
| | | | | $EC_{iw}$ | | | | |
| BAW | 13.33 | 14.18 | 12.06 | 13.75 | 21.65 | 22.09 | 18.85 | 21.87 |
| 4 dS./m | 12.82 | 13.37 | 11.44 | 13.10 | 20.47 | 21.98 | 17.86 | 21.23 |
| 8 dS/m | 10.67 | 10.82 | 9.12 | 10.74 | 17.72 | 18.66 | 12.71 | 18.19 |
| S Em (+) | 0.29 | 0.43 | 0.29 | 0.26 | 0.57 | 0.65 | 0.55 | 0.43 |
| CD (0.05) | 0.83 | 1.24 | 0.83 | 0.73 | 1.66 | 1.90 | 1.62 | 1.23 |
| | | | | Fertility levels (% RDF) | | | | |
| 75 | 10.48 | 10.41 | 9.59 | 10.45 | 17.50 | 17.76 | 15.03 | 17.63 |
| 100 | 12.90 | 13.83 | 11.42 | 13.37 | 20.64 | 22.21 | 17.00 | 21.43 |
| 125 | 13.44 | 14.12 | 11.62 | 13.78 | 21.69 | 22.77 | 17.39 | 22.23 |
| S Em (+) | 0.29 | 0.43 | 0.29 | 0.26 | 0.57 | 0.65 | 0.55 | 0.43 |
| CD (0.05) | 0.83 | 1.24 | 0.83 | 0.73 | 1.66 | 1.90 | 1.62 | 1.23 |

Table 3.39 Combined effect of treatments on grain yield of pearl millet

| Treatments | 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 |
| S Em (+) | 0.44 | | |
| CD (0.05) | 1.26 | | |

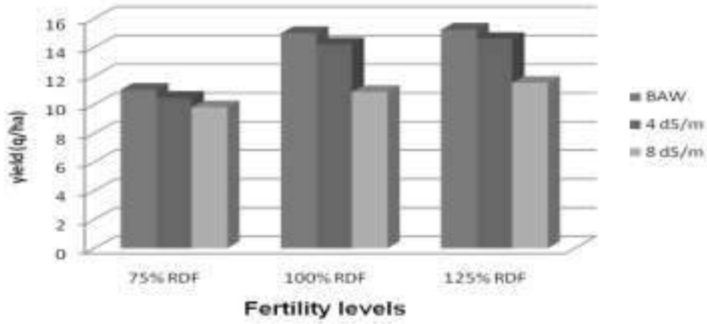



Fig. 3.9 Combined effect of treatments on grain yield (q/ha) of pearl millet

**Integrated Nutrient Management in Pearl millet-wheat under Saline Water Irrigation (Hisar)**

This experiment was initiated during 2015-16 to evaluate the effect of various combinations of organic manures, biofertilizer on pearl millet-wheat cropping system with saline water irrigation and to assess the effect of various organic manures and biofertilizers on soil properties. The treatments comprised of 12 combination of recommended dose of fertilizers and 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 and wheat crop when irrigated with saline water of EC 8 dS/m along with different levels of recommended doses of fertilizer. Seed of both the crops were treated with the microbial cultures '*Azotobacter ST-3* and *Biomix* at the time of sowing. Pearl millet variety HHB 223 and whaet variety WH 1105 sown during kharif and rabi season.

**Results 2016-17**

**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 3.40). The values of yield attributes and yield of pearlmillet were at par in the treatments receiving 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. 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 3.41).

Table 3.40 Effect of various treatments on grain yield and yield attributes of pearl millet

| Treatments | Plant height (cm) | Effective tillers/mrl | Earhead length (cm) | Test weight (g) | Grain yield (q/ha) |
|---|---|---|---|---|---|
| $T_1$: 75% RDF | 186.34 | 20.41 | 19.14 | 7.10 | 26.10 |
| $T_2$: RDF | 200.93 | 25.65 | 20.86 | 7.66 | 29.03 |
| $T_3$: 75% RDF + ST-3 | 186.38 | 20.42 | 19.24 | 7.14 | 26.77 |
| $T_4$: RDF + ST-3 | 201.23 | 25.84 | 20.97 | 7.68 | 29.24 |
| $T_5$: 75% RDF +2.5t/ha biogas slurry + ST-3 | 197.33 | 21.79 | 21.31 | 7.64 | 29.33 |
| $T_6$: RDF +2.5t/ha biogas slurry + ST-3 | 207.51 | 26.52 | 22.33 | 8.01 | 31.65 |
| $T_7$: 75% RDF + 2.5t/ha Vermicompost + ST-3 | 198.23 | 21.87 | 21.40 | 7.66 | 29.53 |
| $T_8$: RDF + 2.5t/ha Vermicompost + ST-3 | 208.49 | 26.55 | 22.53 | 8.02 | 31.58 |
| $T_9$: 75% RDF + 10t/ha FYM + Biomix | 198.83 | 23.02 | 21.83 | 7.81 | 30.08 |
| $T_{10}$: RDF + 10t/ha FYM + Biomix | 211.77 | 27.44 | 22.80 | 8.05 | 32.54 |
| $T_{11}$: 75% RDF + 2.5t/ha Vermicompost + Biomix | 198.62 | 22.31 | 21.77 | 7.72 | 29.67 |
| $T_{12}$: RDF + 2.5t/ha Vermicompost + Biomix | 209.74 | 26.97 | 22.63 | 8.03 | 31.97 |
| CD (p=0.05) | 9.02 | 4.56 | 1.40 | 0.52 | 2.25 |

Table 3.41 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) |
|---|---|---|---|---|
| $T_1$: 75% RDF | 91.23 | 38.29 | 39.57 | 59.18 |
| $T_2$: RDF | 93.20 | 39.73 | 43.91 | 64.64 |
| $T_3$: 75% RDF + ST-3 | 92.87 | 38.73 | 40.73 | 59.33 |
| $T_4$: RDF + ST-3 | 93.25 | 39.60 | 44.64 | 64.85 |
| $T_5$: 75% RDF +2.5t/ha biogas slurry + ST-3 | 97.27 | 39.30 | 44.91 | 65.21 |
| $T_6$: RDF +2.5t/ha biogas slurry + ST-3 | 97.73 | 40.11 | 49.00 | 69.09 |
| $T_7$: 75% RDF + 2.5t/ha Vermicompost + ST-3 | 97.40 | 39.40 | 44.87 | 65.44 |
| $T_8$: RDF + 2.5t/ha Vermicompost + ST-3 | 97.79 | 40.17 | 48.79 | 69.31 |
| $T_9$: 75% RDF + 10t/ha FYM + Biomix | 98.40 | 39.62 | 46.38 | 66.56 |
| $T_{10}$: RDF + 10t/ha FYM + Biomix | 101.70 | 40.53 | 50.01 | 70.75 |
| $T_{11}$: 75% RDF + 2.5t/ha Vermicompost + Biomix | 98.37 | 39.57 | 46.20 | 65.96 |
| $T_{12}$: RDF + 2.5t/ha Vermicompost + Biomix | 99.20 | 40.27 | 49.40 | 69.96 |
| CD (p=0.05) | 4.79 | NS | 4.15 | 4.21 |

**Results 2017-18**

**Pearl millet:** The maximum plant height (215 cm), yield attributes viz., effective tillers/plant, earhead length (cm) and grain yield (36.33 q/ha) of pearl millet was obtained with RDF + FYM 10 t/ha + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (36.08 q/ha). The minimum grain yield (29.21 q/ha) was recorded with 75% RDF alone (Table 3.42 and 3.43).

Table 3.42 Effect of various treatments on yield attributes of pearl millet under saline water irrigation

| Treatments (Pearl millet) | Plant height at maturity (cm) | No. of effective tillers/plant | Earhead length (cm) |
|---|---|---|---|
| $T_1$: 75% RDF | 189.20 | 2.20 | 19.37 |
| $T_2$: RDF | 204.00 | 2.81 | 21.13 |
| $T_3$: 75% RDF + ST-3 | 189.22 | 2.23 | 19.51 |
| $T_4$: RDF + ST-3 | 204.33 | 2.82 | 21.23 |
| $T_5$: 75% RDF +2.5t/ha biogas slurry + ST-3 | 200.37 | 2.48 | 21.58 |
| $T_6$: RDF +2.5t/ha biogas slurry + ST-3 | 210.67 | 3.08 | 22.61 |
| $T_7$: 75% RDF + 2.5t/ha Vermicompost + ST-3 | 201.27 | 2.50 | 21.67 |
| $T_8$: RDF + 2.5t/ha Vermicompost + ST-3 | 211.67 | 3.09 | 22.82 |
| $T_9$: 75% RDF + 10t/ha FYM + Biomix | 201.87 | 2.56 | 22.58 |
| $T_{10}$: RDF + 10t/ha FYM + Biomix | 215.00 | 3.20 | 22.92 |
| $T_{11}$: 75% RDF + 2.5t/ha Vermicompost + Biomix | 201.67 | 2.63 | 22.03 |
| $T_{12}$: RDF + 2.5t/ha Vermicompost + Biomix | 212.93 | 3.15 | 22.90 |
| CD (p=0.05) | 9.29 | 0.57 | 1.39 |

Table 3.43 Effect of various treatments on yield (q/ha) of pearl millet under saline water irrigation

| Treatment | Grain yield (q/ha) | Stover yield (q/ha) |
|---|---|---|
| 75% RDF | 29.21 | 85.61 |
| RDF | 32.98 | 94.19 |
| 75% RDF +ST-3 | 29.96 | 86.87 |
| RDF +ST-3 | 33.01 | 94.35 |
| 75% RDF +2.5t/ha biogas slurry + ST-3 | 33.73 | 94.30 |
| RDF +2.5t/ha biogas slurry + ST-3 | 36.04 | 100.60 |
| 75% RDF + 2.5t/ha Vermicompost + ST-3 | 33.26 | 94.37 |
| RDF + 2.5t/ha Vermicompost + ST-3 | 36.08 | 100.68 |
| 75% RDF + 10t/ha FYM + Biomix | 33.95 | 95.46 |
| RDF + 10t/ha FYM + Biomix | 36.33 | 101.75 |
| 75% RDF + 2.5t/ha Vermicompost + Biomix | 33.85 | 95.06 |
| RDF + 2.5t/ha Vermicompost + Biomix | 36.21 | 101.38 |
| CD (p=0.05) | 2.90 | 5.72 |

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

**Wheat:** The maximum grain yield (52.51 q/ha) of wheat (WH 1105) was obtained with RDF + 10t/ha FYM + Biomix followed by RDF +2.5 t/ha vermicompost + Biomix (52.06 q /ha).The minimum grain yield (41.91 q/ha) was recorded with 75% RDF alone (Table 3.44).

Table 3.44 Effect of various treatments on yield (q/ha) of wheat under saline water irrigation

| Treatment | Grain yield (q/ha) | Straw yield (q/ha) |
|---|---|---|
| $T_1$: 75% RDF | 41.91 | 66.69 |
| $T_2$: RDF | 46.81 | 73.35 |
| $T_3$: 75% RDF + ST-3 | 42.39 | 67.17 |
| $T_4$: RDF + ST-3 | 47.09 | 73.70 |
| $T_5$: 75% RDF +2.5t/ha biogas slurry + ST-3 | 47.83 | 74.04 |
| $T_6$: RDF +2.5t/ha biogas slurry + ST-3 | 51.53 | 77.44 |
| $T_7$: 75% RDF + 2.5t/ha Vermicompost + ST-3 | 48.68 | 74.09 |
| $T_8$: RDF + 2.5t/ha Vermicompost + ST-3 | 52.06 | 78.14 |
| $T_9$: 75% RDF + 10t/ha FYM + Biomix | 50.93 | 76.96 |
| $T_{10}$: RDF + 10t/ha FYM + Biomix | 52.91 | 81.11 |
| $T_{11}$: 75% RDF + 2.5t/ha Vermicompost + Biomix | 50.55 | 74.01 |
| $T_{12}$: RDF + 2.5t/ha Vermicompost + Biomix | 52.66 | 80.29 |
| CD (p=0.05) | 3.71 | 5.82 |

**Evaluation of Sewage-sludge as a Source of NPK for Pearl millet-wheat Rotation Irrigated with Saline Water (Hisar)**

The experiment was carried out at Soil Research Farm, CCS HAU, Hisar in rabi season of 2016-17 and 2017-18 to investigate the availability of NPK from sewage-sludge in pearl millet-wheat cropping system under saline conditions and to determine the effect of incorporation of sewage-sludge on physico-chemical properties of soil. Treatments comprised of 3 water quality (Canal, $EC_{iw}$ 8, 10 dS/m) and three sewage-sludge application (SS: 5 t $ha^{-1}$; SS: 5 t $ha^{-1}$ + 50% RDF; SS: 5 t $ha^{-1}$ + 75% RDF) and replicated thrice in RBD.

**Results (2016-17)**

**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 treatment sewage-sludge 5 t/ha (alone), sewage-sludge 5t/ha + 50% RDF and sewage-sludge 5t/ha + 75% RDF as compared with RDF (Table 3.45).

**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 5t/ha (alone), sewage-sludge 5t/ha + 50% RDF and sewage-sludge 5t/ha + 75% RDF as compared with RDF (Table 3.46). The mean salinity in the soil profile (0-30cm) at wheat harvest varied from 2.88 dS/m (0-15cm) to 10.44 dS/m (15-30cm) in canal water to the highest EC irrigating water (Table 3.47).

Table 3.45 Effect of sewage-sludge on grain yield of pearl millet irrigated with saline water

| Treatment | Grain yield (q/ha) | | | |
|---|---|---|---|---|
| | Canal (0.3) | $EC_{iw}$ 8 dS/m | $EC_{iw}$ 10 dS/m | Mean |
| Sewage-sludge 5t/ha | 25.57 | 19.17 | 17.50 | 20.74 |
| Sewage-sludge 5t/ha+50% RDF | 28.56 | 21.83 | 19.47 | 23.29 |
| Sewage-sludge 5t/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 (p=0.05) | SS: 3.54; Salinity (S): 3.06; SS x S : NS | | | |

Table 3.46 Effect of sewage sludge on grain yield of wheat irrigated with saline water of different salinity

| Treatment | Grain yield (q/ha) | | | |
|---|---|---|---|---|
| | Canal (0.3) | $EC_{iw}$ 8 dS/m | $EC_{iw}$ 10 dS/m | Mean |
| Sewage-sludge 5t/ha | 33.51 | 30.03 | 26.58 | 30.04 |
| Sewage-sludge 5t/ha+50% RDF | 43.84 | 39.81 | 34.29 | 39.31 |
| Sewage-sludge 5t/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 (p=0.05) | SS: 4.05; Salinity (S): 3.51; SS x S : NS | | | |

Table 3.47 Soil salinity at different depths (cm) after wheat harvest

| Treatments | Soil $EC_e$ (dS/m) | | | | | |
|---|---|---|---|---|---|---|
| | Canal | | $EC_{iw}$ 8 dS/m | | $EC_{iw}$ 10 dS/m | |
| | 0-15 | 15-30 | 0-15 | 15-30 | 0-15 | 15-30 |
| Sewage-sludge 5t/ha | 3.10 | 3.20 | 10.18 | 10.78 | 10.72 | 10.84 |
| Sewage-sludge 5t/ha+50% RDF | 3.18 | 336 | 9.00 | 10.30 | 10.18 | 10.80 |
| Sewage-sludge 5t/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 |

**Results (2017-18)**

**Pearl millet**: The grain yield of pearl millet (HHB 226) decreased by 23.03 and 31.08 % in all saline water irrigation of $EC_{iw}$ 8 and 10 dS/m as compared to canal irrigation. A reduction of 20.56, 11.14 and 4.89% in grain yield of pearl millet was observed in sewage-sludge 5 t/ha (alone), sewage-sludge 5t/ha + 50% RDF and sewage-sludge 5t/ha + 75% RDF as compared with RDF (Table 3.48).

**Wheat**: The grain yield of wheat (WH 1105) decreased by 23.1 and 36.25% in all saline water irrigation of $EC_{iw}$ 8 and 10 dS/m as compared to canal water. Reduction of 31.98, 12.33 and 5.98 % in grain yield of wheat was observed in sewage-sludge 5t/ha (alone), sewage-sludge 5t/ha + 50% RDF and sewage-sludge 5t/ha + 75% RDF as compared with RDF (Table 3.49). The mean salinity in the soil profile at wheat harvest varied from 2.87 dS/m (0-15cm) to 12.81 dS/m (0-15cm) in canal water to the highest $EC_{iw}$ (Table 3.50).

Table 3.48 Effect of sewage-sludge on grain yield of pearl millet irrigated with saline water

| Treatments | Grain yield (q/ha) of pearl millet | | | |
|---|---|---|---|---|
| | Canal (0.3) | $EC_{iw}$ 8 dS/m | $EC_{iw}$ 10 dS/m | Mean |
| Sewage-sludge 5t/ha | 27.19 | 21.20 | 18.35 | 22.25 |
| Sewage-sludge 5t/ha+50% RDF | 30.83 | 23.17 | 20.68 | 24.89 |
| Sewage-sludge 5t/ha+75% RDF | 32.59 | 24.75 | 22.58 | 26.64 |
| RDF | 33.57 | 26.47 | 24.00 | 28.01 |
| Mean | 31.05 | 23.90 | 21.40 | |
| CD (p=0.05) | SS: 3.28; Salinity (S): 2.84; SS x S : NS | | | |

*Composition of sewage- sludge: N=1.05 %, P = 0.46 %, K = 0.59 %, Pb = 40.35 ppm, Cd = 6.26 ppm, Cr = 126.57 ppm and Ni = 38.4 ppm*

Table 3.49 Effect of sewage-sludge on grain yield of wheat irrigated with saline water

| Treatments | Grain yield (q/ha) | | | |
|---|---|---|---|---|
| | Canal (0.3) | $EC_{iw}$ 8 dS/m | $EC_{iw}$ 10 dS/m | Mean |
| Sewage sludge 5t/ha | 32.25 | 24.15 | 20.02 | 25.47 |
| Sewage sludge 5t/ha+50% RDF | 40.93 | 31.45 | 26.11 | 32.83 |
| Sewage sludge 5t/ha+75% RDF | 44.17 | 33.77 | 27.78 | 35.21 |
| RDF | 46.04 | 36.12 | 30.18 | 37.45 |
| Mean | 40.83 | 31.37 | 26.02 | |
| CD (p=0.05) | SS: 4.38; Salinity (S): 3.79; SS x S : NS | | | |

Table 3.50 Soil salinity at different depths (0-15cm) after wheat harvest

| Treatments | $EC_e$ (dS/m) | | |
|---|---|---|---|
| | Canal | $EC_{iw}$ 8 dS/m | $EC_{iw}$ 10 dS/m |
| Sewage-sludge 5t/ha | 3.16 | 11.86 | 12.88 |
| Sewage-sludge 5t/ha+50% RDF | 3.04 | 11.15 | 12.68 |
| Sewage-sludge 5t/ha+75% RDF | 2.86 | 10.82 | 12.24 |
| RDF | 2.42 | 10.04 | 11.44 |
| Mean | 2.87 | 10.96 | 12.31 |

**Effect of Nitrogen Fertigation Utilizing Good and Saline Water under Drip Irrigation System in Vegetable Crops (Hisar)**

This experiment was initiated during 2016-17 to study the effect of nitrogen fertigation on onion crop and to study the salt and water dynamics in drip irrigated soil. The treatments comprised of three quality of irrigation water (CW 0.3; SW 2.5, 5.0 dS/m) and three nitrogen fertilizer levels (75% RDN; RDN; 125% RDN).

**Results 2016-17**

The fruit yield of tomato under different N and salinity levels under drip irrigation (Table 3.51) revealed that under 75% RDN application, the relative fruit yields of tomato were 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. With RDN application, the relative fruit yields of tomato were 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. With 125% RDN application, the relative fruit yields of tomato were 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 yield recorded in canal water irrigation. Significant reductions in tomato fruit yields were recorded at $EC_{iw}$ 5.0 and 7.5 dS/m as compared to canal water. 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 3.51 Effect of nitrogen fertigation under saline water drip irrigation on tomato yield

| N Level | Fruit yield of tomato (q/ha) | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | $EC_{iw}$ 2.5 dS/m | $EC_{iw}$ 5.0 dS/m | $EC_{iw}$ 7.5 dS/m | Mean |
| 75% RDN | 390.2 | 378.0 | 345.9 | 298.8 | 353.2 |
| 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 (p=0.05) | | Nitrogen (N): 12.2, | Salinity (S) : 19.2, | N x S : NS | |

**Results 2017-18**

The yield of onion under different N and salinity levels under drip irrigation (Table 3.52) revealed that under 75% RDN application, the relative yields of onion were obtained 94.50 and 65.74 % when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to the yield recorded in canal water irrigation. With RDN application, the relative yields of onion were 95.41 and 69.67% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to yield recorded in canal water irrigation. With 125% RDN application, the relative yields of onion were 94.51 and 68.79% when irrigated with saline water of 2.5 and 5.0 dS/m, respectively, as compared to yield recorded in canal water irrigation. Significant reduction in onion yield was recorded at $EC_{iw}$ 5.0 dS/m as compared to canal water irrigation. Significantly highest yield of onion was recorded with the application of 125% RDN.

Table 3.52 Effect of nitrogen fertigation under saline water in drip irrigation on onion yield (q/ha)

| N Level | Onion yield (q/ha) | | | |
|---|---|---|---|---|
| | Canal | $EC_{iw}$ 2.5 dS/m | $EC_{iw}$ 5.0 dS/m | Mean |
| 75% RDN | 271.77 | 256.84 | 178.67 | 235.76 |
| RDN | 319.95 | 305.27 | 222.93 | 282.72 |
| 125% RDN | 355.75 | 333.35 | 250.23 | 313.11 |
| Mean | 315.82 | 298.49 | 217.28 | |
| CD (p=0.05) | | Nitrogen (N) : 19.94, | Salinity (S) : 17.51, | 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 experiment was to study response of leafy vegetables to saline water irrigation and to study the changes in soil properties. The experiment was conducted during *rabi* 2016-17 and rabi 2017-18 for Radish, Dill and Spinach with five levels of saline water irrigation. Details of experiment during 2016-17 are provided below.

**Results 2016-17**

The intial pH and EC of experimental soil were 6.82 and 2.35 dS/m, respectively. Other chemical properties are provided in Table 3.53. The experimental soil was clay loam in texture, neutral in reaction, medium in available nitrogen and phosphorus and very high in potassium. Details of treatments for saline water use irrigation are given in Table 3.54.

Table 3.53 Initial soil properties of experimental plot

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

Table 3.54 Treatments Details

| A) Crop | B) Salinity of irrigation water |
|---|---|
| Spinach ($C_1$)<br>Dill ($C_2$)<br>Radish ($C_3$) | • Pond water ($T_1$)<br>• 2 $dSm^{-1}$($T_2$)<br>• 4 $dSm^{-1}$($T_3$)<br>• 6 $dSm^{-1}$($T_4$)<br>• 8 $dSm^{-1}$($T_5$) |

The soil salinity values at harvest of vegetable crops (at 90 days) are provided in Table 3.55. There is increase in soil salinity values with increase in irrigation water salinity.

Table 3.55 Soil Electrical Conductivity at 90 days after sowing

| Treatment | Spinach ($C_1$) | Dill ($C_2$) | Radish ($C_3$) | Mean |
|---|---|---|---|---|
| • Pond water ($T_1$) | 6.44 | 6.61 | 6.44 | 6.50 |
| • 2 $dSm^{-1}$($T_2$) | 5.55 | 8.35 | 6.59 | 6.83 |
| • 4 $dSm^{-1}$($T_3$) | 8.86 | 8.48 | 8.59 | 8.64 |
| • 6 $dSm^{-1}$($T_4$) | 8.05 | 8.41 | 8.63 | 8.37 |
| • 8 $dSm^{-1}$($T_5$) | 10.22 | 10.34 | 10.23 | 10.26 |
| Mean | 7.82 | 8.44 | 8.09 | |
| SE± m for salinity levels=0.57 | | SE± m for crop=0.44 | SE± m for interaction=0.99 | |
| CD (5%)=1.65 | | CD (5%)=1.27 | CD (5%)=2.85 | |

Data about influence of irrigation water salinity on crop yield are provided in Table 3.56. 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, $T_1$C3 *i.e.* irrigation of radish crop with pond water recorded significantly higher yield over rest of all the interactions. The irrigation water salinity-yield relations are provided in Table 3.57.

Table 3.56 Influence of irrigation water salinity on crop yield (t/ha)

| Treatments | Spinach ($C_1$) | Dill ($C_2$) | Radish ($C_3$) | MEAN |
|---|---|---|---|---|
| • Pond water ($T_1$) | 9.47 | 10.89 | 20.15 | 13.50 |
| • 2 $dSm^{-1}$($T_2$) | 9.71 | 9.99 | 16.34 | 12.01 |
| • 4 $dSm^{-1}$($T_3$) | 7.28 | 10.40 | 10.48 | 9.39 |
| • 6 $dSm^{-1}$($T_4$) | 9.87 | 7.83 | 15.96 | 11.22 |
| • 8 $dSm^{-1}$($T_5$) | 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 |

Table 3.57 Mathematical models for yield under irrigation with saline water

| Sr. No. | Crop | Equation | $R^2$ Value |
|---|---|---|---|
| 1. | Radish | Y (t $ha^{-1}$)= -0.055*EC (dS $m^{-1}$) + 9.254 | $R^2 = 0.0271$ |
| 2. | Dill | Y (t $ha^{-1}$) = -1.752*EC (dS $m^{-1}$) + 13.72 | $R^2 = 0.768$ |
| 3. | Spinach | Y (t $ha^{-1}$) = -0.85*EC (dS $m^{-1}$) + 18.354 | $R^2 = 0.1517$ |

**Results 2017-18**

The experiment with above explained details continued during 2017-18. The soil salinity at harvest of vegetable crops and crop yields are provided in Table 3.58.

Table 3.58 Soil Electrical Conductivity at 90 days after sowing

| Treatment | Spinach ($C_1$) | Dill ($C_2$) | Radish ($C_3$) | Mean |
|---|---|---|---|---|
| • Pond water ($T_1$) | 6.43 | 6.65 | 6.30 | 6.46 |
| • 2 $dSm^{-1}$($T_2$) | 5.66 | 8.21 | 6.66 | 6.84 |
| • 4 $dSm^{-1}$($T_3$) | 8.87 | 8.45 | 8.53 | 8.62 |
| • 6 $dSm^{-1}$($T_4$) | 8.13 | 8.49 | 8.67 | 8.43 |
| • 8 $dSm^{-1}$($T_5$) | 10.25 | 7.42 | 10.30 | 9.32 |
| Mean | 7.87 | 7.84 | 8.09 | |
| SE± m for salinity levels=0.68 | | SE± m for crop=0.53 | | SE± m for interaction=1.17 |
| CD (5%)=1.96 | | CD (5%)=1.52 | | CD(5%)=3.40 |

Soil salinity data at harvest of first year and second year crops indicated that soil salinity buildup due to saline water irrigation under different treatments was reduced because of leaching in monsoon season. Therefore, there was not cumulative build up of salts as result of two years'saline water irrigation under different treatments.

As far as effect of salinity of irrigation water is concerned, application of pond water $T_1$ (13.47 t $ha^{-1}$) showed significantly higher vegetable yield over rest of all treatments except $T_2$ (11.99 t $ha^{-1}$) which was found to be at par with $T_1$. The crop $C_3$*i.e.* radish (15.63 t $ha^{-1}$) produced significantly higher yield over $C_1$ and $C_2$. In case of interaction effect, $T_1C_3$*i.e.*irrigation of radish crop with pond water recorded significantly higher yield over rest of all the interactions (Table 3.59). The irrigation water salinity-yield relations are provided in Table 3.60.

Table 3.59 Influence of irrigation water salinity on crop yield (t/ha)

| Treatments | Spinach ($C_1$) | Dill ($C_2$) | Radish ($C_3$) | Mean |
|---|---|---|---|---|
| • Pond water ($T_1$) | 9.82 | 10.81 | 19.79 | 13.47 |
| • 2 $dSm^{-1}$($T_2$) | 9.77 | 9.98 | 16.21 | 11.99 |
| • 4 $dSm^{-1}$($T_3$) | 7.31 | 10.33 | 10.39 | 9.34 |
| • 6 $dSm^{-1}$($T_4$) | 9.82 | 7.82 | 15.98 | 11.20 |
| • 8 $dSm^{-1}$($T_5$) | 8.86 | 3.30 | 15.79 | 9.32 |
| MEAN | 9.11 | 8.45 | 15.63 | |
| 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%)=1.36 | CD(5%)=3.04 | |

Table 3.60 Mathematical models for yield under irrigation with saline water

| Sr. No. | Crop | Equation | $R^2$ Value |
|---|---|---|---|
| 1. | Radish | Y (t $ha^{-1}$) = -0.0935*EC (dS $m^{-1}$) + 9.49 | $R^2 = 0.0737$ |
| 2. | Dill | Y (t $ha^{-1}$) = -1.718*EC (dS $m^{-1}$) + 13.602 | $R^2 = 0.7693$ |
| 3. | Spinach | Y(t $ha^{-1}$) = -0.823*EC (dS $m^{-1}$) + 18.101 | $R^2 = 0.1497$ |

## 3.3 MANAGEMENT OF WASTE WATER

### Management of Sewage Water as a Source of Irrigation and Nutrients (Agra)

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

The net profit of different treatments in cluster bean was calculated and presented in Table 3.61. In cluster bean crop, maximum net profit (Rs/ha) and B:C ratio were observed in sewage water irrigation treatment (83,114 & 1.69) and minimum in case of tube well water irrigation treatment (58,496 & 1.21). In the use of recommended dose of fertilizer, 100% RDF gave maximum net profit (Rs/ha) and B:C ratio (80,005 & 1.57) and minimum with tube well water irrigation treatments (64,085 & 1.38).

Table 3.61 Effect of different treatments on attributes and yield of cluster bean (Av. 2016-17 and 2017-18)

| Treatments | Pod length (cm) | Pod yield /plant (g) | Pod yield (q/ha) | | | Net profit (Rs.) | B: C ratio |
|---|---|---|---|---|---|---|---|
| | | | 2016 | 2017 | Mean | | |
| Irrigation water | | | | | | | |
| SW | 11.31 | 343.47 | 117.7 | 121.9 | 119.8 | 83,114 | 1.69 |
| TW | 9.87 | 314.56 | 109.2 | 87.9 | 98.6 | 58,496 | 1.21 |
| 1 SW:1TW | 10.75 | 334.65 | 112.4 | 117.3 | 114.9 | 77,713 | 1.58 |
| CD at 5% | 0.55 | 5.80 | 3.3 | 11.1 | 7.2 | - | - |
| Recommended dose of fertilizer | | | | | | | |
| 50% | 9.99 | 324.43 | 102.5 | 99.6 | 101.1 | 64,085 | 1.38 |
| 75% | 10.44 | 331.11 | 115.5 | 110.6 | 113.0 | 75,235 | 1.54 |
| 100% | 11.20 | 337.28 | 121.3 | 117.6 | 119.5 | 80,005 | 1.57 |
| CD at 5% | 0.55 | 5.80 | 3.3 | 11.1 | 7.2 | - | - |
| IW X F | NS | NS | 8.54 | 19.23 | 13.88 | - | - |

### Interaction

The interaction effect of irrigation water and recommended dose of fertilizer on yield of cluster bean was found significant. A critical examination of the data (Table 3.62) revealed that irrigation water exhibited differential response to RDF. With all irrigation waters, the yield increased with every increase in the rate of RDF up to 100%. When rate of RDF was increased from 75% to 100% RDF, the yield per hectare was marginally increased. The maximum yield was obtained with the use of sewage water and 100% RDF, which was significantly higher than that of rest of combinations. After harvest of cluster bean crop, the cauliflower crop was grown during rabi season with different irrigation waters and recommended dose of fertilizers.

Table 3.63 clearly indicated that the application of irrigation water and dose of fertilizer gave the significant results in no. of leaves per plant and weight of head (g). All attributes were maximum in sewage irrigated treatments and minimum in tube well irrigated treatments. In case of application of fertilizer the highest no. of leaves per plant, circumference (cm) and weight of head (g) was highest in 100% RDF and lowest in 50% RDF. In cauliflower crop, maximum net profit (Rs/ha) and B:C ratio was produced in sewage water irrigation treatment (1,02,583 and 1.68) and minimum was in tube well water irrigation treatments (66,876 & 1.09). The use of recommended dose of fertilizer 100% RDF gave maximum net profit (Rs/ha) and B:C ratio (98,751 and 1.57) and minimum was 50% recommended dose of fertilizer treatments (65,911 and 1.14).

Table 3.62 Interaction effect of irrigation water x fertilizer dose in cluster bean crop (Av. 2016-17 and 2017-18)

| Irrigation water/ fertilizer | 50% | 75% | 100% | Total | Av. |
|---|---|---|---|---|---|
| SW | 110.1 | 121.5 | 127.8 | 359.4 | 119.8 |
| TW | 87.7 | 101.0 | 108.0 | 296.7 | 98.9 |
| 1SW:1TW | 104.7 | 116.6 | 123.5 | 344.8 | 114.9 |
| Total | 302.5 | 339.1 | 359.3 | - | - |
| Av | 100.8 | 113.0 | 119.8 | - | - |
| CD at 5% = | 13.8 | | | | |

Table 3.63 Effect of different treatments on yield attributes and yields of cauliflower (Av. 2016-17 to 2017-18)

| Treatments | No. of green leaves | Flower weight (gm) | yield q/ha | | | Net profit (Rs.) | B: C ratio |
|---|---|---|---|---|---|---|---|
| | | | 2016-17 | 2017-18 | Mean | | |
| | | | Irrigation water | | | | |
| SW | 20.22 | 542.55 | 230.2 | 234.5 | 232.3 | 1,02,583 | 1.68 |
| TW | 14.28 | 417.79 | 187.2 | 177.4 | 182.3 | 66,876 | 1.09 |
| 1 SW:1TW | 17.67 | 469.32 | 214.8 | 217.7 | 216.3 | 91,226 | 1.50 |
| CD at 5% | 3.01 | 9.32 | 7.9 | 7.5 | 7.7 | - | - |
| | | | Recommended dose of fertilizer | | | | |
| 50% | 16.28 | 463.44 | 176.9 | 175.8 | 176.3 | 65,911 | 1.14 |
| 75% | 17.22 | 478.64 | 223.8 | 223.1 | 223.5 | 96,024 | 1.58 |
| 100% | 18.64 | 488.59 | 231.6 | 230.7 | 231.2 | 98,751 | 1.57 |
| CD at 5% | 3.01 | 9.32 | 7.9 | 7.5 | 7.7 | - | - |
| IW X F | NS | NS | 13.76 | 21.22 | 17.49 | - | - |

**Interaction**

The interaction effect of irrigation water and recommended dose of fertilizer on head yield of cauliflower was found to be significant. A critical examination of the data (Table 3.64) revealed that irrigation water exhibited differential response to RDF. The irrigation water use in cauliflower crop, the head yield was increased with every increase in the rate of RDF up to 100%. Where the rate of RDF was increased from 75% to 100% RDF the head yield per hectare marginally increased. The maximum head yield was obtained with the use of sewage water and 100% RDF which was significantly higher than that of rest combinations.

Table 3.64 Interaction effect of irrigation water x fertilizer dose in cauliflower (Av.2016-17 and 2017-18)

| Irrigation water/ fertilizer | 50% | 75% | 100% | Total | Av. |
|---|---|---|---|---|---|
| SW | 196.1 | 247.3 | 253.6 | 697.0 | 232.3 |
| TW | 150.9 | 192.7 | 203.6 | 547.2 | 182.4 |
| 1SW:1TW | 182.1 | 230.3 | 236.3 | 648.7 | 216.2 |
| Total | 529.1 | 670.3 | 693.5 | - | |
| Av | 176.4 | 223.4 | 231.2 | - | |
| CD at 5% = | 17.5 | | | | |

After harvest of cauliflower crop, okra crop was sown in summer season. In okra crop, the significantly maximum pod yield (131.9 q/ha) was produced in sewage water irrigation and minimum (65.7 q/ha) in tube well water irrigation. The application of recommended dose of fertilizer significantly higher pod yield (114.4 q/ha) was produced in 100% RDF and lowest in (80.5 q/ha) in 50% RDF (Table 3.65). In okra crop maximum net profit (Rs/ha) and B:C ratio was produced in sewage water irrigation treatment (1,15,718 & 1.43) and minimum with tube water irrigation treatments (12,965 & 0.17). The use of recommended dose of fertilizer 100% RDF gave maximum net profit (Rs/ha) and B:C ratio (88,379 and 1.06) and minimum was 50% RDF treatments (36,250 and 0.48) .

Table 3.65 Effect of different treatments on yield and economics of okra crop (Av.2016-17 & 2017-18)

| Treatments | Length of pod (cm) | Pod yield per plant (g) | yield (q/ha) | | | Net profit (Rs.) | B: C ratio |
|---|---|---|---|---|---|---|---|
| | | | 2016-17 | 2017-18 | Mean | | |
| Irrigation water | | | | | | | |
| SW | 10.46 | 316.11 | 199.4 | 64.6 | 131.9 | 1,15,718 | 1.43 |
| TW | 8.37 | 244.13 | 102.6 | 28.7 | 65.7 | 12,965 | 0.17 |
| 1 SW:1TW | 9.92 | 280.91 | 158.7 | 44.2 | 101.5 | 64,903 | 0.70 |
| CD at 5% | 1.17 | 7.68 | 7.6 | 8.1 | 7.9 | - | - |
| Recommended dose of fertilizer | | | | | | | |
| 50% | 7.89 | 266.54 | 127.4 | 33.6 | 80.5 | 36,250 | 0.48 |
| 75% | 9.90 | 280.72 | 162.4 | 46.0 | 104.2 | 69,458 | 0.87 |
| 100% | 10.98 | 293.84 | 170.9 | 57.9 | 114.4 | 88,379 | 1.06 |
| CD at 5% | 1.17 | 7.68 | 7.6 | 8.1 | 7.9 | - | - |
| IW X F | NS | NS | 13.22 | 14.08 | 13.65 | - | - |

**Interaction**

The interaction effect of irrigation water and recommended dose of fertilizer on pod yield of okra crop was found to be significant. A critical examination of the data displayed in Table 3.66 revealed that, irrigation water exhibited differential response to RDF. The irrigation water use in okra crop the pod yield was increased with every increase in the rate of RDF up to 100%. Where the rate of RDF was increased from 75% to 100% RDF the 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 that of rest combinations

Table 3.66 Interaction effect of irrigation water x fertilizer dose in okra crop (Av. 2016-17 & 2017-18)

| Irrigation water/ fertilizer | 50% | 75% | 100% | Total | Av. |
|---|---|---|---|---|---|
| SW | 103.7 | 141.2 | 150.9 | 395.8 | 131.9 |
| TW | 53.7 | 65.9 | 77.4 | 197.0 | 65.6 |
| 1SW:1TW | 84.1 | 105.5 | 114.8 | 304.4 | 104.5 |
| Total | 241.5 | 312.6 | 343.1 | - | - |
| Av | 80.5 | 104.2 | 171.6 | - | - |
| CD at 5% = | 13.6 | | | | |

**Rotational net profit and B:C ratio**

The two years average annually net profit for rotation cluster bean-cauliflower-okra was calculated and presented in Table 3.67. The maximum net profit of the three crops grown in one year found in sewage water irrigation treatment Rs. 3,02,415 and lowest in tube well water irrigated treatment Rs. 1,38,337. The benefit cost ratio in this rotation was calculated and maximum in sewage water irrigation treatment (4.80) and minimum in tube well irrigated treatment (2.48).The application of recommended dose of fertilizer the maximum net profit and B: C ratio was found in 100% RDF (Rs.2,67,135 and 4.20) and minimum 50% RDF (Rs. 1,66,246 and 2.92).

Table 3.67 Effect of different treatments on net profit and benefit cost ratio of cluster bean, cauliflower and okra crop (Av. 2016-17 and 2017-18)

| Treat | Net profit(Rs./ha) | | | | B:C ratio | | | |
|---|---|---|---|---|---|---|---|---|
| | Cluster bean | Cauliflower | Okra | Total | Cluster bean | Cauliflower | Okra | Total |
| Irrigation water | | | | | | | | |
| SW | 84,114 | 1,02,583 | 1,15,718 | 3,02,415 | 1.69 | 1.68 | 1.43 | 4.80 |
| TW | 58,496 | 66,876 | 12,965 | 1,38,337 | 1.21 | 1.10 | 0.17 | 2.48 |
| 1 SW:1TW | 77,713 | 91,226 | 64,903 | 2,33,842 | 1.58 | 1.50 | 0.70 | 3.78 |
| Recommended dose of fertilizer | | | | | | | | |
| 50% | 64,085 | 65,911 | 36,250 | 1,66,246 | 1.38 | 1.14 | 0.48 | 3.00 |
| 75% | 75,235 | 96,024 | 69,457 | 2,40,716 | 1.54 | 1.58 | 0.87 | 3.99 |
| 100% | 80,005 | 98,751 | 88,379 | 2,67,135 | 1.57 | 1.57 | 1.06 | 4.20 |

**Cropping System Productivity**

The two years average system productivity of different crops in cluster bean-cauliflower-okra cropping sequence given in Table 3.68. In irrigation water the maximum system yield was observed in treated sewage water irrigation treatment 484.1 q/ha and minimum in tube well irrigated treatments 346.7q/ha. The use of recommended dose of fertilizer maximum system productivity produced in 100% RDF 464.9 q/ha and lowest in 50% RDF 357.9 q/ha.

**Soil analysis at sowing of cluster bean**

The soil sample was collected in different soil depth (0-15,15-30,30-60and 60-90cm) in cluster bean sowing time, cluster bean harvesting time ,cauliflower harvest time and okra harvest time and analyzed different cations and anaions but presented only two years average cluster bean sowing and okra harvest as given below (Table 3.69). The pH recorded in all the treatments at sowing time was in normal range. The sodium range was recorded (17.6-30.5) in the treatments of the experiment. The Ca+Mg present in all the soil samples collected at sowing time, $CO_3$ was not found but $HCO_3$ presence in all the samples. The chloride and sulphate was also present in all the samples collected at sowing of cluster bean crop. The SAR was present in all the collected soil samples but RSC not found any samples of at sowing time soil samples.

Table 3.68 Effect of different treatments on system productivity (Av. 2016-17 and 2017-18)

| Treatments | Cluster bean yield (q/ha) | Cauliflower yield (q/ha) | Okra yield (q/ha) | Cropping system yield (q/ha) |
|---|---|---|---|---|
| Irrigation water | | | | |
| SW | 119.8 | 232.4 | 131.9 | 484.1 |
| TW | 98.6 | 182.4 | 65.7 | 346.7 |
| 1SW:1TW | 114.8 | 216.3 | 101.5 | 432.6 |
| Recommended dose of fertilizer | | | | |
| 50% | 101.0 | 176.4 | 80.5 | 357.9 |
| 75% | 113.1 | 223.5 | 104.2 | 440.8 |
| 100% | 119.4 | 232.1 | 114.4 | 464.9 |

Table 3.69 Soil analysis at sowing of cluster bean crop (Av. 2016-17 and 2017-18)

| Treat. | Soil Depth (cm) | ECe (dS/m) | pH | Na (me/l) | Ca+Mg (me/l) | $CO_3$ (me/l) | $HCO_3$ (me/l) | Cl (me/l) | $SO_4$ (me/l) | SAR $(mmol/l)^{1/2}$ | RSC (me/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SW | 0-15 | 2.9 | 7.4 | 19.6 | 8.9 | - | 5.0 | 8.7 | 14.9 | 9.4 | - |
| 50%RDF | 15-30 | 2.7 | 7.3 | 19.8 | 7.3 | - | 4.5 | 8.1 | 14.4 | 9.2 | - |
| | 30-60 | 2.8 | 7.3 | 18.2 | 9.3 | - | 4.5 | 10.2 | 13.9 | 8.7 | - |
| | 60-90 | 2.7 | 7.2 | 16.7 | 9.4 | - | 4.5 | 7.9 | 13.6 | 8.2 | - |
| SW | 0-15 | 2.8 | 7.5 | 19.8 | 8.2 | - | 4.5 | 10.3 | 13.2 | 9.8 | - |
| 75%RDF | 15-30 | 2.8 | 7.3 | 20.2 | 7.9 | - | 4.5 | 9.1 | 13.9 | 9.5 | - |
| | 30-60 | 2.7 | 7.2 | 18.3 | 8.3 | - | 5.5 | 7.9 | 13.6 | 8.9 | - |
| | 60-90 | 2.7 | 7.3 | 17.7 | 8.7 | - | 4.0 | 7.8 | 14.8 | 8.6 | - |
| SW | 0-15 | 2.9 | 7.3 | 22.2 | 6.9 | - | 4.5 | 9.1 | 15.4 | 13.5 | - |
| 100%RDF | 15-30 | 2.8 | 7.2 | 21.3 | 6.6 | - | 4.5 | 8.9 | 14.7 | 10.3 | - |
| | 30-60 | 2.7 | 7.3 | 18.4 | 8.2 | - | 4.5 | 8.8 | 13.8 | 8.2 | - |
| | 60-90 | 2.7 | 7.3 | 17.6 | 9.3 | - | 5.0 | 9.9 | 11.6 | 8.4 | - |
| TW | 0-15 | 3.6 | 7.5 | 28.8 | 7.7 | - | 4.5 | 8.6 | 23.4 | 14.7 | - |
| 50%RDF | 15-30 | 3.3 | 7.2 | 25.5 | 7.6 | - | 5.0 | 7.3 | 20.8 | 11.9 | - |
| | 30-60 | 3.1 | 7.3 | 22.5 | 7.9 | - | 5.0 | 7.5 | 18.0 | 13.5 | - |
| | 60-90 | 3.0 | 7.3 | 21.4 | 7.7 | - | 4.5 | 9.5 | 15.2 | 12.8 | - |
| TW | 0-15 | 3.7 | 7.5 | 29.8 | 7.7 | - | 5.0 | 9.6 | 22.9 | 13.6 | - |
| 75%RDF | 15-30 | 3.4 | 7.4 | 23.7 | 9.7 | - | 4.5 | 7.3 | 21.8 | 11.7 | - |
| | 30-60 | 3.2 | 7.3 | 22.1 | 8.6 | - | 5.0 | 7.9 | 18.1 | 9.8 | - |
| | 60-90 | 3.1 | 7.3 | 21.9 | 8.2 | - | 5.5 | 8.9 | 15.7 | 9.8 | - |
| TW | 0-15 | 3.7 | 7.5 | 30.5 | 6.7 | - | 5.5 | 8.7 | 23.4 | 21.3 | - |
| 100%RDF | 15-30 | 3.3 | 7.3 | 24.5 | 8.9 | - | 5.5 | 8.1 | 19.9 | 10.7 | - |
| | 30-60 | 3.0 | 7.2 | 23.9 | 6.1 | - | 4.5 | 8.1 | 17.5 | 17.0 | - |
| | 60-90 | 2.9 | 7.3 | 22.7 | 6.8 | - | 5.0 | 8.3 | 16.3 | 14.1 | - |
| 1SW:1TW | 0-15 | 3.2 | 7.4 | 23.8 | 7.6 | - | 5.5 | 7.6 | 18.1 | 10.9 | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50%RDF | 15-30 | 2.9 | 7.2 | 23.8 | 7.6 | - | 5.0 | 7.4 | 16.1 | 9.8 | - |
| | 30-60 | 2.9 | 7.2 | 20.9 | 7.1 | - | 4.5 | 8.8 | 14.8 | 14.4 | - |
| | 60-90 | 2.8 | 7.2 | 19.6 | 7.9 | - | 4.5 | 7.3 | 15.7 | 8.9 | - |
| 1SW:1TW | 0-15 | 3.3 | 7.4 | 24.0 | 8.9 | - | 6.5 | 9.6 | 16.9 | 10.6 | - |
| 75%RDF | 15-30 | 2.9 | 7.3 | 21.8 | 6.8 | - | 6.0 | 7.7 | 14.9 | 15.2 | - |
| | 30-60 | 2.9 | 7.3 | 20.9 | 7.7 | - | 4.5 | 8.4 | 15.7 | 9.6 | - |
| | 60-90 | 2.8 | 7.3 | 19.9 | 7.8 | - | 4.5 | 8.1 | 14.9 | 11.9 | - |
| 1SW:1TW | 0-15 | 3.3 | 7.5 | 24.5 | 9.1 | - | 5.0 | 8.6 | 19.9 | 10.7 | - |
| 100%RDF | 15-30 | 3.1 | 7.3 | 23.1 | 7.8 | - | 4.5 | 8.6 | 17.5 | 14.0 | - |
| | 30-60 | 3.0 | 7.2 | 22.8 | 7.2 | - | 5.5 | 7.8 | 17.1 | 16.1 | - |
| | 60-90 | 2.9 | 7.2 | 21.2 | 7.3 | - | 4.5 | 8.4 | 15.6 | 9.9 | - |

**Soil analysis at harvest of okra crop**

The pH recorded in all the treatments at harvesting time was in normal range. The sodium range was recorded (18.9-33.6 me/l) in the treatments of the experiment, these were slightly higher as compared to harvest of cauliflower crop. The Ca+Mg found present in all the soil samples, but this value was higher compared with at sowing time values of Ca+Mg. The $CO_3$ was not found but $HCO_3$ presence in all the samples. The chloride and sulphate were also present in all the samples collected at harvest of okra crop. (Table 3.70).

Table 3.70 Soil analysis at harvest of Okra crop (Av. 2016-17 and 2017-18)

| Treat. | Soil Depth (cm) | ECe (dS/m) | pH | Na (me/l) | Ca+Mg (me/l) | $CO_3$ (me/l) | $HCO_3$ (me/l) | Cl (me/l) | $SO_4$ (me/l) | SAR $(mmol/l)^{1/2}$ | RSC (me/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SW | 0-15 | 3.5 | 7.6 | 22.9 | 12.1 | - | 7.5 | 12.6 | 14.9 | 10.9 | - |
| 50%RDF | 15-30 | 3.4 | 7.5 | 22.8 | 11.2 | - | 6.5 | 11.4 | 16.2 | 11.6 | - |
| | 30-60 | 3.4 | 7.5 | 21.5 | 12.6 | - | 6.5 | 13.3 | 14.3 | 10.5 | - |
| | 60-90 | 3.3 | 7.4 | 20.2 | 12.3 | - | 6.0 | 11.9 | 14.7 | 10.4 | - |
| SW | 0-15 | 3.6 | 7.6 | 23.8 | 11.8 | - | 6.5 | 13.1 | 15.9 | 11.6 | - |
| 75%RDF | 15-30 | 3.5 | 7.6 | 22.9 | 12.1 | - | 6.0 | 12.9 | 16.1 | 12.4 | - |
| | 30-60 | 3.4 | 7.5 | 22.5 | 11.1 | - | 7.0 | 12.5 | 14.1 | 11.9 | - |
| | 60-90 | 3.3 | 7.5 | 21.9 | 11.1 | - | 6.0 | 12.2 | 14.9 | 11.7 | - |
| SW | 0-15 | 3.5 | 7.6 | 23.8 | 11.3 | - | 6.5 | 13.3 | 15.2 | 11.9 | - |
| 100%RDF | 15-30 | 3.5 | 7.5 | 23.8 | 10.7 | - | 7.0 | 12.3 | 15.3 | 11.9 | - |
| | 30-60 | 3.4 | 7.5 | 21.0 | 12.5 | - | 6.0 | 12.5 | 15.0 | 10.9 | - |
| | 60-90 | 3.3 | 7.6 | 21.1 | 11.9 | - | 7.0 | 12.0 | 14.0 | 9.9 | - |
| TW | 0-15 | 4.5 | 7.7 | 33.6 | 10.9 | - | 6.0 | 13.5 | 25.0 | 17.5 | - |
| 50%RDF | 15-30 | 4.2 | 7.5 | 29.3 | 12.2 | - | 6.5 | 12.0 | 23.0 | 15.1 | - |
| | 30-60 | 3.8 | 7.5 | 25.9 | 12.2 | - | 6.5 | 11.9 | 19.6 | 13.6 | - |
| | 60-90 | 3.6 | 7.4 | 23.8 | 11.7 | - | 7.0 | 13.1 | 15.5 | 11.3 | - |
| TW | 0-15 | 4.5 | 7.7 | 32.5 | 12.0 | - | 7.0 | 13.5 | 24.0 | 15.6 | - |
| 75%RDF | 15-30 | 4.1 | 7.6 | 27.8 | 13.2 | - | 6.5 | 12.2 | 22.4 | 13.5 | - |
| | 30-60 | 3.8 | 7.6 | 24.9 | 13.2 | - | 6.5 | 12.2 | 19.4 | 12.9 | - |
| | 60-90 | 3.8 | 7.5 | 24.8 | 12.7 | - | 7.0 | 12.5 | 18.1 | 12.3 | - |
| TW | 0-15 | 4.5 | 7.7 | 32.3 | 12.8 | - | 7.5 | 12.2 | 25.3 | 16.1 | - |
| 100%RDF | 15-30 | 4.3 | 7.6 | 19.2 | 13.3 | - | 7.0 | 12.8 | 22.7 | 15.2 | - |
| | 30-60 | 3.9 | 7.5 | 28.7 | 10.9 | - | 6.5 | 12.5 | 20.6 | 15.8 | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60-90 | 3.8 | 7.5 | 27.1 | 10.9 | - | 7.5 | 12.0 | 18.5 | 13.4 | - |
| 1SW:1TW | 0-15 | 3.7 | 7.6 | 25.7 | 11.2 | - | 7.0 | 12.4 | 17.6 | 12.9 | - |
| 50%RDF | 15-30 | 3.5 | 7.5 | 23.3 | 11.3 | - | 6.5 | 12.0 | 16.0 | 11.9 | - |
| | 30-60 | 3.4 | 7.4 | 21.1 | 12.4 | - | 6.0 | 12.7 | 14.9 | 10.9 | - |
| | 60-90 | 3.3 | 7.5 | 20.9 | 12.1 | - | 7.0 | 11.6 | 14.5 | 9.9 | - |
| 1SW:1TW | 0-15 | 3.7 | 7.5 | 23.5 | 13.5 | - | 7.0 | 12.3 | 17.7 | 11.2 | - |
| -75%RDF | 15-30 | 3.5 | 7.5 | 22.8 | 12.2 | - | 7.0 | 11.8 | 16.3 | 11.4 | - |
| | 30-60 | 3.4 | 7.5 | 22.6 | 11.4 | - | 6.0 | 12.6 | 15.4 | 12.0 | - |
| | 60-90 | 3.4 | 7.5 | 21.9 | 11.7 | - | 6.0 | 12.0 | 15.5 | 11.5 | - |
| 1SW:1TW | 0-15 | 3.8 | 7.7 | 18.9 | 14.0 | - | 6.5 | 12.9 | 15.6 | 11.2 | - |
| 100%RDF | 15-30 | 3.6 | 7.6 | 22.9 | 12.7 | - | 6.5 | 11.9 | 16.6 | 11.3 | - |
| | 30-60 | 3.5 | 7.4 | 23.1 | 11.9 | - | 6.0 | 12.4 | 16.5 | 12.1 | - |
| | 60-90 | 3.4 | 7.4 | 22.9 | 11.7 | - | 6.0 | 12.5 | 15.0 | 12.2 | - |

**Use of Tertiary Treated Waste Water of Peri-urban Areas for Growing Flower during rabi Season (Panvel)**

The experiment was conducted at Panvel centre to study the qualities of treated water on soil properties and production of flowers. The treatments details are given in Table 3.71.

Table 3.71 Treatment details of experiment

| Crop: | Irrigation water: |
|---|---|
| Marigold (C1) | Treated waste water (100%) (W1) |
| Aster(C2) | Treated waste water (50%) + Pond water (50%) (W2) |
| Gaillardia (C3) | Pond water (100%) (W3) |
| Gladiolus (C4) | |
| Design: RBD; No. of replication: Three Plot Size: 2 x 1m2 | |

The EC of tertiary treated waster was 0.6 dS/m while pH was around 7.2. The treated waste water of the sewage plant of the Panvel Municipal Corporation was got analyzed from the NABL accredited laboratory "PADMAJA AEROBIOLOGIALS (P) LTD" Turbhe, Navi Mumbai. As per the test report, the concentration of lead (Pb), Chromium (Cr), Arsenic (As), Cadmium (Cd), Mercury (Hg) and Nickel (Ni) in treated waste water used for irrigation was less than 0.1 ppm. As irrigation water quality guidelines tertiary treated waste water came under Good category.

The electrical conductivity and pH of the experimental soil before transplanting was 2.06 $dSm^{-1}$ and 6.82, respectively. After transplanting seedlings of Marigold, Gaillardia, Aster and bulb of Gladiolus, the plots were irrigated with pond water. After the transplanting upto one week seedlings did not showed symptoms of any injury or shock. After establishment of seedlings within a week upper portion of marigold and gaillardia plants started to dry. At this stage electrical conductivity of the soil was 14 $dSm^{-1}$ at root zone which was higher than initial value of electrical conductivity (2.06 d $Sm^{-1}$). The gladiolus bulbs did not germinate. All the seedlings were unable to survive due to higher salinity. The plants of Marigold, Aster and Gaillardia were dried in one week. The probable reason for such type of results could be the capaillary rise from shallow saline groundwater and increase in soil salinity above tolerance limit of the crop. In view of above, it was proposed to conduct the trials on ridges and furrows instead of flat bed, during rabi 2018-19.

## 4. ALTERNATE LAND USE

**Seaweed Cultivation for Economic Rehabilitation of Coastal Farmers in Andhra Pradesh Sea Coast (Bapatla)**

An Exposure visit to CSMCRI, Mandapam, Tamilnadu for 6 fishermen from Guntur district, AP was organized during 2017 and fishermen were exposed to various species and methods of seaweed cultivation and processed products developed at Mandapam. In this visit the fisher men could able to see directly the commercial cultivation of seaweed. They came to know the importance of seaweed cultivation and processing products.

Scientist, CSMCRI, ARMS, Mandapam showing the commercial cultivation of seaweed at Kottayam, Tamil Nadu

Scientist, CSMCRI, ARMS, Mandapam explaining the methods of cultivation for different varieties of seaweed

Plate 4.1 Interaction between scientists and farmers regarding seaweed cultivation

Sea weed seed material has been brought from sea six energy private limited, Tutukorin, Tamil Nadu. A training programme has been conducted on installation of seaweed seed and it was installed in raft system as well as in tube method in Bay of Bengal at Suryalnka.

Plate 4.2 Installation of rafts of seed weed

**Evaluation of Silvi-horticultural Crops in Saline/Alkali Soils under Rainfed Conditions (Bapatla)**

This experiment was conducted in Sri. G. Apparao's field (soil pH and EC were 7.8 of 4.5 dS $m^{-1}$) of Peda Vodarevu village. Casuraina, guava, sapota, pomegranate, neem and custard apple saplings were planted as per the recommended spacing. All the saplings of these plants were established. The plant height of casurina (483cm), Neem (345cm), sapota (170cm) custard (86cm) and guava (360cm) and pomegranate (252cm), attained during 2017-18, respectively (Table 4.1).

Table 4.1. Plant growth of horticultural crops

| Name of plant | Plant Height (cm) | |
|---|---|---|
| | 2016-17 | 2017-18 |
| Casurina | 224.0 | 483 |
| Neem | 104.8 | 345 |
| Sapota | 115.0 | 170 |
| Custard apple | 41.3 | 86 |
| Guava | 137.0 | 360 |
| Pomegranate | 89.0 | 252 |

P**erformance of Medicinal Plants with Saline Irrigation Water through Drip System(Bapatla)**

Marigold, chrysanthemum and tulsi were grown with saline water irrigation through drip. Initial soil pH was 7.6 and $EC_e$ was 0.45 dS $m^{-1}$. Marigold, chrysanthemum and tulsi yields were recorded up to five pickings in different salinity levels of water like BAW (0.6 dS $m^{-1}$), 2, 4, 6 and 8. Marigold and chrysanthemum yields were decreased with increase in salinity level of water (Table 4.2).

Table 4.2 Performance of medicinal plants at different salinity levels of water

| EC levels | Plant height (cm) | | No. of flowers/plant | | Plant height (cm) | | No. of flowers/plant | | Plant height (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Chrysanthimum | | | | Marigold | | | | Tulsi | |
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| BAW | 40.2 | 37.8 | 175 | 175 | 62 | 64.8 | 190 | 246 | 57.2 | 37.6 |
| 2EC | 39 | 34.6 | 160 | 170 | 59 | 60.8 | 170 | 231 | 51.0 | 33.6 |
| 4EC | 37.6 | 32.6 | 125 | 164 | 55 | 57.6 | 140 | 202 | 47.6 | 34.4 |
| 6EC | 34.4 | 31.4 | 90 | 158 | 48 | 52.0 | 110 | 151 | 45.3 | 33.6 |
| 8EC | 32 | 30.6 | 70 | 148 | 39 | 49.2 | 75 | 157 | 42.8 | 33.0 |

Plate 4.3 Field view of marigold, chrysanthemum and tulasi crops

## 5. SCREENING OF CROP CULTIVARS AND GENOTYPES

**Screening of Crop Cultivars for Saline Water Irrigation (Agra)**

Screening of mustard cultivars supplied by DRM, Bharatpur was carried out 2016-17 and 2017-18 as per details provided in Table 5.1.

Table 5.1 Details of screening of mustard cultivars

| Particulars | 2016-2017 | 2017-18 |
|---|---|---|
| Water salinity | ECiw 12 dS/m for all cultivars | ECiw 12 dS/m for all cultivars |
| Cultivars | IVT (CSCN-16-1 to CSCN-16-12)<br>AVT (CSCN 16-11 to CSCN 16-19) | IVT (CSCN 17-1 to CSCN 17-10)<br>AVT (CSCN 17.11 to CSCN 17-22) |
| Design | Randomized Block Design (RBD) | Randomized Block Design (RBD) |
| Replication | Three | Three |
| Crop | Rape seed mustard | Rape seed mustard |
| Date of sowing | 28-10-2016 | 28.10.2017 |
| Doses of fertilizer (kg/ha) | N:P:K (120:60:60) | N:P:K (120:60:60) |
| Number of irrigations | 2 ( Pre-sowing and flowering stage ) | 3 (Pre-sowing, flowering stage and siliqua stage) |
| Depth of irrigation | 7 cm | 7 cm |
| Total rainfall during crop period | 47.35 mm | 2.1 mm |
| Date of harvesting | 26-03-2017 | 15.3.2018 |

The yield data of different mustard genotype (IVT) are presented in Table 5.2. The yield of was significantly affected in saline water irrigation. The significantly higher yield was observed for genotype CSCN-16-10 (25.48 q/ha) and lowest was recorded for genotype CSCN-16-6 (20.04 q/ha) during 2016-17. In 2017-18 genotype CSCN 17-10 gave highest yield of 20.80 q/ha and lowest (15.86 q/ha) was recorded in case of CSCN 17-3 and CSCN 17-5.

Table 5.2 Yield of mustard cultivars (IVT) on use of saline water irrigation (ECiw 12dS/m)

| Cultivars | Grain yield (q/ha) | Cultivars | Grain yield (q/ha) |
|---|---|---|---|
| | 2016-17 | | 2017-18 |
| CSCN-16-1 | 21.84 | CSCN 17-1 | 20.38 |
| CSCN-16-2 | 21.93 | CSCN 17-2 | 15.99 |
| CSCN-16-3 | 25.30 | CSCN 17-3 | 15.86 |
| CSCN-16-4 | 23.89 | CSCN 17-4 | 19.81 |
| CSCN-16-5 | 20.71 | CSCN 17-5 | 15.86 |
| CSCN-16-6 | 20.04 | CSCN 17-6 | 15.09 |
| CSCN-16-7 | 20.63 | CSCN 17-7 | 19.94 |
| CSCN-16-8 | 20.44 | CSCN 17-8 | 16.04 |
| CSCN-16-9 | 20.07 | CSCN 17-9 | 15.98 |
| CSCN-16-10 | 25.48 | CSCN 17-10 | 20.80 |
| CSCN-16-11 | 20.33 | CD (P=0.05) | 3.39 |
| CSCN-16-12 | 20.14 | | |
| CD at 5% | 3.51 | | |

In case of AVT (Table 5.3) CSCN 16-19 genotype gave highest yield (26.56 q/ha) and lowest (19.98 q/ha) was for CSCN16-13 during 2016-17. Similarly, highest grain yield was recorded for CSCN 17-13 (20.23q/ha) and lowest was for CSCN 17-11 (15.82 q/ha) during 2017-18.

Table 5.3 Yield of mustard cultivars (AVT) on use of saline water irrigation (ECiw 12dS/m)

| Cultivars | Grain yield (q/ha) | Cultivars | Grain yield (q/ha) |
|---|---|---|---|
| 2016-17 | | 2017-18 | |
| CSCN-16-11 | 26.47 | CSCN-17-11 | 15.82 |
| CSCN-16-12 | 21.23 | CSCN-17-12 | 19.90 |
| CSCN-16-13 | 19.98 | CSCN-17-13 | 20.23 |
| CSCN-16-14 | 20.10 | CSCN-17-14 | 19.78 |
| CSCN-16-15 | 20.26 | CSCN-17-15 | 16.16 |
| CSCN-16-16 | 24.73 | CSCN-17-16 | 19.54 |
| CSCN-16-17 | 24.86 | CSCN-17-17 | 19.93 |
| CSCN-16-18 | 20.14 | CSCN-17-18 | 19.88 |
| CSCN-16-19 | 26.56 | CSCN-17-19 | 15.96 |
| CD at (P=0.05) | 2.27 | CSCN-17-20 | 19.90 |
| | | CSCN-17-21 | 19.60 |
| | | CSCN-17-22 | 19.24 |
| | | CD at (P=0.05) | 2.85 |

**Performance of Promising Mustard (*Brassica juncea*) Entries under different Fertility Levels Irrigated with Saline Water Irrigation (Agra)**

The four mustard entries were supplied by ICAR-DRMR, Sewar , Bharatpur (Raj.) in the year 2016-17 while seven entries were supplied during year 2017-18. The experiment was planned with three fertility levels (i.e., 100, 125 and 150% recommended dose of fertilizers) and two plant spacing i.e. 30 cm x 10 cm and 45 cm x 15 cm.

The data of mustard grain yield (kg $ha^{-1}$) indicated that significant difference in yield was found among the entries (Table 5.4). The highest grain yield was for AG-19 (2803.70 kg/ha) and lowest was for AG-17 (2182.72 kg/ha) but AG-18 and AG-20 were at par. The grain yield of mustard increased significantly for 100%, 125% and 150% RDF. In case of 150% RDF, increase in grain yield was 9.43% and 1.6% compared to 100% RDF and 125% RDF. The application of 125% RDF significantly increase the grain yield of mustard 7.7 % compared with 100% RDF.

Table 5.4 Effect of different treatments on grain yield of mustard (kg/ha) 2016-17

| Entries | Fertility levels | | | |
|---|---|---|---|---|
| | 100%RDF | 125% RDF | 150% RDF | Mean |
| AG-17 | 2033.33 | 2244.44 | 2270.37 | 2182.72 |
| AG-18 | 2177.78 | 2318.82 | 2370.37 | 2288.89 |
| AG-19 | 2696.30 | 2833.33 | 2881.48 | 2803.70 |
| AG-20 | 2085.19 | 2288.89 | 2318.52 | 2230.86 |
| Mean | 2248.15 | 2421.30 | 2460.19 | - |
| CD (p=0.05) | Entries=85.63 | Fertility=41.87 | E X F= NS | |

The data of mustard grain yield (kg $ha^{-1}$) indicated that significant difference in yield was found among the entries (Table 5.5). The highest grain yield was observed in case of AG-17 (2129.49 kg/ha) in plant spacing 30 x10 cm and (2206.72 kg/ha) in plant spacing 45 x 15 cm and lowest AG-14 (1682.01 kg/ha in spacing of 30 x 10 cm and 1720.76 kg/ha in spacing of 45x 15 cm. In case of 150%

RDF, increase in grain yield was 8.68% and 1.23% compared to 100% RDF and 125% RDF for 30 x10 cm spacing. Similarly, increase in grain yield, in case of 150% RDF, was 14.28 % and 6.45% compared to 100% RDF and 125% RDF for 45 x 15 cm spacing.

Table 5.5 Effect of different treatments on grain yield (kg/ha) of mustard 2017-18

| Entries | Spacing 30 x10 cm | | | | Spacing 45 x 15 cm | | | |
|---|---|---|---|---|---|---|---|---|
| | 100%RDF | 125%RDF | 150%RDF | Mean | 100%RDF | 125%RDF | 150%RDF | Mean |
| AG-12 | 1615.15 | 1721.90 | 1789.44 | 1708.95 | 1655.91 | 1770.05 | 1857.43 | 1761.13 |
| AG-13 | 1856.58 | 1979.05 | 2133.25 | 1989.63 | 1887.99 | 2016.72 | 2172.24 | 2025.65 |
| AG-14 | 1622.62 | 1688.60 | 1734.81 | 1682.01 | 1669.66 | 1720.65 | 1771.97 | 1720.76 |
| AG-15 | 2261.58 | 1782.15 | 1975.49 | 2006.41 | 1737.46 | 1870.24 | 2067.27 | 1891.66 |
| AG-16 | 1736.56 | 1872.56 | 2029.67 | 1879.60 | 1779.69 | 1949.50 | 2093.20 | 1940.80 |
| AG-17 | 2065.98 | 2182.27 | 2329.23 | 2129.49 | 2082.42 | 2151.47 | 2386.26 | 2206.72 |
| AG-18 | 1855.50 | 1948.97 | 2152.49 | 1985.64 | 1905.24 | 2059.62 | 2186.25 | 2050.37 |
| Mean | 1859.19 | 1882.21 | 2020.63 | - | 1816.91 | 1934.03 | 2076.37 | |
| CD at 5% | Entries(E) 19.42 | Fertility(F) 8.00 | Spacing(S) 6.53 | Interaction (E X F) 21.16 | Interaction (F X S) NS | Interaction (E X F X S) 29.93 | | |

**Screening of Lentil Entries for Salinity and Sodicity**

The experiment was conducted in micro-plots 4.5 m x 4.0 m size. The irrigation water was prepared synthetically for water salinity.

**General notes to be taken on growing conditions**

| | | | |
|---|---|---|---|
| 1. | Layout Design | | :Randomized Block Design |
| 2. | No. of germplasm | | :Fifteen |
| 3. | No. of Replication | | :Three |
| 4. | Plot size | i. Number of rows | : Three |
| | | ii. Row length | : 4.0m |
| | | iii. Row to row distance | : 22.5cm |
| | | iv. Plant to plant distance | : 10cm |
| | | vii. ECiw | : 6 (dS/m) |
| | | viii. RSCiw | : 6 (meq/l) |
| 5. | Irrigation | i. Number | :Two |
| | | ii. Dates | :9.1.2017 and 6.3.2017 Feb-2016 |
| 6. | Fertilizer application (N:P:K kg/ha) | | : 25:60:60 |
| 7. | Date of sowing | | :2-12-2016 |
| 8. | Date of harvesting/picking | | : 24-03-2017 |
| 9. | Details of intercultural operations : | | |
| | i. Weeding (number & dates) | | :Two (29-12-2016 & 20.1.2017) |
| 10. | Rainfall | | :48.25 mm |

The yield of lentil germplasm was significantly affected in saline water irrigation (Table 5.6). The higher yield was observed for lentil germplasm LSL 16-3 (514.32 kg/ha) and lowest was recorded for germplasm LSL 16-6 (200.00 kg/ha).

Table 5.6 Effect of water salinity on yield of lentil germplasm (2016-17)

| Sr.No. | Germplasm/Code | Grain yield/plot (gm) | Grain yield (kg/ha) |
|---|---|---|---|
| 1. | LSL 16-1 | 79.10 | 292.96 |
| 2. | LSL 16-2 | 81.73 | 302.72 |
| 3. | LSL 16-3 | 138.87 | 514.32 |
| 4. | LSL 16-4 | 73.63 | 272.72 |
| 5. | LSL 16-5 | 110.67 | 409.88 |
| 6. | LSL 16-6 | 54.00 | 200.00 |
| 7. | LSL 16-7 | 130.10 | 481.85 |
| 8. | LSL 16-8 | 74.73 | 276.79 |
| 9. | LSL 16-9 | 127.57 | 472.47 |
| 10. | LSL 16-10 | 86.87 | 321.73 |
| 11. | LSL 16-11 | 89.60 | 331.85 |
| 12. | LSL 16-12 | 78.63 | 291.23 |
| 13. | LSL 16-13 | 90.30 | 334.44 |
| 14. | LSL 16-14 | 92.20 | 341.48 |
| 15. | LSL 16-15 | 86.57 | 320.62 |
| | SEm+ | 16.1 | 59.6 |
| | C.D. at 5% | 33.0 | 122.1 |

The yield data of different lentil germplasm in RSC treated plot are given in Table 5.7. The yield of lentil germplasm was significantly differing in sodic water. The germplasm LSD 16-7 gave higher grain yield (739.38 kg/ha) and lowest yield in LSD 16-6 (293.46 kg/ha).

Table 5.7 Effect of water sodicity on yield of lentil (2016-17)

| Sr.No. | Germplasm/Code | Grain yield/plot (gm) | Grain yield (kg/ha) |
|---|---|---|---|
| 1. | LSD 16-1 | 145.13 | 537.53 |
| 2. | LSD 16-2 | 100.83 | 373.46 |
| 3. | LSD 16-3 | 80.20 | 297.04 |
| 4. | LSD 16-4 | 102.53 | 379.75 |
| 5. | LSD 16-5 | 159.13 | 589.38 |
| 6. | LSD 16-6 | 79.23 | 293.46 |
| 7. | LSD 16-7 | 199.63 | 739.38 |
| 8. | LSD 16-8 | 104.00 | 385.18 |
| 9. | LSD 16-9 | 168.60 | 624.44 |
| 10. | LSD 16-10 | 123.97 | 459.14 |
| 11. | LSD 16-11 | 108.33 | 401.23 |
| 12. | LSD 16-12 | 130.57 | 483.58 |
| 13. | LSD 16-13 | 118.98 | 440.68 |
| 14. | LSD 16-14 | 124.53 | 461.23 |
| 15. | LSD 16-15 | 102.40 | 379.26 |
| | SEm+ | 8.2 | 30.3 |
| | C.D. at 5% | 16.8 | 62.1 |

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

Screening of newly released rice varieties in state of Andhra Pradesh was undertaken to know their salinity tolerance so that suitable variety for saline environment (saline soil/ saline water) can be identified. Following methodology was adopted screening field study.

The names of rice varieties were BPT 2615, MCM 109, BPT 2782, MTU 1010, BPT 2595, CSR 36, BPT 2571, MCM 103, BPT 2776, MCM 100 and MTU 1061. NPK fertilizers were applied as per recommendation of the university.

The experiment was conducted at Bhavanamvaripalem village in 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 $ha^{-1}$). Available nutrients were significantly lower (184, 19.8 and 637.3 kg N-$P_2O_5$- $K_2O$ $ha^{-1}$) 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.

Among the varieties tested for salt tolerance, BPT 2615 was significantly superior over other varieties, the grain and straw yields being 7267 and 7733 kg $ha^{-1}$, while, MCM 103 realized a significantly lower corresponding yields of 5433 and 6100 kg $ha^{-1}$(Table 5.8).

Table 5.8 Biometric observations at different growth periods, yield attributes and yields of rice varieties

| S. No. | Variety | 30 DAT | | 60 DAT | | 90 DAT | | Product-ive tillers | Panicle length cm | No of grains per panicle | Grain Yield kg $ha^{-1}$ | Straw Yield kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant height (cm) | No of Tillers per hill | Plant height (cm) | No of Tillers per hill | Plant height (cm) | No of Tillers per hill | | | | | |
| 1 | BPT 2615 | 84.20 | 15.33 | 128.60 | 21.20 | 130.87 | 20.60 | 12.27 | 24.52 | 160 | 5267 | 6325 |
| 2 | MCM 109 | 87.53 | 15.67 | 134.20 | 15.33 | 135.80 | 14.47 | 11.80 | 24.97 | 171 | 5836 | 6400 |
| 3 | BPT 2782 | 82.20 | 14.00 | 102.67 | 17.13 | 114.20 | 15.73 | 15.40 | 21.79 | 179 | 5783 | 6400 |
| 4 | MTU 1010 | 77.67 | 17.33 | 109.13 | 19.33 | 110.73 | 17.07 | 13.87 | 23.11 | 156 | 5667 | 6785 |
| 5 | BPT 2595 | 75.27 | 17.00 | 101.00 | 14.07 | 107.33 | 13.73 | 13.67 | 22.79 | 154 | 5833 | 6567 |
| 6 | CSR 36 | 72.93 | 16.33 | 112.93 | 19.33 | 129.40 | 18.67 | 18.07 | 23.81 | 189 | 6400 | 7460 |
| 7 | BPT 2571 | 85.00 | 16.00 | 127.33 | 17.87 | 129.87 | 16.87 | 15.80 | 22.99 | 177 | 6167 | 7270 |
| 8 | MCM 103 | 81.20 | 16.33 | 131.47 | 19.60 | 133.53 | 18.47 | 13.53 | 24.73 | 156 | 5433 | 6100 |
| 9 | BPT 2776 | 77.07 | 15.33 | 116.47 | 16.80 | 118.40 | 16.00 | 14.53 | 20.15 | 167 | 6200 | 7215 |
| 10 | MCM 100 | 78.27 | 11.33 | 124.53 | 17.53 | 126.13 | 16.67 | 15.40 | 17.53 | 182 | 5567 | 6033 |
| 11 | MTU 1061 | 73.27 | 17.00 | 120.87 | 17.40 | 145.87 | 16.47 | 15.80 | 20.41 | 160 | 5700 | 6785 |
| | S.E (m) | 0.74 | 0.56 | 1.08 | 0.24 | 1.32 | 0.26 | 0.64 | 0.23 | 4 | 196 | 144 |
| | CD | 2.29 | 1.73 | 3.37 | 0.74 | 4.11 | 0.82 | 1.98 | 0.73 | 13 | 610 | 449 |

**Screening of different Crop Varieties under Drip with Saline Water Irrigation (Bikaner)**

This experiment was initiated during *kharif* 2015 on screening of cluster bean (RGC 1066, RGC 936, RGC 1017 and RGC 1003) varities under three levels of irrigation water salinity (BAW, 4 and 8 dS/m). Pooled results for three years showed that up to $EC_{iw}$ 4 dS/m there was no significant reduction in the grain yield of cluster bean, however, $EC_{iw}$ 8 dS/m caused significant reduction of 41.77 and 39.08 per cent in grain yield, respectively over BAW and $EC_{iw}$ of 4 dS/m. In respect of straw yield, however, significant reduction was observed with every increase in salinity of irrigation water. $EC_{iw}$ of 4 and 8 dS/m caused significant reduction of 5.24 and 43.16 per cent in straw yield of cluster bean as compared to BAW (Table 5.9 and Fig 5.1).

Table 5.9 Evaluation of cluster bean varieties under saline irrigation water through drip

| Treatments | Plant height (cm) | | | | Pods/plant | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | Pooled | 2015 | 2016 | 2017 | Pooled |
| Salinity levels | | | | | | | | |
| BAW | 109.48 | 110.33 | 90.00 | 103.27 | 107.50 | 114.75 | 66.00 | 96.08 |
| 4 dS/m | 105.52 | 107.74 | 84.00 | 99.09 | 104.75 | 109.88 | 63.00 | 92.54 |
| 8 dS/m | 84.65 | 85.84 | 56.00 | 75.50 | 74.63 | 78.66 | 30.00 | 61.10 |
| S Em (±) | 2.26 | 1.10 | 3.16 | 1.26 | 3.31 | 2.55 | 1.00 | 2.09 |
| CD (0.05) | 7.83 | 3.82 | 10.94 | 3.88 | 11.46 | 8.84 | 3.48 | 6.44 |
| Varieties | | | | | | | | |
| RGC 1066 | 125.42 | 128.05 | 108.00 | 120.49 | 119.11 | 127.75 | 81.00 | 109.29 |
| RGC 936 | 74.08 | 75.42 | 50.01 | 51.50 | 70.42 | 73.67 | 32.0 | 58.70 |
| RGC 1017 | 106.78 | 107.93 | 78.00 | 97.57 | 100.86 | 106.55 | 51.00 | 86.14 |
| RGC 1003 | 93.25 | 93.82 | 69.00 | 85.36 | 92.11 | 96.41 | 48.00 | 78.84 |
| S Em (±) | 1.84 | 1.82 | 2.27 | 1.29 | 3.71 | 2.64 | 1.58 | 2.28 |
| CD (0.05) | 5.33 | 5.28 | 6.59 | 3.66 | 10.77 | 7.66 | 4.60 | 6.46 |

| Treatments | Grain Yield (q/ha) | | | | Straw yield (q/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | Pooled | 2015 | 2016 | 2017 | Pooled |
| Salinity levels | | | | | | | | |
| BAW | 10.27 | 12.87 | 12.20 | 11.78 | 12.60 | 14.81 | 13.80 | 13.74 |
| 4 dS/m | 9.79 | 12.30 | 11.70 | 11.26 | 11.91 | 13.96 | 13.20 | 13.02 |
| 8 dS/m | 6.62 | 7.76 | 6.20 | 6.86 | 7.42 | 8.92 | 7.10 | 7.81 |
| S Em (±) | 0.187 | 0.296 | 0.296 | 0.17 | 0.26 | 0.28 | 0.22 | - |
| CD (0.05) | 0.648 | 1.024 | 1.024 | 0.60 | 0.91 | 0.97 | 0.76 | - |
| Varieties | | | | | | | | |
| RGC 1066 | 10.89 | 13.69 | 13.50 | 12.69 | 13.85 | 16.19 | 15.20 | 15.08 |
| RGC 936 | 7.41 | 9.31 | 7.30 | 8.01 | 8.34 | 9.96 | 8.40 | 8.90 |
| RGC 1017 | 9.95 | 11.45 | 10.70 | 10.70 | 12.29 | 14.35 | 12.00 | 12.88 |
| RGC 1003 | 7.33 | 9.44 | 8.50 | 8.42 | 8.08 | 9.76 | 9.80 | 9.21 |
| S Em (±) | 0.214 | 0.239 | 0.240 | 0.20 | 0.29 | 0.31 | 0.23 | - |
| CD (0.05) | 0.620 | 0.694 | 0.69 | 0.57 | 0.85 | 0.91 | 0.66 | - |

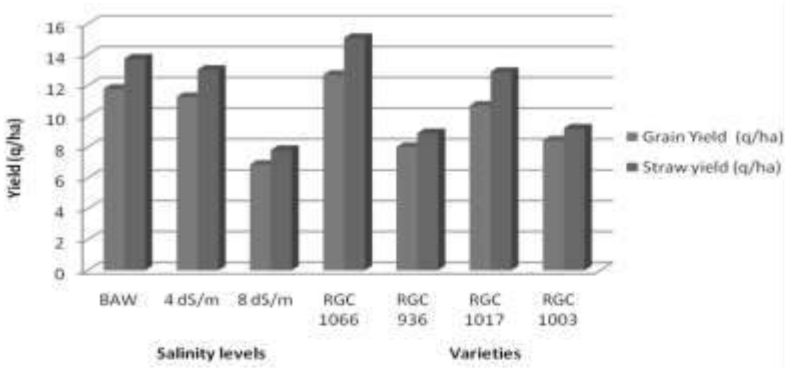



Fig. 5.1 Evaluation of cluster bean varieties under saline irrigation water

Variety RGC 1066 established its superiority by a margin of 36.88, 15.68 and 33.65 per cent in grain yield over RGC 936, RGC 1017 and RGC 1003, respectively. Similarly, in terms of straw yield also variety RGC 1066 recorded significant increases of 40.98, 14.59 and 38.93 per cent over RGC 936, RGC 1017 and RGC 1003, respectively.

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

This experiment was initiated during 2016-17 with screening of 7 cotton, 14 wheat, 14 pearl millet and 19 mustard genotypes with four water qualities (Canal, $EC_{iw}$ 2.5, 5.0, 7.5 dS/m) and cotton and pearl millet genotypes were screened with water qualities (Canal, $EC_{iw}$ 2.5, 5.0, 7.5 dS/m) and wheat and mustard were screened with water qualities (Canal, $EC_{iw}$ 5.0, 7.5, 10. dS/m) during 2017-18.

**Cotton**: Increasing salinity led to a gradual decrease in seed cotton yield (Table 5.10). Among the seven genotypes, H1472 gave the highest (174.60 g/m$^2$) seed cotton yield and H1465 resulted in the lowest seed cotton yield (131.73g/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 H1472 was significantly higher than other genotypes followed by H1098i (199.25 g/m$^2$) and H1465 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.

Table 5.10 Effect of saline waters on seed cotton yield of cotton genotypes

| Genotype | Seed cotton yield (g/m$^2$) | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 2.5 | 5.0 | 7.5 | Mean |
| H1098i | 223.20 | 216.45 | 190.40 | 166.97 | 199.25 |
| H1316 | 179.50 | 172.50 | 151.13 | 136.30 | 159.86 |
| H1353 | 213.30 | 202.30 | 184.27 | 157.33 | 189.30 |
| H1465 | 178.80 | 171.30 | 147.93 | 131.73 | 157.44 |
| H1472 | 242.43 | 229.42 | 196.80 | 174.60 | 210.81 |
| H1489 | 191.35 | 180.93 | 168.07 | 138.63 | 169.74 |
| H1508 | 196.05 | 186.87 | 158.27 | 148.87 | 172.53 |
| Mean | 203.52 | 194.25 | 170.98 | 150.63 | |
| CD (p=0.05) | Variety (V) = 12.97, Salinity (S) = 9.81 V x S = NS | | | | |

**Wheat:** The data showed that the grain yield of different genotypes of wheat decreased with an increase in EC of the irrigation water (Table 5.11).Wheat genotype P-12908 performed the best at ECiw (7.5 dS/m) and gave 31.67% higher grain yield 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 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. Physiological observations for Normalised Difference Vegetation Index (NDVI), Chlorophyll content (SPAD units) and Chlorophyll fluorescence (Fv/Fm ratio) were recorded at heading and anthesis. 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 5.11 Grain yield of wheat genotypes as affected by different saline waters

| Genotype | Grain yield (g/m$^2$) of wheat | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 2.5 | 5.0 | 7.5 | Mean |
| 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 (p=0.05) | Variety (V) = 21.92, Salinity (S)= 11.72, V x S = NS | | | | |

**Pearl millet**

The data showed that the grain yield of different genotypes of pearl millet decreased with an increase in EC of the irrigation water (Table 5.12). Among the pearl millet hybrids, HHB 226 performed best at ECiw (7.5 dS/m) followed by HHB 223 whereas the performance of HHB 272 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$^2$). Among the parents of pearl millet hybrids, ICMB-94555 was the highest yielder with mean grain yield of 116.80 g/m$^2$ whereas ICMB-843-22 was the poorest 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.

**Mustard:** The data on 10 genotypes of IVT and 9 genotypes of AVT showed that seed yield of different genotypes decreased with an increase in EC of the irrigation water (Table 5.13 and 5.14). 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.

Table 5.12 Grain yield (g/m$^2$) of pearl millet genotypes as affected by different saline waters

| Genotype | Grain yield (g/m$^2$) | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 2.5 | 5.0 | 7.5 | Mean |
| 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 (p=0.05) | Variety (V) = 7.70, Salinity (S) = 5.82, V x S =15.41 | | | | |

Table 5.13 Seed yield of mustard genotypes under IVT as affected by waters of different salinities

| Genotype | Seed yield (g/m$^2$) of mustard genotypes | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 2.5 | 5.0 | 7.5 | Mean |
| 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 (p=0.05) | V :17.30 | S : 10.94 | SxV: NS | | |

Table 5.14 Seed yield (g/m$^2$) of mustard genotypes under AVT as affected by different salinity waters

| Genotype | Seed yield (g/m$^2$) of mustard genotypes | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 2.5 | 5.0 | 7.5 | Mean |
| 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 (p=0.05) | V: 18.04 | S : 12.02 | SxV: NS | | |

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. The mean salinity in the soil profile (0-30 cm) at the time of wheat harvest varied from 1.68 dS/m in canal water irrigated plot to 8.54 dS/m in plots receiving saline water irrigation of ECiw 7.5 dS/m (Table 5.15 ).

Table 5.15 Salinity at different soil depths after wheat harvest

| Depth (cm) | $EC_e$ (dS/m) | | | |
|---|---|---|---|---|
| | Canal (0.3) | 2.5 dS/m | 5.0 dS/m | 7.5 dS/m |
| 0-15 | 1.64 | 3.92 | 5.90 | 7.98 |
| 15-30 | 1.71 | 4.38 | 6.65 | 9.11 |
| Mean | 1.68 | 4.15 | 6.27 | 8.54 |

**Results achieved during 2017-2018**

**Cotton**: Increasing salinity results in a gradual decrease in seed cotton yield (Table 5.16). Among the seven genotypes, H-1472 gave the highest (220.63 g/m$^2$) seed cotton yield and H-1465 resulted in the lowest seed cotton yield (166.09 g/m$^2$) at $EC_{iw}$ 7.5 dS/m. The mean seed cotton yield reduced by 11.98% at $EC_{iw}$ 7.5 dS/m as compared to canal irrigation. Overall mean yield (233.90 g/m$^2$) of H-1472 was significantly higher than other genotypes followed by H-1098i (223.33 g/m$^2$) and H-1465 was the lowest yielder (179.99 g/m$^2$).

**Wheat:** The data showed that the grain yield of wheat genotypes decreased with an increase in $EC_{iw}$ (Table 5.17). Wheat genotype WH 1250 performed the best at $EC_{iw}$ 10 dS/m and gave 21.64% higher grain yield as compared to KRL 210 (check). It was followed by WH 1247 which gave 15.97% higher grain yield as compared to KRL 210 whereas the performance of KRL 19 was poor. On the basis of overall mean, WH 1250 gave maximum grain yield (495.72 g/m$^2$) which was 27.74% higher than KRL 210 followed by WH 1247 (476.49 g/m$^2$) which was 22.78% higher than KRL 210. The overall mean yield reduction at 5.0, 7.5 and 10.0 dS/m was 5.4, 21.9 and 38.1%, respectively, as compared to canal water. Physiological observations for Normalised Difference Vegetation Index (NDVI), Chlorophyll Content (SPAD units), Photosynthetic Rate and Transpiration Rate were recorded at heading and anthesis stage. Percent reduction in NDVI at 10 dS/m at anthesis was least in WH 1243 (2.07), WH 1250 (4.17) and WH 1241(5.77). While percent reduction in Photosynthetic Rate was least in WH 1250 (28.6) and WH 1247 (35.2) and in Chlorophyll content (SPAD units) percent reduction was least in WH 1235 (3.07) followed by WH 1246 (5.54) and WH 1242 (6.67). Grain yield was found significant and positively associated with all the physiological traits i.e. NDVI, chlorophyll content, photosynthetic rate and transpiration rate. Highest positive and significant correlation of grain yield was observed with NDVI (0.962$^{**}$) followed by chlorophyll content (0.873$^{**}$), photosynthetic rate (0.845$^{**}$) and transpiration rate (0.667$^{**}$). All the physiological traits were also positively and significantly associated with each other.

**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 5.18). Among the pearl millet hybrids, HHB 226 performed best at $EC_{iw}$ 7.5 dS/m followed by HHB 272 whereas the performance of HHB 146 was the poorest. The mean grain yield (271.96 g/m$^2$) of HHB 226 was higher than other genotypes followed by HHB 272 (233.95 g/m$^2$) and HHB 146 (205.76 g/m$^2$). Among the parents of pearl millet hybrids, ICMB-843-22B was the highest yielder with mean grain yield of 85.47 g/m$^2$ whereas AC-04/13 was the poorest yielder with grain yield of 68.81 g/m$^2$ at $EC_{iw}$ 7.5 dS/m. The overall mean reduction in pearl millet yield at 2.5, 5.0 and 7.5 dS/m was 4.41, 12.72 and 25.77%, respectively as compared to canal water.

**Mustard**

Ten genotypes of IVT and twelve genotypes under AVT mustard were tested. The data showed that the seed yield of different genotypes of mustard decreased with an increase in EC of the irrigation water (Table 5.19 and 5.20). In IVT, the mustard genotypes CSCN-17-10 gave the highest seed yield (221.62 g/m$^2$) followed by CSCN-17-1 (200.08 g/m$^2$) at ECiw 10.0 dS/m and the lowest seed yield (172.67g/m$^2$) was obtained in CSCN-16 -5.

Table 5.16 Effect of saline waters on seed cotton yield (g/m$^2$) of cotton genotypes

| Genotype | Seed cotton yield (g/m$^2$) | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 2.5 | 5.0 | 7.5 | Mean |
| H1098i | 235.18 | 229.30 | 219.85 | 208.97 | 223.33 |
| H1316 | 194.80 | 188.32 | 180.56 | 169.60 | 183.32 |
| H1353 | 222.03 | 215.84 | 208.97 | 194.32 | 210.29 |
| H1465 | 191.21 | 185.89 | 176.75 | 166.09 | 179.99 |
| H1472 | 244.87 | 238.47 | 231.61 | 220.63 | 233.90 |
| H1489 | 201.62 | 195.58 | 187.62 | 177.58 | 190.60 |
| H1508 | 202.66 | 197.89 | 187.30 | 176.35 | 191.05 |
| Mean | 213.20 | 207.33 | 198.95 | 187.65 | |
| CD (p=0.05) | Variety (V) = 12.47, Salinity (S) = 9.43 V x S = NS | | | | |

Table 5.17 Grain yield (g/m$^2$) of wheat genotypes as affected by different saline waters

| Genotype | Grain yield (g/m$^2$) of wheat | | | | |
|---|---|---|---|---|---|
| | Canal | 5.0 | 7.5 | 10.0 | Mean |
| WH 1218 | 428.90 | 393.28 | 339.72 | 269.09 | 357.75 |
| WH 1235 | 395.98 | 376.82 | 311.53 | 251.04 | 333.84 |
| WH 1240 | 466.86 | 442.84 | 366.51 | 286.25 | 390.61 |
| WH 1241 | 475.82 | 451.74 | 371.41 | 297.05 | 399.01 |
| WH 1242 | 484.17 | 460.79 | 380.04 | 308.53 | 408.38 |
| WH 1243 | 436.22 | 405.36 | 330.14 | 259.04 | 357.69 |
| WH 1244 | 486.50 | 469.80 | 377.28 | 290.66 | 406.06 |
| WH 1246 | 556.26 | 524.27 | 430.55 | 329.80 | 460.22 |
| WH 1247 | 565.06 | 539.23 | 450.08 | 351.61 | 476.49 |
| WH 1248 | 453.44 | 421.51 | 342.97 | 274.10 | 373.00 |
| WH 1249 | 501.46 | 473.76 | 400.37 | 331.55 | 426.78 |
| WH 1250 | 585.23 | 567.59 | 461.26 | 368.78 | 495.72 |
| KRL 19 | 441.50 | 413.66 | 327.76 | 247.76 | 357.67 |
| KRL 210 | 454.37 | 431.88 | 362.90 | 303.18 | 388.08 |
| Mean | 480.84 | 455.18 | 375.18 | 297.74 | |
| CD (p=0.05) | Variety (V) : 23.29, Salinity (S): 12.45, V x S: NS | | | | |

Table 5.18 Grain yield ($g/m^2$) of pearl millet genotypes as affected by different saline waters

| Genotype | Grain yield ($g/m^2$) of pearl millet | | | | |
|---|---|---|---|---|---|
| | Canal | 2.5 | 5.0 | 7.5 | Mean |
| HHB 146 | 228.66 | 221.35 | 198.59 | 174.43 | 205.76 |
| HHB 226 | 303.15 | 293.51 | 264.29 | 226.91 | 271.96 |
| HHB 272 | 262.6 | 252.89 | 232.39 | 187.92 | 233.95 |
| HBL-11 | 101.37 | 94.52 | 87.07 | 74.63 | 89.39 |
| HMS-47B | 107.32 | 99.64 | 94.67 | 81.46 | 95.77 |
| AC-04/13 | 93.27 | 87.97 | 81.39 | 68.81 | 82.86 |
| ICMB-843-22B | 115.07 | 108.78 | 99.45 | 85.47 | 102.19 |
| Mean | 173.15 | 165.52 | 151.12 | 128.52 | |
| CD (p=0.05) | Variety (V) = 13.79, Salinity (S) = 10.43, V x S =NS | | | | |

Table 5.19 Seed yield ($g/m^2$) of mustard genotypes under IVT as affected by saline waters

| Genotype | Seed yield ($g/m^2$) of mustard | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 5.0 | 7.5 | 10.0 | Mean |
| CSCN-17-1 | 295.89 | 274.84 | 237.99 | 200.08 | 252.20 |
| CSCN-17-2 | 301.11 | 282.75 | 230.28 | 185.27 | 249.85 |
| CSCN-17-3 | 243.76 | 222.78 | 192.83 | 165.82 | 206.29 |
| CSCN-17-4 | 251.42 | 235.29 | 193.97 | 174.89 | 213.89 |
| CSCN-17-5 | 309.89 | 292.29 | 234.88 | 184.13 | 255.29 |
| CSCN-17-6 | 322.79 | 300.53 | 247.95 | 187.39 | 264.66 |
| CSCN-17-7 | 277.73 | 254.23 | 218.59 | 199.81 | 237.59 |
| CSCN-17-8 | 324.13 | 303.72 | 254.58 | 186.47 | 267.22 |
| CSCN-17-9 | 338.97 | 315.52 | 266.41 | 189.73 | 277.66 |
| CSCN-17-10 | 343.95 | 323.99 | 274.82 | 221.62 | 291.09 |
| Mean | 300.96 | 280.59 | 235.23 | 189.52 | |
| CD (p=0.05) | S : 15.15 | V : 23.96 | SxV : NS | | |

Table 5.20 Seed yield ($g/m^2$) of mustard genotypes under AVT as affected by different salinity waters

| Genotype | Seed yield ($g/m^2$) of mustard | | | | |
|---|---|---|---|---|---|
| | Canal (0.3) | 5.0 | 7.5 | 10.0 | Mean |
| CSCN-17-11 | 316.60 | 297.60 | 241.60 | 181.70 | 259.40 |
| CSCN-17-12 | 296.41 | 279.79 | 224.30 | 191.55 | 248.01 |
| CSCN-17-13 | 354.80 | 336.30 | 280.00 | 221.90 | 298.20 |
| CSCN-17-14 | 345.75 | 327.23 | 267.16 | 200.28 | 285.10 |
| CSCN-17-15 | 359.34 | 329.58 | 280.99 | 187.61 | 289.38 |
| CSCN-17-16 | 287.49 | 270.09 | 217.16 | 189.17 | 240.98 |
| CSCN-17-17 | 325.30 | 309.68 | 259.36 | 204.43 | 274.69 |
| CSCN-17-18 | 362.40 | 346.30 | 289.10 | 206.90 | 301.20 |
| CSCN-17-19 | 349.30 | 327.90 | 261.50 | 183.60 | 280.60 |
| CSCN-17-20 | 323.87 | 297.26 | 246.90 | 201.87 | 267.48 |
| CSCN-17-21 | 343.10 | 318.80 | 265.40 | 210.30 | 284.40 |
| CSCN-17-22 | 378.69 | 357.93 | 297.32 | 218.38 | 313.08 |
| Mean | 336.90 | 316.50 | 260.90 | 199.80 | |
| CD (p=0.05) | V: 24.65; S: 14.23; S x V: NS | | | | |

Relative water content (RWC %) of mustard genotypes under initial variety trial (IVT) decreased from 78.64 to 65.02 with increasing salinity levels i.e. control to 10.0 dS $m^{-1}$. Maximum RWC was observed in CSCN-17-10 (72.05) and minimum in CSCN-17-6 (54.41) at 10.0 dS $m^{-1}$ of salinity. Salinity susceptibility index (SSI) increased with increasing salinity levels and the mean values less than one was recorded in some of the mustard genotype even at 10.0 dS $m^{-1}$ of salinity. In AVT, the mustard genotypes CSCN-17-13 gave the highest seed yield (221.90 $g/m^2$) followed by CSCN-17-22 (218.38 $g/m^2$) at ECiw 10.0 dS/m and the lowest seed yield (181.70 $g/m^2$) was obtained in CSCN-17-11.

Relative water content (RWC %) of mustard genotypes under advance variety trial (AVT) decreased from 74.30 to 67.27 with increasing salinity levels i.e. control to 10.0 dS $m^{-1}$. Maximum RWC was observed in CSCN-17-16 (68.35) followed by CSCN-17-22 (67.27) and minimum in CSCN-17-21 (56.16) at 10.0 dS $m^{-1}$ of salinity. Salinity susceptibility index (SSI) increased with increasing salinity levels and the mean values less than one was recorded in some of the mustard genotype even at 10.0 dS $m^{-1}$ of salinity.The mean salinity in the soil profile at the time of mustard harvest varied from 1.62 dS/m in canal water irrigated plot to 10.29 dS/m in plots receiving saline water irrigation of ECiw 10.0 dS/m (Table 5.21).

Table 5.21 Soil **s**alinity at different soil depths after the mustard harvest

| Depth (cm) | $EC_e$ (dS/m) | | | |
|---|---|---|---|---|
| | Canal | 5.0 | 7.5 | 10.0 |
| 0-15 | 1.57 | 5.31 | 7.61 | 10.13 |
| 15-30 | 1.67 | 5.80 | 7.97 | 10.46 |
| Mean | 1.62 | 5.56 | 7.79 | 10.29 |

**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 5.22. The average grain yield of rice varied from 22.30 to 43.43 q/ha in different varieties. The maximum grain yield of 43.43 q/ha of rice was recorded from variety CSR 36 followed by 41.15 q/ha from CSR 23 and 38.49 q/ha from CSR 43 (Table 5.23). The minimum grain yield of 22.30 q/ha was obtained from CSR 30. The average straw yield of rice varied from 27.69 to 52.93 q/ha in different varieties. The maximum straw yield of 52.93 q/ha was recorded from variety CSR 36 followed by 50.82 q/ha from CSR 23 and 45.86 q/ha from CSR 43. The minimum straw yield of 27.69 q/ha was obtained from CSR 30.

The average grain yield of wheat varied from 27.37 to 36.21 q/ha in different varieties. The maximum average grain yield of 36.21 q/ha was recorded from variety KRL 210 followed by 34.82 q/ha from KRL 213 and 33.41 q/ha from PBW 343 (Table 5.24). The minimum grain yield of 27.37 q/ha was obtained from variety WH 147. The average straw yield varied from 33.06 to 44.29 q/ha. The maximum straw yield of 44.29 q/ha was recorded from variety KRL 210 followed by 42.23 q/ha from KRL 213 and 40.90 q/ha from PBW 343.

Table 5.22 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 |

Table 5.23 Grain and straw yield of rice (q/ha) in sodic soil conditions

| Varieties | Grain yield of rice (q/ha) | | | | Straw yield of rice (q/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | Mean | 2015 | 2016 | 2017 | Mean |
| CSR 23 | 39.82 | 41.57 | 42.07 | 41.15 | 48.77 | 51.12 | 52.59 | 50.82 |
| CSR 27 | 37.65 | 38.24 | 39.35 | 38.41 | 45.68 | 46.65 | 49.18 | 47.17 |
| CSR 30 | 21.27 | 22.52 | 23.12 | 22.30 | 26.22 | 27.46 | 28.90 | 27.69 |
| CSR 43 | 36.38 | 38.85 | 40.25 | 38.49 | 42.38 | 44.89 | 49.31 | 45.86 |
| CSR 36 | 43.52 | 42.64 | 44.15 | 43.43 | 52.57 | 52.02 | 54.20 | 52.93 |
| Pant 12 | 28.69 | 27.83 | 29.30 | 28.60 | 34.86 | 35.53 | 36.63 | 35.67 |
| NDR 359 | 35.12 | 36.33 | 38.41 | 36.62 | 42.92 | 44.11 | 47.15 | 44.72 |
| Kranti | 33.41 | 32.54 | 34.01 | 33.32 | 39.43 | 40.22 | 42.51 | 40.72 |
| CD (0.05) | 2.56 | 2.62 | 2.59 | -- | 2.65 | 2.49 | 2.56 | -- |

Table 5.24 Grain and straw yield of wheat (q/ha) in sodic soil conditions

| Varieties | Grain yield of rice (q/ha) | | | | Straw yield of rice (q/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | Mean | 2015-16 | 2016-17 | 2017-18 | Mean |
| KRL 210 | 34.55 | 36.22 | 37.87 | 36.21 | 42.15 | 44.53 | 46.20 | 44.29 |
| KRL 213 | 33.84 | 34.87 | 35.77 | 34.82 | 40.94 | 42.12 | 43.63 | 42.23 |
| PBW 343 | 32.42 | 33.15 | 34.68 | 33.41 | 39.87 | 40.53 | 42.30 | 40.90 |
| PBW 502 | 31.27 | 30.20 | 32.22 | 31.23 | 36.89 | 35.86 | 39.30 | 37.35 |
| WH 147 | 26.10 | 27.68 | 28.34 | 27.37 | 31.84 | 32.78 | 34.57 | 33.06 |
| K 307 | 28.77 | 29.12 | 31.25 | 29.71 | 34.25 | 35.65 | 38.13 | 36.01 |
| K 8434 | 29.52 | 28.76 | 30.15 | 29.47 | 36.72 | 36.62 | 36.78 | 36.70 |
| DBW 17 | 27.33 | 28.44 | 29.84 | 28.53 | 32.54 | 33.74 | 36.40 | 34.22 |
| CD (0.05) | 1.67 | 1.72 | 1.69 | -- | 1.69 | 1.78 | 1.82 | -- |

The average seed yield of mustard varied from 10.69 to 16.47 q/ha in different varieties. The maximum seed yield of 16.47 q/ha was recorded from variety CS 56 followed by 14.77 q/ha from CS 54 and 13.56 q/ha from CS 52 whereas variety Varuna, Rohini and Kranti were at par in case of grain yield (Table 5.25). The minimum seed yield of 10.69 q/ha was obtained from variety Urvasi. The average stalk yield of mustard varied from 27.05 to 41.69 q/ha in different varieties. The maximum stalk yield of 41.69 q/ha was recorded from variety CS 56 followed by 38.08 q/ha from CS 54 and 34.43 q/ha from CS 52 whereas variety Varuna, Rohini and Kranti were at par in case of stalk yield. The minimum stalk yield of 27.05 q/ha was obtained from variety Urvasi.

Table 5.25 Seed and stalk yield of mustard (q/ha) in sodic soil conditions

| Varieties | Seed yield (q/ha) | | | | Stalk yield (q/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | 2017-18 | Mean | 2015-16 | 2016-17 | 2017-18 | Mean |
| CS-52 | 13.25 | 13.34 | 14.10 | 13.56 | 32.92 | 34.10 | 36.27 | 34.43 |
| CS-54 | 14.78 | 14.42 | 15.12 | 14.77 | 37.82 | 37.00 | 39.42 | 38.08 |
| CS-56 | 16.12 | 16.25 | 17.05 | 16.47 | 40.27 | 41.24 | 43.54 | 41.69 |
| Varuna | 12.97 | 12.25 | 13.22 | 12.81 | 34.25 | 33.72 | 34.37 | 34.11 |
| Pitambri | 11.55 | 11.22 | 12.11 | 11.62 | 29.45 | 28.04 | 31.48 | 29.65 |
| Rohini | 12.32 | 11.67 | 12.40 | 12.13 | 33.74 | 34.52 | 32.24 | 33.05 |
| Urvasi | 10.63 | 10.29 | 11.15 | 10.69 | 26.73 | 25.88 | 28.55 | 27.05 |
| Kranti | 12.14 | 12.10 | 13.17 | 12.47 | 30.35 | 29.48 | 33.45 | 31.09 |
| CD (0.05) | 1.12 | 1.25 | 1.37 | -- | 1.42 | 1.55 | 1.47 | -- |

**Evaluation of chilly and onion for tolerance to sodicity levels (Tiruchirapalli)**

**2016-17**

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<br>• 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.

**2017-18**

A field experiment was conducted to assess the effect of different Exchangeable Sodium Percentage (ESP) levels of soil on growth and yield of onion and to fix optimum sodicity tolerance limits of onion based on the performance under different soil sodicity levels. This experiment was continuous and permanent one, so far different crops were tested for their tolerance to sodicity. In existing experimental field, based on the ESP existed in the different main plots, the sodium bicarbonate was applied to main plots and mixed thoroughly with the soil to create different gradient ESP levels viz., 8, 16, 24, 32, 40 and 48 were artificially. Further, the ESP 8 and 16 were created through application of gypsum and leaching with good quality water. The experimental plot was thoroughly ploughed individually to bring optimum soil tilt and the ridges and furrows were formed and onion bulb of local variety and seedlings of Co 5 were planted with a spacing of 45x10 cm with the application of fertilizers viz., 60:60:60 kg N, $P_2O_5$ and $K_2O$ (50% of N at basal and remaining 50% at 30 DAS). The experiment was carried out with five levels of ESP in main plot and two onion variety in strip plot design with four replications. The results (Table 5.26) revealed that among the different levels of ESP, the bulb yield was declined with increased ESP levels from 8. However, more than 50 per cent yield could be achieved up to 24 ESP level. Among the varieties Co 5 (seed) and local (Bulb), the performance of Co 5 was superior over local. The highest onion bulb yield of 14206 and 16213kg per hectare was recorded in local (onion bulb) and Co5 (seed) varieties respectively. Similar trend with respect to the individual bulb weight per plant was also recorded. Hence, it is concluded that the onion can be grown in sodic soil up to the ESP level of 24 where the 50per cent of yield could be realised.

Table 5.26 Effect of graded levels of sodicity on bulb yield of onion

| Treatments ESP levels | Bulb wt.(g/plant) | | Mean | Bulb Yield (kg/ha) | | Mean |
|---|---|---|---|---|---|---|
| | V1-Onion bulb | V2 –Onion seed (Co5) | | V1-Onion bulb | V2 –Onion seed (Co5) | |
| 8 | 71.2 | 82.3 | 76.8 | 14206 | 16213 | 15209.5 |
| 16 | 54.4 | 68.7 | 61.6 | 10845 | 13642 | 12243.5 |
| 24 | 46.6 | 51.4 | 49.0 | 9286 | 10219 | 9752.5 |
| 32 | 24.6 | 35.7 | 30.2 | 4845 | 7089 | 5967.0 |
| 40 | 10.2 | 15.4 | 12.8 | 1944 | 3026 | 2485.0 |
| 48 | 9.8 | 10.3 | 10.1 | 1887 | 1966 | 1926.5 |
| Mean | 36.13 | 43.97 | | 7168.83 | 8692.5 | |
| Treatments | SED | CD | | SED | CD | |
| ESP levels | 1.45 | 3.08 | | 311.8 | 664.5 | |
| Variety | 0.014 | 0.042 | | 2.38 | 7.57 | |
| ESP at Var | 4.87 | 10.25 | | 961.4 | 2049.2 | |
| Variety at ESP | 3.81 | 8.23 | | 494.6 | 1054.6 | |

Among the different levels of ESP, the bulb yield was declined with increased ESP levels from 8. However, more than 50 per cent yield could be achieved up to 24 ESP level. Among the varieties Co 5 (seed) and local (Bulb), the performance of Co 5 was superior over local. The highest onion bulb yield of 16213kg per hectare was recorded in Co5 (seed) variety. Hence, it is concluded that the onion can be grown in sodic soil up to the ESP level of 24 where the 50per cent of yield could be realised.

**Screening of Clusterbean (Cyamopsis tetragonoloba L.) Germplasm for salinity tolerance (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 5$^{th}$ July, 2016. The crop was harvested on 11 November, 2016. Initial physico-chemical characteristics of soil (0-15 cm) and composition of canal and tube well waters are presented in Table 5.27.

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 5.28 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 5.27 Initial physico-chemical characteristics of soil (0-15 cm) and chemical composition of irrigation water

| Physico-chemical characteristics of soil | | Composition of canal water and tube well water | | |
|---|---|---|---|---|
| Parameter | Particulars | Parameter | Particulars for Canal water | Particulars for Tubewell water |
| Soil texture | Loamy sand (Sand: 80.1 %; Silt: 12.2 %; Clay 7.7%) | EC (dS $m^{-1}$) | 0.32 | 4.40 |
| pH | 8.33 | $Na^{+}$ (me/l) | 1.42 | 36.6 |
| EC (dS $m^{-1}$) | 0.18 | $Ca^{+2}$+ $Mg^{+2}$ (me/l) | 1.78 | 7.4 |
| $CaCO_3$ (%) | 4.15 | $Cl^{-1}$ (me/l) | 0.8 | 11.8 |
| OC (%) | 0.19 | $CO_3^{-2}$ (me/l) | nil | nil |
| Available P (kg $ha^{-1}$) | 9.5 | $HCO_3^{-}$ (me/l) | 1.6 | 6.8 |
| Available K (kg $ha^{-1}$) | 240 | RSC (me/l) | 0 | 0 |
| | | SAR | 1.5 | 19.0 |

Data presented in Table 5.29 revealed that pod length, number of grains/pod and seed index does not affect significantly by poor quality water, whereas, grain yield/plant significantly influenced by poor quality water. It was also reported that maximum grain yield was observed in gremplasm IC 40235 followed by IC 40417 > IC 40752 and IC 40266.

Table 5.28 Effect of poor quality water on pod length, number of grains, grain yield and seed index of different clusterbean (*Cyamopsis tetragonoloba* L.) germplasm (2016-17)

| Sr.No | Cultivars | Pod length (cm) | | | Number of grains/ pods | | | Grain yield /plant | | | Seed Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | TW | Mean | CW | TW | Mean | CW | TW | Mean | CW | TW | Mean |
| 1 | IC 39418 | 5.57 | 5.12 | 5.34 | 9.00 | 8.19 | 8.60 | 14.93 | 7.00 | 10.97 | 2.79 | 2.75 | 2.77 |
| 2 | IC 39980 | 5.78 | 5.42 | 5.60 | 8.50 | 8.25 | 8.38 | 11.82 | 5.55 | 8.68 | 2.83 | 2.76 | 2.79 |
| 3 | IC40004 | 5.63 | 5.13 | 5.38 | 8.17 | 7.50 | 7.83 | 7.08 | 5.57 | 6.32 | 2.48 | 2.41 | 2.44 |
| 4 | IC40230 | 5.92 | 5.63 | 5.78 | 8.67 | 8.23 | 8.45 | 13.16 | 8.84 | 11.00 | 2.86 | 2.65 | 2.75 |
| 5 | IC40235 | 5.75 | 5.40 | 5.58 | 8.33 | 8.00 | 8.17 | 19.42 | 14.61 | 17.01 | 3.10 | 2.99 | 3.04 |
| 6 | IC40249 | 5.65 | 5.53 | 5.59 | 9.01 | 8.33 | 8.67 | 10.66 | 7.16 | 8.91 | 2.94 | 2.73 | 2.84 |
| 7 | IC40256 | 5.83 | 5.33 | 5.58 | 9.23 | 8.50 | 8.87 | 13.95 | 5.70 | 9.83 | 2.92 | 2.74 | 2.83 |
| 8 | IC40417 | 6.15 | 5.33 | 5.74 | 9.00 | 8.50 | 8.75 | 15.53 | 11.98 | 13.75 | 2.94 | 2.84 | 2.89 |
| 9 | IC40458 | 5.43 | 5.30 | 5.37 | 8.82 | 8.55 | 8.68 | 11.52 | 7.82 | 9.67 | 2.66 | 2.55 | 2.60 |
| 10 | IC40741 | 5.38 | 4.97 | 5.18 | 8.00 | 7.68 | 7.84 | 12.84 | 7.58 | 10.21 | 2.71 | 2.52 | 2.61 |
| 11 | IC40752 | 6.00 | 5.62 | 5.81 | 9.00 | 7.80 | 8.40 | 14.68 | 10.11 | 12.39 | 2.99 | 2.82 | 2.91 |
| 12 | IC40162 | 6.20 | 5.12 | 5.66 | 9.00 | 7.33 | 8.17 | 16.23 | 4.24 | 10.24 | 2.89 | 2.60 | 2.74 |
| 13 | IC40266 | 5.72 | 5.65 | 5.68 | 8.67 | 8.55 | 8.61 | 15.77 | 9.42 | 12.60 | 2.94 | 2.81 | 2.87 |
| 14 | IC40682 | 5.45 | 5.15 | 5.30 | 8.83 | 8.43 | 8.63 | 12.58 | 6.81 | 9.69 | 2.98 | 2.94 | 2.96 |
| 15 | IC40763 | 5.75 | 5.50 | 5.63 | 9.00 | 8.21 | 8.60 | 14.27 | 8.54 | 11.41 | 2.82 | 2.61 | 2.71 |
| 16 | IC40998 | 6.05 | 5.74 | 5.89 | 9.15 | 9.08 | 9.12 | 8.23 | 5.37 | 6.80 | 2.93 | 2.74 | 2.84 |
| 17 | IC41189 | 5.53 | 5.33 | 5.43 | 9.40 | 9.17 | 9.28 | 10.05 | 4.91 | 7.48 | 2.51 | 2.46 | 2.48 |
| 18 | IC41202 | 5.42 | 5.22 | 5.32 | 8.33 | 8.08 | 8.21 | 13.01 | 8.49 | 10.75 | 2.88 | 2.13 | 2.50 |
| 19 | IC113578 | 5.58 | 5.52 | 5.55 | 8.15 | 8.00 | 8.08 | 11.42 | 7.71 | 9.56 | 2.39 | 2.16 | 2.27 |
| 20 | IC329038 | 5.08 | 4.87 | 4.98 | 8.67 | 8.00 | 8.33 | 11.27 | 5.70 | 8.49 | 2.88 | 2.66 | 2.77 |
| | Mean | 5.69 | 5.34 | | 8.75 | 8.22 | | 12.92 | 7.65 | | 2.82 | 2.64 | |
| | CD (5%) water Quality=NS | | | | | NS | | | 1.89 | | | NS | |
| | Germplasm | | 0.46 | | | NS | | | 1.98 | | | 0.20 | |
| | Interaction | | NS | | | NS | | | 2.79 | | | NS | |

Table 5.29 Effect of poor quality water on pod length, number of grains, grain yield and seed index of different clusterbean (*Cyamopsis tetragonoloba* L.) Germplasm (2017-18)

| Sr. No | Cultivars | Pod length (cm) | | | Number of grains/ pods | | | Grain yield /plant | | | Seed Index | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | TW | Mean | CW | TW | Mean | CW | TW | Mean | CW | TW | Mean |
| 1 | IC 39418 | 5.33 | 4.69 | 5.01 | 9.1 | 8 | 8.55 | 16.17 | 9.14 | 12.66 | 2.85 | 2.8 | 2.83 |
| 2 | IC 39980 | 5.57 | 5.26 | 5.41 | 8.8 | 8.4 | 8.6 | 15.19 | 9.23 | 12.21 | 2.82 | 2.79 | 2.81 |
| 3 | IC40004 | 4.78 | 4.63 | 4.7 | 8.3 | 8.03 | 8.17 | 9.99 | 6.04 | 8.01 | 2.67 | 2.46 | 2.56 |
| 4 | IC40230 | 5.45 | 5.29 | 5.37 | 8.1 | 7.6 | 7.85 | 13.56 | 9.26 | 11.41 | 2.95 | 2.67 | 2.81 |
| 5 | IC40235 | 4.87 | 4.47 | 4.67 | 8.4 | 7.6 | 8 | 21.81 | 11.52 | 16.66 | 2.97 | 2.68 | 2.82 |
| 6 | IC40249 | 5.2 | 4.87 | 5.03 | 8.5 | 8.4 | 8.45 | 12.18 | 7.65 | 9.91 | 2.96 | 2.87 | 2.91 |
| 7 | IC40256 | 5.33 | 4.99 | 5.16 | 8 | 7.8 | 7.9 | 15.19 | 6.18 | 10.69 | 2.82 | 2.78 | 2.8 |
| 8 | IC40417 | 5.29 | 5.02 | 5.16 | 8.6 | 7.7 | 8.15 | 16.46 | 10.96 | 13.71 | 2.76 | 2.67 | 2.71 |
| 9 | IC40458 | 5.19 | 4.97 | 5.08 | 9.03 | 8.3 | 8.67 | 15.18 | 8.47 | 11.82 | 2.94 | 2.89 | 2.91 |
| 10 | IC40741 | 5.24 | 5.11 | 5.17 | 7.1 | 5.9 | 6.5 | 12.9 | 6.62 | 9.76 | 2.78 | 2.71 | 2.74 |
| 11 | IC40752 | 5.31 | 5.09 | 5.2 | 8.2 | 8.13 | 8.17 | 13.46 | 10.59 | 12.03 | 2.77 | 2.68 | 2.73 |
| 12 | IC40162 | 4.98 | 4.91 | 4.94 | 8.5 | 8.2 | 8.35 | 16.61 | 6.85 | 11.73 | 2.73 | 2.69 | 2.71 |
| 13 | IC40266 | 4.83 | 4.72 | 4.77 | 8.5 | 8.1 | 8.3 | 18.15 | 9.97 | 14.06 | 2.79 | 2.76 | 2.77 |
| 14 | IC40682 | 5.07 | 4.85 | 4.96 | 7.7 | 7.3 | 7.5 | 11.85 | 5.85 | 8.85 | 2.81 | 2.76 | 2.79 |
| 15 | IC40763 | 4.64 | 4.49 | 4.57 | 8.07 | 7.8 | 7.93 | 14.27 | 10.51 | 12.39 | 2.71 | 2.65 | 2.68 |
| 16 | IC40998 | 4.68 | 4.64 | 4.66 | 8.4 | 7.7 | 8.05 | 7.17 | 4.54 | 5.85 | 2.76 | 2.68 | 2.72 |
| 17 | IC41189 | 4.86 | 4.15 | 4.5 | 8 | 6.3 | 7.15 | 12.95 | 4.79 | 8.87 | 2.75 | 2.62 | 2.69 |
| 18 | IC41202 | 5.13 | 5.11 | 5.12 | 8.03 | 7.7 | 7.87 | 17.17 | 10.58 | 13.87 | 2.79 | 2.72 | 2.76 |
| 19 | IC113578 | 4.7 | 4.45 | 4.57 | 8.07 | 7.8 | 7.93 | 15.43 | 10.35 | 12.89 | 2.76 | 2.69 | 2.73 |
| 20 | IC329038 | 4.62 | 4.49 | 4.56 | 8.1 | 7.7 | 7.9 | 14.07 | 6.91 | 10.49 | 2.83 | 2.8 | 2.82 |
| Mean | | 5.05 | 4.81 | | 8.28 | 7.72 | | 14.49 | 8.3 | | 2.81 | 2.72 | |
| CD (5%) water Quality | | 0.12 | | | 0.17 | | | 1.85 | | | NS | | |
| Germplasm | | 0.33 | | | 0.54 | | | 2.07 | | | NS | | |
| Interaction | | NS | | | NS | | | 2.92 | | | NS | | |

**Screening Chickpea (*Cicer arietinum* L.) Germplasm for salinity tolerance (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. Initial soil properties as well as canal and tubewell water quality parameters are provided in Table 5.30.

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 5.31.

Table 5.30 Initial physico-chemical characteristics of soil (0-15 cm) and chemical composition of irrigation water

| Physico-chemical characteristics of soil | | Composition of canal water and tube well water | | |
|---|---|---|---|---|
| Parameter | Particulars | Parameter | Particulars for Canal water | Particulars for Tubewell water |
| Soil texture | Loamy sand (Sand: 80.1 %; Silt: 12.2 %; Clay 7.7%) | EC (dS $m^{-1}$) | 0.30 | 4.30 |
| pH | 8.71 | $Na^+$ (me/l) | 0.68 | 35.5 |
| EC (dS $m^{-1}$) | 0.18 | $Ca^{+2}$+ $Mg^{+2}$ (me/l) | 2.4 | 7.5 |
| $CaCO_3$ (%) | 4.15 | $Cl^{-1}$ (me/l) | 0.4 | 7.2 |
| OC (%) | 0.19 | $CO_3^{-2}$ (me/l) | nil | nil |
| Available P (kg $ha^{-1}$) | 9.2 | $HCO_3^-$ (me/l) | 1.8 | 7.4 |
| Available K (kg $ha^{-1}$) | 240 | RSC (me/l) | 0 | 0 |
| | | SAR | 0.62 | 18.33 |

Table 5.31 Effect of poor quality water on different growth parameters and yield of Chickpea (*Cicer arietinum* L.) germplassm

| S.No | Cultivars | Plant height (cm) | | | Number of primary branches/Plant | | | Yield/plant | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CW | TW | Mean | CW | TW | Mean | CW | TW | Mean |
| 1 | GL-12021 | 45.31 | 21.10 | 33.21 | 8.83 | 6.17 | 7.50 | 10.42 | 4.38 | 7.40 |
| 2 | GL-13042 | 44.38 | 17.73 | 31.05 | 9.50 | 6.83 | 8.17 | 11.27 | 4.35 | 7.81 |
| 3 | GL-29078 | 42.06 | 17.60 | 29.83 | 6.50 | 8.17 | 7.33 | 8.75 | 4.86 | 6.81 |
| 4 | GL-14015 | 48.88 | 19.38 | 34.13 | 7.50 | 5.50 | 6.50 | 11.89 | 6.78 | 9.33 |
| 5 | GNG-2171 | 42.25 | 17.50 | 29.88 | 9.50 | 5.17 | 7.33 | 23.87 | 5.57 | 14.72 |
| 6 | GL-29095 | 39.25 | 21.00 | 30.13 | 8.83 | 4.83 | 6.83 | 13.45 | 6.73 | 10.09 |
| 7 | GLK-07-042 | 40.94 | 14.50 | 27.72 | 6.83 | 4.00 | 5.42 | 12.00 | 2.10 | 7.05 |
| 8 | GLK-14311 | 38.69 | 11.56 | 25.13 | 6.00 | 3.83 | 4.92 | 8.83 | 2.49 | 5.66 |
| 9 | PBG-1 | 44.50 | 18.50 | 31.50 | 9.50 | 5.50 | 7.50 | 14.54 | 4.15 | 9.35 |
| 10 | GL-13037 | 44.50 | 21.88 | 33.19 | 8.50 | 6.83 | 7.67 | 20.45 | 6.67 | 13.56 |
| 11 | JG-62 | 36.94 | 26.25 | 31.59 | 7.50 | 6.83 | 7.17 | 8.13 | 4.52 | 6.33 |
| 12 | GPF-2 | 35.13 | 20.13 | 27.63 | 5.83 | 6.17 | 6.00 | 9.96 | 5.25 | 7.60 |
| 13 | PDG-3 | 43.00 | 24.31 | 33.66 | 7.50 | 4.50 | 6.00 | 15.82 | 7.65 | 11.74 |
| 14 | L-556 | 41.25 | 24.69 | 32.97 | 5.17 | 4.33 | 4.75 | 10.75 | 5.19 | 7.97 |
| 15 | L-552 | 49.00 | 27.06 | 38.03 | 7.67 | 4.83 | 6.25 | 14.00 | 7.21 | 10.60 |
| 16 | PBG-5 | 44.63 | 27.38 | 36.00 | 7.50 | 5.17 | 6.33 | 16.84 | 8.03 | 12.44 |
| 17 | PDG-4 | 43.38 | 28.06 | 35.72 | 8.50 | 8.17 | 8.33 | 13.43 | 8.97 | 11.20 |
| 18 | ICCU-10508 | 39.13 | 25.38 | 32.25 | 5.00 | 5.00 | 5.00 | 11.10 | 7.79 | 9.44 |
| 19 | PBG-7 | 42.44 | 25.31 | 33.88 | 6.17 | 6.83 | 6.50 | 15.02 | 10.91 | 12.96 |
| 20 | Karnal Channa-1 | 37.38 | 25.63 | 31.50 | 5.83 | 6.17 | 6.00 | 19.70 | 15.39 | 17.54 |
| | Mean | 42.15 | 21.75 | | 7.41 | 5.74 | | 13.51 | 6.45 | |
| | CD (5%) water Quality | | 14.66 | | | 1.05 | | | 3.37 | |
| | Germplasm | | 2.80 | | | 0.42 | | | 0.83 | |
| | Interaction | | 3.96 | | | 0.59 | | | 1.17 | |

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.

**Screening of wheat cultivars for salt tolerance (Bathinda)**

The experiment was conducted during Rabi 2017 to asses to salt tolerance of wheat cultivars popularly grown in the region. The seven verities namely HD 3086, HD 2967, KR L 213, Unnat PBW 550, PBW 725, KRL210 and Unnat PBW343 were grown under two quality water ( canal water and Tubewell water) having different chemical compositions. Results of the study showed that height of the plant were non significant, whereas significantly varietals differences were observed in number of tillers and ear length of the cultivars. The maximum number of tillers/ m2 was reported in HD 2967 followed by PBW 725, where as maximum ear length was reported in Unnat PBW 550 followed by HD 2967. It is reported that Unnat PBW 550 and PBW 725 had maximum no of seeds/ear followed by HD 2967. However, maximum grain yield was reported in variety HD 3086 followed by Unnat PBW 550 and PBW 725 under the both conditions (Table 5.32).

Table 5.32 Effect of poor quality water on number of seeds/ear and grain yield of wheat (*Triticum aestivum* L.) cultivars

| S.No | Cultivars | Number of seeds/ ear | | | grain yield (kg/acre) | | |
|---|---|---|---|---|---|---|---|
| | | CW | TW | Mean | CW | TW | Mean |
| 1 | HD 3086 | 59.6 | 58.6 | 59.1 | 2477.7 | 2320.1 | 2398.9 |
| 2 | HD 2967 | 69.8 | 57.0 | 63.4 | 2156.4 | 2130.9 | 2143.6 |
| 3 | KRL 213 | 57.4 | 66.8 | 62.1 | 1663.9 | 1518.6 | 1591.2 |
| 4 | Unnat PBW 550 | 68.2 | 61.5 | 64.8 | 2430.8 | 2206.8 | 2318.8 |
| 5 | PBW 725 | 61.1 | 68.2 | 64.6 | 2369.0 | 2223.5 | 2296.2 |
| 6 | KRL210 | 58.0 | 54.3 | 56.1 | 1922.8 | 1761.4 | 1842.1 |
| 7 | UnnatPBW343 | 59.8 | 59.5 | 59.6 | 2531.3 | 2305.6 | 2418.4 |
| CD (5%) water Quality | | | 0.76 | | | 35.1 | |
| Cultivars | | | 0.47 | | | 59.1 | |
| Interaction | | | 0.67 | | | 83.5 | |

## 6. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

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

The field demonstrations in operational research project for the use of poor quality water were initiated in kharif 1993 in Karanpur village of Mathura district. The village is located at Fareh-Achhnera road only 6 km away from Fareh town. In 1999 the program was extended to two other villages namely Nagla Hridaya and Bhojpur. At these sites, medium and high SAR saline category waters were available. In the year 2000 the program was further extended to Savai village of Agra district to demonstrate the technologies on the use of alkali water. In kharif 2004, ORP was also initiated at Odara village of Bharatpur district in high SAR saline water ($EC_{iw}$ 6.0 to 23.5 dS/m and SAR 11-30 $(mmol/l)^{1/2}$. In 2006, one other site was also selected for dry land salinity demonstrations at Nagla Parasuram in Bharatpur District. In 2015-16, eleven farmers are selected using saline water (ECiw ranges 7.1 to 13.0 dS/m) of different villages i.e. Deen Dayal Dham (Nagla Chandra Bhan), Dhana Khema, Nagla Jalal, Garhi Pachauri and Dalatpur in district Mathura (U.P.) and Odara in Bhratpur district (Rajasthan).

The water quality parameters pertaining to tube well water of the selected farmers are given in Table 6.1. During the year 2016-17, the EC and 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 (2016-17)

| Name of the farmer | $EC_{iw}$ | RSC (meq/l) | SAR $(mmol/l)^{1/2}$ |
|---|---|---|---|
| **RSC water** | | | |
| 1. Mr. Harvans Kumar | 3.0 | 8.8 | 17.0 |
| 2. Mr. Om Prakash | 4.4 | 7.6 | 23.9 |
| 3. Mr. Hakim Singh | 5.1 | 6.2 | 24.7 |
| **Saline Water** | | | |
| 1. Mr. Subhash Chand | 10.0 | - | 11.0 |
| 2. Mr. Ram Bharosee | 15.0 | - | 19.0 |
| 3. Mr. Hari Prasad | 13.5 | - | 12.5 |
| 4. Mr. Lal Hans | 10.9 | - | 16.2 |
| 5. Mr. Dinesh Chand | 11.0 | - | 17.0 |
| 6. Mr. Mukesh Kumar | 13.8 | - | 24.0 |
| 7. Mr. Roop Singh | 23.5 | - | 24.9 |
| 8. Mr. Birendra Singh | 19.9 | - | 23.5 |
| 9. Mr. Jagan Singh | 12.6 | - | 15.5 |

### Kharif season

The demonstrations were conducted at 12 farmers' fields during *kharif* season. Out of 12 farmers, the pearl millet crop was grown on 8 fields (3 with alkali water + 5 with saline water) and sorghum fodder on 4 fields. In alkali water demonstrations, the gypsum was incorporated @ 50% GR in 1/3$^{rd}$ field and 1/3$^{rd}$ field kept control (without gypsum). The N, P, K fertilizers were applied @ 120 kg, 60 kg and 30 kg for pearl millet and 90 kg, 30 kg and 30 kg for sorghum fodder (Table 6.2). In alkali water area, three farmers grew pearl millet. The yield varied from 1.80 to 2.35 t/ha in gypsum incorporated fields and 1.60 to 2.10 t/ha in without gypsum fields. The percent increase was from 11.7 to 12.5 in gypsum added fields over no gypsum (Table 6.2).

In high SAR saline water, the pearl millet crop was grown on five farmers' fields and 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 fields. Increase in yield was from 10.0 to 11.8 per cent as compared to traditional farming. Sorghum fodder yield varied from 37.0 to 40.5 t/ha in ORP demonstration fields. In ORP fields, the Sorghum fodder averaged increased about 14 per cent over conventional method.

Table 6.2 Pearl millet grain yield (t/ha) and Dhaincha Green manure in alkali water and soil Characteristics at harvest crop (0-30cm) 2016

| Name | Treatments | Variety | ORP yield (t/ha) | % increase Over control | ECe (dS/m) | pH2 | SAR (mmol/l)1/2 | ESP |
|---|---|---|---|---|---|---|---|---|
| 1.Mr. Harvans Kumar | Gypsum | Poineer 86M86 | 1.80 | 12.5 | 2.9 | 7.7 | 16.1 | 15.5 |
| | No Gypsum | ,, | 1.60 | - | 4.0 | 7.7 | 16.5 | 18.3 |
| 2. Mr Om Prakash | Gypsum | P. Millet 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 |
| 3. 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 t/ha in saline water and soil Characteristics at harvest crop (0-30cm) 2016

| Name | Crop/ Variety | ORP yield (t/ha) | Farmers Yield (t/ha) | % increase over farmers field | $EC_e$ (dS/m) | pH2 | SAR $(mmol/l)^{1/2}$ |
|---|---|---|---|---|---|---|---|
| 1. Mr.Lal Hans | Sorghum/Poorbi white | 38.25 | 33.50 | 14.17 | 3.2 | 7.2 | 11.2 |
| 2. Mr. Birendra Singh | Pearl millet/Supper Boss | 2.33 | 2.1 | 11.1 | 6.3 | 7.3 | 16.5 |
| 3. Mr. Roop Singh | Sorghum/Poorbi white | 37.00 | 32.50 | 13.84 | 8.2 | 7.1 | 17.0 |
| 4. Mr. Subhash Chand | Pearl millet/ Supper Boss | 2.40 | 2.15 | 11.6 | 2.4 | 7.2 | 6.9 |
| 5. Mr. Ram Bharose | Pearl millet/ Supper Boss | 2.10 | 1.85 | 10.0 | 2.3 | 7.3 | 10.1 |
| 6. Mr. Mukesh Kumar | Sorghum GF/ Poorbiwhite | 40.50 | 35.00 | 15.71 | 2.1 | 7.1 | 11.0 |
| 7. Mr. Hari Prasad | Sorghum/Poorbi white | 37.50 | 33.00 | 13.63 | 6.0 | 7.3 | 13.4 |
| 8. Mr. Dinesh Chand | Pearl millet/ Supper Boss | 1.90 | 1.70 | 11.8 | 2.8 | 7.1 | 8.7 |
| 9. Mr. Jagan Singh | Pearl millet/ MRB 204 | 1.95 | 1.78 | 10.7 | 2.6 | 7.2 | 7.9 |

GF- Green Fodder

**Rabi Season**

The total 19 farmers were selected for sowing the r*abi* season crops. In alkali water (Savai village, Agra district), the wheat crop was sown on 3 farmers' fields. The saline water using rain water harvesting through recharge structures at Odara village, Bharatpur district Rajasthan, the wheat crop was sown on eight farmers' fields and mustard crop was sown on one farmer's field. Other 7 farmers were selected in saline water irrigation condition and all grew wheat crop. The recommended dose of N, P and K fertilizers were 120 kg, 60 kg and 60 kg/ha in wheat and mustard crop along with 12.5 kg/ha Forate and 12.5 kg/ha zinc.

Wheat crop was sown at three farmers' field at Savai village of district Agra. The yield increase was observed in gypsum treated fields over control (without gypsum). The average wheat yield increase was about 12.2 per cent in 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 (Table 6.4).

Table 6.4 Residual effect of Gypsum on wheat yield (t/ha) and soil characteristics (0-30 cm) at harvest (2016-17)

| Name | Treatment | O.R.P yield t/ha | % increase over control | $EC_e$ (dS/m) | pH2 | SAR $(mmol/l)^{1/2}$ | ESP |
|---|---|---|---|---|---|---|---|
| 1.Mr. Harvans Km. | With Gyp. | 4.17 | 13.6 | 5.6 | 7.7 | 18.4 | 19.4 |
| | No gyp | 3.67 | - | 3.7 | 7.8 | 15.2 | 20.2 |
| 2.Mr. Om Prakash | With Gyp. | 4.67 | 11.2 | 4.9 | 7.8 | 16.2 | 17.8 |
| | No gyp. | 4.20 | - | 6.8 | 8.0 | 22.9 | 19.5 |
| 3.Mr. Hakim Singh | With Gyp. | 4.33 | 11.9 | 5.0 | 7.9 | 17.7 | 19.1 |
| | No gyp. | 3.87 | - | 5.2 | 7.8 | 16.6 | 22.8 |

Only one farmer (Mr. Hari Parsad) grew mustard crop in rabi season 2016-17. The seed yield of mustard found 2.37(t/ha) and increase was 12.8 per cent compared to other farmers' yields. The results of soil analysis at harvest of mustard crop are given in Table 6.5.

Table 6.5 Effect of saline water on grain yield of mustard at water recharge sites of Odara village (2016-17)

| Farmers Name | ECiw (dS/m) | variety | O.R.P Yield (t/ha) | Farmers yield (t/ha) | % Increase Over control | $EC_e$ (dS/m) | pH2 | SAR $(mmol/l)^{1/2}$ |
|---|---|---|---|---|---|---|---|---|
| 1. Mr Hari Prasad | 8.1 | Rohini | 2.37 | 2.10 | 12.8 | 7.9 | 7.2 | 16.2 |

The wheat crop was sown at 8 farmers' fields in rain water recharging site and other seven farmers grew wheat crop in saline water irrigation condition Table 6.6. The average of eight farmers' fields, wheat yield increased about 11.3 per cent in rain water recharge site and other seven farmers' fields, yield increased by 10.2 per cent. The soil ECe, pH and SARe are presented in Table 6.6. The ECe ranged 5.7 to 10.5 (dS/m), pH ranged 7.0 to 7.2 and SARe ranged 11.4 to 23.6 $(mmol.l)^{1/2}$ in farmers' fields with recharge sites. The maximum yield (5.00 t/ha) was recorded in the field of Mr. Subhas Chand and lowest of Mr Roop Singh field is 3.75 t/ha. The other farmer's wheat yield was similar.

Table 6.6 Effect of saline water on grain yield of wheat at recharge sites & other farmer's field and soil characteristics (0-30 cm) at harvest (2016-17)

| Name | 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** | | | | | | | | |
| 1. Mr.Lal Hans | 10.9 | Raj.4120 | 4.75 | 4.30 | 10.5 | 7.2 | 7.1 | 20.2 |
| 2. Mr.MukeshKumar | 13.8 | ,, | 4.37 | 3.90 | 12.0 | 5.7 | 7.1 | 14.3 |
| 3. Mr. Ram Bharose | 15.0 | ,, | 4.25 | 3.75 | 13.3 | 6.8 | 7.2 | 11.4 |
| 4. Mr.Birendra Singh | 11.0 | ,, | 4.00 | 3.60 | 11.1 | 10.0 | 7.1 | 15.4 |
| 5.Mr.Roop Singh | 7.8 | Raj.4120 | 3.75 | 3.40 | 10.3 | 10.5 | 7.1 | 23.5 |
| 6. Mr.Subhas Chand | 8.2 | Raj.4238 | 5.00 | 4.45 | 12.3 | 7.5 | 7.2 | 11.6 |
| 7.Mr.Jagan Singh | 7.1 | ,, | 4.87 | 4.40 | 10.7 | 8.6 | 7.0 | 14.9 |
| 8.Mr. Lal Hans | 11.1 | ,, | 4.62 | 4.20 | 10.0 | 6.7 | 7.2 | 23.6 |
| **Other farmers** | | | | | | | | |
| 1.Mr.Bhanwar Singh | 7.1 | KRL-210 | 4.20 | 3.80 | 10.5 | 7.1 | 7.5 | - |
| 2.Mr.Kishan Singh | 6.4 | ,, | 4.33 | 3.90 | 11.0 | 6.3 | 7.3 | - |
| 3.Mr.R.M.Pathak | 6.7 | ,, | 4.50 | 4.05 | 11.1 | 6.7 | 7.2 | - |
| 4.Mr.Mahendra Pratap | 6.3 | ,, | 4.67 | 4.20 | 11.2 | 6.0 | 7.2 | - |
| 5.Mr.Ram Babu | 4.7 | ,, | 4.35 | 4.00 | 8.7 | 4.7 | 7.2 | - |
| 6.Mr.Chandan lal | 7.3 | Raj.4238 | 4.63 | 4.20 | 10.2 | 7.3 | 7.1 | - |
| 7.Mr.Babu lal | 5.8 | KRL-210 | 4.50 | 4.15 | 8.4 | 5.2 | 7.2 | - |

At recharge sites, tube well water the initial ECiw ranged from 10.9 to 23.5 (dS/m) it decreased with rain water recharge. The lowest ECiw was observed for first irrigation i.e. from 4.5 to 5.9 (dS/m), for second irrigation from 5.8 to 7.6 (dS/m), third irrigation from 7.5 to 11.5 (dS/m), forth irrigation from 9.0 to 14.4(dS/m) and fifth irrigation from 10.0 to 12.5 (dS/m). The ECiw of tube well water decreased due dilution of underground water with rain water harvesting (Table 6.7).

Table 6.7 $EC_{iw}$ (dS/m) during different irrigations at rain water recharging sites (2016-17)

| Name | Initial | $I^{st}$ irrigation | $II^{nd}$ irrigation | $III^{rd}$ irrigation | IVth irrigation | Vth irrigation |
|---|---|---|---|---|---|---|
| Mr. Lal Hans | 10.9 | 4.7 | 5.9 | 7.6 | 9.2 | 10.1 |
| Mr. RamBharosi | 15.0 | 4.5 | 7.4 | 9.2 | 10.9 | 12.5 |
| Mr. Jagan Singh | 12.6 | 5.6 | 6.4 | 8.5 | 10.2 | 11.3 |
| Mr Mukesh Km | 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 | 11.0 | 5.7 | 7.0 | 8.7 | 9.6 | 10.0 |

**Low cost technology for dilution of saline ground water through artificial recharge:**

Agra-Bharatpur region in the states of U.P. and Rajasthan are endowed with poor quality groundwater aquifers. Shallow aquifers are relatively more saline (10-15 dS/m) relative to deeper aquifers (2-6 d S/m). The resource poor farmers of the region who cannot afford to drill deep bores are contented with exploiting the saline aquifers to give on 1-2 life saving irrigation (s) to mustard. Thus, under such a situation, yields are reduced due to high salinity. Diluting saline ground water through artificial recharge has been designed and tested on 12 farmers' fields. The technology consisted of diverting the run off to these structures for recharge. The diluted ground water is then pumped to irrigate mustard / wheat. The salinity of the ground water is reduced in most cases to less than 4 dS/m but eventually reached to its original value during 3rd or 4th irrigation. The irrigation with low quality water at initial growth stage boosted the yield to normal level in the case of mustard and wheat.

In the year 2017 this program was shifted Odra to three other villages i.e. Signa in Achhnera block district, Agra and Nagla Jalal and Kurkunda in block Fareh district Mathura. At these sites, high SAR saline water is available.

Table 6.8 clearly indicated that the water quality parameters pertaining to tube well water of the selected farmers. The year 2017-18 eleven farmers were selected in ORP saline water project**.** The selected farmers ECiw ranged from 3.8 to 13.3 dS/m. The pH was almost normal in all the farmers' tube well water samples. The sodium range was recorded (28.9 to 114.7 meq/l). The Ca+Mg was present in all the water samples but this value was ranged from (9.1 to 18.3 meq/l). The all collected water samples, $CO_3$ was not found but $HCO_3$ was present in all samples. The chloride and sulphate were present in all the samples collected at the farmers' tubewell waters. The SAR of all the collected water samples ranged from (13.6 to 36.9) but RSC was not found in any sample.

Table 6.8 Water quality of farmer's tube well water

| Farmers name | ECe | pH | Na | Ca+Mg | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | SAR | RSC |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.Mr.Kishan Gopal | 6.0 | 7.5 | 47.2 | 12.8 | - | 10.5 | 21.7 | 27.8 | 18.7 | - |
| 2. Mr. Vijay Pal Singh | 11.5 | 7.3 | 96.7 | 18.3 | - | 15.8 | 45.2 | 54.0 | 32.0 | - |
| 3. Mr. Mahesh Singh | 5.8 | 7.2 | 47.5 | 10.2 | - | 9.7 | 19.6 | 28.7 | 21.1 | - |
| 4. Mr. Deepak Singh | 10.2 | 7.4 | 90.2 | 11.9 | - | 10.2 | 31.5 | 60.3 | 36.9 | - |
| 5. Mr. Nand Kishor | 6.3 | 7.3 | 49.6 | 13.2 | - | 12.7 | 20.8 | 29.5 | 19.3 | - |
| 6. Mr. Pratap Singh | 7.2 | 7.4 | 59.1 | 12.8 | - | 11.9 | 27.5 | 32.6 | 23.4 | - |
| 7. Mr. Babu lal | 5.3 | 7.6 | 40.3 | 12.7 | - | 11.5 | 20.7 | 20.8 | 15.9 | - |
| 8. Mr. Ram Veer Bhagat | 13.3 | 7.3 | 114.7 | 18.3 | - | 28.7 | 52.5 | 51.8 | 23.7 | - |
| 9. Mr. Bhawar Singh | 6.5 | 7.6 | 54.4 | 10.7 | - | 9.5 | 26.6 | 28.9 | 23.5 | - |
| 10. Mr.Ram Veer Yadav | 6.1 | 7.5 | 50.1 | 10.9 | - | 10.2 | 22.7 | 28.1 | 21.5 | - |
| 11. RBS,Bichpuri,Farm | 3.8 | 7.5 | 28.9 | 9.1 | - | 7.8 | 10.2 | 20.0 | 13.6 | - |

The Table 6.9 clearly indicated that the all mustard growing farmers applied saline water in the field. Among wheat growing farmers, 3 farmers applied irrigation in 2 SW: 2CW mode and one farmer gave 1 SW: 1GW and another two farmers irrigated wheat crop with all saline water. The emphasis during ORP was on different techniques such as optimum plant population in mustard (i.e. 8 plants/ $m^2$), recommended dose of fertilizers for wheat as well mustard and conjunctive use of saline and canal water, if possible.

Table 6.9 Irrigation/irrigation mode of ORP farmers and other farmers

| Farmers name | Crop | Irrigation strategy for ORP farmers | Other farmers |
|---|---|---|---|
| 1.Mr.Kishan Gopal | Mustard | All saline water | All saline water |
| 2. Mr. Vijay Pal Singh | Mustard | All saline water | All saline water |
| 3. Mr. Mahesh Singh | Mustard | All saline water | All saline water |
| 4. Mr. Deepak Singh | Mustard | All saline water | All saline water |
| 5. Mr. Nand Kishor | Mustard | All saline water | All saline water |
| 6. Mr. Pratap Singh | Wheat | 2SW:2CW | All saline water |

| | | | |
|---|---|---|---|
| 7. Mr. Babul lal | Wheat | 2SW:2CW | All saline water |
| 8. Mr. Ram Veer Bhagat | Wheat | 2GW:2SW | All saline water |
| 9. Mr. Bhawar Singh | Wheat | 1SW:IGW | All saline water |
| 10. Mr.Ram Veer Yadav | Wheat | All saline water | All saline water |
| 11. RBS,Bichpuri,Farm | Wheat | All saline water | All saline water |

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

**Mustard crop on ORP fields**

The mustard yields for ORP and non-ORP farmers are presented in Table 6.10 and it clearly indicated that the ORP farmers mustard grain yield ranged from (21.2 to 25.8 q/ha) and was higher compared to other farmers' mustard yields (19.2 to 22.7 q/ha). At the harvest of mustard crop, ECe ranged from (3.6- 4.2 dS/m) and pH (7.2 to 7.4).

Table 6.10 Grain yield of mustard (q/ha) ORP farmers field 2017-18

| Name of farmers | ORP farmers yield | Other farmer yield | % in increase | At harvest ECe(dS/m) | pH |
|---|---|---|---|---|---|
| 1.Mr.Kishan Gopal | 24.5 | 21.6 | 13.4 | 4.1 | 7.4 |
| 2. Mr. Vijay Pal Singh | 21.2 | 19.2 | 10.4 | 3.7 | 7.4 |
| 3. Mr. Mahesh Singh | 25.8 | 22.7 | 13.7 | 3.6 | 7.2 |
| 4. Mr. Deepak Singh | 22.3 | 19.7 | 13.2 | 4.2 | 7.2 |
| 5. Mr. Nand Kishor | 23.1 | 20.2 | 14.4 | 4.2 | 7.3 |

The cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio of mustard crop are presented in Table 6.11 . It is clearly indicated that the cost of cultivation of ORP farmers almost was less compared to other farmers. The gross income (Rs/ha) was higher for ORP farmers compared to other farmers' field. The net profit (Rs/ha) and B: C ratio was also higher for ORP farmers compare to other farmers.

Table 6.11: Cost of cultivation, gross income, net profit and B: C ratio of mustard growing ORP farmers and other farmers (2017-18)

| Farmer name | ORP farmers | | | | Other farmers | | | |
|---|---|---|---|---|---|---|---|---|
| | Cost of cultivation (Rs/ha) | Gross Income Rs/ha | Net Profit Rs/ha | B:C ratio | Cost of cultivation (Rs/ha) | Gross Income Rs/ha | Net Profit Rs/ha | B:C ratio |
| 1.Mr.Kishan Gopal | 17.613 | 87,710 | 70,097 | 3.9 | 19,638 | 77,328 | 57,690 | 2.9 |
| 2. Mr. Vijay Pal Singh | 17,793 | 75,896 | 58,103 | 3.3 | 18,658 | 68,736 | 50,078 | 2.7 |
| 3. Mr. Mahesh Singh | 16,718 | 92,364 | 75,646 | 4.5 | 21,355 | 81,266 | 57,911 | 2.8 |
| 4. Mr. Deepak Singh | 17,248 | 79,834 | 62,586 | 3.6 | 19,083 | 70,526 | 51,443 | 2.7 |
| 5. Mr. Nand Kishor | 17,528 | 82,698 | 65,170 | 3.7 | 19,822 | 72,316 | 52,494 | 2.6 |

**Wheat crop on ORP fields**

In the rabi season 2017-18, wheat crop was sown by six farmers. The wheat variety KRL-210 was sown all the ORP farmers' fields and other farmers grew wheat variety available market/own.
The grain yield data of ORP farmers and other farmers are presented in Table 6.12.

Table 6.12 Grain yield of Wheat crop in different ORP farmers field (q/ha) 2017-18

| Name of farmers | ORP farmers yield | | Other farmer yield | | % in increase of grain yield | At harvest ECe (dS/m) | pH |
|---|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | | | |
| 1.Mr.Pratap Singh | 44.9 | 58.4 | 40.1 | 48.2 | 12.0 | 4.1 | 7.2 |
| 2. Mr. Babu lal | 42.7 | 64.1 | 38.9 | 46.3 | 9.8 | 4.3 | 7.3 |
| 3. Mr. Bhawar Singh | 46.3 | 62.5 | 40.3 | 45.2 | 14.8 | 3.4 | 7.3 |
| 4.Mr.Ram Veer Bhagat* | 47.2 | 60.9 | 41.8 | 47.1 | 12.9 | 2.5 | 7.2 |
| 5.Mr. Ram Kumar Yadav | 43.9 | 61.5 | 39.7 | 44.9 | 10.6 | 3.6 | 7.4 |
| 6.RBS, Farm, Bichpuri | 44.8 | 59.1 | 40.5 | 46.3 | 10.6 | 3.3 | 7.3 |

*Organic farming

The table clearly indicated that the six ORP farmers wheat grain yield ranged from (42.7 to 44.99 q/ha) and was higher than other farmers (38.9 to 40.59 q/ha). The straw yield of wheat crop gave the same trend .The average increase of ORP farmers was 11.8% more over other farmers grain yield. At harvest of wheat crop the ECe ranged from (2.5 – 4.3 dS/m), pH (7.2 - 7.4 ).

The shri Ram veer Singh Bhagat is growing all the crops absolute in organic farming. Mr. Bhagat did not use any chemical fertilizer and other any chemical in the crops. Wheat yield was 47.29 q/ha and straw 60.9 q/ha. The wheat crop yield was almost higher in all other 5 farmers used fertilizer and other chemicals. In wheat crop, the cost of cultivation, gross income, net profit (Rs/ha) and B:C ratio were calculated (Table 6.13). It is clearly indicated that the cost of cultivation of ORP farmers almost less compared with other farmers. The gross income (Rs/ha) were higher in ORP farmers field compared with other farmers field. The net profit (Rs/ha) and B: C ratio was higher in ORP farmers compared with other farmers growing wheat crop. Mr. Ram veer Bhagat growing wheat crop in organic farming got higher price at market compared to others.

Table 6.13 Cost of cultivation, gross income, net profit and B: C ratio of wheat of ORP farmers and other farmers (2017-18)

| Farmer name | ORP farmers | | | | Other farmers | | | |
|---|---|---|---|---|---|---|---|---|
| | Cost of cultivation (Rs/ha) | Gross Income Rs/ha | Net Profit Rs/ha | B:C ratio | Cost of cultivation (Rs/ha) | Gross Income Rs/ha | Net Profit Rs/ha | B:C ratio |
| 1.Mr.Pratap Singh | 33,587 | 93,175 | 59,588 | 1.8 | 34,150 | 82,050 | 47,900 | 1.4 |
| 2. Mr. Babu lal | 31,770 | 90,750 | 58,980 | 1.8 | 37,715 | 79,650 | 41,935 | 1.1 |
| 3. Mr. Bhawar Singh | 33,487 | 97,825 | 64,338 | 1.9 | 33,825 | 81,825 | 48,000 | 1.4 |
| 4.Mr.Ram Veer Bhagat* | 40.420 | 1,34,525 | 94,105 | 2.3 | 35,110 | 84,925 | 49,815 | 1.4 |
| 5.Mr. Ram Kumar Yadav | 32,107 | 92,200 | 60,093 | 1.9 | 36,105 | 80,600 | 44,495 | 1.2 |
| 6.RBS, Farm, Bichpuri | 30,987 | 93,175 | 62,188 | 2.0 | 36,500 | 82,450 | 45,950 | 1.3 |

*Organic farming

**Evaluation of microbial formulations for crop productivity and soil health under different agro-ecosystem**

**Treatments**

T1- Un-inoculated + FYM/VC/ Compost @2.5t/ha +100% RDF
T2- Un-inoculated + FYM/VC/ Compost @2.5t/ha +75% RDF
T3- Halo Azo inoculation + FYM/VC/ Compost @2.5t/ha +75% RDF
T4- Halo PSB inoculation + FYM/VC/ Compost @2.5t/ha +75% RDF
T5- Halo Azo + Halo PSB inoculation + FYM/VC/ Compost @2.5t/ha +75% RDF

The yield and yield attributing characters got significantly affected in different treatments. The highest grain yield (28.5 q/ha) of sorghum was recorded with microbial formulation T5 (Halo Azo + Halo PSB inoculation + FYM/VC/ Compost @2.5t/ha +75% RDF) treatment and lowest (24.0 q/ha) in T2 (Un-inoculated + FYM/VC/ Compost @2.5t/ha +75% RDF). After harvest of crop, the organic carbon, available N, available P and available K in soil profile (0- 30cm) were higher in T5 treatments as compared to other treatments (Table 6.14) The initial and final soil properties are given in Table 6.15 and 6.16.

Table 6.14 Yield attributing characters, grain and dry matter yield of sorghum (2017)

| Treatment | Germination (%) | Plant height (cm) | Cob length (cm) | Grain Yield/plant (gm) | Dry matter yield/plant (gm) | Grain Yield (q/ha) | Stover yield (q/ha) |
|---|---|---|---|---|---|---|---|
| T1 | 73.3 | 337.0 | 23.3 | 71.6 | 316.7 | 25.8 | 130.4 |
| T2 | 72.7 | 322.7 | 20.3 | 68.3 | 306.7 | 24.0 | 120.6 |
| T3 | 74.3 | 353.3 | 26.0 | 3.3 | 346.7 | 27.3 | 142.2 |
| T4 | 74.0 | 352.7 | 25.7 | 80.0 | 343.3 | 26.1 | 137.5 |
| T5 | 74.7 | 353.7 | 26.7 | 83.3 | 370.0 | 28.5 | 149.3 |
| CD at 5% | NS | 8.92 | 1.80 | 4.92 | 25.22 | 1.54 | 11.49 |

Table 6.15 Initial soil status of pH, ECe, OC, available N, P and K (2017)

| Soil Depth (cm) | pH | ECe (dS/m) | OC (%) | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) |
|---|---|---|---|---|---|---|
| 0-15 | 8.5 | 3.13 | 0.255 | 224.0 | 11.6 | 158.8 |
| 15-30 | 8.3 | 3.00 | 0.225 | 190.4 | 10.5 | 154.8 |

Table 6.16 Soil status of pH, ECe, OC, available N, P and K (2017) at harvest of crop

| Treat-ment | Soil Depth (cm) | pH | ECe (dS/m) | OC (%) | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) |
|---|---|---|---|---|---|---|---|
| T1 | 0-15 | 8.4 | 4.32 | 0.300 | 246.4 | 12.8 | 164.0 |
| | 15-30 | 8.1 | 4.10 | 0.285 | 235.2 | 11.6 | 158.8 |
| T2 | 0-15 | 8.5 | 4.84 | 0.285 | 224.0 | 12.5 | 154.8 |
| | 15-30 | 8.3 | 4.10 | 0.255 | 201.6 | 11.7 | 154.4 |
| T3 | 0-15 | 8.4 | 4.10 | 0.285 | 235.2 | 13.2 | 172.2 |
| | 15-30 | 8.2 | 4.10 | 0.225 | 224.0 | 12.2 | 168.0 |
| T4 | 0-15 | 8.5 | 4.04 | 0.262 | 246.4 | 13.1 | 174.4 |
| | 15-30 | 8.3 | 4.21 | 0.255 | 235.2 | 11.7 | 170.0 |
| T5 | 0-15 | 8.4 | 4.37 | 0.315 | 257.6 | 13.2 | 174.4 |
| | 15-30 | 8.4 | 4.42 | 0.292 | 246.4 | 11.7 | 169.6 |

**Studies on performance of fodder crops in salt affected soils on farmer's field**

This experiment was conducted at Bhavanamvari Palem farmer's field with different Fodder crops like cowpea, stylo, Hedge lucerne, alfalfa, CoFS-29, panthchari-6, and sweet sudan grass. The initial soil having pH of 8.5 and EC 0.9 dS $m^{-1}$. The highest green fodder yield was obtained (44.8 t $ha^{-1}$) with sweet sudan grass followed by Panthchari-6 (38.6 t $ha^{-1}$) (Table 6.17).

Table 6.17 Performance of fodder crops at fermer's field

| Treatments | Plant height (m) | Biomass yield (t $ha^{-1}$) |
|---|---|---|
| $T_1$-Cow pea | 1.3 | 20.4 |
| $T_2$-Stylo | 2.0 | 5.3 |
| $T_3$-Hedge lucerne | 1.1 | 25.7 |
| $T_4$-Alfalfa | 1.0 | 33.0 |
| $T_5$-Panthchari-6 | 2.2 | 38.6 |
| $T_6$-CoFS-29 | 2.0 | 40.1 |
| $T_7$-Sweet sudan grass | 2.5 | 44.8 |

**Survey and investigations for planning conjunctive use of Nallamada drain water with Kommamuru canal for augmenting irrigation (Bapatla)**.

The analysis of water samples collected revealed that in a given water year, the quality of water is changing enormously in different reaches of drain as tide water enters in the drain from sea (Table 6.18). The drain water quality is influenced by tidal timings. During rainy reason surface runoff from land prevents entry of tidal water into drain. However, drain water flow remains lean during *rabi* season. The quality of water flowing in the drain during *rabi* season is much poor due to entry of sea water in large quantity and it is not fit for agricultural or domestic use. The study needs to be conducted as per the tidal calendars instead of monthly sampling. The range of salinity is very high as 32.5 dS $m^{-1}$ near the estuary, it is 13.7 and 3.9 dS $m^{-1}$ in the middle and at the upstream again, it is shooting up to 26.5 dS $m^{-1}$. This is very alarming and farmers are to be strictly advised to go for testing of these waters before using it for any crop. If it is possible check dams with sluice gate may be proposed in middle and upstream reaches to prevent tidal water into drain. It will help to prevent salinization of field due to use of drain water for irrigation.

Table 6.18 The maximum and Minimum E.C. (dS $m^{-1}$) values of Nallamada drain course during 2016-17& 2017-18

| Sr. No. | Point of Water Sample Collection | 2016-17 E.C dS $m^{-1}$ | | 2017-18 E.C dS $m^{-1}$ | |
|---|---|---|---|---|---|
| | | Max. | Min. | Max. | Min. |
| 1 | At Pinniboinavaripalem Nallamada drain | 35 | 0.7 | 30.0 | 21.0 |
| 2 | At Nagaraju canal (*kaluva*) - Nallamada Drain | 24 | 0.6 | 23.0 | 8.5 |
| 5 | Confluence of Bheemunivagu at Nallamada at Aquaduct | 2.4 | 0.4 | 3.1 | 0.5 |
| 6 | Nallamada Water at Aquaduct Appikatla | 14.7 | 0.5 | 12.8 | 1.1 |
| 7 | Nallamada - Jillellamudi (7th Mile) | 4.6 | 0.6 | 2.9 | 1.0 |
| 9 | Nallamada at returu - appapuram under tunnel (UT) 16 sluices | 2 | 0.3 | 2.9 | 0.9 |
| 11 | Nallamada drain water at UT in front of 28 sluices | 6.8 | 0.5 | 2.4 | 0.9 |
| 12 | Kondapaturu Nallamada drain | 9.6 | 0.6 | 6.0 | 2.1 |
| 13 | Garlapadu - Nallamada drain | 22.1 | 0.6 | 4.1 | 2.2 |
| 14 | Pedanandipadu - Nallamada drain | 27 | 0.6 | 6.2 | 2.3 |
| 15 | Chilakaluripeta - Nallamda drain | 4.3 | 0.5 | 3.5 | 1.2 |
| 16 | water from bore well (25 feet) in Nallamada drain Chilakaluripeta | 3.4 | 0.6 | 1.9 | 1.1 |
| 17 | Bheemunivagu | 9.6 | 0.3 | 1.3 | 0.7 |

**Effect of Lagoon Sludge/Spent 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 6.19 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 6.19 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 field (Kanpur)**

The experiment was initiated during 2015 to find out the suitable application method of CSR-Bio for vegetable production and to determine the physico-chemical changes in soil. The experiment details are given in Table 6.20.

Table 6.20 Experimental details

| Sr. No. | Item | Details |
|---|---|---|
| 1 | Crop | Tomato and cabbage |
| 2 | Varieties | Azad T-5 and Golden acre |
| 3 | No. of treatments | 3; T1 (control); T2: CSR Bio (soil application); T3: CSR Bio (soil application + foliar spray). |
| 4 | No. of replication | 3 |
| 5 | Design | RBD |
| 6 | Plot size | 20 sqm |
| 7 | Spacing | 40 x40 cm (cabbage)<br>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, fruits/plant, fruit diameter and yield of tomato was 59.6%, 23.72, 3.27 cm and 124.48 q/ha (Table 6.21). The enhancement of yield was 24.07% higher with CSR Bio (soil application + foliar spray) and 19.43 % higher with CSR Bio (soil application) over control.

Table 6.21 Effect of CSR-Bio on yield and yield attributes of tomato

| Treatments | Survival (%) | Fruits/ plant | Fruit diameter (cm) | Yield (q/ha) | Yield Increase (%) |
|---|---|---|---|---|---|
| Control | 46.5 | 19.27 | 2.79 | 94.52 | -- |
| CSR-Bio (soil application) | 57.3 | 22.48 | 3.25 | 117.32 | 19.43 |
| CSR-Bio (soil application + foliar spray) | 59.6 | 23.72 | 3.27 | 124.48 | 24.07 |

**Physico-chemical properties of soil:** Perusal of data in Table 6.22 indicated that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in both the treatments including control, maximum reduction, however, was observed in CSR-Bio (soil application + foliar spray) treated plot. The organic carbon status was improved with the application of CSR-Bio.

Table 6.22 Effect of CSR-Bio on physico chemical properties of experimental soil

| Treatments | pH | EC | ESP | OC |
|---|---|---|---|---|
| Control | 9.0 | 0.94 | 40.6 | 0.30 |
| CSR-Bio (soil application) | 8.8 | 0.91 | 35.2 | 0.34 |
| CSR-Bio (soil application + foliar spray) | 8.9 | 0.90 | 34.8 | 0.36 |
| Initial soil status | 9.1 | 0.96 | 42.2 | 0.29 |

The maximum survival percentage, no. of leaves, head weight and yield of cabbage was 69.5%, 11.45, 0.92 kg and 151.57 q/ha (Table 6.23). The enhancement of yield was 25.30% higher with CSR-Bio (soil application + foliar spray) and 20.71% higher with CSR-Bio (soil application) over control.

Table 6.23. Effect of CSR-Bio on yield and yield attributes of cabbage

| Treatments | Survival (%) | No. of leaves | Head weight (kg) | Yield (q/ha) | Yield Increase (%) |
|---|---|---|---|---|---|
| Control | 55.8 | 9.92 | 0.76 | 113.22 | -- |
| CSR-Bio (soil application) | 67.4 | 10.71 | 0.88 | 142.80 | 20.71 |
| CSR-Bio (soil application + foliar spray) | 69.5 | 11.45 | 0.92 | 151.57 | 25.30 |

**Physico-chemical properties of soil:** Perusal of data in Table 6.24 indicated that there was reduction in pH, electrical conductivity and exchangeable sodium percentage in both the treatments including control, maximum decrease, however was observed in CSR-Bio (soil application + foliar spray) treated plot. The organic carbon improved with the application of CSR-Bio.

Table 6.24 Effect of CSR-Bio on physico-chemical properties of experimental soil

| Treatments | pH | EC (dS/m) | ESP | OC (%) |
|---|---|---|---|---|
| Control | 9.0 | 0.93 | 39.5 | 0.31 |
| CSR-Bio (soil application) | 8.8 | 0.90 | 35.8 | 0.36 |
| CSR-Bio (soil application + foliar spray) | 8.8 | 0.89 | 32.4 | 0.38 |
| Initial soil status | 9.1 | 0.96 | 42.2 | 0.29 |

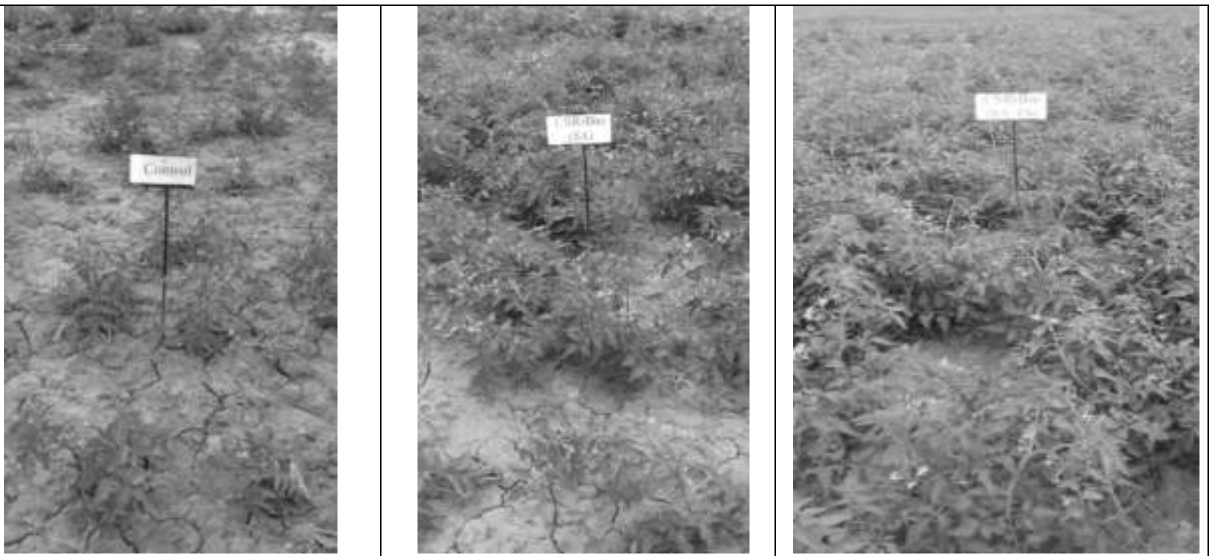



Plate 6.1 View of tomato at farmers field, Vinobanagar

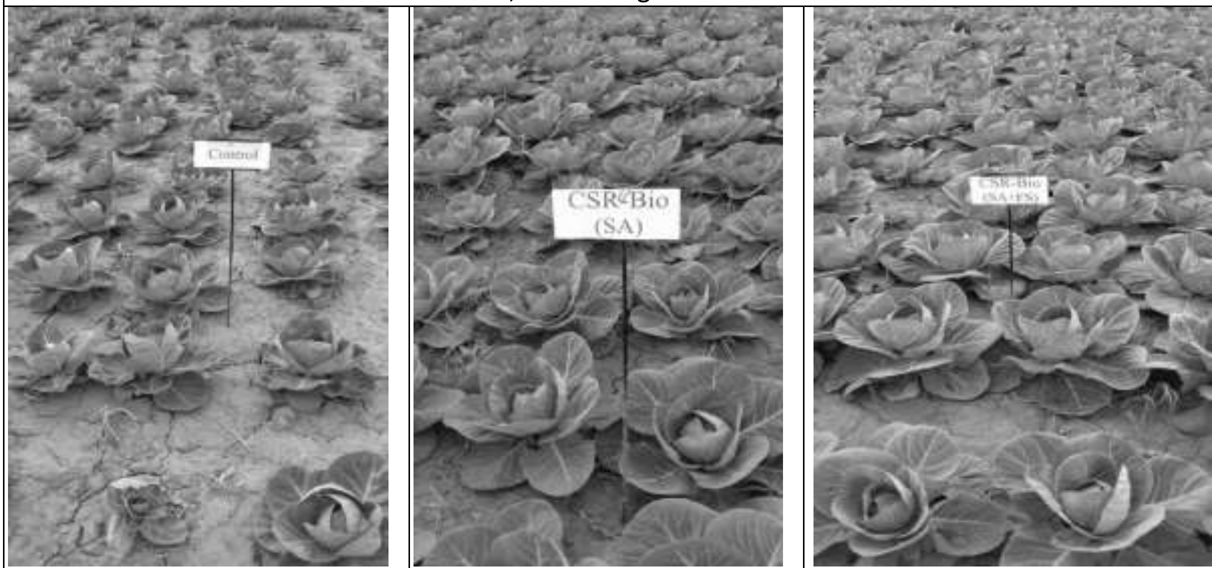



Plate 6.2 View of cabbage at farmers field, Vinobanagar

**Evaluation of microbial formulations for crop productivity and soil health under different agro ecosystem (Tiruchirapalli)**

The purpose of ORP was to evaluate the liquid bio formulations on crop productivity and soil health under sodic soil in *Kharif* season.

**Experimental details**

- ✓ Crops: Soy bean var. JS -335and Bajra var.BOSS 456 D/S: 14.07.17
- ✓ Season: Kharif (July - September) D/H 24.10.17

**Treatments**

- ✓ $T_1$ – Uninoculated + FYM/vermicompost/compost @ 2.5t/ha+100% RDF
- ✓ $T_2$ - Uninoculated + FYM/vermicompost/compost @ 2.5 t/ha+75% RDF
- ✓ $T_3$- Halo Azo inoculated+ FYM/ vermicompost/compost @ 2.5 t /ha+75% RDF
- ✓ $T_4$ - Halo PSB inoculated+ FYM/ vermicompost/compost @ 2.5 t/ha +75% RDF
- ✓ $T_5$ - Halo Azo + Halo PSB inoculated+ FYM/ vermicompost/compost @ 2.5 t/ha +75% RDF

- ✓ Replication: 3; Plot size (approx) = 20$m^2$
- ✓ Dosage of bio-formulation: 100ml per acre of seed

**Inoculation procedure**

Liquid bio-formulation was used as seed treatment. Diluted 100ml bio-formulation with 1L water and mixed the seeds of 1acre, shade dried the seed and then sown.

**Observations to be recorded:**

i) Initial soil properties
ii) Plant growth and biomass
iii) Yield attributes and yield
iv) After harvest soil analysis (pH, EC,OC, available N,P,K etc)

| | |
|---|---|
| Soybean –R & F system<br>RDF 20:80:40 | Bajra – bed system<br>RDF 80:40:40 |

The experiment was conducted in F.No.A4 C of ADAC&RI, Trichy having the pH of 8.94, ESP of 21.97% and EC of 0.79 dS/m classified under the category of sodic soil. Initial soil properties are given in Table 6.25.

Table 6.25 Initial Experimental soil analysis

| pH | 8.94 | OC | 0.43% |
|---|---|---|---|
| EC | 0.79 $dSm^{-1}$ | Available N (Kg/ha) | 151.5 |
| ESP | 21.97 % | Available P (Kg/ha) | 14.5 |
| CEC | 24.5 c. moles(+)/ kg | Available K(Kg/ha) | 178.5 |
| Na | 4.65 m.eq/lit. | | |

When comparing the germination percentage of two crops bajra was found to have good germination per centage under sodic soils than soybean. There was no significant difference in germination percentage of two crops between inoculated seeds and uninoculated seeds (Table 6.26).

There is no significant difference between the microbial formulations inoculated treatment and un inoculated treatments in yield attributes viz., no.of effective tillers/ plant, ear head length and grain and straw yield of Bajra crop under sodic soil (Table 6.27).

Table 6.26 Effect of liquid bio formulation on Germination % of crops under Sodic soil

| | Bajra | | Soy bean | |
|---|---|---|---|---|
| | Treatment | Germination percentage | Treatment | Germination percentage |
| $T_1$ | Uninoculated + FYM/vermicompost/compost @ 2.5t/ha+100% RDF | 95 | Uninoculated + FYM/vermicompost/compost @ 2.5t/ha+100% RDF | 80 |
| $T_2$ | Uninoculated + FYM/vermicompost/compost @ 2.5 t/ha+75% RDF | 93 | Uninoculated + FYM/vermicompost/compost @ 2.5 t/ha +75% RDF | 78 |
| $T_3$ | Halo Azo inoculated+ FYM/ vermicompost/compost@ 2.5 t/ha +75% RDF | 93 | Halo Azo inoculated+ FYM/ vermicompost/compost @ 2.5 t/ha +75% RDF | 75 |
| $T_4$ | Halo PSB inoculated+ FYM/ vermicompost/compost@ 2.5 t/ha +75% RDF | 93 | Halo PSB inoculated+ FYM/ vermicompost/compost @ 2.5 t/ha +75% RDF | 82 |
| $T_5$ | Halo Azo + Halo PSB inoculated+ FYM/ vermicompost/compost@ 2.5 t/ha +75% RDF | 95 | Halo Azo + Halo PSB inoculated+ FYM/ vermicompost/compost @ 2.5 t/ha +75% RDF | 80 |

Table 6.27 Effect of various microbial formulations on Yield and yield attributes (Mean of 3 replications) of Bajra under sodic soil

| Treatments | No. of effective tillers /plant | Ear head length (cm) | Grain yield(kg/ha) | Stover yield (kg/ha) |
|---|---|---|---|---|
| $T_1$ – Uninoculated + FYM/ vermicompost/ compost @ 2.5t/ha+100% RDF | 2.95 | 21.17 | 1088 | 2095 |
| $T_2$- Uninoculated + FYM/ vermicompost/ compost @ 2.5 t/ha+75% RDF | 2.91 | 20.52 | 1073 | 2055 |
| $T_3$- Halo Azo inoculated+ FYM/ vermicompost/ compost@ 2.5 t/ha +75% RDF | 2.85 | 19.56 | 1070 | 2085 |
| $T_4$- Halo PSB inoculated+ FYM/ vermicompost/compost@ 2.5 t/ha +75% RDF | 2.85 | 20.85 | 1080 | 2085 |
| $T_5$-Halo Azo + Halo PSB inoculated+ FYM/ vermicompost/compost @ 2.5 t/ha +75% RDF | 2.98 | 21.05 | 1095 | 2088 |

There is no significant difference between the microbial formulations inoculated treatment and un inoculated treatments in yield attributes viz., no. of pods/ plant, no. of seeds/pod, and grain and haulm yield of soybean crop under sodic soil (Table 6.28).

Table 6.28 Effect of various microbial formulations on Yield and yield attributes (Mean of 3 replications) of Soybean under sodic soil

| Treatments | No. of pods /plant | No. of seeds /pod | Grain yield(kg/ ha) | Haulm yield (kg/ha) |
|---|---|---|---|---|
| $T_1$ – Uninoculated + FYM/vermicompost/compost @ 2.5t/ha+100% RDF | 39.4 | 2.51 | 1020 | 2050 |
| $T_2$- Uninoculated + FYM/vermicompost/compost @ 2.5 t/ha+75% RDF | 33.5 | 2.21 | 995 | 2055 |
| $T_3$- Halo Azo inoculated+ FYM/ vermicompost/compost@ 2.5 t/ha +75% RDF | 35.2 | 2.15 | 1050 | 2080 |
| $T_4$- Halo PSB inoculated+ FYM/ vermicompost/compost@ 2.5 t/ha +75% RDF | 37.1 | 2.18 | 1015 | 2015 |
| $T_5$-Halo Azo + Halo PSB inoculated+ FYM/ vermicompost/compost @ 2.5 t/ha +75% RDF | 39.1 | 2.56 | 1060 | 2045 |

Microbial formulations did not have any impact in changing the sodicity level of post applied experimental soil. However, a slight decrease in available nutrient status of post-harvest soil was noticed due to crop uptake (Table 6.29).

Table 6.29 Effect of various microbial formulations on soil available nutrient status in post harvest soils

| Treatment | Available nitrogen (kg/ha) | Available phosphorus (kg/ha) | Available potassium (kg/ha) | pH | EC | Organic carbon |
|---|---|---|---|---|---|---|
| | | | Cumbu | | | |
| T1 | 140 | 11.5 | 138 | 8.9 | 0.79 | 0.43 |
| T2 | 120.4 | 12.81 | 141 | 8.8 | 0.71 | 0.42 |
| T3 | 142.8 | 12.31 | 140.5 | 8.8 | 0.68 | 0.43 |
| T4 | 151.2 | 13.1 | 153.5 | 8.7 | 0.65 | 0.41 |
| T5 | 134.4 | 15.3 | 163.5 | 8.7 | 0.63 | 0.42 |
| | | | Soy bean | | | |
| T1 | 126 | 11.21 | 139 | 8.9 | 0.71 | 0.42 |
| T2 | 145.6 | 12.31 | 143 | 8.62 | 0.73 | 0.45 |
| T3 | 134.4 | 16.5 | 151 | 8.61 | 0.72 | 0.45 |
| T4 | 128.8 | 15.5 | 168.3 | 8.58 | 0.71 | 0.47 |
| T5 | 137 | 16.8 | 171.5 | 8.65 | 0.73 | 0.48 |

The performance of microbial formulation inoculated seeds was compared with the uninculated seeds of rainfed Bajra and Soybean under sodic soil during Khariff season. There is no significant difference observed for germination percentage, yield attributes and yield of two crops as well as post-harvest soil nutrients due to inoculation with microbial formulations.

**CSR BIO –an organic bioproduct for productivity enhancement of Banana in salt affected soils (Tiruchirapalli)**

Among the four banana growing fields, Mr.Selvaraj S/o.Chinnasamy,Panaiyur,Therkupatti post, Megalur village,Thogamali, Kuzhithalai field was identified for experimental purpose. Initial soil properties are given in Table 6.30.

**Treatments imposed**

- ✓ 4 months after planting -100 g/plant
- ✓ 8 months after planting -100 g /plant
- ✓ Location: Thenkaraikurichi village of Kuzhithalaitaluk.Trichy dt

**Soil analysis**

- ✓ pH - 8.8
- ✓ EC - 0.85 dS/m
- ✓ ESP - 23.5 %

**Impact (Based on farmer's opinion)**

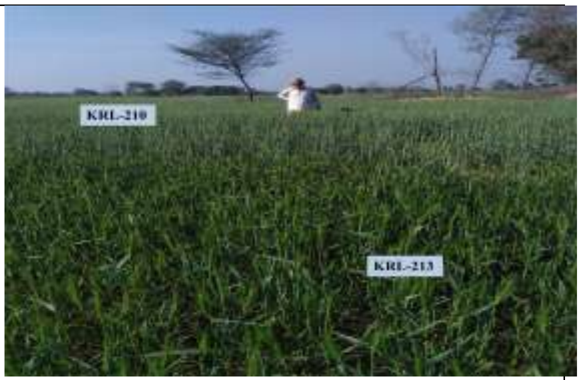
- About 40 % yield increment was noticed in CSR -BIO treated plot when compared to untreated plot.
- Prevents scorching of leaf from salinity problems
- Reduced the incidence of sigatoka leafspot

Table 6.30 Initial Experimental soil analysis

| Sr. NO. | Field locations | pH | EC (dS/m) | ESP |
|---|---|---|---|---|
| 1 | Mr.Chinnathambi,S/o. Maruthai Thenkaraikurichi,Kurichi (post) Kurichi -9344177662 | 8.1 | 0.55 | 13.8 |
| 2. | Mr.Tamilazhgan,Neithalur colony, Panaiyur,Thogamalai-9159811151 | 8.3 | 0.68 | 15.5 |
| 3. | Mr.Arevazhagan,Thenkaraikurichi Kurichipost,Nangavaram via Kuzhithalai,Karur - 639110 8489462414 | 8.2 | 0.77 | 13.5 |
| 4. | Mr.Selvaraj, S/o.Chinnasamy Panaiyur,Therkupatti post, Megalur village,Thogamali, Kuzhithalai. 9751805646 | 8.8 | 0.85 | 23.5 |

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

An on farm demonstration of wheat varieties (KRL-210 and KRL-213) at Shri Gurdeep Singh's field was conducted in village Bandi, Sangat block Bathinda to popularize the salt tolerance variety of wheat developed by ICAR-CSSRI, Karnal for salt affected areas. There is no canal water available on selected farmer's field and used completely Tubewell water for crop cultivation in both the season. The quality parameters of Tubewell water are given below.




| Quality parameter | Value | |
|---|---|---|
| $CO_3$ (meq/L) | NIL | |
| $HCO_3$(meq/L) | 5.4 | |
| $Cl^-$ (meq/L) | 7.5 | |
| $Ca^+ + Mg^+$ (meq/L) | 20.0 | |
| RSC (meq/L) | -ve | |
| EC (dS/m) | 4.6 | Date of sowing: 25.11.2017<br>Varieties: HD 2967; KRL-210 and KRL-213<br>Date of harvesting: 16.04.2018 |

Plate 6.3 Demonstration of wheat varieties (KRL-210 and KRL-213) at farmer's field

The nutrient availability of soil is presented in Table 6.31. It showed that the soil is slightly alkaline in reaction having low organic carbon, available phosphorus and Zn. Three varieties namely HD2967, KRL-210 and KRL 213 were shown at farmer's field. Data (Table 6.32) showed that variety KRL210 showed higher plant height, whereas HD 2967 perform higher number of tillers/$m^2$ and ear length among the varieties tested. The variety KRL-213 showed higher number of seed/ear followed by HD 2967, whereas, higher grain yield was observed in variety HD2976 followed by KRL 210 and KRL213.

Table 6.31 Soil fertility status of farmer's field before sowing and after crop harvesting

| | pH (1:2) | EC (1:2) | OC (%) | $P_2O_5$ (kg/ha) | $K_2O$ (kg/ha) | Fe (mg/kg) | Cu (mg/kg) | Zn (mg/kg) | Mn (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| Initial | 8.60 | 0.78 | 0.24 | 11.2 | 385 | 5.1 | 0.37 | 0.46 | 3.56 |
| After harvesting | 8.55 | 0.79 | 0.21 | 11.8 | 375 | 4.8 | 0.35 | 0.55 | 3.51 |

Table 6.32 Response of wheat cultivars to saline water

| Sr.N. | Cultivars | Plant height (cm) | Number of tillers/$m^2$ | Ear length (cm) | Number of seeds/ ear | grain yield (kg/acre) |
|---|---|---|---|---|---|---|
| 1 | HD 2967 | 95.8 | 98.70 | 11.2 | 56.4 | 2142.6 |
| 2 | KRL210 | 97.7 | 93.67 | 10.8 | 53.4 | 1760.4 |
| 3 | KRL 213 | 90.1 | 85.66 | 10.4 | 64.6 | 1514.8 |

## 7. GENERAL

### 7.1 ORGANIZATION

The All India Coordinated Project on Use of Saline Water in Agriculture was first sanctioned during the IVth Five Year Plan under the aegis of Indian Council of Agricultural Research, New Delhi at four research centres namely Agra, Bapatla, Dharwad and Nagpur to undertake researches on saline water use for semi–arid areas with light textured soils, arid areas of black soils region, coastal areas and on the utilization of sewage water respectively. During the Fifth Five Year plan, the work of the project continued at the above four centres. In the Sixth Five Year Plan, four centres namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water Management and Soil Salinity were transferred to this Project whereas the Nagpur Centre was dissociated. As the mandate of the Kanpur and Indore centres included reclamation and management of heavy textured alkali soils of alluvial and black soil regions, the Project was redesignated as All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture. Two of its Centres located at Dharwad and Jobner were shifted to Gangavati (w.e.f. 01.04.1989) and Bikaner (w.e.f. 01.04.1990) respectively to work right at the locations having large chunks of land afflicted with salinity problems. During the Seventh Plan, Project continued at the above locations. During Eighth Five Year Plan, two new centres at Hisar and Tiruchirappalli were added. These Centres started functioning from 1 January 1995 and 1997 respectively. Further, during Twelfth Five Year Plan, four new Volunteer centres namely Bathinda, Port Blair, Panvel and Vyttila were added to this AICRP. These four centres started functioning from 2014. The three Year Plan (2017–2020) 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 and 2017-18 are given in the Section 7.6. The centre wise mandate of the project is as follows:

### 7.2 MANDATES FOR COOPERATING CENTRES

| Main Centre | Mandate |
|---|---|
| Agra | 1. Water quality limits in relation to cropping system<br>2. Develop strategies for conjunctive use of saline and canal water<br>3. Improving the nutrient use efficiency in saline environment<br>4. Improved irrigation techniques and salt water management<br>5. Rain water management for salinity control<br>6. Alternate land use through agro-forestry and horticulture<br>7. Operational research for saline water use |
| Bapatla | 1. Water quality and soil surveys and monitoring of benchmark sites<br>2. Crop-water production functions with saline water in coastal sands<br>3. Water quality limits with improved irrigation technologies<br>4. Improved Dorouv technology<br>5. Upconing problems of sea water in coastal sandy soils<br>6. Fertility management of saline coastal sandy soils.<br>7. Operational research on dorouv technology/saline water use<br>8. Reclamation of abandoned aqua ponds |
| Bikaner | 1. Water quality surveys<br>2. Salt and water balance in gypsiferous soils of the IGNP Command<br>3. Irrigation management for saline water use<br>4. Drainage for control of salinity and water logging<br>5. Develop practices for use of nitrate and fluoride rich waters<br>6. Nutrient management of saline gypsiferous soils |

| | |
|---|---|
| Gangavathi | 1. Ground water quality surveys<br>2. Performance evaluation of drainage system in T.B.P. command<br>3. Reuse of drainage effluents/conjunctive use<br>4. Drainage requirement of crops in saline black soils<br>5. Performance of tree species in saline black soils including bio-drainage<br>6. Organic materials for improving productivity of saline soils<br>7. Tolerance of medicinal and aromatic plants to soil salinity<br>8. Reclamation of rain fed alkali lands |
| Hisar | 1. Ground water quality surveys<br>2. Conjunctive use of canal and saline ground/drainage waters<br>3. Water production functions under salt stress conditions<br>4. Water quality guidelines for sprinklers/drip systems<br>5. Modelling crop yields under salt stress and strategies for mitigation<br>6. Management of alkali water for vegetable production |
| Indore | 1. Ground water and soil surveys<br>2. Management of heavy textured alkali soils<br>3. Crop-water production functions for alkali black soils<br>4. Develop parameters for incorporating the effect of $Cl/SO_4$, Mg/Ca and SAR on sodification and soil permeability<br>5. Hydrosalinity modelling in Omkeshwar Command<br>6. Alternate land use of alkali black soils for agro-forestry<br>7. Tilerance of medicinal and aromatic plants to soil alkali stress<br>8. Management of wastewaters |
| Kanpur | 1. Water treatment techniques for use of alkali water<br>2. Conjunctive use of alkali and canal water<br>3. Performance of tree species in alkali soils<br>4. Fertility management under conditions of alkali water use<br>5. Soil/ land/ water resource inventories in Ramganga/Sharda Sahayak Command<br>6. Resource conservation technologies for alkali soils<br>7. Salt tolerance studies on crop cultivars |
| Tiruchirappalli | 1. Ground water quality surveys of Tamil Nadu<br>2. Mitigation strategies for adverse effects of salts on soil and crops<br>3. Conjunctive use of poor quality ground and canal waters<br>4. Survey of poor quality ground waters and salt affected soils<br>5. Alternate land use of salt-affected soils through agro-forestry<br>6. Multi-enterprise agriculture for higher income<br>7. Use of Distillery Spent wash for alkali land and water reclamation |
| Net work trials | 1. Identification of appropriate cultivars of crops for saline/alkali environments in different agro-ecological regions<br>2. Water quality/salt affected soil resource inventories/mapping |
| Coordinating Unit | 1. Developing guidelines on use of saline water<br>2. Use of saline water in agro-forestry<br>3. Modeling salt and water transport and crop response in saline environment<br>4. Generating chemical/physical parameters for computers models<br>5. Management of domestic and industrial wastewaters<br>6. Bio-drainage and wastewater disposal strategies<br>7. Management of adhoc projects approved by the council |

| Volunteer Centre | Mandate |
| --- | --- |
| Bathinda | 1. Monitoring of ground water quality for irrigation purpose<br>2. Exploring land-water management options for crop cultivation in water logged salt affected areas |
| Panvel | 1. Assessment of soil properties of coastal region<br>2. Development of IFS model<br>3. Assessment of ground water qualities<br>4. Suitability of saline water for irrigation |
| Port Blair | 1. Assessment of ground water quality and soil salinity status of A& N Islands<br>2. Isolation and characterization of microbes to enhance crop performance under saline environment<br>3. Evaluation of alternate land management options |
| Vyttila | 1. Survey, characterization and mapping of ground water quality in the coastal areas of Kerala<br>2. Delineation and mapping of salt affected soils in the coastal areas of Kerala<br>3. Integrated farming system for sustainable land use in Pokkali lands |

**7.3 STAFF POSITION As on 31.03.2018**

| XII plan | Agra | Bapatla | Bikaner | Gangavati | Hisar | Indore | Kanpur | Trichy | Total |
|---|---|---|---|---|---|---|---|---|---|
| Scientific | 2 | 2 | 2 | 4 | 2 | 2 | 4 | 2 | 20 |
| Technical | 2 | 1 | 4 | 5 | 1 | 4 | 5 | 2 | 24 |
| Administrative | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 06 |
| Supporting | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 1 | 11 |
| **Total** | **6** | **5** | **9** | **12** | **4** | **8** | **12** | **5** | **61** |

**STAFF POSITION AS ON 31.03. 2018**

| Name of the post | No. | Name of incumbent | Date of joining | Date of leaving |
|---|---|---|---|---|
| **Coordinating Unit, CSSRI, KARNAL** | | | | |
| Project Coordinator | 1 | Dr. M.J. Kaledhonkar | 28.03.2016 | Contd. |
| Sr. Agronomist | 1 | Dr. R. L. Meena | 18.07.2007 | Contd. |
| Soil Scientist | 1 | Dr. B.L. Meena | 30.01.2013 | Contd. |
| Technical Officer | 2 | Vacant | - | 01.02.2014 |
| | | Sh. Anil Sharma | 22.10.2011 | Contd. |
| Technical Assistant | 1 | Vacant | - | - |
| Sr. Technician | 1 | Vacant | | |
| Personal Assistant | 1 | Vacant | - | - |
| Lab. Attendent | 1 | Sh. Sukhbir Singh | 19.04.2017 | Contd. |
| **Cooperating Centres** | | | | |
| **AGRA** | | | | |
| Soil Chemist & OIC | 1 | Vacant – Charge taken over by Dr. R.B. Singh | 01.01.2012 | Contd. |
| Jr. Soil Physicist | 1 | Dr. R.B. Singh | 30.11.1987 | Contd. |
| Jr. Agronomist | 1 | Dr. S.K. Chauhan | 15.03.1996 | Contd. |
| Jr. Soil Chemist | 1 | Vacant | - | - |
| Sr. Tech. Assistant (Soils) | 2 | Dr. R.S. Chauhan | 01.08.1991 | Contd. |
| | | Dr. P.K. Shishodia | 11.07.1994 | Contd. |
| UDC | 1 | Sh. Rajeev Chauhan | 04.09.1991 | Contd. |
| Field Assistant | 2 | Vacant | | |
| Lab Assistant | 1 | Sh. Sarnam Singh | 18.12.1989 | Contd. |
| Driver | 1 | Vacant | | |
| Lab. Attendant | 1 | Vacant | | |
| Messenger | 1 | Vacant | - | - |
| **BAPATLA** | | | | |
| Pr. Scientist (SS) &In-charge | 1 | Dr. P. Prasuna Rani | 22-06-2016 | 29-08-2017 |
| | | Dr. K. Anny Mrudhula | 30.08.2017 | 05.09.2017 |
| | | Dr. V Sailaja | 06.09.2017 | 31.05.2018 |
| Soil Scientist | 1 | Smt. K. Hema | 08.08.2012 | 03.02.2016 |
| Sr. Scientist | | Dr. P. Mohana Rao | 10-02-2016 | 23.03.2018 |
| Jr. Soil Chemist | 1 | Dr. Y. Sudha Rani | 21.02.2014 | 22.03.2018 |

| | | | | |
|---|---|---|---|---|
| Scientist (SWE) –I | 1 | Sh. A. Sambaiah | 06.02.2013 | 31.03.2018 |
| Scientist Agronomist | 1 | Dr. K. Anny Mrudhula | 10.12.2013 | Contd. |
| Scientist | 1 | Vacant | - | - |
| Sr. Assistant | 1 | Sh. D Bullaiah | 02.09.2013 | 12.04.2018 |
| Lab. Assistant | 1 | Sh. S. Baba Vali | 04.09.1990 | 06.04.2018 |
| Field Assistant | 2 | Sh. M. Venkata Rao | 02.01.2012 | Contd. |
| | | Sh.Y. Kiran Kumar | 25-04-2015 | 06.04.2018 |
| UDC | 1 | Sh. S.K. Mastan Vali | 01.03.2011 | Contd. |
| Record Assistant | 1 | Sh. D.V. Siva Rao | 16.07.1992 | 12.04.2018 |
| Driver | 1 | Vacant | - | - |
| Messenger | 1 | Sh. D. Krishana Reddy | 01.08.2017 | 09.04.2018 |
| **BIKANER** | | | | |
| Chief Scientist & OIC | 1 | Dr. SR Yadav | | |
| | | Dr. I.J. Gulati | 24.07.2012 | Contd. |
| Soil Chemist | 1 | Vacant | - | 30.04.2009 |
| Jr. Soil Chemist | 1 | Vacant | 30.07.2014 | - |
| Jr. Agronomist | 1 | Vacant | - | - |
| Jr. Drainage Engineer | 1 | Er. A.K. Singh | 10.09.2001 | Contd. |
| Technical Assistant | 2 | Dr. Deepak Gupta | 04.08.2010 | Contd. |
| | | Sh. R.L. Sharma | 23.07.2014 | Contd. |
| Agil. Supervisor | 1 | Sh. G.S. Pareek | 01.06.2013 | Contd. |
| LDC | 1 | Mr. Manohar Singh | 02.04.2011 | Contd. |
| Lab. Assistant | 1 | Sh. S.K.Bazad | 14.02.1994 | Contd. |
| Driver | 1 | Vacant | - | 01.06.2013 |
| Lab. Attendant | 1 | Sh. Sawai Singh | 14.09.17 | Contd. |
| Messenger | 1 | Sh. Ganesh Ram | 25.03.1994 | Contd. |
| **GANGAVATI** | | | | |
| Jr. Agronomist | 1 | Dr. Anand S.R. | 07.11.2012 | Contd. |
| Scientist (SWE) | 1 | Er. Rajkumar H. | 27.05.2011 | Contd. |
| Jr. Drainage Engineer | 1 | Er. A.V. Karegoudar | 12.12.2009 | Contd. |
| Junior Asstt.(UDC) | 1 | Smt. Renuka Benakanadoni | 21.12.2009 | Contd. |
| Sr. Field Assistant | 1 | Sh. K. Veeranna | 02.04.1998 | Contd. |
| Field Assistant | 2 | Sh. P. Balasaheb | 19.11.2001 | Contd. |
| | | Mr. Ramappa H. Talwar | 09.07.2012 | Contd. |
| Lab. Assistant | 1 | Mr. Prakash Banakar | 21.04.2011 | Contd. |
| L.V. Driver | 1 | Mr. Basker D. Golasangi | 13.08.2010 | Contd. |
| Lab. Attendant | 1 | Sh. Sameer Hejib | 10.09.2013 | 06.06.2015 |
| | | Sh. Veeresh S. Akki | 06.06.2015 | Contd. |
| Messenger | 1 | Mr. Doddabaappa S. | 01.02.1992 | Contd. |

| | | | | |
|---|---|---|---|---|
| **HISAR** | | | | |
| Agronomist & OIC | 1 | Dr. Satyavan | 11.03.1997 | Contd. |
| Jr. Soil Chemist | 1 | Dr. Ramparkash | 24.05.2011 | Contd. |
| Soil Water Engineer | 1 | Er. Krishan Kumar | 18.05.2013 | 09.10.2016 |
| Field Assistant | 1 | Sh. Jagdish Chander | 03.02.2001 | 06.02.2017 |
| | | Sh Umed Singh | 07.02.2017 | Contd. |
| Lab Assistant | 1 | Sh. Dhan Singh | 02.03.2009 | 28.02.2017 |
| LDC | 1 | Vacant | - | 12.09.2013 |
| Lab. Attendant | **1** | Sh. Surat Singh | 25.05.2010 | 31.03.2017 |
| Messenger | 1 | Vacant | | 01.05.2012 |
| **INDORE** | | | | |
| Soil Chemist & OIC | 1 | Dr. U.R. Khandkar | 02.09.2008 | Contd. |
| Drainage Engineer | 1 | Er. R.K. Sharma | 09.05.2000 | 31.03.2018 |
| Jr. Soil Survey Officer | 1 | Sh. B.B. Parmar | 02.09.2009 | Contd. |
| Jr. Soil Chemist | 1 | Vacant | - | 22.07.2010 |
| Technical Assistant | 1 | Sh. S.C. Tiwari | 04.03.1989 | Contd. |
| UDC | 1 | A. K. Vijayvargiya | 08.02.2016 | Contd. |
| Field Assistant | 1 | Sh. N.S. Tomar | 04.04.1996 | Contd. |
| Field man | 1 | Sh. S.R. Hirve | 25.08.2003 | 31.08.2017 |
| Lab Assistant | 1 | Ms. R. Ansari | 16.11.1995 | Contd. |
| Jeep Driver | 1 | Sh. Jageshwar Vishkarma | - | Contd. |
| Lab. Attendant | 1 | Sh. D. S. Baghel | 01.04.2011 | Contd. |
| Messenger | 1 | Vacant | - | - |
| **KANPUR** | | | | |
| Soil Chemist & OIC | 1 | Dr. Ravendra Kumar | 09.05.2008 | Contd. |
| Soil Physicist | 1 | Dr. Devendra Singh | 01.07.2014 | Contd. |
| Asstt. Agronomist | 1 | Dr. S.N.Pandey | 01.07.2009 | Contd. |
| Asstt. Soil Survey Officer | 1 | Dr. Vinod Kumar | 29.12.2011 | Contd. |
| Sr.Technical Assistant | 1 | Sh. G.S. Tripathi | 01.08.2004 | Contd. |
| Field Assistant | 2 | Sh. Ved prakash | 16.08.2014 | Contd. |
| | | Sh. Vinay Kumar | 03.07.2013 | Contd. |
| UDC | 1 | Sh. Kulbhushan Kumar | 02.01.2015 | Contd. |
| Lab. Assistant | 1 | Sh. P.S.Katiyar | 01.08.2004 | Contd. |
| Driver | 1 | Sh. Madan Mohan | 01.01.2016 | Contd. |
| Lab. Attendant | 1 | Sh. Gaya Prasad | 01.05.1988 | Contd. |
| Messenger | 1 | Sh. Ram Moort | 01.10.2010 | Contd. |

| TIRUCHIRAPPALLI | | | | |
|---|---|---|---|---|
| Soil Chemist & OIC | 1 | Dr. P. Balasubramaniam | 02.03.2016 | Contd. |
| Jr. Soil Chemist | 1 | Dr. M. Bhaskar | 09.05.2008 | 04.04.2017 |
| | | Dr.T.Shrene Jenita Rajammal | 05.04.2017 | 31.03.2018 |
| Jr. Agronomist | 1 | Dr. A.Alagesan | 07.04.2015 | Contd. |
| Jr. Soil Water Engineer | 1 | Dr. M. Selvamurugan | 08.04.2015 | 31. 03.2018 |
| Sr. Technical Assistant | 2 | Sh. K. Karikalan | 09.06.2014 | Contd. |
| | | Sh. R. Mutharasan | 09.06.2011 | 31.03.2108 |
| Field Assistant | 1 | Sh. U. Jossephraj | 01.04.2011 | 31.03.2018 |
| UDC | 1 | Sh. Muhammod Ali | 01.03.2016 | 31.03.2018 |
| Lab. Assistant | 1 | Sh. P. Sakthivel | 01.07.2016 | Contd. |
| Lab. Attendant | 1 | Sh. R. Santhanam | 01.07.2015 | 31.03.2108 |
| Messenger | 1 | Sh. V. Palaniyandi | 01.04.1995 | 31.08.2017 |

**Volunteer Centre**

| Name of the post | No. | Name of incumbent | Date of joining | Date of leaving |
|---|---|---|---|---|
| **Bathinda** | | | | |
| Asst. Soil Chemist & Nodal officer | 1 | Dr. Brijesh Kumar Yadav | 16.05.2014 | Continue |
| Assistant Agril. Engineer | 1 | Dr. Sudhir Thaman | 16.05.2014 | Continue |
| Senior Research Fellow | 1 | Deepak Kumar | 07.08.2015 | 31.03.2017 |
| **PANVEL** | | | | |
| Soil Scientist & Nodal Officer | 1 | Dr. K. D. Patil | 05.05.2014 | 30.05.2017 |
| | | Dr. S. B.Dodake | 01.06.2017 | Continue |
| SRF | 1 | Shri. Palkar J. J. | 06.11.2017 | Continue |
| | | Miss. S. S. Khobragade | 22.08.2016 | 31/03/2017 |
| **PORT BLAIR** | | | | |
| Soil Scientist & Nodal Officer | 1 | Dr. A Velmurugan | | |
| SRF | 1 | Dr. Waseem Iqbal | | |
| **VYTTILA** | | | | |
| Soil Scientist & Nodal Officer | 1 | Dr. Sreelatha, A. K. | 3.07.2014 | Contd. |
| SRF | 1 | Manju Roshni K | 12.05.2015 | 31.03.2017 |
| SRF | | Anila T. Sasi | 01.08.2016 | 31.03.2017 |

**7.4 WEATHER DATA (2016-18)**

**AGRA**

Latitude - $27^0 20'$ N Longitude - $77^0 90'$ E

| Months | Temperature (°C) | | Relative humidity (%) | Rainfall (mm) | Evaporation (mm/day) | Water table (m) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | | | | |
| | | | 2016-17 | | | |
| April 2016 | 40.1 | 22.8 | 51.3 | 0.000 | 5.3 | 15.9 |
| May | 41.5 | 26.6 | 67.6 | 40.00 | 7.3 | 15.3 |
| June | 40.3 | 28.8 | 78 | 62.90 | 7.6 | 15.5 |
| July | 37.1 | 27.5 | 67.2 | 634.9 | 6.2 | 15.6 |
| August | 32.8 | 26.3 | 93.8 | 175.3 | 6 | 15.4 |
| September | 34.7 | 25.4 | 87.6 | 27.80 | 5.7 | 16.5 |
| October | 34.5 | 19.6 | 90.6 | 7.000 | 5.4 | 16.9 |
| November | 29.5 | 11.5 | 86.6 | - | 5.6 | 17.7 |
| December | 23.5 | 8.90 | 87.1 | - | 5.6 | 17.8 |
| January 2017 | 21.0 | 7.60 | 94.9 | 26.50 | 5.3 | 18.2 |
| February | 26.7 | 10.3 | 84.9 | - | 5.4 | 18.2 |
| March | 31.6 | 14.9 | 71.7 | 21.80 | 6.1 | 18.5 |
| | | | 2017-18 | | | |
| April 2017 | 40.6 | 21.8 | 53.1 | - | 6.2 | 18.6 |
| May | 39.9 | 26.2 | 65.9 | 51.20 | 6.1 | 18.5 |
| June | 39.7 | 27.9 | 7.40 | 42.80 | 6.2 | 18.7 |
| July | 35.8 | 27.3 | 90.3 | 31.30 | 4.3 | 18.6 |
| August | 34.3 | 26.4 | 94.0 | 128.0 | 3.2 | 18.7 |
| September | 36.3 | 25.3 | 91.6 | 16.00 | 3.4 | 18.7 |
| October | 37.3 | 19.9 | 82.1 | - | 4.2 | 18.7 |
| November | 28.8 | 12.9 | 88.5 | - | 1.9 | 19.1 |
| December | 23.7 | 9.30 | 94.1 | 2.10 | 1.3 | 19.9 |
| January 2018 | 21.1 | 6.10 | 12.4 | - | 1.0 | 19.3 |
| February | 26.6 | 10.7 | 74.8 | - | 2.0 | 19.3 |
| March | 34.0 | 15.7 | 82.6 | - | 4.0 | 19.8 |

**BAPATLA**

Latitude - 15° 54′ N Longitude - 80° 28′ E

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | *Evaporation (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | |
| | | | 2016-17 | | | |
| April 2016 | 35.6 | 26.8 | 72 | 71 | - | - |
| May | 37.6 | 27.0 | 69 | 63 | 232.0 | - |
| June | 35.1 | 25.5 | 78 | 68 | 187.5 | - |
| July | 35.1 | 25.9 | 74 | 64 | 115.9 | - |
| August | 35.7 | 25.7 | 69 | 56 | 128.9 | - |
| September | 32.6 | 25.0 | 82 | 73 | 302.7 | - |
| October | 33.9 | 23.0 | 78 | 63 | 25.70 | - |
| November | 32.4 | 20.5 | 82 | 62 | - | - |
| December | 30.7 | 18.5 | 86 | 64 | 33.40 | - |
| January, 2017 | 30.7 | 18.2 | 89 | 62 | - | - |
| February | 31.8 | 19.1 | 88 | 60 | - | - |
| March | 33.5 | 24.1 | 78 | 70 | - | - |
| | | | 2017-18 | | | |
| April 2017 | 35.2 | 26.9 | 73 | 73 | 4.40 | - |
| May | 38.5 | 27.9 | 65 | 58 | 8.40 | - |
| June | 37.1 | 26.3 | 71 | 57 | 103.0 | - |
| July | 35.8 | 25.6 | 73 | 57 | 88.5 | - |
| August | 33.7 | 24.6 | 82 | 70 | 294.2 | - |
| September | 33.5 | 25.6 | 80 | 75 | 239.2 | - |
| October | 33.0 | 24.5 | 84 | 73 | 121.0 | - |
| November | 31.5 | 21.7 | 84 | 69 | 32.5 | - |
| December | 30.5 | 17.6 | 86 | 59 | - | - |
| January 2018 | 30.1 | 17.4 | 88 | 60 | - | - |
| February | 31.4 | 18.0 | 84 | 53 | - | - |
| March | 33.3 | 21.7 | 83 | 64 | 1.20 | - |

* **Note:** The data of Evaporation is not available at Saline Water Scheme, Bapatla.

**BIKANER**

Latitude – 28° 01′ N    Longitude – 73° 35′ E

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Wind velocity (km/hr) | Evaporation (mm/day) |
|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | | |
| | | | 2016-17 | | | | |
| April 2016 | 39.4 | 22.0 | 54.5 | 21.7 | 0.0 | 7.6 | 39.4 |
| May | 43.6 | 28.3 | 59.7 | 30.6 | 0.0 | 10.8 | 43.6 |
| June | 42.8 | 30.5 | 69.5 | 34.8 | 54.2 | 15.5 | 42.8 |
| July | 38.9 | 28.4 | 77.1 | 48.1 | 107.8 | 10 | 9 |
| August | 34.8 | 26 | 86.5 | 62.5 | 152.3 | 6.1 | 6.2 |
| September | 38 | 24.4 | 75.4 | 40 | 4.4 | 6.7 | 9.8 |
| October | 36.2 | 20.5 | 72.7 | 35.1 | 28.4 | 5.5 | 9.2 |
| November | 32.0 | 12.0 | 74.0 | 29.5 | 0.0 | 3.0 | 5.5 |
| December | 29.1 | 9.0 | 84.0 | 33.2 | 0.0 | 3.1 | 3.4 |
| January 2017 | 20.7 | 6.4 | 88.4 | 54.4 | 2.2 | 3.9 | 2.1 |
| February | 28.3 | 9.3 | 74.4 | 24.6 | 0.0 | 4.7 | 5.0 |
| March | 33.7 | 15.6 | 60.3. | 21.0 | 0.8 | 5.6 | 7.2 |
| | | | 2017-18 | | | | |
| April 2017 | 40.6 | 22.9 | 57.4 | 29.4 | 18.8 | 8.4 | 11.7 |
| May | 42.9 | 26.8 | 54.6 | 27.3 | 19.2 | 8.4 | 11.9 |
| June | 39.8 | 27.5 | 69.7 | 38.5 | 123.0 | 10.3 | 9.3 |
| July | 38.4 | 27.5 | 78.7 | 47.4 | 29.3 | 8.1 | 8.2 |
| August | 37.4 | 26.7 | 76.1 | 47.5 | 90.6 | 9.7 | 7.9 |
| September | 37.8 | 24.0 | 71.8 | 36.5 | 6.0 | 5.7 | 6.6 |
| October | 38.7 | 18.4 | 49.2 | 20.4 | 0.0 | 3.8 | 6.3 |
| November | 30.4 | 11.2 | 69.7 | 27.2 | 1.4 | 2.8 | 3.4 |
| December | 25.5 | 6.5 | 72.2 | 31.5 | 2.0 | 3.1 | 2.7 |
| January 2018 | 25.4 | 5.3 | 78.6 | 29.5 | 0.0 | 3.1 | 2.5 |
| February | 29.1 | 10.3 | 70.4 | 27.8 | 0.0 | 4.6 | 4.1 |
| March | 35.3 | 16.5 | 54.9 | 19.6 | 1.4 | 5.8 | 7.0 |

**GANGAVATI**

Latitude – 15° 00’N Longitude – 76° 00’ E

| Months | Temperature ( °C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation* (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | 8.0 AM | 2.0 PM | | |
| | | | 2016-17 | | | |
| April 2016 | 40.41 | 26.03 | 41.07 | 16.67 | 0.00 | - |
| May | 37.84 | 26.06 | 55.75 | 25.60 | 46.2 | - |
| June | 32.33 | 23.53 | 67.00 | 46.23 | 135 | - |
| July | 30.41 | 23.32 | 67.52 | 54.40 | 68.3 | - |
| August | 30.74 | 22.96 | 67.25 | 51.09 | 48.0 | - |
| September | 29.53 | 22.53 | 71.33 | 59.88 | 72.4 | - |
| October | 31.97 | 20.16 | 53.62 | 38.54 | 1.00 | - |
| November | 31.13 | 15.79 | 52.14 | 32.88 | 0.00 | - |
| December | 30.61 | 15.00 | 51.75 | 29.86 | 2.30 | - |
| January 2017 | 31.22 | 14.77 | 49.18 | 24.04 | 0.00 | - |
| February | 37.95 | 14.84 | 36.35 | 16.03 | 0.00 | - |
| March | 37.09 | 20.09 | 32.94 | 13.32 | 6.30 | - |
| | | | 2017-18 | | | |
| April 2017 | 39.96 | 24.86 | 60.2 | 50.03 | 13.7 | - |
| May | 38.48 | 24.22 | 50.2 | 53.93 | 21.1 | - |
| June | 33.36 | 24.20 | 56.5 | 57.05 | 33.6 | - |
| July | 33.0 | 23.64 | 55.9 | 58.75 | 38.0 | - |
| August | 31.70 | 23.38 | 64.4 | 68.58 | 46.4 | - |
| September | 31.4 | 22.90 | 71.1 | 78.40 | 53.2 | - |
| October | 31.20 | 22.10 | 60.3 | 86.00 | 52.5 | - |
| November | 29.7 | 18.80 | 69.1 | 74.50 | 44.8 | - |
| December | 28.67 | 16.13 | 62.4 | 80.25 | 30.1 | - |
| January 2018 | 29.74 | 15.48 | 53.8 | 76.80 | 28.7 | - |
| February | 31.42 | 15.94 | 49.8 | 62.58 | 21.6 | - |
| March | 35.45 | 18.41 | 37.3 | 61.43 | 23.8 | - |

** Data not available*

**HISAR**

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

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | M | E | | |
| | | | 2016-17 | | | |
| April 2016 | 37.9 | 18.4 | 61 | 25 | 0.0 | 6.8 |
| May | 41.0 | 24.8 | 63 | 35 | 44.3 | 9.1 |
| June | 39.6 | 27.6 | 71 | 44 | 91.1 | 7.2 |
| July | 35.1 | 26.1 | 90 | 72 | 245 | 4.8 |
| August | 34.0 | 25.6 | 90 | 69 | 80.4 | 4.2 |
| September | 35.2 | 24.2 | 86 | 54 | 2.80 | 4.8 |
| October | 34.6 | 18.4 | 84 | 42 | 12.0 | 3.9 |
| November | 29.4 | 11.1 | 92 | 48 | 0.00 | 1.9 |
| December | 25.9 | 7.80 | 95 | 51 | 0.00 | 1.5 |
| January 2017 | 18.6 | 6.90 | 99 | 71 | 41.2 | 1.1 |
| February | 24.3 | 7.80 | 92 | 46 | 0.00 | 2.1 |
| March | 29.0 | 11.3 | 90 | 38 | 0.00 | 3.6 |
| | | | 2017-18 | | | |
| April 2017 | 40.4 | 23.2 | 54 | 23 | 0.6 | 8.5 |
| May | 39.7 | 25.4 | 67 | 38 | 14.7 | 8.9 |
| June | 35.3 | 26.6 | 86 | 62 | 67.0 | 4.3 |
| July | 34.4 | 26.7 | 91 | 71 | 15.8 | 4.3 |
| August | 34.2 | 25.6 | 91 | 71 | 36.5 | 4.2 |
| September | 35.6 | 22.4 | 85 | 41 | 0.0 | 4.4 |
| October | 34.0 | 16.5 | 88 | 31 | 0.0 | 2.9 |
| November | 26.6 | 9.9 | 90 | 37 | 0.0 | 2.9 |
| December | 21.4 | 6.2 | 90 | 44 | 1.0 | 1.2 |
| January 2018 | 20.1 | 4.7 | 96 | 56 | 2.7 | 1.3 |
| February | 23.9 | 7.3 | 92 | 56 | 0.3 | 1.8 |
| March | 30.7 | 12.3 | 83 | 37 | 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 | Maximum | Minimum | | |
| | | | 2016-17 | | | |
| April 2016 | - | - | - | - | 0.00 | 91.3 |
| May | - | - | - | - | 0.00 | 117 |
| June | - | - | - | - | 51.5 | 85.5 |
| July | - | - | - | - | 236 | 31.6 |
| August | - | - | - | - | 162 | 21.8 |
| September | - | - | - | - | 135 | 28.8 |
| October | - | - | - | - | 42.4 | 23.8 |
| November | - | - | - | - | 0.00 | 22.3 |
| December | - | - | - | - | 0.00 | 20.8 |
| January 2017 | - | - | - | - | 0.00 | 22.0 |
| February | - | - | - | - | 0.00 | 32.5 |
| March | - | - | - | - | 0.00 | 24.2 |
| | | | 2017-18 | | | |
| April 2017 | - | - | - | - | 0.00 | 102 |
| May | - | - | - | - | 5.80 | 123 |
| June | - | - | - | - | 88.3 | 64.3 |
| July | - | - | - | - | 322 | 28.5 |
| August | - | - | - | - | 167 | 20.8 |
| September | - | - | - | - | 135 | 17.8 |
| October | - | - | - | - | 67.0 | 23.0 |
| November | - | - | - | - | 0.00 | 22.0 |
| December | - | - | - | - | 0.00 | 20.8 |
| January 2018 | - | - | - | - | 0.00 | 22.0 |
| February | - | - | - | - | 0.00 | 30.3 |
| March | - | - | - | - | 0.00 | 102 |

** Data not available*

**KANPUR**

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

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | |
| | | | 2016-17 | | | |
| April 2016 | 40.0 | 22.2 | 54.0 | 37.0 | 0.0 | 4.6 |
| May | 39.0 | 25.5 | 64.0 | 41.0 | 49.6 | 7.0 |
| June | 37.8 | 27.3 | 79.0 | 52.0 | 113.4 | 6.9 |
| July | 32.2 | 25.7 | 89.0 | 80.0 | 309.3 | 4.2 |
| August | 32.7 | 25.9 | 88.0 | 72.0 | 137.1 | 3.6 |
| September | 33.1 | 25.2 | 88.0 | 69.0 | 23.6 | 4.3 |
| October | 33.7 | 19.3 | 83.0 | 45.0 | 34.0 | 3.9 |
| November | 29.3 | 12.6 | 84.0 | 43.0 | 0.0 | 2.8 |
| December | 22.5 | 09.3 | 96.0 | 61.0 | 0.0 | 1.5 |
| January 2017 | 21.1 | 08.1 | 93.0 | 49.0 | 28.2 | 1.2 |
| February | 25.8 | 10.5 | 87.0 | 49.0 | 0.0 | 2.1 |
| March | 31.4 | 14.8 | 74.0 | 46.0 | 0.6 | 3.2 |
| | | | 2017-18 | | | |
| April 2017 | 39.0 | 22.5 | 61.0 | 33.0 | 7.30 | 4.5 |
| May | 39.8 | 25.4 | 57.0 | 32.0 | 14.7 | 6.8 |
| June | 38.9 | 27.2 | 70.0 | 47.0 | 50.6 | 7.4 |
| July | 31.6 | 25.5 | 92.0 | 77.0 | 323 | 3.9 |
| August | 33.2 | 25.7 | 90.0 | 74.0 | 206 | 3.2 |
| September | 34.7 | 25.0 | 89.0 | 66.0 | 38.3 | 3.0 |
| October | 34.9 | 14.7 | 86.0 | 41.0 | 0.00 | 3.1 |
| November | 28.6 | 12.2 | 84.0 | 43.0 | 0.00 | 3.0 |
| December | 23.6 | 08.8 | 90.0 | 52.0 | 1.20 | 2.1 |
| January 2016 | 20.8 | 6.00 | 94.0 | 61.0 | 4.20 | 1.3 |
| February | 26.4 | 10.9 | 87.0 | 46.0 | 0.00 | 1.9 |
| March | 33.3 | 15.7 | 68.0 | 34.0 | 0.00 | 3.2 |

**KARNAL**

Latitude – 29° 43′ N Longitude – 76° 58′ E

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | |
| | | | 2016-17 | | | |
| April 2016 | 37.6 | 18.6 | 54 | 15 | 0.00 | 6.1 |
| May | 38.4 | 23.6 | 60 | 33 | 1.60 | 8.7 |
| June | 37.7 | 26.6 | 73 | 46 | 1.40 | 7.8 |
| July | 33.3 | 26.4 | 88 | 72 | 6.00 | 4.6 |
| August | 32.4 | 25.5 | 90 | 75 | 9.20 | 3.3 |
| September | 32.2 | 24.1 | 89 | 63 | 0.70 | 3.4 |
| October | 33.1 | 17.8 | 88 | 42 | 0.00 | 2.9 |
| November | 28.7 | 11.1 | 88 | 36 | 0.00 | 2.6 |
| December | 22.0 | 8.30 | 97 | 58 | 0.00 | 1.2 |
| January 2017 | 19.1 | 6.80 | 99 | 64 | 2.80 | 0.9 |
| February | 23.1 | 8.40 | 91 | 52 | 0.00 | 2.0 |
| March | 28.0 | 11.6 | 83 | 40 | 0.30 | 2.9 |
| | | | 2017-18 | | | |
| April 2017 | 37.6 | 18.9 | 57 | 21 | 0.10 | 5.7 |
| May | 38.9 | 23.4 | 55 | 28 | 0.20 | 6.5 |
| June | 36.5 | 25.1 | 70 | 46 | 8.20 | 6.7 |
| July | 33.6 | 26.4 | 82 | 67 | 1.80 | 4.7 |
| August | 33.0 | 25.9 | 86 | 72 | 5.30 | 4.2 |
| September | 32.3 | 23.1 | 92 | 67 | 7.50 | 3.4 |
| October | 32.8 | 17.4 | 92 | 43 | 0.00 | 3.4 |
| November | 25.0 | 11.1 | 93 | 49 | 0.10 | 1.9 |
| December | 21.4 | 7.70 | 94 | 54 | 0.17 | 1.7 |
| January 2018 | 8.4 | 5.80 | 97 | 62 | 1.10 | 1.5 |
| February | 22.8 | 8.50 | 94 | 52 | 1.00 | 2.8 |
| March | 29.4 | 13.10 | 85 | 41 | 0.00 | 4.2 |

**TIRUCHIRAPPALLI**

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

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | |
| | | | 2016-17 | | | |
| April 2016 | 40.2 | 28.01 | 74.7 | 38.7 | 0 | 8.3 |
| May | 38.0 | 26.5 | 76.0 | 44.1 | 123.9 | 6.8 |
| June | 36.6 | 26.5 | 75.4 | 46.7 | 30.7 | 8.2 |
| July | 36.1 | 26.3 | 80.7 | 52.5 | 162.2 | 7.8 |
| August | 36.7 | 26.5 | 72.9 | 39.6 | 16.8 | 8.8 |
| September | 36.7 | 25.9 | 71.4 | 41.6 | 61.2 | 7.2 |
| October | 36.0 | 25.3 | 77.5 | 43.4 | 66.8 | 6.1 |
| November | 33.0 | 23.5 | 81.9 | 51.7 | 0 | 5.0 |
| December | 31.7 | 21.6 | 86.5 | 53.8 | 65.6 | 4.1 |
| January 2017 | 25.7 | 17.3 | 68.8 | 35.2 | 18.8 | 3.5 |
| February | 31.7 | 20.6 | 84.3 | 41.1 | 0.00 | 6.1 |
| March | 36.7 | 24.3 | 85.4 | 41.9 | 41.4 | 7.2 |
| | | | 2017-18 | | | |
| April 2017 | 40.5 | 27.1 | 72.5 | 34.3 | 0 | 8.7 |
| May | 39.0 | 27.8 | 68.4 | 42.7 | 92.4 | 8.7 |
| June | 38.5 | 27.5 | 65.3 | 37.9 | 28.0 | 8.9 |
| July | 38.3 | 28.1 | 65.0 | 37.4 | 25.2 | 9.7 |
| August | 35.8 | 26.2 | 75.7 | 44.6 | 177 | 6.6 |
| September | 35.0 | 24.8 | 82.8 | 49.1 | 176 | 5.4 |
| October | 34.3 | 24.9 | 86.4 | 57.0 | 111 | 3.8 |
| November | 31.3 | 23.5 | 91.1 | 70.4 | 54.8 | 2.9 |
| December | 30.0 | 22.6 | 83.1 | 64.4 | 72.8 | 3.3 |
| January 2016 | 31.0 | 19.4 | 90.7 | 53.6 | 9.40 | 4.0 |
| February | 32.3 | 20.2 | 87.3 | 45.5 | 20.2 | 5.5 |
| March | 34.5 | 23.9 | 82.8 | 47.7 | 6.30 | 6.4 |

**Volunteer Centre**

**BATHINDA**

Latitude – 30° 23′ N    Longitude – 74° 95′ E

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation (mm/day) | Wind velocity (km/hr) |
|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Morning | Evening | | | |
| 2016-17 | | | | | | | |
| April 2016 | 37.3 | 19.5 | 74.2 | 28.5 | 0.0 | 16.4 | 5.6 |
| May | 40.9 | 25.1 | 63.5 | 27.8 | 34.6 | 14.3 | 6.6 |
| June | 40.3 | 27.9 | 73.6 | 41.2 | 33.5 | 13.1 | 8.2 |
| July | 35.2 | 27.3 | 82.1 | 64.9 | 128.6 | 7.80 | 6.2 |
| August | 33.6 | 26.0 | 85.1 | 71.4 | 361.7 | 5.60 | 4.9 |
| September | 34.5 | 24.1 | 84.9 | 61.9 | 0.00 | 6.80 | 3.2 |
| October | 34.2 | 18.3 | 77.7 | 45.3 | 0.00 | 5.70 | 2.1 |
| November | 28.5 | 10.8 | 84.8 | 41.8 | 0.00 | 3.50 | 2.2 |
| December | 23.1 | 07.8 | 91.7 | 55.4 | 0.00 | 2.20 | 2.3 |
| January 2017 | 18.5 | 06.4 | 61.9 | 2.20 | 9.50 | 1.70 | 2.2 |
| February | 24.1 | 07.8 | 48.1 | 2.70 | 0.00 | 3.80 | 2.7 |
| March | 28.9 | 11.8 | 44.7 | 3.50 | 0.00 | 6.70 | 3.5 |
| 2017-18 | | | | | | | |
| April 2017 | 37.5 | 18.8 | 63.5 | 39.9 | 20.6 | 12.6 | 6.0 |
| May | 40.3 | 24.4 | 61.0 | 31.8 | 1.80 | 15.0 | 5.5 |
| June | 36.8 | 25.3 | 73.2 | 49.7 | 177 | 9.60 | 5.0 |
| July | 35.8 | 27.0 | 81.1 | 60.3 | 52.5 | 9.10 | 3.0 |
| August | 34.8 | 26.0 | 83.2 | 62.8 | 106 | 8.40 | 1.9 |
| September | 34.6 | 23.9 | 84.8 | 61.0 | 0.00 | 6.80 | 3.2 |
| October | 34.1 | 17.2 | 90.3 | 53.6 | 0.00 | 5.40 | 1.9 |
| November | 24.9 | 10.0 | 89.3 | 53.7 | 14.0 | 2.00 | 1.4 |
| December | 21.9 | 5.30 | 88.5 | 47.6 | 6.00 | 2.30 | 0.9 |
| January 2018 | 18.9 | 4.40 | 90.7 | 56.2 | 10.8 | 1.80 | 0.8 |
| February | 23.9 | 7.90 | 84.8 | 50.9 | 2.70 | 3.60 | 1.2 |
| March | 29.9 | 12.6 | 78.2 | 39.7 | 3.80 | 6.00 | 1.3 |

**PANVEL**

Latitude – 18° 59’ N                                                                                    Longitude – 73° 06’ E

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | |
| | | | 2016-17 | | | |
| April 2016 | 40.0 | 22.0 | 96.0 | 73.0 | 0.0 | 2.6 |
| May | 38.6 | 24.2 | 94.0 | 78.0 | 0.0 | 2.5 |
| June | 35.6 | 22.5 | 98.0 | 82.0 | 840.4 | 2.4 |
| July | 30.2 | 22.8 | 98.0 | 86.0 | 1091.4 | 1.4 |
| August | 30.8 | 22.7 | 98.0 | 85.0 | 936.6 | 1.6 |
| September | 31.2 | 22.3 | 98.0 | 83.0 | 503.0 | 1.8 |
| October | 35.0 | 17.8 | 96.0 | 69.0 | 121.9 | 2.0 |
| November | 37.0 | 15.3 | 92.0 | 69.0 | 1.8 | 1.2 |
| December | 36.5 | 13.3 | 98.0 | 63.0 | 0.0 | 1.4 |
| January 2017 | 36.0 | 12.2 | 94.0 | 48.0 | 0.0 | 1.6 |
| February | 39.5 | 14.8 | 94.0 | 68.0 | 0.0 | 2.8 |
| March | 42.0 | 17.2 | 94.0 | 56.0 | 0.0 | 4.2 |
| | | | 2017-18 | | | |
| April 2017 | 42.0 | 18.7 | 95.0 | 50.0 | 0.00 | 5.2 |
| May | 38.5 | 24.3 | 97.0 | 63.0 | 0.00 | 7.9 |
| June | 37.2 | 20.3 | 100 | 81.0 | 439 | 3.4 |
| July | 31.9 | 23.5 | 98.0 | 88.0 | 1161 | 1.1 |
| August | 32.4 | 21.2 | 98.0 | 85.0 | 719 | 3.9 |
| September | 36.3 | 22.0 | 100 | 82.0 | 631 | 28 |
| October | 37.0 | 20.0 | 98.0 | 60.0 | 57.0 | 4.1 |
| November | 37.0 | 13.6 | 96.0 | 49.0 | 0.00 | 3.8 |
| December | 35.5 | 14.4 | 98.0 | 42.0 | 0.00 | 2.8 |
| January 2018 | 37.2 | 13.5 | 98.0 | 23.0 | 0.00 | 3.7 |
| February | 40.3 | 15.0 | 94.0 | 44.0 | 0.00 | 5.3 |
| March | 45.0 | 19.5 | 95.0 | 47.0 | 0.00 | 6.8 |

**PORT BLAIR**

Latitude – 11° 36′ N                                                                 Longitude – 92° 42′ E

| Months | Temperature (°C) | | Relative humidity (%) | Rainfall (mm) | Evaporation (mm/day) |
|---|---|---|---|---|---|
| | Maximum | Minimum | Average | | |
| | | | 2016-17 | | |
| April 2016 | 33.4 | 25.6 | 44 | 7.00 | - |
| May | 33.3 | 26.5 | 73 | 271 | - |
| June | 30 | 25 | 87 | 496 | - |
| July | 30.6 | 25.2 | 86 | 425 | - |
| August | 31 | 25.2 | 84 | 325 | - |
| September | 29.5 | 24.0 | 89.2 | 956 | - |
| October | 31.0 | 24.3 | 81.8 | 359 | - |
| November | 31.0 | 25.1 | 77.7 | 167 | - |
| December | 29.3 | 24.1 | 78.1 | 445 | - |
| January 2017 | 27.2 | 21.3 | 69.6 | 94.7 | - |
| February | 30.7 | 24.2 | 68.3 | 0.60 | - |
| March | 31.9 | 24.1 | 65 | 6.80 | - |
| | | | 2017-18 | | |
| April 2017 | 32.4 | 25.7 | 73 | 94.7 | - |
| May | 32.4 | 25.8 | 77 | 178 | - |
| June | 30.3 | 24.7 | 85 | 622 | - |
| July | 30.7 | 24.7 | 91 | 473 | - |
| August | 30.0 | 24.9 | 86 | 571 | - |
| September | 30.5 | 25.0 | 81 | 569 | - |
| October | 30.6 | 24.8 | 81 | 258 | - |
| November | 31.2 | 25.5 | 75 | 192 | - |
| December | 30.2 | 24.5 | 76 | 202 | - |
| January 2018 | 30.0 | 24.1 | 79 | 128 | - |
| February | 30.3 | 25.0 | 77 | 29.1 | - |
| March | 31.6 | 23.8 | 70 | 48.2 | - |

**VYTTILA**

Latitude – 09° 97′ N

Longitude – 76° 32′ E

| Months | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Evaporation (mm/day) |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | |
| | | | 2016-17 | | | |
| April 2016 | NA | NA | NA | NA | NA | NA |
| May | NA | NA | NA | NA | NA | NA |
| June | 30.8 | 23.6 | NA | NA | 431 | NA |
| July | 31.4 | 24.6 | NA | NA | 545 | NA |
| August | 31.2 | 24.3 | NA | NA | 179 | NA |
| September | 30.5 | 24.3 | NA | NA | 30.5 | NA |
| October | 32.3 | 22.4 | NA | NA | 131 | NA |
| November | NA | NA | NA | NA | 115 | NA |
| December | NA | NA | NA | NA | 19.5 | NA |
| January 2017 | 34.0 | 21.3 | NA | NA | 16.8 | NA |
| February | 34.8 | 22.2 | NA | NA | 0.00 | NA |
| March | 34.4 | 24.3 | NA | NA | 97.9 | NA |
| | | | 2017-18 | | | |
| April 2017 | 35.3 | 26.7 | NA | NA | 31.4 | NA |
| May | 33.8 | 24.8 | NA | NA | 306 | NA |
| June | 30.2 | 23.6 | NA | NA | 706 | NA |
| July | 30.1 | 23.4 | NA | NA | 435 | NA |
| August | 29.3 | 24.3 | NA | NA | 256 | NA |
| September | 30.2 | 24.1 | NA | NA | 519 | NA |
| October | 30.6 | 24.1 | 90.4 | 75.2 | 139 | 3.27 |
| November | 31.2 | 23.9 | 89.5 | 65.1 | 83.3 | 3.80 |
| December | 31.0 | 22.4 | 84.9 | 58.9 | 15.4 | 3.63 |
| January 2018 | 31.2 | 22.2 | 86.3 | 56.1 | 0.00 | 4.08 |
| February | 32.2 | 23.4 | 85.7 | 54.0 | 0.00 | 4.60 |
| March | 32.6 | 25.0 | 88.7 | 60.9 | 9.20 | 4.58 |

## 7.5 LIST OF PUBLICATIONS (2016-18)

### AGRA

**Research Papers**


Chauhan SK (2016) Effect of spacing and salinity of irrigation water on growth and flower yield of marigold in semi-arid condition. *Annals of Agricultural Research, New Series* 37 (4): 1-4.

Chauhan SK (2017) Guava (*Psidium guajava*) grown in drip and furrow irrigation system in saline water condition of semi-arid areas. *The Journal of Agricultural & Scientific Research* 40(1):54-57.

Chauhan SK (2017) Performance of mustard genotype growing in saline water irrigation condition in semi-arid climate. *TECHNOFAME- A Journal of Multidisciplinary Advance Research* 6(2): 115-116.

Chauhan SK (2017) Performance of mustard genotype in saline water irrigation in semi-arid zone of Western Uttar Pradesh. *Annals of Plant and Soil Research* 19(3):336-337.

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

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

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

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

Chauhan SK and Singh SK (2017) Effect of alkali and canal waters in cyclic and blended mode on potato (*Solanum tuberosum*)–sunflower (*Helianthus annuus*)–sesbania (*Sesbania sesban*) cropping sequence*: Indian Journal of Agronomy* 62 (2): 22-29.

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

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

Pal Devendra, Kumar Arvind, Lal Munna, Laxman M Ahire and Singh RB (2018) Effect of rates of efnoxa prop p-ethyl and isoroturon on wheat and associated weeds. *The Journal of Rural and Agricultural Research* 18(1):78-80.

Singh Jogendra, Sharma PC, Satyavan, Singh TP, Chauhan SK, Singh Vijayata and Neeraj (2018) Notification of crop varieties and registration of gerplasm. *Indian Journal of Genetics and Plant Breeding* 78(3):398-400

Singh SB and Chauhan SK (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* 5 (1): 20-23.

Singh SB and Chauhan SK (2017) Effect of Isabgol (*Plantago ovate* forsk) varieties to levels of potash in semi-arid condition of western part of Uttar Pradesh. *The Journal of Agricultural & Scientific Research* 40(1):50-53.

Singh SB, Singh VR and Chauhan SK (2017) Impact of crop diversification and intensification on yield, productivity and economics of different cropping systems growing in Western Uttar Pradesh. *Indian Research Journal of Genetics and Biotechnology* 9 (2):283-287.

Singh SB, Singh VR and Chauhan SK (2017) Studies on crop yields and economics based on organic farming in Clusterbean-Potato-Onion cropping system for North – Western plain zone. *Indian Research Journal of Genetics and Biotechnology* 9(2):255-259.

**Popular Articles**

Chauhan SK (2018) Sinchai me lavniya jal ki samasya evam uska samadhan. Balwant Krishi Patrika, KVK, RBS College Bichpuri Agra.

Shishodia PK (2018) Jal sankat, global warming aur hum. Balwant Krishi Patrika, KVK, RBS College Bichpuri Agra.

**BAPATLA**

Arunselvi K, Ganesh Babu R, Bhaskara Rao and Prasuna Rani P (2016) Effect of drip irrigation with saline water and water use efficiency of Okra (*Abelmoschus esculentus L.). The Andhra Agricultural Journal* 63 (2):430-434.

Divya SV, Krishnayya PV, Madhumathi T, Manoj Kumar V and Prasuna Rani P (2016) Influence of water quality on the efficacy of certain insecticides on *Spodoptera litura* Fab. (Noctuidae: Lepidoptera). *The Andhra Agricultural Journal* 63(4): 844-888.

Goutami N, Prasuna Rani P, Ravindra Babu P and Lakshmi Pathy R (2016) Effect of nitrogen levels, Bio-fertilizers and FYM on content and uptake of nutrients by rice-fallow sorghum. *The Andhra Agricultural Journal* 63 (1): 110-116.

Joga Rao P, Prasad PRK, Lalitha Kumari A, Prasuna Rani P and Pulla Rao Ch (2016) Effect of long term fertilization on nutrient content, uptake and yield of cotton. *The Andhra Agricultural Journal* 63 (2):343-347.

Joga Rao P, Prasad PRK, Lalitha Kumari A, Prasuna Rani P and Pulla Rao Ch (2017) Field and fiber qualities of cotton (*Gossypium hirsutum*) as influenced by long-term manures and fertilizers on cotton mono-cropping. *The Andhra Agricultural Journal* 64(1): 120-122.

Kalyani K, Sailaja V and Rao, PC (2017) Relationship of inorganic potassium fractions to yield of cauliflower (*Brassica oleracea* var. Botrytis) and soil properties of light textured soils of Rangareddy district. *Indian Journal of Agricultural Research* 51 (1): 59-63.

Lakshmi PK, Madhu VP, Prasuna Rani P and Venkateswarlu B (2017) Fertility status of soils of Narasaraopet revenue division in Guntur district. *The Andhra Agricultural Journal* 64(1): 117-115.

Mohana Rao P, Prasad PRK, Ravindra Babu P, Narasimha Rao K L and Subbaiah G (2016) Influence of different Sources of Nutrients on Available Nutrient Status of soil after harvest of rice crop. *The Andhra Agricultural Journal* 63(1): 121-127.

Mohana Rao P, Prasad PRK, Ravindra Babu P, Narasimha Rao KL and Subbaiah G (2016) Influence of different sources of nutrients on physic-chemical and physical properties of soil in rice crop. *The Andhra Agricultural Journal* 63(2): 338-342.

Mohana Rao Puli, Prasad PRK, Jayalakshmi M and Srihari Rao B (2017) Effect of Organic and Inorganic Sources of Nutrients on NPK Uptake by Rice Crop at Various Growth Periods. *Research Journal of Agricultural Sciences* 8(1): 64-69.

Mohana Rao Puli, Prasad PRK, Jayalakshmi M and Srihari Rao B (2017) Effect of Organic and Inorganic Sources of Nutrients on Secondary and Micro Nutrient Uptake by Rice at various Growth Periods. *Research Journal of Agricultural Sciences* 8(1): 20-24.

Mohana Rao Puli, Prasad PRK, Babu PR, Jayalakshmi M and Burla SR (2016) Effect of organic and inorganic sources of nutrients on rice crop. *ORYZA-An International Journal on Rice* 53 (2):151-159.

Mohana Rao Puli, Prasad PRK, Babu PR, Rao KLN and Subbaiah G (2017) Residual effect of different organics on available micronutrients in soil after harvest of maize in rice fallow maize cropping system. *Trends in Biosciences*, 10 (44):9069-9073.

Nancy Jasmine K, Prasuna Rani P, Prasad PRK and Lakshmi Pathy R (2016) Characterization of saline soils of Uppugunduru Region, Prakasam district, Andhra Pradesh. *The Andhra Agricultural Journal* 63(4): 838-843.

Prasada Rao V, Venkateswarlu B, Rao AS, Balkrishna Yadav, Rao KLN and Prasuna Rani P (2017) Response of aerobic rice to sub surface drip fertigation. *The Andhra Agricultural Journal* 64(1):3-7.

Prasada Rao V, Venkateswarlu B, Rao AS, Balkrishna Yadav, Rao KLN and Prasuna Rani P (2016) Response of zero tillage maize to sub surface drip fertigation *The Andhra Agricultural Journal* 63(4): 758-762.

Puli MR, Prasad PRK, Babu PR, KLN Rao and Subbaiah G (2017) Residual effect of different organics on physico-chemical properties of soil after harvest of maize in rice fallow maize cropping system. *Trends in Biosciences* 10 (44):9083-9086.

Rambabu N, Prabhu Prasadini P and Sailaja V (2017) Effect of urban compost application to soil on ground water quality. *Journal of Research – ANGRAU* 45: 59-63.

Revathi K, Sree Rekha M, Venkata Lakshmi N and Prasuna Rani P (2016) Influence of planting densities and nitrogen levels on yield of *rabi* Maize. *The Andhra Agricultural Journal* 63(4): 751-754.

Sivadevika O, Ratna Prasad P, Prasuna Rani P and Lakshmi Pathy R (2016) Influence of Biochar on yield and yield attributes of sweet corn. *The Andhra Agricultural Journal* 63(4): 849-851.

Sowjanya A, Sree Rekha M, Murthy VRK and Prasuna Rani P (2017) Drymatter and yield of rice as influenced by organics and inorganics of nitrogen. *The Andhra Agricultural Journal* 64(1): 46-49.

Sowjanya P, Prasuna Rani P and Madhu Vani P (2016) Available Nutrient Status and Fertility Capability Grouping of Soils of Bobbili Mandal, Vizianagaram District, Andhra Pradesh. *Indian Society of Coastal agricultural Research* 34(1): 25-32.

Sowjanya P, Prasuna Rani P, Madhu Vani P and Srinivasa Rao V (2016) Spatial variability of soils of Bobbili mandal, vizianagaram district, Andhra Pradesh. *The Andhra Agricultural Journal* 63(1): 137-142.

Srinivasan R, Jeevan Rao K, Sailaja V and Reza SK (2017) Release of Nitrogen and $CO_2$ evolution from manures and fertilisers applied to soil-An incubation study. *Agropedology* 27 (1): 48-55.

Srinivasarao Ch, Rani YS, Veni VG, Sharma KL, Maruthi Sankar GR, JVNS Prasad, Prasad YG and Sahrawat KL (2016) Assessing village-level carbon balance due to greenhouse gas mitigation interventions using EX-ACT model. *International Journal of Environmental Science and Technology* 13:97–112.

Sujala Ch, Prasuna Rani P, Prasad PRK and Rao AS (2016) Performance of sweet corn as influenced by organics in clay loam soil. *The Andhra Agricultural Journal* 63(1): 132-136.

Venkata Lakshmi M, Venkateswarlu B, Prasad P V N and Prasuna Rani P (2016) Performance of baby corn as influenced by plant densities and levels of nitrogen. *The Andhra Agricultural Journal* 63(3): 531-534.

**Awards / Honours**

Awarded “Meritorious Scientist Award” by Government of Andhra Pradesh on the eve of Republic Day on 26-01-2017 to Er. A. Sambaiah, Scientist.

Awarded ANGRAU Meritorious Performance Award-2016 on 15$^{th}$ August, 2016 to Sri Shaik Mastan Vali, A.E.O.

**BIKANER**

**Research Papers**

Gulati IJ, Yadav NS, Singh AK and Gupta Deepak (2016) Mitigating adverse effect of saline water by exogenous application of bioregulators in wheat grown under drip irrigation. *Journal of Soil Salinity and Water Quality* 8(2): 180-187.

Kumar H, Singh AK and Singh P (2017) Effect of fertigation on yield attributes and economics of cucumber (*Cucumus sativus* L.) under polyhouse. *Annals of Agri Bio Research* 22(2): 275-277.

Kumar H, Singh AK and Singh P (2017) Effect of water regime and coloured mulches on productivity of tomato (*Solanum lycopersicon* Mill). *International Journal of Current Microbiology and Applied Sciences* 6(3): 1827-1830.

Kumar H, Yadav PK, Shekhawat JS, Singh AK, Singh P and Kumar D (2017) Impact of water regime and fertigation on quality and nutrient content of sweet orange (*Citrus sinensis* Osbeck) cv. *Mosambi* and on nutrient availability in soil. *Annals of Biology* 33(2): 260-264.

Kumar H, Yadav PK, Singh AK, Singh P, Kumar D, Shekhawat JS and Kumar A (2017) Interactive effect of water regime and fertigation on nutrient availability in soil, fruit yield, economics and leaf nutrient content in sweet orange (*Citrus sinensis* Osbeck) cv. *Mosambi. Chemical Science Review and Letters* 6(21): 172-176.

**GANGAVATI**

**Research Papers**

Anand SR, Vishwanatha J and RH Rajkumar (2017) Site specific nutrient management (SSNM) using “nutrient expert” for hybrid maize (*Zea mays* L.) under zero tillage in Thunabhadra project (TBP) command area of Karnataka. *International Journal of Current Microbiology and Applied Sciences* 6(8):3597-3605.

Bharath Kumar KS, Vishwanath J, Veeresh H, SN Bhat, BG Mastana Reddy, K Tamil Vendan and RV Beladhadi (2017) Effect of distillery raw spentwash on soil microbial properties and yield of paddy in a sodic vertisol. *International Journal of Current Microbiology and Applied Sciences* 6(12): 1152-1160.

Mahantashivaogayya K, Mahendrakumar, Basavaraj S, Lakkundi, Kuchunur PH and Vishwanath J (2016) Genetic variability studies on rice (*Oryza Sativa L.*) mutants for yield and yield components in normal and saline stress soil. 2016. *The Ecoscan 10 (1&2):207-11.*

Rajkumar RH, Subhas B, Anand SR, Karegoudar AV and Vishwanatha J (2016) In-situ rainwater harvesting stratergies on soil properties,growth and yield of sunflower *(Helianthus Annus* L) in rainfed sodic soils of Northern Karnataka. *Indian Journal of Soil Conservation* 44 (1):63-66.

Rajkumar RH, Vishwanatha J, Anand SR, Karegoudar AV, Dandekar AT and Kaledhonkar MJ (2017) Effect of laser land leveling on crop yield and water production efficiency of paddy (*Oryza sativa*) in Tungabhadra project command. *Journal of Soil Salinity and Water Quality* 9 (2): 213-2.

Vishwanatha J, Ravikumar D, Karegoudar AV, Anand SR and Rajkumar RH (2016) Characterization of Ground water for irrigation in Dharwad district of Karnataka. *Journal of Soil salinity and water quality* 8 (2): 202-206.

**HISAR**

**Research Papers**

Bhat Amin, Mohammad, Grewal MS, Ramprakash, Rajpaul, Wani AS and Dar AE (2016) Assessment of Groundwater quality for irrigation purposes using chemical Indices. *Indian Journal of Ecology* 43 (2):574-579.

Dhaka AK, Kumar S, Pannu RK, Malik K, Singh B and Ramprakash (2017) Production potential, energy efficiency and economics of wheat *(Triticum aestivum* L.*)* succeeding fodder sorghum intercropped in seed crop of dhaincha *(Sesbania aculeate*). *Indian journal of Agricultural Sciences* 87 (2):225-33.

Dhaka AK, Kumar S, Pannu RK, Malik K, Singh B and Ramprakash (2017) Production potential, energy efficiency and economics of wheat *(Triticum aestivum* L.*)* succeeding fodder sorghum intercropped in seed crop of dhaincha *(Sesbania aculeate*). *Indian Journal of Agricultural Sciences* 87 (2): 225-33.

Gagandeep, RamPrakash, Kumar S, Rajpaul, Satyavan and Sharma SK (2017) Groundwater quality assessment for irrigation in Palwal block of Palwal district, Haryana, India. *Journals of Applied and Natural Science* 9 (1):34-38.

Jeane M, Kumar S, Rajpaul, Prakash R, Sharma SK and Satyavan (2016) Assessment of groundwater quality of Ellenabad block of Sirsa district, Haryana. *Annals of Biology* 32 (2):219-223.

Kumar N, Jhorar RK, Kumar S, Yadav Rajpaul, Ramprakash, and Singh A (2018) Effect of fertigation on nitrogen use efficiency and productivity of tomato utilizing saline water through drip irrigation. *Journal of Soil Salinity and Water Quality* 9 (2): 205-212.

Kumar S, Kumar S, Sharma SK, Jhorar RK and Ramprakash (2016) Response of Okra (*Abelmoschus esculentus* L.) under drip irrigation with different levels of saline water. *Annals of Agri-Bio research* 21 (1):61-65.

Kumar S, Kumar S, Sharma SK, Rajpaul and RamPrakash (2016) Effect of irrigation frequency and salinity under drip irrigation on Okra (*Abelmoschus esculentus* L.). *Annals of Agri-Bio research* 21 (1):66-70.

Kumar S, Satyavan, Jakhar DS and Sihag (2018) Effect of integrated nutrient management practices on soil properties and nutrient availability to wheat (*Triticumaestivum* L.) under saline and non saline irrigation water. *International Journal of Chemical Studies* 6 (2): 3701-3704.

Kumar S, Sharma SK, RamPrakash, Yadav R and Satyavan (2016) Spatial variation of groundwater quality of Meham block of Rohtak district, Haryana. *Indian Journal of Soil Conservation* 44 (2):163-167.

Kumari S, Ramprakash and Kumari B (2016) Dissipation of bifenthrin in Soil under laboratory condition. *Environment and Ecology* 34 (2):580-582.

Ram Prakash, Rajpaul, Sharma SK and Satyavan (2016) Use of sewage sludge as a source of fertilizer for wheat crop irrigated with saline water. *Environment and Ecology* 34 (3B):1330-1335.

Rathi P, Ramprakash, Kumar S, Rathi N and Vikas (2018) Mapping of variability in quality of groundwater in Rajaund block of Kaithal District (Haryana). *Journal of Pharmacognosy and Phytochemistry* 7 **(**1):1056-1059.

Rathi P, Ramprakash, Kumar S, Satyavan and Rathi N (2018) Characterization of groundwater quality in Siwan block of Kaithal district in Haryana. *International Journal of Chemical Studies* 6 (1): 981-985.

Sangwan M, Singh S and Satyavan (2016) Effect of sequrntial application of imazepthapyr + imazamox and propaquizafop in clusterbean (*Cyamopsis tetragonoloba*) in two texturally different soils. *Indian Journal of Agronomy* 61 (4): 519-522.

Singh M, Yadav DB, Punia SS, Khedwal RS, Singh Rajbir, Kumar N, RamPrakash, and Dabur KR (2017) Influence of different Basmati cultivars and nitrogen scheduling on nutrient content, uptake and nitrogen use efficiency. *Journal of Soil Salinity and Water Quality 9* (1):84-93.

Singh M, Yadav DB, Punia SS, Singh R, Kumar N, Ramprakash and Dabur KR (2017) Influence of different basmati cultivars and nitrogen scheduling on nutrient content, uptake and nitrogen use efficiency. *Journal of Soil Salinity and Water Quality* 9 (1): 84-93.

Singh M, Yadav DB, RamPrakash, Khedwal RS, Kumar N, Dabur KR and Singh NK (2017) Quality and economics of cultivars under DSR as influence by split application of nitrogenous fertilizers. *International Journal of Current Research* 9 (1):45341-45344.

Singh SK, Ram Prakash, Kumari S and Singh A (2016) Effect of chelating agents on Phytoextraction of Ni from contaminated soil by Zea mays. *Journal of applied and Natural Science*8 (4):1975-1980.

Singh Vijaykant, Ramprakash, Rajpaul, Kumar S, Singh K and Satyavan (2018) Evaluation of groundwater quality for irrigation in Gulha block of Kaithal district in Haryana. *Journal of Soil Salinity and Water Quality* 9 (2): 241-248.

**Popular Articles**

Ankush, Ramprakash and Singh V (2017) Krishi bhumi ki samshaya avam samadhan. *Krishak Jagat*, 14: 5.

Ankush, Singh V, Kumar V and Ramprakash (2017) An overview of drip fertigation technology. *Indian Farmer,* 4(10): 744-747.

Singh A, Vikram and Ramprakash (2017) Revitalizing techniques for saline soil. *Indian Farmer,* 4(8): 706-709.

Singh K, Yadav Rajpaul and RamPrakash (2016) Adhik khadyanoe utapadan hetu ushar –kallar bhumi ka sudhar. *Haryana Kheti* 49(2); 28-30 Feb. 2016.

**INDORE**

**Research Papers**

Khandkar UR, Tiwari SC, Sharma RK, Verma SK, Meena RL and Kaledhonkar MJ (2017) Relative Efficacy of Amendments for Reclamation of Sodic Vertisols and their Effects on Crop Production. *Journal Soil Salinity and Water Quality* 9(2): 187-193.

Sharma RK, Tiwari SC, Khandkar UR and Parmar BB (2016) Assessing Pre-canal Irrigation Scenario of Soil, Water and Crop in Head-reach of Indira Sagar Command. *Journal Soil Salinity and Water Quality* 8(1): 82-91.

Thakur R, Khandkar UR, Devbrata N, Patidar RK and Kumar N (2017) Documentation on enhancing nutrient uptake and yield of rice with application of sewage sludge and different fertility levels on sodic vertisols. *International Journal of Current Microbiology and Applied Sciences* 6(10): 2986-2998.

Thakur R, Khandkar UR, Devbrata N, Patidar RK and Patidar NK (2017) Impact of sewage sludge on enhancing chemical properties and fertility levels of sodic vertisols of Madhya Pradesh. *Green Farming* 8:1- 5.

Verma SK, Singh Anil Kumar and Khandkar UR (2015) Innovations in reclamation and management of salt affected soils. *JNKVV Res. Journal 49 (3):442-455.*

Vishwakarma M, Khandkar UR and Tiwari SC (2017) Effect of different levels of fertilizer and biogas slurry on yield and chemical composition of wheat grown under Sodic Vertisols. *Journal Soil Salinity and Water Quality* 9(2): 200-204.

**KANPUR**

**Research Papers**

Kumar R, Singh D and Kumar A (2017) Assessment of underground irrigation water quality of Kanpur dehat district of Uttar Pradesh. *Annals of Plant and Soil Research* 19(3):334-335.

Kumar R, Singh A, Kumar G and Pandey SN (2016) Comparative effect of gypsum and phosphogypsum on crops irrigated with alkali water under Sodic Soil conditions. *Environment and Ecology* 34 (4B): 2212-2216.

Kumar R, Singh D and Yadav VP (2018) Effect of RSC Water, Using Different Ameliorants on Crop Production and Soil Fertility in Sodic Soil. *An International Referred Peer Reviewed and Indexed Quarterly Journal in Science, Agriculture & Engineering* 8: 303-305.

Kumar R, Singh D and Yadav VP (2018) Quality of Underground Irrigation Water of Fatehpur District, Uttar Pradesh. *An International Referred Peer Reviewed and Indexed Quarterly Journal in Science, Agriculture & Engineering* 8:306-308.

Kumar V, Kumar R, Swaroop N, Singh D, Kumar G and Rani R (2016) Evaluation and characterization of groundwater quality for irrigation of Kannauj district of U.P., India. *Progressive Research11 (1):58-60.*

Yadav GS, Singh D and Kumar R (2017) Effect of Integrated Use of Organic Manures and Inorganic Fertilizers in Rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry* SP1: 296-298.

**Popular Articles**

Kumar R and Singh D (2016) Phasloutpadan Main Mitti Parichhan Ka Mahtau. *Krashak Bharti CSAU of A & Tech. Kanpur*, 62-63.

**KARNAL**

**Research Papers**

Dotaniya ML, Datta SC, Biswas DR, Dotaniya CK, Meena BL, Rajendiran S, Regar KL, Manju Lata (2016) Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. *International Journal of Recycling of Organic Waste in Agriculture* 5(3): 263-272.

Fagodiya RK, Pathak H, Meena BL, Meena RK, Nagdev R (2017) Need to Estimate Net Global Warming Potential of Nitrogenous Fertilizers. *Advances in Plants & Agriculture Research* 6(4): 00220. DOI: 10.15406/apar.2017.06.00220.

Kumar A, Bhatia A, Fagodiya RK, Malyan SK and Meena BL (2017) Eddy Covariance Flux Tower: A Promising Technique for Greenhouse Gases Measurement. *Advances in Plants & Agriculture Research* 7(4):00263.DOI:10.15406/apar.2017.07. 00263

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### 7.6 FINANCE

The Three Year Plan (2017–2020) 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 and 2017–18 is given below:

**Agra**

| Budget head | 2016-17 | | 2017-18 | |
|---|---|---|---|---|
| | Released ICAR share (100%) | Expenditure ICAR share (100%) | Released ICAR share (100%) | Expenditure ICAR share (100%) |
| Pay & Allowances | 6200000 | 7084127 | 7500000 | 7741580 |
| TA & POL | 100000 | 61260 | 55000 | 13590 |
| Contingencies | | | | |
| Recurring/Res. | 350000 | 349383 | 95000 | 94024 |
| Non-recurring | 0 | 0 | 0 | 0 |
| Works | 0 | 0 | 0 | 0 |
| Total | 6650000 | 7494770 | 7650000 | 7849194 |
| **ORP** | | | | |
| TA | 100000 | 72336 | 30000 | 10146 |
| Rec.conti./Misce. | 250000 | 258970 | 290000 | 285095 |
| Total | 350000 | 331306 | 320000 | 295241 |
| **Grand Total** | **7000000** | 7826076 | **7970000** | **8144435** |

**Bapatla**

| Budget head | 2016-17 | | 2017-18 | |
|---|---|---|---|---|
| | Released ICAR share (75%) | Expenditure ICAR share (75%) | Released ICAR share (75%) | Expenditure ICAR share (75%) |
| Pay & Allowances | 5000000 | 7349355 | 7400000 | 7733063 |
| TA & POL | 130000 | 129878 | 85000 | 84524 |
| Contingencies | | | | |
| Recurring | 300000 | 349603 | 115000 | 114850 |
| Non-recurring | 0 | 0 | 0 | 0 |
| Works | 0 | 0 | 0 | 0 |
| Total | 5430000 | 7828836 | 7600000 | 7932437 |
| **ORP** | | | | |
| TA | 100000 | 99736 | 40000 | 39994 |
| Rec.contingencies/Misc | 200000 | 249268 | 250000 | 248832 |
| Total | 300000 | 349004 | 290000 | 288826 |
| **Grand Total** | **5730000** | 8177840 | 7890000 | 8221263 |

**Bikaner**

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

**Gangavati**

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

**Hisar**

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

**Indore**

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

**Kanpur**

| Budget head | 2016-17 | | 2017-18 | |
|---|---|---|---|---|
| | Released ICAR share (75%) | Expenditure ICAR share (75%) | Released ICAR share (75%) | Released ICAR share (75%) |
| Pay & Allowances | 5000000 | 6836412 | 7800000 | 7665682 |
| TA & POL | 100000 | 99463 | 75000 | 74935 |
| Contingencies | | | | |
| Recurring | 400000 | 396937 | 80000 | 79985 |
| Non-recurring | 0 | | 170000 | 169942 |
| **Total** | **5500000** | **7332812** | **8125000** | **7990544** |

**Karnal**

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

**Tiruchirappalli**

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

**VOLUNTEER CENTRES**

**Bathinda**

| Budget head | 2016-17 | | 2017-18 | |
|---|---|---|---|---|
| | Released | Expenditure | Released | Expenditure |
| Pay & Allowances | 0 | 0 | 0 | 339637 |
| TA & POL | 75000 | 1212009 | 40000 | 0 |
| Contingencies | | | | |
| Recurring | 675000 | 0 | 100000 | 0 |
| Non-recurring | 0 | 0 | 200000 | 0 |
| **Total** | **750000** | **1212009** | **340000** | **339637** |

**Port Blair**

| Budget head | 2016-17 | | 2017-18 | |
|---|---|---|---|---|
| | Released | Expenditure | Released | Expenditure |
| Pay & Allowances | 0 | 562374 | 295000 | 295000 |
| TA & POL | 100000 | 78430 | 0 | 0 |
| Contingencies | | | | |
| Recurring | 700000 | 237606 | 0 | 0 |
| Non-recurring | 0 | 30267 | 0 | |
| **Total** | **800000** | **908677** | **295000** | **295000** |

**Panvel**

| Budget head | 2016-17 | | 2017-18 | |
|---|---|---|---|---|
| | Released | Expenditure | Released | Expenditure |
| Pay & Allowances | 0 | 0 | 0 | 0 |
| TA & POL | 100000 | 88354 | 55000 | 335370 |
| Contingencies | | | | |
| Recurring | 700000 | 788782 | 100000 | 0 |
| Non-recurring | 0 | 0 | 205000 | 0 |
| **Total** | **800000** | **877136** | **360000** | **335370** |

**Vyttila**

| Budget head | 2016-17 | | 2017-18 | |
|---|---|---|---|---|
| | Released | Expenditure | Released | Expenditure |
| Pay & Allowances | 0 | 831351 | 0 | 360000 |
| TA & POL | 100000 | 0 | 55000 | 0 |
| Contingencies | | | | |
| Recurring | 700000 | 0 | 100000 | 0 |
| Non-recurring | 0 | 0 | 205000 | 0 |
| **Total** | **800000** | **831351** | **360000** | **360000** |

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