अखिल भारतीय समन्वित अनुसंधान परियोजना

लवणग्रस्त मृदाओं का प्रबंध एवं खारे जल का कृषि में उपयोग

All India Coordinated Research Project

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

द्विवार्षिक प्रतिवेदन
Biennial Report
(2012-14)

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

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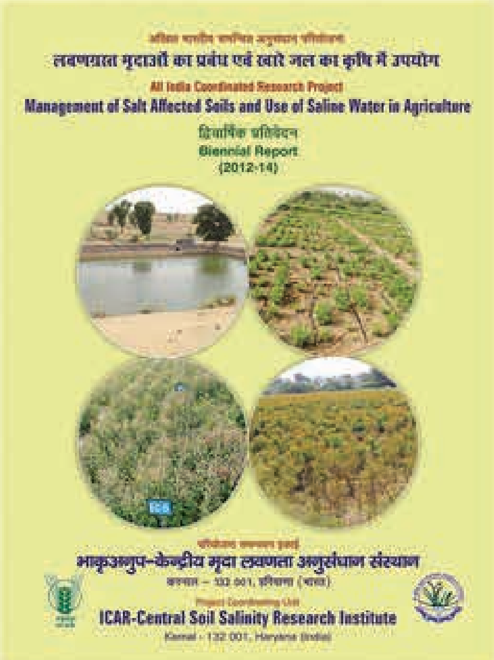
Citation: Biennial Report (2012-14). All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture, ICAR-Central Soil Salinity Research Institute, Karnal. 218 p.

Edited by: RL Meena, BL Meena, SK Gupta and DK Sharma



Published by Director, ICAR-Central Soil Salinity Research Institute, Karnal
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Printed by: Intech Printers & Publishers
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Contact No. 0184-4043541, 3292951; Email: jobs.ipp@gmail.com

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द्विवार्षिक प्रतिवेदन

Biennial Report
2012-14

Cooperating Centres

1. Raja Balwant Singh College, Bichpuri, Agra (Uttar Pradesh)
2. Regional Research Station, ANG Ranga Agricultural University Bapatla (Andhra Pradesh)
3. SK Rajasthan Agricultural University, Bikaner (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences, Gangawati (Karnataka)
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4. Rice Research Station, Kerala Agril University, Vyttila, Kochi (Kerala)

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FOREWORD

Agriculture occupies an important place in the economy of the country. It contributes about 14% to total GDP while supporting livelihoods to more than 60% population. Since independence farming has been shaped to attain self sufficiency in food grain production. The diverse agro-climatic conditions of the country enable farmers to produce variety of crops. About one third of the world's irrigated land is salt affected. Water is another critical resource whose availability is diminishing continuously for agricultural use due to enhanced demand from other sectors. Quality of ground water resources is being deteriorated due to disposal of pollutants, sewage and effluents from industries. Abundant surface, ground and rain water needs to be managed efficiently for enhanced and sustainable crop production. Management and reclamation of salt affected soils is of paramount importance to bring more areas under cultivation apart from use of poor and marginal quality of water for irrigation.

Degradation of water quality is of particular concern as water resources, both surface and point sources such as ground water, are being increasingly polluted through non-point sources such as agriculture and unscientific disposal of industrial pollutants and municipal effluents. The demand for agricultural commodities is steeply rising not only because of the increasing population but also because of food preferences of the next-generation consumers. Under this scenario, 6.73 mha of degraded salt affected soils could be turned into an opportunity, irrigation with naturally occurring saline/alkali waters and inadequately treated domestic/industrial effluents could help to tide the fresh water crunch in the agricultural sector. It is matter of great satisfaction that the ICAR-Central Soil Salinity Research Institute, Karnal and All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture with its eight Centres in seven states came out with innovative technologies for the reclamation of salt affected soils and use of saline water in the country. As a result, about 1.8 million ha salt affected lands could be reclaimed adding about 12-15 mt of food grains annually to the food grain basket of the nation. Recent initiatives of these organizations in the fields of multiple uses of water, resource conservation technologies, ground water recharge etc would prove to be highly useful to increase production, enhance profitability, improve soil and water quality and combat the challenges posed by climate change.

The eight centres of AICRP located in various agro-ecological settings besides independently working on location specific problems also act as outreach network centres of CSSRI. It is satisfying that soil and ground water characterisation studies being undertaken in different states are being synthesized to produce soil and ground water quality maps and to finalize new criteria and guidelines for their use. Several technologies notably reclamation of black alkali soils, skimming wells and alternative technologies to develop water resources in coastal sandy soils and cost effective agronomical interventions to mange saline/alkali waters are being demonstrated through ORPs and field demonstrations. The technology transfer programmes have yielded rich dividends as the technologies could be tested under farmer's endowment. I believe that the site-specific technologies developed by the Coordinating Unit and Cooperating Centres have the potential of application not only within the states but also beyond the boundaries of the state.

The biennial report 2012-14 contains the research results of the biennium at coordinating unit and 8 research centres covering arid, semiarid, irrigated, rain fed and coastal ecologies on alluvial, Vertisols and coastal waterlogged saline/alkali soils. I am sure that with the collective wisdom of invited experts, CSSRI scientific staff and scientists of AICRP centres, it would be possible to develop a innovative programme that would be able to address the current challenges of soil quality, ground water depletion and pollution particularly by fluoride and nitrate, dry land salinity, wastewater use, water logging and subsurface drainage, use of remote sensing and GIS for preparation of soil and water quality maps, environmental degradation and climatic change.

I take this opportunity to express my sincere thanks and gratitude to Dr S Ayyappan, Secretary, DARE and DG, ICAR for providing financial support and taking keen interest in its activities. His initiative to monitor AICRP project activities by interacting with PC's would help to further strengthen the functioning of the project. I also express my deep sense of gratitude to Dr AK Sikka, DDG (NRM), ICAR for guiding the technical program and providing unstinted support to the project.

Heartfelt thanks are due to Dr SK Chaudhari, ADG (SWM) for his excellent support to the project and cooperation in all spheres. I also thanks to Dr SK Gupta, Ex-Project Coordinator for their support as and when needed during the period. I wish to extend my sincere thanks to colleagues at AICRP centers Dr RB Singh, Dr (Mrs) GV Lakshmi, Dr IJ Gulati, Dr Vishwanath Jowkin, Dr SK Sharma, Dr UR Khandkar, Dr Ravindra Kumar and Dr A Saravanan/ Dr P Subramaniam/Dr L Chithra for undertaking research programs and compiling centers report in time.

Special word of appreciation to Dr RL Meena and Dr BL Meena for excellent cooperation and helping in smooth running of the project during last two years and their concerted efforts in coordinating the biennial workshop activities and compilation, editing and bringing out the biennial report deserves special appreciation. I have a special word of appreciation for Dr SK Ambast, Ex-Project Coordinator for his contribution in streamlining and coordinating the project activities. The staff at coordinating unit Sh AK Sharma, Sh Manish Pandey and Sh. Rajkumar has extended willing support for project operations is thankfully acknowledged. It would be my pleasure to extend all support to the project that may be required to achieve the targets set forth in the biennial workshop.

(DK Sharma)
Director & Project Coordinator

CONTENTS

SUMMARY OF RESEARCH ACCOMPLISHMENTS

AGRA

Survey and characterization of ground waters for irrigation

Comparing the ground water quality this year and 35 years ago in Agra district, it emerged that the good quality waters in all the seven surveyed blocks have reduced sharply. In majority of samples in all blocks except Fatehpur Sikri, high SAR saline water has increased over the last 35 years.

Impact of Agra canal on ground water quality, soil properties and crop performance

The waters of Agra canal and ground water in different places along the Agra canal i.e. Okhala (Delhi), Palwal (Haryana), Kosi (Mathura), Goverdhan (Mathura) and Bichpuri (Agra) are used for irrigation for different vegetables, cereals and pulse crops. The crops yield data showed that maximum net profit was recorded in crops grown with Agra canal water. Net profit was less in underground water irrigated crops. Analysis of soil samples for cation, anion and available nutrients revealed that these were higher in Agra canal water irrigated soils as compared to underground water irrigated soils.

Assessment of treated sewage water on soil, crop and ground water qualities

The sewage water and drinking water samples were collected seasonally from different locations in STP command, Dandhupura, district Agra wherein treated STP water is being used for irrigating different crops. The water salinity ranged between 31-36 dS/m in sewage water and between 22.5-35.0 dS/m in drinking water. BOD ranged between 27.5-225.5 mg/l. Bicarbonates between 483.2-969.9 mg/l, chloride 450.9-711.8 mg/l and sulphate 165.6-777.6 mg/l. Among the cations calcium ranged between 84.2-212.4 mg/l, magnesium 201.3-334.4 mg/l, sodium 592.3-682.5 mg/l in inlet, out let and 1 km away from STP water samples. The potassium ranged between 30.2-44.8 mg/l, SAR 10.4-12.1 and RSC was nil. Concentration of heavy metals such as Copper, Zinc, Cobalt, Chromium, Lead and Iron were found higher in sewage water than the permissible limits laid down by WHO and CPCB.

Screening of wheat, rice and mustard cultivars under saline water irrigation

Screening of 88 wheat cultivars was carried out during 2012-13 with saline water of EC_{iw} 10 dS/m. The highest grain yield was recorded in Kharchia 65 and KRL 3-4. During 2013, twenty nine rice genotypes were grown with saline water of EC_{iw} 9 dS/m. Some genotype gave good yield while others produced poor grain yield. During 2012-13, screening of mustard cultivars with saline water of EC_{iw} 10 dS/m revealed that highest yield of mustard in L 16 (2.21 t/ha) and lowest in L 4 (1.65 t/ha). During 2013-14, cultivars L 8 produced highest grain yield (1.28 t/ha) and L 9 lowest yield (1.01 t/ha). In CSCN highest yield was recorded in CSCN -12-2 (1.98 t/ha) and lowest in CSCN- 12-6 (1.41 t/ha) during 2012-13 while during 2013-14 highest grain yield was recorded in CSCN-13-7 (1.71 t/ha) and lowest in CSCN-13-1 (1.24 t/ha). In AVT highest yield was obtained in AVT- 13-12 (1.74 t/ha) and lowest in AVT- 13-9 (1.24 t/ha).

Plastic low tunnel technology for off season cultivation of vegetables using saline water with drip irrigation

The experiment was carried out in micro-plots with tomato-bitter gourd crop rotation in plastic low tunnel with drip and surface irrigation. On an average EC_{iw} 4 and 8 dS/m reduced the fruit yield of tomato by 6.9 and 16.5% in plastic low tunnel with drip irrigation and 13.3 and 23.8% in surface irrigation, respectively. In bitter gourd this reduction was 2.7 and 10.4% in drip and 13.2 and 29.9% in surface irrigation. The fruit yield of tomato was non-significant with IW/CPE ratio in both plastic low tunnel with drip and surface irrigation. In plastic low tunnel with drip irrigation water use efficiency in tomato was 707.5 kg/ha-cm in canal, 647.4 in EC_{iw} 4 dS/m and 584.6 kg/ha-cm in EC_{iw} 8 dS/m, whereas in surface irrigation these were 250.6, 219.5 and 181.9 kg/ha-cm, respectively.

Crop water/salinity production function for crops using sprinkler irrigation

An experiment with cowpea-mustard crop rotation was conducted to determine the production function in relation to water and salinity/sodicity using sprinkler lines of BAW (EC_{iw} 3.6 dS/m and RSC_{iw} nil), saline (EC_{iw} 10 dS/m) and RSC (RSC_{iw} 10 meq/l) waters for creating gradients of moisture and salinity/sodicity. Mustard grain yield was affected by moisture gradient and salinity/sodicity. In case of moisture gradient the grain yield increased with increased moisture in terms of depth of irrigation from 0.74 to 3.64 cm per irrigation. Contrary to this, grain yield declined with increased salinity gradient of irrigation water from 4.7 to 8.4 dS/m. In RSC_{iw}, the grain yield was also affected in the gradient range from 1.8 to 7.8 meq/l of water.

Operational Research Project on Use of poor quality ground water at farmer's field

In alkali water having RSC (6.2- 8.8 meq/l), gypsum was applied @ 50% GR to compare with control (without gypsum). During *kharif* pearl millet crop was grown at five farmer's fields, with yield variying from 1.5 and 2.1 t/ha with gypsum treated field and 1.3 and 1.8 t/ha without gypsum. In high SAR saline water, ten farmers grew pearl millet and the yield varied from 1.5 to 2.2 t/ha being 17.1 to 17.9% higher over traditional practice

Five farmers cultivated wheat with alkali water, the yield increased by 12% in gypsum treated field over control (without gypsum). The mustard cultivars (CS 52 and CS 56) grown on one farmer's fields (saline condition) and KVK, Awagarh (alkali condition var. CS 54), the mustard yield was found 2.07, 2.17 and 2.25 t/ha in CS 52, CS 56 and CS 54, respectively. Under N fertilization at six farmer's field, 150 kgN/ha resulted in 10.13% increase over 120 kgN/ha. At recharge sites, wheat yield (4.25 to 4.99 t/ha) was at par to the irrigation water by diluting the high SAR saline water with rain water. The soil salinity buid-up in surface layer was observed.

BAPATLA

Studies at benchmark locations in Guntur district to monitor the changes in ground water quality and soil properties

Studies conducted at benchmark locations in Guntur district revealed that salinity of ground water substantially increased at Nidubrolu-I (1.90 to 10.10 dS/m), Nidubrolu-II (1.20 to 5.76 dS/m), Machavaram (1.40 to 3.83 dS/m) and Chintalapudi (1.80 to 3.20 dS/m) which could be due to over exploitation of ground water leading to upconing of salt water and sea water intrusion. Salinity decreased at Potarlanka (2.00 to 0.62), Amarthaluru (2.60 to 1.18) and Angalakuduru (0.72 to 0.58 dS/m) and marginally increased at Chiluvuru (1.85 to 2.11 dS/m). Initial high RSC decreased at all locations due to continuous pumping of water.

Reclamation of abandoned aqua ponds

This experiment was implemented in three villages viz., Adavuladeevi, Gokarnamatam and Ganapavaram at 16 farmer's fields during *kharif* 2012-14. Highest yield was recorded in Sri Edukondalu field (51.65 and 56.25 q/ha) during 2012-13 and 2013-14, respectively. The rice yield increased from 12 to 30% as compared to control due to adoption of reclamation technologies.

ORP on Improvisation and demonstration of reclamation technologies for alkali soils

This experiment was implemented in five farmer's fields at PBV Palem village of Guntur district during *kharif* 2012-13. With the leaching of soluble salts using gypsum, in-situ incorporation of green manure dhaincha and application of zinc sulphate @ 20 kg/ha, the highest yield was recorded in Sri P. Bikshalu field (62.0 q/ha) resulting in 12 to 27% increase in rice yield as compared to control.

Effect of sea water intrusion on ground water quality in coastal belt of Krishna Zone, AP

About 120 water samples were collected with GPS locations along the 25 km distance from sea coast at four locations during June - December, 2012. EC values of ground water samples ranged between 0.57 to 13.9 dS/m and 0.66 to 12.7 dS/m, respectively in both the seasons. In these samples sodium ion is dominant and high SAR value of 33.4 was observed. During 2013, samples were collected along 50 km distance from sea coast at four locations and highest EC of 8.4 dS/m at Suryalanaka and high value of SAR (21.5) was observed at Kanaparthi point.

Delineation and mapping of salt affected soils of Andhra Pradesh

Delineation and mapping of salt affected soils for Srikakulam, Vijayanagaram, Visakhapatnam, Chitoor, Nellore, Krishna, West Godavari and East Godavari districts were completed with the help of imageries procured from NRSA during 2010. During 2013-14, survey was conducted and soil samples of salt affected Ananthapur district were analyzed and EC_e values ranged between 0.3 -14.1 dS/m, while the pH_s ranged between 7.0 to 9.4.

Screening of maize, bengal gram, Bt. Cotton, mustard and paddy varieties for salt tolerance

Maize: Three maize hybrids viz., Sandhya, DHM 117 and 30V 92 were tested at five water salinity levels (BAW, 2, 4, 6 and 8 dS/m). Decreasing trend in yield was observed with increasing EC levels of irrigation water and pooled data revealed that 30V 92 hybrid recorded the highest yield (60.08 q/ha) with best performance as compared to Sandhya and DHM-117. Highest K and lowest Na was also observed in this hybrid.

Bengalgram: Among four varieties of bengal gram (JG-11, JG-130, KAK-2 and Nbeg) tested, highest yield was recorded in KAK-2 (10.17 q/ha) followed by JG-11 (9.34 q/ha). Highest Na (0.195%) and lowest K (0.156%) accumulation was observed in KAK-2 variety among all the varieties.

Paddy: Experiment conducted with six paddy varieties viz., CSR 36, CSR 27, MCM 100, MTM 1010, MCM 101 and MTU 1061 during *kharif* 2013 at Ponnapalli vIllage revealed that CSR 36 recorded highest grain yield (5.8 t/ha) followed by CSR 27 (5.3 t/ha), MTU 1061 recorded lowest the grain yield (4.4 t/ha).

Management of high RSC water in heavy textured soils

Experiment conducted during 2010-12 revealed that application of gypsum based on neutralization of water RSC (>2.4 meq/l) gave significantly higher grain yield (39.71 q/ha) than farmer's practice of no application of gypsum.

Performance of groundnut with saline water through drip irrigation system

The experiment was conducted on sandy loam soils at Bapatla during *rabi* 2013-14 with three groundnut varieties (K6, K7 and Anantha) with 5 different EC of irrigation water (BAW, 2, 4, 6 and 8 dS/m). Significantly higher pod yield was recorded in K-7 (15.15 q/ha) followed by K-6 (12.38 q/ha) and Anantha (12.05 q/ha).

Strategies for conjunctive use of fresh and saline ground waters for improving productivity of rice

During *kharif* 2012, significantly higher grain yields were recorded at farmer's field in Ponnapalli village Guntur district when irrigation water was given as 2CW:1SW cyclic mode than saline ground water but it was at par with only canal water or 1CW:1SW.

Micro (drip) irrigation system with saline water for different vegetable crops in coastal sandy soils

Results of the experiments during 2012-13, showed that use of fresh water recorded the highest yield as compared to different levels of saline irrigation water. During 2013-14, mean yield of palak, cluster bean and capsicum reduced linearly with salinity of irrigation water. The regression equation, Y (t/ha): -0.801*EC (dS/m)+7.988 with R^2=0.988; Y (t/ha) = -0.681*EC (dS/m)+7.616 with R^2 = 0.988 and Y (t/ha) = -0.334* EC (dS/m)+2.964 with R^2 = 0.972 for palak, cluster bean and capsicum, respectively.

Use of saline water in shadenets for different vegetable crops in Krishna Western Delta

The experiment was conducted during 2013-14 with capsicum at Bobbepalli shadenets farm with BAW, 2, 4, 6 and 8 dS/m irrigation water salinity. Capsicum yield decreased with the salinity of irrigation water. The equation is Y (t/ha) = 0.085 EC^2-1.773*EC (dS/m)+14.94 with R^2 = 0.910. A comparative study of capsicum suggested that the performance of crop under shadenets is far better than open field cultivation under different levels of saline water irrigation.

BIKANER

Survey and characterization of ground waters for irrigation

Sikar district: During 2012-13, ground water samples from 90 tubewells in 73 villages of three tehsils of Sikar district were collected and analyzed for ionic composition. Nearly all water samples in Lachhmangarh tehsil showed pH > 8.5 whereas about 37.5 and 62.5 per cent water samples in Sikar tehsil and 28.6 and 71.4 per cent water samples in Neem ka Thana tehsil showed pH in the range of 8.0 to 8.5 and >8.5, respectively. Salinity 93.3, and 6.7 per cent water samples in Lachhmangarh, 82.1 and 17.9 per cent water samples in Neem ka Thana tehsil showed EC in the range of <2.0 and 2.0-4.0 dS/m, while in Sikar tehsil 100 per cent water samples had EC in the range of <2.0 dS/m.

Soil analysis indicated that soil was alkali in nature in 50 to 43% villages of Lacfhhmangarh and Neem ka Thana and 15.6% villages of Sikar tehsils. It is because ground water having RSC 5.0 to 7.5 and pH >8.5 to 9.7 were being used to irrigate the soils. On the basis of overall quality, about 23.3, 26.7 and 50.0 per cent water in Laxmangarh, 71.9, 12.5 and 15.6% in Sikar and 35.7, 21.4 and 42.9% water samples in Neem ka Thana tehsil are under good, marginally alkali and alkali categories, respectively.

Sri Ganganagar district: During 2013-14, water samples collected from 40 villages of Sri Ganganagar district were analyzed for chemical characteristics. The EC and pH of water in Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils ranged from 1.20 to 10.50 dS/m, 5.33 to 6.80 dS/m, 1.16 to 10.50 dS/m and 1.22 to 8.16 dS/m and 8.0 to 8.5, 8.0 to 8.1, 7.7 to 8.5 and 7.6 to 8.5, respectively. RSC of water samples ranged from nil to 9.0, and nil to 4.6 meq/L in Sri Ganganagar and Sadulshar tehsils, respectively. About 92.8, 100.0, 100.0 and 94.5% water samples in Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils, respectively, had RSC less than 2.5 meq/l.

About 7.1, 7.1, 50.0, 7.1 and 28.6% water samples in Sri Ganganagar were under good, marginally saline, high SAR saline, marginally alkali and highly alkali, while 100% water samples of Padampur tehsil are under high SAR saline category. In Sri Karanpur tehsils about 25.0 and 75.0% water samples fall under good and high SAR saline category, respectively. In Sadulshar tehsils about 5.6, 83.3 and 11.1% samples are good, high SAR saline and highly alkali category, respectively.

Monitoring of ground water level and water quality in IGNP stage II

The monitoring of water level in IGNP stage-II was initiated in 1992 by CAD authorities. The data collected during 2013 along with record of previous years were analysed to evaluate the fluctuations in ground water levels and to assess change in extent of water logged, critical and potentially sensitive area. Analysis revealed extent of area under all the three categories i.e. potentially sensitive, critical and waterlogged area decreased over the years. Analysis of samples collected during 2013 showed that salinity level at most of the locations near the canal is decreasing by 0.5 to 3 dS/m compared to locations away from canal, where the average decrease in salinity is about 1.5 dS/m during the last 6 years.

Tolerance of brinjal to saline water under drip and flood irrigation systems

This study was initiated during *kharif* 2011 with three levels of water quality (EC_{iw} 0.25, 3.0 and 6.0 dS/m) and two irrigation methods (drip and flood). Highest fruit yield of brinjal was obtained under drip irrigation with EC 3.0 dS/m, over other treatments with a significant decrease in yield at EC 6.0 dS/m. Drip method was superior to flood method at all levels of EC_{iw} giving 26.5% higher fruit yield. EC_e of soil recorded after harvest of brinjal crop showed that maximum salinity was at 30 cm distance from emitters with 6.0 dS/m saline water. The trend indicated that high salt accumulation on the soil surface decreased gradually with the depth of root zone under all the treatments.

Study to optimize water requirement of groundnut-isabgol using saline water under drip irrigation

To work out optimum irrigation geometry for groundnut and isabgol under drip system using varying levels of saline water, an experiment with three salinity levels and three drip geometries was conducted. It was observed that increasing levels of salinity of irrigation water caused significant reduction in the pod yield of groundnut during both the years. Pooled data show that as compared to BAW (38.83 q/ha), EC_{iw} 4.0 and 8.0 dS/m caused significant reduction in the pod yield being 29.6 and 65.6%, respectively. Irrigation geometry (lateral x emitter) at 60 cm x 30 cm recorded the highest pod yield (32.2 q/ha). Drip laterals spaced at 90 and 120 cm caused significant reduction (17.5 and 35.6%) in pod yield, respectively.

During *rabi*, isabgol crop grown on the same field where groundnut was taken. From the pooled data, it is inferred that increased salinity of irrigation water from 0.25 dS/m (BAW) to 4 dS/m resulted in significant increase grain yield (10.5%), but further increase in the level of salinity (8 dS/m) resulted in significant reduction of 29.9 and 36.6% over 4 dS/m and BAW irrigation, respectively. Irrigation geometry at 60 cm X 30 cm gave highest grain yield of 7.62 q/ha. As compared to laterals spaced at 60 cm, drip laterals spaced at 90 and 120 cm resulted in significant reduction (13.5 and 40.8%) in grain yield of isabgol, respectively.

Study on groundnut-isabgol crop sequence under drip irrigation system to mitigate the adverse effect of saline water using bio-regulators

Impact of bio-regulators in mitigating the adverse effect of saline irrigation water on groundnut-isabgol cropping sequence under drip system was evaluated. Significant reduction of 20.6, 53.6 and 82.0% in pod yield of groundnut was recorded, when irrigated with 4.0, 8.0 and 12 dS/m saline waters, respectively, as compared to BAW (37.98 q/ha). Among different bio-regulators, Ascorbic acid (100 ppm), Cycocel (500 ppm) and K_2SO_4 (200 ppm) brought about significant improvement in pod yield by 8.1, 4.1 and 16.2%, respectively over control. Apparently, K_2SO_4 proved to be most effective.

Pooled data of Isabgol showed that grain yield of isabgol increased non-significantly with increasing salinity of irrigation water from 0.25 dS/m (BAW) to 4 dS/m. However, at 8 dS/m, significant reduction of 20.5 and 22.4% in grain yield was recorded as compared to BAW (7.87 q/ha) and 4 dS/m (8.07 q/ha). Among different foliar spray treatments, K_2SO_4 (200 ppm) produced significant improvement in grain yield of 21.5, 7.8 and 12.1 per cent over control, Ascorbic acid and benzyl adenine (200 ppm), respectively. Among different bio-regulators, K_2SO_4 proved to be the most effective particularly with increasing salinity of irrigation water.

Performance of wheat varieties under saline irrigation water through drip system

Results of the field experiment conducted to evaluate the performance of wheat varieties (Raj 3077, Raj 4188, KRL 210 and KRL 213) under drip using varying levels of salinity of irrigation water (BAW, 4, 8 and 12 dS/m) showed that salinity of irrigation water beyond 4 dS/m had significant effect on crop growth, yield attributes and yield of wheat varieties. The highest grain yield was recorded with BAW (29.47 q/ha), which was, however, at par with EC_{iw} 4 dS/m. As compared to BAW, EC_{iw} of 8 and 12 dS/m resulted in significant reduction of 14.1 and 32.6% in the grain yield, respectively. Wheat variety Raj 3077 established its superiority by a significant margin of 61.5, 17.0 and 24.3% over Raj 4188, KRL 210 and KRL 213, respectively. Raj 3077 produced significantly higher grain yield over other varieties at all level of saline irrigation.

Study on wheat under drip irrigation system to mitigate the adverse effect of saline water by seed soaking/foliar application of bio-regulators

Use of saline irrigation water of 8 and 12 dS/m resulted in significant reduction of 14.9 and 34.0% in grain yield, respectively as compared to BAW (33.18 q/ha). Among different seed soaking/foliar spray treatments, K_2SO_4 (200 ppm) brought about significant improvement in grain yield by a margin of 12.2, 7.3 and 9.4% over control, Ascorbic acid and benzyl adenine (200 ppm), respectively. All the growth and yield attributes improved significantly under the influence of different seed soaking/foliar spray treatments. Seed soaking/spray of K_2SO_4 resulted in less reduction in the grain yield of wheat at 8 and 12 dS/m levels of salinity of irrigation water as compared to other treatments of seed soaking/foliar sprays. It may be noted that reduction in the grain yield at 8 and 12 dS/m over control was 16.98 and 36.53 per cent, whereas respective reduction in the yield under the influence of K_2SO_4 was 11.57 and 14.05 per cent only. It is also important to note that K_2SO_4 treatment exhibited its superiority in respect of chlorophyll content at all levels of saline water irrigation.

Screening of mustard genotypes for salt tolerance under flood irrigation

Performance of twenty mustard genotypes was evaluated under saline water (EC_{iw} 10 dS/m). Significantly higher seed and stover yield was obtained under genotype L9 followed by L4, L8, L3, L12 and L18 over CH-1 whereas lower seed and stover yields were recorded with L11, L17, L10, L6, L15 and L14 than CH-1. The EC_e of soil after harvest of crop increased up to 0-45 cm depth.

During 2013-14, twelve mustard genotypes were evaluated. Significantly higher seed yield was obtained under genotype L9 followed by L10, L2, L3, L8, L5 and L1 over CH-1 whereas lower seed yields were recorded with L7, L6 and L4 than CH-1.

NPK drip fertigation with saline water irrigation for tomato under arid condition

A field experiment was conducted to evaluate the performance of tomato with varying saline water irrigation and fertigation levels. The crop was completely damaged due to frost injury in the first week of January 2014. However, crop recovered partially with foliar spray of 1 % glucose. The maximum fruit yield of tomato per plant was obtained with application of canal water (EC_{iw} 0.25 dS/m) which was significantly higher over EC_{iw} 4, 8 and 12 dS/m. Application of 125% RDF through fertigation produced maximum fruit yield, however, it remained at par with 75 and 100% RDF. Maximum soil salinity build-up after harvest of tomato was observed in surface layers with increasing levels of saline water irrigation and it decreased in subsurface soil layers.

GANGAWATI

Effect of micro irrigation techniques and fertilizer levels on root yield and quality of sugar beet under saline soils of TBP command

Sugar beet, being a short duration and less water requiring crop than sugarcane can fit well in the cropping system under saline soils. The results of the present study (*kharif* 2013) revealed that significantly higher root yield (49.17 t/ha), weight of ten beets (8.83 kg) and brix (23.67 %) was recorded with fertilizer level of 200-100-100 kg NPK/ha compared to 100-50-50 and 120-60-60 kg NPK/ha levels. The yield was however, at par with 175-75-75 kg NPK/ha.

A large scale demonstration (1 acre) on response of sugar beet to sowing dates under saline Vertisols of TBP command during *Kharif* 2013 revealed that higher root yield (42.25 t/ha), weight of ten beets (8.77 kg) and brix (21.33%) was recorded with sowing during 1st fortnight of August as compared to other dates of sowing.

Evaluation of controlled drainage system (CDS) in Vertisols of TBP irrigation command

Controlled drainage system (CDS) is a slight modification of the conventional SSD (50 m spacing) designed at Agricultural Research Station, Gangawati during 2012-13 and continued up to *Kharif* 2014. At crop harvest of *Kharif* 2014, the average soil salinity reduced from 7.02 to 2.5, 6.92 to 1.86 dS/m at 0-15 cm, 7.46 to 1.97, 8.73 to 4.52 at 15-30 cm and 7.61 to 3.7, 11.25 to 6.94 at 30-60 cm and 8.16 to 5.32, 12.73 to 6.62dS/m at 60-90 cm depth under conventional and controlled drainage systems respectively. Average of four seasons indicated that 13 cm to 34.1 cm of irrigation water was saved in controlled drainage as compared to conventional SSD system.

Conventional SSD system gave higher drainage discharge in all four season (3.85, 1.81, 1.4 and 1.61 mm/d) over the controlled drainage system. The removal of salts was nearly 1.93 vs. 0.56, 4.61 vs. 1.22, 3.64 vs. 1.16 and 3.85 vs. 1.06 t/ha through conventional and controlled system respectively. The mean loss of nitrogen (NO_3-N) over four season was more (11.20 kg/ha) under conventional as compared to controlled SSD (5.32 kg/ha).

Screening of forage grasses in salt affected soils of TBP command

Acute shortage of green fodder in the command can be overcome by growing perennial forage grasses in degraded and marginal land such as saline/alkali soils. Screening of forage grasses for saline soils was carried out with five forage grasses namely Hybrid napier (DHN 6), Guinea grass, Grazing guinea, Para and Rhodes grass. These forage grasses were grown in three rows along the soil salinity gradient with EC_e varying from <2 to 20 dS/m. The results over two years revealed that forage yield of Rhodes (26.7 t/ha), Para (28.8 t/ha) and Grazing guinea (28.3 t/ha) grass were higher at soil salinity of <4.0 dS/m. At soil salinity range of 4.0 – 8.0 dS/m there was <10% decrease in the forage yield of Rhodes, Para and Grazing guinea while 50% reduction in case of Guinea grass. Much higher reduction in forage yield of all the grasses was observed at EC_e 8-12, 12-16 and >16. Rhodes, Para and Grazing guinea grass can be successfully grown in a salinity range of EC_e 4-8 dS/m.

Response of cotton to drip irrigation in saline soils under conservation agricultural practices

Response of cotton to drip irrigation: A field study to optimize micro-irrigation for cotton in saline soils (6-8 dS/m) under conservation agriculture was initiated during 2011-12 and was continued up to 2013-14. Pooled over three years, seed cotton yield was significantly higher with drip irrigation at 1.2 ET (27.16 q/ha) followed by 1.0 ET (26.16 q/ha), 0.8 ET (24.15 q/ha) and least in furrow irrigation (21.04 q/ha). Significantly higher seed cotton yield (26.49 q/ha) was obtained with mulching as compared to without mulch (23.01 q/ha). Water use efficiency (productivity) was significantly higher in drip irrigation with 0.8 ET (0.78 kg/cubic m) followed by 1.0 ET (0.67 kg/cubic m), 1.2 ET (0.59 kg/cubic m) and least in furrow irrigation (0.38 kg/cubic m). Significantly higher water use efficiency (0.65 kg/cubic m) was obtained with mulching as compared to without mulch treatment (0.56 kg/cubic m). Pooled over three years (2011-12 to 2013-14), the water requirement in furrow was 44, 29.4 and 16.8% more that of 0.8, 1.0 and 1.2 ET treatments, respectively. Net returns (Rs. 29459) and B:C ratio (1.59) was significantly higher under mulch treatment as compared to without mulch treatment (Rs. 22422 and 1.49). Among irrigation levels net returns and BC ratio was significantly higher under 1.2 ET (Rs. 33245 and 1.67) as compared to other irrigation levels.

Response of cotton to fertigation: Results of the experiment initiated during *kharif* 2014 showed that 125% RDF produced significantly higher seed cotton yield (28.6 q/ha) as compared to 50% RDF (24.64 q/ha) and it was at par with 75% (27.34 q/ha) and 100% RDF (27.02 q/ha).

Assessment and mapping of salt affected soils of TBP command area of Karnataka

Unscientific land and water management and violation of cropping pattern over the years in TBP command has resulted in the twin problems of soil salinity and water logging. To start with, survey and soil sampling was carried out in Koppal district during April-May 2014. Soil sampling was carried out on a grid basis to a depth of 90 cm. A total of 230 soil samples were obtained from 59 sampling grid points in the district. The project work is in progress.

Evaluation of DSW as an amendment for reclamation of sodic soils of TBP command

Sodic soils are reported to occupy an area of more than 15000 ha in the Koppal, Bellary and Raichur districts of Northern Karnataka and over 28000 ha in Karnataka. Distillery spent wash (DSW) a by-product of alcohol industry is gaining importance in the reclamation of non-saline sodic soils as it is highly acidic and contains fairly good amount of Ca, Mg and other essential plant nutrients. Since, the application of distillery spent wash needs to be applied to a sodic soil at least two months prior to planting, field experimental layout and application of DSW supplied by M/s. Vijayanagar Sugars Pvt Ltd., Mundaragi (Tq: Gadag) as per the treatment (main-plot @1.0, 1.5, 2.0, 2.5 and 3.0 lakh lit/ha) was completed during May 2014. Prior to and one month after the application of DSW, soil samples from each plot were collected and are being analyzed. The experiment is in progress.

Evaluation of spacing and controlled subsurface drainage system on soil properties, water table, crop yield and nutrient loss in rice fields of TBP Command

The experiment was initiated at ARS, Gangawati and farmer's field. 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 installed at Agricultural Research Station, Gangawati during r*abi-summer* 2013-14. The mean soil salinity (EC_e) of 40 and 60 m experimental area were 7.69, 9.55, 9.17 and 8.42 dS/m 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.

The average drain discharge was 0.4, 2.4 and 1.85 mm/day under conventional and 0.1, 0.2 and 1.25 mm/day under controlled drainage systems at 40, 50 and 60 m spacing, respectively. The salinity of drainage effluent was 4.23, 3.05 and 4.8 dS/m under conventional and 3.92, 3.27 and 2.75 dS/m under controlled SSD while total salt removal was 0.25 vs. 0.11, 1.88 vs. 0.92 and 1.69 vs. 0.57 t/ha at 40, 50 and 60 m spacing under conventional and controlled SSD systems. Irrespective of spacing, higher drainage discharge lead to more salt removal under conventional SSD system.
A similar experiment with 40, 50 and 60 m spacing with a lateral depth of 1.0 m was initiated in an area of approx. 50 ha during *kharif* 2013-14 at Mallapur village. Mean soil pH and EC_e were 8.20 and 12.23 dS/m, 8.32 and 11.1 dS/m and 8.29 and 11.50 dS/m at 0-15, 15-30 and 30-60 cm, respectively.

The average drain discharge was 0.08, 0.074 and 0.13 mm/d at 40, 50 and 60 m spacing respectively during *kharif* 2013 with the corresponding 0.15, 0.15 and 0.31 mm/d in *rabi-summer* (2013-14) respectively. The average salinity of the drainage effluent was 12.3, 8.9 and 11.2 dS/m during *kharif* 2013 and 12.6, 10.7 and 8.7 dS/m during *rabi/summer* at 40, 50 and 60 m spacing, respectively. Total salt removal was 170, 47 and 117 kg/ha during *kharif* 2013 and 200, 61.3 and 104 kg/ha during *rabi/summer* at 40,50 and 60 m spacing, respectively. Paddy grain yields increased from initial 25-30 q/ha (Pre SSD), to 43.25 q/ha (40 m spacing) and 49.27 q/ha (60 m spacing) during *kharif* 2013 and 43.7 q/ha (40 m spacing) to 49.8 q/ha (60 m spacing) during *rabi* 2013-14.

Evaluation of subsurface drip irrigation on soil physico-chemical properties, growth and yield of salt tolerant sugarcane in saline Vertisols of TBP command

The experiment was initiated during summer 2013-14 with main plot treatments comprised of surface drip, subsurface drip and furrow irrigation (control) with sub-plot treatments of irrigation at IW/CPE ratios of 0.8, 1.0 and 1.2. Sugarcane salt tolerant variety viz., Co-91010 (Dhanush) was sown during Feb.2014 in paired row system. Nine observation wells were installed at each treatment to know the effect of methods of irrigation on water table. Soil samples were drawn before sowing for initial EC_e, pH and NPK contents. The soluble fertilisers were applied through venture as per the fertigation schedule. The experiment is in progress.

Effect of laser land levelling, micro-irrigation technique and conservation agriculture practices in direct seeded rice under saline Vertisols of TBP command

Exp.I: Effect of laser land levelling and conservation agriculture practices: The experiment was initiated during *kharif* 2013 at ARS, Gangawati. Significantly higher grain yield (45.97 q/ha) was obtained in puddled transplanted rice (PTR) followed by laser levelling in DSR with mulch (27.77 q/ha) and least with laser levelling in DSR without mulch (27.42 q/ha). Among ET levels, the paddy yield was significantly higher with 2.0 ET (44.42 q/ha) followed by 1.5 ET (33.28 q/ha) and least at 1.0 ET (23.46 q/ha). The lower grain yields under DSR as compared to PTR could partly be attributed to slightly higher soil salinity under DSR plots. The experiment will be continued during 2014-15.

Exp.II: Evaluation of alternative crops under different tillage methods for rice (DSR)-fallows in saline soils of TBP command: Evaluation of alternative crops for different tillage methods for rice (DSR)-fallows was initiated during *rabi/summer* 2013-14. Main plot treatments consisted of tillage (zero, minimum and conventional tillage) practices and sub-plots consisted of sorghum, sunflower and cluster bean crops. The results showed that, zero tillage recorded significantly higher grain yield of sorghum and sunflower (17.12 and 9.67 q/ha) as compared to minimum tillage (15.33 and 9.11 q/ha) and conventional tillage (12.99 and 7.93 q/ha), respectively. Grain yield of cluster bean under zero tillage was 7.45 q/ha but under crop failed to establish properly under minimum and conventional tillage method due to water stagnation.

Development of profitable Integrated Farming system (IFS) module for saline Vertisols of TBP command of Karnataka

This project was approved during June 2013. Selecetion of land, land leveling and preparation of bunds according to various components have been completed. 150 seedlings of drum stick were planted on the bunds. The survival was 50%. Amongst the cropping systems, only finger millet crop was taken up with a harvest of 480 kg in an area of 0.2 ha (22 q/ha). Under vegetables, beet root was taken up with a harvest of 400 kg in 0.05 ha (8 t/ha). Excavation of farm pond and set up of vermicompost unit have been completed. Under conventional cropping systems, rice followed by rice were taken up with paddy grain yield of 43.8 q/ha during *kharif 2013* and 35.0 q/ha during *rabi-summer* 2013-14.

HISAR

Survey and characterization of ground waters for irrigation

The survey and characterization of ground water for irrigation in Fatehabad district was undertaken during 2012-13. Analysis of 525 ground water samples showed that 47.2, 14.1, 2.3, 16.8, 5.1, 3.4, and 11.0% samples were in good, marginally saline, saline, high SAR saline, marginally alkali, alkali and high alkali categories, respectively.

In 2013-14, survey and characterization of ground water for irrigation in Sirsa district revealed that out of 646 ground water samples 29.1% were in good, 64.7% saline and 6.2% alkali category.

Strategies for conjunctive use of saline and canal water in cotton-wheat crop rotation

The data revealed that during 2012-2013 the highest seed cotton yield of 23.7 q/ha was recorded in all canal irrigation followed by 2CW:1SW cyclic irrigation. The lowest yield (15.93 q/ha) was obtained under all saline irrigated plots. A reduction of 32.8 and 25.0% was observed in all saline and 2SW:1CW irrigations, respectively as compared to canal irrigation. The irrigation water productivity (WP) was highest (1.32 kg/m^3) under canal and lowest (0.88 kg/m^3) under saline water irrigation. The initial EC_e in 0-15 cm ranged from 2.50 to 9.96 dS/m at sowing and 2.13 to 6.85 dS/m at harvesting.

The highest yield of wheat (47 q/ha) and lowest (29.43 q/ha) was obtained in all canal and all saline irrigations. The irrigation water productivity (WP) was highest (1.57 kg/m^3) under canal and lowest (0.98 kg/m^3) under saline water irrigation. Average EC_e of soil profile upto 120 cm before sowing varied from 2.34 to 5.82 dS/m and from 2.41 to 6.92 dS/m at harvesting of the crops. Similar results were also obtained during 2013-14.

Screening of elite varieties of crops irrigated with poor quality waters

During 2012-2013, tolerance of 7 genotypes of cotton, 14 genotypes of wheat, 7 genotype of pearl millet and 8 genotypes of mustard were evaluated under different saline water irrigation i.e. canal water and EC_{iw} of 2.5, 5.0 and 7.5 dS/m.

Genotype P-9007 performed best at highest saline water irrigation (7.5 dS/m) and gave 11.3 per cent higher yield as compared to KRL 210 (check). Pearl millet, variety HHB-234 performed best at highest saline water irrigation (7.5 dS/m), followed by HHB-226. Mustard genotype, under IVT-I (CSCN-12-2) gave the highest seed yield (318.2 g/m^2) followed by CSCN-11-3 (287.8 g/m^2) at EC_{iw} of 7.5 dS/m. The mean soil EC_e at sowing varied from 2.12 to 10.61 dS/m in canal water to highest salinity water irrigation.

During 2013-2014, tolerance of 7 genotypes of cotton, 14 genotypes of wheat, 7 genotype of pearl millet and 14 genotypes of mustard were evaluated under different saline water irrigations.

Average seed cotton yield of (256.4 g/m^2) obtained in Bunty 2113 was significantly higher than other genotypes followed by Boiseed-6588 (221.7 g/m^2). Average soil EC_e upto 60 cm varied from 3.30 to 9.94 dS/m. Wheat genotype P-9012 performed best at highest saline water irrigation (7.5 dS/m) and gave 40.8% higher yield as compared to KRL 210 (check). Pearl millet, variety HHB-234 performed best at the highest saline water irrigation (7.5 dS/m), followed by HHB-226. The mean yield (349.5 g/m^2) of HHB-226 was higher than other genotypes followed by HHB-223 (343.6 g/m^2) and HHB-234 (326.1 g/m^2). Among IVT, genotypes CSCN-13-8 gave the highest seed yield (235.5 g/m^2) followed by CSCN-13-3 (225.9g/m^2) at EC_{iw} of 7.5 dS/m. Avegare soil salinity (0-45 cm) at sowing varied from 1.64 to 10.22 dS/m.

Integrated nutrient management in wheat and pearl millet under saline and fresh water irrigation

The results revealed that mean reduction in grain yield of wheat under saline water (EC 8 dS/m) irrigation was 16.3 per cent as compared to canal water irrigation. Inoculation (*Azotobacter* & *Pseudomonas* 36) + Vermicompost @ 5 t/ha increased the grain yield by 6.13 per cent over control. The grain yield of pearl millet decreased in saline water irrigation as compared to control. The mean reduction in grain yield was 11.7 per cent as compared to canal water. Inoculation (*Azotobacter* &*Pseudomonas* 36) + Vermicompost @ 5 t/ha increased the grain yield by 5.4 per cent over control (without inoculation).

Salt and water dynamics in soil under drip irrigation system on vegetable crops

The study was conducted to investigate the effect of frequency and salinity levels of irrigation water on cole crop (brocolli). In canal water irrigation (0.5 dS/m), the soil moisture content was not affected with the time in the upper layers but in lower layers it was depleted slightly with time. With increasing salinity, the depletion of moisture decreased. This indicates that the increase in osmotic stress restricted the water and nutrient availability to the crop resulting in less depletion of moisture content. In saline water irrigation (7.5 dS/m), the steep increase in EC was observed in the root zone with time. In daily drip irrigation, the relative yields of broccoli were 102.1, 92.1 and 78.2 per cent when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to canal water irrigation. In alternate day drip irrigation, the relative yields of broccoli obtained were 101.6, 87.6 and 83.3 per cent when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to canal irrigation. On comparing drip irrigation frequency treatments, 6.3, 6.8, 9.4 and 11.2% higher crop yield was observed in daily irrigation as compared to alternate day irrigation. This indicates that increase in irrigation frequency can manage saline water in a better way. Similar results was also obtained in okra grown under saline water irrigation.

To optimize the zinc requirement of wheat crop irrigated with sodic water

The study on Zn requirement of wheat irrigated with sodic water in relation to different gypsum (0, 25, 50, 75 and 100% neutralization of RSC) and zinc levels (0, 25, and 50 kg/ha) was conducted at Village Bhurjat, district Mahendergarh during 2012-13 and 2013-14. Significantly higher yield was observed with increasing levels of gypsum as compared to control. The mean yield increased by 41.2, 104.5, 145.7 and 202.0% in G25, G50, G75 and G100 treatments, respectively, as compared to control, irrigated with sodic water having RSC 13.8 meq/l. The application of $ZnSO_4.7H_2O$ @ 25, 50 and 75 kg/ha resulted in 11.1, 19.6 and 24.3% increase in yield, respectively, as compared to control.

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

The grain yield of wheat (WH 711) decreased by 4.0 and 8.1 per cent in all saline water irrigation (EC 8 and 10 dS/m) as compared to control. Reduction in grain yield of wheat (WH 711) by 15.6, 8.4 and 4.1 per cent was observed under sewage sludge (SS) 5t/ha, SS 5t/ha + 50% RDF and SS 5 t/ha + 75% RDF as compared to 100% RDF.

INDORE

Survey and characterization of ground water for irrigation and soil salinity associated problems

Survey of the ground waters in Hoshangabad district was conducted during 2011-12 & 2012-13. Out of 445 samples collected, 425 (95.5%) were under good category, 16 (3.6%) marginally saline, 01 (0.2%) saline, high SAR saline and 02 (0.5%) under marginally alkali category.

Ground water survey of Dhar district was conducted during 2013-14. Out of 233 ground water samples 216 (92.7%) were under good, 14 (6.01%) marginally saline, 01 (0.43%) saline, alkali and highly alkali categories each.

Characterization and delineation of salt affected soils

The soil survey of Hoshangabad and Dhar districts was carried out using remote sensing data of two different seasons to identify saline/alkali soils. The villages with such soils were identified and area estimated as 2054 and 9208 ha in Hoshangabad and Dhar districts respectively. The maps of salt affected soils of the districts were prepared using Remote Sensing and GIS techniques.

Effect of long-term application of organic/green manures in sodic Vertisols

The experiment was initiated in 2005-06 to observe the effect of green manuring on soil properties and crop yield in alkali soil. The highest yield of paddy (2.28 and 2.03 t/ha) and wheat (3.18 and 2.73 t/ha) was recorded at soil ESP 25 during 2012-13 and 2013-14, respectively. Among various treatments incorporation of *dhaincha* produced the highest yield of crops.

Effect of methods of irrigation water quality on performance of fruit trees in a sodic environment

Effect of irrigation methods and quality of irrigation water on performance of fruit plants was studied in sodic black soils. The highest yield of ber (64.81 q/ha) and sapota (10.19 q/ha) was recorded in embedded pipe irrigation method with diluted spent wash water followed by drip irrigation. The fruit yield of ber increased by 94.4 and 77.8% in diluted spent wash water applied through embedded pipe and drip irrigation methods over check basin method, respectively. Similarly, sapota yield increment was 83.3 and 44.4% over check basin method of irrigation.

Assessing pre and post canal irrigation effect on soil, water and crops in Vertisols of Narmada Sagar Command

Degradation of soil physical and chemical environment is a serious problem in command areas of the country. Irrigation in Narmada Sagar command has yet to start in a year or two after completion of canal network. To build-up data base on physico-chemical properties, ground water fluctuation, crop productivity and hydrologic characteristics for comparison in future. The pre and post monsoon water levels in open wells were in 2005 and 2012 in the head reach of the ISC canal ranged from 2.50 to 5.1 m and 0 to 4.9.

Developing multi-enterprise farming system for sodic Vertisols

During year 2010 various farming system viz. raise and sunken bed (RS), sole crop, agro-horticulture, agro-forestry were developed. Under RS system on cotton raised bed and paddy in sunken beds were grown. Ber and sapota fruit plant along with tomato and brinjal vegetable crops were grown in agro-horticulture system, Similarly, Neem (*Azadirachta indica*), and Babool (*Accacia nilotica*) were planted under agro-forestry system.

The average percolation losses through water harvesting tank of 1890 m^3 during dry spell of 23 days were observed around 17.0 mm/ day. The stored water could manage to deliver 2335 mm depth of water for irrigating 1.58 ha. The yields of cotton (18.05 and 11.67 q/ha) and paddy (23.33 and 36.66 q/ha) under raised and sunken bed farming were recorded. Cotton yield obtained in sole crop farming system was 18.00 and 13.67 q/ha during 2012 and 2013 respectively, However, grain yield of wheat under sole crop was 50.88 and 48.22 q/ha. Similarly, yields of tomato, brinjal and cabbage crops under agro-horticulture farming system were 13.38, 18.55 and 97.19 q/ha respectively during 2012-13 and yields of cabbage and cauliflower were 81.48 and 67.59 q/ha respectively during 2013-14.

Relative efficacy of distillery and sugar industry waste on reclamation and crop production in sodic Vertisols

The results of the experiment initiated during 2011-12 showed that application of Lagoon sludge (LS) @5 t/ha + Raw Spent Wash (RSW) @ 2.5 lakh L/ha significantly increased the grain and straw yield of rice and wheat as compared to gypsum @ 75% GR as well as LS @ 10 t/ha and PM @ 5 t/ha application. Highest grain yield of paddy (2.78 and 2.34 t/ha) and wheat (3.65 and 3.75 t/ha) was recorded in case of LS 5 t/ha + RSW @ 2.5 lakh L/ha application, respectively during 2012-13 and 2013-14. ESP of post harvest soil reduced significantly with the application of different amendments.

Screening of vegetable crops for sodicity tolerance under sodic black clay soils

The experiment on screening of vegetable crops for sodicity tolerance under sodic black clay soils was initiated during *rabi* 2011-12. The survival percentage and yield of vegetable crops decreased with increasing levels of ESP. During 2012-13, the maximum survival per cent and yield was observed in brinjal followed by cauliflower. The survival percentage of tomato and bitter gourd was less than 50% at ESP 35, whereas the survival percentage of brinjal was more than 50% even at ESP 55. However, during 2013-14, highest yield was recorded in case of cabbage (15.70 t/ha) followed by brinjal (10.50 t/ha) and cauliflower (9.80 t/ha) at ESP 25. The survival percentage of cabbage and cauliflower was <50% at ESP 45, but the survival percentage of brinjal continued to be >50% even at ESP 55 as recorded in 2012-13.

ORP on Effect of gypsum and spent wash application on crop production and soil chemical environment on farmer's fields

During 2012-13, addition of Raw Spent Wash @ 5 lakh L/ha increased the seed yield of soybean by 85 per cent over control. The ESP decreased with application of amendments, however, lowest ESP was found with the addition of Raw Spent Wash @ 5 lakh L/ha. Similarly during 2013-14, application of Raw Spent Wash @ 5 lakh L/ha increased seed and straw yield of wheat by 93.9 and 88.5% over control. The reduction in ESP was noticed in case of Raw Spent Wash @ 5.0 lakh L/ha from 38.4 to 22.8 as compared to control.

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

The experiment was initiated in *rabi* 2013-14. The minimum water expense was obtained 34 cm in case of sprinkler irrigation with irrigation depth of 2 cm followed by 36 cm in SI with irrigation depth 3 cm. The highest yield of 21.46 q/ha and lowest yield of 13.57 q/ha was obtained in case of SI with irrigation depth 3 cm and surface irrigatyion with COD 65% respectively. Similar trend was obtained for water productivity with 59.6 and 33.9 kg/ha-cm.

KANPUR

Survey and Characterization of ground water for irrigation

The ground water survey of Kannauj district was conducted. Out of 291 samples, 258 (88.66%) were under good, 30 (10.31%) marginally saline, 01 (0.34%) saline, 01 (0.34%) highly saline and 01 (0.34%) marginally alkali categories.

Efficacy of phosphogypsum as an amendment for alkali soils

The average grain yield of rice and wheat varied from 29.45-40.00 and 25.73-36.41 q/ha, respectively. Highest yield of both crops 40.00 and 36.41 q/ha were obtained under 15 cm phosphogypsum bed. Lowest grain yield of both crops recorded in plots treated with RSCW alone. The chemical properties of soil pH, EC, ESP and OC showed considerable improvement under amended water passed through gypsum/phosphogypsum bed. Dissolution of gypsum and phosphogypsum reduced soil pH to 8.26 and 8.18 respectively.

Effect of management practices on resodification of reclaimed sodic lands at benchmark sites on farmer's field

The average yield of paddy at farmer's field varied from 21.14 to 41.71 q/ha under partially reclaimed sodic soil. During *rabi* the yield of wheat (PBW 343) ranged from 21.26 to 37.49 q/ha. The physico-chemical properties of selected farmer's fields revealed that pH, EC, OC, and ESP ranged from 8.8-9.4, 2.2-2.5 dS/m, 0.1-1.5 %, and 40.0-55.1, respectively upto 0-15 cm depth.

Evaluation of resource conservation technology for rice-wheat cropping system under reclaimed sodic soils

The average yield of rice and wheat ranged from 34.24 to 40.74 and 26.16 to 33.27 q/ha, respectively. The highest response was noticed in conventional rice transplanting after *Sesbania* green manuring/wheat in zero tillage followed by conventional rice transplanting after WRI (wheat residue incorporation)/conventional wheat sowing after RRI (rice residue incorporation). Minimum yield of rice 34.24 q/ha and wheat 26.16 q/ha was obtained in DSR in zero tillage/wheat in zero tillage.

The minimum soil pH (8.51) was found in conventional rice transplanting after WRI (wheat residue incorporation)/conventional wheat sowing after RRI (rice residue incorporation) followed by 8.53 in conservational rice transplanting after *Sesbania* green manuring/wheat in zero tillage. The maximum reduction in ESP from 45.2 to 35.2 was noticed in conservational rice transplanting after *Sesbania* green manuring/wheat in zero tillage. Organic carbon content varied from 0.17-0.33% under different resource conservation technologies.

Integrated response of fly ash, gypsum and organic manures to sustain the production of rice and wheat in partially reclaimed sodic soil

The average grain yield of rice and wheat varied from 17.73-40.24 q/ha and 13.96-31.85 q/ha, respectively. The highest grain yield of paddy (40.24 q/ha) and wheat (31.85 q/ha) was recorded underv fly ash @ 20 t/ha + gypsum @50% GR + GM @ 10 t/ha. The responses of various levels of fly ash in conjunction with different doses of gypsum and green manure showed comparably higher performance in comparision to alone application at each levels. The maximum reduction in soil pH was noticed with fly ash along with green manure and gypsum in comparison to flyash alone. The minimum pH 8.70 was recorded with fly ash @ 20t/ha + gypsum 50% GR + GM @ 10 t/ha followed by application of 100% gypsum alone (8.81). The variation in EC ranged from 1.72 to 1.99 dS/m. Highest organic carbon content (0.31%) was observed under fly ash @ 20t/ha + gypsum@ 50% GR + GM @ 10 t/ha.

Effect of RSC water, using different ameliorants on crop production and soil health of partially reclaimed sodic soil

The highest grain yield of rice (42.38 q/ha) and wheat (38.80 q/ha) was obtained with phosphogypsum followed by gypsum, pyrites and press mud. The percentage response of various ameliorants on grain yield of rice (CSR 36) were phosphogypsum (93.96) > gypsum (81.86) > pyrite (62.70) > press mud (44.58) and for wheat (KRL 210) were phosphogypsum (114.72) > gypsum (98.73) > pyrite (78.20) > press mud (52.08) respectively, over RSC water treated plots.

Demonstration of salt tolerant varieties of mustard at farmer's fields

The results obtained from various demonstrations of mustard conducted at farmer's fields revealed that the grain yield of CS 52, CS 54 and CS 56 varied from 8.44 to 8.92, 10.85 to 11.17 and 12.10 to12.35 q/ha with average of 8.68, 11.01 and 12.23 q/ha, respectively.

Demonstration of salt tolerant varieties of wheat at farmer's fields

The grain yield of KRL 213 and KRL 210 varied from 28.60 to 30.20 q/ha and 27.54 to 29.12 q/ha. These salt tolerant varieties produced 26.66 and 21.78% higher grain yield over LOK 1 and 16.36 and 11.87% over PBW 343 as check sown by farmers, respectively. KRL 213 showed its superiority over KRL 210 under at the same agronomical practices.

Performance of mustard varieties under alkali conditions
18 varieties with two check and 10 varieties with two check of Indian mustard were tested for their salt tolerance at ESP 50.0 and 52.2 respectively. The seed yield of varied from 320.6 g/plot (CSCN10-09) to 552.1 g/plot (CSCN10-14) and 0997.64 g/plot (L 9) to 1269.42 g/plot (check-1) during 2012-13 and 2013-14, respectively.

TIRUCHIRAPPALLI

Survey and characterization of ground water for irrigation
Ground water quality survey of Thanjavur and Thiruvarur districts were completed. In all 412 water samples from Thanjavur distict and 161 water samples from Thiruvarur district were collected. In Thanjavur out of 412 samples 84.5% are good, 2.04% marginally saline, 8.7% marginally alkali, 4.1% alkali, 0.44% saline and 0.22% high SAR saline category. In Thiruvarur, out of 161 samples 83.2% are good, 9.93% marginally saline, 3.72% marginally alkali, 1.24% alkali, 0.62% high SAR saline and 1.24% highly alkali category.

Conjunctive use of canal and alkali water in rice based cropping system
Results revealed that canal water irrigation gave high yields (6.23 and 6.30 t/ha) Lowest grain and straw yields were recorded for alkali water irrigation (4.45 and 4.31 t/ha grain and 5.26 and 5.34 t/ha straw yields) during 2012 and 2013. Among methods of planting, square planting registered high grain yield (5.85 and 5.90 t/ha) during 2012 and 2013 followed by line planting and machine planting. Among the different vegetables grown, brinjal registered the higher yield of 16.8 t/ha by canal water irrigation with maximum income of Rs. 3.024 lakhs/ha. Performance of vegetable under cyclic irrigation with 1CW:1AW showed that brinjal registered highest income of Rs. 2.592 lakhs /ha followed by okra (Rs. 0.879 lakhs/ha). Among the vegetables tried, okra registered the highest yield of 6.83 t/ha in canal water irrigation. It also recorded the highest income of Rs. 1.866 lakh/ha.

Identifying suitable pressurized irrigation methods for vegetable crops in sodic soils
Field experiments were conducted during 2012-13 and 2013-14 to identify suitable pressurized irrigation methods for vegetable crops under sodic environment. Drip irrigation was found superior in increasing the yield of vegetable crops as compared to sprinkler and flood irrigation. The maximum yield of okra under drip irrigation was 52.16 and 48.16 q/ha and the yield increase over flood irrigation was 82% and 58% during 2012-13 and 2013-14 respectively.

Integrated farming system (IFS) suitable for problem soil areas of Tamil Nadu
This experiment was conducted during 2012-13 and 2013-14 to compare the conventional cropping system and integrated farming system in terms of income and profitability in sodic soils. An overall profit of Rs. 115328 and 73097 was obtained from all three components of IFS program, maximum being from fisheries and poultry components. In comparison with a pure crop program for 0.40 ha, the IFS program (0.30 ha for crop and 0.10 ha for poultry and fisheries) yielded high net returns and BC ratio of 3.01 and 2.41 during 2012-13 and 2013-14, respectively.

Evaluation of different crops for their tolerance to sodicity levels
The results revealed that amongst the different ESP levels tested during 2012-13 and 2013-14, the cotton hybrid RCH-20 recorded a maximum seed cotton yield of 21.64 q/ha and 29.54 q/ha and the variety SVPR-2 recorded the lowest seed cotton yield. In general, irrespective of the variety and hybrids tested under different ESP levels the seed cotton yield decreased with increasing ESP levels. The post

harvest soil analysis showed that soil pH increased with increasing ESP. However, there is not much difference in build-up of soil salinity at harvest as compared to initial soil EC during both the years of study.

Studies on the long-term effects of sewage irrigation on soil and crops

In order to assess the long-term metal accumulation in sewage water irrigated fields, OFT experiments were initiated at farmer's fields using rice as the test crop. The result showed that rice grain yield was higher in sewage irrigated fields than bore well irrigated fields. The increase in yield might be due to the addition of nutrients through sewage water compared to bore well water. The sewage water samples analysed showed that heavy metals Pb, Cd, Cr and Ni concentrations are below the critical limits prescribed by Indian standards(2000), WHO/FAO standards (1993) and European Union standards (EUS, 2002). It indicates that the sewage water can be safely used for irrigating the field crops without any metal contamination to the soil or crop.

Long-term effects of distillery effluent on soil properties and yield of sugarcane

Long-term field experiment was initiated during 2002 at EID Parry (I) Ltd., cane farm, Edayanvelli to evaluate the long-term effect of pre-plant application of PME along with different combinations of N, P and K on soil physico-chemical properties, fertility status, exchangeable cations, and cane yield. The results revealed that yield of sugarcane increased progressively with the application of increasing doses of PME. An increased cane yield of 23.2, 33.6, 44.8 and 52.5% during 2013 and 27.03, 41.09, 51.56 and 60.16% during 2014 were recorded in 1.25, 2.5, 3.75 and 5.0 lakh L/ha as compared to control.

To study the long-term effect of application of TDE through irrigation water, an experiment was conducted with the same layout as 11^{th} and 12^{th} crop of long-term experiment which is in progress since 2002. The TDE was discharged @ 1.00, 0.50, 0.33, 0.25 and 0.20 lakh L/ha to get the dilutions of 1: 10, 1:20, 1:30, 1:40 and 1:50, respectively. It was applied four times at 40 days interval starting from 45^{th} day after planting. The results revealed that sugarcane responded positively to the application of PME at different ratios along with irrigation water (4 times per year) consecutively for twelve years. The highest cane yield was recorded at 1:10 dilution. However, the increase in cane yield was significant up to 1:20 dilution in sandy loam soil. An increase 40, 35, 28.8, 20 and 10% during 2013 and 42.1, 36.8, 27.6, 17.1 and 9.2% during 2014 were recorded in the dilutions of 1:10, 1:20, 1:30, 1:40 and 1:50 respectively over control.

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 centers 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 centers. In the Sixth Five Year Plan, four centers namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water Management and Soil Salinity were transferred to this Project whereas the Nagpur Center was dissociated. As the mandate of the Kanpur and Indore centers 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 centers located at Dharwad and Jobner were shifted to Gangawati (w.e.f. 1.4.1989) and 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 centers at Hisar and Tiruchirapalli were added. These Centers started functioning from 1st January 1995 and 1997 respectively. Further, four new Volunteer Centres has been added to this AICRP in 2014. During the Eleventh Plan, the project continued with the same centers with an outlay of Rs 2125.15 lakhs. During XIIth Plan, Project continued with an outlay of Rs 4638.67 lakhs with ICAR Share of Rs 3675.00 lakhs at the following centers with the Coordinating Unit at ICAR-Central Soil Salinity Research Institute, Karnal.

Cooperating Centres with Addresses

1. Raja Balwant Singh College, Bichpuri, Agra (Uttar Pradesh)
2. Regional Research Station, Acharya N.G. 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 Agril. College and Research Institute, Tamil Nadu 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)

However, with the establishment of Agricultural Universities at Gwalior in Madhya Pradesh and Raichur in Karnataka, the administrative control of the centres at Indore and Gangawati has been transferred to these respective universities.

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
- Resodification of reclaimed alkali lands and comparative performance of various amendments
- Dry land reclamation technologies
- Land drainage of waterlogged saline lands for cost minimization
- Conservation agriculture/multi-enterprise agriculture/ multiple use of water
- Alternate land management including cultivation of unconventional petro-plants, medicinal, aromatic and plants of industrial application

Finance

The Twelfth Five Year Plan (2012–2017) was sanctioned by the Council vide letter No. NRM-24-4/2013-I-II dated 28-02-2014 with an outlay of Rs 4638.67 lakhs (ICAR Share Rs 3675.00 lakh). The budget head and center wise statement of expenditure for 2012-13 and 2013–14 is given in the annexure 6.

AGRA: RESEARCH ACCOMPLISHMENTS

Survey and characterization of ground water for irrigation

The ground water survey of Agra district was conducted during 1975-79 and was initiated again in 2012 to assess the changes during the period. Seven blocks viz Fatehpur Sikri, Akola, Achhnera, Bichpuri, Jagner, Sainya and Kheragarh were surveyed. A total of 366 samples were collected during December to March and analyzed for different water constituents viz., pH, EC, cations (Ca, Mg, Na and K) and anions (CO_3, HCO_3, Cl and SO_4), SAR and RSC. Classification of water quality was done on the basis of EC, SAR and RSC values as per AICRP guidelines.

The range of EC, pH, SAR and RSC presented in Table 1 revealed that EC, RSC and SAR ranges between 2.10 to 26.3 dS/m, nil - 13.8 meq/l and 1.4 - 55.1 $(mmol/l)^{1/2}$ in Fatehpur Sikri block, 2.0 - 19.5 dS/m, nil - 28.2 meq/l and 7.5 - 38.6 $(mmol/l)^{1/2}$ in Akola, 1.9 - 25.4 dS/m , nil - 9.4 meq/l and 5.2 - 52.4 $(mmol/l)^{1/2}$ in Achnera block, 1.7 - 23.2 dS/m, nil - 9.1 meq/l and 6.5 - 37.9 $(mmol/l)^{1/2}$ in Bichpuri, 0.7-11.2 dS/m, nil - 17.4 meq/l and 1.0 - 39.2 $(mmol/l)^{1/2}$ in Jagner, 0.60 to 13.9 dS/m, nil - 13.2 meq/l and 1.6 - 15.6 $(mmol/l)^{1/2}$ in Sainya and 0.80 - 12.0 dS/m, nil - 12.2 meq/l and 2.5 - 31.3 $(mmol/l)^{1/2}$ in Kheragarh block of Agra district.

The distribution of water samples for EC, SAR and RSC revealed that no water sample had EC class <1.5 dS/m in Fatehpur Sikri, Akola and Achhnera blocks while 34, 16.7 and 11.9 per cent samples were found in Jagner, Sainya and Kheragarh blocks respectively (Table 2). The maximum samples fell in the range of 3 - 10 dS/m, while 15 - 27 per cent samples in Fatehpur Sikri, Akola, Achhnera and Bichpuri came under >10.0 meq/l EC range. RSC of water samples revealed that maximum (40-80%) samples showed nil RSC. In Fatehpur Sikri, Akola, Jagner, Sainya and Kheragarh block, the RSC >10 meq/l was recorded. The SAR in majority of water samples were in 10-20 and 20-30 $(mmol/l)^{1/2}$ classes in Fatehpur Sikri, Akola, Achhnera and Sainya blocks. However, SAR >40 $(mmol/l)^{1/2}$ was found in Fatehpur Sikri and Achhnera blocks to a very limited extent only (Table 2).

Table 1: Minimum and maximum values of different water constituents

Blocks	EC (dS/m)		pH		RSC (meq/l)		SAR $(mmol/l)^{1/2}$	
	Range	Mean	Range	Mean	Range	Mean*	Range	Mean
Fatehpur Sikri	2.1-26	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	7.538.6	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-17.4	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

**Mean RSC of the positive values*

Nitrate: The nitrate was detected only in 15 per cent samples of Fatehpur Sikri block and equally found in 0-2.5 and 2.5-5.0 meq/l classes, respectively (Table 3). No nitrate was observed in Jagner, Kheragarh and Sainya blocks.

Table 2: Frequency distribution of wayet samples in EC_{iw}, RSC and SAR classes of Agra district

Particulars	Fatehpur Sikri (60)	Akola (40)	Achhnera (58)	Bichpuri (45)	Jagner (50)	Sainya (54	Kheragarh (59)
EC_{iw} Classes (dS/m)							
0-1.5	-	-	-	-	34.0	16.7	11.9
1.5-3.0	3.33	25.0	25.9	24.40	36.0	35.2	37.3
3.0-5.0	30.00	22.5	24.1	22.22	20.0	22.2	27.1
5.0-10.0	46.67	37.5	32.8	26.67	6.0	16.7	15.2
>10.0	20.00	15.0	17.2	26.67	4.0	9.2	8.5
RSC Classes (meq/l)							
Absent	80.0	60.0	65.5	75.55	40.0	51.8	55.9
0-2.5	5.00	15.0	19.0	13.33	26.0	18.5	10.2
2.5-5.0	3.33	10.0	10.3	6.67	10.0	13.0	11.9
5.0-10.0	8.33	10.0	5.2	4.44	14.0	14.8	20.3
>10.0	3.33	5.0	-	-	10.0	1.9	1.7
SAR Classes $(mmol/l)^{1/2}$							
0-10	10.00	10.0	13.8	42.2	70.0	42.6	49.1
10-20	46.67	60.0	51.7	35.5	24.0	57.4	45.8
20-30	23.33	22.5	27.6	20.0	4.0	--	3.4
30-40	18.33	7.5	5.2	2.2	2.0	--	1.7
>40	1.67	-	1.7	-	--	--	--

Table 3: Fluoride and nitrate in water of different blocks of Agra district

Particulars	Fatehpur Sikri (60)	Akola (40)	Achhnera (58)	Bichpuri (45)
Fluoride concentration (ppm)				
0-2.5	95.0	90.0	94.8	100.0
2.5-5.0	5.0	10.0	5.2	-
5.0-7.5	-	-	-	-
7.5-10.0	-	-	-	-
>10.0	-	-	-	-
Nitrate concentration (meq/l)*				
0-2.5	50.0	-	-	-
2.5-5.0	50.0	-	-	-
5.0-7.5	-	-	-	-
7.5-10.0	-	-	-	-
>10.0	-	-	-	-

**only 15% samples (9) contained nitrate out of 60 samples*

The cationic and anionic order was same in all seven blocks being Na>Mg>Ca>K and $Cl>SO_4>HCO_3>CO_3$. Majority of samples contain Na and Cl as dominant ions.

The distribution of water samples in different water quality classes (Table 4) revealed that about 40-80% samples came under high SAR saline category in all blocks except Jagner, whereas 5-10% marginally saline and 6-19% under high alkali category. In Bichpuri, Jagner, Sainya and Kheragarh blocks few samples are of good quality water.

Table 4: Distribution of water samples in different water quality ratings in Agra district

Blocks	No. of Samples	Good	Marginally Saline	Saline	High SAR Saline	Marginally Alkali	Alkali	High Alkali
Fatehpur Sikri	60	-	6.67	3.37	80.0	-	-	10.0
Akola	40	-	5.0	-	80.0	-	2.5	12.5
Achhnera	58	-	10.34	1.72	79.31	-	-	8.62
Bichpuri	45	4.44	8.89	-	80.0	-	-	6.67
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

Comparing the water quality for the years 2012-14 with that of 35 years before, it can be observed that the good quality water have reduced in all the blocks sharply except Jagner and Sainya blocks. The majority of samples fall in high SAR saline water quality during both surveys except Jagner and Sainya block. High SAR saline water has increased in other five blocks (Table 5). The saline water quality (marginally saline and saline) decreased in Fatehpur Sikri, Bichpuri, Jagner, Sainya and Kheragarh with slight increase in alkali water whereas no change in water quality was observed in three blocks i.e. Jagner, Sainya and Kheragarh even after three decades.

Table 5: 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	Highly 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

Based on area wise distribution of different water quality classes in the seven blocks, water quality map has been prepared for Agra district showing that water quality is a big issue for agriculture in the district (Fig. 1).

Impact of Agra canal on ground water quality, soil properties and crop performance

Yields of cereals, pulses and vegetable crops were recorded at different locations irrigated with Agra canal and ground water i.e. Palwal (Haryana), Kosi (Mathura, U.P), Goverdhan (Mathura, U.P.) and Bichpuri (Agra). The data were analyzed for cost of cultivation, net profit (Rs/ha) and benefit:cost ratio (B:C ratio). The farmers of Palwal area are growing wheat, rice, pearl millet, sorghum (fodder), mustard, berseem (fodder), moong, radish, potato, brinjal, cauliflower, cabbage, chilli etc. Data given in Table 6 clearly indicates that mustard crop irrigated with Agra canal water gave highest B:C ratio as compared with ground water irrigated crop. Further Table 6 showed that all cereal crops gave maximum net profit and B: C ratio as compared to ground water irrigated crops. Other vegetable crops also gave maximum net return and B: C ratio grown with Agra canal water as compared to ground water irrigated fields.

The farmers of Kosi area are growing mostly cereal crops i.e. wheat, rice, pearl millet, sorghum (fodder), berseem (fodder), moong, cotton, dhaincha, barley and oats. Some farmers also grow vegetables but for their own consumption using ground water for irrigation. The results show that all cereal crops gave highest net return and B:C ratio with Agra canal as compared to ground water irrigation (Table 7). Similar results for Goverdhan area and Bichpuri area are shown in Table 8 and 9 showing similar results for these two sites.

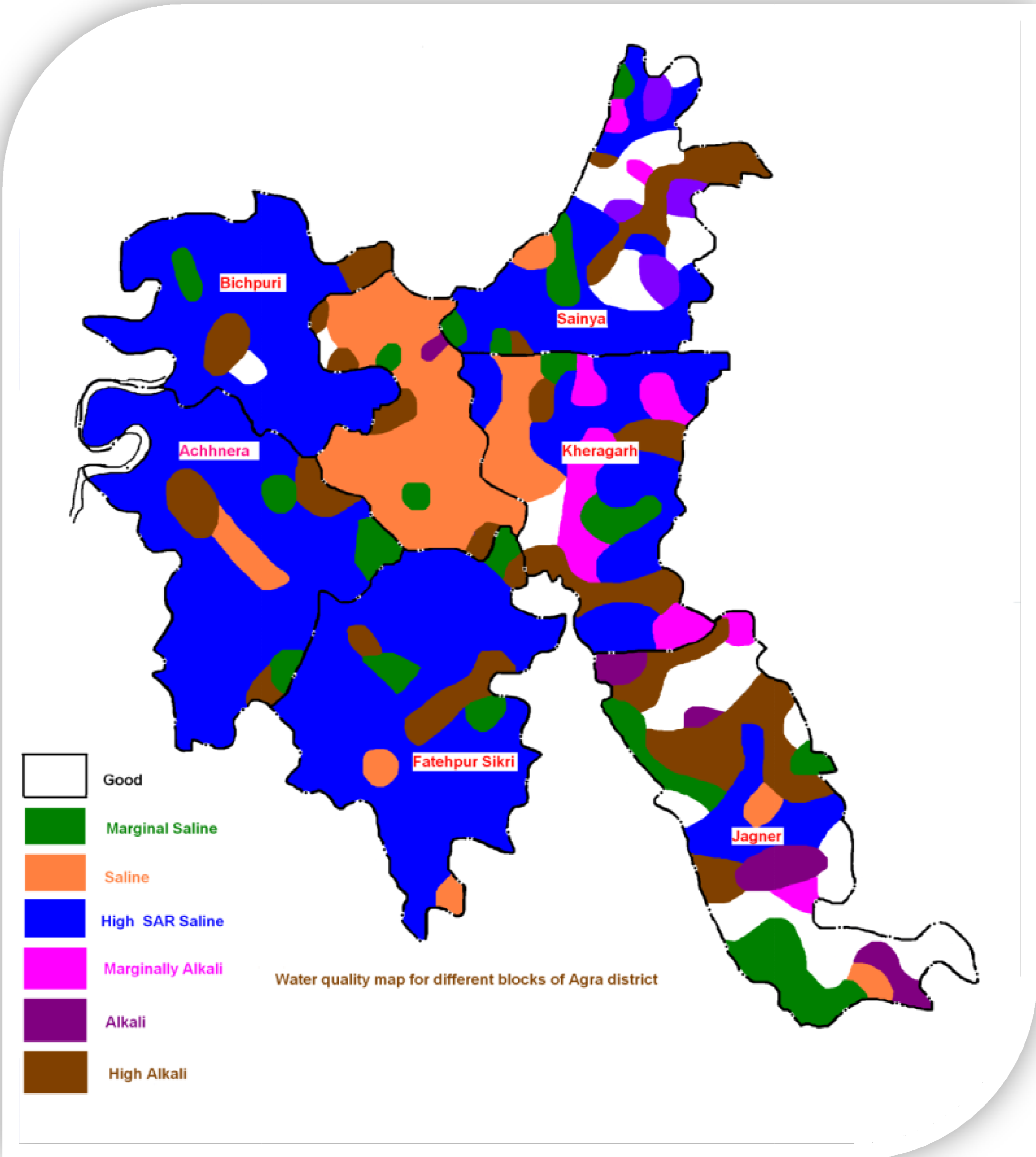


Fig. 1: Water quality map of Agra district

Table 6: Yield and net profit of crops grown with Agra canal and ground water (Palwal, Haryana)

Crops	Crops irrigated with Agra canal water				Crops irrigated with ground water			
	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net profit (Rs/ha)	B:C ratio	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Wheat	52.0	20,915	63,800	3.05	45.0	23,915	48,335	2.02
Rice	65.0	35,455	77,465	2.18	55.0	37,455	58,245	1.56
Pearl millet	24.0	12,475	13,625	1.09	20.0	14,475	7,025	0.49
Sorghum(F)	150.0	10,385	12,115	1.17	120.0	12,385	5,615	0.45
Mustard	24.0	15,605	61,195	3.92	18.0	17,605	39,995	2.27
Berseem(F)	125.0	11,820	13,180	1.12	100.0	13,820	6,180	0.45
Moong	14.0	14,070	27,280	1.85	10.0	17,070	12,930	0.76
Barley	35.0	19,355	27,895	1.44	30.0	21,355	19,145	0.90
Vegetables								
Radish	185.0	15,230	64,750	4.25	160.0	17,230	38,770	2.25
Potato	360.0	47,135	96,865	2.05	320.0	51,135	76,865	1.50
Brinjal	300.0	25,260	94750	3.75	225.0	28,260	61,740	2.18
Cauliflower	280.0	31,205	1,36,795	4.38	240.0	34,205	1,09,795	3.20
Cabbage	480.0	29,935	1,10,065	3.68	320.0	32,935	1,10,000	3.33
Chilly	90.0	29,945	60,045	2.00	75.0	32,945	42,055	1.28

Table 7: Yield and net profit of crops grown using Agra canal and ground water (Kosi-Mathura)

Crops	Crops irrigated with Agra canal water				Crops irrigated with ground water			
	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net Profit (Rs/ha)	B:C ratio	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net Profit (Rs/ha)	B:C ratio
Wheat	49.0	20,915	58,635	2.80	46.0	23,915	50,285	2.10
Rice	61.0	35,945	70,195	1.95	56.0	37,455	59,985	1.60
Pearl millet	22.0	12,475	11,325	0.90	18.5	14,475	6,675	0.46
Sorghum(F)	135.0	10,385	9,870	0.95	122.0	12,385	5,915	0.47
Mustard	18.0	15,605	61,195	3.92	12.0	17,605	39,995	2.27
Berseem(F)	115.0	11,820	11,180	0.95	106.0	13,820	7,380	0.55
Moong	12.5	14,070	23,430	1.66	10.2	17,070	13,530	0.79
Barley	33.0	19,355	25,195	1.30	30.0	21,355	19,145	0.90
Oat (F)	105.0	11,235	9,765	0.87	98.0	12,675	6,925	0.55
Cotton	22.0	26,270	72,800	2.77	18.0	28,270	52,730	1.86
Dhaincha	11.0	8,250	15,950	1.93	9.0	9,125	10,675	1.17

Soil pH (1:2) did not register any significant change (Table 10) following wheat harvest when irrigated with Agra canal water. However, EC (1:2) revealed increasing trend in the upper (0-30 cm) layer in different locations at Palwal and Bichpuri area irrigated with Agra canal water. Comparatively higher EC was recorded in the fields irrigated with ground water in last many years. The sodium was recorded higher in ground water irrigated fields as compared with Agra canal irrigated fields. The Ca + Mg, HCO_3, Cl, SO_4 were found in all samples but CO_3 and RSC was not observed in any sample. The organic carbon (OC), organic matter (OM) and nutrients status is depicted in Table 11.

Table 8: Yield and net profit of crops grown using Agra canal and ground water (Goverdhan-Mathura)

Crops	Yield of crops irrigated with Agra canal water				Yield of crops irrigated with ground water			
	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net Profit (Rs/ha)	B:C ratio	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net Profit (Rs/ha)	B:C ratio
Wheat	50.0	20,915	60,600	2.89	47.0	23,915	51,235	2.14
Rice	62.0	35,455	72,425	2.04	59.0	37,455	65,205	1.74
Pearl millet	23.5	12,475	12,675	1.02	20.2	14,475	6,705	0.46
Sorghum(F)	145.0	10,385	11,365	1.09	136.0	12,385	8,015	0.65
Mustard	24.0	15,605	61,195	3.92	20.0	17,605	46,395	2.64
Berseem(F)	126.0	11,820	13,380	1.13	120.0	13,820	10,180	0.74
Barley	34.0	19,355	26,895	1.45	31.0	21,355	20,145	1.00
Cowpea	10.8	15,170	19,390	1.28	9.0	17,250	11,550	0.66
Clusterbean	11.2	14,035	36,365	2.59	10.2	16,078	29,822	1.85
Oats(F)	115.0	11,235	11,765	1.05	105.0	13,225	7,775	0.58
Vegetable crops								
Radish	178.0	15,230	47,070	3.09	160.0	17,230	38,770	2.25
Potato	320.0	47,135	80,865	1.71	290.0	51,135	64,865	1.26
Brinjal	250.0	28,260	72,500	2.56	225.0	30,260	65,250	2.15
Cauliflower	295.0	31,205	1,45,795	4.67	260.0	34,205	1,21,795	3.56
Cabbage	275.0	29,935	1,07,565	3.59	210.0	32,935	72,065	2.18
Chilli	80.0	29,945	50,055	1.67	78.7	32,945	45,755	1.38
Cucumber	110.0	21,435	66,565	3.10	98.0	24,435	53,965	2.20
Water melon	150.0	19,275	90,000	4.66	128.0	20,275	56,525	2.78
Muskmelon	125.0	22,875	75,000	3.28	115.0	22,875	45,125	1.89

Table 9: Yield and net profit of crops grown using Agra canal and ground water (Bichpuri-Agra)

Crops	Crops irrigated with Agra canal water				Crops irrigated with ground water			
	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net Profit (Rs/ha)	B:C ratio	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net Profit (Rs/ha)	B:C ratio
Wheat	51.0	20,915	62,230	2.97	48.0	23,915	53,185	2.22
Pearl millet	25.0	12,475	14,525	1.39	22.0	14,475	9,075	0.63
Sorghum(F)	148.0	10,385	15,515	1.49	142.0	12,385	12,465	1.00
Mustard	26.0	15,605	68,135	4.36	33.0	17,605	52,795	2.99
Berseem(F)	130.0	11,820	14,180	1.19	124.0	13,820	10,980	0.79
Barley	38.0	19,355	31,945	1.65	33.0	21,355	22,195	0.99
Cowpea	11.5	15,170	21,632	1.42	9.0	17,170	11,630	0.68
Cluster bean	12.5	16,208	40,042	2.47	10.5	19,280	27,970	1.45
Vegetables								
Radish	180.0	15,230	47,770	3.14	165.0	17,230	40,520	2.35
Potato	380.0	47,135	1,04,865	2.22	330.0	51,135	80,865	1.58
Brinjal	240.0	26,260	69,740	2.66	222.0	29,260	59,540	2.03
Cauliflower	290.0	31,205	1,42,795	4.57	265.0	34,205	1,25,795	3.78
Cabbage	360.0	29,935	1,50,065	5.01	310.0	32,935	1,22,265	3.73
Carrot	270.0	20,780	87,215	4.20	230.0	22,785	69,215	3.03
Okra	170.0	17,035	50,965	2.99	155.0	19,035	42,965	2.25
Tomato	250.0	30,055	1,19,945	3.99	200.0	33,055	86,945	2.63
Capsicum	160.0	35,215	1,24,785	3.54	145.0	38,215	1,06,785	2.79

Table 10: Chemical properties of the soil in Palwal area of Agra canal site

Crop and site	Soil Depth	EC_e	pH	Na	Ca+Mg	CO_3	HCO_3	Cl	SO_4	SAR	RSC
Wheat (TW)											
	0-15	7.5	7.5	57.0	22.0	-	14.0	28.0	35.0	17.2	-
	15-30	7.5	7.4	65.0	25.0	-	17.0	24.0	36.0	9.5	-
	30-60	7.3	7.4	56.0	18.0	-	15.0	22.0	38.0	18.7	-
	60-90	7.3	7.5	55.0	25.0	-	16.0	25.0	39.0	9.5	-
Wheat (CW)											
	0-15	3.3	7.4	21.0	14.0	-	9.0	11.0	15.0	11.2	-
	15-30	3.7	7.4	26.0	13.0	-	11.0	12.0	15.0	10.2	-
	30-60	2.8	7.4	17.0	13.0	-	8.0	10.0	13.0	6.7	-
	60-90	2.7	7.5	22.0	7.0	-	10.0	9.0	11.0	11.8	-

Table 11: Soil OC and available nutrients at harvest under with Agra canal and ground water (Palwal)

Site of sampling	Soil depth (cm)	OC (%)	OM (%)	Av. N Kg/ha	Av. P_2O_5 Kg/ha	Av. K_2O Kg/ha
Wheat (TW)						
	0-15	0.30	0.52	278.5	13.6	281.8
	15-30	0.28	0.48	255.6	12.5	265.6
	30-60	0.22	0.38	248.3	8.1	218.7
	60-90	0.20	0.35	198.2	6.2	195.3
Wheat (CW)						
	0-15	0.32	0.55	269.9	14.2	290.7
	15-30	0.29	0.50	258.3	12.8	262.3
	30-60	0.25	0.43	226.3	7.2	225.7
	60-90	0.22	0.38	192.3	5.3	182.3

Data presented in Table 12 and 13 indicates that soil EC_e decreased with depth and organic carbon was higher in upper surface layer in all soil samples at Bichpuri. The organic carbon and available nitrogen increased in Agra canal water irrigated soils. Available K increased positively with years of irrigation with canal water.

Table 12: Chemical properties of the soil in Bichpuri area of Agra canal site

Crop and site	Soil depth (cm)	EC_e (dS/m)	pH	Na	Ca+Mg	CO_3	HCO_3	Cl	SO_4	SAR	RSC
Wheat (TW)											
	0-15	6.3	7.4	55.0	9.0	-	14.0	15.0	36.0	25.9	-
	15-30	6.5	7.5	52.0	15.0	-	13.0	14.0	39.0	19.1	-
	30-60	5.8	7.5	48.0	11.0	-	11.0	11.0	38.0	20.5	-
	60-90	5.5	7.4	47.0	10.0	-	13.0	12.0	31.0	21.1	-
Wheat (CW)											
	0-15	3.8	7.5	27.0	13.0	-	10.0	12.0	18.0	11.3	-
	15-30	3.5	7.5	31.0	7.0	-	11.0	12.0	15.0	20.1	-
	30-60	3.3	7.4	20.0	15.0	-	11.0	9.0	15.0	11.2	-
	60-90	3.2	7.4	25.0	10.0	-	10.0	12.0	12.0	15.0	-

Table 13: Soil OC and available nutrients under Agra canal and ground water irrigation (Bichpuri-Agra)

Site of sampling	Soil depth (cm)	OC (%)	OM (%)	Av. N (Kg/ha)	Av. P_2O_5 (Kg/ha)	Av. K_2O (Kg/ha)
Wheat (TW)						
	0-15	0.31	0.54	278.6	13.9	270.5
	15-30	0.28	0.48	252.7	12.8	242.3
	30-60	0.22	0.38	200.1	7.8	212.6
	60-90	0.19	0.33	198.3	5.8	199.5
Wheat (CW)						
	0-15	0.32	0.55	298.7	14.8	262.8
	15-30	0.29	0.50	256.2	12.6	257.3
	30-60	0.25	0.43	225.8	8.2	223.3
	60-90	0.21	0.36	198.3	7.5	200.1

Assessment of treated sewage water on soil, crop and ground water qualities

The sewage and drinking water samples were collected during 2012-13 and 2013-14 from different locations of STP Dandhupura, Agra, which is used for irrigating different crops. Sewage water samples were at inlt of STP before rains, after rains and during winter. The water showed high EC values before rains, slight increase in pH (7.1-7.5) before monsoon, BOD range 156.5-225.5 mg/l but highest value (225.5 mg/l) being before monsoon. Bicarbonate increased during winter season, while chloride increased before monsoon. Calcium was dominant cation before monsoon, RSC was absent in all samples while SAR ranged between 11.0-12.1. Heavy metals concentration also varied and was copper 0.059-0.083 mg/l, zinc 0.021-0.033 mg/l, cobalt 0.005-0.038 mg/l, iron 0.003-0.012 mg/l, chromium 0.128-0.245mg/l and lead 0.041-0.095 mg/l (Table 14).

Treated sewage water samples were collected from STP ponds with primary treatment. The salinity of water ranged between 3.30-3.35 dS/m being highest before monsoon, slight increase in pH (7.2-7.4) was observed, BOD ranged between 47-68 mg/l with highest value (68 mg/l) before monsoon. Carbonate was observed in outlet samples collected during all season. Range of bicarbonate content was 707.6-969.9 mg/l, chloride 521.9-711.8 mg/l, nitrate 164.8-181.1 mg/l, calcium 92.2-186.4 mg/l, and magnesium 212.9-323.2 mg/l. Sodium content was high 565.6-664.1 mg/l, potassium 31.1-43.5 mg/l. SAR ranged between 10.4-11.5 while no RSC was observed. Heavy metals i.e. copper ranged between 0.038-0.067 mg/l, zinc 0.015-0.019 mg/l, cobalt 0.009-0.048 mg/l, iron 0.138-0.247 mg/l chromium 0.138- 0.247 mg/l and lead 0.045-0.099 mg/l.

The treated sewage water samples collected at 1 km from STP thrice a year. The EC of water ranged from 3.25 to 3.55 dS/m, being highest during winter, BOD ranged between 27.5-74.5 mg/l highest observed during winter. Carbonate and bicarbonate observed in all collected samples. Nitrate ranged between 138.8-177.3 mg/l, calcium 84.2-212.4 mg/l, magnesium 201.3-334.4 mg/l, sodium 658.9-668.8 mg/l, and potassium 30.2-44.8 mg/l. RSC was not observed but SAR ranged between 10.8-11.8 (Table 14).

The pH of drinking water samples collected from submersible pumps near to sewage canal at Kuankheda ranged between 7.4-7.7 and EC 2.95-3.50 dS/m. Amongst anions bicarbonate was the dominant ion and ranged between 280.6-616.1 mg/l, chloride 249.0-511.2 mg/l and sulphate 523.3-993.6 mg/l. Higher concentration of calcium, magnesium, sodium and potassium were observed compared to standard limits of WHO and CPCB. RSC was nil in all samples while SAR was between 10.6-17.0. Higher concentration of heavy metals were also found; copper 0.029-0.081 mg/l, zinc 0.016-0.022 mg/l, cobalt 0.015-0.036 mg/l, iron 0.007-0.033 mg/l, chromium 0.087-0.249 mg/l and lead 0.047-0.081 mg/l. Samples collected from hand pump revealed that pH was normal (7.4-7.7) whereas, EC ranged between 2.25-3.15 dS/m, which was higher than the limits set by WHO and CPCB. Bicarbonate was higher and ranged from 344.2 to 402.6 mg/l. Similar pattern was observed in case of chloride. The sulphate content ranged between 624.0-1156.8 mg/l and nitrate 111.4-114.1 mg/l, potassium was high (37.9-49.3 mg/l) in drinking water and RSC was nil and SAR ranged between 9.6-17.6. Heavy metals were also higher, copper ranged between 0.025-0.043 mg/l, zinc 0.020-0.025 mg/l, cobalt 0.007-0.040 mg/l, iron 0.008-0.050 mg/l chromium 0.105-0.226 mg/l and lead 0.013-0.079 mg/l (Table 15).

Table 14: Sewage water quality at inlet, outlet and 1 km from Dandhpura STP (Av. of 2 years)

Parameters	At inlet of STP			At outlet of STP			At 1 km from STP		
	Post monsoon	Winter	Pre monsoon	Post monsoon	Winter	Pre monsoon	Post monsoon	Winter	Pre monsoon
pH	7.3	7.1	7.5	7.2	7.4	7.6	7.5	7.5	7.6
EC (dS/m)	3.05	3.05	3.40	3.35	3.30	3.35	3.25	3.55	3.50
BOD (mg/l)	169.5	156.5	225.5	47.0	63.5	68.5	27.5	50.5	74.5
COD (mg/l)	256.0	214.5	238.5	110.0	107.0	108.5	112.5	110.0	105.5
CO_3 (mg/l)	54.0	24.0	36.0	126.0	6.0	30.0	42.0	90.0	24.0
HCO_3 (mg/l)	483.2	987.8	817.4	707.6	969.9	835.7	854.0	494.1	854.0
Cl (mg/l)	493.5	564.5	639.0	521.9	711.8	528.9	532.5	543.2	450.9
SO_4(mg/l)	619.2	177.6	393.6	465.6	165.6	451.2	412.8	777.6	696.0
NO_3 (mg/l)	204.2	184.8	172.4	181.1	127.7	164.8	177.3	152.5	138.8
Ca (mg/l)	158.3	146.7	168.3	92.2	186.4	182.4	84.2	188.4	212.4
Mg (mg/l)	212.0	236.9	295.4	323.2	212.9	239.5	334.4	201.3	238.4
Na (mg/l)	671.6	671.6	682.5	664.1	592.3	565.6	668.8	664.7	658.9
K (mg/l)	33.5	39.1	40.8	31.1	37.2	43.5	30.2	36.9	44.8
Cu (mg/l)	0.079	0.083	0.059	0.067	0.064	0.038	0.066	0.066	0.086
Zn (mg/l)	0.021	0.033	0.027	0.019	0.018	0.015	0.012	0.017	0.017
Co (mg/l)	0.038	0.005	0.037	0.021	0.009	0.048	0.015	0.013	0.028
Fe (mg/l)	0.003	0.010	0.012	0.009	0.037	0.021	0.017	0.005	0.016
Cr (mg/l)	0.128	0.141	0.245	0.138	0.187	0.247	0.154	0.219	0.243
Pb (mg/l)	0.041	0.080	0.095	0.045	0.066	0.099	0.050	0.074	0.098
SAR	12.1	11.9	11.0	11.5	10.4	11.2	11.2	11.8	10.8
RSC	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

The drinking water samples collected from hand pump at Budhana village revealed that pH was normal (7.3-7.7) whereas, EC ranged between 2.30-2.95 dS/m, which was higher than the limits set by WHO and CPCB. Bicarbonate and chloride were higher ranged between 335.5-366.0 mg/l and 184.6-326.6 respectively. Sulphate content ranged between 742.8-998.4 mg/l and nitrate 94.3-125.2 mg/l, potassium was high ranged between 36.1-39.3 mg/l, RSC was nil, SAR ranged between 10.6-18.5. Heavy metals; copper ranged between 0.039-0.054 mg/l, zinc 0.022-0.027 mg/l, cobalt 0.003-0.039 mg/l, iron 0.006-0.045 mg/l chromium 0.101-0.247 mg/l, and lead ranged between 0.051-0.082 mg/l (Table 15).

Table 15: Ground water quality analysis for STP area (Av. of 2 years)

Parameters	At inlet of STP			At outlet of STP			At 1 km from STP		
	Post monsoon	Winter	Pre monsoon	Post monsoon	Winter	Pre monsoon	Post monsoon	Winter	Pre monsoon
pH	7.5	7.4	7.7	7.4	7.6	7.7	7.3	7.6	7.7
EC (dS/m)	3.10	2.95	3.50	3.15	2.25	3.10	2.95	2.30	2.90
BOD(mg/l)	8	5.5	5.5	2.5	2.5	2.0	2.5	2.5	2.5
COD (mg/l)	3.5	5.5	3.5	6.5	7.5	7.5	6.5	8.5	7.0
CO_3 (mg/l)	54.0	84.0	18.0	120.0	42.0	60.4	18.0	24.0	42.0
HCO_3(mg/l)	616.1	280.6	347.7	384.3	402.6	344.2	359.9	335.5	366.0
Cl (mg/l)	511.2	259.2	249.0	516.2	213.0	209.5	326.6	184.6	234.3
SO_4(mg/l)	523.2	993.6	744.1	628.8	624.0	1156.8	945.6	742.8	998.4
NO^3 (mg/l)	125.3	143.9	107.9	114.1	111.4	112.9	105.4	125.2	94.3
Ca (mg/l)	114.2	130.2	122.3	102.2	126.2	158.3	106.2	98.1	108.2
Mg (mg/l)	272.2	256.2	222.3	367.9	310.4	221.6	212.6	149.7	184.8
Na (mg/l)	941.9	599.2	624.5	1091.4	598.0	537.1	985.6	624.5	518.7
K (mg/l)	44.9	54.3	36.7	41.1	49.3	37.9	39.3	36.1	38.9
Cu (mg/l)	0.081	0.035	0.029	0.025	0.046	0.033	0.054	0.039	0.044
Zn (mg/l)	0.020	0.016	0.022	0.025	0.020	0.021	0.025	0.027	0.022
Co (mg/l)	0.015	0.025	0.036	0.007	0.023	0.040	0.003	0.024	0.039
Fe (mg/l)	0.033	0.007	0.009	0.050	0.008	0.025	0.045	0.006	0.024
Cr (mg/l)	0.087	0.227	0.249	0.105	0.195	0.226	0.101	0.125	0.247
Pb (mg/l)	0.047	0059	0.081	0.049	0.013	0.079	0.051	0.068	0.082
SAR	17.0	10.6	11.8	17.7	12.3	9.6	18.5	13.8	10.6
RSC	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Pearl millet, wheat, mustard, sorghum, berseem and several other crops were grown with treated sewage and ground water. The maximum net profit was obtained where treated sewage water was used compared to where ground water was the source of irrigation (Table 16).

Table 16: Yield and net profit of different crops irrigated with treated sewage and ground water

Crops	Crops irrigated with treated sewage water				Crops irrigated with ground water			
	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net benefits (Rs/ha)	B:C ratio	Yield (q/ha)	Cost of cultivation (Rs/ha)	Net benefits (Rs/ha)	B:C ratio
Wheat	52.0	20,900	63,800	3.05	48.0	24,000	54,300	2.26
Pearl millet	26.0	12,500	15,400	1.48	22.0	15,000	8,550	0.57
Sorghum(F)	200.0	10,400	19,600	1.90	165.0	13,000	11,750	0.90
Mustard	28.0	16,000	73,600	4.60	21.0	24,000	43,200	1.80
Berseem (F)	170.0	12,000	22,000	1.83	155.0	14,000	17,000	1.21
Vegetables								
Radish	200.0	18,000	52,000	2.88	160.0	22,000	34,000	1.55
Potato	390.0	48,000	1,08,000	2.25	300.0	50,000	70,000	1.40
Brinjal	240.0	26,260	69,740	2.66	225.0	28,260	59,490	2.03
Cauliflower	298.0	30,000	1,48,000	4.96	210.0	35,000	91,000	2.60
Cabbage	375.0	30,000	1,57,500	5.25	325.0	35,000	1,27,500	3.64
Okra	185.0	17,500	51,500	3.30	145.0	18,000	40,000	2.22
Coriander	60.0	22,000	98,000	4.45	40.0	24,000	56,000	2.33

Palak	110.0	12,000	32,000	2.67	75.0	13,500	16,500	1.22
Flowers								
Rose	35.0	40,000	1,00,000	2.50	30.0	45,000	75,000	1.67
Marigold	210.0	38,000	67,000	1.76	170.0	42,000	46,000	1.10

Analysis of soil samples revealed not much change in soil pH (1:2) with varying period of irrigation by treated sewage water. However, EC (1:2) showed increasing trend in the upper (0-30 cm) layer, though even higher EC was observed in the fields irrigated with ground water. Sodium was higher in treated sewage irrigated areas (Table 17). Carbonate was not detected in any soil sample while bicarbonate was observed in all samples in treated sewage water and ground water irrigated fields. The chloride and sulphate were found. Data given in Table 18 indicates that the organic carbon was higher in the upper surface layer in all soil samples in STP treated irrigated area. Available K also increased in treated sewage irrigated fields.

Table 17: Chemical properties of soil in STP and ground water irrigated fields (at crop harvest)

Crop/mode	Soil depth(cm)	EC_e	pH	Na	Ca+Mg	HCO_3	Cl	SO_4	SAR
Wheat (SW)	0-15	2.4	7.6	16.0	10.0	9.0	10.0	5.0	7.0
	15-30	2.3	7.5	14.0	9.0	8.0	11.0	6.0	9.9
	30-60	2.3	7.5	14.0	11.0	6.0	12.0	7.0	5.9
	60-90	2.2	7.5	15.0	8.0	5.0	13.0	6.0	7.5
Sorghum -F (SW)	0-15	3.2	7.5	18.0	15.0	7.0	16.0	10.0	6.6
	15-30	2.8	7.5	12.0	17.0	4.0	16.0	10.0	4.0
	30-60	2.6	7.4	11.0	13.0	3.0	17.0	8.0	4.3
	60-90	2.5	7.4	12.0	15.0	5.0	16.0	6.0	4.4
Cauliflower (SW)	0-15	3.8	7.5	24.0	16.0	6.0	28.0	6.0	8.5
	15-30	3.6	7.4	23.0	15.0	5.0	26.0	7.0	8.4
	30-60	3.5	7.4	21.0	16.0	8.0	20.0	9.0	7.4
	60-90	2.8	7.4	19.0	11.0	7.0	17.0	8.0	8.1
Cabbage (SW)	0-15	3.7	7.6	27.0	11.0	8.0	22.0	10.0	11.5
	15-30	3.5	7.5	25.0	12.0	4.0	28.0	6.0	10.2
	30-60	3.3	7.4	24.0	10.0	5.0	22.0	10.0	10.7
	60-90	3.2	7.4	22.0	11.0	6.0	21.0	7.0	9.4
Berseem (SW)	0-15	2.9	7.5	14.0	16.0	7.0	18.0	5.0	4.9
	15-30	2.6	7.5	12.0	14.0	5.0	19.0	6.0	4.5
	30-60	2.5	7.5	12.0	14.0	6.0	16.0	5.0	4.5
	60-90	2.4	7.4	11.0	15.0	5.0	14.0	6.0	4.0
Wheat (TW)	0-15	7.8	7.6	45.0	35.0	10.0	55.0	15.0	10.9
	15-30	5.6	7.5	38.0	19.0	8.0	38.0	12.0	12.3
	30-60	4.8	7.5	30.0	20.0	7.0	37.0	6.0	9.5
	60-90	3.8	7.5	28.0	12.0	5.0	28.0	7.0	11.5
Mustard (TW)	0-15	4.5	7.5	28.0	11.0	11.0	28.0	8.0	16.2
	15-30	3.8	7.6	22.0	17.0	8.0	24.0	7.0	7.5
	30-60	3.5	7.5	18.0	18.0	5.0	26.0	6.0	6.0
	60-90	3.4	7.4	16.0	20.0	6.0	22.0	8.0	5.1

SW: sewage water; TW: tube well water; CO_3 and RSC: Nil

Table 18: Soil organic carbon and available nutrients at harvest of crops collected from STP area

Crop/mode	Soil depth (cm)	OC (%)	OM (%)	Available nutrients (kg/ha)		
				N	P	K
Wheat (SW)	0-15	0.62	1.07	288.5	15.8	282.1
	15-30	0.50	0.87	268.0	12.3	189.2
	30-60	0.32	0.55	210.0	10.2	118.5
	60-90	0.30	0.52	180.0	8.7	95.2
Sorghum (F) (SW)	0-15	0.58	1.00	275.5	14.2	300.2
	15-30	0.50	0.87	261.0	11.8	268.7
	30-60	0.30	0.52	208.0	10.1	175.2
	60-90	0.28	0.48	193.0	6.5	111.8
Cauliflower (SW)	0-15	0.65	1.12	289.8	14.2	297.3
	15-30	0.58	1.00	275.7	12.7	262.3
	30-60	0.40	0.69	218.3	9.8	195.7
	60-90	0.30	0.52	178.5	6.2	107.3
Cabbage (SW)	0-15	0.61	1.05	299.7	13.8	289.8
	15-30	0.48	0.83	280.7	10.8	265.3
	30-60	0.32	0.55	218.1	9.2	190.4
	60-90	0.28	0.48	190.3	6.2	111.6
Berseem (SW)	0-15	0.60	1.04	278.3	15.2	278.3
	15-30	0.48	0.83	262.5	13.8	251.3
	30-60	0.30	0.52	216.3	10.2	178.0
	60-90	0.28	0.48	175.4	7.5	114.6
Wheat (TW)	0-15	0.35	0.60	210.7	13.2	218.3
	15-30	0.30	0.52	198.3	10.8	199.3
	30-60	0.43	0.43	125.0	4.5	110.2
	60-90	0.17	0.31	80.2	3.8	88.3
Mustard (TW)	0-15	0.33	0.58	190.3	10.2	178.3
	15-30	0.28	0.48	185.2	9.5	166.3
	30-60	0.25	0.43	128.7	5.3	126.4
	60-90	0.17	0.29	89.3	3.6	78.2

SW: sewage water; TW: tube well water

Screening of wheat, rice and mustard cultivars under saline water irrigation

Wheat cultivars: Screening of 88 wheat cultivars supplied by CSSRI, Karnal was carried out during 2012-13. All cultivars were irrigated with saline water of EC_{iw} 10 dS/m. The higher grain yield was recorded in Kharchia 65 and KRL 3-4 followed by other cultivars (Table 19).

Mustard cultivars: Screening of mustard cultivars supplied by DRM, Bharatpur was carried out during 2012-13 and 2013-14 (Table 20, 21). All cultivars were irrigated with saline water of EC_{iw} 10 dS/m. Highest yield of mustard cultivars was recorded in L16 (2.20 t/ha) and L4 the lowest (1.65 t/ha) during 2012-13. During 2013-14 cultivar L8 produced highest grain yield (1.28 t/ha) and L9 produced the lowest grain yield (1.01 t/ha). In CSCN highest yield was recorded in CSCN -12-2 (1.98 t/ha) and CSCN-12-6 produced the lowest (1.41 t/ha) during 2012-13 while during 2013-14 highest grain yield was recorded in CSCN-13-7 (1.71 t/ha) and lowest in CSCN-13-1 (1.24 t/ha). In AVT 2013-14, highest yield was obtained in AVT- 13-12 (1.74 t/ha) and lowest in AVT- 13-9 (1.24 t/ha).

Table 19: Yield of wheat cultivars on use of saline water in irrigation

Culture	Grain yield (g/plot)	Culture	Grain yield (g/plot)	Culture	Grain Yield (g/plot)	Culture	Grain yield (g/plot)
Border KRL 19	375	Raj 4369	315	KRL 19(C)	280	PS 1078	295
Border KRL 19	300	Raj 4370	365	Kharchia 65(C)	425	PS 1079	440
KRL (C)	420	Raj 4371	450	HD 4530(C)	150	PS 1080	400
Kharchia 65(C)	385	Raj 4372	375	KRL 3-4(C)	605	PS 1081	325
HD 4530(C)	195	KRS 1201	420	KRL 210(C)	330	PS 1082	355
KRL 3-4(C)	415	KRS 1202	325	KRS 1214	335	NW 6008	415
KRL 210(C)	345	KRS 1203	390	KRS 1215	430	KRL 19(C)	290
LBP2012-21	365	KRS 1204	430	KRS 1216	340	Kharchia65(C)	460
LBP2012-22	345	KRL 19(C)	325	KRS 1217	420	HD 4530(C)	205
LBP2012-23	305	Kharchia 65(C)	410	KRS 1218	270	KRL 3-4(C)	520
LBP2012-24	355	HD 4530(C)	135	KRS 1219	410	KRL 210(C)	310
LBP2012-25	335	KRL 3-4(C)	580	KRS 1220	295	NW 6009	310
RWP2012-17	335	KRL 210(C)	340	WH 1301	355	NW 6010	440
RWP2012-18	360	KRS 1205	375	WH 1302	325	NW 6011	350
RWP2012-19	400	KRS 1206	460	KRL 19(C)	310	NW 6012	320
RWP2012-20	415	KRS 1207	370	Kharchia 65(C)	490	WS 1201	320
KRL19(C)	265	KRS 1208	430	HD 4530(C)	155	WS 1202	240
Kharchia 65(C)	475	KRS 1209	350	KRL 3-4(C)	515	WS 1203	295
HD 4530(C)	105	KRS 1210	403	KRL 210(C)	375	WS 1204	436
KRL 3-4(C)	565	KRS 1211	370	WH 1303	390	WS 1205	310
KRL 210(C)	285	KRS 1212	400	WH 1148	395	BorderKRL-19	395
Raj 4368	340	KRS 2013	365	WH 1149	375	BorderKRL-19	425

Table 20: Yield of mustard cultivars on use of saline water irrigation (EC_{iw} 10dS/m)

2012-13		2013-14	
Cultivars	Grain yield (t/ha)	Cultivars	Grain yield (t/ha)
L1	1.69	L1	1.14
L2	1.74	L2	1.05
L3	1.86	L3	1.03
L4	1.65	L4	1.26
L5	1.88	L5	1.09
L6	1.93	L6	1.27
L7	1.87	L7	1.05
L8	1.91	L8	1.28
L9	1.76	L9	1.01
L10	1.87	L10	1.22
L11	1.88	CH-1	1.13
L12	1.77	CH-2	1.09
L13	1.93	CD (5%)	0.03
L14	2.04		
L15	1.86		
L16	2.20		
L17	1.87		
L18	2.21		

CH-1	1.91
CH-2	1.89
CD (5%)	0.22

Table 21: Yield of mustard cultivars with saline water irrigation (EC_{iw} 10 dS/m)

Cultivars	Grain yield (t/ha)	Cultivars	Grain yield (t/ha)	Cultivars	Grain yield (t/ha)
2012-13		2013-14		2013-14	
CSCN-12-1	1.89	CSCN-13-1	1.24	AVT-13-9	1.24
CSCN-12-2	1.98	CSCN-13-2	1.68	AVT-13-10	1.68
CSCN-12-3	1.81	CSCN-13-3	1.50	AVT-13-11	1.65
CSCN-12-4	1.65	CSCN-13-4	1.64	AVT-13-12	1.74
CSCN-12-5	1.71	CSCN-13-5	1.34	AVT-13-13	1.44
CSCN-12-6	1.41	CSCN-13-6	1.48	AVT-13-14	1.43
CSCN-12-7	1.92	CSCN-13-7	1.71	CD (5%)	0.02
CSCN-12-8	1.69	CSCN-13-8	1.33		
CD (5%)	0.01		0.01		

Plastic low tunnel technology for off season cultivation of vegetables using saline water with drip irrigation

An experiment on tolerance of tomato-bitter gourd crop rotation was carried out under drip irrigation in low tunnel and surface irrigation systems. The treatments included a combination of saline irrigation waters (Canal, 4 and 8 dS/m) and irrigation schedule (IW/CPE ratio 0.75, 1.00 and 1.25).

Fruit yield: The fruit yield of tomato significantly decreased with increasing EC_{iw} levels in both plastic low tunnel with drip and surface irrigation system. On an average EC_{iw} 4 and 8 dS/m reduced the tomato fruit yield by 6.9 and 16.5 per cent in plastic low tunnel with drip irrigation and 13.3 and 23.8 per cent in surface irrigation, respectively. The IW/CPE ratio was non-significant under drip with low tunnel and surface irrigation. Plastic low tunnel with drip irrigation is quite effective in increasing fruit yield of tomato. The fruit yield increased with low tunnel in drip irrigation by 112 per cent in canal, 128 per cent in EC_{iw} 4 and 149 per cent in EC_{iw} 8 dS/m as compared to surface irrigation. Bitter gourd fruit yield reduced by 2.7 and 10.4 per cent in drip irrigation and 13.2 and 29.9 per cent in surface irrigation in EC_{iw} 4 and 8 dS/m over control. Bitter gourd yield increased with drip by 131, 158 and 195 per cent in canal, EC_{iw} 4 and 8 dS/m as compared to surface irrigation, respectively (Table 22).

Water use efficiency: Averaged water use by the tomato crop varied from 32.5 to 50.7 cm in drip and 43.2 to 66.7 cm in surface irrigation system (Table 23). Water use efficiency was highest in canal irrigation of both plastic low tunnel with drip and surface irrigation. The WUE decreased with increasing EC_{iw} levels, being 707.5, 647.4 and 584.6 kg/ha-cm in drip with plastic low tunnel and 250.6, 219.5 and 181.9 kg/ha-cm in surface irrigation system, respectively. The WUE was higher in IW/CPE 0.75 in both plastic low tunnel with drip and surface irrigation as compared to other ratios. About 30 per cent water saving was recorded in drip irrigation as compared to surface irrigation systems.

Table 22: Effect of different treatments on fruit yield of tomato and bitter gourd (Av. of two years)

Treatments	Tomato (t/ha)		Bitter gourd (t/ha)	
	Plastic low tunnel with drip irrigation	Surface irrigation	Drip irrigation	Surface irrigation
Irrigation water				
Canal	29.33	13.84	9.66	4.18
4 dS/m	27.31	12.00	9.40	3.63
8 dS/m	24.50	9.85	8.65	2.93
CD (5%)	2.95	1.42	1.26	0.95
IW/CPE ratio				
0.75	26.59	11.94	9.57	3.70
1.00	27.11	12.06	9.22	3.64
1.25	27.48	11.65	8.74	3.43
CD (5%)	NS	NS	NS	NS
EC x IW/CPE ratio	NS	NS	NS	NS

Table 23: Water use and water use efficiency under different treatments in tomato (Av. of two years)

Treatments	Low tunnel with drip irrigation		Surface irrigation	
	Water use (cm)	Water use efficiency (kg/ha/cm)	Water use (cm)	Water use efficiency (kg/ha/cm)
Irrigation water				
Canal	41.2	707.5	55.3	250.6
4 dS/m	41.5	647.4	55.1	219.5
8 dS/m	41.4	584.6	54.9	181.9
IW/CPE ratio				
0.75	32.5	815.6	43.2	274.4
1.00	41.7	673.6	55.4	220.6
1.25	50.7	532.9	66.7	175.4

Soil salinity: On an average the EC_e in soil profile (0-60 cm) increased with increasing levels of EC_{iw} and IW/CPE ratio in the whole profile (Fig. 2). At harvest of tomato in plastic low tunnel with drip irrigation, EC_e of the surface layer (0-10 cm) ranged between 4.0 - 4.2 dS/m in control, 8.1 to 8.8 with EC_{iw} 4 and 11.8-12.7 dS/m with EC_{iw} 8 dS/m at a distance of 5-25 cm from the plant. Corresponding value for the lower depth (30-60 cm) are 3.10 to 3.3, 5.0 to 5.5 and 7.0 to 7.8 dS/m, respectively. In surface irrigation, salinity build-up was higher in surface layer as compared to lower depths (Table 24). At harvest of tomato crop the EC_e in surface layer (0-10 cm) were 4.1, 9.8 and 15.1 dS/m with canal, EC_{iw} 4 and 8 dS/m, respectively. The EC_e in surface layer at IW/CPE ratios of 0.75, 1.00 and 1.75 were 8.2, 9.8 and 11.1 dS/m, respectively.

At harvest of bitter gourd in drip irrigation, EC_e of the surface layer (0-10 cm) ranged between 2.5 - 3.2 dS/m in control, 4.3 - 4.7 at EC_{iw} 4 and 7.3 - 8.0 dS/m at EC_{iw} 8 dS/m at a distance of 5 - 25 cm from the plant. Corresponding values for the lower depths (30-60 cm) are 2.3 - 2.5, 3.3 - 3.5 and 4.6 - 5.0 dS/m, respectively (Fig. 3). In surface irrigation, the salinity build up was higher in surface layer as compared to lower depths (Table 24). At harvest of bitter gourd the EC_e in surface layer (0-10 cm) were 3.3, 6.7 and 8.8 dS/m with canal, EC_{iw} 4 and 8 dS/m, respectively. The EC_e in surface layer at IW/CPE ratios of 0.75, 1.00 and 1.75 were 5.1, 6.3 and 7.4 dS/m, respectively.

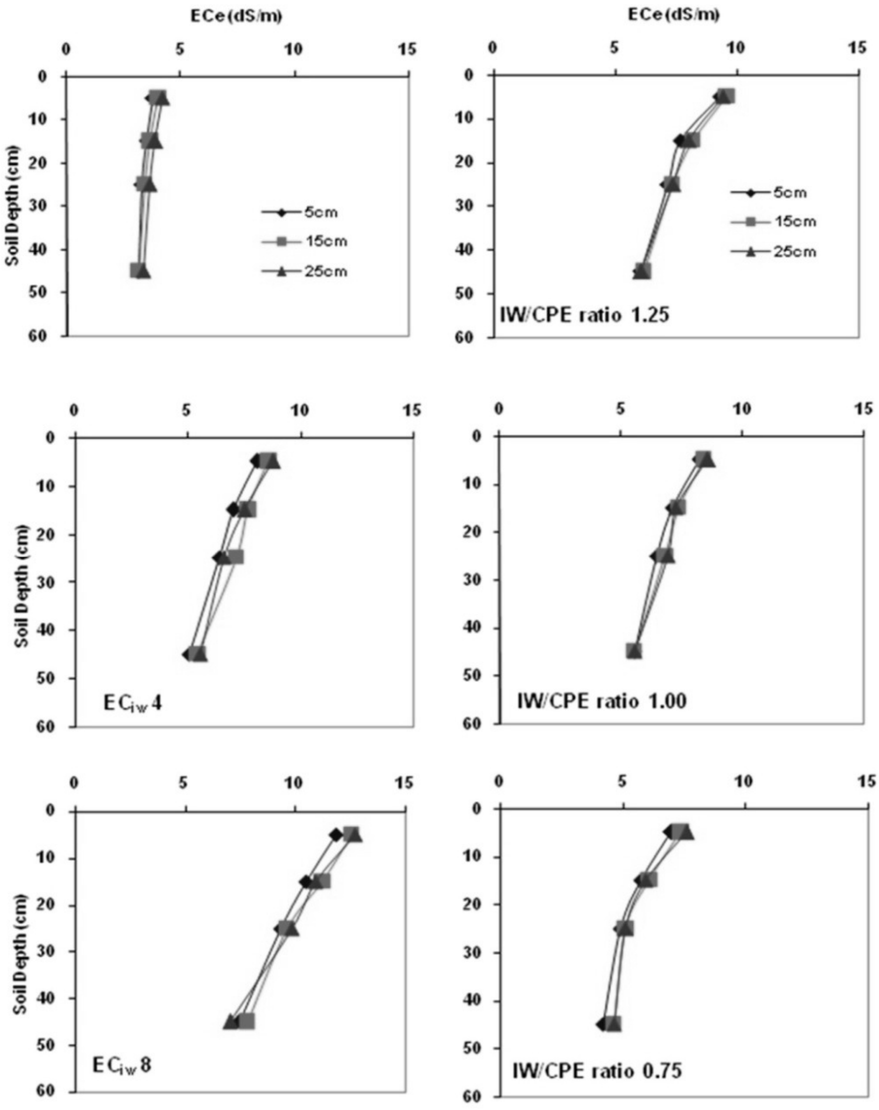


Fig. 2: EC_e (dS/m) in different EC_{iw} levels and IW/CPE ratios at harvest of Tomato in plastic low tunnel with drip irrigation (Average of 2012-13 and 2013-14)

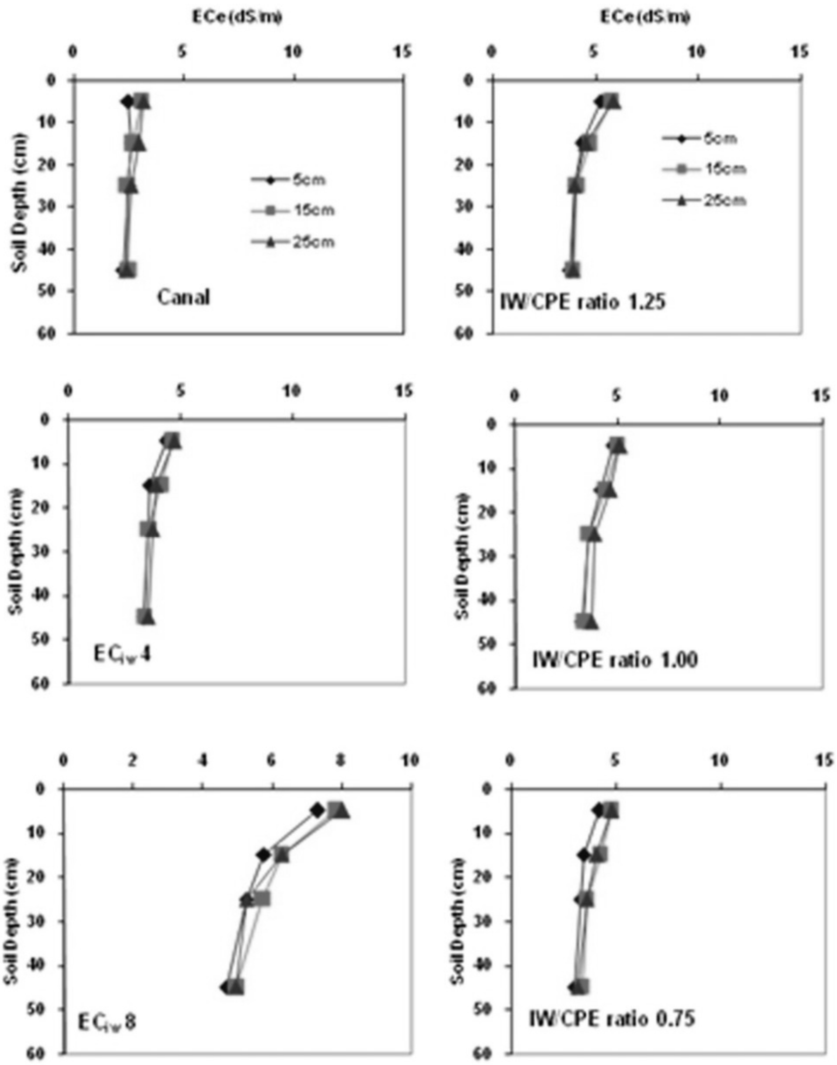


Fig. 3: EC_e (dS/m) in different EC_{iw} levels and IW/CPE ratios at harvest of Bitter gourd in drip irrigation (Average of 2012 and 2013)

Table 24: Salinity levels at different EC_{iw} levels and IW/CPE ratios at crop harvest in surface irrigation (Av. of two years)

Treatments	Soil depth (cm)	EC_e (dS/m)	
		Tomato	Bitter gourd
Control	0- 10	4.1	3.3
	10-20	3.8	2.8
	20-30	3.7	2.7
	30-60	3.3	2.5
EC_{iw} 4	0-10	9.8	6.7
	10-20	8.5	3.9
	20-30	7.5	3.0
	30-60	6.3	2.9
EC_{iw} 8	0-10	15.1	8.8
	10-20	13.1	6.2
	20-30	12.0	5.4
	30-60	10.3	4.5

IW/CPE ratio			
1.25	0-10	11.1	7.4
	10-20	9.5	4.9
	20-30	8.5	4.1
	30-60	7.4	3.6
1.00	0-10	9.8	6.3
	10-20	8.4	4.1
	20-30	7.5	3.7
	30-60	6.5	3.3
0.75	0-10	8.2	5.1
	10-20	7.6	3.9
	20-30	7.1	3.3
	30-60	5.6	2.9

Crop water/salinity production functions for different crops using sprinkler irrigation

An experiment to develop crop water production function of cowpea-mustard crop rotation by creating salinity/alkalinity gradients through sprinkler irrigation was conducted during 2012-13 and 2013-14. The treatments included three salinity levels (BAW, EC_{iw} 9.5 dS/m and mixture of two) and three RSC levels (BAW, RSC 9.5 meq/l and mixture of two). Pre sowing irrigation was applied by surface irrigation with BAW water and mustard crop was sown, rest of the irrigations were given as per treatments through sprinkler lines @ 2 cm each at 0.7 IW/CPE ratios.

Depth of water applied: Application of water depth decreased with increase in distance from sprinkler line in case of saline/RSC and BAW alone (Fig. 4). In saline and BAW alone, the depth of irrigation was recorded from 0.74 to 3.64 cm per irrigation at different points. In case of mixing the irrigation depth was 3.38 to 5.35 cm per irrigation. The depth of irrigation water was same in RSC water.

Quality of irrigation water: The salinity or RSC of irrigation water remained same irrespective of depth in the area where single saline (EC_{iw} 9.5 dS/m)/alkali (RSC 9.5 meq/l) or BAW (EC_{iw} 3.6 dS/m and RSC_{iw} nil) irrigations were applied. However, in case of mixing the EC_{iw} and RSC varied with distance. In case of saline irrigation, EC_{iw} ranged between 4.7 - 8.4 dS/m, and in RSC irrigated plots RSC_{iw} ranged between 1.8 - 7.7 meq/l (Fig. 5).

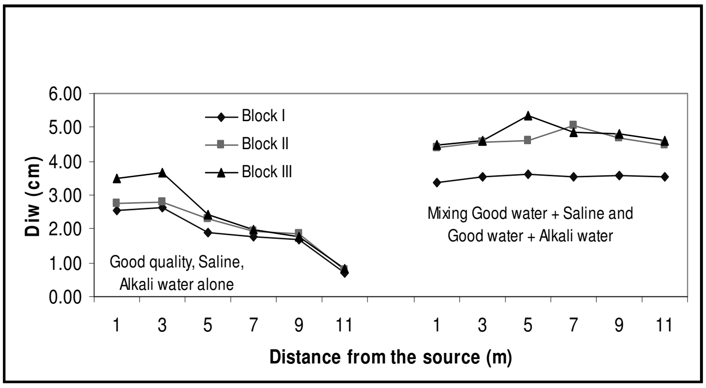


Fig. 4: Average quantity of water applied for each irrigation (D_{iw}) as a function of distance from the sprinkler line source

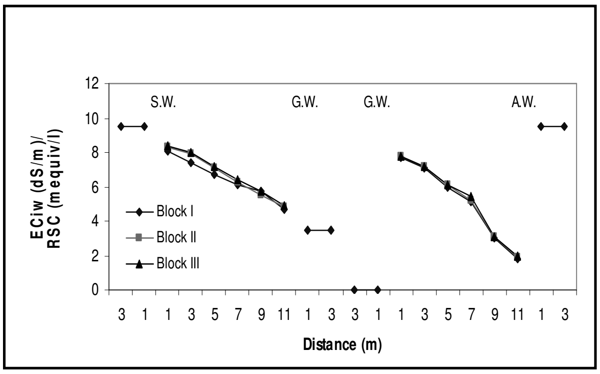


Fig. 5: Salinity (EC_{iw}) and RSC of applied water as a function of distance from the sprinkle line sources

Yield: Seed yield of cowpea was found at par in all the treatments as no irrigation was applied. The seed yield of cowpea slightly increased with best available water irrigation. Whereas in RSC water irrigated plots the yield was poor as compared to other treatments, probably because of the residual effect.

Mustard grain yield was affected by water and salinity/RSC gradients. The yield decreased with the decrease in depth of irrigation water away from sprinkler lines and decreased by 7.8 per cent in saline (EC_{iw} 10 dS/m), 19.4 per cent in alkali water and 23.6 per cent in best available water as the depth varied from 0.74 to 2.65 cm per irrigation. In mixing (BAW + EC_{iw} 10 dS/m) plots, the irrigation depth varied marginally from initial to last point. However, EC_{iw} ranged between 8.3$\pm$0.5 - 4.8$\pm$2.7 dS/m and yield declined by 10.6 per cent, whereas in alkali water RSC ranged between 8.3$\pm$0.5 to 4.8$\pm$2.7 meq/l, the mustard yield reduced by 8.6 per cent (Table 25).

Table 25: Grain yield of mustard under quantity and quality of irrigation water (Av. of 2 years)

Treatments	Grain yield of mustard (t/ha)		
	Ground water	Saline water	Alkali water
Water applied (cm)			
26.00±2.58	2.14	1.80	2.02
26.15±2.22	2.09	1.85	1.97
24.15±0.45	1.98	1.80	1.95
23.06±0.30	1.95	1.75	1.86
22.13±0.24	1.87	1.62	1.81
20.27±0.21	1.69	1.43	1.66
Mean	1.94	1.70	1.86
CD (5%)	0.07	0.15	0.10
EC_{iw} (dS/m)/RSC_{iw} (meq/l)		MSW	MAW
8.3±0.5		1.81	1.92
7.9±0.7		1.90	1.97
7.1±1.0		1.98	1.93
6.3±1.1		2.02	2.06
5.5±2.4		2.05	2.07
4.8±3.1		2.11	2.11
Mean		1.98	2.07
CD (5%)		0.12	0.12

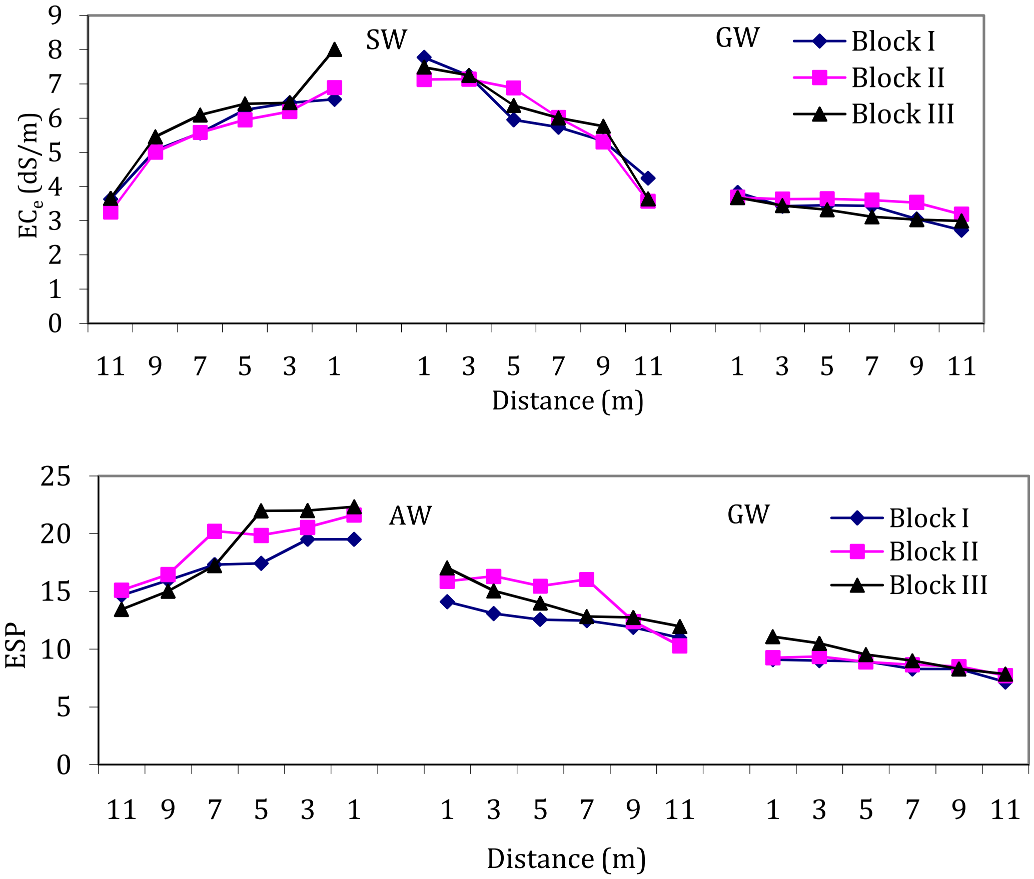


Fig. 6: EC_e and ESP of the surface 0-0.30m soil at the harvest of mustard as function of distance from the sprinkler sources (Average 2012-13 and 2013-14)

Soil studies: After harvest of mustard crop, the soil samples were collected at 1, 3, 5, 7, 9 and 11 m distance from sprinkler line and analyzed for EC_e and ESP (Fig. 6). On an average (2012-13 and 2013-14) EC_e of 0-30 cm depth was relatively higher at adjacent points of both saline and BAW alone sprinkler line and in mixing plots. The EC_e decreased with increased distance due to less water applied. The EC_e (0-30 cm depth) of salinity block varied from 3.6 to 6.55 dS/m in block I; 3.2 to 6.9 dS/m in block II and 3.6 to 8.1 dS/m in block III. In case of mixing, EC_e varied from 4.2 to 7.7 dS/m, 3.6 to 7.1 and 3.6 to 7.5 dS/m and in BAW block EC_e varied from 2.7 to 3.8 dS/m, 3.1 to 3.7 dS/m and 3.0 to 3.7 dS/m, respectively. In case of RSC block the ESP of 0-15 cm depth, trend was same as of soil salinity. The ESP varied from 14.7 to 19.5 meq/l in block I, from 15.1 to 21.6 meq/l in block II and from 13.4 to 22.3 meq/l in block III. In case of mixing, ESP varied from 11.0 to 14.1 meq/l, 10.3 to 15.9 meq/l and 12.0 to 17.0 meq/l and in BAW block ESP ranges between 7.1 - 9.1 meq/l, 7.7 to 9.2 meq/l and 7.8 to 11.1 meq/l, respectively.

Operational Research Project on Use of saline ground water at farmer's field

The field demonstrations under ORP on use of poor quality water were initiated during *kharif* 1993 in Karanpur, Mathura district. During 1999 the program was extended to two other villages' i.e. Nagla Hridaya and Bhojpur. At these sites, medium and high SAR saline water was available for irrigation.

During 2000 the program was extended to Savai village of Agra district to demonstrate the technologies on the use of alkali water. During *kharif* 2004, ORP was also initiated at Odara village of Bharatpur in medium and high saline water (EC_{iw} 6-23.5 dS/m and SAR 11-30 $(mmol/l)^{1/2}$. During 2006, one other site was also selected for dry land salinity demonstrations at Nagla Parasuram, Bharatpur district.

During 2012-13 and 2013-14, demonstrations were conducted at 25 farmer's field. The farmers were selected based on the availability of alkali, saline and good quality water for irrigation. The water quality parameters pertaining to tube well water of the selected farmers are given in Table 26. Gypsum was added on the basis of soil test. During these years, alkali water in Sawai village had EC_{iw} between 2.7-5.1 dS/m, RSC 6.2-12.0 meq/l and SAR 13.5-24.7 $(mmol/l)^{1/2}$ while saline water at Odara and Nagla Parasuram had EC_{iw} in the range of 5.8 to 23.5 dS/m and SAR in the range of 11.0-30.0 $(mmol/l)^{1/2}$.

Table 26: Water quality of farmer's tube well

Name of the farmer	EC_{iw} (dS/m)	RSC (meq/l)	SAR $(mmol/l)^{1/2}$
	RSC water		
Harvans Kumar	3.0	8.8	17.0
Om Prakash	4.4	7.6	23.9
Laxman Singh	3.0	7.8	13.5
Hakim Singh	5.1	6.2	24.7
Vijay Dixit	3.5	12.0	19.0
Satya Prakash	2.7	11.8	16.0
	Saline Water		
Subhash Chand	10.0	-	11.0
Dhara Singh	15.2	-	20.8
Amar Chand	13.5	-	12.5
Ram Bharosee	15.0	-	19.0
Hari Prasad	13.5	-	12.5
Lal Hans	10.9	-	16.2
Dinesh Chand	11.0	-	17.0
Mukesh Kumar	13.8	-	24.0
Roop Singh	23.5	-	24.9
Virendra Singh	19.9	-	23.5
Jagan Singh	12.6	-	15.5
Dal Chand	12.5	-	17.3
Munsi lal	12.0	-	13.8
Rohan Singh	13.2	-	23.3
Narayan Singh	6.0	-	13.1
Mukesh (NP)	15.2	-	13.2
Dara Singh	23.0	-	30.0
Mohan Singh	5.8	-	12.9
Gyanedra Singh	16.7	-	13.9

Kharif season

Alkali water: During 2012-14, trials were conducted on five ORP farmers' field. The gypsum was incorporated in five farmer's field, having alkali water on the basis of basis of soil test (50% GR). Pearl millet crop was grown. The yield showed that the incorporation of gypsum increased the grain yield by

13.3 to 19.3 per cent. The application of gypsum decreased soil EC, pH and ESP as compared to without gypsum (Table 27).

Table 27: Pearl millet yield with alkali water and soil characteristics at crop harvest (Av. of 2 years)

Name	Treatments	Yield (t/ha)	Per cent increase	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$	ESP
Harvans Kumar	Gypsum 50%GR	1.85	19.3	2.1	7.5	7.9	15.3
	No Gypsum	1.55	-	1.5	7.5	7.2	28.0
Om Prakash	Gypsum 50%GR	2.0	14.3	1.6	7.7	7.4	23.1
	No Gypsum	1.75	-	1.6	7.5	8.5	24.9
Hakim Singh	Gypsum 50%GR	2.1	16.7	2.9	7.7	10.6	17.0
	No Gypsum	1.8	-	3.0	7.7	12.5	25.1
Satya Prakash	Gypsum 50%GR	1.7	13.3	2.5	7.4	9.1	8.9
	No Gypsum	1.5	-	2.1	7.6	10.7	10.2
Laxman Singh	Gypsum 50%GR	1.5	15.4	3.0	8.0	13.0	17.0
	No Gypsum	1.3	-	2.4	7.8	9.1	18.8

Saline water: In high SAR saline water, the pearl millet was grown on 10 farmer's field (Table 28). The pearl millet grain yield varied from 1.5 to 2.23 t/ha in ORP and the yield was 17.1 to 17.9 per cent higher as compared to traditional farming.

Table 28: Pearl millet and sorghum yield in saline water irrigation and soil properties at harvest

Name of farmer	Crop	ORP yield (t/ha)*	Farmers yield (t/ha)*	Per cent increase	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
			Saline water				
Jagan Singh	Sorghum F	28.7	-	-	2.7	7.4	8.7
Birendra Singh	Pearl millet	1.71	-	-	3.1	7.4	11.8
Roop Singh	Pearl millet	1.65	-	-	3.6	7.6	13.1
Shubhash Chand	Pearl millet	1.95	1.66	17.15	2.0	7.6	8.3
DharaSingh	Pearl millet	1.73	-	-	1.5	7.8	10.4
Lal Hans	Pearl millet	1.75	1.48	17.95	3.4	7.8	11.3
Ram Bharose	Pearl millet	1.67	-	-	2.2	7.8	11.6
Hari Prasad	Sorghum F	21.34	-	-	4.3	7.6	13.2
Amar Chand	Sorghum F	23.33	-	-	3.4	7.8	14.0
Mukesh Kumar	Sorghum F	24.0	-	-	3.2	7.9	16.9
Dal Chand	Sorghum F	22.33	-	-	1.5	8.2	7.8
Rohan Singh	Pearl millet	1.80	-	-	2.8	7.9	10.6
Dinesh Chand	Sorghum F	21.68	-	-	2.4	7.7	12.2
Munsi Lal	Sorghum F	28.0	-	-	2.1	7.9	9.3
Mukesh (NP)	Sorghum F	30.0	-	-	2.7	7.6	11.3
Narayan Singh	Pearl millet	2.23	-	-	1.8	8.1	8.5
Mohan Singh	Pearl millet	1.53	-	-	2.7	7.4	11.7
Gyanendra Singh	Pearl millet	1.50	-	-	1.6	7.9	8.5

**Average yield of two years*

Rabi Season

Alkali Water: At Savai (Mangalpur), wheat crop was sown at 5 farmer's field (Table 29). The yield increased in gypsum treated fields as compared to control (without gypsum). The average wheat yield increased from 11.5 to 12.8 per cent in gypsum treated fields over control. The soil pH, SAR and ESP decreased in gypsum treated fields over control. The highest yield (4.83 t/ha) was recorded in the fields of Mr Harvans Kumar and Mr Satya Prakash having alkali water. Same trend was observed in mustard crop of Mr Harvans Kumar with 18.4 per cent increase over control (without gypsum).

Table 29: Effect of gypsum on wheat and mustard yield and soil characteristics at harvest

Name of farmer	Treatments	ORP yield (t/ha)	% increase over control	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$	ESP
		Grain yield of wheat (t/ha)*					
Harvans Kumar	Gypsum	4.83	11.5	2.9	7.6	11.0	16.4
	No gypsum	4.33		2.8	7.8	11.0	22.5
Om Prakash	Gypsum	4.67	12.2	4.1	7.7	22.8	21.0
	No gypsum	4.16		4.1	7.8	27.2	24.3
Hakim Singh	Gypsum	4.42	12.8	6.4	7.8	22.0	29.3
	No gypsum	3.92		5.9	8.0	23.0	28.4
Satya Prakash	Gypsum	4.83	11.5	3.6	8.2	18.5	25.0
	No gypsum	4.33		2.7	8.2	20.7	28.9
Laxman Singh	Gypsum	3.93	12.3	3.7	8.6	14.5	26.9
	No gypsum	3.50		3.7	8.8	18.8	26.9
		Seed yield of mustard (t/ha)*					
Harvans Kumar	Gypsum	2.57	18.4	3.2	7.6	15.2	16.4
	No gypsum	2.17		3.1	7.8	13.8	22.5

**Average of two years*

Saline water: Among different varieties tested, Mahyco variety of mustard produced the highest seed yield (2.35 t/ha) followed by CS 54. Overall crop performance was better (Table 30).

Table 30: Yield of mustard varieties in saline and alkali water irrigation (2012-13)

Name of farmer	Variety	ORP yield (t/ha)	Farmers yield (t/ha)	% increase in ORP	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
Hari Prasad (EC)	CS-52	2.07	-	-	10.0	6.9	16.7
	CS-56	2.17	-	-	12.95	6.7	15.5
Awagarh farm (RSC)	CS-54	2.25	-	-	4.0	7.9	11.0
Subhash Chand (EC)	Mahyco Bold	2.35	2.0	17.5	9.5	7.3	27.3

Fertilizer management: Two fertilizer levels i.e. 120 kg N, 60 kg P_2O_5 & 30 kg K_2O and 150 kg N, 60 kg P_2O_5 and 30 kg K_2O were applied in wheat (variety Raj 4037). The growth and yield attributes were found superior with higher dose of nitrogen (Table 31). The grain yield of wheat were 9.24 to 12.0 per cent higher with application of 150 kg N/ha as compared to 120 kg N/ha.

Table 31: N fertilization in wheat under saline water irrigation and soil parameters at harvest

Name of farmer	Treatments N (kg/ha)	ORP Yield (t/ha)	% increase over 120 kg N	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
Dal Chand	120 kg N	4.50		8.2	7.5	23.7
	150 kg N	5.00	11.11	8.0	7.5	24.6
Munsi lal	120 kg N	4.00		18.5	7.4	21.9
	150 kg N	4.40	10.00	18.6	7.6	22.3
Rohan Singh	120 kg N	3.50		18.7	8.1	29.9
	150 kg N	3.83	9.43	14.1	8.2	27.9
Mukesh	120 kg N	4.17		13.2	7.5	28.5
(N. Pasuram)	150 kg N	4.67	12.00	11.5	7.6	21.3
Dara Singh	120 kg N	4.33		14.1	7.5	24.9
	150 kg N	4.73	9.24	14.7	7.6	23.7
Narayan Singh	120 kg N	3.67		6.95	7.6	27.5
	150 kg N	4.00	9.00	6.65	8.1	22.4

Demonstrations were conducted at 9 recharge sites and compared with other farmer's yield (Table 32). The wheat yield varied from 4.12 to 4.99 t/ha while on other farmers fields the yield varied from 3.67 to 4.45 t/ha where high saline water was used as such. The increase in wheat yield varied from 7.7 to 12.1 per cent over farmer's field.

Table 32: Effect of saline water irrigation on wheat at recharge sites and soil parameters at harvest

Name of farmer	ORP yield (t/ha)	Farmer's yield (t/ha)	% Increase	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
Jagan Singh	4.99	4.45	12.1	11.3	7.3	21.9
Mukesh Kumar	4.67	4.20	11.1	12.5	7.3	24.0
Birendra Singh	4.25	3.80	11.8	19.0	7.2	27.0
Lal Hans	4.59	4.15	10.6	10.9	7.5	24.2
Dinesh Chand	4.31	4.00	7.7	12.7	7.6	27.6
Dhara Singh	4.85	4.40	10.2	11.6	7.3	21.0
Ram Bharosi (Raj. 4037)	4.25	3.80	11.8	16.45	7.2	33.6
Roop Singh	4.12	3.67	12.1	12.3	7.2	23.3
Hari Prasad	4.77	4.30	10.9	11.4	7.3	21.6

Table 33: EC_{iw} (dS/m) during different irrigations at rain water recharging sites (2012-13)

Name of farmer	Initial	Ist	IInd	IIIrd	IVth	Vth
Lal Hans	10.9	7.7	9.3	10.3	11.1	10.9
Ram Bharosi	15.0	10.7	11.8	13.1	14.6	14.4
Jagan Singh	12.6	9.2	11.0	13.3	14.1	10.8
Dhara Singh	15.2	9.1	11.8	13.2	15.3	13.7
Mukesh Kumar	13.8	9.1	10.3	11.6	13.7	13.4
Hari Prasad	13.5	10.0	11.9	13.1	13.5	13.5
Dinesh Chand	11.0	8.8	9.6	10.4	11.5	11.0
Birendra Singh	19.9	9.9	12.9	16.2	19.1	16.6
Roop Singh	23.5	8.9	13.4	17.2	20.1	20.5

The average water salinity at recharge sites varied from 7.7 to 10.7 dS/m at pre-sowing irrigation, 9.3 to 13.4 (dS/m) at 2nd irrigation, 10.3 to 17.2 at 3rd irrigation, 11.1 to 20.1 at 4th irrigation and 10.9 to 20.5 dS/m at 5th irrigation. Whereas the initial water salinity varied from 10.9 to 23.5 dS/m during 2012-13 (Table 33). During 2013-14, due to frequent rains in *rabi* season, the salinity of recharge waters did not increase as in previous year and only three irrigations were required for the maturity of the wheat crop (Table 34).

Table 34: EC_{iw} (dS/m) during different irrigations at rain water recharging sites (2013-14)

Name of farmer	Initial	Pre-sowing irrigation	Ist irrigation	IInd irrigation	IIIrd irrigation
Lal Hans	10.9	RCM	4.27	7.88	9.47
RamBharosi	15.0	„	5.91	8.12	-
Jagan Singh	12.6	„	5.36	8.73	10.56
Dhara Singh	15.2	„	5.36	8.77	12.17
Mukesh Km	13.8	„	5.50	8.66	11.23
Hari Prasad	13.5	„	5.89	8.98	11.28
DineshChand	11.0	„	5.06	8.26	10.31
BirendraSingh	19.9	„	5.59	9.11	13.21
Roop Singh	23.5	„	5.91	9.84	15.58

RCM: Rain conserved moisture

Low cost technology for dilution of saline ground water through artificial recharge

Agra-Bharatpur region in the states of Uttar Pradesh and Rajasthan are endowed with poor quality ground water aquifers. Shallow aquifers are relatively more saline (EC >10 dS/m) than deeper aquifers (EC 2-6 dS/m). The resource poor farmers of the region cannot afford to drill deep bores. They exploit the saline aquifers to irrigate crop by giving 1-2 life saving irrigations to mustard. Thus, under such a situation, yields are reduced due to high irrigation water salinity. Diluting saline ground water through artificial recharge could be adopted as a means to overcome this problem. In all, the technology has been designed and tested on 12 farmer's field. The technology consisted of diverting the run off to these structures for recharge (Fig. 71). The diluted ground water is then applied to irrigate mustard/wheat crops. The salinity of the ground water is reduced in most cases to about 4-6 dS/m but eventually reaches to its original value during 3rd or 4th irrigation. The irrigation with low quality water at initial growth stage boosts the yield to normal level in case of mustard and wheat.

Fig. 7: Low cost technology for dilution of saline groundwater through artificial recharge

BAPATLA: RESEARCH ACCOMPLISHMENTS

Studies at benchmark locations in Guntur district to monitor the changes in ground water quality and soil properties

Studies at 8 benchmark sites in Guntur district to monitor the changes in water quality revealed that salinity in ground water substantially increased at Nidubrolu-I (1.90 to 10.10 dS/m), Nidubrolu-II (1.20 to 5.76 dS/m), Machavaram (1.40 to 3.83 dS/m) and Chintalapudi (1.80 to 3.20 dS/m) which could be due to over exploitation of ground water leading to upconing of salt water and sea water intrusion. It decreased at Potarlanka (2.00 to 0.62 dS/m), Amarthaluru (2.60 to 1.18 dS/m) and Angalakuduru (0.72 to 0.58 dS/m) and marginally increased at Chiluvuru (1.85 to 2.11 dS/m). Initial high RSC decreased at all locations due to continuous pumping of water. The differences in pH were very marginal at all locations (Table 1). The salt content in soils at Patarlanka, Amarthaluru and Angalakuduru decreased over initial while slight salinity build-up occured at Chintalapudi and Machavaram locations (Table 2).

Table 1: Ionic composition of ground water at benchmark sites (2012-13)

Locations	Years	pH	EC (dS/m)	SAR $(mmol/l)^{1/2}$
Nidubrolu-I	1974	7.90	1.90	7.06
	2012-13	7.71	10.10	14.66
Nidubrolu-II	1974	7.50	1.20	0.21
	2012-13	7.88	5.76	13.03
Chintalapudi	1974	7.60	1.80	5.44
	2012-13	8.07	3.20	1.74
Machavaram	1974	7.90	1.40	4.45
	2012-13	8.04	3.83	1.75
Chiluvuru	2000	8.24	1.85	10.21
	2012-13	7.98	2.11	3.66
Potarlanka	2000	8.42	2.00	12.04
	2012-13	8.60	0.62	4.71
Amrutaluru	2000	8.35	2.60	15.59
	2012-13	8.77	1.18	6.02
Angalakuduru	2000	8.34	0.72	4.00
	2010-11	8.09	0.58	2.53

Table 2: Ionic composition of soil profiles at benchmark sites* (2012-13)

Locations	Depth (cm)	pH	EC_e (dS/m)	SAR (mmole/l) ½
Nidubrolu-I				
	0-15	8.06	1.65	0.76
	15-30	8.27	2.00	5.06
	30-60	8.37	1.85	3.55
Nidubrolu-II				
	0-15	8.15	3.01	5.40
	15-30	8.06	3.04	5.30
	30-60	8.12	3.03	6.28

Chintalapudi				
	0-15	5.61	3.12	2.65
	15-30	7.21	2.88	3.18
	30-60	7.70	3.89	1.58
Machavaram				
	0-15	7.98	2.34	0.84
	15-30	8.01	2.35	2.45
	30-60	7.26	2.85	3.86
Chiluvuru				
	0-15	6.78	1.98	0.58
	15-30	7.02	2.03	1.14
	30-60	6.92	1.79	1.68
Potarlanka				
	0-15	7.26	1.12	3.49
	15-30	6.92	1.38	0.73
	30-60	7.14	1.25	2.64
Amrutaluru				
	0-15	7.18	1.12	3.61
	15-30	7.25	0.92	3.03
	30-60	7.54	1.06	5.00
Angalakuduru				
	0-15	6.82	1.08	0.55
	15-30	7.27	0.8	0.78
	30-60	7.47	0.89	1.28

**samples were taken before monsoon*

Reclamation of abandoned aqua ponds

The experiment was conducted at 16 farmer's fields covering three villages during *kharif* 2012-13. Initial soil analysis indicated that pH and EC_e values ranged between 7.21-8.06 and 1.03-11.61 dS/m, respectively. Selected farmer's fields were levelled, leached using gypsum and dhaincha green manure was incorporated in-situ. Rice was taken with two different varieties viz., MTU-2716 and BPT-5204. A basal dose of $ZnSO_4$ was applied @ 50 kg/ha. N-P_2O_5 –K_2O was applied @ 180-40-40 kg/ha. With the adoption of these practices, fields of Edukondalu followed by V. Sivaramakrishna produced good yields (51.65 and 51.25 q/ha) as compared to other fields (Table 3, 4, 5).

During 2013-14, experiment was conducted in three villages namely Gokarnamatam, Adavuladeevi and Ganapavaram of Guntur district at 16 selected farmers' fields for raising rice. Initial soil pH, EC, available nitrogen, phosphorous and potassium ranged between 6.40- 8.45, 6.20-17.50 dS/m, 231-398, 22.8-45.3 and 303-480 kg/ ha, respectively. Initially chlorides and sodium were dominant anion and cations (Table 6). About 12 to 30 per cent increase in rice yield was observed as compared to check with the adoption of good reclamation practices. The highest yield (56.25 kg/ha) was recorded in Dasaradha Rami Reddy and V. Sivaramakrishna fields among the sixteen farmers (Table 7). EC values and chloride and sodium concentration in soils decreased as compared to initial values (Table 8). Available nitrogen decreased, whereas P_2O_5 and K_2O contents increased slightly as compared to initial status of the soil.

Table 3: Initial soil analysis for pH, EC and ionic composition during 2012-13

List of farmer	pH	EC_e (dS/m)	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	SAR $(mmol/l)^{1/2}$
			(meq/l)								
F1	7.38	4.09	0.0	3.80	22.12	15.22	8.5	11.20	17.09	4.81	5.45
F2	7.21	1.05	0.0	1.00	5.24	4.16	1.28	4.24	5.48	0.87	3.30
F3	7.22	2.42	0.0	1.60	13.12	9.17	1.85	4.40	18.42	1.35	10.42
F4	7.43	4.33	0.0	1.85	18.54	23.25	4.85	13.20	24.05	1.34	8.01
F5	7.53	3.51	0.0	1.84	16.30	17.5	4.80	15.20	13.88	1.16	4.39
F6	7.61	1.43	0.0	0.80	6.58	7.04	4.20	6.85	3.95	0.30	1.68
F7	7.45	1.88	0.0	1.10	6.54	10.65	1.60	8.35	7.25	0.98	3.25
F8	7.81	1.38	0.0	1.42	5.80	6.16	1.20	5.60	6.17	0.80	3.35
F9	7.42	3.68	0.0	4.40	10.20	21.55	2.80	8.56	24.25	1.24	10.18
F10	8.06	1.87	0.2	7.60	4.70	5.55	3.20	5.60	9.88	0.81	4.71
F11	7.53	1.03	0.0	1.20	4.66	5.22	1.58	4.80	5.96	0.17	3.34
F12	7.52	11.61	0.0	20.50	56.12	39.30	28.40	39.14	44.50	4.66	7.66
F13	7.46	5.24	0.0	1.60	24.20	26.20	1.20	14.50	36.25	1.67	12.94
F14	7.71	3.67	0.0	1.60	12.80	22.30	5.35	10.84	19.75	2.26	6.94
F15	7.73	10.82	0.0	10.20	46.50	51.50	21.6	32.50	51.08	2.75	9.82
F16	7.76	1.37	0.0	0.50	2.05	11.42	2.20	4.70	6.27	0.56	3.38

Name of farmers: F1: Dasaradharami Reddy; F2: Edukondalu; F3: Uppala Pushpavathi; F4: Vankayala Sivaramakrishna; F5: Vankayala Sambasiva Rao; F6: Morla Suri Babu; F7: MorlaVenkateswara Rao; F8: Veeranki Venkateswara Rao; F9: Sonti Naga Krishna; F10: UppalaVenkateswara Rao; F11: A. Sambasiva Rao; F12: Kodala Dakshnayamma; F13: Kodala Syamala Kumar; F14: Devireddy Srinivasa Rao; F15: Sanivarapu Edukondalu; F16: Punugu Venkateswara Reddy

Table 4: Rice yield obtained in Aqua ponds of farmer's during 2012-13

List of farmers	Village	Untreated (q/ha)	Treated (q/ha)
F1	Gokarnamatam	35.85	41.50
F2	"	40.50	51.65
F3	Adavuladeevi	39.50	50.25
F4	"	41.50	51.25
F5	"	35.65	48.50
F6	"	40.25	50.50
F7	"	Crop damaged due to heavy rainfall	
F8	"	38.65	42.50
F9	"	Crop damaged due to heavy rainfall	
F10	"	40.25	50.25
F11	"	38.50	42.50
F12	Ganapavaram	35.50	40.50
F13	"	Crop damaged due to heavy rainfall	
F14	"	39.55	46.35
F15	"	38.65	47.50
F16	"	35.65	41.25

Table 5: Final soils analysis for pH, EC and ionic composition during 2012-13

List of farmer	pH	EC (dS/m)	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	SAR mmol/l$^{1/2}$
			(meq/l)								
F1	7.15	2.15	0.0	0.80	1.51	1.45	0.52	1.07	0.70	0.23	0.79
F2	7.11	0.95	0.0	1.00	5.74	2.56	1.28	4.24	3.48	0.45	2.09
F3	7.05	1.45	0.0	0.60	8.12	5.17	0.85	4.40	8.42	0.58	5.20
F4	7.11	1.85	0.0	0.85	5.55	11.85	4.85	11.58	2.56	1.34	0.89
F5	7.36	1.25	0.0	0.84	5.30	6.50	3.65	5.20	3.25	0.16	1.54
F6	7.28	0.87	0.0	0.80	5.58	1.14	2.40	3.85	1.95	0.30	1.10
F7	7.15	0.92	0.0	1.10	4.84	3.58	0.80	6.35	2.15	0.98	1.14
F8	7.08	0.97	0.0	1.05	3.56	5.40	1.25	3.6	5.17	0.80	3.32
F9	7.15	1.55	0.0	2.50	7.20	6.55	2.80	8.56	4.25	1.24	1.78
F10	7.48	0.88	0.2	1.60	2.70	5.55	3.20	5.60	0.80	0.54	0.38
F11	7.25	0.52	0.0	0.20	4.66	1.22	0.58	2.80	1.96	0.17	1.51
F12	7.33	5.65	0.0	10.15	26.12	20.3	18.4	29.14	4.58	4.66	0.94
F13	7.20	1.25	0.0	1.60	9.20	1.87	2.70	4.50	4.25	1.37	2.24
F14	7.20	0.75	0.0	1.60	2.80	3.80	1.35	4.84	1.40	0.26	0.80
F15	7.11	4.35	0.0	10.20	26.5	7.25	11.6	22.5	9.08	0.75	2.20
F16	7.22	1.15	0.0	1.50	4.05	6.42	2.20	4.7	4.27	0.56	2.30

Table 6: Initial soil analysis for pH, EC and ionic composition during 2013-14

List of farmer	pH	EC (dS/m)	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	SAR mmol/l$^{1/2}$
			(meq/l)								
F1	7.96	16.45	0.0	3.2	159.0	2.38	32.0	55.6	75.13	2.88	11.35
F2	7.85	11.35	0.0	5.6	110.0	0.32	18.0	26.0	69.40	1.31	14.80
F3	8.36	9.73	0.0	6.6	91.6	0.23	18.0	25.0	54.00	1.76	11.65
F4	8.45	6.20	0.0	4.2	58.0	0.27	8.0	4.4	49.00	0.97	19.68
F5	7.84	13.00	0.0	5.4	125.0	0.36	15.6	28.4	84.70	1.67	18.06
F6	8.86	14.50	0.0	6.4	138.6	0.21	35.8	22.8	84.60	1.80	15.63
F7	8.40	10.37	0.0	6.8	97.2	0.25	10.0	26.0	66.18	1.40	15.60
F8	8.48	9.07	0.0	3.6	88.0	0.34	13.6	14.2	60.70	1.55	16.28
F9	8.77	9.55	0.0	5.4	89.5	0.65	11.2	18.4	64.09	1.46	16.66
F10	8.30	9.30	0.0	2.0	90.6	0.43	13.6	17.2	60.83	1.42	15.50
F11	8.20	11.30	0.0	4.8	108.0	0.09	16.0	16.8	79.00	1.49	19.51
F12	7.65	5.80	0.0	4.8	54.0	0.30	14.4	7.6	34.89	1.22	10.52
F13	7.97	11.50	0.0	5.6	110.0	0.24	12.8	9.6	92.00	1.15	27.49
F14	8.40	11.10	0.0	1.2	110.0	0.28	14.8	21.2	74.80	1.35	17.63
F15	7.88	17.50	0.0	6.8	168.0	0.25	21.2	41.6	112.00	1.50	19.99
F16	7.47	12.90	0.0	5.9	124.0	0.54	21.2	15.2	91.10	1.76	21.35

Table 7: Rice yield obtained in Aqua ponds of farmers during 2013-14

List of farmer	Village	Untreated (q/ha)	Treated (q/ha)	Yield increase (%)
F1	Gokarnamatam	45.00	56.25	25
F2	"	39.38	48.75	24
F3	Adavuladeevi	41.25	46.88	14
F4	"	46.88	56.25	20
F5	"	37.50	46.88	25
F6	"	35.63	45.00	26
F7	"	33.75	43.13	28
F8	"	37.50	46.88	25
F9	"	37.50	45.00	20
F10	"	31.88	37.50	18
F11	"	37.50	48.75	30
F12	Ganapavaram	39.38	48.75	24
F13	"	41.25	48.75	18
F14	"	41.25	52.50	27
F15	"	48.75	54.38	12
F16	"	35.63	45.00	26

Table 8: Final soils analysis for pH, EC and ionic composition during 2013-14

List of farmer	pH	EC (dS/m)	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	SAR mmol/l$^{1/2}$
			(meq/l)								
F1	7.1	2.97	0.00	1.30	18.80	0.40	5.60	3.60	19.32	0.65	9.0
F2	7.6	5.06	0.00	1.30	48.60	0.81	16.80	11.00	21.57	1.28	5.8
F3	7.9	2.42	0.00	2.00	22.00	0.82	6.80	6.40	10.32	0.83	4.0
F4	7.6	3.81	0.00	1.80	36.00	0.67	7.20	11.20	18.66	1.27	6.2
F5	7.4	3.72	0.00	1.30	34.86	1.19	4.80	3.60	28.20	2.00	13.8
F6	8.3	3.50	0.00	2.90	32.00	0.28	4.00	3.60	27.29	0.59	14.0
F7	8.2	3.11	0.00	2.20	28.00	1.01	4.60	3.40	22.54	0.78	11.3
F8	8.3	2.81	0.00	3.00	26.00	0.49	4.80	2.00	20.63	0.68	11.2
F9	8.5	3.10	0.00	3.60	28.00	0.28	3.20	2.40	25.56	0.65	15.3
F10	8.2	3.33	0.00	3.20	30.00	0.14	5.20	3.40	23.40	1.14	11.3
F11	7.4	3.65	0.00	1.20	34.00	2.06	8.60	6.40	20.98	1.77	7.7
F12	7.3	2.48	0.00	1.20	22.00	2.20	5.60	4.80	14.00	1.15	6.1
F13	7.4	3.86	0.00	1.40	36.00	1.98	11.80	8.00	18.00	1.16	5.7
F14	7.9	5.19	0.00	2.20	48.80	0.54	6.00	11.92	32.81	0.63	11.0
F15	7.6	4.60	0.00	0.80	45.20	0.19	4.40	8.00	34.20	0.46	13.7
F16	7.3	4.05	0.00	3.80	36.00	0.85	12.40	8.60	16.89	0.58	5.2

ORP on Improvisation and demonstration of reclamation technologies for alkali soils

Five farmers were identified in Guntur district and initial soil samples were collected and analyzed for EC, pH, ESP, available N, P, and K. The pH and EC of soil samples varied from 8.52 to 8.85 and 0.17 to 0.37 dS/m, respectively. Soil available N was low (135-198 kg/ha), P_2O_5 was low to medium (15.8-21.2

kg/ha) and K_2O was low to high (178-320 kg/ha). The inputs like green manure (Dhaincha) seed @ 30 kg/ha and zinc sulfate @ 50 kg/ha were distributed to the identified farmers. Dhaincha as green manure crop was incorporated at 50 per cent flowering stage. The rice (var. NLR- 9674) was transplanted during Oct, 2012. Final soil samples were collected after harvest of the crop in January, 2013. Highest yield (62.00 q/ha) was recorded in P. Bikshalu field with the application of reclamation practices (Table 9, 10, 11).

Table 9: Details of ORP sites in village PV Palem, Bapatla, district Guntur during 2012-13

Name of farmer	Cropping System	Initial soil properties							
		pH	EC (dS/m)	CEC	Ex. Na	ESP (%)	Av. N (kg/ha)	Av.P_2O_5 (kg/ha)	Av. K_2O (kg/ha)
D Gopaiah	Rice – Fallow	8.76	0.37	35.5	7.27	20.5	135	15.8	178
PS Reddy	Rice - Fallow	8.52	0.23	34.8	6.50	18.7	177	20.5	270
D Venkaiah Reddy	Rice- Fallow	8.83	0.17	32.5	5.13	15.8	156	16.7	185
D Krishna Rao	Rice - Fallow	8.85	0.43	35.5	6.53	18.4	183	21.2	320
P Bikshalu	Rice-Fallow	8.80	0.35	34.7	7.13	20.5	198	20.85	255

(Area 0.5 ha)

Table 10: Final soil properties during 2012-13

Name of farmer	pH	EC (dS/m)	CEC	Ex. Na	ESP (%)	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)
D Gopaiah	7.71	0.23	31.8	4.89	15.4	141	23.5	206
PS Reddy	7.30	0.21	32.5	4.29	13.2	182	26.8	287
D Venkaiah Reddy	7.20	0.42	30.8	3.85	12.5	168	25.2	201
D Krishna Rao	7.25	0.32	34.8	5.84	16.8	190	28.9	332
P Bikshalu	7.15	0.30	32.5	5.07	15.6	205	25.3	269

Table 11: Rice yield as influenced by adoption of reclamation technologies in alkali soils of Guntur district during 2012-13

Name of farmer	Yield (q/ha)		% increase over untreated	Gross returns (Rs/ha)*	Net returns (Rs/ha)*
	Treated	Untreated			
D Gopaiah	51.35	40.35	27.3	82160	38760
PS Reddy	55.85	48.55	15.0	89360	45960
D Venkaiah Reddy	60.75	49.25	23.4	97200	53800
D Krishna Rao	58.50	44.65	31.0	93600	50200
P Bikshalu	62.00	50.15	23.6	99200	55800

** Gross and net returns for treated fields; cost of cultivation: Rs. 43400/ha; Price of Rice: Rs. 1600/q*

The soil properties viz., EC, pH and ESP were studied and it was found that these got reduced as compared to initial values. The available nutrients (NPK) of the soil improved and it might be due to release of fixed nutrients from the soil and incorporation of dhaincha as green manure (Table 9, 10).

The data presented in Table 11 showed that higher grain yield was recorded in treated plots as compared to un-treated plots at all locations. The increase in yield ranged between 15.0-31.0 per cent at all locations. Highest gross and net returns were recorded in treated plots than farmers practice.

Effect of sea water intrusion on ground water quality in coastal belt of Krishna Zone, AP

During 2012-13, one hundred twenty water samples were collected by fixing GPS coordinates along the coastal region of Krishna Zone of Andhra Pradesh. The pH and EC values of ground water samples during June, 2012 were 6.95 to 9.11 and 0.57 to 20.6 dS/m respectively (Table 12). It is found that the Na salt content was high among all ions. Intrusion of sea water during June, 2012 was confirmed based on the ionic ratios of water samples. Water samples collected during December 2012 were presented in Table 13. During Pre-monsoon period, highest EC (13.85 dS/m) observed in Machilipatnam, highest pH (8.84) in Nizampatnam, highest SAR (33.37) in Kanaparthi and highest RSC (12.6 meq/l) were observed in Nizampatnam points. During post-monsoon period EC ranges between 0.66-12.69 dS/m and pH showed neutral to medium alkaline in nature at all the points.

Table 12: Point wise ranges of pH and EC during pre and post monsoon periods (2012)

Points	Pre-monsoon			Post-monsoon		
	EC (dS/m)		pH	EC (dS/m)		pH
	Range	Mean	Range	Range	Mean	Range
Suryalanka	1.0-8.6	2.67	6.95 - 8.52	0.7-8.3	2.98	6.97 - 8.08
Machilipatnam	0.6-20.6	3.99	7.21 - 8.54	0.7-12.4	3.52	7.25 - 8.12
Nizampatnam	0.9-7.9	2.42	7.51 - 9.11	0.7-12.7	2.93	6.95 - 8.38
Kanaparthi	0.9-5.8	2.81	7.18 - 9.07	0.7-5.5	3.12	6.68 - 8.53

Table 13: Ionic ratios of good quality and sea water

Ionic ratio	Good quality water	Sea water
Ca/Mg	3.72	0.18
Ca/Na	3.74	0.04
Mg/Na	3.85	0.26
Ca/SO_4	0.41	3.16
Mg/HCO_3	0.52	18.96
Cl/HCO_3	0.20	65.72
SO_4/HCO_3	0.45	7.10
HCO_3/SO_4	2.32	0.08
HCO_3/Cl	4.58	0.007
Cl/SO_4	0.45	9.85

Table 14: Point wise ranges of pH and EC during post monsoon periods during December 2013

Points	Post-monsoon					
	EC (dS/m)		pH	RSC (meq/l)	SAR	
	Range	Mean	Range	Range	Range	Mean
Suryalanka	0.80 - 7.59	2.43	6.38 - 7.96	Nil-5.80	1.38 -20.36	7.28
Machilipatnam	0.58 - 4.60	1.99	6.9 - 7.8	Nil-5.80	1.45 - 13.79	4.64
Nizampatnam	0.65 - 8.41	2.22	6.60 - 7.65	Nil-5.20	1.56 - 14.65	5.61
Kanaparthi	0.39 - 6.40	2.31	7.23 - 7.86	Nil-2.40	0.63 - 21.52	5.56

During 2013-14 also one hundred twenty water samples were collected. The pH and EC of ground water samples during December 2013 ranged between 6.38 - 7.96 and 0.39 - 8.41 dS/m. The pH was neutral to medium alkaline in nature at all the points. During post monsoon, highest pH (7.96) and EC (8.41 dS/m) was observed in Nizampatnam and Suryalanka, respectively. Highest SAR (21.52) and RSC (5.80 meq/l) were recorded in Kanaparthi and Suryalanka (Table 14).

Delineation and mapping of salt affected soils of Andhra Pradesh

Delineation and mapping of salt affected soils is carried out by using satellite imageries. During 2012-13, satellite imaginaries of Vijayanagaram and Srikakulam were obtained from NRSC Hyderabad. Digitization work and collection of soil samples for Srikakulam, Vijayanagaram, Visakhapatnam and Chittoor is completed. Analysis of soil samples was completed and tabulated (Table 15). Digitization and mapping work is in progress.

Table 15: Soil EC and pH of different districts for delineation and mapping of salt affected soils

District	Depth	pH range	EC range
Srikakulam	0-20	6.52 - 7.93	0.31 - 10.90
	21-50	6.39 -7.96	0.23 - 14.18
	51-80	6.58 - 7.92	0.28 - 20.60
Vizianagaram	0-20	6.74 - 8.07	0.17 - 11.93
	21-50	6.98 - 8.15	0.19 - 14.90
	51-80	6.89 - 8.23	0.21 - 12.50
Visakhapatnam	0-20	67.9 - 7.90	0.27 - 17.88
	21-50	6.95 - 8.03	0.22 - 9.75
	51-80	7.02 - 8.10	0.24 - 10.77
Chittoor	0-20	6.72 - 7.96	0.32 - 11.52
	21-50	6.48 - 8.01	0.26 - 12.52
	51-80	6.34 - 8.12	0.31 - 10.75

During 2013-14, soil survey was conducted in 10 districts of Andhra Pradesh. Mapping and digitisation of surveyed area has been done done based on satellite imageries of 2010. Soil pH_s and EC_e values of three districts viz., West Godavari, East Godavari and Ananthapur are presented in Table 16. The analytical data indicated that the soil electrical conductivity (EC_e) ranged between 0.23-53.0 dS/m and pH_s ranged between 7.0 - 9.4.

Table 16: Analysis of soils of different districts for delineation and mapping of salt affected soils

District	Depth	pH_s range	EC_e range (dS/m)
West Godavari	0-20	7.13 - 8.49	0.24 - 2.64
	21-50	7.22 - 8.04	0.23 - 1.98
East Godavari	0-20	6.58 - 7.66	12.5 - 53.0
	21-50	6.65 - 7.63	8.9 - 35.5
	51-80	7.60 - 7.62	13.4 - 31.9
Ananthapur	0-20	7.00 - 9.30	0.4 - 14.1
	15-30	7.20 - 9.40	0.3 - 13.4
	30-60	7.40 - 9.10	0.3 - 9.5

Screening of maize, bengal gram, Bt. Cotton, mustard and paddy varieties for salt tolerance

During 2012-13, experiment was laid out in factorial RBD. The treatments comprised 3 maize hybrids viz., Sandhya, DHM 117 and 30V 92 with five levels of saline water (BAW, 2, 4, 6 and 8 dS/m). The crop was sown on 17-11-2012. At EC 8 dS/m the germination of maize was about 40%. Initial soil samples revealed that pH was 7.11 and EC was 0.17 dS/m, available nitrogen 292 kg/ha, available phosphorus 33.6 kg/ha and available potash 413 kg/ha (Table 17). The highest seed yield was recorded in hybrid Sandhya (71.58 q/ha) with best available water, the yields decreased with increased EC of irrigation water. Hybrid 30V 92 produced highest grain yield at different EC levels as compared to other hybrids during 2012-13 (Table 18). Pooled data of maize revealed that 30V 92 hybrid recorded highest yield (60.08 q/ha) and performed best with increasing EC levels of irrigation water as compared to Sandhya and DHM -117 (Table 19). Among all hybrids significant yield decrease was recorded with increasing EC of irrigation water. Analysis of final soil samples after harvest of the crop showed that soil EC increased slightly (Table 20) over initial values because of heavy rainfall (69.4 mm) received during February 2013. Available NPK were decreased as compared to initial values, this might be due to heavy uptake of nutrients by the crop.

Table 17: Initial soil analysis of experimental field

pH	EC (dS/m)	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O kg/ha)
		(meq/l)										
7.11	0.17	0.0	2.52	1.95	0.52	3.50	2.80	35.50	0.52	292	33.6	413

Table 18: Effect of different salinity levels of irrigation water on yield of maize (q/ha)

Treatments	30V 92	Sandhya	DHM-117
EC of irrigation water			
BAW	68.95	71.58	69.72
2 dS/m	63.37	58.21	54.27
4 dS/m	55.37	43.32	44.28
6 dS/m	50.29	42.66	38.58
8 dS/m	45.18	35.86	33.52
Mean	56.63	51.33	48.08
	S Em ±	CD (5%)	CV (%)
Main	11.9	34.60	8.89
Sub	15.4	44.67	8.89
Interaction	26.7	NS	-

Table 19: Yield of maize at different EC levels during 2010-11 to 2012-13

Treatments	Yield (q/ha)			
	2010-11	2011-12	2012-13	Pooled
Hybrids				
30V 92	75.71	76.17	56.63	60.08
Sandhya	81.83	65.74	51.32	52.08
DHM 117	67.78	53.38	48.08	52.01
S Em ±	2.91	1.75	1.19	1.16
CD (5%)	8.53	5.14	3.46	1.63
CV (%)	13.42	8.05	8.89	8.18

EC of irrigation water (dS/m)				
BAW	85.08	88.06	70.08	80.08
2 dS/m	82.45	66.83	58.62	69.30
4 dS/m	68.29	58.15	49.33	58.59
6 dS/m	64.58	50.34	43.85	52.93
8 dS/m	-	-	38.19	12.73
S Em $\pm$	3.36	1.52	1.54	2.11
CD (5%)	9.85	4.45	4.47	4.32
CV (%)	13.42	8.05	8.89	8.18
Interaction				
S Em $\pm$	5.82	3.04	2.67	3.65
CD (5%)	NS	1051	NS	7.48

Table 20: Final soil analysis data of maize crop to different salinity levels of irrigation

Treatments	EC (dS/m)	pH	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)
			Sandhya		
BAW	0.16	7.45	275	29	380
2 dS/m	0.13	7.32	245	35	340
4 dS/m	0.13	7.28	230	34	362
6 dS/m	0.20	7.67	255	28	345
8 dS/m	0.21	7.55	282	33	343
			30V 92		
BAW	0.17	8.01	195	30	395
2 dS/m	0.18	7.83	220	31	365
4 dS/m	0.16	7.67	235	30	354
6 dS/m	0.20	7.49	220	26	389
8 dS/m	0.22	7.25	215	34	333
			DHM 117		
BAW	0.15	7.76	275	28	384
2 dS/m	0.17	7.72	258	30	389
4 dS/m	0.18	7.43	270	32	370
6 dS/m	0.20	7.32	265	27	345
8 dS/m	0.24	7.25	260	34	356
Bulk	0.15	7.39	270	31	350

Bengal gram

During 2012-13, an experiment was laid out in RBD with five replications at Uppugunduru village of Prakasam district with four Bengal gram varieties viz., JG-11, JG-130, KAK-2 and Nbeg. Seed was treated with Rhizobium culture before sowing. Initial soil pH was 7.13 and EC was 4.99 dS/m, available nitrogen was 188 kg/ha, phosphorus 21.0 kg/ha and potasium 484 kg/ha (Table 21). The highest yield was recorded in KAK-2 variety (10.17 q/ha) followed by JG-11 (9.34 q/ha) during 2012 (Table 22). Pooled data revealed that variety KAK-2 performed well and significantly highest yield (3.57 q/ha in 2010 and 10.03 q/ha in 2011 and 10.17 q/ha in 2012 was observed than JG-11 and JG-130 varieties. The lowest yield obtained during 2010 was due to delayed sowing and continuous rainfall. Available nitrogen was slightly increased over initial status and phosphorus and potassium were decreased as compared to initial values (Table 23).

Table 21: Initial soil parameters

Soil parameters	Value	Soil parameters	Value
pH	7.13	Mg (meq/l)	11.48
EC (dS/m)	4.99	Na (meq/l)	36.5
CO_3 (meq/l)	-	K (meq/l)	0.65
HCO_3 (meq/l)	1.85	Available Nitrogen (kg/ha)	188
Cl (meq/l)	5.60	Available phosphorus (kg/ha)	21
SO_4 (meq/l)	4.16	Available potassium (kg/ha)	484
Ca (meq/l)	20.55		

Table 22: Pooled yield data of Bengal gram crop

Bengal gram varieties	2010	2011	2012	Pooled
KAK-2	3.57	10.03	10.17	7.92
JG-11	1.64	9.20	9.34	6.73
JG-130	1.62	8.05	8.08	5.92
NBeg	2.14	7.90	8.39	6.18
CD (5%)	2.98	143.5	10.15	8.28
CV (%)	9.7	10.4	8.2	9.0

Table 23: Final soil parameters and sodium and potassium in plant samples of Bengal gram

Soil characters	JG-11	JG-130	KAK-2	Nbeg
pH	7.20	6.9	7.16	7.02
EC (dS/m)	4.95	4.89	5.05	4.85
Av. N (kg/ha)	260	268	248	240
Av. P_2O_5(kg/ha)	34.0	31.5	31.0	29.3
Av. K_2O (kg/ha)	482	452	480	452
Na (%) in plant	0.172	0.135	0.195	0.085
K (%) in plant	2.15	2.38	1.68	2.26

Bt. cotton: The experiment was not initiated during *kharif* 2013-14 due to unfavorable climatic and soil conditions at the beginning of the season. Excessive rainfall (64%) was received than the normal (271 mm) from June to August, 2013.

Mustard: The experiment was conducted at Uppugunduru village (ORP site) with three mustard varieties viz., CS-52, CS-54 and CS-56 during *rabi* 2013. Excessive rainfall (407.8 mm) was received during November than the normal rainfall (251.3 mm) (Table 24). The optimum plant population was not established in the all the three varieties due to excessive soil moisture. Hence, the experiment was not monitored.

Table 24: Rainfall received during June-September 2013

Months	Rainfall (mm)		
	Normal	Received	% excess to normal
June	57.8	67.8	17.3
July	95.1	141.6	48.9
August	118.0	235.2	99.3
September	163.7	179.6	9.7

Experiment was conducted at SWS fields with three mustard varieties viz., CS-52, CS-54 and CS-56, 10 germplasm lines viz., L1 to L10, check-1 and check-2 with different EC irrigation water during *rabi* 2013. Yield and yield parameters presented in Table 25, 26. Among three varieties, CS-56 recorded the highest yield as compared to other varieties. Among germplasm lines, L4 line recorded the highest yield followed by L3 and L5 as compared to check-1 and check-2.

Table 25: Performance of mustard germplasm lines at SWS field, Bapatla during *rabi* 2013-14

Variety/ Germplasm Line	Germination (%)	Days to 50% flowering	Plant height (cm)	No. of primary branches	No. of secondary branches	Main shoot length (cm)	Siliqua on main shoot	Seed yield (q/ha)
L1	92	60	96	5.5	9.7	92	85	9.58
L2	95	59	113	5.33	9.2	108	90	9.90
L3	91	62	119	6.33	11.5	115	115	10.68
L4	88	55	116	6.59	10.3	112	88	11.43
L5	89	59	108	6.50	10.6	102	95	10.48
L6	89	62	115	3.4	6.7	104	90	6.90
L7	90	56	105	4.84	8.6	100	88	9.35
L8	91	53	122	4.4	8.5	120	97	8.20
L9	95	59	122	3.7	5.9	118	96	5.18
L10	90	53	139	4.8	6.3	126	90	5.48
Check- I	89	60	122	4.8	10.9	118	85	7.25
Check- II	92	57	127	5.1	8.1	124	100	9.55

Date of sowing: 20-11-2013; date of harvesting: 20-02-2014

Table 26: Performance of mustard varieties at SWS fields, during *rabi* 2013-14

Variety	Germination (%)	Days to 50% flowering	Plant height (cm)	No. of primary branches	No. of secondary branches	Main shoot length (cm)	No. of siliqua on main shoot	Seed yield (q/ha)
CS-52	96	52	94	6.50	10.58	84	112	7.93
CS-54	92	57	97	7.60	11.92	90	118	8.10
CS-56	95	55	92	7.22	11.40	86	115	9.86

Date of harvesting: 15-02-2014

Paddy: This experiment was conducted in Ponnapalli village. In this experiment yield and yield attributing characters viz., productive tillers, grains per panicle and test weight was higher in CSR 36 variety as compared to other varieties. Grain yield (57.5 q/ha) of CSR 36 was highest (Table 26) as compared to other varieties and lowest yield was recorded with MTU 1061 variety (52.0 q/ha).

Table 27: Yield attributes and yield of paddy varieties

Variety	Plant height (cm)	Productive tillers/m^2	Filled grains/ panicle	Grain Yield (q/ha)	Straw Yield (q/ha)	Test weight (g)	Harvest index (%)
CSR 36	93.0	504	175	57.50	76.96	28.7	42.77
CSR 27	99.5	576	155	52.50	67.50	26.8	43.82
MCM 100	98.0	330	150	48.00	57.70	24.5	45.43
MTU 1010	84.0	315	120	45.00	54.10	25.4	45.35
MCM 101	97.0	352	165	46.00	55.10	22.5	45.47
MTU 1061	95.0	350	135	44.00	52.00	18.9	47.57
S Em ±	3.57	15.94	10.12	2.25	2.51	0.99	1.51
CD (5%)	NS	47.03	29.85	6.65	7.40	2.92	NS
CV (%)	8.5	8.8	15.1	10.6	9.3	9.1	7.5

Management of high RSC water in heavy textured soils

The experiment was initiated at Perumgudipalli of Kanigiri mandal in Prakasam district during *kharif* 2012 (Table 28, 29). The results suggested that application of gypsum based on neutralization of RSC (>2.4 meq/l) gave significantly higher grain yield (58.14 q/ha) and straw yields (71.08 q/ha) than the grain yield by farmers practice (41.30 q/ha), being higher by about 40.8%. The highest grain yields might be due to contribution of higher number of tillers per hill and filled grains per panicle (Table 30). Harvest index was found to be superior with gypsum based neutralization of RSC water than other treatments (Table 31). The nutrient (macro and micro) status improved after three years of study which might be due to application of gypsum. Pooled data for 2010-2012 also revealed the same trend.

Table 28: Soil status of the experimental site

Treatments	Initial					Final				
	EC_e (dS/m)	pH	Nutrient status (kg/ha)			EC_e (dS/m)	pH	Nutrient status (kg/ha)		
			N	P	K			N	P	K
T_1	2.63	8.01	167	28.5	414	0.53	8.75	190	34.9	431
T_2	2.75	8.09	220	35.2	319	0.43	8.55	241	42.5	355
T_3	3.56	7.89	185	42.2	408	0.31	7.68	232	38.9	425
T_4	4.36	7.79	209	32.4	393	0.66	7.54	218	41.5	411
T_5	2.35	8.05	159	24.1	356	0.43	7.60	192	39.8	382

T_1: Foliar spray (2) with 2% $FeSO_4$ at 5 days interval; T_2:Passing RSC water through gypsum; T_3:Gypsum application; T_4:Top dressing of gypsum thrice @3.75 t/ha at 20,30,40 days; T_5: Control

Table 29: Water analysis of the experimental site

Initial			Final		
EC (dS/m)	pH	RSC (meq/l)	EC (dS/m)	pH	RSC (meq/l)
2.91	7.92	6.30	3.21	7.85	7.1

Table 30: Yield attributes of rice as influenced by treatments under management of high RSC water

Treatments	Effective tillers/sqm			Filled grains/panicle			Test weight (g)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
T_1	332	264	310	126	134	144	15.3	16.9	15.4
T_2	259	240	328	118	140	145	14.8	17.2	16.5
T_3	296	366	350	136	149	159	14.8	17.4	16.8
T_4	405	449	410	147	150	167	15.3	17.5	17.0
T_5	286	251	295	124	130	145	15.0	16.8	15.0
CD (5%)	56	71	67	NS	8	16	NS	0.3	0.4
CV (%)	14.8	16.8	12.8	11.5	4.2	6.7	3.5	1.1	1.5

Table 31: Rice as influenced by different treatments under management of high RSC water

Treatments	Grain yield (q/ha)			Straw yield (q/ha)			Harvest Index (%)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
T_1	39.96	38.37	42.23	63.50	59.70	57.53	38.6	39.0	42.3
T_2	43.61	41.16	48.98	60.50	57.94	72.94	41.9	42.0	40.2
T_3	44.24	48.52	44.91	64.00	65.04	66.30	40.9	43.0	40.4
T_4	52.20	54.20	58.14	70.10	70.86	71.08	42.7	43.0	45.0
T_5	38.66	37.81	41.30	63.50	54.25	61.24	37.8	41.0	40.3
CD (5%)	4.13	4.72	5.26	4.97	6.30	6.51	-	-	-
CV (%)	6.7	8.0	7.2	6.1	7.6	6.4	-	-	-

Performance of groundnut with saline water through drip irrigation system

The experiment was conducted on sandy loam soils at SWS fields, Bapatla during *rabi* 2013-14. The soil was neutral in reaction with pH 7.5 and EC 0.5 dS/m. Initial soil available NPK status was low, medium and high respectively (Table 32). The results revealed that maximum pod yield (15.15 q/ha) was recorded in Kadiri 7 variety which was at par with Kadiri 6 (12.38 q/ha). The lowest yield (12.05 q/ha) was obtained with Anantha variety (Table 33). Among salinity levels, highest pod yield (17.25 q/ha) was obtained with BAW which was superior to all EC levels. However, groundnut varieties can be grown with saline water of EC 4 dS/m.

Table 32: Initial soil status

pH	EC_e (dS/m)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_20 (kg/ha)
7.5	0.5	295	27	320

Table 33: Groundnut as influenced by saline water irrigation through drip system

Treatments	Plant height (cm)	Dry matter accumulation (kg/ha)	Grain yield (kg/ha)	Stover yield (kg/ha)	Oil content (%)
Varieties					
Anantha	17.87	2828	1205	2431	45.05
Kadiri 6	23.42	3153	1238	2563	46.14
Kadiri 7	24.15	3226	1515	2735	38.09
S Em ±	0.41	51	30	34	0.11
CD (5%)	1.40	176.76	102.0	116.26	0.36
CV (%)	5.87	5.26	7.0	4.12	0.77
EC of irrigation water					
BAW	26.54	3588	1725	3229	47.38
2 dS/m	24.42	3369	1525	2948	45.25
4 dS/m	23.13	3100	1408	2767	43.85
6 dS/m	18.58	2700	1050	2079	41.26
8 dS/m	16.42	2588	888	1858	37.75
S Em ±	0.59	85.4	64.59	69.98	0.13
CD (5%)	1.65	236.73	179.0	193.96	0.36
CV (%)	6.6	6.81	11.9	6.65	0.75
Interaction					
S Em ±	0.63	90.6	68.5	74.23	0.14
CD (5%)	NS	251.0	NS	NS	0.39
CV (%)	6.7	6.8	12	6.7	0.8

Strategies for conjunctive use of canal and saline ground waters for improving productivity of rice

During *kharif* 2012-13, experiment was carried out in farmer's field at Ponnapalli village of Cherukupalli mandal in Guntur district. Six treatments comprised of T_1 (1 CW: 1 SW); T_2 (1 SW : 1 CW); T_3 (1 CW : 2 SW); T_4 (2 CW : 1 SW); T_5 (CW only) and T_6 (SW only). The experimental soil was sandy clay loam, its initial and final properties are given in Table 34. EC, pH and RSC of canal and ground water were 0.91 dS/m, 7.25, 1.85 meq/l and 6.82 dS/m, 7.10, 6.20 meq/l respectively.

Table 34: Soil characteristics and nutrient status of the experimental site

Treatments	EC_e (dS/m)	pH	Av. N (kg/ha)	Av. P_2O_5 (kg/ha)	Av. K_2O (kg/ha)
Initial	1.03	7.35	262	36.7	459
Final					
T_1	1.05	7.26	251	31.9	431
T_2	1.27	7.30	262	34.5	455
T_3	1.10	7.01	241	28.0	416
T_4	0.25	7.15	228	22.9	441
T_5	0.98	7.22	255	25.7	450
T_6	1.87	7.17	230	23.1	425

The plant height was highest with 1 CW:1 SW irrigation (Table 35). The yield components (effective tillers/sqm, filled grains/panicle and test weight) were higher with only canal water irrigation but was at par with 2CW:1SW. Results revealed that significantly highest grain yields were recorded with 2CW:1SW in cyclic mode than only saline ground water and it was at par with only canal water or 1CW:1SW. Similar trend was observed in straw yield. The maximum harvest index (45.9%) was recorded with 2CW:1SW irrigation.

Table 35: Rice as influenced by conjunctive use of canal and ground water for irrigation

Treatments	Plant height (cm)	Effective tillers (sqm)	Filled grains per panicle	Test weight (g)	Yield (q/ha)		HI (%)
					Grain	Straw	
T_1	92.8	303	138	20.3	41.68	53.15	44.0
T_2	87.3	283	142	22.0	45.63	56.05	44.9
T_3	84.3	271	143	21.1	45.53	56.11	44.8
T_4	88.0	337	161	21.9	54.26	63.84	45.9
T_5	86.5	348	159	22.6	49.16	60.19	45.0
T_6	78.8	262	139	21.8	41.50	52.39	44.2
CD (5%)	6.0	62	13	1.3	3.70	7.49	-
CV (%)	4.6	13.7	6.1	3.9	5.3	8.7	-

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

During 2012-13, the experiment was laid out with four levels of irrigation i.e., Fresh water of horizontal skimming well (<0.5 dS/m) and saline water of EC_{iw} 2, 4, 6 and 8 dS/m (by mixing of fresh water and sea water of 35 dS/m or more) to know the response of different vegetables viz., radish, cluster bean and leafy vegetables. Cluster bean was harvested during January 2012. Leafy vegetable palak was harvested during December, 2012 and January, 2013 (Table 36). No clogging of pipes/drippers was observed due to accumulation of salts during the crop season. The mean yield of cluster bean showed that CW with drip irrigation recorded highest yield of 2.39 t/ha followed by 2.15, 1.97, 1.67 and 1.44 t/ha with 2, 4, 6 and 8 dS/m saline water treatments, which caused 10, 17.5, 30 and 39.7% yield reduction, respectively (Table 36). The threshold salinity levels for 90, 75 and 50% yield of cluster bean are 2.4, 5.2 and 9.9 dS/m respectively.

The mean yield of palak showed that drip irrigation with CW treatment recorded highest yield of 1.07 t/ha followed by 1.00, 0.91, 0.85 and 0.74 t/ha with 2, 4, 6 and 8 dS/m water. Saline water of 2, 4, 6 and 8 dS/m caused 6.7, 14.4, 20.2 and 31.0% yield reduction, respectively. The threshold salinity levels for 90, 75 and 50% yield of palak are 3.0, 6.8 and 13 dS/m, respectively.

Table 36: Effect of different quality waters on yield of vegetables through drip lines (2012-13)

Drip line	Cluster bean (t/ha)*					Palak (t/ha)*				
	CW	2	4	6	8	CW	2	4	6	8
1	2.21	2.16	2.05	1.74	1.50	0.98	0.93	0.88	0.83	0.71
2	2.36	2.26	2.13	1.93	1.76	1.04	1.03	0.94	0.87	0.72
3	2.56	2.37	2.22	1.91	1.59	1.02	0.99	0.84	0.79	0.69
4	2.26	2.01	1.91	1.71	1.35	1.06	0.96	0.86	0.80	0.69
5	2.39	2.16	2.01	1.55	1.29	1.16	1.05	0.96	0.88	0.70

6	2.29	1.99	1.83	1.59	1.46	1.10	1.02	0.94	0.89	0.73
7	2.43	2.05	1.65	1.29	1.24	1.17	1.05	0.97	0.93	0.87
8	2.60	2.18	1.95	1.64	1.33	1.00	0.93	0.92	0.82	0.79
Mean	2.39	2.15	1.97	1.67	1.44	1.07	1.00	0.91	0.85	0.74

** crop got damaged during November due to heavy rains*

To develop a relationship between salinity and yield, the salinity levels v/s mean yields were plotted and best fit equations were developed. The best fit equations in nature presented as follows (Fig.1):

Cluster bean Y(t/ha) = -0.126EC (dS/m)+ 2.445 with R^2 = 0.993
Palak Y(t/ha) = -0.043EC (dS/m) + 1.09 with R^2 = 0.990

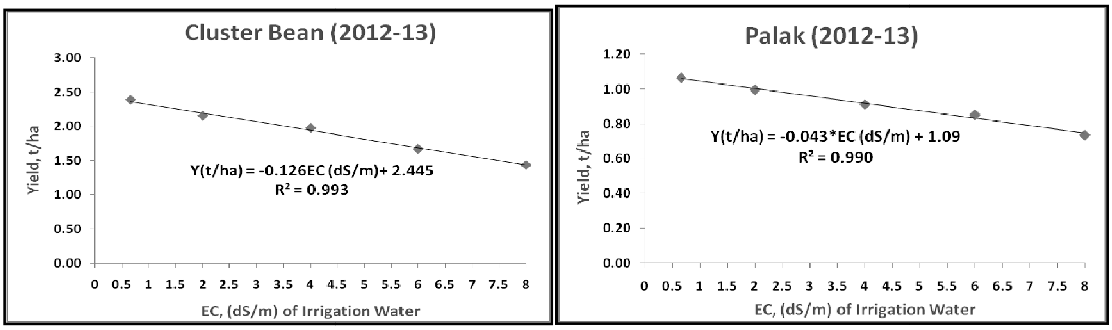


Fig. 1: Yield of cluster bean and palak under saline water irrigation

Leafy Vegetable: Palak (All Green)

The leafy vegetable (Palak - All Green) was transplanted in the experimental field of SWS during 2013-14 in an area of 217.25 m^2 with BAW, 2, 4, 6 and 8 dS/m irrigation water salinity at spacing of 20 x 10 cm. Mean yield of palak harvested so far is found to follow the linear equation with the salinity of irrigation water and is represented by the equation, Y (t/ha) = -0.801*EC (dS/m)+7.988 with R^2=0.988. The plant parameters and yield as affected by irrigation water salinity are presented in the Fig. 2.

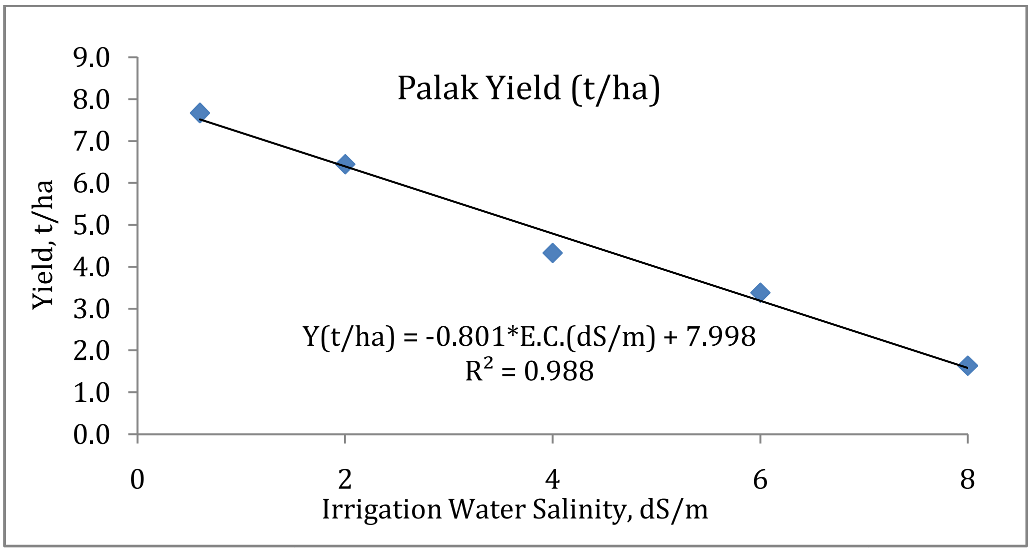


Fig. 2: Yield response of palak to different levels of saline water irrigation

Cluster Bean: Cluster bean (Pusa Navabahar) was transplanted in an area of 217.25 m^2 with BAW, 2, 4, 6 and 8 dS/m irrigation water salinity at spacing of 45 x 15 cm. Mean yield of cluster bean harvested so far is found to follow the linear equation with the salinity of irrigation water and is represented by equation, Y (t/ha) = -0.681*EC (dS/m)+7.616 with R^2 = 0.988. Plant parameters like plant height, pod length, and weight of 10 pods etc. are depicted in Fig. 3.

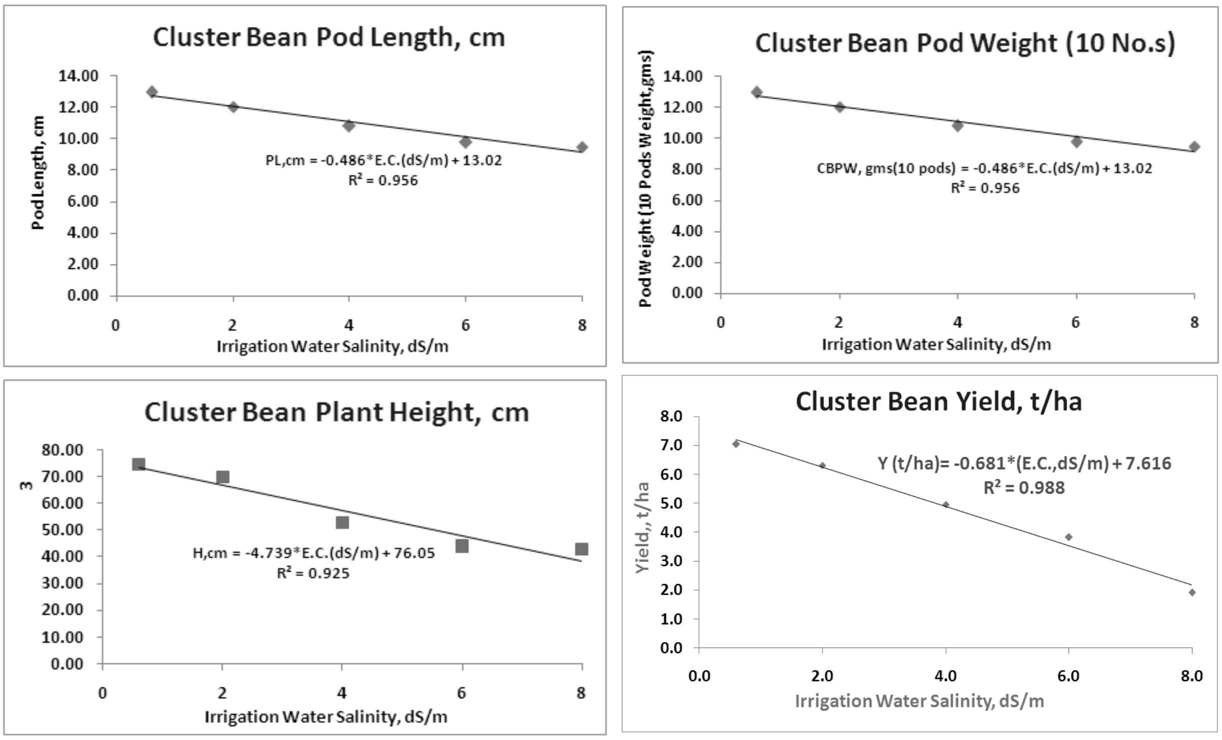


Fig. 3: Response of cluster bean to different levels of saline water irrigation

Capsicum: The hybrid capsicum (Syngenta–Orebelle) was transplanted in an area of 217.25 m^2 with BAW, 2, 4, 6 and 8 dS/m irrigation water salinity at spacing of 60 x 45 cm. Mean yield of capsicum is found to follow the linear equation with the salinity of irrigation water and is represented by equation Y (t/ha) = -0.334* EC (dS/m)+2.964 with R^2 = 0.972. The plant parameters like plant height, length of fruit, fruit diameter are given in Table 37.

Table 37: Yield attributes and yield of capsicum

Irrigation water salinity (dS/m)	Fruit length (L), cm	Fruit circumference (cm)	Fruit diameter (D), cm	Fruit weight (gm)	Av. Plant height (cm)	L/D ratio	Yield (t/ha)
0.6	7.4	21.7	6.9	126.5	43.8	1.1	3.0
2	6.5	23.7	7.5	114.0	37.6	0.9	2.1
4	5.9	21.6	6.9	107.3	33.8	0.9	1.6
6	5.8	21.8	6.9	106.0	31.6	0.8	0.9
8	3.3	14.2	4.5	24.4	29.1	0.7	0.4

The relationships between the irrigation water salinity and plant parameters are presented by Fig. 4. The relative tolerance of three vegetable crops shown in Fig. 5 showed that at 50% yield level, cluster bean is most sensitive. Capsicum is more tolerant to both palak and cluster bean.

Clogging of drip lines: About 50% drip lines got clogged after 8 years under saline water application.

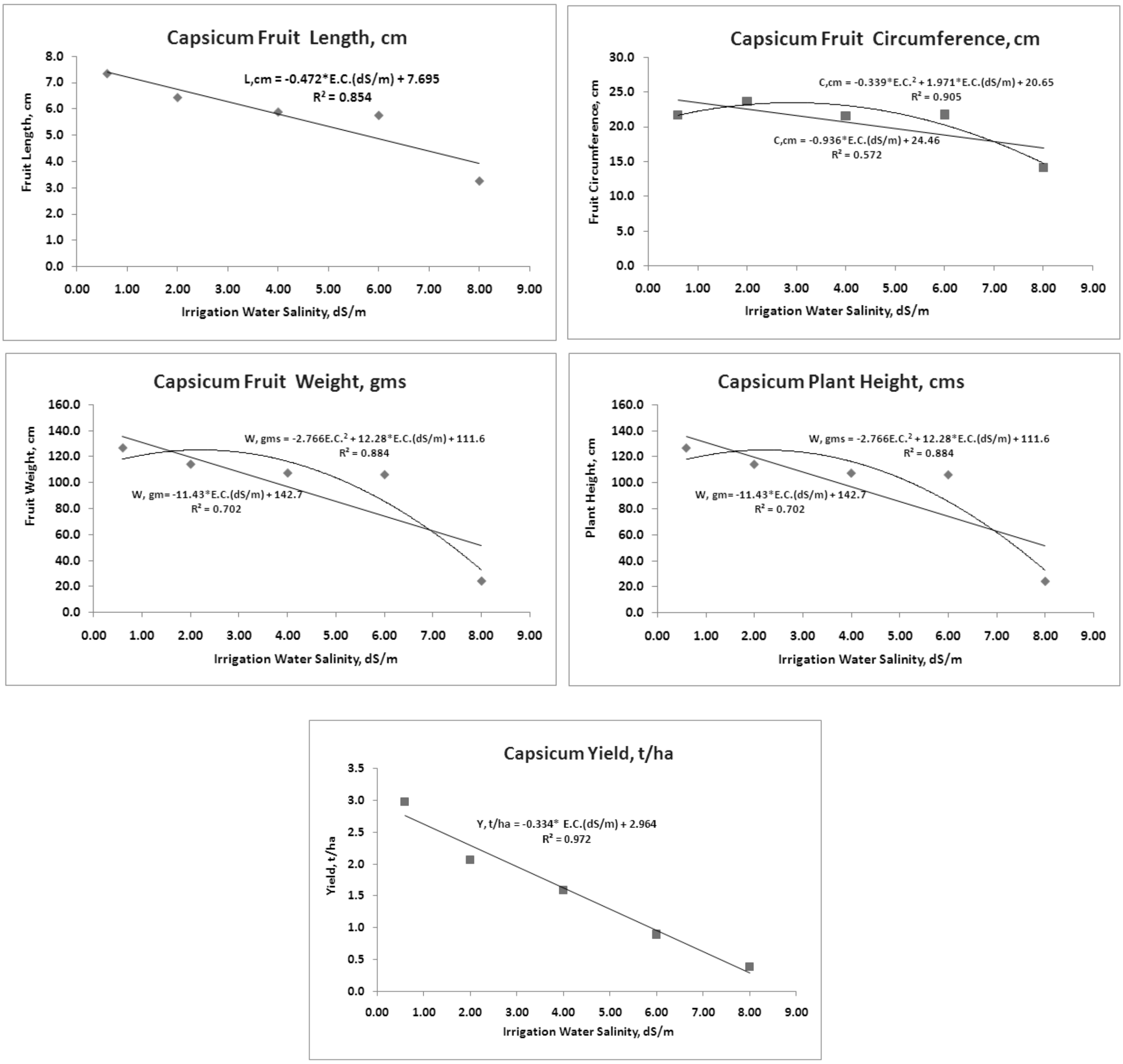


Fig. 4: Response of capsicum to different levels of saline water irrigation

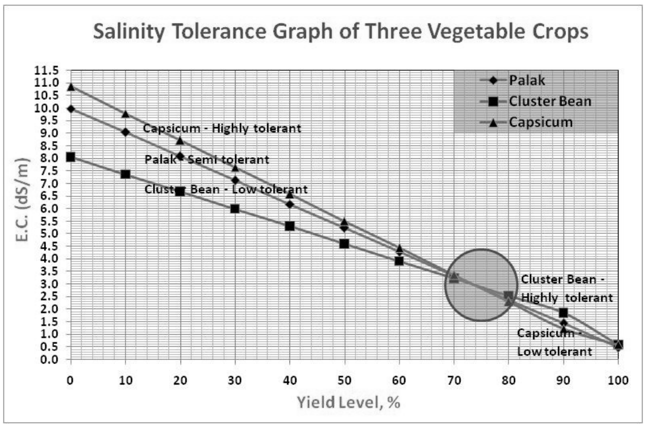


Fig. 5: Relative salinity tolerance graph of three vegetable crops

Use of saline water in shadenets for different vegetable crops in Krishna Western Delta

During 2013-14, capsicum was transplanted in the experimental beds of shadenets in an area of 56.35 m^2 with BAW, 2, 4, 6 and 8 dS/m irrigation water salinity at spacing of 60 x 45 cm. The mean yield of capsicum is found to follow the linear equation with the salinity of irrigation water and is represented through the equation, Y (t/ha) = $0.085EC^2 - 1.773*EC + 14.94$ with $R^2 = 0.910$ (Fig. 6).

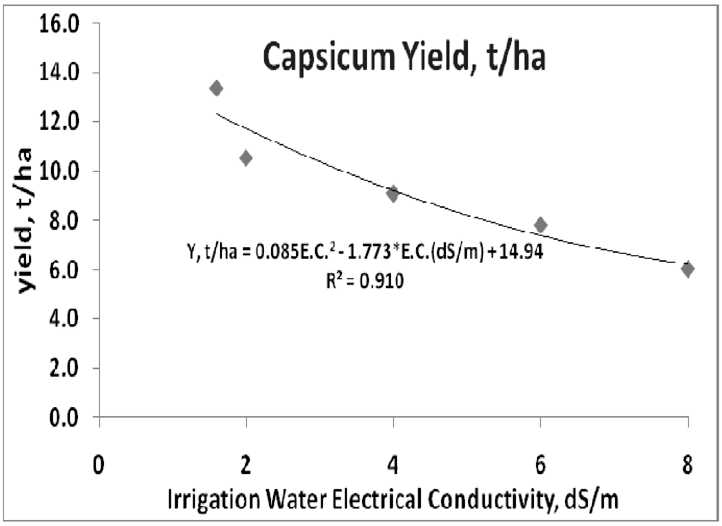


Fig. 6: Yield of capsicum under shadenets with saline water irrigation

BIKANER: RESEARCH ACCOMPLISHMENTS

Survey and characterization of ground water for irrigation

Sikar district: In the present study, ground water samples from 90 tube wells distributed in 24 villages of Lachhmangarh, 26 villages of Sikar and 23 villages of Neem ka Thana tehsils were collected and analyzed for ionic composition (Table 1). The water table in Lachhmangarh, Sikar and Neem ka Thana varied from 45.0 to 121, 85 to 121 and 18 to 268 m, respectively. EC of water ranged between 0.69 - 2.76, 0.56 - 1.66 and 0.48 - 3.07 dS/m and and pH between 8.6 - 9.7, 8.1 - 9.2 and 8.3 - 9.4 in Lachhmangarh, Sikar and Neem ka Thana tehsils, respectively. Bicarbonate and sodium were the dominant anion and cation, respectively. The SAR of water ranged from 2.0 to 7.4, 1.7 to 7.2 and 1.9 to 8.2 whereas soluble sodium percentage (SSP) ranged from 35.5 to 73.4, 36.1 to 68.3 and 33.0 to 64.6, respectively for Lachhmangarh, Sikar and Neem ka Thana tehsils (Table 1)

The data presented in Table 2 revealed that RSC of water ranged from 1.0 to 9.1, 0.6 to 5.8 and 0.4 to 9.6 me/L in Lachhmangarh, Sikar and Neem ka Thana tehsils, respectively. About 23.3, 53.3, 16.7 and 6.7 per cent water samples in Lachhmangarh and 35.7,35.7, 17.9 and 10.7 per cent water samples in Neem ka Thana tehsils had RSC in the range of <2.5, 2.5-5.0, 5.0-7.5 and >7.5 meq/l, respectively whereas in Sikar tehsil 75.0, 18.7 and 6.3 per cent water samples had RSC in the range of < 2.5, 2.5-5.0 and 5.0-7.5 meq/l, respectively. The salinity in 93.3, and 6.7 per cent water samples in Lachhmangarh, 82.1 and 17.9 per cent water samples in Neem ka Thana tehsil showed EC <2.0 and 2.0-4.0 dS/m, while in Sikar tehsil 100 per cent water samples had EC <2.0 dS/m (Table 3).

About 23.3, 26.7 and 50.0 per cent water samples in Lachhmangarh, 71.9, 12.5 and 15.6 per cent in Sikar and 35.7, 21.4 and 42.9 per cent in Neem ka Thana tehsils are of good, marginally alkali and alkali categories, respectively (Table 4, Fig. 1).

Percent distribution of water samples in relation to pH, EC, SAR, SSP, Mg/Ca ratio, fluoride and nitrate content is presented in Table 5. About 100 per cent water samples showed pH >8.5 in Lachhmangarh tehsil whereas about 37.5 and 62.5 per cent in Sikar tehsils and 28.6 and 71.4 per cent in neem ka Thana tehsils showed pH 8.0 to 8.5 and > 8.5, respectively. In Lachhmangarh 90.0 and 10.0 per cent and in Neem ka Thana 82.1 and 17.9 per cent water samples showed EC <2.0 and 2.0 to 4.0 dS/m.

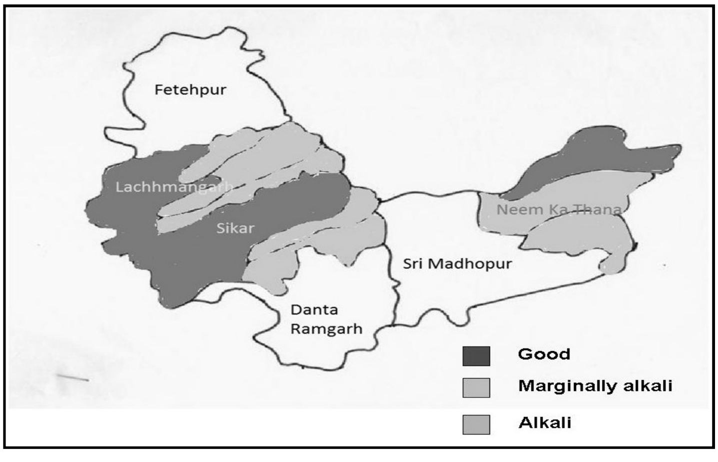


Fig. 1: Water quality map of Lachhmangarh, Sikar and Neem ka Thana tehsils of Sikar district

Table 1: Chemical characteristics of tube well water and soils of Lachhmangarh, Sikar and Neem ka Thana tehsils

Characteristics	Lachhmangarh		Sikar		Neem ka Thana	
	Water (30)*	Soil (30)*	Water (32)*	Soil (32)*	Water (28)*	Soil (28)*
pH	8.6-9.7 (9.1)	8.6-9.7 (9.1)	8.1-9.2 (8.6)	8.1-9.2 (8.6)	8.3-9.4 (8.7)	8.3-9.4 (8.6)
EC (dS/m)	0.69-2.76 (1.38)	0.07-0.29 (0.16)	0.56-1.66 (0.90)	0.06-0.16 (0.10)	0.48-3.07 (1.35)	0.05-0.36 (0.12)
Ca (meq/l)	1.20-6.7	0.15-1.70	1.2-6.8	0.14-0.97	1.2-7.4	0.18-1.87
Mg (meq/l)	0.5-6.3	0.04-0.59	0.4-2.9	0.05-0.43	0.4-6.3	0.04-0.59
Na (meq/l)	3.2-13.5	0.22-0.83	2.1-7.4	0.14-0.61	2.4-10.8	0.13-0.93
K (meq/l)	0.2-1.0	0.02-0.32	0.1-1.5	0.03-0.11	0.1-8.0	0.05-0.51
CO_3+ HCO_3 (meq/l)	3.7-22.6	0.51-1.6	2.5-11.4	0.46-1.21	3.0-21.2	0.35-2.11
Cl (meq/l)	2.0-5.0	0.13-1.26	1.2-5.6	0.10-0.39	1.0-10.0	0.10-1.15
SO_4 (meq/l)	0.1-1.2	0.03-0.26	0.2-0.9	0.02-1.01	0.1-1.7	0.03-0.36
RSC (meq/l)	1.0-9.1	-	0.6-5.8	-	0.4-9.6	-
SAR	2.0-7.4	0.31-1.11	1.7-7.2	0.17-1.39	1.9-8.2	0.35-1.33
SSP	35.5-73.4	-	36.1-68.3	-	33.0-64.6	-
Mg/Ca ratio	0.2-1.7	-	0.2-2.0	-	0.1-1.3	-
Fluoride (mg/l)	0.91-1.98	-	0.80-2.31	-	0.56-2.16	-
Nitrate (mg/l)	110-290	-	100-270	-	125-320	-
Water table (m)	45-121	-	85-121	-	18-268	-

** No. of samples analysed; figure in parenthesis for pH and EC are the average value*

Table 2: Distribution (per cent) of water samples in different ranges of EC and RSC of Lachhmangarh, Sikar and Neem ka Thana tehsils of Sikar district

RSC (meq/l)	EC of irrigation water (dS/m)																	
	< 1			1-2			2-3			3-4			>4			Total		
	L	S	N	L	S	N	L	S	N	L	S	N	L	S	N	L	S	N
<2.5	23.3	68.7	32.1	-	6.3	3.6	-	-	-	-	-	-	-	-	-	23.3	75.0	35.7
2.5-5.0	10.0	-	3.6	43.3	18.7	28.5	-	-	3.6	-	-	-	-	-	-	53.3	18.7	35.7
5.0- 7.5	-	-	-	16.7	6.3	10.7	-	-	3.6	-	-	3.6	-	-	-	16.7	6.3	17.9
> 7.5	-	-	-	-	-	3.6	6.7	-	7.1	-	-	-	-	-	-	6.7	-	10.7
Total	33.3	68.7	35.7	60.0	31.3	46.4	6.7	-	14.3	-	-	3.6	-	-	-	100	100	100

Where L: Lachhmangarh; S: Sikar; N: Neem ka Thana

Table 3: Chemical characteristics of ground water of Lachhmangarh, Sikar and Neem ka Thana tehsils

Range	Water table Depth (m)	pH	EC (dS/m)	Ionic composition (meq/l)							RSC (meq/l)	SAR	Potential Salinity (meq/l)	SSP	Mg/ Ca Ratio
				Ca	Mg	Na	K	CO_3+ HCO_3	Cl	SO_4					
Lachhmangarh Tehsil															
Maximum	121	9.70	2.76	6.7	6.3	13.5	1.0	22.6	5.0	1.2	9.1	7.4	5.2	73.4	1.7
Minimum	45	8.60	0.69	1.2	0.5	3.2	0.2	3.7	2.0	0.1	1.0	2.0	2.2	35.5	0.2
Average	88.5	9.15	1.38	3.2	2.6	9.6	0.6	9.7	3.6	0.6	3.9	4.7	3.9	54.8	0.8
Sikar Tehsil															
Maximum	121	9.27	1.66	6.0	2.9	7.4	1.5	11.4	5.6	0.9	5.8	7.1	6.1	68.3	2.0

Range	Water table Depth (m)	pH	EC (dS/m)	Ionic composition (meq/l)							RSC (meq/l)	SAR	Potential Salinity (meq/l)	SSP	Mg/ Ca Ratio
				Ca	Mg	Na	K	CO_3+ HCO_3	Cl	SO_4					
Minimum	85	8.14	0.56	1.2	0.4	2.1	0.1	2.5	1.2	0.2	0.6	1.7	1.5	36.1	0.2
Average	113	8.63	0.90	2.4	1.3	4.7	0.7	5.7	2.9	0.5	1.9	3.6	3.1	50.0	0.6
Neem Ka Thana Tehsil															
Maximum	268	9.40	3.07	7.4	6.3	10.8	8.0	21.2	10.0	1.7	9.6	8.2	10.8	64.6	1.3
Minimum	18	8.33	0.48	1.2	0.4	2.4	0.1	3.0	1.0	0.1	0.4	1.9	1.2	33.0	0.1
Average	112.2	8.67	1.35	3.5	1.8	6.0	2.2	9.1	3.6	0.8	3.8	3.8	4.0	46.1	0.5

Nearly 100% water samples having SAR of 0-10 in Lachhmangarh and Sikar tehsils while 96.4 and 3.6 per cent sampls having SAR of 0-10 and 10-20, respectively in Neem ka Thana tehsil. About 43.3, 16.7, 33.3 and 6.7 per cent water samples of Lachhmangarh tehsil showed SSP < 50, 50 to 60, 60 to 70 and 70 to 80, respectively whereas in Sikar SSP was 43.8, 34.4 and 21.8 per cent and in Neem ka Thana 57.2, 35.7 and 7.1 per cent having SSP <50, 50 to 60 and 60 to 70, respectively. About 73.3 and 26.7 per cent water samples in Lachhmangarh, 87.5 and 12.5 per cent in Sikar and 96.4 and 3.6 per cent in Neem ka Thana had Mg/Ca ratio <1 and 1 to 2, respectively. About 66.7 and 33.3 per cent water samples in Lachhmangarh, 81.3 and 18.7 per cent in Sikar and 67.9 and 32.1 per cent in Neem ka Thana tehsils contains fluoride <1.5 and 1.5 to 5.0 mg/l, respectively. All water samples of Lachhmangarh, Sikar and Neem ka Thana tehsils showed nitrate content >100 mg/l (Table 6).

The data in Table 7 indicated that pH_2 of soil samples in Lachhmangarh tehsil varied from 8.6 to 9.6, in Sikar from 8.1 to 9.2 and in Neem ka Thana from 8.3 to 9.4, whereas the corresponding EC_2 ranged from 0.07 to 0.29, 0.06 to 0.16 and 0.05 to 0.36 dS/m, respectively. There is problem of alkalinity in 50 to 43 per cent villages of Lacfhhmangarh and Neem ka Thana and 15.6 per cent villages of Sikar tehsils in ground water having RSC 5.0 to 7.5 and pH >8.5 to 9.7, which indicates that soils are deteriorated with the use of poor quality waters. Farmers are advised to apply 25% more seed and fertilizers as per recommendations of soil testing laboratory under such situations.

Table 4: Villages of Lachhmangarh, Sikar and neem ka Thana under water quality categories

Water quality	Name of villages in tehsils		
	Lachhmangarh (%)	Sikar (%)	Neem ka Thana (%)
Good (EC <2 dS/m SAR <10 RSC <2.5 meq/l)	Narodata, Posani, Khinwasar, Beedasar, Dudwa, Khirwa (23.3 %)	Rashidpura, Badadar, Gokulpura, Jhigarbadi, Bhairoopura, Sabalpura, Cholasi,Sihot, Mollasi, Tarsarchhoti, Aaspura, Rampura, Puradadi, Kashi ka Bas, Kadma ka bas, Dujod, Ramnagar, Chainpura (71.9 %)	Sirohi, Bhagega, Bhagot, Govindpura, Arjanpura, Baasdi, Chhapar, Jhirana, Doken (35.7 %)
Marginally saline (EC 2-4 dS/m, SAR <10 RSC <2.5meq/l)	-	-	-

Saline (EC >4 dS/m SAR<10 RSC <2.5meq/ l)	-	-	-
High-SAR-saline (EC > 4 dS/m, SAR>10 RSC <2.5 meq/l)	-	-	-
Marginally alkali (EC< 4 dS/m SAR <10 RSC 2.0-4.0 meq/l)	Sanwali, Hapaas, Narsaas, Patoda, Narodada, Laalaasi, Paaldi, Ghassu (26.7 %)	Mollasi, Kasha ka Bas, Sikar, Peeprali (12.5 %)	Chala, Khora, Neemod Rajpura, Bhaageshwar, Nathuwala (21.4 %)
Alkali (EC<4 dS/m SAR <10 RSC >4.0 meq/l)	Alakpura, Chhihhas, Kumas, Jatan, Deenwa, Jatan, Bagdi, Sanwali, Khedu Dantujala,, Alakpura Bogan, Yaalsar, Dolas, Lachhmangarh, Khudibadi (50 %)	Nani, Sewa, Phagalwa, Sewad, Kanwarpura (15.6%)	Sirohi, Ganeshwar, Bhudoli, Manpura, Bharala, Hemrajpura, Raipur, Hasaanpur, Patan, Mandoli (42.9 %)

Table 5: Distribution of water samples in relation to pH, EC, SAR, SSP, Mg / Ca ratio, fluoride and nitrate of Lachhmangarh, Sikar and Neem ka Thana tehsils of Sikar district

Characteristics	Lachhmangarh (%)	Sikar (%)	Neem ka Thana (%)
pH			
7.0-7.5	-	-	-
7.5-8.0	-	-	-
8.0-8.5	-	37.5	28.6
>8.5	100	62.5	71.4
EC (dS/m)			
<2	90	100	82.1
2-4	10	-	17.9
4-6	-	-	-
>6	-	-	-
SAR			
0-10	100	100	96.4
10-20	-	-	3.6
20-30	-	-	-
>30	-	-	-
SSP			
<50	43.3	43.8	57.2
50-60	16.7	34.4	35.7
60-70	33.3	21.8	7.1
70-80	6.7	-	-
>80	-	-	-

Mg/Ca ratio			
<1	73.3	87.5	96.4
1-2	26.7	12.5	3.6
2-3	-	-	-
>3	-	-	-
Fluoride (mg/l)			
<1.5	66.7	81.3	67.9
1.5-5.0	33.3	18.7	32.1
5.0-10.0	-	-	-
>10.0	-	-	-
Nitrate (mg/l)			
<20	-	-	-
20-50	-	-	-
50-100	-	-	-
>100	100	100	100

Table 6: Fluoride and nitrate in ground waters of Lachhmangarh, Sikar and Neem Ka Thana

Villages	Fluoride (mg/l)	Nitrate (mg/l)	Villages	Fluoride (mg/l)	Nitrate (mg/l)
Lachhmangarh tehsil					
Alakpura	1.37	210	Narodada	1.36	239
Chhihhas	0.98	241	Laalaasi	1.96	215
Kumas Jatan	1.10	183	Yaalsar	1.84	180
Deenwa Jatan	1.00	194	Paaldi	1.32	227
Bagdi	1.22	215	Posani	1.61	233
Bagdi	1.17	219	Khinwasar	1.44	240
Bagdi	1.26	221	Khinwasar	1.26	194
Sanwali	1.98	177	Beedasar	1.76	266
Sanwali	0.91	144	Dudwa	1.13	278
Khedi Dantujala	0.94	216	Khirwa	1.29	199
Hapaas	1.40	140	Dolas	1.81	133
Alakpura Bogan	1.76	157	Lachhmangarh	1.93	145
Narsaas	1.90	210	Lachhmangarh	1.89	136
Patuda	1.92	206	Ghassu	1.41	290
Narodada	1.24	235	Khudidadi	1.10	110
Sikar tehsil					
Rashidpura	1.22	161	Kanwarpura	1.36	236
Badadar	1.24	130	Aaspura	1.29	240
Jhigarbadi	1.18	141	Rampura	2.15	256
Bhairoonpura	1.20	134	Rampura	2.24	159
Sabalpura	1.44	144	Purabadi	1.20	128
Nani	1.27	136	Purabadi	1.21	136
Sabalpura	0.86	115	Kashi ka Bas	2.29	151
Nani	0.92	119	Kadama ka Bas	2.17	147
Cholasi	1.06	130	Kadama ka Bas	2.11	151
Sihod	1.29	150	Dujod	0.80	122

Sewa	1.38	210	Dujod	0.94	119
Phagalwa	1.14	100	Ramnagar	1.12	129
Sewad	2.11	270	Sikar	1.46	240
Mollasi	0.91	127	Gokulpura	1.44	230
Mollasi	0.88	132	Peeprali	2.29	144
Tasar Chhodi	1.10	184	Chainpura	2.31	149
			Neem Ka Thana tehsil		
Chala	1.19	150	Neemod	0.85	220
Sirohi	2.11	156	Manpura	1.71	251
Sirohi	2.00	160	Bharala	2.16	289
Bhagega	0.81	125	Nathuwala	1.65	310
Bhagot	0.86	146	Hemrajpura	1.40	218
Bhagot	0.89	120	Raipur	0.64	286
Govindpura	1.51	249	Hasaanpur	0.80	340
Arjanpura	1.30	169	Rajpura	0.95	234
Baasdi	2.15	251	Patan	0.56	240
Chhapar	1.20	146	Patan	0.65	255
Jhirana	1.39	270	Patan	0.65	149
Ganeshwar	0.66	233	Doken	1.65	320
Khora	0.69	211	Bhaageshwar	1.37	244
Bhudoli	0.89	248	Mandoli	1.40	227

Table 7: Chemical characteristics of soil irrigated with ground waters 3 tehsils of Sikar district

Range	pH	EC_2 (dS/m)	Ionic composition (meq/l)							SAR
			Ca	Mg	Na	K	CO_3+HCO_3	Cl	SO_4	
				Lachhmangarh Tehsil						
Maximum	9.69	0.29	1.70	0.59	0.83	0.32	1.60	1.26	0.26	1.10
Minimum	8.60	0.07	0.15	0.04	0.22	0.02	0.51	0.13	0.03	0.31
Average	9.14	0.16	0.76	0.26	0.47	0.08	1.07	0.39	0.10	0.68
				Sikar tehsil						
Maximum	9.22	0.16	0.97	0.43	0.61	0.11	1.21	0.39	1.01	1.39
Minimum	8.14	0.06	0.14	0.05	0.14	0.03	0.46	0.10	0.02	0.17
Average	8.64	0.10	0.42	0.17	0.34	0.06	0.76	0.16	0.17	0.67
				Neem Ka Thana tehsil						
Maximum	9.40	0.36	1.87	0.59	0.93	0.51	2.11	1.15	0.36	1.33
Minimum	8.33	0.05	0.18	0.04	0.13	0.05	0.35	0.10	0.03	0.35
Average	8.66	0.12	0.50	0.19	0.40	0.15	0.89	0.26	0.11	0.68

Conclusion: About 23.3, 26.7 and 50.0 per cent water samples in Lachhmangarh, 71.9, 12.5 and 15.6 per cent in Sikar and 35.7, 21.4 and 42.9 per cent in Neem ka Thana tehsils are under good, marginally alkali and alkali categories, respectively. The water in the category "good" can safely be used in all types of soils for most crops whereas “marginally saline” waters can be used in coarse textured soils. Also the ground water categorized as marginally sodic (RSC 2.5 to 4.0) can be used effectively with gypsum application. The water categorized as highly alkali are not suitable with normal irrigation practices.

Sriganganagar district

In present study ground water samples from 40 tubewells distributed in 14 villages of Sri Ganganagar, 4 villages of Padampur, 4 villages of Sri Karanpur and 18 villages of Sadulshar tehsils of Sri Ganganagar district were collected and analyzed for ionic composition. The range of chemical characteristics of tube well waters is presented in Table 8. The water table in Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils varied from 10 to 65, 25 to 40, 20 to 30 and 16 to 30 m, respectively. The EC ranged from 1.20 to 10.50 dS/m, 5.33 to 6.80 dS/m, 1.16 to 10.50 dS/m and 1.22 to 8.16 dS/m and pH from 8.0 to 8.5, 8.0 to 8.1, 7.7 to 8.5 and 7.6 to 8.5 in water samples of Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils respectively. The SAR of water samples ranged from 7.3 to 19.6, 14.9 to 22.0, 7.1 to 15.4 and 6.4 to 24.6 whereas soluble sodium percentage (SSP) of water samples ranged from 63.5 to 88.6, 69.4 to 84.7, 60.5 to 74.8 and 69.6 to 96.4, respectively for Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils of Sri Ganganagar district.

The distribution of water samples in different ranges of EC and RSC are presented in Table 9. About 92.8, 100, 100 and 94.5 per cent water samples in Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils having RSC of <2.5 meq/l, respectively. Salinity in 7.1, 35.7, 7.1 and 50.0 per cent water samples in Sri Ganganagar tehsil showed EC of 1 to 2, 2 to 3, 3 to 4 and >4 dS/m, while in Padampur and Sri Karanpur tehsils 100 per cent water samples had EC of >4 dS/m. About 5.6, 5.6 and 88.8 per cent water samples of Sadulshar tehsil ranged between 1 to 2, 3 to 4 and > 4 dS/m. Detailed chemical characteristics of water samples of Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils are presented in Table 10.

Villages falling under different quality characteristics are reported in Table 11 and water quality map is depicted in Fig 2. About 7.1, 7.1, 50.0, 7.1 and 28.6 per cent water samples in Sri Ganganagar, are under good, marginally saline, high SAR saline, marginally alkali and highly alkali while 100 per cent water samples of Padampur tehsil are under high SAR saline category, respectively. In Sri Karanpur tehsils about 25.0 and 75.0 per cent water samples fall under good and high SAR saline category. In Sadulshar tehsils about 5.6, 83.3 and 11.1 per cent water samples were under good, high SAR saline and highly alkali category, respectively.

Table 8: Chemical characteristics of tube well waters and soils of 4 tehsils of Sri Ganganagar

Characteristics	Sri Ganganagar		Padampur		Sri Karanpur		Sadulshar	
	Water (14)*	Soil (14)*	Water (4)*	Soil (4)*	Water (4)*	Soil (4)*	Water (18)*	Soil (18)*
pH	8.0-8.5 (8.2)	8.3-9.6 (8.8)**	8.0-8.1 (8.0)	8.6-9.1 (8.8)	7.7-8.5 (7.9)	8.5-8.9 (8.7)	7.6-8.5 (8.0)	7.9-9.3 (8.6)
EC (dS/m)	1.20-10.50 (4.99)	0.16-1.80 (0.52)	5.33-6.80 (6.25)	0.14-0.32 (0.23)	1.16-10.50 (6.20)	0.16-0.88 (0.52)	1.22-8.16 (5.55)	0.13-1.73 (0.69)
Ca (meq/l)	1.0-15.1	0.23-2.51	2.6-7.2	0.67-1.04	1.4-14.5	0.82-2.46	1.2-9.4	0.48-2.61
Mg (meq/l)	1.5-22.4	0.14-2.18	5.2-12.9	0.22-1.08	1.7-23.6	0.28-3.16	2.4-13.7	0.49-2.14
Na (meq/l)	8.8-66.3	0.72-13.52	44.8-47.3	0.39-1.46	8.8-66.8	0.33-5.84	8.7-60.6	0.62-12.69
K (meq/l)	0.2-0.9	0.06-0.60	0.1-0.7	0.11-0.24	0.1-0.3	0.08-0.56	0.2-0.9	0.06-0.96
CO_3+ HCO_3	2.5-27.2	0.67-2.39	3.4-12.1	1.12-1.40	2.2-29.6	1.13-3.25	2.8-21.7	0.74-4.31
Cl (meq/l)	9.2-62.8	0.52-13.30	38.7-54.8	0.19-1.56	6.8-60.4	0.28-4.46	8.6-73.6	0.33-12.48
SO_4 (meq/l)	0.2-15.2	0.12-3.11	1.2-11.4	0.10-0.60	1.2-14.8	0.07-2.36	0.1-10.4	0.06-2.56
RSC (meq/l)	Nil-9.0	-	Nil-10.0	-	Nil-0.9	-	Nil-4.6	-

SAR	7.3-19.6	0.8-9.0	14.9-22.0	0.5-1.5	7.1-15.4	0.4-5.4	6.4-24.6	0.8-8.4
SSP	63.5-88.6	-	69.4-84.7	-	60.5-74.8	-	69.6-96.4	-
Mg/Ca ratio	1.1-2.1	-	1.8-2.0	-	1.2-1.7	-	1.3-3.3	-
F (mg/l)	0.96-2.81	-	3.68-3.90	-	1.37-1.88	-	0.83-4.74	-
Nitrate (mg/l)	12.6-44.8	-	63.9-70.1	-	26.4-77.6	-	16.6-86.5	-
Water table (m)	10-65	-	25-40	-	20-30	-	16-30	-

** No. of samples analysed; Figure in parenthesis for pH and EC are the average value*

Table 9: Distribution (per cent) of water samples in different ranges of EC and RSC

RSC (meq/l)	EC of irrigation water (dS/m)																							
	< 1				1-2				2-3				3-4				>4				Total			
	SG	PD	SK	SD	SG	PD	SK	SD	SG	PD	SK	SD	SG	PD	SK	SD	SG	PD	SK	SD	SG	PD	SK	SD
<2.5	-	-	-	-	7.1	-	-	5.6	28.6	-	-	-	7.1	-	-	5.6	50.0	100	100	83.3	92.8	100	100	94.5
2.5-5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.5	-	-	-	5.5
5.0 – 7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
> 7.5	-	-	-	-	-	-	-	-	7.1	-	-	-	-	-	-	-	-	-	-	-	7.2		-	-
Total	-	-	-	-	7.1	-	-	5.6	35.7	-	-	-	7.1	-	-	5.6	50.0	100	100	88.8	100	100	100	100

Where SG: Sri Ganganagr tehsil; PD: Padampur tehsil; SK: Sri Karanpur tehsil; SD: Sadulshar tehsil

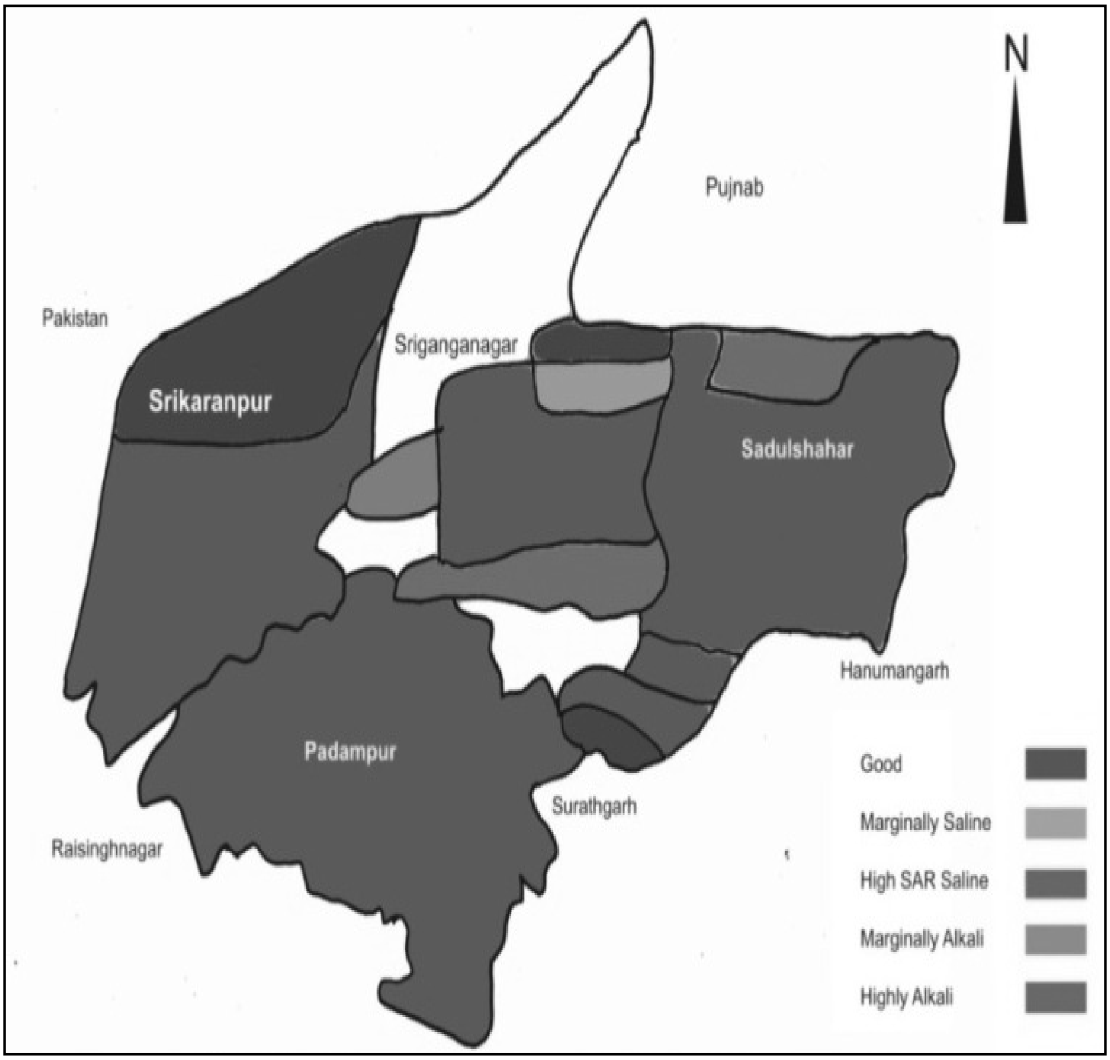


Fig. 2: Water quality map of Sriganganagar, Padampur, Srikaranpur and Sadulsahar tehsils

Table 10: Chemical characteristics of ground irrigation water of 4 tehsils of Sri Ganganagar

Range	Water table depth (m)	pH	EC (dS/m)	Ionic composition (meq/L)							RSC	SAR	SSP	Mg/Ca Ratio
				Ca	Mg	Na	K	CO_3 + HCO_3	Cl	SO_4				
					Sri Ganganagar Tehsil									
Maximum	65	8.5	10.5	15.1	22.4	16.3	0.9	27.2	62.8	15.2	9.0	19.6	88.6	2.1
Minimum	10	8.0	1.2	1.0	1.5	8.8	0.2	2.5	9.2	0.2	Nil	7.3	63.5	1.1
Average	37	8.3	5.0	5.5	8.6	35.3	0.4	11.4	33.8	4.7	Nil	13.7	72.8	1.5
					Padampur Tehsil									
Maximum	40	8.1	6.8	7.2	12.9	47.3	0.7	12.1	54.8	11.4	Nil	22.9	84.7	2.0
Minimum	25	8.0	5.3	2.6	5.2	44.8	0.1	3.4	38.7	1.2	Nil	14.9	69.4	1.8
Average	32	8.1	6.3	5.7	10.4	45.9	0.3	8.9	48.9	4.5	Nil	17.0	74.0	1.8
					Sri Karanpur Tehsil									
Maximum	30	8.1	10.5	14.5	23.6	66.8	0.3	29.6	60.4	14.8	Nil	15.4	74.9	1.7
Minimum	20	7.8	1.2	1.4	1.7	8.8	0.1	2.2	6.8	1.2	Nil	7.1	60.6	1.2
Average	25	7.9	6.2	8.65	12.7	40.3	0.3	15.8	38.1	8.1	Nil	12.3	68.1	1.4
					Sadulshar Tehsil									
Maximum	30	8.5	8.2	9.4	13.7	60.0	0.9	21.7	73.6	10.4	4.6	24.7	96.4	3.3
Minimum	16	7.7	1.2	1.2	2.4	8.7	0.2	2.8	8.6	0.1	Nil	6.4	69.6	1.3
Average	23	8.1	5.6	4.2	7.9	42.0	0.5	8.3	43.7	2.2	4.1	17.4	78.3	1.9

Percent distribution of water samples in relation to pH, EC, SAR, SSP, Mg/Ca ratio, fluoride and nitrate content is presented in Table 12. About 100 per cent water samples showed pH >8.5 in Sri Ganganagar and Padampur tehsils whereas about 75 and 25 per cent in Sri Karanpur tehsil and 33.3 and 66.7 per cent in Sadulshar tehsil showed pH of 7.5 to 8.0 and 8.0 to 8.5, respectively. In Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils 28.6, 75.0, 50.0 and 33.3 per cent water samples showed EC of >6 dS/m. Nearly 85.7, 75.0, 75.0 and 77.8 per cent water having SAR in the range of 10-20 in Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils. About 78.6, 100.0, 50.0 and 77.8 per cent water samples of Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils having fluoride between 1.5 to 5.0 mg/l, respectively. All the water samples of Padampur tehsils showed nitrate content in the range of 50 to 100 mg/l while 25.0 and 22.2 per cent in Sri Karanpur and Sadulshar tehsils. About 64.3, 75.0 and 72.2 per cent water samples having nitrate in the range of 20 to 50 mg/l in Sri Ganganagar, Sri Karanpur and Sadulshar tehsils, respectively (Table 13).

Table 11: Villages under different categories of water quality in 4 tehsils

Water quality	Name of villages in tehsils			
	Sri Ganganagr	Padampur	Sri Karanpur	Sadulshar
Good (EC <2 dS/m, SAR <10 RSC <2.5 meq/l)	Sri Ganganagr (7.1%)	-	Sri Karanpur (25%)	8 BNW-1 (5.6%)
Marginally saline (EC 2-4 dS/m, SAR <10 RSC <2.5 meq/l)	6 A - Chhoti-1 (7.1%)	-	-	-
Saline (EC >4 dS/m,	-	-	-	-

SAR <10 RSC <2.5 meq/l)				
High SAR saline (EC >4 dS/m, SAR >10 RSC <2.5 meq/l)	6 A – Chhoti-2, 7 G- Chhoti-1, 7 G- Chhoti-2, Chunawad-3, Ratiwala-1, Ratiwala-2 (50%)	Padampur, Laxinagar, 14 BB, 29 BB (100%)	Motasar, Baluwala, lakhiya (75.0%)	8 BNW-2, 8 BNW-3, 8 BNW-4, 6 BNW-1, 6BNW-2, 9 BNW, Lalgarh Jatan, Mummal Kheda, Pratapura, Sadulshar-1, sadulshar-2, Hamakmabad-1, Ganeshgarh-1, Ganeshgarh-2, Ganeshgarh-3 (83.3%)
Marginally alkali (EC <4 dS/m, SAR <10 RSC 2.5-4 meq/l)	6 A Chhoti-1 (7.1%)	-	-	-
Alkali (EC <4 dS/m, SAR<10 RSC >4 meq/l)	-	-	-	-
Highly alkali (EC <4 dS/m, SAR >10 RSC >4 meq/l)	9 A Chhoti, 2 E Chhoti, Mahiyawali-1, Mahiyawali-2 (28.6%)	-	-	Banwala, Hakmabad-2 (11.1%)

Table 12: Distribution of water samples in relation to pH, EC, SAR, SSP, Mg/Ca ratio, fluoride and nitrate of Sri Ganganagar, Padampur, Sri Karanpur and Sadulshar tehsils

Characteristics	Sri Ganganagar (%)	Padampur (%)	Sri Karanpur (%)	Sadulpur (%)
pH				
7.0-7.5	-	-	-	-
7.5-8.0	-	-	75	33.3
8.0-8.5	100	100	25	66.7
>8.5	-	-	-	-
EC (dS/m)				
<2	7.1	-	25	5.6
2-4	42.9	-	-	5.6
4-6	14.2	25	25	55.5
>6	28.6	75	50	33.3
SAR				
0-10	14.3	-	25	5.6
10-20	85.7	75	75	77.8
20-30	-	25	-	16.6
>30	-	-	-	-
SSP				
<50	-	-	-	-
50-60	-	-	-	-
60-70	35.8	25	50	5.6

70-80	57.8	50	50	55.6
>80	7.1	25	-	38.8
Mg/Ca ratio				
<1	-	-	-	-
1-2	85.7	100	75	72.2
2-3	14.3	-	-	22.2
>3	-	-	-	5.6
Fluoride (mg/l)				
<1.5	21.4	-	50	22.2
1.5-5.0	78.6	100	50	77.8
5.0-10.0	-	-	-	-
>10.0	-	-	-	-
Nitrate (mg/l)				
<20	35.7	-	-	5.6
20-50	64.3	-	75	72.2
50-100	-	100	25	22.2
>100	-	-	-	-

Table 13: Fluoride and nitrate contents in ground irrigation waters of 4 tehsils of district

Villages	Fluoride (mg/l)	Nitrate (mg/l)	Villages	Fluoride (mg/l)	Nitrate (mg/l)
			Sri Ganganagar tehsil		
6 A – Chhoti-1	1.34	12.6	Chunawad-3	2.21	38.8
6 A – Chhoti-2	1.46	34.7	Ratiwala-1	2.33	39.1
9 A – Chhoti	2.28	20.2	Ratiwala-2	2.29	39.6
7 G – Chhoti-1	2.19	35.3	Sri Ganganagr	2.23	16.9
7 G – Chhoti-2	2.24	37.8	2E- Chhoti	2.81	15.7
Chunawad-1	2.45	13.4	Mahiyawali-1	2.42	14.4
Chunawad-2	2.16	38.2	Mahiyawali-2	0.96	44.8
			Sri Karanpur tehsil		
Motasar	1.72	26.4	Baluwala	1.46	30.1
Sri Karanpur	1.88	77.6	Lakhiya	1.37	28.9
			Padampur tehsil		
Padampur	3.77	70.1	14 BB	3.90	64.5
Laxinagar	3.68	66.8	29 BB	3.84	63.9
			Sadulsahar tehsil		
8 BNW-1	2.11	16.6	Mummad Kheda	1.75	25.8
Banwala	1.14	86.5	Pratapura	1.67	23.4
8 BNW -2	4.74	76.3	Sadulshar-1	1.69	26.2
8 BNW -3	1.86	45.7	Sadulshar-2	1.88	24.6
8 BNW -4	4.66	66.1	Hakmabaad-1	1.84	25.5
6 BNW -1	3.98	71.4	Hakmabaad-2	1.91	27.4
6 BNW -2	1.41	30.2	Ganeshgarh-1	2.63	23.1
9 BNW	1.37	29.7	Ganeshgarh-2	2.22	39.6
Lalgarh Jatan	0.83	40.1	Ganeshgarh-3	2.34	40.8

Monitoring of ground water level and quality in IGNP stage II

The monitoring of water level in IGNP stage-II was initiated in 1992 by CAD authorities. IGNP stage-II covering parts of Bikaner, Jodhpur, Jaisalmer, Barmer and parts of Churu district between RD 620 (Sattasar head) and RD 1453 (Mohangarh). Physiographically the area consists of former flood plains and Aeolian sands. There are six lift canals namely Sahwa, Gajner, Bangarsar, Kolyat, Phalodi and Pokhran and Jodhpur water supply in Rajasthan. There is no major drainage system in the area except few intermittent and ephemeral channel which terminate in sand dunes.

The data collected during 2013 along with records of previous years were analysed to evaluate the fluctuations in ground water levels and to assess change in extent of water logged, critical and potentially sensitive area. The water sample collected from peizometers were chemically analysed to record the changes in chemical quality.

Table 14: Area wise average water level fluctuations during last 10 years

Area	Av. water level (m)	Average fluctuation (m)	Water level (m)		Fluctuation rise (m)		Fluctuation depletion (m)	
			Max.	Min.	Max.	Min.	Max.	Min.
Command area IGNP II	21.29	-0.10	46.32	1.10	5.13	0.04	5.92	0.10
In vicinity of canal	10.32	-0.21	17.14	1.10	2.34	0.07	3.42	0.13

Water level changes: The analysis of water level data (Table 14) indicated that during last 10 years, the average water level fluctuation in stage II is -0.10 m/year whereas, the fluctuation of water table in the vicinity of canal is -0.21 m/year showing depleting trend. Analysis of data also revealed that there is decrease in extent of area under all three categories i.e. potentially sensitive, critical and waterlogged area. The overall decrease in three categories of area is attributed to variation in rainfall, availability of water in canal system and return flow of irrigation

Ground water quality: In IGNP-II, command, natural ground water is saline, having EC around 10 dS/m However, chemical quality in the vicinity of canal is better with EC value 3 dS/m which shows fresh water horizon, is developing gradually over natural ground water. The fresh water cushion has acquired significant thickness at many places. The maximum and minimum salinity during 2007-08 were recorded as 35.5 dS/m and 0.67 dS/m at SMG 190 RD and at Andhuri head, respectively, in stage II. Analysis of sample collected during 2013 show that salinity level at most of the location in vicinity of canal are decreasing by 0.5 to 3 dS/m as compared to locations away from canal where the average decrease in salinity is about 1.5 dS/m during last 6 years.

Tolerance of brinjal to saline water under drip and flood irrigation systems

The study was conducted during *kharif* 2011 and 2012, to evaluate the performance of brinjal under saline water through drip and flood irrigation system. The treatments consisted of three levels of water quality (EC_{iw} 0.25, 3.0 and 6.0 dS/m) with two irrigation methods (drip and flood). Drip method was found superior over flood method at all the levels of EC_{iw} and resulted in 26.5% higher fruit yield (Table 15). Highest fruit yield of brinjal was obtained under drip method of irrigation with water having EC_{iw} 0.25 dS/m (BAW) over rest of the treatments. A significant decrease in yield was observed with water having EC_{iw} 6.0 dS/m in both the years and in pooled mean. The critical level of EC_{iw} for brinjal under drip irrigation system was observed to be 3.0 dS/m.

The EC_e of soil recorded after harvest of brinjal crop as affected by salinity levels of irrigation water in 0-45 cm soil profile at 0, 15 and 30 cm lateral distances from the emitter has shown that the maximum salinity was registered at 30 cm distance from emitters with 6.0 dS/m saline water. The trend clearly indicates that the soluble salt distribution (EC_e, dS/m) in the root zone show accumulation on the surface and decreased gradually with the depth for all the treatments (Table 16).

Table 15: Effect of methods of irrigation and salinity of irrigation water on yield of brinjal

Treatments	*Kharif* 2011			*Kharif* 2012			Pooled	
	Fruit wt. (g)	Fruits/ plant	Yield (q/ha)	Fruit wt. (g)	Fruits/ plant	Yield (q/ha)	Fruit wt. (g)	Yield (q/ha)
Drip irrigation								
EC_{iw} 0.25 dS/m	56.7	6.9	187.8	56.4	7.4	215.3	56.5	201.5
EC_{iw} 3.0 dS/m	49.3	5.6	183.9	69.8	9.8	235.6	59.5	209.7
EC_{iw} 6.0 dS/m	33.2	4.2	154.7	48.1	5.3	186.2	40.6	170.3
Flood irrigation								
EC_{iw} 0.25 dS/m	41.4	6.1	170.5	49.6	6.8	193.5	45.5	182.0
EC_{iw} 3.0 dS/m	39.6	4.8	141.0	44.9	5.1	156.8	42.1	148.9
EC_{iw} 6.0 dS/m	26.5	2.6	120.2	39.3	3.4	137.1	32.9	128.6
S EM ±	2.5	0.4	2.8	1.6	0.5	8.3	1.6	4.4
CD (5%)	7.9	1.2	8.9	5.0	1.6	26.0	4.7	12.9

Table 16: Salinity (EC_e) build-up in the soil profile after harvest of brinjal

Distance from emitter (cm)	Soil depth (cm)	*Kharif* 2011						*Kharif* 2012					
		Drip irrigation			Flood irrigation			Drip irrigation			Flood irrigation		
		0.25	3.0	6.0	0.25	3.0	6.0	0.25	3.0	6.0	0.25	3.0	6.0
0	0-15	0.44	1.49	1.84	0.41	1.81	2.94	0.49	0.80	0.98	0.60	1.20	1.33
	15-30	0.42	1.30	1.68	0.39	1.58	2.29	0.45	0.73	0.88	0.35	0.98	1.22
	30-45	0.37	1.15	1.53	0.33	1.26	1.61	0.35	0.60	0.80	0.30	0.75	1.10
15	0-15	0.59	1.65	2.28	-	-	-	0.55	0.85	1.08	-	-	-
	15-30	0.55	1.54	1.99	-	-	-	0.53	0.79	1.00	-	-	-
	30-45	0.49	1.19	1.76	-	-	-	0.47	0.68	0.95	-	-	-
30	0-15	0.66	1.79	2.71	-	-	-	0.63	0.98	1.16	-	-	-
	15-30	0.63	1.76	2.63	-	-	-	0.58	0.90	1.13	-	-	-
	30-45	0.53	1.34	2.34	-	-	-	0.53	0.75	1.03	-	-	-

Study to optimize water requirement of groundnut – isabgol using saline water under drip irrigation

Groundnut: An experiment was conducted to work out optimum irrigation geometry for groundnut grown under drip system using saline irrigation water (Fig. 3). The treatment consisted of three levels of salinity of irrigation water (BAW, 4 and 8 dS/m) and three irrigation geometry (lateral x emitter) viz., 60 cm x 30 cm, 90 cm x 30 cm and 120 cm x 30 cm. Data presented in Table 17 showed that increasing levels of salinity of irrigation water resulted in significant reduction in the pod yield of groundnut during both the years. Pooled data showed that BAW produced pod yield of 38.83 q/ha, which got reduced significantly at EC_{iw} 4 and 8 dS/m by 29.6 and 65.6 per cent, respectively. Irrigation geometry (lateral x emitter) maintained at 60 cm x 30 cm recorded the highest pod yield of 32.2 q/ha. As compared to laterals spaced at 60 cm, drip laterals spaced at 90 and 120 cm resulted in significant reduction in yield by 17.5 and 35.6 per cent, respectively.

Table 17: Effect of saline irrigation water and drip geometry on groundnut

Treatments	Pod yield (q/ha)			Plant height (cm)			Pods per plant			Pod weight per plant (g)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
EC_{iw} (dS/m)												
BAW	39.2	38.46	38.83	28.9	27.05	27.98	28.9	27.6	28.25	31.06	27.29	29.18
4	27.66	27.01	27.34	23.2	21.82	22.51	22.6	19.98	21.29	22.33	19.18	20.76
8	11.38	15.3	13.34	20.2	18.72	19.46	16.9	14.82	15.86	9.15	12.00	10.58
CD (5%)	1.59	1.71	1.40	1.8	1.89	1.28	1.6	1.17	0.90	1.33	1.00	1.28
Irrigation geometry (Lateral x Emitter)												
60 x 30 cm	29.48	34.9	32.19	25.9	25.57	25.74	25.8	23.68	24.74	23.58	22.80	23.19
90 x 30 cm	26.35	26.83	26.56	24.8	22.56	23.68	23.5	21.97	22.74	20.88	19.19	20.04
120 x 30 cm	22.42	19.03	20.73	21.7	19.47	20.59	19.2	16.75	17.98	18.07	16.48	17.28
CD (5%)	1.59	1.71	1.40	1.8	1.89	1.28	1.6	1.17	0.90	1.33	1.00	1.28

Combined effects of treatments showed that BAW recorded the highest pod yield (46.5 q/ha) with lateral x emitter spacing of 60cm x 30cm. Increase in salinity of irrigation water beyond 0.25 dS/m resulted in significant reduction in pod yield at all drip geometries, however, reduction was more pronounced beyond 4 dS/m (Table 18). Drip geometry of 60cm x 30cm, when compared with BAW, EC_{iw} 4 and 8 dS/m caused significant reduction of 29.0 and 63.3 per cent in pod yield. At drip geometry of 90cm x 30cm, significant reduction of pod yield by 33.2 and 64.4 per cent was observed.

Table 18: Combined effect of treatments on pod yield of groundnut

Treatments	Pod yield (q/ha) on pooled basis		
	60cm x 30cm	90cm x 30cm	120cm x 30cm
BAW	46.5	39.4	30.6
4 dS/m	33.0	26.3	22.7
8 dS/m	17.1	14.0	8.9
S Em ±	0.85	-	-
CD (5%)	2.83	-	-

The moisture per cent of soil showed a decreasing trend as one move away from the emission points. Minimum moisture was obtained mid way between central lines in all the geometries at all levels of irrigation water salinity. The soil salinity showed an increasing trend from wetted/saturated zone to wetting zone indicating movement of salts with soil water. Higher soil salinity was observed at locations with lower moisture content. This may be attributed to salt accumulation at outward periphery of wetted zone extending upto wetting front due to pushing away of salts with moisture front.

Fig. 3: Groundnut under saline water through drip irrigation

Isabgol: After groundnut, isabgol was grown with same levels of salinity of irrigation water and irrigation geometries. Pooled data (Table 19a, b) showed that increase in level of salinity of irrigation water from BAW to 4 dS/m resulted in significant increase of 10.5 per cent in grain yield, but further increase in salinity (8 dS/m) resulted in significant reduction of 29.9 and 36.6 per cent, over 4 dS/m and BAW (6.67 q/ha) levels of salinity, respectively. Irrigation geometry (lateral x emitter) maintained at 60cm x 30cm gave highest grain yield of 7.62 q/ha. As compared to laterals spaced at 60 cm, drip laterals spaced at 90cm and 120 cm resulted in significant reduction of 13.5 and 40.8 per cent, respectively in grain yield of isabgol.

The combined effect of treatments showed that the highest grain yield of isabgol (8.90 q/ha) was recorded under drip geometry of 60 cm x 30 cm with 4 dS/m salinity of irrigation water and differed significantly to rest of the other treatment combinations (Table 20).

Table 19a: Plant height and yield attributes of Isabgol under saline water and drip geometry

Treatments	Plant height (cm)			Tillers/ plant			Ears/plant		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
EC of irrigation water (dS/m)									
0.25 (BAW)	25.5	21.7	23.6	11.7	8.2	10.0	6.31	5.22	5.78
4	22.3	17.7	20.0	10.8	7.7	9.3	5.60	6.18	5.11
8	19.2	14.3	16.8	8.0	6.5	7.2	3.84	3.27	3.49
CD (5%)	1.8	2.6	0.4	0.6	0.8	0.1	0.28	0.32	0.05
Drip geometry (Lateral x Emitters)									
60cm x 30cm	25.3	21.1	23.2	11.4	8.6	10.0	6.31	5.20	5.77
90cm x 30cm	23.0	19.2	21.1	10.3	7.4	8.9	5.64	6.24	5.16
120cm x 30cm	18.7	13.4	16.0	8.7	6.5	7.6	3.80	3.22	3.46
CD (5%)	1.8	2.6	0.4	0.6	0.8	0.1	0.28	0.32	0.05

Table 19b: Seed and biological yield of Isabgol under saline water irrigation and drip geometry

Treatments	Seed yield (q/ha)			Biological yield (q/ha)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
EC of irrigation water						
0.25 (BAW)	7.70	5.64	6.67	24.87	17.89	21.37
4	8.45	6.30	7.37	28.60	21.02	24.81
8	6.00	3.34	4.67	24.01	12.94	18.48
CD (5%)	0.51	0.59	0.09	1.78	1.92	0.42
Drip geometry						
60cm x 30cm	9.00	6.23	7.62	29.50	19.96	24.73
90cm x 30cm	7.35	5.83	6.59	25.76	19.88	22.82
120cm x 30cm	5.80	3.22	4.51	22.22	12.01	17.11
CD (5%)	0.51	0.59	0.09	1.78	1.92	0.42

Table 20: Combined effect of EC and drip geometry on isabgol (pooled over two years)

Treatments	EC of irrigation water		
	BAW	4 dS/m	8 dS/m
	Seed yield (q/ha)		
60cm x 30cm	8.56	8.90	5.38
90cm x 30cm	6.79	7.95	5.01
120cm x 30cm	4.65	5.27	3.61
CD (5%)		0.26	
	Ears/plant		
60cm x 30cm	6.6	6.4	4.3
90cm x 30cm	6.0	5.4	4.0
120cm x 30cm	4.7	3.5	2.1
CD (5%)		0.1	
	Biological yield (q/ha)		
60cm x 30cm	25.97	27.85	20.37
90cm x 30cm	22.12	27.80	18.53
120cm x 30cm	16.03	18.78	16.53
CD (5%)		1.25	

Study on groundnut-isabgol crop sequence under drip irrigation system to mitigate the adverse effect of saline water by using bio-regulators

Groundnut: Groundnut grown under drip to evaluate the impact of bio-regulators in mitigating the adverse effect of saline irrigation water (Fig. 4). The treatments comprised of four levels of salinity of irrigation water (BAW, 4, 8 and 12 dS/m) and four bio-regulators viz., control, Ascorbic acid (100 ppm), Cycocel (500 ppm) and K_2SO_4 (200 ppm) used as soaking plus foliar sprays (Table 21, 22). The bio-regulators were sprayed twice at 45 and 60 days after sowing. A significant reduction of 20.6, 53.6 and 82.0 per cent in pod yield of groundnut was observed, when irrigated with 4, 8 and 12 dS/m saline waters, respectively, as compared to BAW (37.98 q/ha). An improvement in chlorophyll content at EC_{iw} 4.0 dS/m was observed, however further increase in EC_{iw} 8 and 12 dS/m caused significant reduction in chlorophyll content as compared to BAW.

Different bio-regulators have shown promising effect in mitigating adverse effect of saline irrigation water. Among different bio-regulator treatments, Ascorbic acid (100 ppm), Cycocel (500 ppm) and K_2SO_4 (200 ppm) brought about significant improvement in pod yield by a margin of 8.1, 4.1 and 16.2 per cent, respectively, over control, however, K_2SO_4 proved to be most effective bio-regulator. The plant height increased significantly by 4.9, 9.2 and 21.2 per cent with Ascorbic acid (100 ppm), Cycocel (500 ppm) and K_2SO_4 (200 ppm), respectively, over control. Similarly increase in pods per plant (12.0, 17.1 and 25.3 per cent), pod weight/plant (14.4, 16.0 and 22.3 per cent), chlorophyll content (5.6, 6.3 and 17.3 per cent) and membrane stability index (8.4, 10.8 and 18.3 per cent) was recorded.

Combined effect of treatments indicated that bio-regulators had significant effect on pod yield when used with saline irrigation water (Table 22). Under irrigation water of 4 dS/m, K_2SO_4 recorded the pod yield of 33.48 q/ha, which was significantly higher by 23.5, 9.8 and 13.5 per cent, over control, Ascorbic acid and Cycocel, respectively. At 8 and 12 dS/m, however, K_2SO_4 proved to be most effective and recorded increase of the order of 22.6 and 30.0 per cent, respectively, over control as against 12.1 and 14.3 per cent with Ascorbic acid and 6.7 and 9.3 per cent with cycocel. Increase in salinity of irrigation water significantly decreased the pod yield even with the use of chemicals (Table 23) but the magnitude of reduction was less when K_2SO_4 was used.

Table 21: Effect of saline irrigation water and foliar application of bio-regulators on groundnut

Treatments	Pod yield (q/ha)			Plant height (cm)			Pods per plant			Pod weight per plant (g)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
EC of irrigation water (dS/m)												
BAW	38.58	37.37	37.98	25.9	23.8	24.8	25.4	23.4	24.4	36.07	33.10	34.59
4	28.77	31.51	30.14	26.7	21.0	23.9	23.6	20.5	22.1	30.33	20.54	25.44
8	18.15	17.12	17.64	19.5	17.7	18.6	18.2	12.1	15.1	14.47	12.06	13.27
12	7.49	6.18	6.84	12.5	12.9	12.7	13.2	7.1	10.1	8.94	7.05	8.00
CD (5%)	1.35	1.43	1.11	1.2	1.0	0.8	0.9	0.9	0.7	1.76	0.81	0.79
Seed soaking/Foliar Spray												
Control	21.79	21.44	21.62	19.5	17.2	18.4	17.5	14.2	15.8	19.41	16.50	17.96
AscorbicAcid (100 ppm)	23.46	23.27	23.37	20.1	18.5	19.3	19.5	15.8	17.7	22.68	18.40	20.54
Cycocel (500 ppm)	22.61	22.39	22.50	21.0	19.1	20.1	20.9	16.1	18.5	23.27	18.40	20.84
K_2SO_4 (200 ppm)	25.13	25.11	25.12	24.0	20.5	22.3	22.5	17.0	19.8	24.45	19.46	21.96
CD (5%)	1.11	0.90	0.87	1.2	0.6	0.5	0.8	0.6	0.4	1.44	0.53	0.41

Table 22: Effect of saline irrigation water and foliar application of bio-regulators on groundnut

Treatments	Chlorophyll content			Membrane stability index		
	2012	2013	Pooled	2012	2013	Pooled
EC of Irrigation water (dS/m)						
BAW	1.115	1.056	1.0855	47.33	46.66	46.99
4	1.195	1.137	1.166	40.47	39.74	40.10
8	1.052	0.825	0.9385	41.59	36.33	38.96
12	0.843	0.487	0.665	37.04	31.96	34.5
CD (5%)	0.025	0.195	0.17	1.68	1.13	1.28
Seed soaking/Foliar Spray						
Control	0.981	0.815	0.898	38.44	34.97	36.70
Ascorbic Acid (100 ppm)	1.048	0.849	0.9485	41.04	38.52	39.78
Cycocel (500 ppm)	1.045	0.865	0.955	42.28	39.06	40.67
K_2SO_4 (200 ppm)	1.13	0.977	1.0535	44.7	42.14	43.42
CD (5%)	0.028	0.053	0.04	1.25	1.55	1.15

Table 23: Combined effect of treatments on pod yield (q/ha) (Pooled)

Treatments	Control	Ascorbic Acid (100 ppm)	Cycocel (500 ppm)	K_2SO_4 (200 ppm)
BAW	37.33	38.17	36.86	39.56
4 dS/m	27.12	30.48	29.5	33.48
8 dS/m	15.99	17.92	17.06	19.6
12 dS/m	6.03	6.89	6.59	7.84
CD (5%)		1.37		

Fig. 4: Groundnut under drip irrigation of saline water and bio-regulators

Isabgol: An experiment on Isabgol with three salinity of irrigation water (BAW, 4 and 8 dS/m) and four foliar sprays viz., control, Ascorbic acid (100 ppm), K_2SO_4 (200 ppm) and benzyl adenine (200 ppm) was conducted to study the effect of exogenous application of growth substances to mitigate adverse effect of saline irrigation water. Pooled data (Table 24a, b and 25) showed that grain yield of isabgol increased substantially as the levels of salinity of irrigation water increased from 0.25 (BAW) to 4 dS/m, but not found statistically significant. However, at 8 dS/m, significant reduction of 20.5 and 22.4 per cent in grain yield was recorded as compared to BAW (7.87 q/ha) and 4 dS/m (8.07 q/ha). Among different foliar spray treatments, K_2SO_4 (200 ppm) produced significant improvement in grain yield by a margin of 21.5, 7.8 and 12.1 per cent over control, Ascotbic acid and benzyl adenine (200 ppm), respectively. Among different bio-regulators, K_2SO_4 has been found most effective particularly with increased salinity of irrigation water (Table 26).

Table 24a: Effect of salinity of irrigation water and foliar application of bio-regulators on isabgol

Treatments	Plant height (cm)			No. of tillers per plant			No. of ears/plant		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
EC of irrigation water									
0.25 dS/m	26.40	21.20	23.80	12.24	10.30	11.27	6.57	5.13	5.85
4 dS/m	25.50	19.70	22.60	10.78	9.10	9.94	6.05	5.24	5.65
8 dS/m	20.00	12.70	16.35	8.67	6.60	7.64	5.35	4.88	5.12
CD (5%)	0.80	0.60	0.40	0.40	0.40	0.24	0.14	0.20	0.09
Foliar spray/Seed soaking									
Control	23.00	17.10	20.05	9.67	8.00	8.84	5.68	4.77	5.23
Ascorbic acid (100 ppm)	23.60	17.60	20.60	10.43	8.70	9.57	5.94	5.09	5.52
K_2SO_4 (200ppm)	25.10	18.60	21.85	11.41	9.20	10.31	6.28	5.32	5.80
Benzyl adenine (200ppm)	24.30	18.10	21.20	10.74	8.80	9.77	6.07	5.14	5.61
CD (5%)	0.90	0.70	0.58	0.47	0.50	0.36	0.16	0.20	0.12

Table 24b: Effect of salinity of irrigation water and foliar application of bio-regulators on isabgol

Treatments	Seed yield (q/ha)			Biological yield (q/ha)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
EC of irrigation water						
0.25 dS/m	8.51	7.23	7.87	26.14	22.22	24.18
4 dS/m	8.64	7.50	8.07	26.32	21.97	24.15
8 dS/m	7.00	5.52	6.26	21.12	16.65	18.89
CD (5%)	0.18	0.40	0.21	0.56	1.31	0.68
Foliar spray/Seed soaking						
Control	7.65	5.72	6.69	23.43	17.27	20.35
Ascorbic acid (100ppm)	8.16	6.92	7.54	24.85	20.65	22.75
K_2SO_4 (200ppm)	8.45	7.81	8.13	25.63	23.29	24.46
Benzyl adenine (200ppm)	7.94	6.56	7.25	24.19	19.90	22.05
CD (5%)	0.21	0.47	0.26	0.65	1.27	0.70

Table 25: Effect of salinity of irrigation water and foliar application of bioregulators on isabgol

Treatments	Chlorophyll content			Membrane stability		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
EC of irrigation water						
0.25 (BAW)	0.969	0.917	0.943	55.70	56.15	55.93
4 dS/m	0.911	0.877	0.894	47.20	50.69	48.95
8 dS/m	0.768	0.788	0.778	34.80	36.14	35.47
CD (5%)	0.061	0.018	0.030	1.20	1.03	0.78
Foliar spray/Seed soaking						
Control	0.811	0.788	0.800	43.30	44.99	44.15
Ascorbic acid (100ppm)	0.879	0.886	0.883	46.50	48.31	47.41
K_2SO_4 (200ppm)	0.941	0.905	0.923	48.60	50.44	49.52
Benzyl adenine (200ppm)	0.899	0.863	0.881	45.20	46.89	46.05
CD (5%)	0.071	0.021	0.040	1.30	1.29	0.90

Table 26: Combined effect of treatments on chlorophyll and membrane stability of Isabgol

Treatments	Control	Ascorbic Acid	K_2SO_4	Benzyladenine
		Chlorophyll		
BAW	0.929	0.954	0.959	0.929
4 dS/m	0.836	0.869	0.946	0.926
8 dS/m	0.633	0.825	0.864	0.789
CD (5%)		0.063		
		Membrane Stability		
BAW	54.57	56.77	57.43	54.96
4 dS/m	47.22	49.27	51.18	48.07
8 dS/m	30.62	36.25	39.90	35.07
CD (5%)		1.57		

Performance of wheat varieties under saline irrigation water through drip system

A field experiment was conducted to evaluate the performance of wheat varieties (Raj 3077, Raj 4188, KRL 210 and KRL 213) under drip using varying salinity of irrigation water (BAW, 4, 8 and 12 dS/m).

Data presented in Table 27, 28 showed that salinity of water >4 dS/m had significant effect on crop growth, yield attributes and yield of wheat varieties. Highest grain yield was obtained with BAW (29.47 q/ha), which was at par with EC_{iw} 4 dS/m. As compared to BAW, EC_{iw} 8 and 12 dS/m resulted in significant reduction (14.1 and 32.6 per cent) in grain yield, respectively. Grain yield of variety Raj 3077 established its superiority by significant margin of 61.5, 17.0 and 24.3 per cent over Raj 4188, KRL 210 and KRL 213, respectively. Significantly higher straw yield was recorded with KRL 213 as compared to other varieties. Combined effect of saline irrigation and wheat varieties on grain yield was also found significant. Wheat variety Raj 3077 produced significantly higher grain yield over other varieties with any saline water irrigation. Application of BAW in conjunction with Raj 3077 produced highest grain yield over other combinations. It is important to note that reduction in the grain yield due to increased salinity of irrigation water was of lesser magnitude in case of KRL 210 and KRL 213. (Table 29, Fig.5)

Table 27: Performance of wheat varieties under saline water irrigation

Treatments	Grain yield (q/ha)			Straw yield (q/ha)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
EC of irrigation water						
BAW	30.89	28.06	29.47	43.97	36.25	40.11
4 dS/m	28.66	28.28	28.47	41.48	33.60	37.54
8 dS/m	27.22	23.41	25.31	37.85	29.65	33.75
12 dS/m	23.41	16.28	19.85	35.24	22.22	28.73
CD (5%)	2.92	0.82	1.41	2.46	3.61	2.33
Varieties						
Raj 3077	32.63	30.27	31.45	38.49	28.03	33.26
Raj 4188	21.17	17.76	19.47	37.09	31.31	34.20
KRL 210	29.15	24.60	26.88	38.63	28.91	33.77
KRL 213	27.22	23.39	25.31	44.35	33.46	38.90
CD (5%)	2.01	0.73	1.05	3.26	3.73	2.33

Table 28: Performance of wheat varieties under saline water irrigation

Treatments	Plant height (cm)			Ear length (cm)			Grains/ear			Test weight (g)		
	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled	2012-13	2013-14	Pooled
EC of irrigation water												
BAW	72	69.34	70.67	8.28	8.09	8.19	36.12	32.05	34.09	35.5	34.79	35.15
4 dS/m	69.81	67.58	68.70	8.08	8.18	8.13	35.64	29.98	32.81	35.25	34.36	34.81
8 dS/m	66.25	64.16	65.21	7.89	7.95	7.92	34.32	30.54	32.43	34.06	35.5	34.78
12 dS/m	61.13	56.04	58.59	7.5	7.09	7.30	29.39	24.55	26.97	33.63	33.18	33.41
S Em±	2.30	0.79	0.66	0.10	0.10	0.07	1.28	0.46	0.33	0.58	0.42	0.19
CD (5%)	7.36	2.54	1.84	0.32	0.31	0.18	4.11	1.46	0.94	NS	1.33	0.54
Varieties												
Raj 3077	65.25	63.07	64.16	7.76	7.7	7.73	35.05	32.9	33.98	35	35.1	35.05
Raj 4188	68.88	64.65	66.77	7.61	7.88	7.75	32.97	25.04	29.01	34.38	33.43	33.91
KRL 210	67.63	64.16	65.90	8.64	7.81	8.23	34.39	31.32	32.86	35.5	34.68	35.09
KRL 213	67.44	65.24	66.34	7.74	7.93	7.84	33.08	27.86	30.47	33.56	33.61	33.59
S Em±	1.90	1.41	0.66	0.10	0.14	0.07	1.11	0.71	0.33	0.52	0.37	0.19
CD (5%)	NS	NS	NS	0.28	NS	NS	NS	2.04	0.94	NS	1.08	0.54

Table 29: Combined effect of saline irrigation and varieties on grain yield and yield reduction

Wheat varieties	EC_{iw} levels (dS/m)				Yield reduction (%)		
	0.25	4	8	12	4	8	12
Raj 3077	35.83	35.19	31.50	23.26	1.78	10.50	26.15
Raj 4188	23.18	22.61	18.31	13.78	2.46	19.04	24.73
KRL 210	30.51	28.67	26.64	21.69	6.05	7.07	18.56
KRL 213	28.36	27.40	24.81	20.65	3.38	9.48	16.74
CD (5%)	1.48				-	-	-

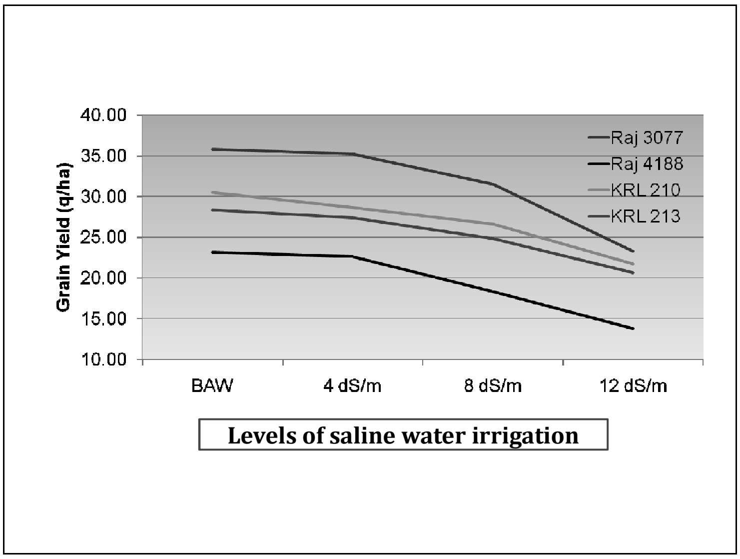


Fig. 5: Combined effect of treatments on grain yield of wheat (pooled over two years)

The EC_e of soil at harvest of wheat was affected by salinity levels of irrigation water in different soil layers up to 45cm depth at 0, 15 and 30 cm lateral distances from the drippers (Table 30). Maximum salinity was observed at 30cm distances from drippers under EC_{iw} 12.0 dS/m while minimum salinity was found just below the dripper with canal water (0.25 dS/m). The salt concentration in soil profile increased with increase in lateral as well as vertical distances from the drippers. It can be inferred that salts have leached away from active root zone of plant providing better growth conditions.

Table 30: Salinity (EC_e) build-up in soil profile after wheat under saline water drip irrigation

Distance from dripper (cm)	Soil depth (cm)	EC_{iw} (dS/m)			
		0.25 (BAW)	4	8	12
0	0-15	0.18	0.39	0.48	0.56
	15-30	0.14	0.32	0.44	0.48
	30-45	0.11	0.26	0.38	0.45
15	0-15	0.23	0.42	0.55	0.62
	15-30	0.21	0.34	0.52	0.57
	30-45	0.19	0.30	0.41	0.53
30	0-15	0.26	0.44	0.58	0.71
	15-30	0.24	0.37	0.56	0.66
	30-45	0.22	0.32	0.50	0.63

Study on wheat under drip irrigation system to mitigate the adverse effect of saline water by seed soaking/foliar application of bio-regulators

An experiment with four levels of salinity of irrigation water (BAW, 4, 8 and 12 dS/m) and four treatments of seed soaking/foliar sprays viz., control, Ascorbic acid (100 ppm), K_2SO_4 (200 ppm) and benzyl adenine (200 ppm) was conducted. It is observed that use of saline water of 8 and 12 dS/m resulted in significant reduction of 14.9 and 34.0 per cent in grain yield of wheat variety Raj 3077 over BAW (33.18 q/ha). Grain yield at EC_{iw} 4 dS/m and 8 dS/m remained statistically at par. Among different seed soaking/foliar spray treatments, K_2SO_4 (200 ppm) produced significant improvement in grain yield by a margin of 12.2, 7.3 and 9.4 per cent over control, Ascorbic acid and benzyl adenine (200 ppm), respectively (Table 31 and 32). All the growth and yield attributes affected significantly under different seed soaking/foliar spray treatments. Significant effects have also been noticed in respect of chlorophyll content and membrane stability index.

Results of combined effect revealed that all growth and yield attributes showed a sharp decline with increase in salinity of irrigation water >4 dS/m (Table 33). Among bio-regulators, K_2SO_4 has been found most effective particularly with increased salinity of irrigation water. Seed soaking/spray of K_2SO_4 resulted in less reduction in the grain yield of wheat at 8 and 12 dS/m salinity of irrigation water as compared to other treatments. Reduction in the grain yield at EC_{iw} 8 and 12 dS/m under control was 16.98 and 36.53 per cent, whereas respective reduction in the yield under the influence of K_2SO_4 was 11.57 and 14.05 per cent only. It is also important to note that K_2SO_4 exhibited its superiority in respect of chlorophyll content at all the salinity levels of irrigation water.

Table 31: Effects of water salinity and chemicals on grain yield of wheat under drip irrigation

Treatments	Grain yield (q/ha)			StrawyYield (q/ha)			Chlorophyll content (%)		Membrane stability index	
	2012-13	2013-14	pooled	2012-13	2013-14	pooled	2012-13	2013-14	2012-13	2013-14
EC of irrigation water										
0.25 dS/m	32.19	34.16	33.18	38.61	30.99	34.80	1.455	1.428	54.05	53.63
4 dS/m	33.33	32.07	32.70	37.78	32.53	35.16	1.413	1.458	51.76	48.85
8 dS/m	28.22	28.21	28.22	31.49	27.27	29.38	1.321	1.419	42.15	41.62
12 dS/m	25.44	18.38	21.91	29.43	25.31	27.37	1.248	1.239	35.10	32.10
S Em±	0.24	0.29	0.19	0.70	1.05	0.56	0.009	0.016	0.23	0.39
CD (5%)	0.68	0.82	0.52	1.98	3.36	1.65	0.025	0.047	0.66	1.10
Foliar spray/Seed soaking										
Control	28.73	26.61	27.67	35.97	30.91	33.44	1.31	1.358	43.12	41.51
Ascorbic acid (100 ppm)	30.2	27.67	28.94	34.92	29.06	31.99	1.37	1.367	45.91	44.22
K_2SO_4 (200 ppm)	31.85	30.22	31.04	33.92	28.99	31.46	1.403	1.441	48.45	46.63
Benzyl adenine (200 ppm)	28.4	28.31	28.36	32.51	27.15	29.83	1.354	1.378	45.58	43.84
S Em±	0.24	0.29	0.19	0.7	0.79	0.55	0.009	0.016	0.23	0.39
CD (5%)	0.68	0.82	0.52	1.98	2.26	1.54	0.025	0.047	0.66	1.1

Table 32: Effects of water salinity and chemicals on yield attributes of wheat under drip irrigation

Treatments	Plant height (cm)		Tillers/sqm		Panicle/sqm		Grains/panicle		Test weight (g)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
EC of irrigation water										
0.25 (BAW)	83.31	85.2	341.6	282.4	326.1	246.1	23.3	30.6	0.431	41.9
4 dS/m	81.19	82.1	352.8	278.7	335	229.6	24	33.3	0.432	42.4
8 dS/m	79.41	82	309.5	249.7	287.4	208.3	20.6	28.6	0.431	42.2
12 dS/m	76.79	69.6	278.3	218.2	252.3	171.4	18.1	23	0.432	40.3
S Em±	1.61	1.7	2.6	7.6	3.5	3.7	0.3	0.35	0.004	0.6
CD (5%)	NS	5.5	7.5	24.2	10	11.7	0.7	1.13	NS	NS
Spray/Seed soaking										
Control (water spray)	78.1	77.6	311.1	254.1	277.9	191.6	16.1	24	0.421	40.4
Ascorbic acid (100 ppm)	81.63	80.2	323.6	255.4	306.1	219.9	21	28.5	0.428	41.5
K_2SO_4(200ppm)	80.98	81.1	338.9	268.9	326.1	239.5	26	32.9	0.438	43.2
Benzyl adenine (200 ppm)	79.99	79.9	308.5	250.4	290.8	204.4	23	30.1	0.439	41.6
S Em±	1.61	1.7	2.6	4.4	3.5	3	0.3	0.3	0.004	0.06
CD (5%)	NS	NS	7.5	12.7	10	8.7	0.7	0.9	0.012	1.6

Table 33: Combined effect of treatments (Pooled over two years)

Treatments	BAW	4 dS/m	8 dS/m	12 dS/m
	Grain yield			
Control	32.31	33.25	27.60	17.52
Ascorbic acid	32.96	32.17	28.40	22.15
K_2SO_4	34.13	34.04	30.10	25.88
Benzyladenine	33.29	31.35	26.77	22.00
CD (5%)	0.74			
	Straw yield			
Control	34.21	36.90	33.38	29.27
Ascorbic acid	34.65	35.88	30.96	26.48
K_2SO_4	36.58	33.75	26.17	29.31
Benzyladenine	33.77	34.10	27.02	24.42
CD (5%)	2.18			
	No. of panicle per m^2			
Control	264.875	268.500	216.875	188.750
Ascorbic acid	295.500	277.250	263.375	215.750
K_2SO_4	299.000	306.375	274.375	251.500
Benzyladenine	285.000	277.125	236.750	191.375
CD (5%)	9.10			
	No. of grains per panicle			
Control	21.40	23.65	18.95	16.05
Ascorbic acid	26.48	27.25	24.93	20.35
K_2SO_4	30.45	32.98	28.90	25.30
Benzyladenine	29.50	30.60	25.60	20.50
CD (5%)	0.8			
	Chlorophyll content			
Control	1.43	1.39	1.28	1.23
Ascorbic acid	1.47	1.40	1.37	1.23
K_2SO_4	1.47	1.51	1.42	1.29
Benzyladenine	1.40	1.44	1.41	1.22
CD (5%)	0.037			
	Membrane stability			
Control	51.56	48.32	38.10	31.27
Ascorbic acid	54.60	50.31	42.14	33.21
K_2SO_4	55.62	52.28	45.17	37.09
Benzyladenine	53.59	50.31	42.13	32.82
CD (5%)	0.89			

Screening of mustard genotypes for salt tolerance under flood irrigation

During 2012-13, twenty mustard genotypes including two checks were evaluated. Check (CH-1) produced significantly higher plant height, test weight, seed and stover yield over check (CH-2), hence genotype entries were evaluated on the basis of CH-1 for seed yield. Significantly higher seed and stover yield was obtained under genotype L9 followed by L4, L8, L3, L12 and L18 over CH-1 whereas lower seed and stover yields were recorded with L11, L17, L10, L6, L15 and L14 than CH-1 (Table 34).

The EC_e in soil profile before sowing and after harvest of mustard crop is presented in Table 35. The EC_e of soil increased with increasing soil depth significantly in 30-45 cm over 0-15 cm layer before sowing. The EC_e of soil after harvest of crop increased with saline irrigation (10 dS/m) in 0-45 cm depth.

Table 34: Effect of saline irrigation on growth, yield attributes and yield of mustard genotypes

Mustard varieties (Coded)	Plant height (cm)	Branches/ plant	Siliquae/ plant	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ha)
L1	150.3	20.3	431.8	4.33	17.19	42.65
L2	132.3	12.0	346.7	4.29	17.10	41.87
L3	119.7	12.3	342.7	4.85	21.67	49.62
L4	138.0	11.4	357.0	4.99	22.90	52.21
L5	131.7	12.6	345.5	4.65	18.87	45.47
L6	112.0	7.0	261.0	4.14	10.44	29.33
L7	129.6	11.3	396.6	4.66	19.17	45.43
L8	143.4	9.0	324.7	4.98	22.09	50.80
L9	132.0	11.7	325.0	5.02	23.03	52.74
CH-1	141.8	11.3	352.0	4.85	18.29	44.10
L10	140.3	13.0	398.3	4.61	14.98	37.60
L11	143.5	17.4	480.0	4.72	15.87	39.52
L12	152.7	16.0	433.7	4.87	21.43	48.86
L13	134.3	14.7	388.0	4.84	20.14	47.33
L14	110.3	5.7	183.7	4.10	6.39	16.86
L15	112.0	6.1	242.0	4.16	6.48	16.98
CH-2	139.0	13.0	394.0	4.77	15.90	40.22
L16	150.0	15.3	475.7	4.79	16.45	41.29
L17	144.3	12.7	474.0	4.74	15.18	39.32
L18	145.7	12.0	360.0	4.82	20.29	47.47
SEm ±	6.24	0.54	17.37	0.12	0.69	1.49
CD (5%)	17.66	1.52	49.20	0.34	1.96	4.23
CV (%)	9.23	8.77	9.50	5.19	8.06	7.20

Table 35: Salinity (EC_e) build-up in soil profile before sowing and after harvest of mustard

Soil depth (cm)	EC_e (dS/m)	
	Before sowing	After harvest
0 - 15	0.14	0.89
15 - 30	0.12	0.82
30 - 45	0.11	0.80
S Em ±	0.01	0.02
CD (5%)	0.03	0.06
CV (%)	18.24	5.37

During 2013-14, twelve mustard genotypes including two checks were evaluated on the basis of CH-1 for seed yield (Table 36). Significantly higher seed yield was obtained under genotype L9 followed by L10, L2, L3, L8, L5 and L1 over CH-1 (check) whereas lower seed yields were recorded with L7, L6 and L4 as compared to CH-1 (check).

The EC_e in soil profile before sowing and after harvest of mustard crop is presented in Table 37. The EC_e of soil decreased with increase in depth of soil layers before sowing and after harvest of crop.

Table 36: Effect of saline irrigation on growth, yield attributes and yield of mustard genotypes

Mustard varieties (Coded)	Plant height (cm)	Pimary branches/ plant	Secondary branches/ plant	Days to flowering	Days to maturity	Siliqua/ plant	Seed yield (q/ha)
L1	157.44	3.67	16.16	47.00	150.33	137.00	16.78
L2	163.22	4.67	18.73	45.33	148.67	150.56	19.44
L3	126.67	4.11	15.19	45.33	148.00	128.78	18.56
L4	155.22	4.11	17.48	49.67	150.00	145.67	15.09
L5	155.89	4.11	17.54	50.33	152.33	143.11	16.78
L6	148.89	4.00	17.31	48.00	151.67	169.00	13.22
L7	157.11	3.67	16.90	45.00	144.67	145.89	15.00
L8	163.11	4.78	19.62	50.33	152.00	155.56	18.55
L9	162.11	4.22	17.80	47.67	149.67	157.44	20.78
L10	166.78	4.67	19.30	49.00	149.33	151.67	19.89
CH-1	151.11	4.00	17.27	48.00	147.67	133.00	16.33
CH-2	157.00	4.56	18.17	46.67	148.33	152.00	15.89
CD (5%)	12.28	0.73	2.43	2.22	3.79	15.63	2.01

Table 37: Salinity (EC_e) build-up in soil profile before sowing and after harvest of mustard

Soil depth (cm)	EC_e (dS/m)	
	Before sowing	After harvest
0 - 15	0.16	0.96
15 - 30	0.13	0.84
30 - 45	0.11	0.81

NPK drip fertigation with saline irrigation water for tomato under arid condition

A field experiment was conducted to evaluate the performance of tomato under different saline water irrigation and fertigation levels. The crop was completely damaged due to frost injury experienced in the first week of January, 2014. However, partially recovery was observed due to foliar spray of 1% glucose. Perusal of the data presented in Table 38 revealed that only fruit yield could be recorded and highest was obtained with BAW. Increase in the level of saline irrigation water caused significant reduction in fruit yield. However, application of EC_{iw} 4 and 8 dS/m as well as 8 and 12 dS/m produced at par fruit yield. The highest fruit yield was obtained with application of 125% RDF through fertigation under drip system but it did not differ significantly to 75 and 100% RDF, respectively.

The EC_e of soil at harvest of tomato was affected due to increasing levels of saline water irrigation in different soil layers upto 45cm depths at 20cm lateral distances from the drippers. The maximum salinity was observed in upper surface layers at 20 cm distances from drippers under application of EC_{iw} 12 dS/m thereafter, it decreased in sub-surface layers. The maximum salt concentration was found in surface layers which deceased with increasing depths of surface layers due to saline irrigation levels. It can be inferred that salts have leached away from active root zone of the plant providing better and congenial growth conditions (Table 39).

Table 38: Effect of NPK under drip fertigation with saline irrigation water on yield of tomato

Treatments	Fruit yield (g/plant)	Treatments	Fruit yield (g/plant)
EC of irrigation water		Fertigation (RDF) levels	
0.25 dS/m	237.59	50% RDF	213.52
4 dS/m	228.78	75% RDF	230.86
8 dS/m	225.97	100% RDF	235.10
12 dS/m	222.53	125% RDF	235.39
CD (5%)	6.67	CD (5%)	4.84

Table 39: Salinity build-up in soil profile after harvest of tomato under saline water drip irrigation

Distance from dripper (cm)	Soil depth (cm)	EC_{iw} levels (dS/m)			
		0.25	4	8	12
20	0-15	0.18	0.37	0.61	0.84
	15-30	0.15	0.31	0.53	0.69
	30-45	0.11	0.25	0.44	0.56

GANGAWATI: RESEARCH ACCOMPLISHMENTS

Effect of micro irrigation techniques and fertilizer levels on root yield and quality of sugar beet under saline soils of TBP command

Sugar beet is considered to be a suitable crop for saline soils where sugarcane is not a viable crop due to its sensitivity to soil salinity. The experiment was continued during June 2013 with main plot treatments comprised of three irrigation methods (I_1: drip; I_2: sprinkler and I_3: furrow irrigation) and sub-plot treatments comprised of 4 fertlizer levels (F_1: 100-50-50 kg/ha); (F_2: 120-60-60 kg/ha); (F_3: 150-75-75 kg/ha) and (F_4: 200-100-100 kg/ha NPK), replicated thrice in split plot design at spacing of 60cm x 30cm. The variety (Calixta hybrid) was sown on 16-08-2013 and harvested on 20-02-2014. The results of the fertilizer levels revealed that significantly higher root yield (49.17 t/ha), weight of ten beets (8.83 kg) and brix (23.67%) was obtained with fertilizer level F4 as compared to F1 (33.10 t/ha, 6.63 and 18.83%) and F2 (40.67 t/ha, 6.83 and 20.83%) was obtained which was at par with F3 treatment (Table 1). Irrigation methods treatments were not imposed in the experiment.

Table 1: Sugar beet root yield/wt. of 10 beets/brix value as influenced by fertilizer levels

Fertliser treatments (NPK) kg/ha	Root yield (t/ha)	Weight of 10 beets (kg)	Brix value (%)
F_1 (100-50-50)	33.10	6.33	18.83
F_2 (120-60-60)	40.67	6.83	20.33
F_3 (150-75-75)	45.67	7.67	22.17
F_4 (200-100-100)	49.17	8.83	23.67
Mean	42.15	7.42	21.25
S Em ±	1.66	0.25	0.19
CD (5%)	5.32	1.37	1.07

Large scale demonstration on response of sugar beet to dates of sowing under saline Vertisols of TBP command

A large scale demonstration (1 acre) on response of sugar beet to dates of sowing was also conducted at ARS, Gangavati during *kharif* 2013. The results indicated that higher root yield (42.25 t/ha), weight of ten beets (8.77 kg) and brix (21.33%) was recorded on sowing during August 1st fortnight as compared to 2nd fortnight of August and 1st fortnight of September. Similarly, higher gross returns (Rs. 84500), net returns (Rs. 57911) and B:C ratio (3.17) were also recorded with sowing during August 1st fortnight as compared to other dates of sowing (Table 2)

Table 2: Root yield, weight of ten beets, brix and economics of sugar beet as influenced by different dates of sowing under saline soils of TBP command

Treatments	Root yield (t/ha)	Wt. of 10 beets (kg)	Brix (%)	COC (Rs/ha)	GR (Rs/ha)	NR (Rs/ha)	B:C ratio
T_1	42.25	8.77	21.33	26589	84500	57911	3.17
T_2	38.45	7.55	20.10	26589	76900	50311	2.89
T_3	33.56	6.89	19.83	26589	67120	40531	2.52

T_1: Sowing during August Ist fortnight; T_2: Sowing during August IInd fortnight; T_3: Sowing during September Ist fortnight; COC: Cost of cultivation, GR: Gross return, NR: Net return

Evaluation of controlled drainage system (CDS) in Vertisols of TBP irrigation command

Evaluation of controlled drainage in comparison to conventional SSD system was initiated in an area of 1.4 ha at Gangavati during *kharif* 2012 in terms of reclamation of saline soil, nutrient losses and crop yield. The experiment was continued during *kharif* 2014.

Soil salinity: Initial soil salinity of experimental site during 2012 varied from 1.22 to 19.42, 1.33 to 19.68, 0.88 to 22.61, 0.82 to 22.88 dS/m at 0-15, 15-30, 30-60 and 60-90 cm depths, respectively. The soil salinity under conventional SSD reduced to 7.02 to 2.5 (0-15cm), 7.46 to 1.97 (15-30cm), 7.61 to 3.7 (30-60cm) and 8.16 to 5.32 dS/m (60-90cm) at crop harvest during *kharif* 2014. In case of controlled drainage system, the soil salinity reduced from 6.92 to 1.86 (0-15cm), 8.73 to 4.52 (15-30cm), 11.25 to 6.94 (30-60cm) and 12.73 to 6.62 dS/m (60-90cm) respectively (Table 3). 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 may also be attributed to higher levels of salinity observed initially.

Irrigation water and rainfall: The amount of irrigation water applied for controlled and conventional drainage system during *kharif* 2012, *kharif* 2013, *rabi/summer* 2013-14 and *kharif 20*14 was 115.1, 119.2, 138.2 and 130.4 cm in conventional and 102.1, 105.3, 112.3 and 96.3 cm in controlled drainage systems respectively. Comparing these two treatments over four seasons revealed that about 13, 13.9, 26 and 34.1 cm of irrigation water could be saved under controlled as compared to conventional SSD. (Table 4).

Drainage discharge: The drainage discharge was higher under conventional as compared to controlled SSD system and it varied from 5.91 (*kharif* 2012) to 2.03 mm/day (*kharif* 2014) and 2.06 (*kharif* 2012) to 0.42 mm/day (*kharif* 2014) in conventional and controlled SSD respectively (Table 5). The average drain discharge in conventional system was 3.8, 1.81, 1.4 and 1.61 mm/day higher over the controlled system during this period. The average salinity of drainage water was 2.9, 6.61, 3.1 and 2.5 dS/m in conventional system and 2.03, 3.21, 3.5 and 3.07 dS/m in controlled system respectively. With higher drainage water salinity, removal of salts was 1.94, 4.61, 3.64 and 3.85 t/ha under conventional as compared to 0.56, 1.22, 1.16 and 1.06 t/ha under controlled SSD system.

Salt balance studies: Salt balance of conventional and controlled drainage system was worked out by considering the amount of salts added through irrigation and fertiliser and the salts removed through the drainage system. Irrigation water salinity varied from 0.1 to 0.13 dS/m.

The amount of salt added (input) and removal varied from 1.31 (*rabi-summer* 2013) to 2.03 t/ha (*kharif* 2014) with a mean of 1.59 t/ha and 1.94 (*kharif* 2012) to 4.61 t/ha (*kharif* 2013) with a mean of 3.51 t/ha under conventional SSD system. In case of controlled drainage system, salt input varied from 0.42 (*kharif* 2014) to 1.39 t/ha (*rabi-summer* 2013-14) with a mean of 1.12 t/ha and salt removal varied from 0.56 (*kharif* 2012) to 1.22 (*kharif* 2013) with a mean of 1.0 t/ha. The average amount of salts removed from the conventional drainage system was more than 3.5 times higher than controlled drainage system.

Nutrient loss through drainage system: Loss of nutrients though drainage is also an important aspect of SSD system. Average loss of nutrients such as nitrogen (NO_3-N) was 11.20 kg/ha under conventional and 5.32 kg/ha under controlled drainage system. The overall loss of N under conventional SSD was about 52.5% more than controlled SSD (Table 6). The loss of phosphorus was 0.24 and 0.35 kg/ha and 0.11 and 0.02 kg/ha, loss of potassium was 0.78 to 6.56 kg/ha and 0.31 and 1.19 kg/ha under conventional and controlled drainage systems during *kharif* 2012 and *kharif* 2013, respectively.

Grain yield: There was improvement in grain yields in both the systems. Though not much difference was observed between conventional and controlled drainage system, within the system the yield increase was from 38.4 (Pre-SSD) to 51.4 q/ha (*kharif* 2014) and 37.6 (Pre-SSD) to 48.3 q/ha (*kharif* 2014) respectively (Table 7).

Economic analysis: The initial investment cost of the subsurface drainage system was worked out to be Rs.70,000 per ha (including nala cleaning up to 500 meter length and 0.5 meter depth) and extra Rs.1000 per ha are required for fitting of controlled drainage device. The Annual maintenance cost of the system was Rs1500 per ha.

Table 3: Average soil salinity (EC_e, dS/m) at different depths as influenced by drainage systems

Crop season	Conventional SSD				Controlled SSD			
	0-15 cm	15-30 cm	30-60 cm	60-90 cm	0-15 cm	15-30 cm	30-60 cm	60-90 cm
Initial	7.02	7.46	7.61	8.16	6.92	8.73	11.25	12.73
Kharif 2012	4.57	5.28	6.02	5.45	6.51	8.4	12.41	14.05
Rabi/summer 2012-13	-	-	-	-	-	-	-	-
Kharif 2013	4.3	5.1	5.93	5.25	6.28	8.3	12.01	13.85
Rabi/summer 2013-14	7.79	7.79	8.03	7.95	3.72	6.22	8.33	10.91
Kharif 2014	2.5	1.97	3.7	5.32	1.86	4.52	6.94	6.62

**Due to water shortage no crop was taken during rabi/summer 2012-13*

Table 4: Applied irrigation water depth and precipitation during cropping seasons

Season	Irrigation depth (cm)		Rainfall (cm)
	Conventional SSD	Controlled SSD	
Kharif 2012	115.1	102.1	31.67
Rabi/summer 2012-13	-	-	-
Kharif 2013	119.24	105.32	16.38
Rabi/summer 2013-14	138.23	112.3	-
Kharif 2014	130.4	96.30	22.83

Table 5: Mean drainage discharge rate, salinity, salt input and removal under different SSD systems

Season	Conventional SSD				Controlled SSD			
	Drain discharge (mm/d)	EC_{dw} (dS/m)	Salt input (t/ha)	Salt removal (t/ha)	Drain discharge (mm/d)	EC_{dw} (dS/m)	Salt input (t/ha)	Salt removal (t/ha)
Kharif 2012	5.91	2.90	1.48	1.939	2.06	2.03	1.31	0.56
R/S 2012-13	-	-	-	-	-	-	-	-
Kharif 2013	2.60	3.61	1.53	4.61	0.79	3.21	1.35	1.22
*R/S 20*13-14	2.6	3.1	1.31	3.64	1.2	3.5	1.39	1.16
Kharif 2014	2.03	2.5	2.03	3.85	0.42	3.07	0.42	1.09

Table 6: Nutrient loss (kg/ha) through drainage discharge under different SSD systems

Season	Nitrogen		Phosphorous		Potassium	
	Conventional	Controlled	Conventional	Controlled	Conventional	Controlled
Kharif 2012	6.59	3.0	0.24	0.11	0.78	0.31
Rabi/summer 2012-13	-	-	-	-	-	-
Kharif 2013	21.33	7.50	0.35	0.02	6.56	1.19
Rabi/summer 2013-14	11.45	4.03	-	-	-	-
Kharif 2014	5.40	6.75	-	-	-	-
Avg	11.19	5.32	-	-	-	-

Table 7: Variation in crop yield under different SSD systems

Season	Conventional SSD	Controlled SSD
Initial	38.4	37.6
Kharif 2012	41.8	47.51
R/S 2012-13	-	-
Kharif 2013	46.8	45.8
R/S 2013-14	44.4	40.6
Kharif 2014	51.4	48.3

Screening of forage grasses in salt affected soils of TBP command

Due to acute shortage of green fodder, growing of forage grasses in degraded and marginal land in TBP command could be an option. Hence, screening of forage grasses for their suitability to saline soils of TBP command was initiated during 2011-12 and continued through 2013-14.

Four perennial forage grasses viz., Guinea grass, Grazing guinea grass, Para grass and Rhodes grass were grown on natural soil salinity gradient wherein soil salinity varied from <4 to >20 dS/m. The biomass yield of forage grasses was pooled for 2012-13 and 2013-14 and grouped under soil salinity range (Table 8). The results indicated that, forage yield of Rhodes (26.7 t/ha), Para (28.8 t/ha) and Grazing guinea (28.3 t/ha) grasses were higher at soil salinity of <4 dS/m. At soil salinity of 4-8 dS/m there was <10% reduction in forage yield of Rhodes (24.2 t/ha), Para (25.2 t/ha) and Grazing guinea (27.2 t/ha) whereas it was 50% in Guinea (20.2 to 10.2 t/ha) grass. Further, drastic reduction in forage yield of all the forage grasses was observed in the soil salinity range of 8-12, 12-16 and >16. Rhodes, para and grazing guinea grasses can be successfully grown in the salinity range of EC_e 4-8 dS/m.

Table 8: Soil salinity and biomass yield of forage grasses pooled over two seasons

Soil EC_e range (dS/m)	Green forage yield (t/ha)			
	Rhodes grass	Para grass	Grazing guinea	Guinea grass
<4	26.67	28.78	28.33	20.22
4-8	24.17	25.22	27.21	10.22
8-12	17.23	10.21	17.90	10.74
12-16	17.52	15.14	14.11	6.01
>16	13.19	13.89	14.59	10.93

Response of cotton to drip irrigation in saline soils under conservation agricultural practices

The study was initiated at ARS, Gangavati during 2011-12 and continued up to 2013-14. Initially, soil sampling was done to know the EC range in the experiment plot. Eight observation wells were installed at different treatment to know the influence of irrigation levels on water table. Hydraulic conductivity of the experiment block was measured by inverse auger hole (Porchet) method. U.S.W.B. Class 'A' pan evaporimeter was installed to know the daily evaporation, and from the evaporation data the daily water requirement of cotton crop was calculated and frequency of drip irrigation for each treatment was fixed. Soil moisture content from each treatment at a depth of 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm was recorded two times. The initial surface (0-15 cm) soil pH and EC varied from 8.25 to 8.8 and 3.51 to 9.4 dS/m. The bulk density and soil porosity of experimental site ranged between 1.46-1.61 gm/cc and 42.8-47.2% respectively.

Main plot treatments comprised of without residue (M_1) and with residue (M_2) and sub plot treatments of drip irrigation at 0.8 ET (S_1); 1.0 ET (S_2); 1.2 ET (S_3) and furrow irrigation (S_4) and replicated thrice in split plot design. The cotton variety RAHS 14 was sown on 27-09-2013 and fertilizer dose of 80:40:40 kg NPK/ha was applied. Dripper discharge was 4 lph, placed at 0.6m spacing with 4 plants/dripper.

The pooled data on germination percentage, plant height, monopodial branches, primary sympodial branches, bowls per plant, seed cotton yield, water requirement and water use efficiency from 2011-12 to 2013-14 are presented in Table 9. In case of conservation practices, there was no significant difference in germination percentage and plant height. But in case of irrigation methods/treatments, significantly higher germination percentage was observed and there was no significant difference in plant height. In case of number of monopodial and sympodial branches, with mulch treatment recorded significantly higher number (4.14 and 21.64) compared to without mulch treatment (2.92 and 17.56). Significantly more numbers of bolls per plant were observed in case of mulch treatment (116.6) compared to without mulch treatments (108.7). In case of ET level treatments, significantly more number of bolls per plant was observed in drip irrigated with 1.2 ET level (120.6) followed by drip with 1.0 ET (114.4), drip with 0.8 ET (112.2) and least in case of furrow irrigated treatment (103.5).

With respect to seed cotton yield, significantly higher cotton yield was obtained in case of mulch treatments (26.49 q/ha) compared to without mulch treatments (23.01 q/ha). Among ET level, significantly higher seed cotton yield (Table 9) was obtained in case of drip irrigated at 1.2 ET (27.16 q/ha) followed by drip irrigated at 1.0 ET (26.16 q/ha), drip irrigated at 0.8 ET (24.15 q/ha) and least in case of furrow irrigation (21.04 q/ha). Significantly higher water use efficiency was obtained in case of mulch treatments (0.65 kg/m^3) as compared to without mulch treatments (0.56 kg/m^3). Among ETc levels, significantly higher water use efficiency (WUE) was obtained (Table 9) at drip irrigated with 0.8 ET (0.78 kg/m^3) followed by drip irrigated with 1.0 ET (0.67 kg/m^3), drip irrigated at 1.2 ET (0.59 kg/m^3) and least in case of furrow irrigation (0.38 kg/m^3). The water requirement of control treatment was 44, 29.4 and 16.8 % more than 0.8, 1.0 and 1.2 ET treatments, respectively.

Water table depth: Depth to water table measurement revealed that upto the middle of December 2013 (over 5½ months of crop growth), M_2S_2 (0.38 to 0.98 m) and M_1S_4 (0.34 to 0.85 m) treatments had lowest and highest depth to water table as compared to other treatments respectively. Over the season, the mean depth to water table was deepest in M_2S_3 (0.88 m) and shallow in M_1S_4 (0.64 m). It was observed that because of higher rainfall during September and October the water table was shallower in all the treatment and thereafter depth to water table deepened and attained almost constant level during summer months. With the deeper depth to water table in M_2S_3 might have helped in keeping the soil salinity effect at minimum compared to other treatments and would have thus contributed to higher seed cotton yield.

Table 9: Effect of different irrigation levels and mulching on cotton (pooled for 3 years)

Treatments	Germination (%)	Plant height (cm)	Monopodial branches	Sympodial branches	Bolls/ plant	Seed cotton yield (q/ha)	WR (ha-cm)	WUE (kg/m^3)
Conservation practices (M)								
No Mulch (M_1)	89.7	54.6	2.9	17.6	108.7	23.01	41.1	0.56
With Mulch (M_2)	90.3	58.1	4.1	21.6	116.6	26.49	40.8	0.65
S Em ±	0.61	1.53	0.12	0.75	1.48	0.47	-	0.01
CD (5%)	NS	NS	0.52	3.23	6.35	2.04	-	0.05
Irrigation levels (S)								
0.8 ET (S_1)	90.1	56.5	3.2	18.7	112.2	24.15	31.0	0.78
1.0 ET (S_2)	90.3	58.0	3.6	20.8	114.4	26.16	39.1	0.67
1.2 ET (S_3)	90.7	58.7	3.9	22.8	120.6	27.16	46.1	0.59
Control (S_4)	88.8	52.4	3.3	16.1	103.5	21.04	55.4	0.38
S Em ±	0.61	2.14	0.28	0.68	2.03	0.48	-	0.01
CD (5%)	1.33	NS	NS	1.49	4.43	1.05	-	0.03
Interaction								
S Em ±	0.86	3.03	0.4	0.96	2.87	0.68		0.02
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS

Economic analysis: Net returns and B:C ratio was significantly higher under mulching (Rs. 29459 and 1.59) as compared to without mulch (Rs. 22422 and 1.49) (Table 10). The interaction effect between conservation agriculture practices and irrigation levels was significant. Among irrigation levels net return and BC ratio was significantly higher under 1.2 ET (Rs. 33245 and 1.67) as compared to other irrigation levels. The treatment M_2S_3 (mulch with drip at 1.2 ET) had net returns (Rs. 38177) significantly higher as compared to other combinations with least net returns (Rs. 15212) observed under M_1S_1 (without mulch drip at 0.8 ET). The payback period was early in case of drip irrigation at 1.2 ET with mulch (3.15 years) followed by drip irrigation at 1.0 ET with mulch (3.79 years) and it was late in case of drip irrigation at 0.8 ET without mulch (8.82 years).

Table 10: Economic viability of drip and surface irrigation at different irrigation levels and conservation practices (Pooled over 3 years)

Irrigation levels (ET)	Net income (Rs/ha)			B:C ratio		
	Without mulch (M1)	With mulch (M2)	Mean	Without mulch (M1)	With mulch (M2)	Mean
0.8 ET (S_1)	15212	22287	18750	1.29	1.4	1.35
1.0 ET (S_2)	24412	33107	28760	1.51	1.64	1.58
1.2 ET (S_3)	28312	38177	33245	1.59	1.74	1.67
Control	21750	24265	23008	1.57	1.58	1.58
Mean	22422	29459		1.49	1.59	
S Em ±	Conservation: 108; Irrigation levels: 153 Interaction: 217			Conservation: 0.02; Irrigation levels: 0.02 Interaction: 0.03		
CD (5%)	Conservation: 466; Irrigation levels: 334 Interaction: 472			Conservation: 0.07; Irrigation levels: 0.05 Interaction: NS		

Assessment and mapping of salt affected soils of TBP command area of Karnataka

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. This project was approved in June 2013, since, the survey and soil sampling in the command could only be initiated during ensuing summer, to start with survey and soil sampling was carried out for Koppal district during April-May 2014. With the aid of GPS, soil sampling was carried out on a grid basis to a depth of 90 cm with an increment of 0-15, 15-30, 30-60 and 60-90 cm. A total of 59 sampling grid points (about 230 soil samples) were covered in the command. The project work is in progress.

Evaluation of DSW as an amendment for reclamation of sodic soils of TBP command

Sodic soils are reported to occupy an area of more than 15000 ha in the districts of Koppal, Bellary and Raichur of Northern Karnataka and over 28000 ha in Karnataka. Distillery spent wash a by-product of alcohol industry is gaining its importance in the reclamation of non-saline sodic soils as it is highly acidic and contains fairly good amount of Ca, Mg and other essential plant nutrients. The application of distillery spent wash needs to be applied to a sodic soil at least two months prior to planting. During May 2014, field experiment layout and application of DSW supplied by M/s. Vijayanagar Sugars Pvt Ltd., Mundaragi (Tq: Gadag) as per the treatment (main plot @1.0, 1.5, 2.0, 2.5 and 3.0 lakh lit/ha) was taken up at ARS, Gangavati. Prior to and one month after the application of DSW, soil samples from each of these plots were collected and are being analyzed. Paddy transplanting and basal fertilizer application (sub-plot @ 75, 100 and 125% RDF) was completed during August 2014. The experiment is in progress.

Evaluation of spacing and controlled subsurface drainage system on soil properties, water table, crop yield and nutrient loss in rice fields of TBP Command

Under IDNP, works on reclamation of salt affected soils through sub-surface drainage system with varying depths was carried out. Based on the results, 50 m spacing of lateral for UKP area was recommended and same is being implement in TBP. To arrive at proper spacing for TBP and to suggest solutions for clogging outlets and reduce the nutrient losses in drainage effluent, this project was initiated considering different spacing along with controlled drainage approach.

Exp 1: A field experiment was laid out at ARS, Gangavati in an area of 6 ha adjacent to the existing SSD experiment (50 m spacing) initiated during 2012-13 with four additional treatments i.e., conventional and controlled SSD with 40 and 60 m spacing, with a lateral depth of 1.0 m.

Pre-drainage investigation: In order to assess the technical feasibility of the sub-surface drainage and to design and construct an efficient and cost effective system, investigation of the site conditions is an essential pre-requisite. Survey and investigations were carried out to design an appropriate system.

Drainage discharge: During *rabi* 2013-14, in conventional sub-surface drainage system, the average drain discharge was 0.4, 2.4 and 1.85 mm/d at 40, 50 and 60m spacing, respectively (Table 11). In case of controlled drainage system fitted with water table control PVC pipe set device, the average drain discharge was 0.1, 0.2 and 1.25 mm/d at 40, 50 and 60m spacing, respectively. Thus, drain discharge in conventional SSD at all spacing was higher over the controlled SSD system. In conventional system, the average salinity of the drainage effluent was 4.23, 3.05 and 4.8 dS/m at 40, 50 and 60m spacing as compared to 3.92, 3.27 and 2.75 dS/m at 40, 50 and 60m spacings in controlled SSD system, respectively. Thus, in conventional system about 0.254, 1.878 and 1.698 t/ha of salts was removed through drainage effluent while in case of controlled system salt removal was 0.113, 0.916 and 0.568 t/ha at 40, 50 and 60m spacings, respectively (Table 11). It showed that due to higher drainage discharge in conventional system, salt removal was also more over the controlled system.

Nutrient loss through drainage system: Loss of nitrogen at 40, 50 and 60 m spacing was 1.85 vs. 0.62, 11.45 vs.4.03 and 4.07 vs. 2.87 kg/ha under conventional and controlled SSD systems, respectively (Table 12). Irrespective of SSD systems and spacing, the loss of phosphorus through drainage water was minimum. The loss of potash through drainage discharge was 1.66, 4.44 and 4.8 kg/ha under conventional as compared to 0.25, 1.06 and 0.98 kg/ha in controlled drainage system at 40, 50 and 60m spacings, respectively.

Grain yield: Pre-SSD, paddy grain yields varied from 31.4 (at 40m controlled SSD) to 36.5 q/ha (at 60m controlled SSD) (Table 13). The pre-SSD grain yields obtained at 50m spacing in both conventional (46.8 q/ha) and controlled (45.8 q/ha) systems during *kharif* 2013. During *rabi* 2013-14 grain yields were 39.3 vs. 41.5 q/ha, 48.4 vs. 49.2 and 42.4 vs. 44.5 q/ha under conventional and controlled drainage systems at 40, 50 and 60m spacings, respectively. Slightly higher grain yields at 50m spacing under conventional and controlled drainage system as compared to other treatments could be partly attributed to early planting and meeting crop water requirement appropriately.

Table 11: Drainage discharge/salinity of effluent and salt removal as influenced by spacing of conventional and controlled SSD systems

	Conventional SSD				Controlled SSD			
Spacing	Jan 2014	Feb 2014	Mar 2014	Mean	Jan 2014	Feb 2014	Mar 2014	Mean
	Drainage discharge (mm/day)							
40m	0.60	0.30	0.30	0.4	0.24	0.093	0.10	0.10
50m	2.06	2.97	2.16	2.4	0.6	1.23	1.83	0.20
60m	1.90	1.8	-	1.85	1.2	1.3	-	1.25
	Salinity of drainage effluent (dS/m)							
40m	3.80	4.8	4.1	4.23	3.67	3.99	4.20	3.92
50m	3.01	3.17	2.98	3.05	2.96	3.87	2.975	3.27
60m	4.60	5.00	-	4.80	2.80	2.70	-	2.75
	Salt removal (t/ha)							
40m	0.075	0.139	0.04	0.254	0.033	0.041	0.04	0.113
50m	0.311	1.303	0.264	1.878	0.093	0.64	0.183	0.916
60m	0.498	1.200		1.698	0.176	0.392		0.568

Table 12: Nutrient loss through drainage discharge under different SSD systems

Spacing	Conventional SSD			Controlled SSD		
	Nitrogen (kg/ha)	Phophorous (kg/ha)	Potassium (kg/ha)	Nitrogen (kg/ha)	Phophorous (kg/ha)	Potassium (kg/ha)
40m	1.85	0.07	1.66	0.62	0.002	0.25
50m	11.45	0.25	4.44	4.03	0.01	1.06
60m	4.07	0.14	4.80	2.87	0.004	0.98

Table 13: Variation in crop yields (q/ha) under different SSD systems

Season	Conventional SSD			Controlled SSD		
	40m	50m	60m	40m	50m	60m
Kharif 2013 (Pre-SSD)	33.2	46.8	36.3	31.4	45.8	36.5
Rabi 2013-14	39.3	48.4	42.4	41.5	49.2	44.5

Evaluation of spacing of sub-surface drainage system on soil properties water table, crop yield and nutrient losses in rice fields of TBP Command (Farmer's Field)

Unlike research farm fields, land, water and nutrient management practices by the farmer's are quite different. Hence, span of reclamation, discharge rate, extent of nutrient losses could vary at farmer's field. This experiment was carried out at farmer's field in Mallapur block (Sindhanur Taluk) in an area of 50 ha with three SSD spacings 40m, 50m and 60m spacing with lateral depth of 1.0 m. A total of 73 soil samples upto 60cm (0-15, 15-30 and 30-60cm) were collected using GPS during May-June 2012 and analyzed. Surface soil pH varied from 7.21 to 9.30 and EC_e 1.17 to 61.18 dS/m, at 15-30cm soil pH (7.29 to 9.23) and EC_e (1.65 to 55.86 dS/m), at 30-60cm soil pH (7.33 to 9.19) and EC_e (2.10 to 53.20 dS/m), respectively. The hydraulic conductivity of the soil at 1.2 m depth varied from 0.089 to 0.451 m/day. The water table depth was measured by augur hole method ranged from 111 to 144 cm below the ground. The soil texture at 60-90 cm was found to be clay with clay content varying from 45 to 60% in the study area. Laying of SSD was completed in *kharif* 2013. Monitoring of drainage discharge was carried out thrice during *kharif* 2013 and twice during *rabi* 2013-14, respectively.

Drainage discharge/drainage salinity/salt removal: The average drainage discharge observed was 0.08, 0.074 and 0.13 mm/d at 40, 50 and 60m spacings during in *kharif* 2013. During rabi/summer the average drain discharge was 0.15, 0.155 and 0.305 mm/d at 40, 50 and 60 m spacing respectively. Thus, the discharge was maximum at 60m spacing and this could be partly attributed to large cultivated area as compared to 40 and 50m spacing. The average salinity of the drainage effluent was 12.3, 8.9 and 11.2 dS/m at 40, 50 and 60m spacing during *kharif* 2013. In rabi/summer season, average salinity of the drainage effluent was 12.6, 10.7 and 8.7 dS/m at 40, 50 and 60m spacing (Table 14).

Table 14: Drainage discharge/salinity/salt removal as influenced by spacing of SSD systems

Spacing	Kharif 2013				Rabi 2014		
	Oct. 2013	Nov. 2013	Dec. 2013	Av.	Feb. 2014	March 2014	Av.
			Drainage discharge (mm/day)				
40m	0.09	0.07	0.1	0.08	0.15	0.15	0.15
50m	0.13	0.05	0.04	0.074	0.1	0.23	0.165
60m	0.21	0.12	0.06	0.13	0.2	0.41	0.305
			Salinity of drainage effluent (dS/m)				
40m	10.76	12.65	13.46	12.30	12.57	12.7	12.6
50m	6.35	10.92	9.48	8.90	10.34	11.0	10.7
60m	8.62	12.32	12.66	11.2	9.35	8.01	8.70
			Total salt removal (t/ha)				
40m	0.863	0.761	1.212	2.84	1.103	1.221	2.32
50m	1.089	0.911	0.323	2.32	1.372	1.876	3.25
60m	2.27	1.599	0.878	4.75	2.634	4.768	7.40

Note: Pre-SSD yield varied in the range of 25-30 q/ha.

During *kharif* season 2.84, 2.32 and 4.75 t/ha of salts was removed through drainage effluent at 40, 50 and 60m spacing. In rabi/summer season 2.32, 3.25 and 7.4 t/ha at 40, 50 and 60m spacing (Table 14). In both the season 60 m spacing gave higher drainage discharge and the salt removal than other spacing.

Crop yield: Pre-SSD, paddy grain yield were 25-30 q/ha as told by farmers. Based on the yield data collected randomly at different spacing, grain yields varied from 43.25 q/ha (40m) to 49.27 q/ha (60m) during *kharif* 2013 and from 43.7 (40m) to 49.8 q/ha (60m) during rabi 2013-14 season reflecting increased grain yields due to SSD at all the spacings as compared to pre-SSD yield levels(Table 15).

Table 15: Variation in crop yield as influenced by spacing of sub-surface drainage systems

Spacing	Paddy grain yield (q/ha)	
(m)	*Kharif* 2013	*Rabi* 2013-14
40	43.25	43.70
50	46.53	47.10
60	49.27	49.80

Effect of laser land levelling, micro-irrigation technique and conservation agriculture practices in direct seeded rice under saline Vertisols of TBP command

By traditional land leveling and unscientific methods of using water for paddy-paddy cropping system in TBP command, farmers are facing non-uniform on-field distribution of water, less or no availability of water to the tail end farmers, reduced water and nutrient use efficiencies, uneven growth and reduced yields etc. In addition, farmers are also facing water logging and soil salinity problems due to unscientific soil, water and crop management practices in the command. Precision land leveling by laser leveler could partly overcome these constraints in sustainable crop production.

In recent years, due to delay in canal water release coupled with short supply of water, farmers especially at tail-end, finding it difficult to take up second crop of paddy in rabi/summer. Hence, the concept of direct seeded rice (DSR) is gaining importance in the command. Limited water usage under DSR also prevents development of water logging and soil salinization. However, there is need to develop suitable alternate crop(s) for DSR fallows in saline soils of the command.

Exp.1: Effect of laser land levelling and conservation agriculture practices in DSR: The experiment was initiated during *Kharif* 2013 at ARS, Gangavati. Land was prepared with minimum tillage and leveled by laser leveler. Initial soil salinity of the experimental plot varied from 7.07-9.67 dS/m and 6.95-9.97 dS/m at 0-15 and 15-30 cm depths, in DSR plots and 3.85-7.1 dS/m and 4.5-7.5 dS/m at 0-15 and 15-30 cm depths, respectively in puddled transplanted rice (PTR) plots. The salt tolerant variety viz, CSR-22 was used as a test crop. The soil salinity after harvest varied from 4.03-7.25 dS/m and 5.29-9.63 dS/m at 0-15 and 15-30 cm depth in DSR plot and 4.37-7.45 dS/m and 3.6-5.93 dS/m at 0-15 and 15-30 cm depth in PTR plots, respectively.

The main plot treatments comprised of three conservation practices (Laser leveling+DSR+without residue (M_1); Laser levelling + DSR +with residue (M_2); Farmer's practice in saline soils (puddling & transplanting) (M_3) and sub plot treatments, 1.0 ET (S_1); 1.5 ET (S_2); 2.0 ET (S_3).

Results showed that among conservation practices, plant height and number of grains per panicles were found non-significant (Table 16). Whereas, number of tillers per hill and number of panicles per square meter were significantly higher in transplanting method (17.8 and 219.1) as compared to laser leveling+DSR without mulch (7.89 and 120) and laser leveling+DSR with mulch (7.98, 130) treatments. Among Irrigation levels, plant height and number of panicles per square meter were significantly higher at 2.0 ET as compared to 1.0 ET but it was at par with 1.5 ET. However, number of tillers per hill and number of grains per panicles were non-significant with respect to irrigation levels.

The paddy grain yield differed significantly due to treatments (Table 17). Significantly higher grain yield (45.97 q/ha) was observed in PTR (M_3) followed by laser leveling in DSR with mulch (27.77 q/ha) and least in case of laser leveling in DSR without mulch (27.42 q/ha). Among ET levels, the yield was significantly higher in case of paddy irrigated with 2.0 ET (44.42 q/ha) followed by 1.5 ET (33.28 q/ha) and least in case of 1.0 ET (23.46 q/ha). Significantly lower grain yields under DSR as compared to PTR could partly be attributed to slightly higher soil salinity under DSR plots as compared to PTR plots.

Table 16: Paddy growth and yield attributes as influenced by irrigation levels and mulching

Treatments	Plant height (cm)	Tillers/hill	Panicles/sqm	Grains/panicle
Conservation practices				
Laser leveling+DSR without mulch	83.6	7.89	120	125
Laser leveling + DSR with mulch	78.7	7.98	130	135
Transplanting (control)	86.1	17.9	219.1	112.0
S Em ±	1.7	0.5	3.16	4.4
CD (0.05)	NS	2.0	12.4	NS
Irrigation levels				
1.0 ETc	78.00	10.9	142.4	121.9
1.5 ETc	82.8	10.9	156.6	125.3
2.0 ETc	87.6	11.9	170.1	124.8
S Em ±	2.0	0.4	2.3	1.5
CD (0.05)	6.3	NS	7.2	NS
Interaction (CP x I)				
S Em ±	3.5	0.6	4.1	2.6
CD (0.05)	NS	NS	NS	NS

ETc-Crop evapotranspiration

Table 17: Paddy grain yield as influenced by irrigation levels and mulching

Irrigation level	Paddy yield (q/ha)		
	Laser leveling+DSR without mulch (M_1)	Laser leveling+DSR with mulch (M_2)	Transplanting (M_3)
1.0 Etc (S_1)	14.27	13.71	42.41
1.5 Etc (S_2)	26.91	25.55	47.37
2.0 Etc (S_3)	41.09	44.04	48.14
CD (5%	M: 9.36; S: 7.24; MxS: NS		

Exp. 2: Evaluation of alternative crops under different tillage methods for rice (DSR) fallows in saline soils of TBP command

The experiment was initiated during Rabi/summer 2013-14 at ARS, Gangavati in saline soil (6-8 dS/m) after first crop of DSR during *kharif* 2013. In the first year of shifting from puddle transplanted rice (PTR) to DSR during *kharif* 2013, perennial weed (*Cyperus sp.*) problem was noticed in these plots. The experiment was conducted in split plot design with three tillage practices in main plot, (M_1- Zero tillage; M_2- Minimum tillage; M_3- Conventional tillage) and crops were cultivated in sub-plots (T_1 : Sweet sorghum; T_2 : Cluster bean; T_3 : Sunflower).

Plant height and grain yield of sorghum, sunflower and cluster bean were recorded (Table 18). Though significant differences were observed in plant height of sunflower and sorghum under tillage methods, no consistent trend was observed. Among these crops, sorghum and sunflower performed well under all the tillage methods but cluster bean could not perform well especially under minimum and conventional tillage methods. Among different tillage methods, zero tillage recorded significantly higher yield of sorghum (15.15 q/ha), sunflower (8.90 q/ha) and cluster bean (2.48 q/ha) as compared to other tillage methods. The significantly lower yields under conventional tillage in all the crops could be partly attributed to perennial weed (Cyperus sp.) infestation as compared to other tillage. Soil disturbance under conventional tillage might have encouraged the profuse growth of Cyperus and non-availability of post-emergent herbicide suitable for these crops was also a factor in weed infestation.

Table 18: Grain yield and plant height of different crops as influenced by tillage methods

Treatments	Sorghum		Sunflower		Cluster bean	
	Plant height (cm)	Grain yield (q/ha)	Plant height (cm)	Grain yield (q/ha)	Plant height (cm)	Grain yield (q/ha)
T_1	133.3	17.1	61.7	9.7	27.3	7.45
T_2	128.3	15.3	68.3	9.1	0.0	0.0
T_3	134.7	12.9	65.0	7.9	0.0	0.0
		Plant height			Grain yield	
	Main	Sub	Main x Sub	Main	Sub	Main x Sub
S Em ±	1.55	0.72	1.08	0.55	0.34	0.52
CD (5%)	4.65	2.65	4.86	1.65	1.26	2.32

T_1: Zero tillage T_2: Minimum tillage; T_3: Conventional tillage

Evaluation of sub-surface drip irrigation on soil physico-chemical properties, growth and yield of salt tolerant sugarcane in saline Vertisols of TBP command

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 could be one solution to minimize the area becoming waterlogged and salt affected. Sugarcane which requires no standing water was dominant/traditional crop in the region few decades back but its area declined gradually due to several local problems. In recent years, its cultivation in the TBP command is looking promising as already it is occupying more than 3500 ha land due to constant increase in the price for sugarcane and establishment of more and more number of sugarcane crushing industries. Though sugarcane is considered to be moderately sensitive to soil salinity, availability of salt tolerant sugarcane varieties make it possible to grow under saline soils of TBP command.

Unlike in previous decades where furrow irrigation was in vogue for sugarcane, micro-irrigation techniques are being followed in recent years. So far, surface drip irrigation approach was common. However, surface drip irrigation under saline soils is less effective as the water applied may not effectively leach down salts and also there might be shallower root system as water is applied on the surface. In minimizing evaporation losses and maximizing leaching of salts from root zone, sub-surface drip irrigation may play an important role. Sub-surface drip irrigation which is being practiced for sugarcane in non-saline soils can become complimentary for growing it under saline conditions as well.

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. Sugarcane salt tolerant variety Co-91010 (Dhanush) was sown during Feb-2014 in paired row system (0.6x1.20x0.6 m) and replicated thrice in split design with main plot treatments (Surface drip, subsurface drip and furrow irrigation) and sub plot treatments (0.8, 1.0 and 1.2 ET). 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 EC_e, pH and N, P, K distribution. According to the fertigation schedule, the soluble fertilisers were given through venturi. The soil samples are being collected at regular six months interval. The experiment is in progress.

Development of profitable Integrated Farming System (IFS) module for saline Vertisols of TBP command of Karnataka

Agriculture in Tungabhadra Project command area of Karnataka is dominated by rice-rice mono cropping system. Out of 3.62 lakhs 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 uncertainity 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 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 effect 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 with the following components.

I. Cropping system (Rice-Sorghum-Sunhemp: 0.30 ha; Bajra-Sunflower-Sunhemp: 0.20 ha; Finger millet-Cluster bean-Vegetable cowpea: 0.20 ha)
II. Fodder + Goat rearing (Jamnapari/Shirohi-5+1): 0.10 ha
III. Fishery (six species of common carps) in pond: 0.06 ha

IV. Poultry (Giriraja-1 and Girirani-5): -
V. Vermi composting: 0.01 ha
VI. Vegetables (Okra, beet root and cabbage): 0.05 ha
VII. Horticulture (Pomegranate, Amla, drum stick): 0.08 ha
Conventional cropping system (control): (Rice-Rice-Fallow): 1.00 ha

During 2013, selection of land and preparation of bunds as per different components have been made. 150 drum stick seedlings were planted on the bunds and among these, 50% plants survived at the end of year and growth of remaining plants are good. With regards to cropping systems, only finger millet crop was grown and harvested 480 kg in an area of 0.2 ha (25 q/ha). Under vegetable component, beet root crop was grown and harvested 400 kg beet root in an area of 0.05 ha (8 t/ha). Under conventional cropping system, rice followed by rice were taken and paddy grain yield of 43.75 q/ha was obtained during 2013 and 35 q/ha during rabi 2013-14.

HISAR: RESEARCH ACCOMPLISHMENTS

Survey and characterization of ground waters for irrigation

The survey and characterization of ground irrigation water of Tohana, Fatehabad, Bhuna, Bhattu Kalan, Jakhal and Ratia blocks of Fatehabad during 2012-13 and Baragudha, Dabwali, Ellenabad, Nathusari Chopta, Odhan, Rania and Sirsa blocks of Sirsa districts was undertaken during 2013-14.

Fatehabad district: Fatehabad district is located in the west part of Haryana, lies between 29^{o}14' 22'' to 29^{o}49'18'' N latitude and between 75^{o} 13'9'' to 76^{o}57'28'' E longitude. The district is surrounded by Mansa district of Punjab in north, by Jind, Hisar and Sirsa districts of Haryana in east, south and west, and Hanumangarh district of Rajasthan in south. District has a geographical area of 2517.85 km^2 with 331 villages having cultivable area of 2.28 lakh ha and uncultivated land about 3000 ha. Due to proximity of the district to the desert of Rajasthan, winds bring lots of sands which settle down as mounds, ridge and even dunes making land unproductive.

Fatehabad district is bestowed with good irrigation facilities. The canal irrigation is mainly practiced in areas underlain by poor quality ground water. About 1.40 lakh ha land is irrigated by canal and 0.76 lakh ha irrigated by tube wells. Canal irrigation is mainly done by Ratia and Fatehabad branches of Bhakra main branch. Tube wells are located in areas where groundwater is fresh at shallow depths and can be used for irrigation. Maximum groundwater irrigation is practiced in Tohana and Ratia.

The district is located in the Indo-gangetic alluvial plains. The soils of the district are sandy loam to loamy sands. Paddy, cotton, sugarcane, bajra, guar and arhar are the major crops during *kharif* season, whereas, wheat and mustard are in *rabi* season. The main fodder crops are jowar, barseem and cluster bean. Apart from this, *kharif* vegetables, onions, turmeric, cucumber, cabbage and cauliflower are grown as minor crops.

Fatehabad district can be classified into tropical desert and steppe, arid and hot which is mainly dry with very hot summer and cold winter except during monsoon when moist air of oceanic origin penetrates into the district. The normal annual rainfall of the district is 373 mm which is unevenly distributed over the area in 22 days.

A total of 525 ground water samples were collected with the spatial points marker using GPS for all blocks (Fig.1). Overall in Fatehabad district, 248, 88, 74, 58, 27, 18, and 12 samples were good, high SAR saline, marginally saline, high alkali, marginally alkali, alkali and saline, respectively (Table 1). About 47.2 per cent of the ground water in the district are under good category followed by high SAR saline (16.8 per cent). Category wise per cent samples in different blocks are shown in Fig. 2. Only 12 samples were found under saline category in the whole district. On the basis of block analysis, Bhattu Kalan is severely affected by the poorest quality of groundwater (high SAR saline) in which 45.5 percent water samples were categorized

Table 1: Number of samples in different classes of ground water quality

AICRP Classification	Number of samples	Per cent sample
Good	248	47.2
Marginally saline	74	14.1
Saline	12	2.3
High SAR saline	88	16.8
Marginally alkali	27	5.1
Alkali	18	3.4
High alkali	58	11.0
Total	525	100.0

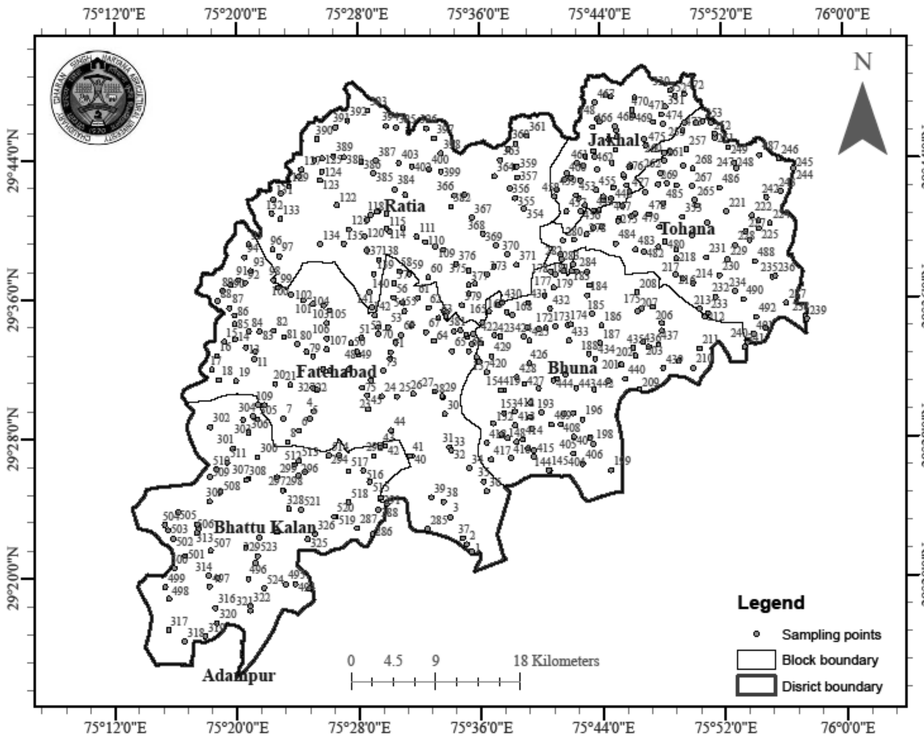


Fig. 1: Location map of the sampling points in Fatehabad district

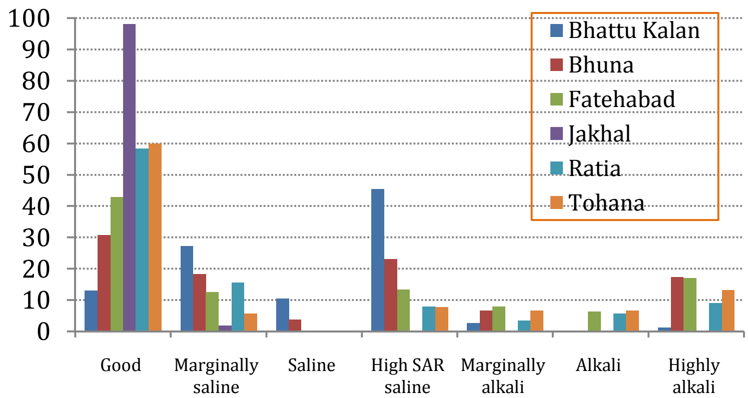


Fig. 2: Per cent samples of ground water in different water quality

In Fatehabad district, EC ranged between 0.2-15.8 dS/m (Table 2). The lowest electrical conductivity EC_{iw} 0.2 dS/m was observed on north side of village Thuiyan of Bhattu Kalan block, whereas, the highest EC_{iw} 15.8 dS/m is in village Mochiwala of Bhuna block. The study revealed that 79.6% samples showed EC_{iw} <4 dS/m. It was observed from the spatial variable map (Fig. 3) that EC of groundwater is highly scattered but Jakhal block is showing uniform trend of EC_{iw}. In the map, the EC values are divided into 8 classes (0-2, 2-4, 4-6, 6-8, 8-10 10-12, 12-14 and 14-15) and reflected by different colours. The highest EC_{iw} 14 to 16 dS/m can be seen in Bhattu Kalan, Bhuna and Fatehabad blocks of the district.

In the district, SAR ranged between 1.7-53.6 mmol/l$^{1/2}$ (Table 2). In the spatial variable map, the SAR values are divided into 11 classes (0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, 35-40, 40-45, 45-50 and 50-55) and reflected by different colours (Fig. 4). The highest SAR 50-55 can be seen at some spots in Bhutu Kalan, Bhuna and Fatehabad blocks of the district.

Table 2: Range and average of different water quality parameters in Fatehabad district

Parameters	Range	Average
EC (dS/m)	0.2-15.8	2.4
pH	7.0-9.9	8.4
CO_3 (meq/l)	0.0-7.5	0.3
HCO_3 (meq/l)	0.2-12.0	3.3
Cl (meq/l)	1.3-117.5	15.9
SO_4 (meq/l)	0.0-53.2	4.3
Ca (meq/l)	0.15-9.4	1.0
Mg (meq/l)	0.6-17.5	3.02
Na (meq/l)	1.1-133.2	19.1
K (meq/l)	0.2-2.9	0.5
RSC (meq/l)	0.0-9.4	1.13
SAR (mmol/l)^{½}	1.7-53.6	13.2

In the district, RSC ranged between nil-9.4 meq/l (Table 2). In the spatial variable map, the RSC values are divided into 6 classes (0, 0-2, 2-4, 4-6, 6-8, and 8-10) and reflected by different colours (Fig. 5). The highest RSC of 8-10 can be seen at some spots in Bhuna, Fatehabad, Ratia and Tohana blocks the district.

Map for spatial distribution of groundwater quality of Fatehabad district was prepared (Fig. 6). There is less existence of saline water category (<2.3 per cent) and was very scattered.

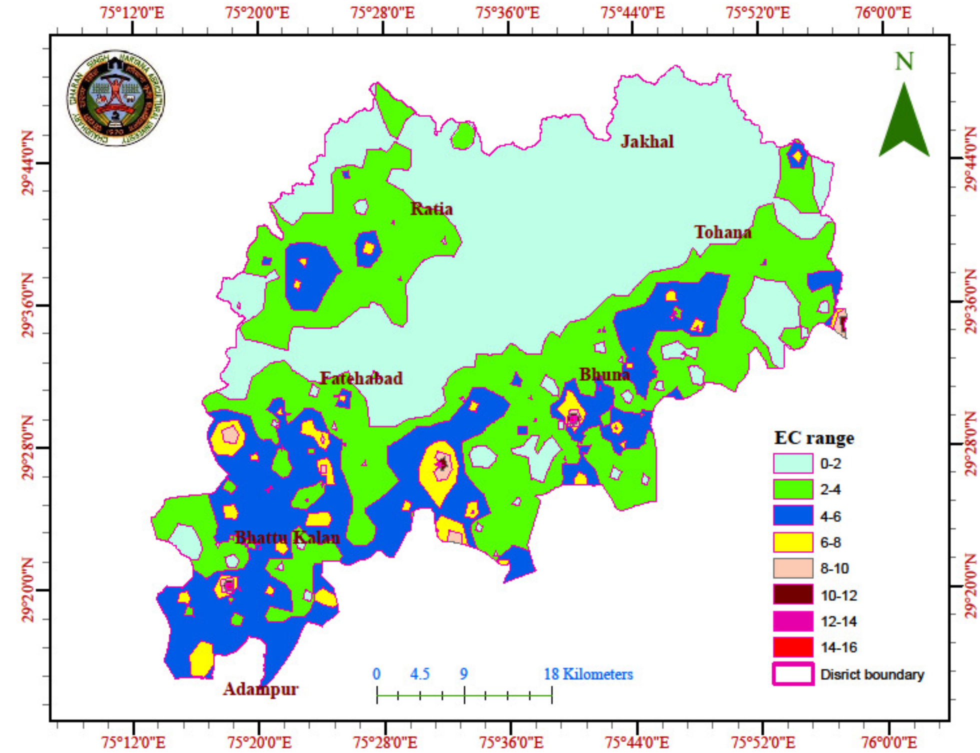


Fig. 3: Spatial variability map of EC of ground water in Fatehabad district

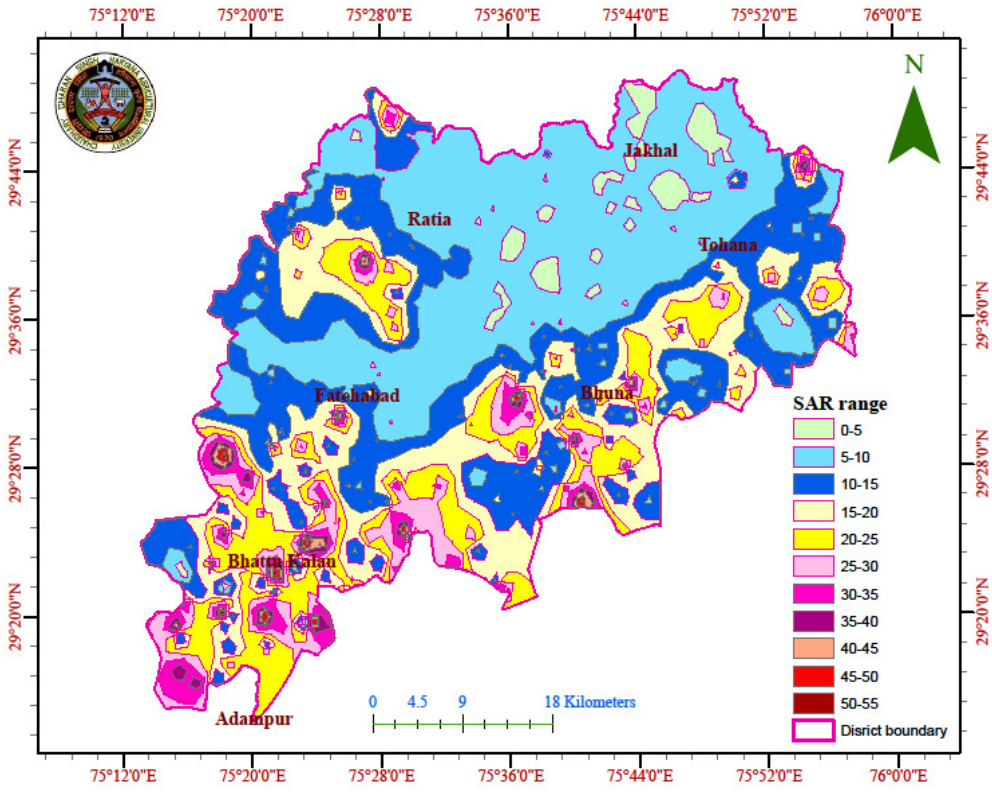


Fig. 4: Spatial variability of SAR of ground water of Fatehabad district

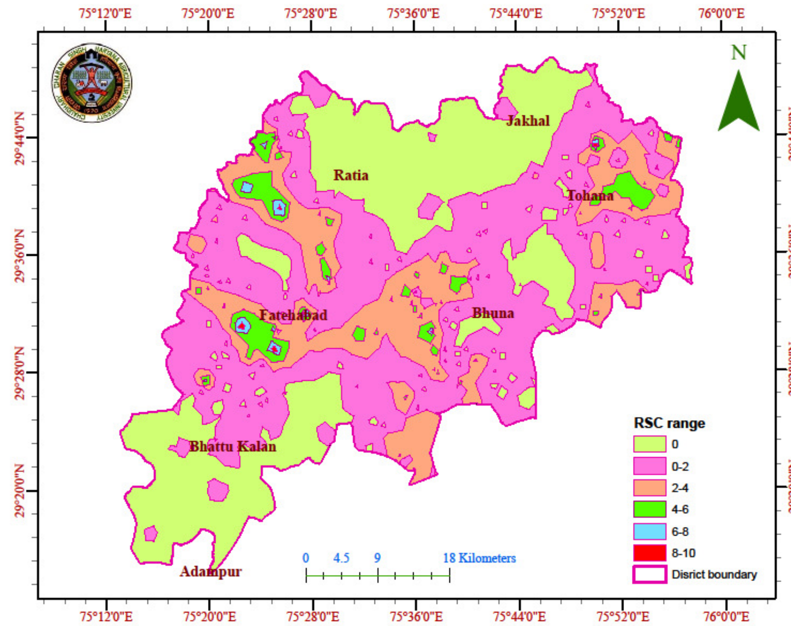


Fig. 5: Spatial variability map of RSC of ground water in Fatehabad district

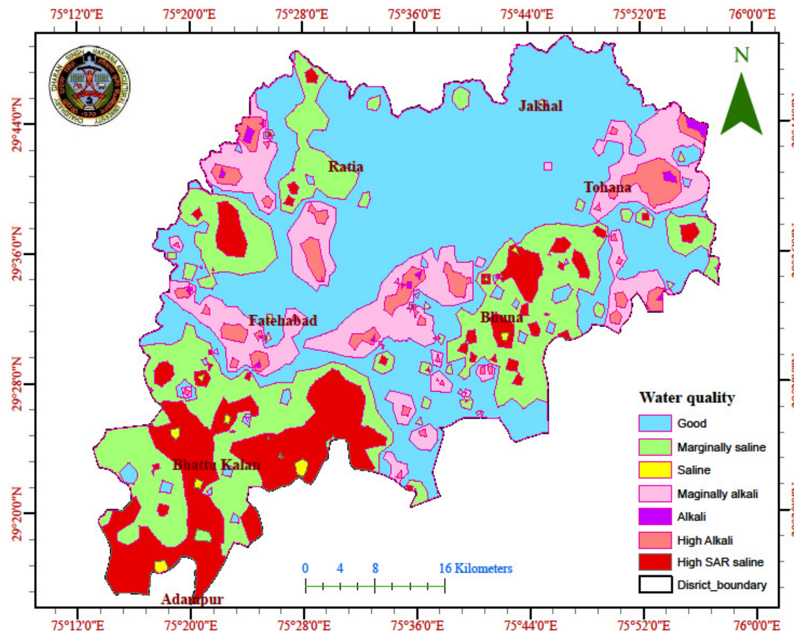


Fig. 6: Spatial variable map of ground water quality in Fatehabad district

Sirsa District: Sirsa district lies in the extreme north-western corner of Haryana with a geographical area of 4270 km^2. It lies between 29^{o}13'10'' to 30^{o}00'00'' N latitude and 74^{o}28'10'' to 75^{o}18'10'' E longitude. It is surrounded by Muktsar and Bathinda districts of Punjab in north, by Mansa district of Punjab in east, by Fatehabad district in south-east and by Hanumangarh of Rajasthan in south and west. Sirsa district consists of 7 blocks viz., Baragudha, Dabwali, Ellenabad, Nathusari Chopta, Odhan, Rania and Sirsa. Ghaggar, an important seasonal river in the district is a major drainage facility of the area which passes through Sirsa, Rania and Ellenabad blocks. The area is also drained by the artificial drains which are used during heavy rains by pumpage to the canals. In waterlogged areas, these artificial drains have also been proposed to combat with the waterlogging problems in the area. The climate of Sirsa district can be classified as tropical desert, arid and hot which is mainly dry with very hot summer and cold winter except during monsoon. The mean maximum temperatures reaches upto 41.1°C (May and June) and mean minimum upto 5.1°C (January). The normal annual rainfall of the district is 320-530 mm which is unevenly distributed over the area within 20 days. The irrigation in the district is mainly through Bhakra canal. Out of total irrigated area of 283,552.5 ha about 250,116 ha is irrigated by canal and 33,409 ha area by tube wells. A seasonal river Ghaggar passes through Baragudha, Ellenabad, Rania and Sirsa blocks of the district from eastern side to western side, a barrage in the name of Ch. Devi Lal Ottu Weir has been constructed on this river to utilize the seasonal water for irrigation in the area through distributaries which had already been constructed i.e. Kassawa Minor.

By using the latitude and longitude, a location map of the sampling points in Sirsa district is shown in Fig. 7. Total 646 groundwater samples were collected randomly.

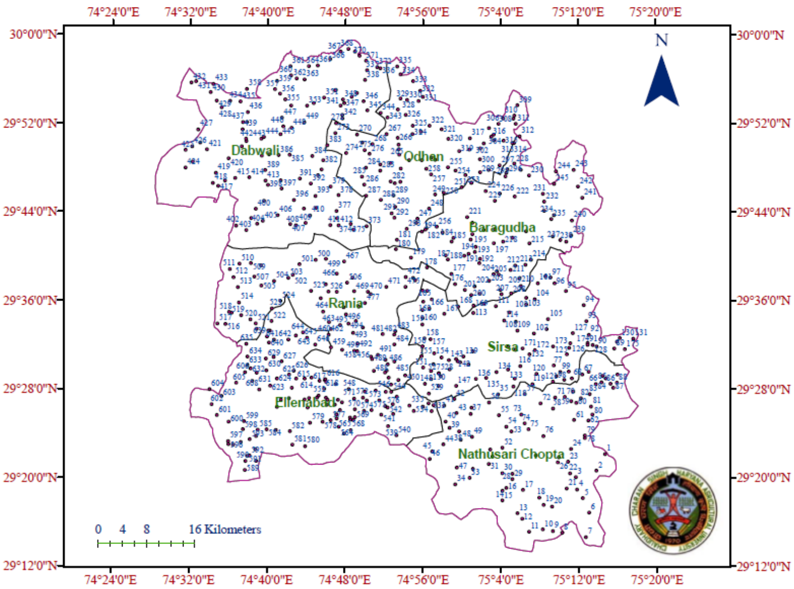


Fig. 7: Location map of the sampling points in Sirsa district

In the Sirsa district, EC_{iw} ranged between 0.2-15.4 dS/m. To visualize its variability in different samples of the district, a graph is drawn between the sample points and their respective value of EC_{iw}. It was observed that in Sirsa district, 26 samples had EC >10 dS/m, 238 samples had EC between 4-10 dS/m, 151 samples had EC between 2-4 dS/m and 231 samples had EC_{iw} <2 dS/m.

To study the spatial distribution of EC in the whole block, a spatial variable map was prepared by using ArcGIS through the interpolation of the available data at 646 sampling points (Fig. 8). The variation of EC is grouped into 8 classes with a class interval of 2 dS/m. The most dominating range of EC is 2-4 dS/m which occupied maximum area in the district and covering all the blocks of the district. The next dominating range was 4-6 dS/m which is covering a large portion of central and southern parts of the district. EC ranging from 6-8 dS/m is covering some central and south parts of the block. EC ranges from 0-2 dS/m is mostly in Sirsa and Ellenabad blocks adjoining of Ghaggar river passing through these blocks. Dabwali block has EC less than two as adjoing to the Punjab start.

Table 3: Range and mean of different water quality parameters for Sirsa district

Parameters	Range	Mean
EC (dS/m)	0.2-15.4	3.9
pH	6.8-10.0	8.4
CO_3 (meq/l)	0.0-4.6	0.4
HCO_3 (meq/l)	0.2-18.7	4.5
Cl (meq/l)	1.4-118.1	25.3
SO_4 (meq/l)	0.1-49.01	8.2
Ca (meq/l)	0.1-11.6	3.2
Mg (meq/l)	0.6-35.3	9.7
Na (meq/l)	0.8-107.8	25.0
K (meq/l)	0.0 -2.6	0.3
RSC (meq/l)	0.0 - 5.5	0.3
SAR $(mmol/l)^{1/2}$	0.7-29.2	9.3

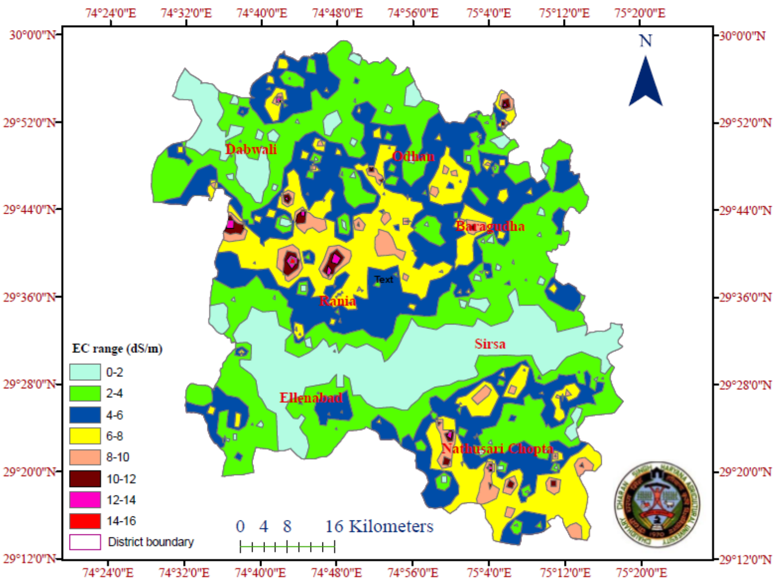


Fig. 8: Spatial variability of EC of ground water used for irrigation in Sirsa district

The pH ranged between 6.8-10.0 with a mean of 8.4 (Table 3). The SAR ranged from 0.7 to 29.2 and lowest SAR value of 0.7 $(mmol/l)^{½}$ was recorded in village Gidranwali of Ellenabad block and the highest SAR 29.2 $(mmol/l)^{½}$ was recorded in Sukar village of Nathusari Chopta block. The RSC ranged between nil- 5.5 meq/l.

EC was grouped into different classes with an interval of one unit upto 10 dS/m, remaining sample having EC value >10 dS/m were confined in one group. The percent distribution of sample in different EC classes is shown in Table 4. Percentage of samples in different EC classes is variable, its highest percentage (18.4) was found in EC class of 1-2 dS/m and its lowest percentage (2.2) was found in EC class 9-10 dS/m. since 35.7 per cent samples are in EC range of 0-2 dS/m. It is an indication of good quality groundwater as per AICRP guidelines.

Table 4: Chemical composition of ground water samples in different EC classes

EC classes	Percent of samples	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	RSC	SAR
		(meq/l)									$(mmol/l)^{1/2}$
0-1	17.3	0.2	2.6	3.6	0.7	0.7	2.2	4.1	0.2	0.6	3.5
1-2	18.4	0.4	4.3	8.1	2.2	1.2	3.6	9.9	0.3	1.1	6.6
2-3	12.7	0.4	3.9	15.8	4.9	2.1	6.5	16.0	0.3	0.1	8.0
3-4	10.7	0.5	4.4	22.2	7.0	3.2	10.3	20.1	0.3	0.0	7.9
4-5	10.2	0.4	5.0	29.5	8.9	3.9	11.8	27.5	0.3	0.0	10.3
5-6	7.7	0.5	5.7	36.3	11.6	4.6	13.8	35.1	0.3	0.0	12.1
6-7	7.7	0.4	6.0	41.9	15.9	5.3	15.9	42.7	0.3	0.0	13.5
7-8	10.7	0.2	5.3	50.6	18.6	5.8	17.4	49.3	0.6	0.0	15.4
8-9	5.4	0.5	6.3	58.4	18.6	6.9	20.5	55.8	0.5	0.0	15.8
9-10	2.2	0.1	7.0	66.2	21.6	7.5	22.5	64.4	0.5	0.0	17.4
>10	4.0	0.6	5.2	87.9	27.9	8.9	26.4	84.0	0.8	0.0	20.7

In case of anions, chloride was the dominant anion with maximum value of 118.1 meq/l (Table 3), observed in village Masitan of Dabwali block and minimum of 1.4 meq/l recorded in village Jhiri of Baragudha block. Bicarbonate ranged from 0.2 to 18.7 meq/l, the maximum was observed in village Jalalana of Odhan block and minimum was found in Ganga village of Dabwali block. The mean values for CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} were 0.4, 4.5, 25.3 and 8.2 meq/l, respectively (Table 3). Table 4 illustrate the mean of anions according to the EC classes in Sirsa district, the Cl was the highest and its value increased with the increase in EC. The CO_3^{2-} ranged from 0.14 to 0.6 meq/l. The lowest was found in 9-10 EC class and highest was in class of EC >10 EC with mean values of 0.1 and 0.6 meq/l, respectively.

Among cations, the value of Na^+ was highest and varied widely from 0.8 to 107.8 meq/l (Table 3). Table 4 illustrated the mean of cation according to the different EC classes in Sirsa district, Na^+ was the highest and its value increased with the increase in EC. Its lowest mean value (4.1 meq/l) was found in the class 0-1, the highest mean value (84.0 meq/l) was in the EC class >10. The K^+ ranged from 0.2 to 0.8 meq/l. The highest mean value (0.8 meq/l) was found in class of >10 EC and the lowest mean value (0.2 meq/l) was laid in class of 0-1 EC.

According to AICRP classification, it was found that 29.1 per cent samples are under good quality, 64.7 per cent saline and 6.2 per cent alkali in nature (Fig. 8). Out of the saline water, 23.1, 10.1 and 31.5 per cent were in marginally saline, saline and high SAR saline, respectively. In alkali group 5.3 and 0.9 per cent were in marginally alkali, alkali and high alkali, respectively. Out of six categories of water, maximum (31.5%) of samples in high SAR saline and minimum (0.9%) was found in alkali category.

Ground water quality map for Sirsa district was prepared to study its spatial variability in the block (Fig. 10). In the district, 29.1% samples are under good category but spatial variable map indicates less area under good quality water. It is due to higher concentration of tube wells in that area and accordingly more samples were collected. On comparing spatial variable map of EC (Fig. 8) with water quality map (Fig. 10), most of the area where EC is >4 dS/m comes under high SAR saline in comparison to saline, whereas, in both conditions EC is >4 dS/m. With this fact, area under high SAR saline was increased and area under saline reduced. The problem of alkalinity in ground water of the district because of marginally alkali and alkali categories were observed very scattered with small polygons.

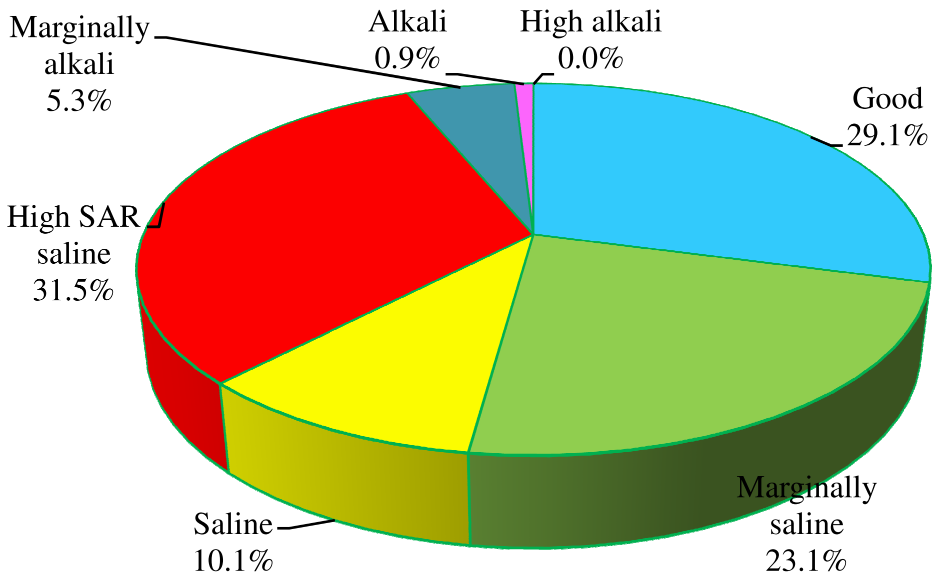


Fig. 9: Distribution of ground water quality in Sirsa district of Haryana

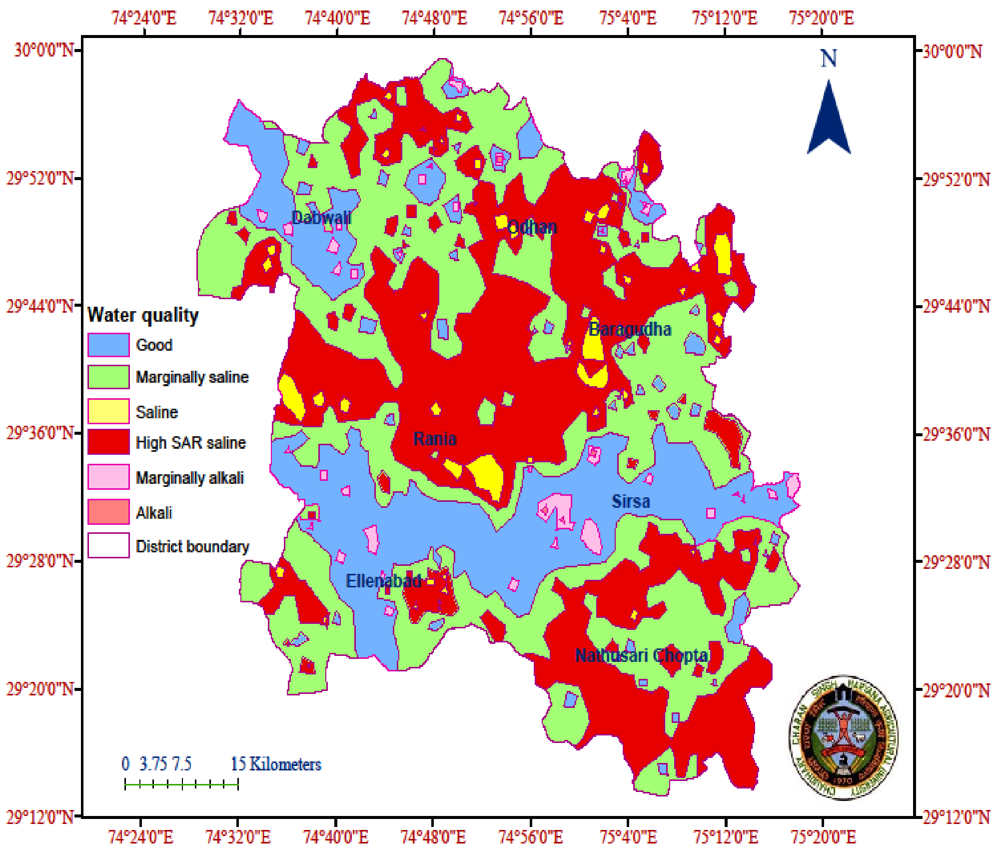


Fig. 10: Ground water quality map of Sirsa district of Haryana

Strategies for conjunctive use of saline and canal water in cotton-wheat crop rotation

Investigations on conjunctive use of canal/saline water on cotton-wheat crop rotation and soil salinity build-up were initiated during *kharif*, 2012 at Hisar. Cotton in *kharif* and wheat in *rabi* season were grown in micro-plots of size 4.5m x 3.0m. Treatments comprised of 8 irrigation water combinations T_1 :Canal water; T_2: 1CW:1SW; T_3: 1SW:1CW; T_4: 2CW:1SW; T_5: 2SW:1CW; T_6: 1S:RTC; T_7: 1CW:RTS and T_8: SW only and replicated thrice in the randomized block design. Recommended dose of fertilizers (87.5:30:25 kg/ha, N, P and zinc) in cotton and (150:60:25 kg/ha, N, P and zinc) in wheat were applied. In cotton, full dose of DAP and zinc sulphate were applied at the time of sowing and urea was applied in two splits. In wheat, 1/3rd N and full dose of P was applied at the time of sowing and the remaining N was applied in two equal splits at first and second irrigation. The electrical conductivity of canal water and tube well/saline water were 0.4 and 6.0-8.0 dS/m, respectively. Soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm layers before sowing and after the harvesting of each crop. Cotton variety (H-1098-1) and wheat variety (WH 711) was sown on 6 June and 7 Dec. during 2012-13 and on 19 May and 2 Dec. during 2013-14 respectively. Cotton was harvested on 28 Nov. and 26 Nov. during 2012-13 while wheat was harvested on 14 April and 13 April during 2013-14 respectively.

Initial soil properties: The soil of the experimental site is sandy loam upto 1.5 m soil profile (Table 5). The soil profile contains 66.8 to 74.8% sand particles whereas clay content from 12.4 to 17.0%. The bulk density (D_b) ranged from 1.42-1.51 mg/m. The hydraulic conductivity (K_s) decreased with soil depth and varied from 4.78 x 10^{-7} m/s to 8.54 x 10^{-7} m/s. The cation exchange capacity (CEC) ranged from 12.2 to 16.7 cmol/kg soil. The organic carbon followed a decreasing trend with depth being the maximum (0.71%) in 15-30 cm layer.

Table 5: Physico-chemical properties of soil of experimental site

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Db (mg/m^3)	K_s (10^{-7} m/s)	pH	CEC (cmol/kg)	OC (%)
0-15	15.6	17.4	67.0	1.45	8.54	8.06	12.70	0.41
15-30	17.0	16.2	66.8	1.42	6.38	8.22	12.20	0.71
30-60	16.8	13.6	69.6	1.48	5.83	8.19	16.35	0.16
60-90	12.4	12.8	74.8	1.42	5.05	8.18	16.70	0.11
90-120	12.6	13.0	74.4	1.50	4.78	8.22	16.70	0.10
120-150	15.8	15.4	68.8	1.51	4.90	8.19	16.00	0.09

Cotton: Results obtained during 2012 showed that irrigation with saline water decreased the seed cotton yield significantly (Table 6). The data revealed that the highest seed cotton yield of 23.7 q/ha was recorded in all canal irrigation treatment followed by 2 CW: 1 SW cyclic irrigation. The lowest yield (15.9 q/ha) was obtained under all saline irrigation. A reduction of 32.8 and 25.0% were observed in all saline and 2SW : 1CW irrigations, respectively, as compared to canal irrigation. The differences among Canal and 2CW : 1SW was, however, non-significant.

Plant height reduced significantly in saline irrigation as compared to canal irrigation. Plant height varied from 131.8 to 150.9 under all saline irrigation to all canal irrigation and registered 12.7% reduction in plant height (Table 6). The maximum bolls/plant (22.3) was recorded in all canal water irrigation and minimum (18.3) was recorded in all saline water treatment. The maximum boll weight of 2.97 gm was recorded in all canal water and minimum (2.83 gm) in all saline water irrigation treatment.

Table 6: Growth, yield attributes, yield and water productivity of cotton

Treatments	Plant height (cm)	Boll per plant	Boll weight (gm)	Seed cotton yield (q/ha)	Relative yield % of canal	Water productivity (kg/m^3)	
						IW	TW
Canal (CW)	150.9	22.3	2.97	23.7	100	1.32	0.40
1CW : 1SW	144.7	21.0	2.95	21.3	88.7	1.18	0.36
1SW : 1CW	136.4	20.0	2.87	19.0	75.3	1.06	0.32
2CW : 1SW	147.3	22.0	3.07	22.2	93.3	1.23	0.37
2SW : 1CW	134.2	20.3	2.88	17.8	66.9	0.99	0.30
SW : RTC	133.1	19.7	2.98	19.1	75.9	1.06	0.32
CW: RTS	148.0	18.7	2.90	19.5	78.5	1.08	0.33
Saline (SW)	131.8	18.3	2.83	15.9	51.0	0.88	0.27
CD (5%)	NS	2.5	NS	2.3	-	-	-

IW: Irrigation water; TW: Total water

In cotton, the irrigation water productivity (IWP) was highest (1.32 kg/m^3) under canal and lowest (0.88 kg/m^3) under saline water, respectively (Table 6). Similarly the total water productivity was highest (0.40 kg/m^3) under canal water and lowest (0.27 kg/m^3) under saline water treatment.

Table 7: Depthwise distribution of EC_e before sowing and after harvesting of cotton

Treatments	Soil depths (cm)					
	0-15	15-30	30-60	60-90	90-120	Mean
EC_e (dS/m) before sowing						
Canal (CW)	2.50	2.80	2.90	3.06	2.65	2.78
1CW : 1SW	7.11	6.33	5.98	5.40	4.95	5.95
1SW : 1CW	7.53	6.42	6.16	5.64	5.06	6.16
2CW : 1SW	6.51	5.51	5.13	4.95	4.55	5.33
2SW : 1CW	9.31	7.15	6.72	6.21	5.71	7.02
SW : RTC	6.21	5.43	4.78	4.60	4.53	5.11
CW: RTS	8.95	7.36	7.15	5.81	5.54	6.96
Saline (SW)	9.96	9.56	9.14	7.69	7.03	8.68
Mean	6.87	5.86	5.55	5.10	4.71	
EC_e (dS/m) after harvesting						
Canal	2.13	2.39	2.53	2.65	2.26	2.39
1CW : 1SW	5.31	4.79	4.45	4.02	3.65	4.44
1SW : 1CW	5.60	4.75	4.56	4.20	3.74	4.57
2CW : 1SW	4.89	4.13	3.86	3.72	3.45	4.01
2SW : 1CW	6.37	4.91	4.61	4.26	3.94	4.82
SW : RTC	4.69	4.11	3.65	3.50	3.45	3.88
CW: RTS	6.12	5.02	4.89	3.99	3.79	4.76
Saline	6.85	6.55	6.32	5.33	4.81	5.97
Mean	5.25	4.58	4.36	3.96	3.64	

Depthwise distribution of EC_e in various treatments before sowing and after harvest of cotton is presented in Table 7. The EC_e in the 0-15 cm layer ranged from 2.50 to 9.96 dS/m at the time of sowing of the crop in various treatments. However, values varied from 2.13 to 6.85 dS/m at the harvest of the crop in the same layer. The average EC_e of the soil profile upto 120 cm depth varied from 2.78 to 8.68 dS/m at sowing and from 2.39 to 5.97 dS/m at harvesting in various treatments.

After harvesting, highest EC_e (6.85 dS/m) was observed in case of all saline water irrigation in the layer 0-15 cm. The EC_e in the surface layer (0-15 cm) decreased downwards in the profile in all the treatments upto 120 cm. Among the cyclic mode treatments, 2SW:1CW and 1CW:RTS had higher EC_e throughout the profile before sowing as well as after harvesting than other cycle modes as 1CW:1SW, 1SW:1CW, 2CW:1SW, SW:RTC treatments.

Wheat: In case of wheat during 2012-13, no significant difference was observed among CW and 2CW:1SW. The highest yield (47.0 q/ha) and lowest yield (29.4 q/ha) of wheat were obtained in all canal and all saline water treatments, respectively (Table 8). The relative yields obtained were 96.5, 91.7, 85.6, 81.0, 79.8, 65.2 and 62.6% in 2CW:1SW, 1CW:1SW, 1SW:1CW, 1CW: RTS (rest with saline), 1SW: RTC (rest with canal), 2SW:1CW, and SW treatments, respectively, as compared to the yield recorded in canal water irrigation assumed to be 100%.

Table 8: Growth, yield attributes, yield and water productivity of wheat

Treatments	Plant height (cm)	Ear heads/m row length	Ear head length (cm)	Grain yield (q/ha)	Relative yield % of canal	Water productivity (kg/m^3)	
						IW	TW
Canal (CW)	77.0	76.3	10.3	47.0	100	1.57	0.99
1CW : 1SW	74.3	72.0	9.7	43.1	91.7	1.44	0.91
1SW : 1CW	71.6	69.0	9.4	40.2	85.6	1.34	0.85
2CW : 1SW	81.3	74.6	10.3	45.4	96.5	1.51	0.96
2SW : 1CW	69.3	69.0	9.7	30.6	65.2	1.02	0.65
SW : RTC	76.6	70.0	9.3	37.5	79.8	1.25	0.80
CW: RTS	75.3	67.3	9.3	38.1	81.0	1.27	0.82
Saline (SW)	65.6	64.0	9.0	29.4	62.6	0.98	0.64
CD (5%)	5.2	5.4	NS	4.9	-	-	-

In wheat, irrigation water productivity was observed highest (1.57 kg/m^3) under canal and lowest (0.98 kg/m^3) under saline water treatment, respectively (Table 8). Similarly, total water productivity was highest (0.99 kg/m^3) under canal and lowest (0.64 kg/m^3) under saline water treatment.

The salinity (EC_e) profiles at sowing and at harvesting of wheat indicated salt build-up with various modes of irrigations (Table 9). The data revealed that average EC_e of the soil profile down to 120 cm before the sowing of wheat varied from 2.34 to 5.82 dS/m in various treatments (Table 9). The mean values of EC_e at the harvest ranged from 2.41 to 6.92 dS/m. The profile distribution of EC_e, in general, showed a deceasing trend from surface to 120 cm depth in all the treatments being maximum in the surface layer. The electrical conductivity of soil saturation extract was higher in saline water irrigated plots than cyclic mode of irrigation. The highest EC_e (7.89 dS/m) was observed in case all saline water irrigation in 0-15 cm layer (Table 9). Among the cyclic mode treatments, 2S: 1C had the highest average salinity (5.57 dS/m) followed by CW:RTS (5.5 dS/m) at the time of wheat harvest. Major accumulation of salts at wheat harvest was observed in 0-30 cm layers.

Cotton: During 2013, irrigation with saline water decreased the yield significantly (Table 10). The data revealed that highest seed cotton yield (19.0 q/ha) was obtained in all canal water followed by 2CW:1SW cyclic irrigation. The lowest yield (13.1 q/ha) was obtained under all saline water. A reduction of 31.1 and 22.7% were obtained in all saline water and 2SW:1CW irrigations, respectively, as compared to canal water irrigation. The differences among CW and 2CW:1SW was, however, non-significant. The plant height reduced significantly in saline water as compared to canal. The plant height varied from 110.73 to 150.17 from all saline irrigation treatment to all canal irrigation treatment and registered a 25.6% reduction in plant height (Table 10). The maximum boll weight of 3.15 gm was recorded in 2CW:1SW treatment and minimum was 2.84 gm in saline water irrigation treatment.

Table 9: Depthwise distribution of EC_e before sowing and after harvesting of wheat

Treatments	Soil depths (cm)					
	0-15	15-30	30-60	60-90	90-120	Mean
			EC_e (dS/m) before sowing			
Canal (CW)	2.09	2.35	2.45	2.56	2.23	2.34
1CW : 1SW	5.21	4.69	4.31	3.87	3.52	4.32
1SW : 1CW	5.43	4.60	4.43	4.05	3.61	4.42
2CW : 1SW	4.75	4.02	3.74	3.60	3.37	3.90
2SW : 1CW	6.23	4.76	4.47	4.16	3.86	4.70
SW : RTC	4.59	4.03	3.54	3.42	3.39	3.78
CW: RTS	5.98	4.86	4.75	3.86	3.72	4.63
Saline (SW)	6.69	6.41	6.18	5.17	4.67	5.82
Mean	5.12	4.47	4.23	3.84	3.55	
			EC_e (dS/m) after harvesting			
Canal (CW)	2.15	2.42	2.50	2.63	2.33	2.41
1CW : 1SW	5.86	5.29	4.87	4.35	3.98	4.86
1SW : 1CW	6.45	5.43	5.16	4.85	4.31	5.24
2CW : 1SW	5.05	4.28	3.99	3.83	3.58	4.13
2SW : 1CW	7.36	5.64	5.30	4.94	4.59	5.57
SW : RTC	5.07	4.43	3.95	3.76	3.68	4.16
CW: RTS	7.05	5.78	5.65	4.59	4.45	5.50
Saline (SW)	7.89	7.65	7.36	6.16	5.54	6.92
Mean	5.86	5.12	4.85	4.39	4.06	

Table 10: Growth, yield attributes and seed cotton yield under different treatments

Treatments	Plant height (cm)	Boll weight (gm)	Seed cotton yield (q/ha)
Canal (CW)	148.8	3.1	19.0
1CW : 1SW	132.0	3.1	19.0
1SW : 1CW	140.0	2.9	16.2
2CW : 1SW	150.2	3.1	18.5
2SW : 1CW	119.0	2.9	14.7
SW : RTC	108.8	2.9	16.5
CW: RTS	141.3	2.8	14.4
Saline (SW)	110.7	2.8	13.1
CD (5%)	15.2	0.18	3.47

Total numbers of irrigations including pre-sowing are:

Depthwise distribution of EC_e under various treatments before sowing and after harvesting of cotton crop is presented in Table 11. The EC_e in the 0-15 cm layer ranged from 2.41 to 9.52 dS/m at the time of sowing of the crop in various treatments. However, values varied from 2.23 to 8.43 dS/m at the time of harvest of the crop in the same layer. The average EC_e of the soil profile down to 120 cm depth varied from 2.67 to 8.27 dS/m at sowing and from 2.48 to 7.01 dS/m at harvesting in various treatments.

Table 11: Depthwise distribution of EC_e before sowing and after the harvest of cotton

Treatments	Soil depth (cm)					
	0-15	15-30	30-60	60-90	90-120	Mean
			EC_e (dS/m) before sowing			
Canal (CW)	2.41	2.68	2.75	2.96	2.55	2.67
1CW : 1SW	6.89	6.13	5.81	5.25	4.76	5.77
1SW : 1CW	7.36	6.43	6.00	5.49	4.89	6.03
2CW : 1SW	6.35	5.21	4.98	4.72	4.35	5.12
2SW : 1CW	9.21	8.10	6.52	6.02	5.54	7.08
SW : RTC	6.05	5.20	4.69	4.42	4.39	4.95
CW: RTS	8.79	7.45	6.98	6.69	5.41	7.06
Saline (SW)	9.52	9.08	8.69	7.24	6.81	8.27
Mean	7.07	6.29	5.80	5.35	4.84	
			EC_e (dS/m) after harvesting			
Canal (CW)	2.23	2.46	2.62	2.72	2.36	2.48
1CW : 1SW	5.89	4.82	4.40	4.12	3.85	4.62
1SW : 1CW	6.66	5.95	5.56	5.20	4.74	5.62
2CW : 1SW	5.01	4.61	4.20	4.01	3.95	4.36
2SW : 1CW	7.39	5.96	5.63	5.28	4.84	5.82
SW : RTC	4.76	4.21	3.85	3.36	3.26	3.89
CW: RTS	7.85	6.55	5.99	5.44	5.09	6.18
Saline (SW)	8.43	7.65	6.95	6.25	5.78	7.01
Mean	6.03	5.28	4.90	4.55	4.23	

After harvesting, the highest EC_e (5.78 dS/m) was observed in case of all saline water irrigation in the layer 0-15 cm. The EC_e in the surface layer (0-15 cm) decreased downwards in the profile in all the treatments up to 120cm. Among the cyclic mode treatments, 2SW:1CW and 1CW:RTS had higher EC_e throughout the profile before sowing as well as after harvest of the crop than other cycle mode as 1CW:1SW, 1SW:1CW, 2CW:1SW, SW:RTC treatments.

Wheat: In wheat, during 2013-14, non-significant differences were observed between CW and 2CW:1SW. The maximun plant height (80.7 cm), no. of ear heads/m row length (78), ear head length (10.6 cm) and straw yield (64.7 q/ha)) was obtained maximum in canal water irrigations followed by 2CW:1SW treatment and minimum plant height (68.3 cm), no. of ear head/m row length (65.7), ear head (9.0 cm) and straw yield (47.5 q/ha) were observed in all saline water irrigation, respectively. The highest yield (43.1 q/ha) and lowest yield (30.8 q/ha) were obtained in all canal and all saline water treatments, respectively. The relative yields obtained were 96.3, 91.6, 86.77, 82.6, 80.0, 75.4 and 71.4% in 2CW:1SW, 1CW:1SW, 1SW:1CW, 1CW: RTS (rest with saline), 1SW: RTC (rest with canal), 2SW:1CW and SW treatments, respectively as compared to canal irrigation assumed to be 100% (Table 12).

The salinity profiles at sowing and harvesting of wheat crop indicating the salt build-up with various modes of irrigations are presented in Fig. 11a, b). The data revealed that average EC_e of the soil profile upto 120 cm before sowing of wheat varied from 2.21 to 6.63 dS/m in various treatments.

The mean EC_e at the harvest ranged from 2.21 to 6.78 dS/m. The profile distribution of EC_e, in general, showed a deceasing trend upto 120 cm depth in all the treatments being maximum in surface layer (Fig. 11a). The EC_e was higher in saline water irrigated plots than cyclic irrigation. The highest EC_e (7.79 dS/m) was observed in all saline water in 0-15 cm layer. Among the cyclic mode treatments, 2SW:

1CW had the highest average salinity (5.4 dS/m) followed by CW:RTS (5.39 dS/m) at wheat harvesting. Major accumulation of salts at wheat harvest was observed in 0-30 cm layers (Fig. 11b).

Table 12: Growth, yield attributes and yield of wheat under different treatments

Treatments	Plant height (cm)	Ear heads/m row length	Ear head length (cm)	Grain yield (q/ha)	Straw yield (q/ha)
Canal (CW)	80.7	78.0	10.6	43.1	64.7
1CW : 1SW	78.9	74.8	9.8	39.5	57.6
1SW : 1CW	76.8	72.8	9.5	37.4	53.9
2CW : 1SW	79.5	76.5	9.1	41.5	59.8
2SW : 1CW	69.5	68.1	9.4	32.5	51.8
SW : RTC	73.1	67.8	9.2	34.5	50.0
CW: RTS	75.8	71.2	9.4	35.6	52.2
Saline (SW)	68.3	65.7	9.0	30.8	47.5
CD (5%)	4.5	4.7	0.8	2.5	8.6

Total numbers of irrigations including pre-sowing are:

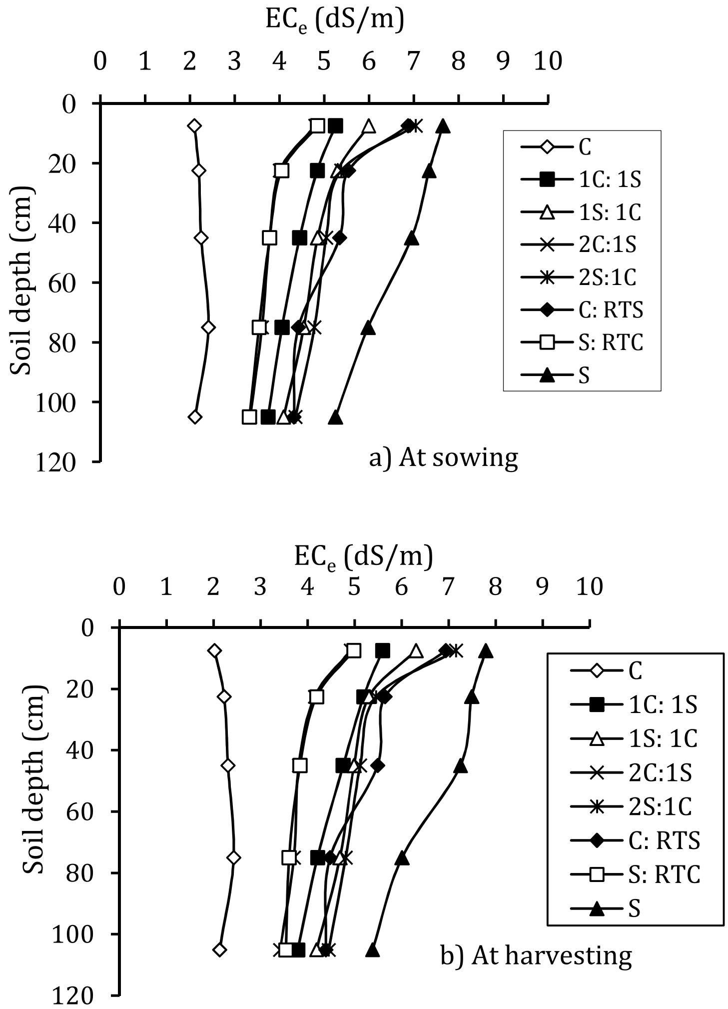


Fig. 11: Depthwise EC_e distribution in various treatments (a) before sowing of cotton, (b) after harvesting of wheat

Screening of elite varieties of crops irrigated with poor quality waters

This experiment was carried out with four water qualities (canal, EC_{iw} 2.5, 5.0, 7.5 dS/m). During 2012-13, cotton genotypes (7), wheat (14), pearl millet (7) and mustard (8) genotypes under IVT-I and during 2013-14, cotton (7), wheat (14), pearl millet (7) and 14 mustard genotypes were tested.

The tolerance of cotton, wheat, pearl millet and mustard genotypes under saline water irrigation treatments was evaluated in lined micro-plots of 2 m x 2 m in size. The plots were constructed above ground and filled with the sandy loam surface soil (0-15 cm). Recommended cultural practices and fertilizer doses were applied in raising the crops. Uniform fertilizer applications were made in all the treatments using urea, DAP and $ZnSO_4$. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. Soil samples were collected before sowing and after harvesting of the crops.

Cotton: Increasing salinity generally led to a gradual decrease in cotton production (Table 13). At EC_{iw} of 7.5 dS/m, mean yield reduced by 47.4% as compared to control. The mean yield (271.7 g/m^2) of Bunty 2113 was significantly higher than other genotypes followed by SP 7007 (221.8 g/m^2) and RCH (215.0 g/m^2). The genotype MRC-7361 was the lowest yielder with mean seed cotton yield of 168.8 g/m^2. Mean EC_e in the soil profile upto 60 cm varied from 3.41 to 10.33 dS/m from control to 7.5 dS/m at the time of sowing.

Table 13: Effect of saline waters on seed cotton yield (g/m^2) of cotton genotypes

Genotypes	EC of irrigation water (dS/m)			
	Control	2.5	5.0	7.5
Nikki-7017	213.5	211.3	189.1	146.6
MRC-7361	259.5	190.4	120.3	105.1
Bioseed-6588	231.8	199.5	143.9	116.6
VICH-310	255.0	232.8	186.5	124.9
Bunty 2113	327.5	322.4	223.1	213.9
SP 7007	323.6	320.8	130.2	112.5
RCH134	268.7	226.4	196.0	168.8
Mean	268.5	243.4	169.9	141.2
CD (5%)	Variety (V): 15.9; Salinity (S); 21.0; V x S : 42.1			

Wheat: The data showed that yield of different varieties of wheat decreased with increase in EC of the irrigation water (Table 14). Wheat genotype P-9007 performed best at the highest saline water irrigation (7.5 dS/m) and gave 11.3% higher yield as compared to KRL 210 (check). It is followed by P-7972 which gave 7.9% higher yield than KRL 210 whereas the performance of P-7758 was the poorest.

Pearl millet: The data showed that the yield of different varieties of pearl millet decreased with an increase in EC of the irrigation water (Table 15, Fig. 12). Pearl-millet variety HHB-234 performed best at the highest saline water irrigation (7.5 dS/m), followed by HHB-226 whereas the performance of HC-20 was the poorest. The mean yield (313.8 g/m^2) of HHB-226 was higher than other genotypes followed by HHB-234 (311.8 g/m^2) and HHB-223 (311.6 g/m^2). The genotype HC 20 was the lowest yielder by having the mean seed yield of 178.4 g/m^2. At EC_{iw} of 7.5 dS/m, mean yield reduced by 32.1% as compared to control treatment.

Table 14: Grain yield (g/m[2]) of wheat varieties under different salinity water irrigation

Genotypes	EC of irrigation water (dS/m)			
	Canal	2.5	5.0	7.5
P-7743	418	382.5	350	312.5
P-7749	494	460	403	337.5
P-7758	429	391	327	298
P-7972	540	458	418	361.5
P-9001	497	393.5	349	313.5
P-9002	500	423	349	320.0
P-9004	480	409	379.5	332.5
P-9006	506	376	355	317.5
P-9007	542	460.5	422	373.0
P-9008	464	377.5	330.5	302.5
P-9015	463	397.5	332.5	308.0
P-9017	421	380	353.5	305
KRL 210	471	437.5	410	335
Kharchia 65	461	412.5	375	322.5
Mean	477	411.3	368.1	324.2
CD (5%)	Variety (V): 20.8; Salinity (S): 11.1; VxS: NS			

Table 15: Grain yield (g/m[2]) of pearl millet varieties under different salinity water irrigation

Genotypes	EC of irrigation water (dS/m)				
	Canal	2.5	5.0	7.5	Mean
HHB-67	323	319	281	260	295.8
HHB-197	397	373	221	189.5	295.0
HHB-223	376	331	284.5	255	311.6
HHB-226	379	311	295	271	313.8
HHB-234	341	323	304.5	279.5	311.8
HC-10	296	244	183.5	162.5	221.3
HC-20	202	188	172.5	152	178.4
Mean	330	298	249	224	-
CD (5%)	Variety (V); 12.1; Salinity (S): 16.1; VxS: 32.1				

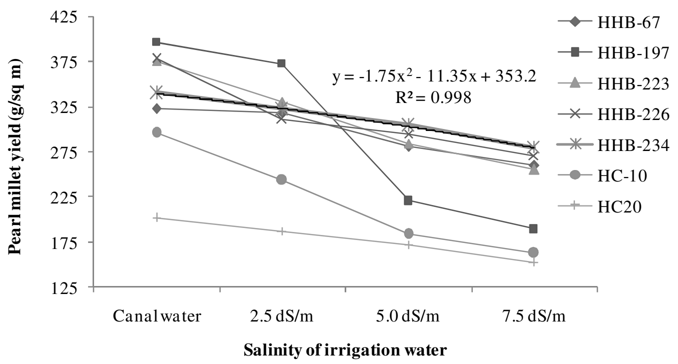


Fig. 12: Crop yield of pearl millet at different saline water treatments

Mustard: Results of eight genotypes of mustard tested under IVT showed that the yield of different genotypes of mustard decreased with increase in EC of the irrigation water (Table 16). Salinity in the soil at sowing is given in Table 17. The genotypes CSCN-12-2 gave the highest seed yield (318.2 g/m^2) followed by CSCN-11-3 (287.8 g/m^2) at EC_{iw} of 7.5 dS/m and the lowest yield (181.8 g/m^2) was obtained in CSCN-12-6. The mean yield varied from 244.28 to 348.48 g/m^2 in genotype CSCN-12-6 and CSCN-12-2, respectively. The mean salinity in the soil at the time of sowing was varying from 2.12 to 10.61 dS/m in canal water to the highest EC water plot (Table 17).

Table 16: Seed yield (g/m^2) of mustard genotypes (IVT) under different salinity water irrigation

Genotypes	EC of irrigation water (dS/m)				
	Canal	2.5	5.0	7.5	Mean
CSCN12-1	310.6	303.0	295.4	280.3	297.33
CSCN12-2	371.2	363.6	340.9	318.2	348.48
CSCN12-3	386.3	310.6	295.4	287.8	320.03
CSCN12-4	378.7	295.4	287.8	272.7	308.65
CSCN12-5	265.1	250.0	250.0	234.8	249.98
CSCN12-6	280.3	257.5	257.5	181.8	244.28
CSCN12-7	257.5	250.0	250.0	242.4	249.98
CSCN12-8	280.3	257.5	234.8	212.1	246.18
Mean	316.3	285.95	276.5	253.8	-
CD (5%)	Variety (V): 12.5; Salinity(S): 8.9; VxS: 25.1				

Table 17: Soil salinity (EC_e) at sowing of mustard under different salinity irrigation

Depth of soil (cm)	EC of irrigation water (dS/m)			
	Canal	2.5	5.0	7.5
0-15	1.95	4.42	8.55	10.99
15-30	2.29	5.58	9.35	10.89
30-45	2.12	5.27	8.27	9.94
Mean	2.12	5.09	8.72	10.61

Cotton: During 2013-14, increasing salinity led to a gradual decrease in cotton production (Table 18). Among the 7 genotypes of cotton, the seed yield was highest (203.2 g/m^2) in Bt cotton Bunty 2113 and lowest (73.1 g/m^2) in Bt MRC-7017 genotype at salinity of 7.5 dS/m. At EC_{iw} of 7.5 dS/m, mean yield reduced by 49.1% as compared to control. Overall mean yield (256.4 g/m^2) of Bunty 2113 was significantly higher than other genotypes followed by Boiseed-6588 (221.7 g/m^2), and the genotype MRC-7017 was the lowest yielder by having the mean seed cotton yield of 115.6 g/m^2. Mean EC_e in the soil profile upto 60 cm varied from 3.30 to 9.94 dS/m from control to 7.5 dS/m plots (Fig. 13) at sowing.

Wheat: The data showed that yield of different varieties of wheat decreased with an increase in EC of the irrigation water (Table 19). Wheat genotype P 9012 performed best at the highest saline water irrigation (7.5 dS/m) and gave 40.8% higher yield as compared with KRL 210 (check). It was followed by P 9038 which gave 32.9 per cent higher yield than KRL 210.

Table 18: Effect of saline water irrigation on seed cotton yield (g/m²) of cotton genotypes

Genotypes	EC of irrigation water (dS/m)				
	Control	2.5	5.0	7.5	Mean
MRC 7017	139.9	125.8	123.8	73.1	115.6
Bioseed 6588	257.5	240.6	223.5	165.3	221.7
VICH 310	276.5	178.6	139.5	119.6	178.8
Bunty 2113	352.9	254.1	215.5	203.2	256.4
SP 7007	249.4	181.9	158.5	121.0	177.7
H 1300	180.2	130.1	109.2	100.5	130.0
H 1098i	275.3	145.4	138.0	98.4	164.3
Mean	247.4	179.5	158.3	125.9	-
CD (0.05)	Variety (V): 9.6; Salinty (S): 7.3; VxS: 19.2				

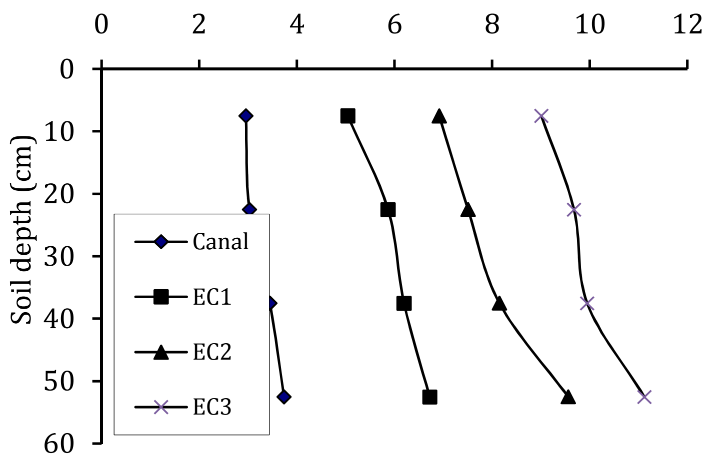


Fig. 13: Soil EC_e at sowing of cotton under saline water irrigation

Table 19: Grain yield (g/m²) of wheat varieties under different salinity water irrigation

Genotype/ variety	EC of irrigation water (dS/m)				
	Canal	2.5	5.0	7.5	Mean
P-7973	384.8	324.8	300.2	259.2	317.3
P-8034	368.3	340.4	272.6	234.7	304.0
P-9003	451.9	405.7	356.4	332.7	386.7
P-9005	424.2	407.6	391.8	357.5	395.3
P-9012	587.2	568.3	529.3	515.9	550.2
P-9013	449.5	429.0	399.7	392.5	417.7
P-9017	588.0	548.0	520.5	401.9	514.6
P-9019	505.0	443.3	411.4	388.7	437.1
P-9034	568.3	545.0	524.6	392.4	507.6
P-9035	449.6	360.6	343.6	241.1	348.7
P-9037	490.1	431.7	436.0	417.2	443.8
P-9038	544.1	507.9	503.5	487.0	510.6
KRL 210	539.8	474.0	417.4	366.4	449.4
KH 65	438.9	386.0	357.0	339.5	380.4
Mean	485.0	440.9	411.7	366.2	
CD (5%)	Variety (V): 20.0; Salinity (S): 10.7; VxS: 40.1				

Pearl millet: The data showed that yield of different varieties of pearl millet decreased with an increase in EC of the irrigation water (Table 20, Fig. 14). Pearl millet variety HHB-234 performed best at the highest saline water irrigation (7.5 dS/m), followed by HHB-226 whereas the performance of HC-20 was the poorest. The mean yield (349.5 g/m^2) of HHB-226 was higher than other genotypes followed by HHB-223 (343.6 g/m^2) and HHB-234 (326.1 g/m^2). The genotype HC20 was the lowest yielder having mean seed yield of 189.8 g/m^2. At EC_{iw} of 7.5 dS/m, overall mean yield reduced by 20.5% as compared to canal water treatment.

Table 20: Grain yield (g/m^2) of pearl millet varieties under different salinity water irrigation

Genotype/variety	EC of irrigation water (dS/m)				
	Canal	2.5	5.0	7.5	Mean
HHB-67	350.0	343.7	330.4	286.8	327.7
HHB-197	332.8	317.2	282.5	235.4	292.0
HHB-223	377.6	358.6	338.6	299.8	343.6
HHB-226	386.2	358.1	353.1	300.8	349.5
HHB-234	351.4	323.1	316.5	313.3	326.1
HC-10	275.4	225.8	217.8	209.3	232.1
HC-20	213.9	190.2	183.2	172.1	189.8
Mean	326.7	302.4	288.9	259.6	
CD (5%)	Variety (V): 16.7; Salinity (S): 12.6; VxS: NS				

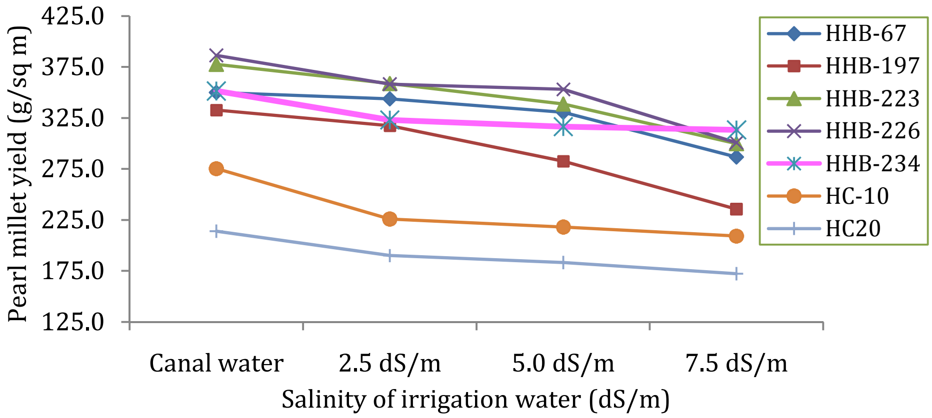


Fig. 14: Pearl millet yield at different saline water irrigation

Mustard: Eight and six genotypes of mustard were tested under IVT and AVT-1. The data showed that the yield of different genotypes of mustard decreased with increase in EC of the irrigation water (Table 21, 22). Soil Salinity at the time of sowing is given in Table 23. The genotypes CSCN-13-8 gave the highest seed yield (235.5 g/m^2) followed by CSCN-13-3 (225.9g/m^2) at EC_{iw} of 7.5 dS/m and the lowest yield (154.4 g/m^2) was obtained in CSCN-13-4. In AVT -1 among the six genotype of mustard CSCN-13-12 gave the highest seed yield (226.3 g/m2) and lowest seed yield (186.8g/m2) was obtained in CSCN-13-14 at ECiw of 7.5 dS/m. The mean salinity in the soil profile (0-45cm) at the time of sowing was varying from 1.64 to 10.22 dS/m under canal water to the highest EC irrigation plot (Table 23).

Table 21: Seed yield (g/m^2) of mustard genotypes in IVT under different salinities waters

Genotype	EC of irrigation water (dS/m)				Mean
	Canal	2.5	5.0	7.5	
CSCN-13-1	250.0	238.2	188.4	164.4	210.3
CSCN-13-2	243.2	256.2	201.3	184.4	221.3
CSCN-13-3	302.5	299.7	248.8	225.9	269.3
CSCN-13-4	267.7	246.4	186.7	154.4	213.8
CSCN-13-5	224.1	125.0	198.2	185.9	183.3
CSCN-13-6	255.7	216.9	208.7	195.9	219.3
CSCN-13-7	279.2	266.3	245.7	200.5	248.0
CSCN-13-8	289.6	276.5	245.8	235.5	261.9
Mean	264.0	240.7	215.5	193.4	
CD (5%)	Genotype (G): 14.2; Salinity (S): 10.1; GxS: 28.5				

Table 22: Seed yield (g/m^2) of mustard in AVT-1 under different salinity water irrigation

Genotype/ Variety	EC of irrigation water (dS/m)				Mean
	Canal	2.5	5.0	7.5	
CSCN-13-9	287.2	256.8	233.8	215.6	248.4
CSCN-13-10	297.8	267.4	225.3	187.1	244.4
CSCN-13-11	325.1	274.3	245.6	196.9	260.5
CSCN-13-12	267.2	254.7	246.0	226.3	248.5
CSCN-13-13	265.3	244.9	216.1	196.2	230.6
CSCN-13-14	256.2	224.1	208.5	186.8	218.9
Mean	283.1	253.7	229.2	201.5	
CD (5%)	Genotype (G): 15.4; Salinity (S): 12.6; SxV: NS				

Table 23: Soil salinity EC_e (dS/m) at sowing of mustard under saline water irrigation

Depth of soil (cm)	EC of irrigation water (dS/m)			
	Canal	2.5	5.0	7.5
0-15	1.95	4.42	8.55	10.99
15-30	2.29	5.58	9.35	10.89
30-45	2.12	5.27	8.27	9.94
Mean	2.12	5.09	8.72	10.61

Integrated nutrient management in wheat and pearl millet under saline and fresh water irrigation

The experiment was initiated during 2009-10 with two qualities of irrigation water (canal and EC_{iw} 8 dS/m) in main plot, four inoculation and vermicompost treatments (T1: control, T2: vermicompost @ 5 t/ha, T3: inoculation (*Azotobactor* & *Pseudomonas* 36),T4: inoculation (*Azotobator* & *Pseudomonas* 36+vermicompost @ 5 t/ha) in sub-plots and three fertilizer levels (75, 100 and 125% RDF) in sub-sub plots in split plot design with three replications.

The study was carried out at Hisar on performance of microbial culture on the wheat (2012-2013) and pearl millet- wheat (2013-2014) under saline water (EC_{iw} 8 dS/m) irrigation alongwith different levels of doses of fertilizer. Wheat seed was treated with the microbial cultures '*Azotobacter* &

Pseudomonas 36' before sowing. During 2012-13, wheat (WH 711) was sown and 150-60-25 kg/ha N-P-Zn was applied and crop was harvested in April 2013. During 2013-14, pearl millet (HHB 223) was sown during *kharif* 2013 with 125-60-25 kg/ha N-P-Zn application, the crop was harvested in Oct. 2013. During 2013 wheat was sown in *rabi* and harvested in April 2014. Five irrigations were applied in wheat and one irrigation in pearl millet.

The grain yield of wheat (WH 711) decreased under saline water irrigation as compared to control. The mean reduction in grain yield was 16.3 per cent as compared to canal water. Inoculation (*Azotobacter* & *Pseudomonas* 36) + Vermicompost @ 5 t/ha increased the grain yield by 6.13 per cent over control. 100% RDF produced significantly higher grain yield than 75% RDF, however, yield was at par with 125% of RDF application (Table 24).

The viable count of *Azotobacter* indicated that free living salt tolerant strain of *Azotobacter* established itself in saline water irrigated field. Further inoculation of salinity tolerant strain of *Azotobacter* alongwith *Pseudomonas* had more population of *Azotobacter* which increased the yield over control. Inoculation of these strains in the presence of the vermicompost enhanced the yield and increased the viable count of *Azotobacter* by 29.1 per cent as compared to (*Azotobacter* & *Pseudomonas* 36) (Table 24).

Table 24: Effect of various treatments on growth, yield attributes and yield of wheat (2012-13)

Treatments	Plant height (cm)	Earhead/ mrl	Earhead length (cm)	Test wt. (g)	Grain yield (q/ha)	Straw yield (q/ha)	Viable count ($x10^5$)
Irrigation water quality							
Canal water	80.9	88.2	9.78	38.89	46.3	64.0	8.2
Saline water	71.6	75.3	9.43	38.95	38.8	51.1	11.3
CD (5%)	1.99	2.36	0.25	NS	1.9	2.1	
Inoculation and vermicompost							
T1	75.4	78.7	9.57	38.95	41.5	52.7	9.1
T2	75.6	81.4	9.60	39.06	42.2	58.6	21.4
T3	75.8	81.5	9.59	38.91	42.3	56.5	41.6
T4	78.3	85.4	9.65	38.77	44.1	62.4	53.7
CD (5%)	NS	3.33	NS	NS	NS	3.1	
Fertilizers							
75% of RDF	74.5	79.0	9.61	38.91	39.8	55.9	16.9
100% of RDF	76.2	82.6	9.56	39.19	43.2	57.6	20.3
125% of RDF	78.0	83.7	9.63	38.66	44.8	59.1	18.9
CD (5%)	2.1	2.84	NS	NS	2.2	1.5	

During 2013-14, grain yield of pearl millet decreased in saline irrigation as compared to control The mean reduction in grain yield under saline water was 11.7% as compared to canal water. Inoculation (*Azotobacter* &*Pseudomonas* 36) + Vermicompost @ 5 t/ha increased the grain yield by 5.4 per cent over control (without inoculation). 100% RDF produced significantly higher yield than 75% of RDF. (Table 25).

The grain yield of wheat (WH 711) decreased in saline irrigation as compared to control during 2013-14 (Table 26). Inoculation (*Azotobacter* &*Pseudomonas* 36) + Vermicompost @ 5 t/ha increased the grain yield by 2.1 per cent over control. 100 per cent of RDF gave significantly higher yield than 75% of RDF.

Table 25: Effect of various treatments on yield attributes and yield of pearl millet (2013)

Treatments	Plant height (cm)	Ear heads/m	Ear length (cm)	Grain yield (q/ha)
Irrigation water quality				
Canal water	171	24.7	24.0	25.8
Saline water	166	21.1	23.6	22.8
CD (5%)	NS	1.1	NS	NS
Inoculation and Vermicompost				
T1	163	22.2	22.4	23.7
T2	169	23.4	23.6	24.5
T3	167	22.2	24.3	24.1
T4	174	23.9	24.9	25.0
CD (5%)	NS	NS	NS	NS
Fertlizers				
75% of RDF	167	21.8	23.2	22.7
100% of RDF	168	23.7	23.9	24.6
125% of RDF	170	23.3	23.8	25.7
CD (5%)	NS	1.2	NS	1.8

Table 26: Effect of various treatments on growth, yield attributes and yield of wheat (2013-14)

Treatment	Plant height (cm)	Ear heads per m	Ear length (cm)	Grain yield (q/ha)	Straw yield (q/ha)
Irrigation water quality					
Canal water	80.3	87.0	9.69	44.5	63.5
Saline water	71.6	74.0	9.57	41.8	51.0
CD (5%)	1.83	2.35	NS	2.26	2.14
Inoculation and vermicompost					
T1	74.96	77.55	9.63	42.9	52.2
T2	75.40	80.22	9.52	43.1	58.4
T3	75.40	80.38	9.61	42.8	56.3
T4	77.94	84.0	9.75	43.8	62.1
CD (5%)	NS	3.32	NS	NS	3.02
Fertilizers					
75% of RDF	74.47	77.95	9.53	41.9	55.6
100% of RDF	75.82	81.25	9.64	43.5	57.4
125% of RDF	77.49	82.42	9.72	44.1	58.7
CD (5%)	1.89	2.37	NS	1.46	1.56

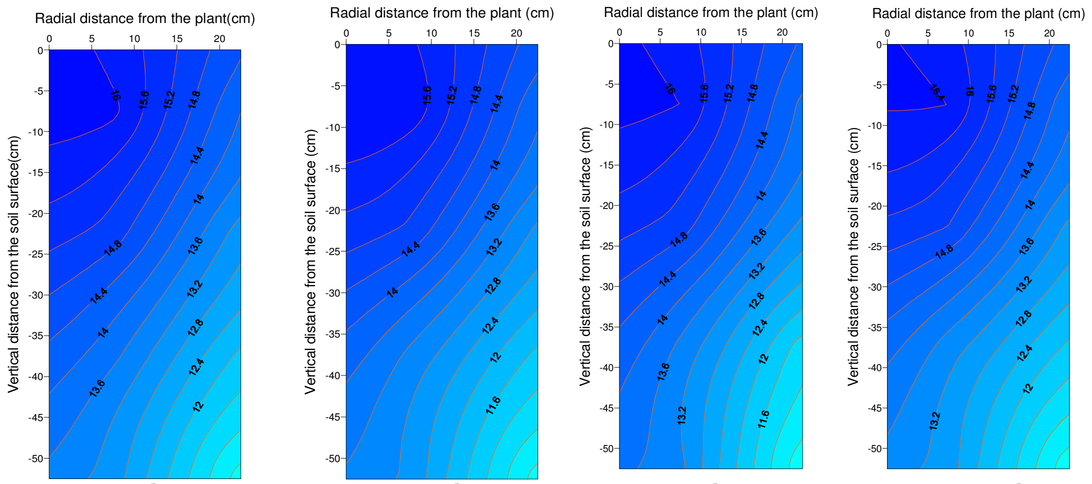
Salt and water dynamics in soil under drip irrigation system on vegetable crops

The experiment was initiated during 2012-13 with two irrigation frequency levels; daily irrigation (F_1) and alternate day irrigation (F_2) and five salinity levels (Canal water (S_1); EC_{iw} :2.5 dS/m (S_2); EC_{iw} :5.0 dS/m(S_3); EC_{iw} : 7.5 dS/m (S_4).

Results obtained during 2012-13, showed that under canal water irrigation (0.5 dS/m), the soil moisture content was not affected with time in the upper layers but in lower layers it was depleted with time (Fig. 15, 16). With increasing salinity, moisture depletion decreased. This indicates that the increase in osmotic stress due to salinity at higher EC_{iw} restricted the water and nutrient availability to the crops resulting in less depletion in moisture content. Average EC_e in the rootzone before experiment was 1.25 dS/m. In all treatments, EC_e increased in the root zone with time (Fig. 17, 18) with 7.5 dS/m water. In daily irrigation, after 30 days of transplantation, at 7.5 cm distance from the plant, average EC_e in the rootzone (0-60 cm) was 1.7, 2.0, 2.3 and 3.4 dS/m under canal water, 2.5, 5.0 and 7.5 dS/m, whereas, at 22.5 cm it was 2.0, 2.5, 3.8 and 5.1 dS/m, respectively. In daily drip irrigation (Table 27), the relative yields of broccoli were 102.1, 92.1 and 78.2% and in alternate day drip irrigation, 101.6, 87.6 and 83.3% when irrigated with saline water of 2.5, 5.0, 7.5 dS/m, respectively, as compared to canal irrigation. On comparing drip irrigation frequency treatments, 6.3, 6.8, 9.4 and 11.2% higher crop yield was observed in daily as compared to alternate day irrigation (Table 27, Fig. 19). This indicates that increased irrigation frequency can manage saline water in a better way.

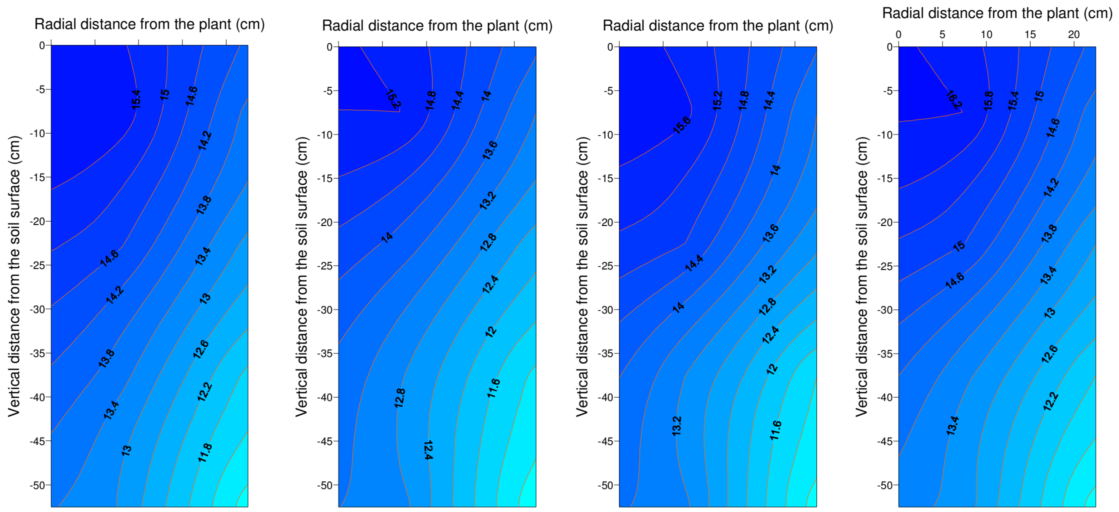
Table 27: Effect of salinity and irrigation frequency on the yield (q/ha) of broccoli

Treatments	Irrigation frequency (F)		Average crop yield (q/ha)
	Daily irrigation	Alternate irrigation	
Irrigation water salinity (S) dS/m			
Canal water	115.4	108.1	111.8
EC 2.5	117.8	109.8	113.8
EC 5.0	106.25	96.2	101.2
EC 7.5	90.2	80.1	85.2
Average	107.4	98.6	
CD (5%)	Irrigation frequency (F): 8.8; Salinity (S): 12.4; FxS: NS		



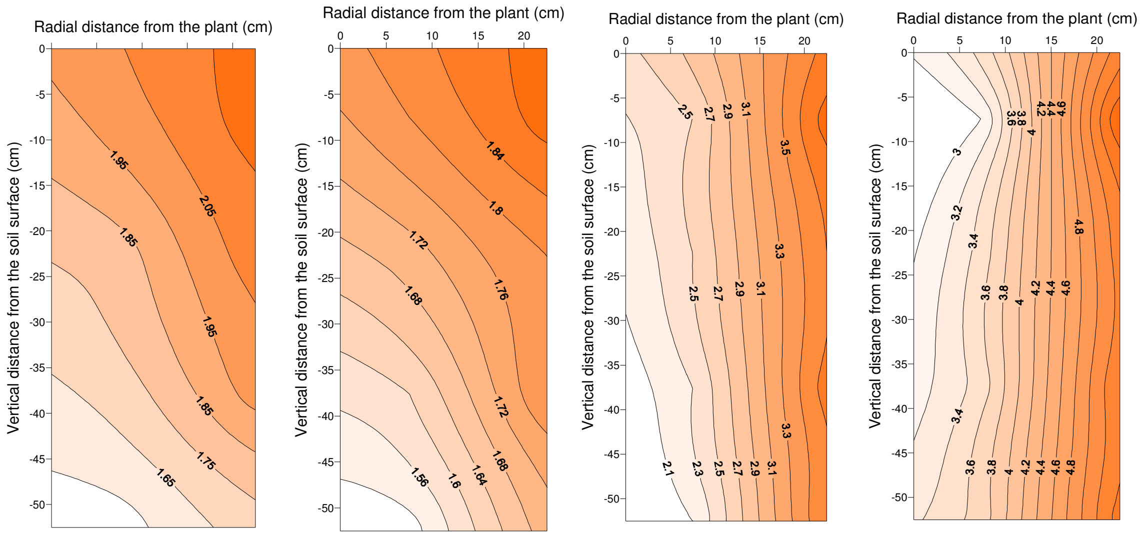
30 days 60 days 30 days 60 days

Fig. 15: Spatial and temporal movement of moisture content under daily irrigation in F_1S_1 and F_1S_3 treatments



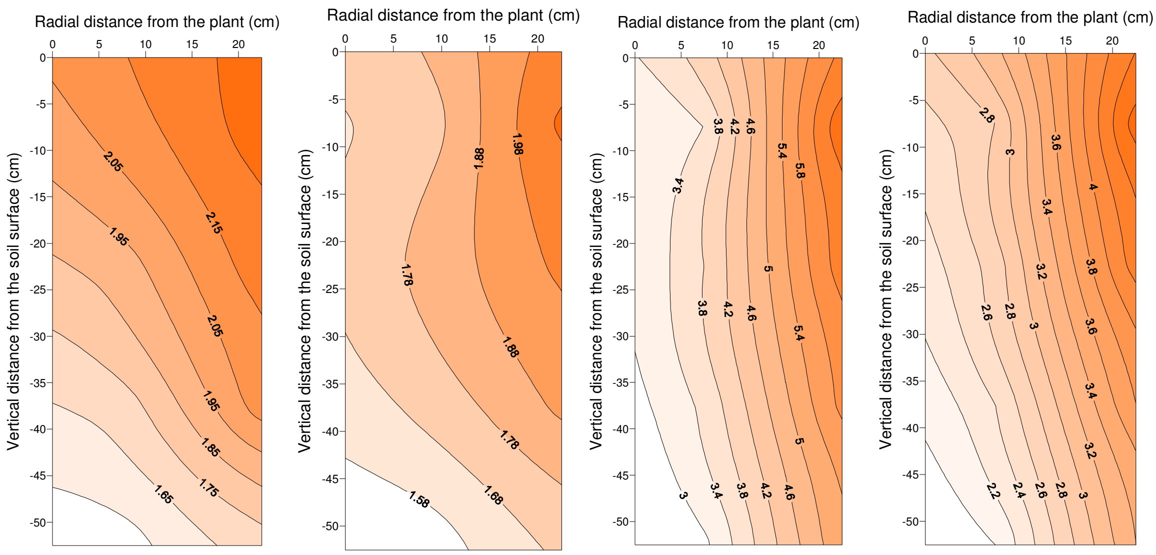
30 days 60 days 30 days 60 days

Fig. 16: Spatial and temporal movement of moisture under alternate day irrigation in F_2S_1 and F_2S_3 treatments



30 days 60 days 30 days 60 days

Fig. 17: Spatial and temporal movement of salt under daily irrigation in F_1S_1 and F_1S_3 treatments



30 days 60 days 30 days 60 days

Fig. 18: Spatial and temporal movement of salt under alternate day irrigation in F_2S_1 and F_2S_3 treatments

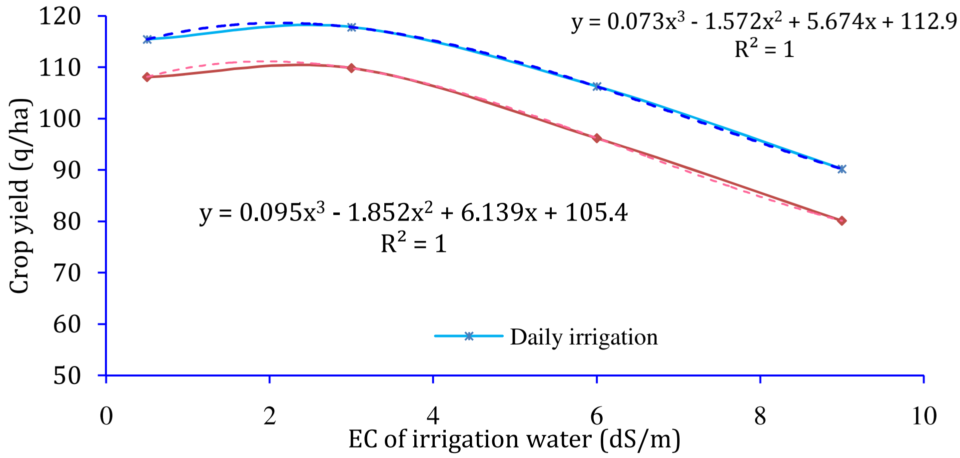
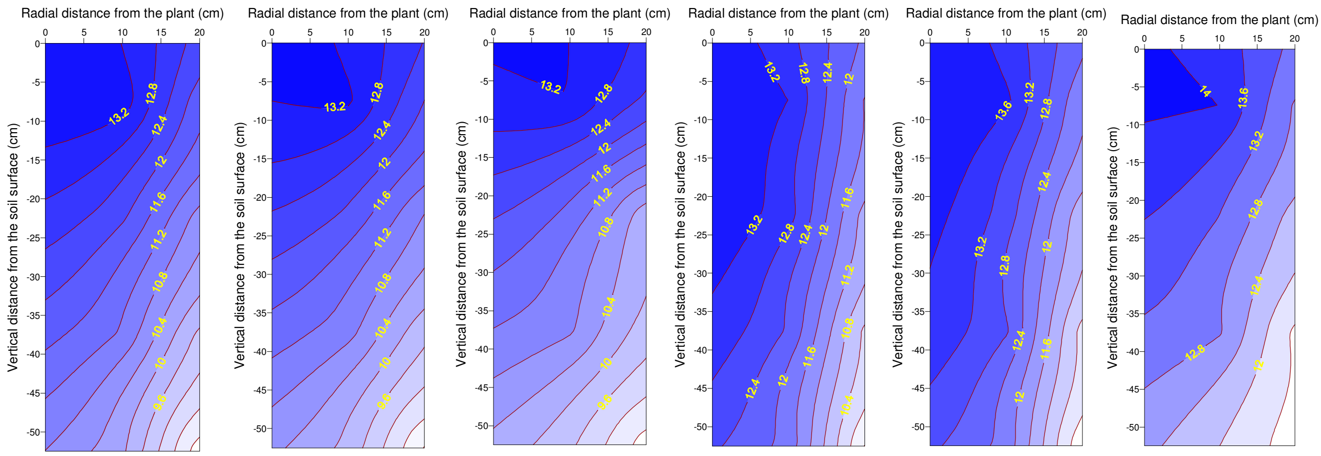


Fig. 19: Effect of irrigation frequency and saline water on yield of broccoli

Wetting pattern under daily irrigation: The results on wetting pattern for 2013-14 under different saline water treatments i.e. F_1S_1, F_1S_2, F_1S_3 and F_1S_4, at 20, 40 and 60 days of sowing are shown in Fig 20). In canal water irrigation, the soil moisture content was slowly depleted with the time in the upper layers as compared to lower layers (Fig. 20). The contour of 12.8% moisture was at a depth of 20cm below the plant at 20 days. This contour rises up with time and reached to 15 and 12cm below the plant at 40 and 60 days of sowing, respectively. The upward movement of contour or depletion in moisture content with time indicates the extraction of more water by the roots as the length and density of the roots increased with time. Less depletion is shown by contour in the upper layer which may be due to daily supply of water through the drip system and simultaneously extracted by the roots before reaching to the lower part of the root zone. On comparing the contours of Fig. 2 to 5 at 20 days of sowing, it was observed that pattern of moisture in the root zone varied with salinity of water. The contour of 13.2 per cent moisture content was at a depth of 27cm, 33cm, and 22cm below the plant under salinity level of EC_{iw} 2.5, 5.0 and 7.5 dS/m. Contours at 60 days of sowing, has shown slight increase in moisture content upto EC_{iw} 2.5 dS/m and thereafter, rapid increase in moisture content which may be due to accumulation of salt in the root zone.

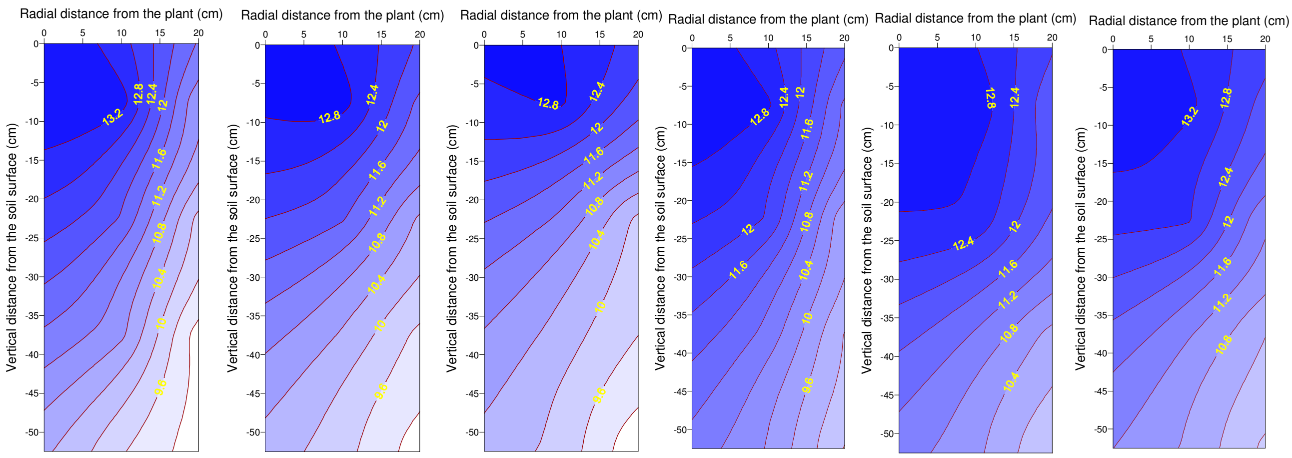
Wetting pattern under alternate day irrigation: Fig. 21 showed the wetting pattern (moisture content) under alternate day irrigation with saline water treatment i.e. F_2S_1, F_2S_2, F_2S_3 and F_2S_4 at 20, 40 and 60 days of sowing. Under this frequency in canal water irrigation, the soil moisture content depleted with the time in the upper layer as well as in the lower layers (Fig. 21). The contour of 12.8% moisture content was at a depth of 20cm below the plant at 20 days of sowing. This contour rises with time and reached to 10 and 5 cm below the plant at 40 and 60 days of sowing, respectively. On comparing the contours of Fig. 6 to 9 at 20 days of sowing, it was observed that the pattern of moisture in the root zone varied with salinity of water. The contour of 12.8% moisture content was at a depth of 40, 15 and 22.5cm below the plant at EC_{iw} 2.5, 5.0, and 7.5 dS/m. Similar variation in moisture content was observed at 60 days of sowing in daily irrigation frequency.

Salt distribution under daily irrigation: Fig. 22 showed the distribution pattern of EC_e under daily irrigation with different saline water treatments i.e. F_1S_1, F_1S_2, F_1S_3 and F_1S_4 at 20, 40 and 60 days of sowing. On comparing the contours of these figures at 20 days after sowing, it was observed that the value of EC_e in the root zone is increasing slightly with increased level of water. Where as contours at 60 days of sowing has shown steep increase in salinity of the root zone with increasing EC of irrigation water. In F_1S_1 treatment, it was observed that overall salinity in the root zone decreased with time. Salinity at 10cm distance decreased with time, whereas at 20cm distance from the plant its value increased which indicates that when canal water is being used for irrigation salts move radially as well as vertically downward. In F_1S_2 treatment, a little increase in the existing pattern of EC_e was observed in the root zone with time. In F_1S_3 treatment, moderate increase in the EC_e was observed in the root zone with time. In F_1S_4 treatment, a steep increase in the EC_e was observed in the root zone with time. The salt built-up in the root zone as a result of use of saline water was lesser near the points of water application (near plants) and increased as the distance from the plants increased thereby demonstrating the ability of the drip irrigation to push salts towards the outer periphery of the wetted zone. Moreover, it is well known fact that the salts move from the higher moisture content to lower moisture content. It is due to this reason that EC_e of the root zone remained lower than the EC_e of the irrigation water used in respective treatments.



20 days 40 days 60 days 20 days 40 days 60 days

Fig. 20: Spatial and temporal movement of moisture content under daily irrigation in F_1S_1 and F_1S_3 treatments



20 days 40 days 60 days 20 days 40 days 60 days

Fig. 21: Spatial and temporal movement of moisture under alternate day irrigation in F_2S_1 and F_2S_3 treatment

Salt distribution under alternate day irrigation treatment: Fig. 23 showed the EC_e distribution pattern under alternate day irrigation with different saline water treatments i.e. F_2S_1, F_2S_2, F_2S_3 and F_2S_4, at 20, 40 and 60 days of sowing. On comparing the contours of these figures for 20 days after sowing, it was observed that the values of EC_e in the root zone increased slightly with increasing EC_{iw} as in daily irrigation frequency. Similarly, contours for 60 days after sowing has shown steep increase in EC_e of the root zone with increasing levels of EC_{iw}. In alternate irrigation almost similar rend was observed as in daily irrigation. Salt build-up in the root zone under alternate day irrigation as compared to daily irrigation was higher. This higher salt built-up suggested that increasing irrigation interval under drip irrigation while keeping the same amount of water application may cause salt built-up in the root zone if the amount of water applied is equal to crop water requirement as it was in the present study.

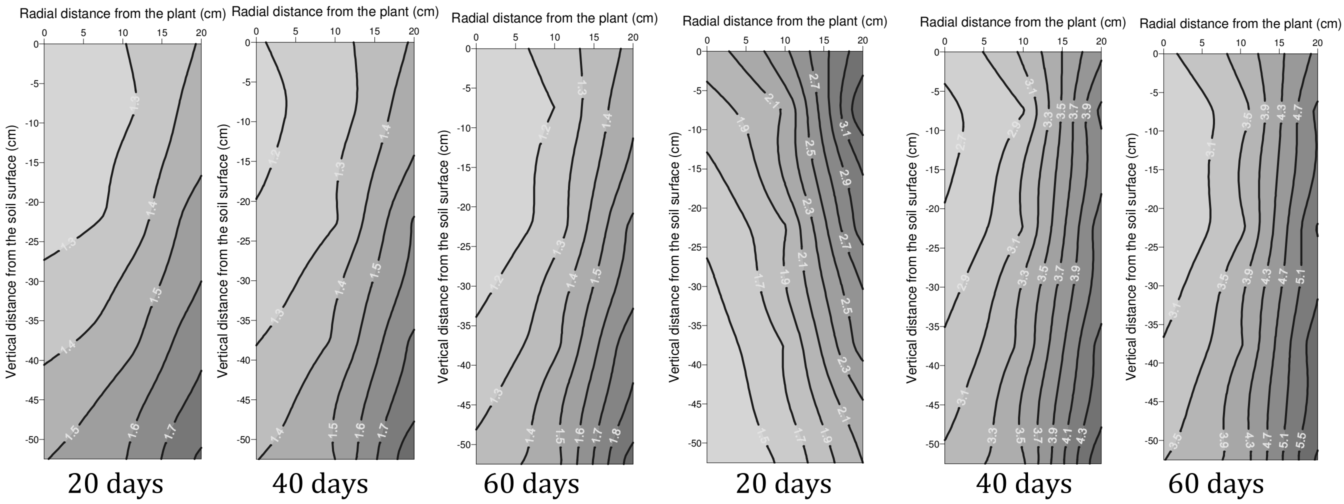


Fig. 22: Spatial and temporal movement of salt under daily irrigation in F_1S_1 and F_1S_3 treatments

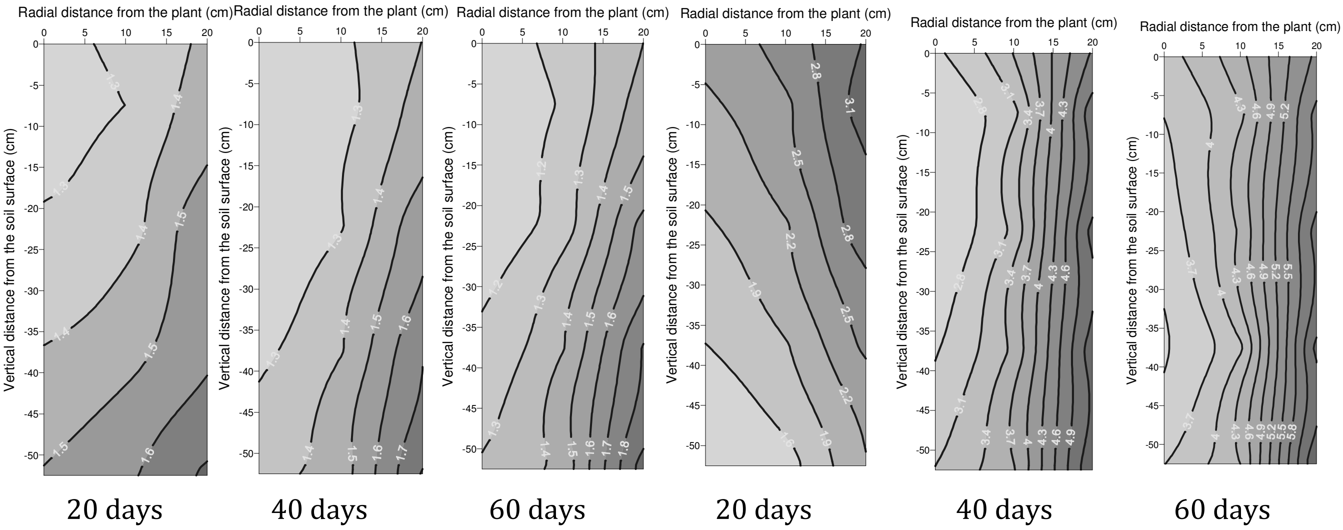


Fig. 23: Spatial and temporal movement of salt under alternate day irrigation in F_2S_1 and F_2S_3 treatments

Data presented in Table 28 showed that in daily irrigation, highest crop yield (95.8q/ha) was produced in saline water of EC_{iw} 2.5 dS/m (F_1S_2) treatment and in alternate day irrigation, highest yield (90.9q/ha) was also obtained in saline water of EC_{iw} 2.5 dS/m (F_2S_2) treatment. In daily irrigation, the relative yields obtained were 102.3, 89.2, and 79.8% in F_1S_2, F_1S_3 and F_1S_4 treatments, respectively, as compared to the yield recorded in canal irrigation (F_1S_1). In alternate day irrigation, relative yields obtained were 104.6, 83.1 and 70.8% in F_2S_2, F_2S_3 and F_2S_4 treatments, respectively, as compared to the yield recorded in canal irrigation (F_2S_1).

Table 28: Effect of salinity and irrigation frequency on the yield (q/ha) of okra

Treatments	Irrigation frequency (F)		Average yield (q/ha)
	Daily irrigation	Alternate irrigation	
Irrigation water salinity (dS/m)			
Canal water	93.6	86.8	90.2
EC 2.5	95.8	90.9	93.3
EC 5.0	83.5	72.2	77.8
EC 7.5	74.7	61.5	68.1
Mean	86.9	77.8	82.4
CD (5%)	Irrigation frequency (F): 7.9; Salinity (S): 11.2; FxS: NS		

To optimize the zinc requirement of wheat crop irrigated with sodic water

This experiment was initiated at farmer's field in village Bhurjat of Mahendragarh district under sodic soil/water conditions during *rabi* 2007 with five gypsum levels (0, 25, 50, 75 and 100% neutralization of RSC), and three Zn levels (0, 25, 50 and 75 kg/ha) in split plot design and replicated thrice.

The initial soil pH of the experimental plot during 2012-2013 was 9.64, 9.52, 9.47 and 9.37 respectively in 0-15, 15-30, 30-45 and 45-60 cm soil depths and during 2013-2014, initial soil pH was 9.21, 9.58, 9.63 and 9.62 in 0-15, 15-30, 30-45 and 45-60cm depths, respectively. The gypsum requirement of the soil was determined on the basis of exchangeable Na. The requisite quanity of gypsum on the basis of soil and water analysis was applied in a single dose before sowing of crop and mixed well in the soil.

The crops were irrigated with sodic water having RSC 13.8 meq/l and SAR 17.7 mmol/l$^{1/2}$ having the ionic composition as in Table 29. The water is bicarbonate type with 16.3 meq/l HCO_3^- content. The soil samples collected before sowing and after harvesting of the crop and analyzed for soil properties.

Table 29: Ionic composition and quality parameters of irrigation water

Ion	Value	Parameter	Value
CO_3 (meq/l)	Nil	EC (dS/m)	2.31
HCO_3 (meq/l)	16.3	RSC (meq/l)	13.8
Ca (meq/l)	0.7	SAR (m mol/l)$^{1/2}$	17.7
Mg (meq/l)	1.8		
Na (meq/l)	19.8		
Cl (meq/l)	5.8		

Wheat (WH 711) was sown on 13 Nov. 2012 and 19 Nov. 2013, and ferlitilzers 150-60 kg NP /ha was applied. Crop was given 7 irrigations and harvested on 8 April 2013 and 13 April 1014.

The data showed that significantly higher yield was obtained with increasing levels of gypsum as compared to control. The mean yield increased by 41.2, 104.5, 145.7 and 202 per cent in G_{25}, G_{50}, G_{75} and G_{100} treatments, respectively as compared to control (Table 30). The application of $ZnSO_4.7H_2O$ @ 25, 50 and 75 kg/ha produced an increase of 11.1, 19.6 and 24.3% in yield, respectively, as compared to control. The variation in yield with respect to gypsum and Zn can be expressed by quadratic equation with a coefficient of correlation (R^2) of 0.98 and 0.91, respectively.

Table 30: Grain yield of wheat irrigated with sodic water in relation to Zn and gypsum application

Gypsum levels	Levels of Zn (kg/ha)				Mean
	Control	25	50	75	
	Grain yield of wheat (q/ha)				
G_0	9.26	12.56	15.3	15.57	13.16
G_{25}	15.39	17.44	20.4	21.13	18.58
G_{50}	24.43	26.56	27.6	29.06	26.91
G_{75}	30.24	31.30	32.7	35.12	32.33
G_{100}	35.60	39.86	41.5	41.99	39.74
Mean	22.98	25.54	27.5	28.57	
CD (5%)	Gypsum level (G)			1.41	
	Level of Zn			1.26	
	G x Zn			2.82	

The soil pH at harvesting varied from 8.44 to 9.70 in 0-15 cm layer in different treatments (Fig. 3). Whereas, average pH of the soil at harvest varied from 8.79 to 9.53 from G_{100} to G_0 treatments.

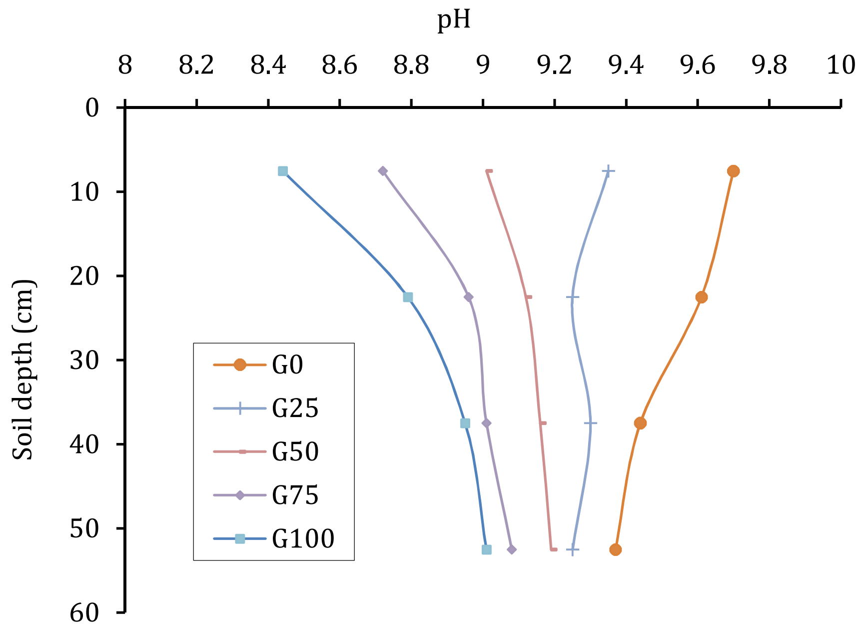


Fig. 24: Depthwise pH of the soil under different treatments at harvesting of wheat

The results obtained during 2013-14, showed that significantly higher yield of wheat was recorded with increasing levels of gypsum as compared to control. The overall mean yield increased by 52.3, 119.0, 166.3 and 219.9% in G_{25}, G_{50}, G_{75} and G_{100} treatments, respectively, as compared to control (Table 31). Application of $ZnSO_4.7H_2O$ @ 25, 50 and 75 kg/ha resulted in 9.7, 21.7 and 27.4% increase in yield, respectively, as compared to control. The variation in yield with respect to gypsum and Zn can be expressed by quadratic equation with a coefficient (R^2) of 0.99 and 0.98, respectively.

Table 31: Grain yield of wheat irrigated with sodic water in relation to Zn and gypsum application

Gypsum levels	Levels of Zn (kg/ha)				Mean
	Control	25	50	75	
	Grain yield of wheat (q/ha)				
G_0	9.0	12.3	15.5	16.5	13.33
G_{25}	16.2	19.6	22.1	23.3	20.30
G_{50}	25.6	29.0	30.1	32.1	29.19
G_{75}	32.2	34.3	36.6	38.8	35.48
G_{100}	39.9	39.6	45.4	45.7	42.63
Mean	24.57	26.96	29.91	31.31	
CD (5%)	Gypsum (G): 3.1; Zinc (Zn): 2.8; G x Zn: NS				

The pH of the soil at harvest varied from 8.84 to 9.62 from G_{100} to G_0 treatments (Fig. 25).

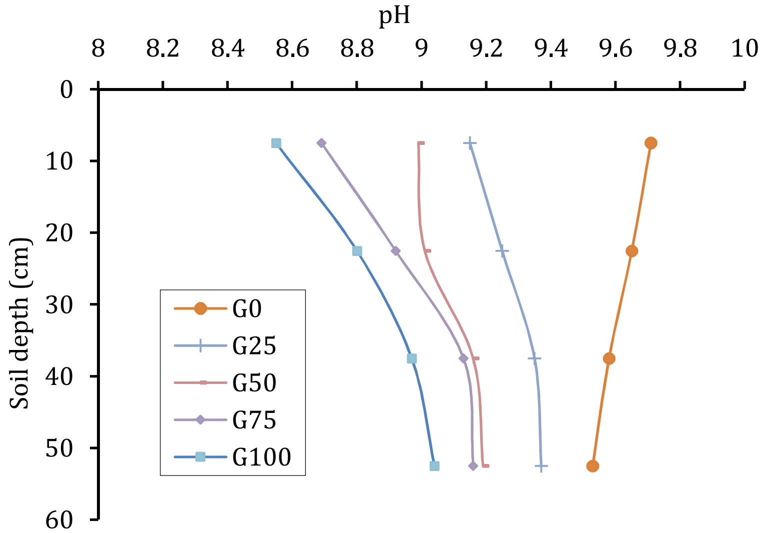


Fig. 25: Depthwise pH of the soil under different treatments at harvesting of wheat

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

This experiment was initiated during rabi 2013-14 at Hisar with three qualities of irrigation water (canal, 8 and 10 dSm) in main plots and four treatments comprised of sewage-sludge application levels (SS @ 5t/ha, SS@ 5 t/ha+50% RDF, SS@ 5t/ha+75% RDF and 100% RDF) in sub plots. Initial physico-chemical characteristics of the experimental soil and Sewage sludge are given in Table 32.

Data presented in Table 33 showed that grain yield of wheat (WH 711) decreased by 4.0 and 8.1% in all saline irrigation (8 and 10 dS/m) as compared to control. Reduction in grain yield of wheat was 15.6, 8.4 and 4.1% under sewage sludge (SS) 5 t/ha, SS 5 t/ha+50% RDF and SS 5 t/ha+75% RDF as compared to 100% RDF.

Table 32: Physico-chemical characteristics of the experimental soil and sewage sludge

Properties	Contents			Contents	
	Soil	Sewage sludge		Soil	Sewage sludge
Mechanical composition			Total metals		
Sand (%)	69.70	-	Cromium (Cr)	0.12	7.2
Silt (%)	16.50	-	Lead (Pb)	0.98	64.2
Clay (%)	13.80	-	Cadmium (Cd)	3.22	7.2
Textural class	Sandy loam	-	Nikel (Ni)	11.37	64.2
pH_2	8.10	7.20	Zinc (Zn)	29.72	215.0
EC_2 (dS/m	0.50	2.10	Manganese (Mn)	145.90	360.0
Organic carbon (%)	0.32	12.20	Iron (Fe)	4321.36	9460.0
CEC [Cmol(P^+)/ kg]	11.80	-	Copper (Cu)	22.10	263.0
$CaCO_3$ (%)	0.40	0.25			
Total Nutrients (%)					
Nitrogen	0.09	1.29			
Phosphorus	0.01	0.41			
Potassium	0.10	0.73			

Table 33: Grain yield of wheat with saline water irrigation and sewage sludge

Treatment	Saline water irrigation (dS/m)			
	Canal	8	10	Mean
	Grain yield of wheat (q/ha)			
Sewage sludge (5 t/ha)	36.4	35.9	33.7	35.3
Sewage sludge (5 t/ha+50% RDF)	40.4	37.2	37.2	38.3
Sewage sludge (5 t/ha+75% RDF)	41.3	40.8	38.1	40.1
100% RDF	43.9	41.7	39.7	41.8
Mean	40.5	38.9	37.2	
CD (5%)	Treatment (T): 1.7; Salinity (S): 1.5; TxS: NS			

INDORE: RESEARCH ACCOMPLISHMENTS

Survey and characterization of ground water for irrigation and soil salinity associated problems

Hoshangabad district: The survey and characterisation of ground water for irrigation of Hoshangabad, Itarsi, Babai, Sivani Malwa, Bankhedi, Pipariya and Sohagpur Tehsils of Hoshangabad district of Madhya Pradesh was undertaken during 2011-12 and 2012-13. The district is situated in the central part of the state and lies between 21^{o} 53" to 22^{o} 59" N latitude and 76^{o} 47" to 78^{o} 44" E longitude. The district has hot sub-humid climate characterized by hot summers and mild winters. Annual rainfall of the district is 1300-1500 mm. Maximum and minimum temperatures are 42.1°C and 11.7°C respectively. During south-west monsoon, relative humidity generally exceeds 91% (August). The main crops of the district are soybean, rice, wheat and gram etc.

A total of 445 ground water samples from open and tube wells in Hoshangabad district were collected. The quality of ground water samples collected from the district indicates that pH, EC, SAR and RSC range between 7.00-8.85, 0.15-7.05 dS/m, 0.0-11.64 and nil-3.8 meq/l, respectively (Table 1). Out of these 445 samples, 425 (95.5%) belongs to category 'A', 16 (3.6 %) belong to category 'B_1', 01 (0.27 %) sample each belongs to category 'B_2' & 'B_3', 02 (0.54 %) belongs to category 'C_1' (Table 2).

Table 1: Salient features of ground water samples of Hoshangabad district

Tehsils	pH	EC (dS/m)	SAR	RSC (meq/l)
Itarsi	7.45 - 8..85	0.29 - 3.16	0.00 - 11.64	Nil-3.80
Hoshangabad	7.02 - 8.52	0.20 - 2.32	0.18 -3.49	Nil-1.10
Babai	7.00 - 8.53	0.32 - 2.32	0.11 -7.18	Nil-2.60
Shivni Malwa	7.00 - 8.49	0.31 - 3.87	0.05 - 7.83	Nil-1.40
Bankhedi	7.06 - 8.10	0.37 - 0.94	1.43 - 1.80	Nil
Pipariya	7.39 - 8.10	0.15 - 2.09	1.69 - 5.11	Nil
Sohagpur	7.50 - 8.08	0.32 - 7.05	1.29 - 3.02	Nil

Table 2: Frequency distribution of water samples into different categories of water quality

Category	Itarsi	Hoshangabad	Babai	Shivni Malwa	Sohagpur	Pipariya	Bankhedi	Total
A	131 (96.4)	91 (98.9)	59 (96.8)	75 (90.4)	23 (92.0)	21 (91.3)	25 (100)	425 (95.5)
B_1	3 (2.2)	1 (1.1)	1 (1.6)	8 (9.6)	1 (4.0)	2 (8.7)	0	16 (3.6)
B_2	0	0	0	0	1 (4.0)	0	0	1 (0.2)
B_3	1 (0.7)	0	0	0		0	0	1 (0.2)
C_1	1 (0.7)	0	1 (1.6)	0		0	0	2 (0.5)
C_2	0	0	0	0		0	0	0
C_3	0	0	0	0		0	0	0
Total	136	92	61	83	25	23	25	445

Figures in parenthesis are percentage

The ground water quality map was generated using water quality data, ground truth and geographical situation of the sampling sites. The map was prepared with the help of remote sensing and GIS software, ERDAS IMAGINE 8.7 (Fig. 1).

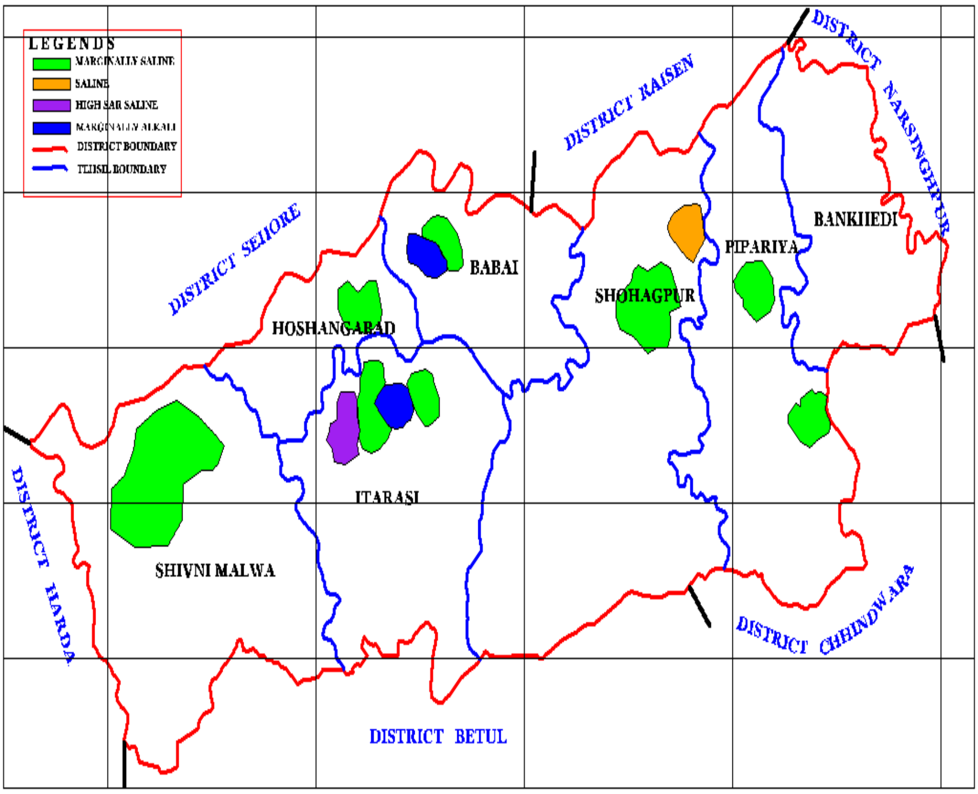


Fig. 1: Ground water quality map of Hoshangabad district of Madhya Pradesh

Dhar district: The survey and characterisation of ground irrigation water of Dhar, Badnawar, Sardarpur, Kukshi, Manawar, Gandhwani and Dharampuri Tehsils of Dhar district of Madhya Pradesh was undertaken during 2013-14. The district is situated in the southern part of the state and lies in between 22^{o} 00"-23^{o} 10" N latitude and 74^{o} 28" to 75^{o} 42" E longitude. The district has hot sub-humid climate characterized by hot summer and mild winters. The district receives an annual rainfall of 833 mm. Maximum and minimum temperatures are 43°C and 8.7°C respectively. A variety of crops like soy bean, cotton, wheat and gram etc. are the main crops grown in the district.

About 233 ground water samples (open and tube wells) from tehsils of Dhar district were collected. The wells/ tube wells vary in depth from 5 to 200 m. The quality of ground water samples indicated that pH, EC, SAR and RSC range between 7.14 - 8.89, 0.23 - 20.8 dS/m, 0.04 - 10.04 and 0.0 - 6.20 meq/l, respectively (Table 3). Out of the 233 samples, 216 (92.7%) belongs to category 'A', 14 (6.01 %) belong to category 'B_1', 01 (0.43 %) sample each belongs to category 'B_2', 'C_2' and 'C_3' (Table 4).

Table 3: Salient features of ground water quality of Dhar district

Tehsils	pH	EC (dS/m)	SAR	RSC (meq/l)
Dhar	7.55-8.89	0.23-3.69	0.23-9.94	Nil-6.2
Badnawar	6.44-8.32	0.34-20.80	0.04-10.04	Nil-0.80
Sardarpur	7.17-8.40	0.48-2.93	0.05-8.19	Nil-2.60
Kukshi	7.14-8.65	0.57-4.28	0.06-8.55	Nil-3.80
Manawar	7.61-8.48	0.45-2.22	1.00-7.27	Nil-3.80
Gandhwani	7.70-8.60	0.47-1.56	0.69-7.94	Nil-6.20
Dharampuri	8.04-8.59	0.88-1.82	2.43-6.48	Nil-6.20

Table 4: Frequency distribution of water samples into different categories of water quality

Category	Dhar	Badnawar	Sardarpur	Kukshi	Manawar	Gandhwani	Dharapuri	Total
A	58	27	32	41	28	16	14	216
B_1	4	1	5	3	1	0	0	14
B_2	0	0	0	1	0	0	0	1
B_3	0	0	0	0	0	0	0	0
C_1	0	0	0	0	0	0	0	0
C_2	1	0	0	0	0	0	0	1
C_3	0	1	0	0	0	0	0	1
Total sample	63	29	37	45	29	16	14	233

A ground water quality map was generated by use of water quality data obtained from the laboratory analysis, ground truth and geographical situation of the sampling sites. The map was prepared with the help of remote sensing and GIS soft ware (ERDAS IMAGINE 8.7) (Fig. 2).

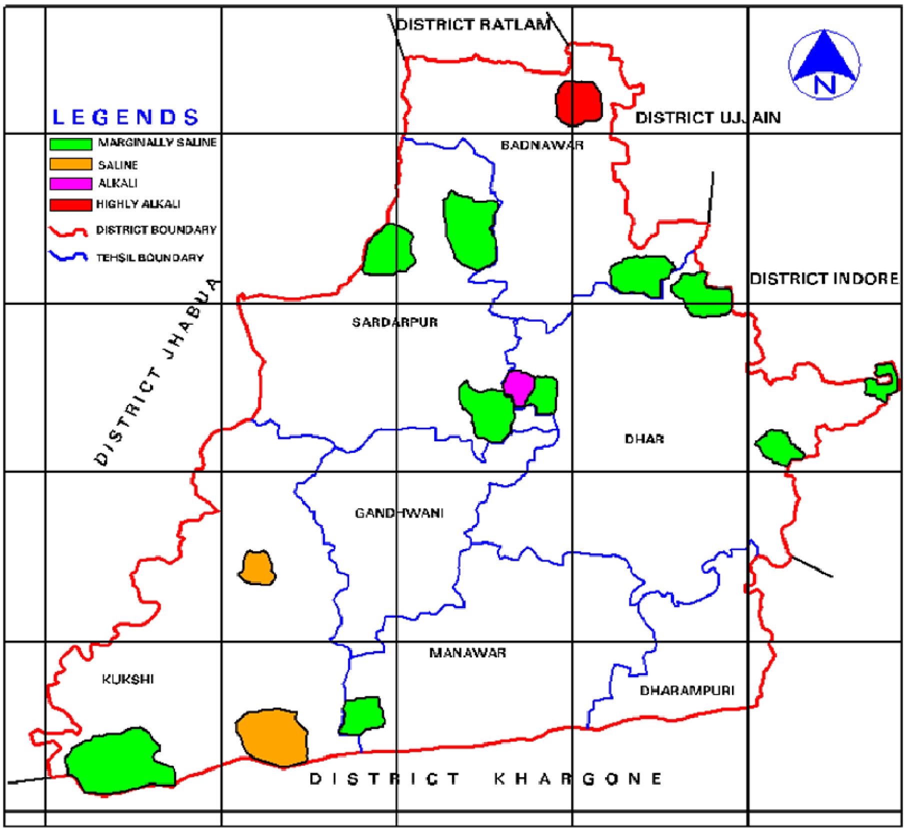


Fig. 2: Ground water quality map of Dhar district of Madhya Pradesh

Characterization and delineation of salt affected soils

Hoshangabad district: Detailed reconnaissance soil survey was carried out in different tehsils of Hoshangabad district of Madhya Pradesh to find out locations, extent and nature of salt affected soils. 62 surface soil samples were collected from villages of Hoshangabad district. Soil pH_s in the surface layer is alkaline, ranging between 7.0-8.7. EC_e ranged between 0.2-3.8 dS/m. Among cations, Na was the dominant in all samples and ranged between 0.7-14.6 meq/l. The SAR ranged between 0.9-4.2. Data pertaining to exchangeable cations, CEC and ESP revealed that exchangeable Ca, Mg and Na ranged between 24.38-33.58, 13.13-18.08 and 3.7-12.7 cmol(p+)/kg respectively. CEC ranged from 48.9 to 56.1 cmol (p+)/kg, whereas ESP varied from 7.06 to 24.42, respectively.

According to salinity and alkalinity hazards, the soil was classified in to three categories of salinity (slight (EC_e 4-8 dS/m), moderate (EC_e 8-15 dS/m) and high (EC_e >15 dS/m) and alkalinity (slight (ESP 15-25), moderate (ESP 25-40) and High (ESP >40). All of the salt affected area comes under the category of slightly saline and slightly alkali. The total area of salt affected soils in the district is 2054 ha and occurs only in one tehsil Babai (Table 5). The map of the district has been prepared (Fig. 3).

Dhar district: Detailed reconnaissance soil survey was carried out in different tehsils of Dhar district of Madhya Pradesh to find out locations, extent and nature of salt affected soils. 233 surface soil samples were collected from different villages of Dhar district. The soil pH in surface layer is alkaline. pH_s ranged between 7.0 - 8.9, EC_e ranged between 0.13 - 3.90 dS/m. Among cations, Na ranged between 0.02 - 22.5 meq/l, SAR between 0.9 - 4.2. Data pertaining to exchangeable cations, CEC and ESP revealed that exchangeable Ca, Mg and Na ranged between 11.6 - 29.4, 5.7 - 20.6 and 1.1 - 20.3 cmol(p+)/kg respectively, CEC ranged from 33.6 to 16.7 cmol (p+)/kg, whereas ESP varied from 3.1 to 53.7.

On the basis of degree of salinity and alkalinity, the soils were classified and map of the district was generated (Fig. 4). Most of the salt affected area come under the category of slightly saline and moderately alkali (5324 ha) out of total area of 9208 ha (Table 5).

Table 5: Distribution of salt affected soils in different categories, area and villages

Category	Tehsil	Area (ha)	Name of villages
Hoshangabad			
Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	Babai	2054	Madhavan, Aari, Sangakheda, Babai, Manwada, Majolpur
Dhar			
Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	Badnawar	1859	Amodia, Kanvan, Moinda, Osar, Mosar, Badbai, Dattigara, Kherigara, Khajuria
Slightly saline and moderately alkali (EC 4-8 dS/m and ESP 25-40)	Dhar	5324	Angarakheri, Sagaur, Mandlavada, Bagboon, Kheda, Jagodi, Akolia, Pithampur, Tarpura, Mirjapur, Shyamla, Karanjata, Niyamatkhedi, Najikbaroda, Piplya, Kalsada, Kherod, Teesgaon
Slightly saline and strongly alkali (EC 4-8 dS/m and ESP >40)	Dhar	801	Berchha, Khhapar, Pinjrad, Kanaval, Kalsada, Karadia, Chidavad
	Badnawar	1224	Kheda
Total		9208	

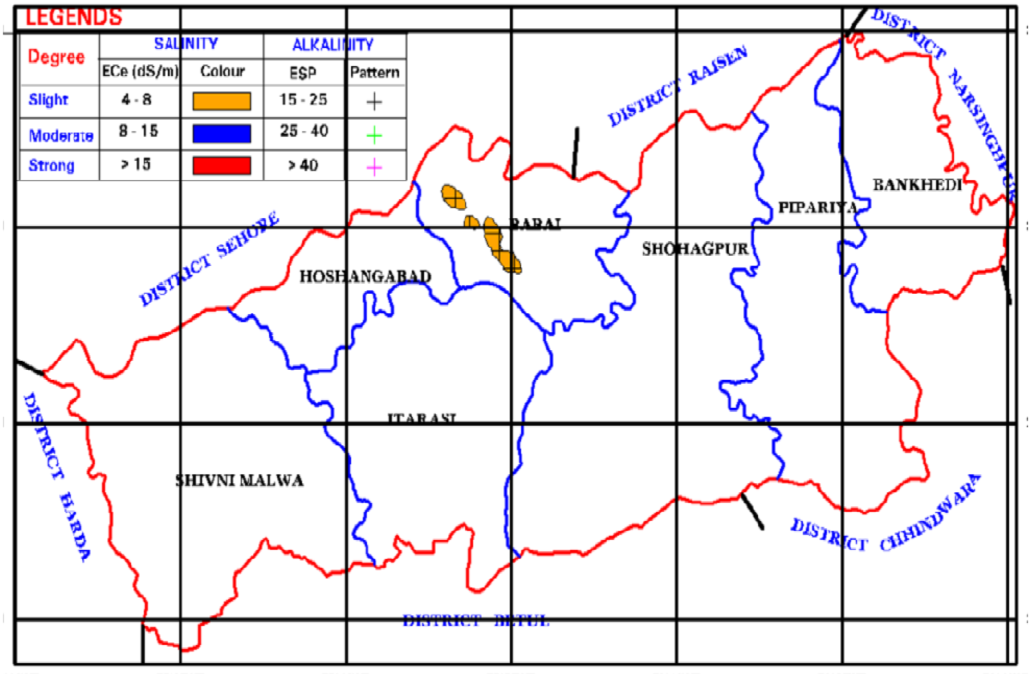


Fig. 3: Distribution of salt affected soils in Hoshangabad district of MP

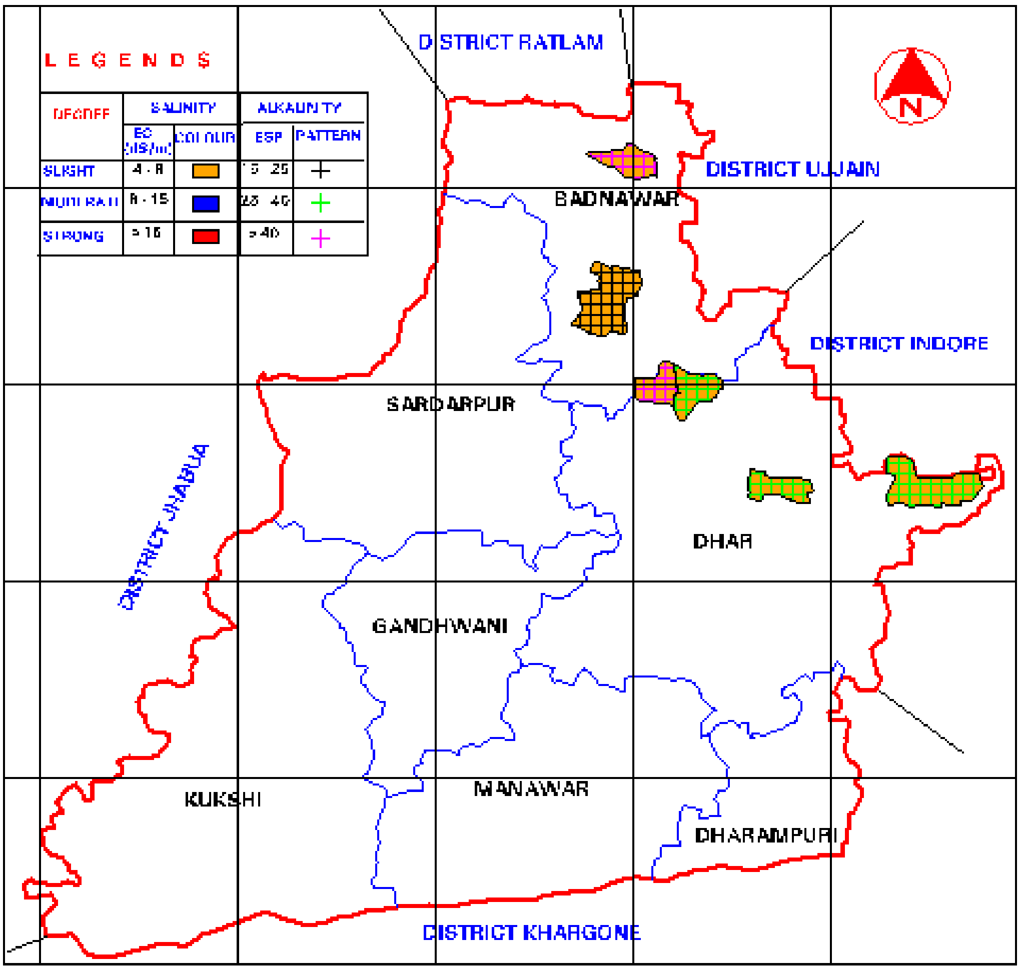


Fig. 4: Distribution of salt affected soils in Dhar district of MP

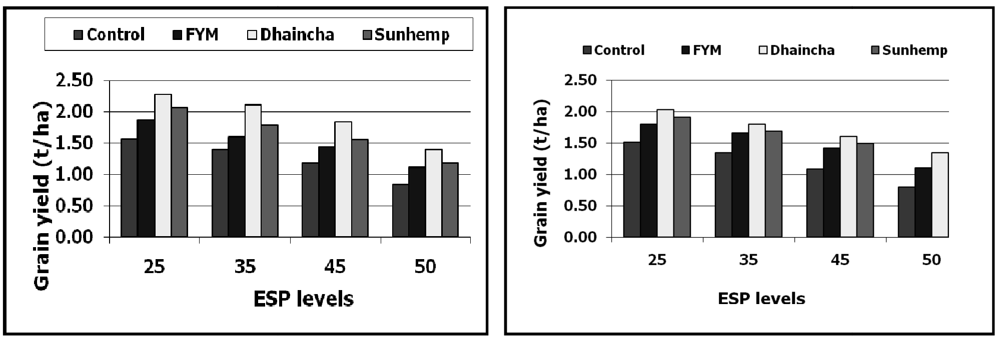
Effect of long-term application of organic/green manures in sodic Vertisols

The various green manure crops were cultivated in gypsum treated plots (to create different levels of soil ESP). Gypsum was applied only, before sowing of green manuring crop during April/ May 2005. The green manure crop was cultivated and buried in the soil at 45 days well before the sowing of the *kharif* crop. The experiment is planned to be carried out on a long-term basis for identification of impact of organic manuring. The paddy-wheat crop rotation, recommended for such soils, is being followed.

Paddy: The data presented in Table 6, Fig. 5 revealed that grain yield of paddy decreased significantly with increase in soil ESP but incorporation of green manure increased the paddy yield significantly over control. Highest grain yield of paddy was recorded during 2012-13 and 2013-14 in case of dhaincha (2.28 and 2.03 t/ha) followed by sunhemp (2.06 and 1.92 t/ha) respectively at soil ESP of 25.

Table 6: Grain yield of paddy as influenced by green manures/ FYM at different ESP levels

Green manures	Soil ESP				
	25	35	45	50	Mean
	Grain yield (q/ha) of paddy during 2012-13				
Control	1.56	1.40	1.18	0.84	1.24
FYM @ 10 t/ha	1.88	1.60	1.44	1.11	1.51
Dhaincha	2.28	2.11	1.84	1.40	1.91
Sunhemp	2.06	1.79	1.56	1.19	1.65
Mean	1.94	1.72	1.50	1.13	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD (5%)	0.12	0.11	NS	NS	
	Grain yield (q/ha) of paddy during 2013-14				
Control	1.52	1.35	1.09	0.80	1.19
FYM @ 10 t/ha	1.81	1.67	1.42	1.11	1.50
Dhaincha	2.03	1.80	1.61	1.35	1.70
Sunhemp	1.92	1.69	1.50	1.20	1.58
Mean	1.82	1.63	1.41	1.12	
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD (5%)	0.06	0.05	NS	NS	



2012-13 2013-14

Fig. 5: Effect of incorporation of green manures/ FYM on grain yield of paddy

Wheat: The data in Table 7 revealed that grain yield of wheat decreased significantly with increase in soil ESP. Incorporation of green manure enhanced the grain yield of wheat significantly over control. Interaction effects were also significant. The highest grain yield of wheat was obtained in case of dhaincha (3.18 and 2.73 t/ha) followed by sunhemp (3.01 and 2.58 t/ha) during 2012-13 and 2013-14, respectively at soil ESP of 25. Incorporation of dhaincha among various treatments gave the highest yield and lowest was observed in control plot.

Table 7: Grain yield of wheat as influenced by green manures/ FYM at different ESP levels

Green manures	Soil ESP				Mean
	25	35	45	50	
	Grain yield (q/ha) of wheat during 2012-13				
Control	2.12	1.83	1.26	0.92	1.53
FYM @ 10 t/ha	2.38	2.20	1.65	1.30	1.88
Dhaincha	3.18	2.95	2.09	1.59	2.45
Sunhemp	3.01	2.64	1.98	1.57	2.30
Mean	2.67	2.40	1.74	1.35	-
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD (5%)	0.08	0.05	0.12	0.11	
	Grain yield (q/ha) of wheat during 2013-14				
Control	1.70	1.53	1.27	0.87	1.35
FYM @ 10 t/ha	1.92	1.82	1.60	1.23	1.64
Dhaincha	2.73	2.54	2.02	1.52	2.20
Sunhemp	2.58	2.31	1.90	1.49	2.07
Mean	2.23	2.05	1.70	1.28	-
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD (5%)	0.09	0.04	0.11	0.08	

Effect of green manures/FYM on soil properties: The data presented in Table 8 indicated that pH_s and EC_e of soil remained the same. However, ESP decreased marginally with the incorporation of green manures/ FYM at all the levels. The lowest ESP was recorded in case of dhaincha followed by sunhemp.

Table 8: Soil ESP as influenced by application of green manures/ FYM

Green manures	Soil ESP				Mean
	25	35	45	50	
	Soil ESP during 2012-13				
Control	23.98	32.47	42.05	46.47	36.24
FYM @ 10 t/ha	19.84	29.01	37.98	42.53	32.34
Dhaincha	16.17	24.59	31.39	35.67	26.95
Sunhemp	18.82	27.17	36.28	37.84	30.03
Mean	19.70	28.31	36.92	40.63	-
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD (5%)	0.66	0.53	1.12	1.06	
	Soil ESP during 2013-14				
Control	23.78	32.13	41.64	46.06	35.90
FYM @ 10 t/ha	19.63	28.19	36.89	41.62	31.58
Dhaincha	16.03	23.94	30.71	33.49	26.04
Sunhemp	18.61	26.43	35.02	36.14	29.05
Mean	19.51	27.67	36.06	39.33	-
	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
CD (5%)	0.79	0.65	1.36	1.30	

Effect of methods of irrigation water quality on performance of fruit trees in a sodic environment

The study was carried out in sodic black soils of Barwaha. The saplings of Sapota (Kalipatti), Ber (Deshi) and Pomegranate (Ganesh) were transplanted at 3m x 3m grid. Irrigation treatments were superimposed after establishment of Ber (Banarsi Kadaka). Two different quality irrigation waters i.e. BAW, and spent wash diluted water were used for irrigation. 12 plants of each fruit plants were irrigated by each irrigation method and quality of irrigation water. Two biometric parameters i.e. girth and heights were recorded every year since planting. The EC and SAR of normal water were 0.5 dS/m, 1.1 $(mmol/l)^{½}$ and nil RSC, respectively. However the EC, SAR and RSC of diluted spent wash (1:30 ratio) were 0.93 dS/m, 7.3 $(mmol/l)^{½}$ and nil, respectively. The pomegranate failed to survive and replaced by Sapota during 2010-11.

Change in bio-metric parameters

Girth: The change in average girth was worked out by considering average girth of plants under each treatment at the time of planting and during 2012-13 (Table 9). Better growth in terms of girth was observed in case of embedded pipe and drip irrigation as compared to check basin in all the fruit plants. The data also revealed that the change in girth was more in case of irrigation by diluted spent wash as compared to irrigation by best available irrigation water.

Table 9: Change in average girth (cm) of fruit trees under different methods of irrigation

Methods	Best available water			Diluted spent wash water		
	2005-06	2012-13	Change	2005-06	2012-13	Change
			Girth of ber			
Check basin	5.00	16.88	11.88	3.97	16.88	12.91
Embedded pipe	3.60	21.96	18.36	2.88	24.42	21.54
Drip	4.30	20.41	16.11	2.52	21.65	19.13
			Girth of sapota			
Check basin	2.60	12.16	9.56	3.04	12.8	9.76
Embedded pipe	2.50	20.38	17.88	2.60	21.71	19.11
Drip	2.90	18.91	16.01	2.76	20.10	17.34

Yield: The data presented in Table 10 revealed that the highest yield of ber (64.81 q/ha) was recorded in case of embedded pipe irrigation method with diluted spent wash water followed by drip irrigation method with 59.26 q/ha yield during 2013-14. Similarly, highest yield (10.19 q/ha) of sapota was obtained in case of embedded pipe irrigation with diluted spent wash water followed by 8.02 q/ha yield in case of drip irrigation. The increase in fruit yield of ber was 94.4 and 77.8% in case of diluted spent wash water applied through embedded pipe and drip irrigation over check basin, respectively. Similarly sapota yield increment was 83.3 and 44.4% over check basin.

Table 10: Yield and yield increment under methods and quality of irrigation water

Methods	Best available water		Diluted spent wash water	
	Yield (q/ha)	% increase over CB	Yield (q/ha)	% increase over CB
		Ber		
Check basin (CB)	25.93	-	33.33	-
Embedded pipe	49.07	89.29	64.81	94.44
Drip	44.44	71.43	59.26	77.78
		Sapota		
Check basin (CB)	3.70	-	5.56	-
Embedded pipe	6.48	75.00	10.19	83.33
Drip	5.25	41.67	8.02	44.44

Assessing pre and post canal irrigation effect on soil, water and crops in Vertisols of Narmada Sagar command

Black soils are considered problem soils for agriculture as these are difficult to work when wet or dry. These soils are characterized by low infiltration, slow water transmission within soil profile and prone to chemical degradation under impeded drainage conditions. The study conducted to generate database on impact of irrigation project on soil, water and crops to plan strategies for enhancing production on sustainable basis in Narmada Sagar command.

The data on area under various *kharif* and *rab*i crops along with productivity were collected for the pre canal irrigation period in Khandawa district. The water table in open wells situated in head reaches of Indira Sagar Command (ISC) were also recorded and procured for the pre canal irrigation period. The soil samples were also collected from 0-15 and 30-60 cm depth for ascertaining physico-chemical properties of soil at Kelwa distributary (KD) and main canal, at the interval of 50, 200, 500 and 1000 m away from the canal, in the head reach area of Indira Sagar command.

Water table fluctuation of pre canal irrigation period: The pre and post monsoon water levels in open wells were recorded during May and November months, respectively during 2005 and 2012 in and around main canal. The pre and post monsoon water table fluctuation in 13 wells during 2005 and 2012 ranged from 2.5 to 5.1 m and 0 to 4.9.

Cropped area: The procured data on cropped area indicate the wheat and gram are major *rabi* crops grown on an area of 59721 and 15254 ha, respectively. Year-wise distribution of area, under both crops is shown in Fig. 6. Similarly, major *kharif* crops are soybean and cotton grown on an area of 150382 and 69312 ha, respectively. Year wise distribution of area under both crops shown in Fig. 7. It is obvious that major crop sequence prevailing in the area is soybean-wheat or cotton-wheat.

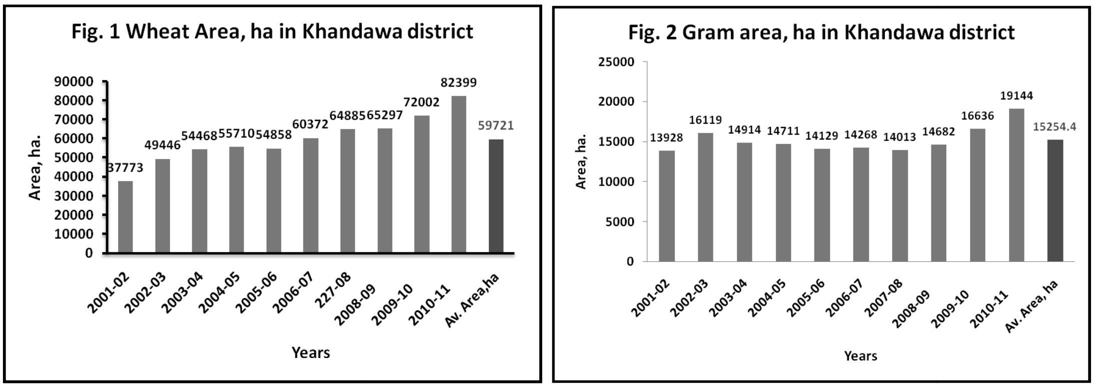


Fig. 6: Wheat and gram area in Khandawa district

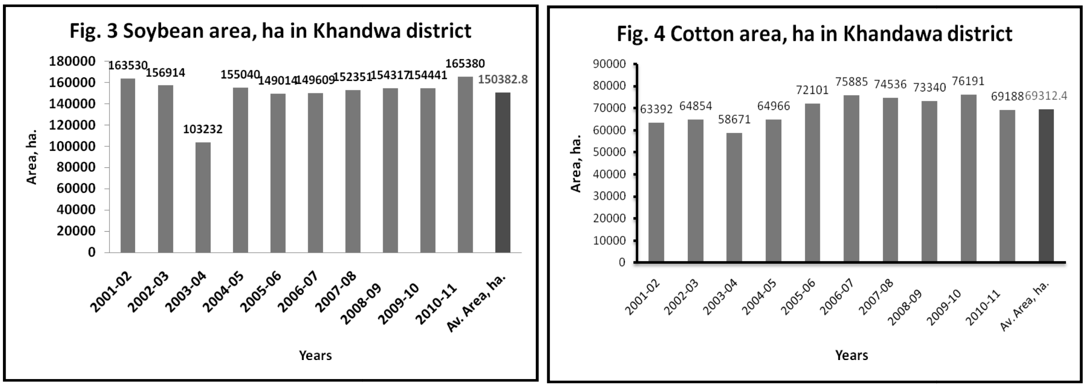


Fig. 7: Soybean and cotton area in Khandawa district

Developing multi-enterprise farming system for sodic Vertisols

After the renovation of water harvesting pond to enhance storage capacity and development of uncultivated fields during 2012, various crops were grown in developed farming system viz. raised and sunken bed, sole crop, agro-horticulture, agro-forestry. Under RS system, cotton was grown on raised beds in *kharif* season. Similarly, paddy was grown in sunken beds during *kharif* and wheat during *rabi,* respectively. Ber and sapota fruit plant along with cauliflower and cabbage were grown in agro-horticulture system, Similarly, Neem (*Azadirachtaindica*), Babool (*Accacia nilotica*) and Vilayati Babool (*Prosopis juliflora*) were planted under agro-forestry system in which cotton (Jawahar Tapti) was grown during *kharif*.

Yield: Yield data (2012-13 and 2013-14) of various crops grown under different farming systems are presented in Table 11. The yields of cotton and paddy grown during 2012-13 under raised and sunken bed system were 18.05 and 23.33 q/ha, respectively. Wheat grown in sunken beds during *rabi* produced yield of 39.83 q/ha. Sole cotton yield was 18.00 q/ha. Similarly, yields of tomato, brinjal and cabbage under agro-horticulture system were 13.38, 18.55 and 97.19 q/ha, respectively. Total returns were Rs 11676 and 17575 under various systems during 2012-13 and 2013-14, respectively.

The yields of cotton and paddy crops grown during 2013-14 under raised and sunken bed system were 11.66 and 36.66 q/ha, respectively. Sole cotton and wheat yield was 13.66 and 48.22 q/ha. Similarly, yields of cabbage and cauliflower under agro-horticulture system were 81.48 and 67.59 q/ha, respectively.

Table 11: Production and its cost of various crops under farming systems

Name of system	Crops	Plot area (m²)		Yield (kg/plot)		Yield (q/ha)		Gross return/plot (Rs)	
		12-13	13-14	12-13	13-14	12-13	13-14	12-13	13-14
RB -Kharif	Cotton	180	180	32.5	21.0	18.05	11.66	1326	1097
SB -Kharif	Paddy	180	180	42.0	66.0	23.33	36.66	409	634
-Rabi	Wheat	180	180	71.7	42.5	39.83	2344	1075	728
SC -Kharif	Cotton	450	450	81.0	61.5	18.00	13.66	3304	3213
-Rabi	Wheat	450	450	229	217.0	50.88	48.22	3435	3743
Agro-horticulture	Tomato	360	-	50.0	-	13.38	-	100	-
Agro-horticulture	Brinjal	360	-	668	-	18.55	-	2441	-
Agro-horticulture	Cabbage	360	540	350	440.0	97.19	81.48	510	3960
Agro-horticulture	Cauliflower	-	540	-	365.0	-	67.59	-	3650
Agroforestry	Cotton	720	720	-	10.0	-	-	245	550.0
Total		3240	3240					11676	17575

Irrigation from tank water: The water harvesting tank has 1890 m^3 of maximum storage capacity which was utilized to irrigate paddy and cotton crops. The details of tank water irrigation (life saving irrigation only) are given in Table 12. The stored water could manage to deliver 1510 mm depth of water for irrigating paddy, cotton, brinjal and tomato crops in a total cropped area of 1.583 ha.

Table 12: Details of life saving irrigation through pond water

Name of crop	Area of crop (m²)	Depth of irrigation water from tank (mm)
Paddy	2100	150
Paddy	2100	150
Paddy	840	120
Paddy	2100	170
Paddy	840	70
Cotton	900	170
Tomato	300	50
Brinjal	300	50
Cotton	300	70
Cotton	450	70
Cotton	3500	220
Paddy	2100	220
Total	15830	1510

Water harvesting: Surface water through runoff was harvested in small dug-out pond. Average percolation losses through the pond was observed around 17 mm/ day. Life saving irrigation was not required due to well distributed as well as prolonged period of rainfall during 2013.

Relative efficacy of distillery and sugar industry waste on reclamation and crop production in sodic Vertisols

The experiment was conducted during *kharif* and *rabi* of 2012-14at Barwaha with rice (CSR 30)-wheat (HI 1077) cropping sequence. The experiment comprised of 7 treatments replicated four times in RBD.

Paddy: Growth, yield attributes and yield of paddy given in Table 13, Fig. 8 revealed that significant increase in all the parameters was observed due to amendments over control. Application of LS 5 t/ha + RSW @ 2.5 lakh L/ha significantly increased the plant height, grain and stover yield of paddy as compared to gypsum @ 75 % GR as well as LS @ 10 t/ha and PM @ 5 t/ha application. Highest grain (2.78 and 2.34 t/ha) and stover (8.47 and 5.46 t/ha) yield was produced with the application of LS 5 t/ha + RSW @ 2.5 lakh L/ha application during 2012-13 and 2013-14.

Wheat: The data presented in Table 14 indicated that yield of wheat increased significantly with application of amendments over control. Addition of LS 5 t/ha + RSW @ 2.5 lakh L/ha significantly increased the grain and straw yield as compared to gypsum @ 75% GR as well as LS @ 10 t/ha and PM @ 5 t/ha application. Highest grain (3.65 and 3.75 t/ha) and straw (4.49 and 4.41 t/ha) yield was recorded in case of LS 5 t/ha + RSW @ 2.5 lakh L/ha application in 2012-13 and 2013-14 respectively.

Table 13: Growth, yield attributes and yields of paddy as influenced by different treatments

Treatments	Tillers per hill		Plant height (cm)		Length of penicle (cm)		Grain yield (t/ha)		Straw Yield (t/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
T_1	14.0	9.8	97.8	91.9	14.2	13.6	1.40	1.09	4.26	2.54
T_2	24.1	16.2	123.8	114.4	20.5	19.5	2.37	1.83	7.50	4.42
T_3	26.8	17.4	126.3	119.9	21.7	20.9	2.63	2.17	7.87	5.08
T_4	22.8	15.0	121.2	115.2	19.1	18.3	2.30	1.72	7.16	4.13
T_5	21.2	14.7	120.0	114.1	18.6	17.8	2.18	1.65	6.86	3.84
T_6	29.2	19.8	127.5	121.1	23.7	22.8	2.78	2.34	8.47	5.46
T_7	25.6	16.7	126.1	119.7	21.0	20.2	2.50	2.02	7.80	4.79
S Em±	1.12	0.88	2.10	1.67	0.95	0.95	0.06	0.08	0.24	0.17
CD (5%)	3.34	2.62	6.25	4.97	2.83	2.81	0.16	0.24	0.72	0.51

T_1 : Control; T_2 : Gypsum @ 75% GR; T_3 : Raw Spent Wash (RSW) @ 5 lakh L/ha; T_4 : Lagoon Sludge (LS) @ 10 t/ha; T_5 : Press Mud (PM) @ 5 t/ha; T_6 : Lagoon Sludge (LS) @ 5 t/ha + Raw Spent Wash (RSW) @ 2.5 lakh L/ha; T_7: Press Mud (PM) @ 2.5 t/ha + Raw Spent Wash (RSW) @ 2.5 lakh L/ha

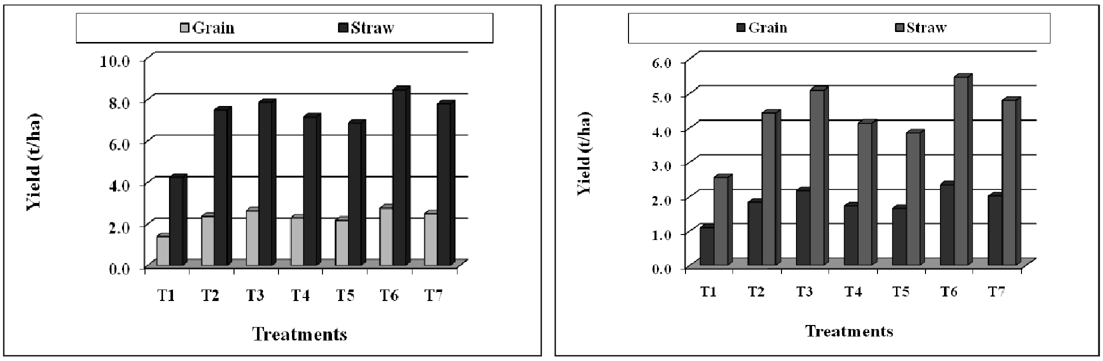
Table 14: Grain and straw yield of wheat as influenced by different treatments

Treatments	Grain yield (t/ha)		Straw yield (t/ha)	
	2012-13	2013-14	2012-13	2013-14
T_1	1.94	2.06	2.26	2.37
T_2	3.23	3.15	4.07	3.50
T_3	3.28	3.57	3.83	4.01
T_4	2.69	2.99	3.13	3.45
T_5	2.41	2.80	2.83	3.22
T_6	3.65	3.75	4.49	4.41
T_7	3.25	3.46	3.80	3.95
S Em ±	0.06	0.10	0.08	0.08
CD (5%)	0.18	0.30	0.22	0.24

Changes in ESP after harvest of paddy and wheat: The perusal of the data depicted in Table 15 indicated that ESP of post harvest soil reduced significantly with the application of different amendments. Lowest ESP was observed under the application of Lagoon Sludge @ 5 t/ha +Raw Spent Wash @ 2.5 lakh L/ha after harvest of paddy and wheat.

Table 15: ESP after harvest of crop as influenced by different treatments

Treatments	ESP after paddy		ESP after wheat	
	2012	2013	2012-13	2013-14
Control	37.6	36.6	37.4	36.4
GR @ 75 %	24.6	22.8	23.8	21.7
RSW @ 5 lakh L/ha	22.2	19.5	21.6	19.1
LS @ 10 t/ha	27.3	23.8	25.6	23.4
PM @ 5 t/ha	28.5	26.9	27.3	26.5
LS @ 5 t/ha +RSW @ 2.5 lakh L/ha	19.1	16.9	17.9	16.6
PM @ 2.5 t/ha +RSW @ 2.5 lakh L/ha	22.6	20.7	22.3	20.3
S Em ±	0.32	0.52	0.39	0.46
CD (5%)	0.94	1.55	1.17	1.37



2012 2013

Fig. 8: Effect of different treatments on grain and stover yield of paddy

Fig. 9: Crop performance in different treatments under sodic conditions

Screening of vegetable crops for sodicity tolerance under sodic black clay soils

This experiment was initiated on sodicity tolerance of vegetable crops under sodic black clay soils with 4 ESP levels (25, 35, 45 and 55) in main plot and 5 vegetables (Tomato, Brinjal, Bitter gourd, Bottle gourd, Cabbage and Cauliflower) in sub-plots and replicated four times in split plot design.

Results of experiment during 2012-13 presented in Table 16 indicated that survival percentage and yield of vegetable crops decreased with increasing levels of ESP. The maximum survival per cent and yield was observed in brinjal followed by cauliflower and bottle gourd at ESP 25. The survival percentage of tomato was less than 50% at ESP 35 however, the survival percentage of brinjal was more than 50% even at ESP 55.

Table 16: Survival and yield of vegetable crops at different ESP levels

Crops	ESP levels			
	25	35	45	55
		Survival (%)		
Cauliflower	80	64	35	24
Tomato	62	44	26	13
Brinjal	92	79	62	51
Bitter gourd	24	18	8	5
Bottle gourd	78	51	34	20
		Yield (t/ha)		
Cauliflower	11.05	8.86	4.82	3.29
Tomato	9.47	6.31	5.26	1.25
Brinjal	14.74	13.33	6.67	5.26
Bitter gourd	0	0	0	0
Bottle gourd	11.05	4.39	3.51	2.63

The data presented in Table 17 indicated that during 2013-14, survival percentage and yield of vegetables decreased with increasing levels of ESP. The maximum survival was observed in brinjal followed by cabbage and cauliflower at ESP 25. Highest yield was recorded in cabbage (15.7 t/ha) followed by brinjal (10.5 t/ha) and cauliflower (9.8 t/ha) at ESP 25. The survival percentage of cabbage and cauliflower was <50% at ESP 45, however, survival of brinjal was >50% even at ESP 55 (Fig. 10).

Table 17: Survival and yield of vegetable crops at different ESP levels

Crops	ESP levels			
	25	35	45	55
		Survival (%)		
Cauliflower	87.8	68.3	37.9	15.3
Cabbage	91.2	67.3	38.1	26.4
Brinjal	93.4	78.2	59.8	53.1
		Yield (t/ha)		
Cauliflower	9.80	6.82	3.31	1.56
Cabbage	15.70	11.12	5.81	3.84
Brinjal	10.50	8.24	5.21	4.12

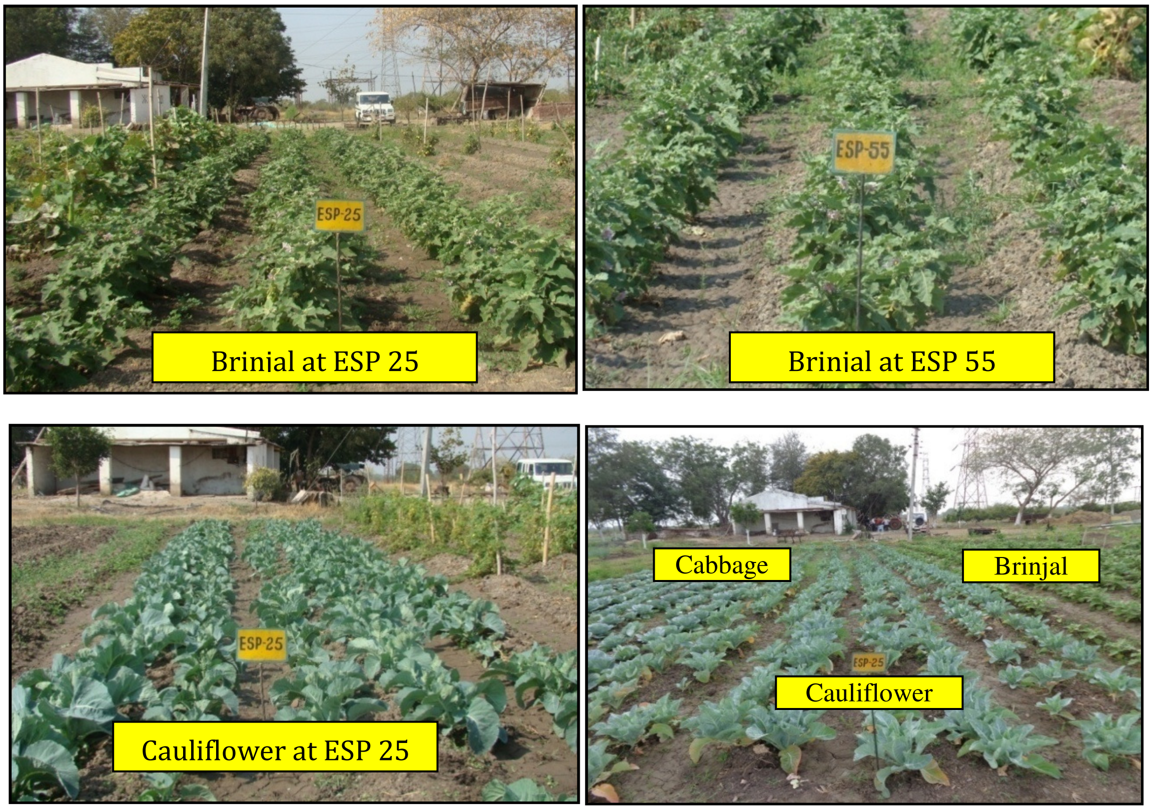


Fig. 10: Crop performance in different treatments under sodic condition

ORP on Effect of gypsum and spent wash application on crop production and soil chemical environment on farmers' fields

The demonstration on farmer's field was conducted with soybean during 2012 and wheat during 2013-14. The initial ESP, CEC and EC_e of the soil were 30.8, 40.4 cmol(p+)/kg and 2.2 dS/m, respectively during 2012-13. However, in 2013-14, the initial ESP, CEC and EC_e of the soil were 38.4, 42.4 cmol (p+)/kg and 2.7 dS/m, respectively. Gypsum was applied on the basis of GR estimated before start of experiment.

The data obtained during 2012-13 revealed that application of gypsum increased seed and straw yield of soybean over control (Table 18, Fig. 11). Application of RSW @ 5 LL/ha registered an increase of 85% in seed yield of soybean over control. However, addition of gypsum @ 75% GR and lagoon sludge @ 10 t/ha enhanced the seed yield of soybean by 43.8 and 57.8% over control. Maximum reduction in ESP was found in case of Raw Spent Wash @ 5.0 lakh L/ha followed by lagoon sludge @ 10 t/ha.

Table 18: Effect of various amendments on yield of soybean on farmer's field

Treatments	Seed yield (t/ha)	Straw yield (t/ha)	% increase in seed yield over control	ESP after harvest of soybean
Control	0.80	0.88	-	30.4
Gypsum @ 75% GR	1.15	1.35	43.8	22.2
Raw Spent Wash @ 5 LL/ha	1.48	1.75	85.0	19.5
Lagoon Sludge @ 10 t/ha	1.27	1.50	57.8	20.2

Fig. 11: Soybean under different treatments at farmer's field under sodic condition

The data given in Table 19 revealed that of application of Raw Spent Wash @ 5.0 lakh L/ha during 2013-14, results in 93.9 and 88.5% increase in grain and straw yield of wheat over control. The reduction in ESP was noticed in case of Raw Spent Wash @ 5.0 lakh L/ha form 38.4 to 22.8 as compared to control.

Table 19: Effect of spent wash applications on wheat and soil ESP on farmer's field

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	% increase in yield over control		ESP after harvest of wheat
Control	1.64	1.74	-	-	38.2
Raw Spent Wash @ 5 LL/ha	3.18	3.28	93.9	88.5	22.8

Performance of wheat as influenced by depths and frequency of irrigation under different methods of irrigation in sodic Vertisols

The study was initiated during 2013-14 in sodic black soils of Barwaha having ESP 35. Wheat (HI-1077) was sown in this experiment under border strip irrigation (BSI) with 8 lps stream size at 65, 75 and 85% cutoff distance (COD) and sprinkler irrigation (SI) scheduled on the basis of IW/CPE ratio as 1.2.

Water expense and yield: Three borders each one of size 50 x 6m were irrigated up to COD 65, 75 and 85% respectively by BSI. Similarly, three plots each one of size 50 x 24m were irrigated to depth of 2, 3 and 5 cm respectively by SI. The minimum water expense (WE) was obtained as 34 cm in case of SI with 2 cm depth followed by 36 cm in SI with 3cm depth and maximum WE was 44 cm in case of BSI with

COD 85% followed by 43 cm in BSI with COD 75% (Table 20). The highest yield of 21.46 q/ha and the lowest yield of 13.35 q/ha was obtained in case of SI with irrigation depth 3cm and BSI with COD 65% respectively. Similar trend was observed in case of water productivity with 59.6 and 33.9 kg/ha-cm.

Table 20: Water expense, yield and water productivity under different irrigation system

Name of system	Irrigation (No.)	Depth of irrigation (cm)	Water expense (cm)	Yield (kg/ha)	Water productivity (kg/ha-cm)
BSI with COD 65%	07	5.76	40	1357	33.9
BSI with COD 75%	06	7.2	43	1803	41.9
BSI with COD 85%	05	8.8	44	1997	45.4
SI with irrigation depth 2 cm	17	2	34	1600	47.0
SI with irrigation depth 3 cm	12	3	36	2146	59.6
SI with irrigation depth 5 cm	08	5	40	1952	48.8

Soil chemical properties: The soil samples collected before sowing of crop under various irrigation systems were analyzed for chemical properties (Table 21). The initial chemical properties pH, EC and ESP ranged from 7.9 to 8.3, 1.49 to 0.80 dS/m and 33.5 to 34.4 respectively.

Table 21: Initial chemical properties of soils under different irrigation systems

Irrigation system	pH_s	EC_e (dS/m)	Anion (meq/l)				Cation (meq/l)			ESP
			Ca	Mg	Na	K	CO_3	HCO_3	Cl	
BSI with COD 65%	7.95	1.49	3.0	1.0	9.7	0.48	1.0	4.0	5.0	34.4
BSI with COD 75%	8.12	1.40	3.0	0.5	9.8	0.84	1.0	5.0	4.0	34.2
BSI with COD 85%	8.30	1.29	2.5	1.5	8.2	0.52	0	4.0	4.0	33.6
SI with irrigation depth 2cm	8.22	0.85	2.5	0.5	4.6	0.20	0	4.0	5.0	34.1
SI with irrigation depth 3cm	8.31	0.80	3.0	0.5	3.5	0.42	0	4.0	5.0	33.8
SI with irrigation depth 5cm	7.92	1.13	3.5	1.5	5.8	0.62	0	5.0	3.0	33.5

Screening of wheat germplasm for sodicity tolerance in a sodic Vertisols

Fifty four wheat germplasms were tested for sodicity tolerance against five checks at Barwaha during *rabi* 2012-13. The data pertaining to the plant stand at germination and maturity, growth, plant height and grain yield (g/plot) are presented in Table 22. Highest grain yield (1000 g/plot) was recorded under germplasm WS 1204 followed by WS 1205.

Table 22: Plant stand at germination and maturity, growth and yield of wheat cultures

Cultures	Plant stand (%)		Growth Vigor	Plant height (cm)	Grain yield (g/plot)
	Germination	Maturity			
Border KRL 19	70	66	5	80	110
Border KRL 19	70	65	5	80	100
KRL 19 (C)	72	65	3	80	445
Kharchia 65 (C)	73	66	3	62	485
HD 4530 (C)	72	60	4	63	305
KRL 3-4 (C)	75	68	3	57	525
KRL 210 (C)	73	65	3	96	450

LBP 2012-21	74	69	3	61	595
LBP 2012-22	75	70	3	70	505
LBP 2012-23	75	71	2	70	655
LBP 2012-24	77	73	2	81	695
LBP 2012-25	72	66	3	76	425
RWP 2012-17	73	67	3	70	550
RWP 2012-18	73	64	3	72	445
RWP 2012-19	72	65	3	80	450
RWP 2012-20	73	66	3	76	555
KRL 19 (C)	72	66	3	85	435
Kharchia 65 (C)	73	67	3	67	490
HD 4530 (C)	72	61	4	59	265
KRL 3-4 (C)	75	69	3	58	550
KRL 210 (C)	73	64	3	91	400
Raj 4368	71	61	4	67	350
Raj 4369	71	61	4	76	350
Raj 4370	72	65	3	70	505
Raj 4371	78	69	3	76	550
Raj 4372	72	68	2	80	695
KRS 1201	72	66	4	78	355
KRS 1202	74	68	3	66	595
KRS 1203	77	70	2	78	690
KRS 1204	75	69	2	75	600
KRL 19 (C)	72	64	3	77	465
Kharchia 65 (C)	73	65	3	67	460
HD 4530 (C)	72	61	4	60	250
KRL 3-4 (C)	75	66	3	58	550
KRL 210 (C)	73	65	3	91	455
KRS 1205	72	67	3	61	450
KRS 1206	73	68	3	72	410
KRS 1207	70	61	4	64	205
KRS 1208	72	63	4	57	300
KRS 1209	70	62	4	58	255
KRS 1210	72	65	3	63	400
KRS 1211	70	63	4	57	305
KRS 1212	73	68	3	58	550
KRS 1213	72	68	3	70	405
KRL 19 (C)	72	67	3	83	485
Kharchia 65 (C)	73	69	3	63	550
HD 4530 (C)	72	62	4	57	295
KRL 3-4 (C)	75	69	3	56	575
KRL 210 (C)	73	67	3	90	490
KRS 1214	75	70	2	80	650
KRS 1215	73	69	3	75	455
KRS 1216	75	71	2	80	605
KRS 1217	74	69	3	67	490

KRS 1218	73	68	3	70	400
KRS 1219	76	71	2	80	655
KRS 1220	75	71	2	73	605
WH 1301	75	69	3	70	595
WH 1302	75	72	2	99	650
KRL 19 (C)	72	66	3	83	495
Kharchia 65 (C)	73	65	3	63	495
HD 4530 (C)	72	61	4	57	290
KRL 3-4 (C)	75	66	3	58	505
KRL 210 (C)	73	64	3	91	400
WH 1303	73	68	3	73	500
WH 1148	74	70	3	78	550
WH 1149	73	69	3	57	500
PS 1078	75	71	2	68	605
PS 1079	70	66	2	76	650
PS 1080	72	64	4	63	365
PS 1081	74	69	3	77	450
PS 1082	74	68	3	74	450
NW 6008	72	66	3	77	400
KRL 19 (C)	72	65	3	80	490
Kharchia 65 (C)	73	66	3	60	450
HD 4530 (C)	72	60	4	58	300
KRL 3-4 (C)	75	70	3	60	550
KRL 210 (C)	73	68	3	87	510
NW 6009	74	69	3	73	555
NW 6010	75	71	2	75	650
NW 6011	75	72	2	80	650
NW 6012	75	71	2	99	650
WS 1201	75	69	2	89	650
WS 1202	73	67	3	83	450
WS 1203	76	75	1	88	800
WS 1204	80	79	1	86	1000
WS 1205	77	72	1	81	900
Border KRL 19	70	65	5	80	95
Border KRL 19	70	66	5	80	110

Demonstrations on varietal performance (mustard and wheat) on farmer's fields

Demonstrations on wheat varieties were conducted at two locations for each variety. The data on ESP at the time of sowing and yield of wheat are presented in Table 23. The yields of the demonstrations conducted Barwaha were low as compared to the yields of demonstrations taken at farmers fields in Indore district due to the facts that the soils are sodified to a great depth and having high bulk density.

Table 23: Wheat yield at different stress levels of ESP

Variety	Name of farmer/research farm	Level of stress (ESP)	Yield (q/ha)
KRL 210	Makhan Chaudhary, Depalpur, Indore	38.7	29.7
	Salinity Research Farm, Barwaha	38.6	22.6
KRL 213	Chandrashekhar, Depalpur, Indore	33.8	34.4
	Salinity Research Farm, Barwaha	36.4	21.8

DOS: 18.11.2012; DOH: 19.03.2013

KANPUR: RESEARCH ACCOMPLISHMENTS

Survey and characterization of ground water for irrigation

A total of 291 ground water samples were collected from Kannauj district and analysed. Out of total samples, 57, 15, 34, 25, 43, 40, 55 and 22 samples collected from Kannauj, Gugrapur, Jalalabad, Haseran, Talgram, Chhibramau, Umarda and Saurikh blocks of the district, respectively (Table 1, 2).

Kannauj: The quality of ground water of Kannauj block indicated that pH, EC, SAR and RSC ranged from 7.2 to 7.9, 0.34 to 3.28 dS/m, 0.0 to 9.3 and 0.0 to 3.8 meq/l, respectively. Most of samples were good (52 samples). Out of 57 samples, only 4 samples marginal saline and 01 marginal alkali water category.

Jalalabad: The quality of ground water samples of Jalalabad block indicated that pH, EC, SAR and RSC varies from 7.3 to 8.1, 0.38 to 2.06 dS/m, 0.9 to 9.0 and 0.0 to 0.5 meq/l, respectively. Out of 34 ground water samples, 32 samples are good and 02 water samples were in marginally saline category.

Talgram: The quality of ground water of Talgram block indicated that pH, EC , SAR and RSC ranged from 7.4 to 8.5, 0.35 to 2.10 dS/m, 0.7 to 9.0 and 0.0 to 1.0 meq/l, respectively. Most of water samples belong to good category (38 samples). Out of 43, only 05 samples were in marginally saline category.

Chhibramau: The quality of ground water samples of Chhibramau block indicated that pH, EC, SAR and RSC varies from 7.4 to 8.4, 0.28 to 2.03 dS/m, 0.6 to 9.0 and nil-2.0 meq/l, respectively. Out of 40 ground water samples, 39 samples were in good and 01 sample in marginally saline categories.

Umarda: The quality of ground water of Umarda block indicated that pH, EC, SAR and RSC varies from 7.2 to 8.2, 0.28 to 6.05 dS/m, 0.5 to 11.3 and nil-0.4 meq/l, respectively. Out of 55 ground water samples, 47 were good, 06 marginally saline, 01 sample saline and 01 highly saline categories.

Saurikk: The quality of ground water samples of Saurikh block indicated that pH, EC, SAR and RSC varies from 7.3 to 8.0, 0.24 to 2.11 dS/m, 0.6 to 9.1 and nil-0.1 meq/l, respectively. Out of 22 ground water samples, 19 samples were in good and 03 sample in marginally saline category.

Frequency distribution of water samples: Out of total 291 samples 258 (88.66%) belongs were good, 30 (10.31%) marginally saline, 01 (0.34%) saline, 01 (0.34%) highly saline and 01 (0.34%) sample belongs to marginally alkali water category (Table 2).

Table 1: Salient features of ground water samples of blocks of Kannauj district

Blocks	pH	EC (dS/m)	SAR	RSC (meq/l)
Kannauj	7.2-7.9	0.34-3.28	0.0-9.3	Nil-3.8
Gugrapur	7.1-8.0	0.40-2.40	1.0-8.3	Nil-1.5
Jalalabad	7.3-8.1	0.38-2.06	0.9-9.0	Nil-0.5
Haseran	7.8-8.5	0.28-2.04	0.6-6.2	Nil-0.6
Talgram	7.4-8.5	0.35-2.10	0.7-9.0	Nil-1.0
Chhibramau	7.4-8.4	0.28-2.03	0.6-9.0	Nil-2.0
Umarda	7.2-8.2	0.28-6.05	0.5-11.3	Nil-0.4
Saurikh	7.3-8.0	0.24-2.11	0.6-9.1	Nil-0.1

Table 2: Frequency of different categories of ground water quality of Kannauj district

Category	Kannauj	Gugrapur	Jalalabad	Haseran	Talgram	Chhibramau	Umarda	Saurikh	Total
Good	52	13	32	20	38	37	47	19	258
Marginally Saline	4	2	2	5	5	3	6	3	30
Saline	-	-	-	-	-	-	1	-	1
Highly Saline	-	-	-	-	-	-	1	-	1
Marginally Alkali	1	-	-	-	-	-	-	-	1
Alkali	-	-	-	-	-	-	-	-	-
Highly Alkali	-	-	-	-	-	-	-	-	-
Samples	57	15	34	25	43	40	55	22	291

Efficacy of phosphogypsum as an amendment for alkali soils

This experiment was initiated during *kharif* 2009 at Kanpur with 6 treatments comprised of T_1 : RSCW (Untreated); T_2 : BAW; T_3 : RSCW (15cm phosphogypsum bed); T_4 : Soil application of Phosphogypsum (as in T_3); T_5 : RSCW (15cm gypsum bed) and T_6 : Soil application of gypsum (as in T_5). Rice (CSR 27) and Wheat (KRL 213) was sown with 4 replications in RBD. Fertlizer dose of 120-60-60 NPK kg/ha was applied in both crops. The initial soil pH was 9.10, EC 2.6 dS/m, ESP 46.7, OC 0.28%, GR 11.5 t/ha, soil was sandy clay loam. Gypsum and phosphogypsum dissolution based on GR is given in Table 3.

Table 3: Gypsum and phosphogypsum dissolutions by irrigation water through bed (15 cm)

Year	Treatments	Kharif (t/ha)	Rabi (t/ha)	Total (t/ha)	Cumulative (t/ha)
2009-10	Gypsum	0.51	0.85	1.36 (11.8%)	1.36 (11.8%)
2010-11	Gypsum	0.53	0.89	1.42 (12.3%)	2.78 (24.2%)
2011-12	Gypsum	0.38	0.86	1.24 (10.8%)	4.02 (35.0%)
2012-13	Gypsum	0.50	0.88	1.38 (12.0%)	5.40 (46.9%)
2013-14	Gypsum	0.55	0.91	1.46 (12.7%)	6.86 (59.6%)
2009-10	Phosphogypsum	0.59	0.99	1.58 (13.7%)	1.58 (13.7%)
2010-11	Phosphogypsum	0.60	1.01	1.61 (14.0%)	3.19 (27.7%)
2011-12	Phosphogypsum	0.43	1.00	1.43 (12.4%)	4.62 (40.2%)
2012-13	Phosphogypsum	0.62	1.02	1.64 (14.3%)	6.26 (54.4%)
2013-14	Phosphogypsum	0.64	1.05	1.69 (14.7%)	7.95 (69.1%)

The data presented in Table 4, 5 revealed that the average grain yield of rice and wheat varied from 29.45-40.00 and 25.73-36.41 q/ha, respectively. Highest yield of both crops 40.0 and 36.4q/ha were obtained under 15 cm phosphogypsum bed treatments. Lowest grain yield of both crops was recorded RSCW (T_1) alone.

Soil Properties: The chemical properties of soil pH, EC, ESP and OC showed considerable improvement under amended water passed through gypsum/phosphogypsum beds (Table 6). The maximum soil pH (9.49) was recorded in RSC treated plots followed by BAW (8.91). Dissolution of gypsum and phosphogypsum reduced soil pH to 8.26 and 8.18 respectively. No much variation in soil pH was observed with soil application of gypsum and phosphogypsum but had more effect as compared to BAW. The soil EC 2.69 dS/m was maximum in RSC treated plots followed by BAW, phosphogypsum and gypsum application. The ESP value in RSC treated plots remained highest (47.88) followed by BAW (42.54), gypsum dissolution (34.43) and phosphogypsum (33.35). Organic carbon varied from 0.27-0.49% under the influence of soil amendments.

Table 4: Effect of treatments on grain yield of rice

Treatments	Grain yield (q/ha) of rice					
	2009	2010	2011	2012	2013	Mean
T_1	30.20	30.35	29.75	29.12	27.87	29.45
T_2	32.65	33.30	35.00	35.28	35.78	34.40
T_3	36.40	37.92	39.75	42.32	43.63	40.00
T_4	34.25	35.27	37.50	38.19	38.67	36.77
T_5	34.60	36.11	39.00	40.05	40.72	38.53
T_6	32.83	33.76	36.00	36.22	36.35	35.03
CD (5%)	1.69	1.74	1.30	1.54	1.43	-

Table 5: effect of different treatments on grain yield of wheat

Treatments	Grain yield of wheat (q/ha)					
	2009-10	2010-11	2011-12	2012-13	2013-14	Mean
T_1	26.15	26.30	26.12	25.45	24.64	25.73
T_2	28.41	29.50	31.24	30.18	30.30	29.93
T_3	32.80	34.22	37.53	39.66	40.65	36.41
T_4	30.12	31.60	34.18	34.22	32.50	32.51
T_5	31.60	33.10	35.76	36.52	34.00	34.20
T_6	28.55	30.70	32. 38	31.25	31.30	30.90
CD (5%)	1.75	1.82	1.80	1.68	1.64	-

Table 6: Effect of treatments on physico-chemical properties of soil after five years

Treatments	pH	EC (dS/m)	ESP	OC (%)
T_1	9.49	2.69	47.88	0.27
T_2	8.91	2.55	42.54	0.38
T_3	8.18	2.61	33.35	0.49
T_4	8.12	2.52	31.23	0.44
T_5	8.26	2.63	34.43	0.45
T_6	8.19	2.59	32.66	0.41

Change in ionic composition of RSC water: Crops irrigated with RSC water of 8.87 meq/l passed through 15cm gypsum or phosphogypsum bed showed reduction in RSC and changes in ionic composition (Table 7). No significant change in pH_{iw} was observed but EC_{iw} increased slightly. Initial average RSC 8.87 reduced to 4.21 and 4.08 meq/l using gypsum and phosphogypsum, respectively.

Table 7: Change in ionic composition of RSC irrigated water under gypsum and phosphogypsum

Treatments	pH	EC (dS/m)	Anions (meq/l)				Cations (meq/l)		RSC (meq/l)
			CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na+K	
RSC (untreated)	8.82	1.11	0	10.52	0.58	0.50	1.63	9.81	8.87
RSC (treated with gypsum)	7.86	1.52	0	10.16	1.12	3.66	5.94	9.15	4.21
RSC (treated with phosphogypsum)	7.88	1.51	0	10.23	1.22	3.70	6.15	9.10	4.08
BAW	7.46	0.71	0	4.11	3.31	0.11	6.40	1.02	Nil

Effect of management practices on resodification of reclaimed sodic lands at benchmark sites on farmer's field

This study was initiated during 2010. Eight benchmark sites (four each representing good and poorly managed) on reclaimed sodic lands at farmer's field were identified and soil samples at different depths (upto 150 cm) were collected and analysed to evaluate the causes of resodification.

In general the hard kanker layer was found at 90-125 cm depth from the surface. The physico-chemical properties of selected farmer's fields revealed that pH, EC, OC, and ESP ranged from 8.8-9.4, 2.2-2.5 dS/m, 0.1-1.5%, and 40.0-55.1, respectively from 0-15 cm depth (Table 8).

Table 8: Physico-chemical properties of resodified soil at various depths at benchmark sites

Depth (cm)	pH		EC (dS/m)		Organic carbon (%)		ESP	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
0-15	8.8-9.4	9.17	2.2-2.5	2.36	0.10- 1.52	0.34	40.0-55.1	47.45
15-30	8.7-9.3	9.07	2.1-2.4	2.27	0.12-1.30	0.31	38.2-50.2	44.45
30-60	8.6-9.3	8.99	2.0-2.3	2.16	0.10-1.11	0.25	38.7-47.2	41.41
60-90	8.5-9.1	8.87	1.9-2.2	2.06	0.07-0.13	0.19	31.4-46.0	38.35
90-120	8.4-9.0	8.79	1.7-2.2	1.97	0.05-0.54	0.13	27.3-40.0	33.55
120-150	8.3-8.9	8.67	1.7-2.0	1.87	0.03-0.32	0.13	25.4-38.1	29.76

It is evident from the data presented in Table 9 that average yield of paddy at farmer's field varied from 21.14 to 41.71 q/ha under partially reclaimed sodic soils. The yield of wheat (PBW 343) ranged from 21.26 to 37.49 q/ha.

Table 9: Yield of paddy and wheat in selected farmer's fields

Name of farmer	Yield of crops (q/ha)									
	Paddy (Kranti)					Wheat (PBW 343)				
	2010	2011	2012	2013	Mean	2010-11	2011-12	2012-13	2013-14	Mean
DeepNarayan	29.00	32.20	33.17	34.55	32.23	27.50	29.20	30.15	31.00	29.46
Suresh	37.30	41.50	43.16	44.88	41.71	28.00	30.76	32.80	33.95	31.38
Indrajeet	19.80	22.70	23.22	25.15	22.71	20.80	22.35	20.17	22.86	21.55
Vijai Bahadur	17.50	21.00	22.06	24.00	21.14	18.80	20.55	22.04	23.65	21.26
Mool Chandra	38.70	42.60	41.75	42.35	41.35	32.00	35.77	37.00	37.18	35.48
Radhey Lal	39.50	43.00	40.02	42.75	41.32	32.50	36.00	38.12	39.00	36.40
Puspendra	37.80	42.00	42.12	43.86	41.44	33.00	37.10	39.15	38.69	37.49
Ram Narain	35.50	40.80	38.75	39.92	38.62	27.80	30.45	32.40	31.78	30.60

Evaluation of resource conservation technology for rice-wheat cropping system under reclaimed sodic soils

This experiment was initiated with 9 resource conservation treatments in rice (CSR 27)-wheat (KRL 213) cropping system during 2010. The initial soil pH was 9.2, EC_e 2.6 dS/m, ESP 45.2, OC 0.13% and soil texture was clay loam. The resource conservation technologies comprised of T_1: Conventional rice transplanting/conventional wheat sowing; T_2:Conventional rice transplanting after WRI (wheat residue incorporation)/conventional wheat sowing after RRI (rice residue incorporation); T_3 :Direct seeded rice/wheat in reduced tillage; T_4 :Direct seeded rice after WRI/wheat in reduced tillage after RRI; T_5 :Direct seeded rice/wheat in zero tillage; T_6 :Direct seeded rice in zero tillage/wheat in zero tillage; T_7 :Direct seeded rice in zero tillage after WRI/wheat in zero tillage; T_8 :Direct seeded rice+sesbania/wheat in zero tillage and T_9 : Conservational rice transplanting after sesbania green manuring/wheat in zero tillage.

The average yield of rice and wheat ranged from 34.24 to 40.74 and 26.16 to 33.27 q/ha, respectively (Table 10). The highest response was observed in conventional rice transplanting after sesbania green manuring/wheat in zero tillage followed by conventional rice transplanting after WRI (wheat residue incorporation)/conventional wheat sowing after RRI (rice residue incorporation) 40.74 q/ha in rice and conventional rice transplanting after WRI/conventional wheat sown after RRI 33.27 q/ha followed by direct seeded rice after WRI/wheat in reduced tillage after RRI in wheat crop. The lowest yield of rice 34.24 q/ha and wheat 26.16 q/ha was obtained from DSR in zero tillage/wheat in zero tillage (Fig. 1).

Fig. 1: Salt tolerant variety (KRL 213) and local variety (HD 1553) of wheat

Soil properties: The chemical properties of soil pH, EC, ESP and OC showed considerable improvement under the different resource conservation technology treatments. The minimum soil pH 8.51 was found in conventional rice transplanting after WRI (wheat residue incorporation) /conventional wheat sowing after RRI (Rice residue incorporation) followed by 8.53 in conventional rice transplanting after sesbania green manuring /wheat in zero tillage. The variation in EC from 2.13-2.51 dS/m was recorded in different treatments. The maximum reduction in ESP from 45.2 to 35.2 was found in conventional rice transplanting after sesbania green manuring /wheat in zero tillage. Organic carbon varied from 0.17 to 0.33% under different resource conservation technologies.

Table 10: Effect of conservation technologies on grain yield (q/ha) of rice and wheat

Treat.	Rice (2010)	Rice (2011)	Rice (2012)	Rice (2013)	Mean	Wheat (10-11)	Wheat (11-12)	Wheat (12-13)	Wheat (13-14)	Mean
T_1	34.20	35.90	37.85	39.22	36.79	27.10	28.78	30.28	31.85	29.50
T_2	34.30	38.05	41.12	43.56	39.25	29.35	32.29	34.79	36.65	33.27
T_3	32.25	34.30	35.85	37.12	34.88	26.00	27.10	28.62	29.27	27.74
T_4	32.38	36.20	39.18	41.56	37.33	28.10	30.63	33.43	35.56	31.93
T_5	32.25	34.10	35.75	37.10	34.80	25.70	26.52	27.98	29.00	27.30
T_6	31.10	33.57	35.38	36.90	34.24	24.60	25.10	26.80	28.12	26.16
T_7	31.28	34.50	37.27	39.85	35.73	26.50	29.39	30.69	32.25	29.70
T_8	34.00	36.60	38.70	39.72	37.25	26.80	28.00	29.87	31.32	29.99
T_9	36.35	39.50	42.29	44.82	40.74	27.40	29.69	32.55	34.72	31.09
CD (5%)	2.52	1.25	1.67	1.47	-	1.83	1.98	1.74	1.68	-

Integrated response of fly ash, gypsum and organic manures to sustain the production of rice and wheat in partially reclaimed sodic soil

The experiment was initiated during 2011 with rice (CSR 43) and wheat (KRL 213) with 12 treatments comprised of T_1 : Control; T_2 : Flyash @ 10 t/ha; T_3 :Flyash @ 20 t/ha; T_4 :100% Gypsum; T_5 :Flyash @ 10 t/ha+Gypsum @ 25% GR; T_6 :Flyash @ 10 t/ha+Gypsum @ 50% GR; T_7 :Flyash @ 10 t/ha+Gypsum @ 25% GR+ GM @ 10 t/ha; T_8 :Flyash @ 10 t/ha+Gypsum 50% GR+GM @ 10 t/ha; T_9 :Flyash @ 20 t/ha+Gypsum @ 25% GR; T_{10} :Flyash @ 20 t/ha+ Gypsum @ 50% GR; T_{11} :Flyash @ 20 t/ha+Gypsum @ 25% GR+GM @ 10 t/ha and T_{12} :Flyash @ 20 t/ha+Gypsum @ 50% GR+GM @ 10 t/ha. The initial soil pH was 9.5, EC 1.98 dS/m, ESP, 54.2, CEC 13.4 cmol (p+)/kg, OC 0.12% and soil texture was clay loam with 31.5% water holding capacity.

Physico-chemical characteristics of fly ash: pH 6.8, EC 0.65 dS/m, OC 1.7 g/kg, av. N 24.2, P 29.6, K 320.5 mg/kg, Zn 0.28, Fe 1.62, Cu 0.12, Mn 0.75 mg/kg, Ca 0.85, Mg 0.35, S 0.82% .

The average grain yield of rice and wheat varied from 17.73-40.24 q/ha and 13.96-31.85 q/ha, respectively (Table 11). The highest grain yield of paddy (40.24 q/ha) and wheat (31.85 q/ha) was recorded with treatment T_{12} followed by T_8, T_{11} and T_4. The responses of fly ash in conjunction with different doses of gypsum and green manure showed comparatively higher performance as compared to alone.

Soil properties: Soil chemical properties pH, EC, ESP and OC showed considerable improvement under various levels of fly ash in conjunction with doses of gypsum and green manure (Table 12). The maximum reduction in soil pH was observed with application of flyash along with green manure and gypsum as compared to flyash alone. The minimum pH 8.70 was found with flyash @ 20 t/ha+ Gyp. 50% GR+GM @ 10 t/ha followed by 100% Gypsum alone (8.81). The EC varied from 1.72 to 1.99 dS/m under different treatments. The reduction in ESP was found in 100% Gypsum alone followed by Flyash @ 20 t/ha+Gypsum @ 50% GR+ GM @ 10 t/ha. Organic carbon varied from 0.16 to 0.31%, maximum being with Flyash @ 20 t/ha+Gypsum 50% GR+GM @ 10 t/ha.

Table 11: Effect of different treatments on grain yield of rice and wheat

Treatments	Grain yield of rice (q/ha)				Grain yield of wheat (q/ha)			
	2011	2012	2013	Mean	2011-12	2012-13	2013-14	Mean
T_1	16.75	17.85	18.58	17.73	13.48	14.10	14.30	13.96
T_2	19.50	21.02	23.15	21.22	15.25	16.57	17.90	16.57
T_3	21.80	24.34	26.91	24.35	17.20	19.28	20.25	18.91
T_4	31.00	33.80	36.37	33.72	27.92	30.47	31.32	29.57
T_5	22.25	24.86	27.44	24.85	17.37	19.50	21.05	19.30
T_6	25.50	28.12	31.09	28.24	19.85	22.08	25.55	22.39
T_7	29.15	31.85	34.15	31.72	22.93	25.13	29.30	25.79
T_8	34.25	36.95	39.36	36.85	27.64	28.93	32.60	29.72
T_9	24.10	26.72	29.68	26.83	19.10	21.05	23.75	21.30
T_{10}	28.00	30.45	33.27	30.57	21.92	23.88	28.95	24.92
T_{11}	32.00	40.35	42.88	40.24	25.15	27.31	32.45	31.85
T_{12}	37.50	40.35	42.88	40.24	29.42	31.70	34.45	31.85
CD (5%)	1.12	1.27	1.35	-	1.65	1.72	1.78	-

Table 12: Effect of treatments on physico-chemical properties of soil after three years

Treatments	pH	EC (dS/m)	ESP	OC (%)
T_1	9.33	1.99	53.8	0.16
T_2	9.24	1.97	51.9	0.18
T_3	9.16	1.96	50.1	0.20
T_4	8.81	1.82	39.8	0.26
T_5	9.13	1.84	48.5	0.21
T_6	9.02	1.93	45.6	0.22
T_7	8.91	1.82	47.3	0.27
T_8	8.84	1.85	42.6	0.28
T_9	9.03	1.90	47.2	0.23
T_{10}	8.92	1.72	43.4	0.25
T_{11}	8.93	1.84	45.8	0.29
T_{12}	8.70	1.93	40.2	0.31

Effect of RSC water, using different ameliorants on crop production and soil health of partially reclaimed sodic soil

This study was initiated during *kharif* 2011 and paddy variety (CSR 36) and wheat variety (KRL 210) were cultivated at farmer's fields with 5 treatments comprised of RSC water (control); pressmud @10 t/ha; gypsum @ 50%GR; pyrites @ 50%GR and phosphogypsum @ 50%GR and replicated thrice in RBD. The initial soil status of selected fields is given in Table 13.

Table 13: Initial soil status of selected farmer's field

Name of farmer	pH	EC	ESP	OC (%)	Texture
Narendra	9.7	2.10	61.00	0.15	Clay loam
Ramphal	9.7	2.15	60.15	0.20	Clay loam
Ramesh Yadav	8.1	3.25	48.80	0.45	Sandy clay loam
Bachhu Lal	8.4	3.35	49.10	0.43	Sandy clay loam

The experiments were conducted at farmer's field of village Ajura (Umarda, Kannauj), Gosai Khera (Ashoha, Unnao). It is clear from the data depicted in Table 14, 15 that the highest grain yield of rice and wheat cultivar 42.4 and 38.8 q/ha, respectively were obtained from phosphogypsum treatment followed by gypsum, pyrites and press mud. Although, in general each ameliorants used in the experiments showed beneficial response on the grain yield of rice and wheat crops but response of phosphogypsum was more pronounced in both crops. The percentage response of various ameliorants on grain yield of rice CSR 36 and wheat KRL 210 cultivars could be arranged as: phosphogypsum (93.96)> gypsum (81.86)> pyrite (62.70)> Press mud (44.58) and phosphogypsum (114.72)> gypsum (98.73)> pyrite (78.20)> Press mud (52.08) respectively, over RSC water treated plots (Table 16).

Table 14: The response of various ameliorants on rice under RSC water irrigated conditions

Treatments	Ggrain yield of rice (q/ha) Av. of three years				
	Narendra	Ramphal	Ramesh Yadav	Bachhu Lal	Mean
RSC water	17.52	20.24	24.57	25.07	21.85
Press mud	26.43	32.52	33.27	34.15	31.59
Pyrites	29.38	35.46	38.07	39.28	35.55
Gypsum	33.94	39.96	41.35	43.36	39.65
Phosphogypsum	36.69	43.33	44.98	44.52	42.38

Table 15: The response of various ameliorants on wheat under RSC water irrigated condition

Treatments	Ggrain yield of wheat (q/ha) Av. of three years				
	Narendra	Ramphal	Ramesh Yadav	Bachhu Lal	Mean
RSC water	15.91	13.23	21.06	22.06	18.07
Press mud	23.36	26.87	28.86	30.85	27.48
Pyrites	26.67	32.40	34.22	35.52	32.20
Gypsum	30.73	36.37	37.58	38.97	35.91
Phosphogypsum	33.86	38.54	41.18	41.62	38.80

Table 16: Average yield and response of crops under different treatments at farmer's field

Treatments	Average yield Rice (q/ha)	Response of treatment (%)	Average yield Wheat (q/ha)	Response of treatment (%)
RSC Water	21.85	--	18.07	--
Press mud	31.59	44.58	27.48	52.08
Pyrites	35.55	62.70	32.20	78.20
Gypsum	39.65	81.46	35.91	98.73
Phosphogypsum	42.38	93.96	38.80	114.72

The quality parameters of ground water used for irrigation by farmer's are presented in Table 17.

Table 17: Range and average of ground water qualities at farmer's field

Parameters	Range	Average
pH (1:2.5)	7.8-10.6	8.6
EC (dS/m)	0.8-9.5	1.98
Na (meq/l)	1.50-58.5	15.70
Ca (meq/l)	0.5-20.20	2.95
Mg (meq/l)	0.30-22.8	4.65
Cl (meq/l)	1.50-79.3	12.70
CO_3 (meq/l)	0.0-4.9	0.68
HCO_3 (meq/l)	0.7-15.1	5.40
SAR (mmol/l)	0.65-18.20	9.50
RSC (meq/l)	1.5-12.70	4.65

Demonstration of salt tolerant varieties of mustard at farmer's fields

The demonstration results of mustard at farmer's field revealed that the grain yield of CS 52, CS 54 and CS 56 varied from 8.44 to 8.92, 10.85 to 11.17 and 12.10 to12.35 q/ha, in 2012-13 (Table 18, Fig. 2).

Table 18: Mustard varieties at farmer's fields

Name of farmer	Village	District	Variety	Area (Acre)	Yield (q/ha)
Lakhan Singh	Bikaru	Kanpur	CS 52	0.50	08.92
Suresh	Vinovanagar	Kanpur Dehat	CS 52	0.40	08.44
Chhunna Lal	Sujjanivada	Kanpur	CS 54	0.60	10.85
Suresh	Vinovanagar	Kanpur Dehat	CS 54	0.40	11.17
Indrajeet	Vinovanagar	Kanpur Dehat	CS 56	0.40	12.10
Suresh	Vinovanagar	Kanpur Dehat	CS 56	0.60	12.35

The results of various demonstration of mustard during 2013-14 revealed that yield of CS 52, CS 54 and CS 56 varied from 11.75 to 12.62, 13.35 to 14.42 and 14.82 to15.53 q/ha, respectively (Table 19).

Table 19: Mustard varieties at farmer's fields in Kanpur Dehat (Area: 0.50 acre)

Name of farmer	Village	Variety	Yield (q/ha)
Vijay Bahadur	Vinovanagar	CS-52	12.62
Narendra Kumar	Vinovanagar	CS-52	11.75
Narendra Kumar	Vinovanagar	CS-54	14.42
Indrajeet	Kakardahi	CS-54	13.35
Indrajeet	Kakardahi	CS-56	15.53
Mahesh Chandra	Kakardahi	CS-56	14.82

Fig. 2: Mustard varieties (CS 52, CS 54 and CS 56) at farmer's fields

Demonstration of salt tolerant varieties of wheat at farmer's fields

The results of various demonstration of wheat crop at farmer's field revealed that grain yield of wheat variety KRL 213 and KRL 210 varied from 28.60 to 30.20 q/ha and 27.54 to 29.12 q/ha (Table 20). These salt tolerant varieties showed their superiority by 26.66 and 21.78% over LOK 1 and 16.36 and 11.87% over PBW 343 sown by farmers.

Table 20: Wheat varieties at farmer's fields

Name	Village	District	Variety	Area (acre)	Yield (q/ha)	Check	Yield (q/ha)
Ramesh Singh	Sujja nevada	Kanpur	KRL 213	0.40	28.60	LOK-1	22.70
Bheje Lal	Sujja nevada	Kanpur	KRL 210	0.40	29.12	LOK-1	23.15
Lakhan Singh	Sujja nevada	Kanpur	KRL 213	0.60	30.20	LOK-1	23.56
GuddanKanaujia	Bikrupur	Kanpur	KRL 210	0.50	27.54	PBW-343	24.24
Pavan Dixit	Bikrupur	Kanpur	KRL 210	0.50	28.15	PBW-343	25.54
Vijay Bahadur	Vinovanagar	Kanpur Dehat	KRL 213	0.80	29.12	PBW-343	26.20
Indrajeet	Vinovanagar	Kanpur Dehat	KRL 210	0.30	27.90	PBW-343	24.76

Performance of mustard varieties under alkali conditions

The performance of 18 germplasm with 2 checks during 2012-13 and 10 germplasm with 2 checks of Indian mustard during 2013-14 were evaluated at sodicity level of 50.0 and 52.2 ESP, respectively. The seed yield of germplasms varied from 320.6 g/plot (CSCN10-09) to 552.1 g/plot (CSCN10-14) and 0997.64 g/plot (L9) to 1269.42 g/plot (check-1) during 2012-13 and 2013-14 respectively (Table 21).

Table 21: Screening of salt tolerant Indian mustard germplasm

2012-13		2013-14	
Germplasm	Seed yield (g/plot)	Germplasm	Seed yield (g/plot)
CSCN10-01	530.6	L1	1169.15
CSCN10-02	417.1	L2	1120.25
CSCN10-03	446.3	L3	1011.10
CSCN10-04	447.8	L4	1162.12
CSCN10-05	432.7	Check-1	1269.42
CSCN10-06	468.6	L5	1045.40
CSCN10-07	366.1	L6	1245.64

CSCN10-08	388.4	L7	1177.42
CSCN10-09	320.6	L8	1252.67
CSCN10-10	569.1	Check-2	1127.28
CSCN10-11	453.3	L9	0997.64
CSCN10-12	458.3	L10	1049.35
CSCN10-13	479.3		
CSCN10-14	552.1		
CSCN10-15	471.1		
CSCN10-16	496.3		
CSCN10-17	540.3		
CSCN10-18	381.3		
Check-1	502.8		
Check-2	490.2		

TIRUCHIRAPPALLI: RESEARCH ACCOMPLISHMENTS

Survey and characterization of ground water for irrigation

Ground water quality surveys of Delta districts Thanjavur and Thiruvarur were completed. In all 412 water samples from Thanjavur district and 161 water samples from Thiruvarur district were collected from all the blocks. The water samples were analyzed for pH, EC, cations, anions and SAR and RSC were calculated. Classification of water quality was done on the basis of EC, SAR and RSC values as per AICRP guidelines.

Thanjavur district: Thanjavur district has 14 blocks namely Ammapettai, Budalur, Kumpakonam, Mathukur, Orathanadu, Papanasam, Peravurani, Pattukottai, Sethubavasathiram, Thanjavur, Thiruppanadal, Thiruvaiyaru, Thiruvidaimarudur and Thiruvonam. Out of the total samples collected in Thanjavur district, 84.2% were of good quality, 2.19% marginally saline, 9.3% marginally alkali, 3.6% alkali, 0.46% saline and 0.25% high SAR saline. 100% good quality water was found in Thiruppanadal and Thiruvonam blocks (Table 1, 2, 3, Fig.1). More than 90 per cent water samples from Mathukur, Orathanadu, Papanasam, Peravurani, and Thiruvidaimarudur blocks came under good quality category. Marginally saline water was found in Ammapettai (10%), Pattukottai (6.66%), Sethubavasathiram (15.4%) and Thanjavur (4.54%) blocks. Saline water was found only in two blocks namely, Ammapettai (93.3%) and Budalur (5%). High SAR saline water was present in Budalur (5%) only. Saline water was found in some blocks (3.7-28.0%) except Ammapettai, Orathanadu, Sethubasathiram, Thirupananthal, Thiruvidaimarudur and Thiruvonam blocks. Alkali water was found in Ammapettai (3.33%), Budalur (3%), Kumpakonam (5.71%), Orathanadu (3%), Pattukottai (6.66%), Sethubavasathiram (2.56%), Thiruvaiyaru (12%) and Thiruvidaimarudur (8.51%) blocks (Fig. 2).

Table 1: Water quality distribution (per cent) in Thanjavur district

Blocks	No. of samples	Good	Marginally saline	Saline	High SAR saline	Marginally alkali	Alkali	Highly alkali
Ammapettai	30	83.3	10	3.3	-	-	3.3	-
Budalur	20	60.0	-	-	5	20	15	-
Kumpakonam	35	77.1	-	-	-	17.14	5.7	-
Mathukur	24	91.6	-	-	-	8.33	-	-
Orathanadu	33	97.0	-	-	-	-	3.0	-
Papanasam	27	96.3	-	-	-	3.70	-	-
Peravurani	32	93.7	-	-	-	6.3	-	--
Pattukottai	15	73.3	6.7	-	-	13.3	6.7	-
Sethubavasathiram	39	82.1	15.4	-	-		2.6	-
Thanjavur	22	81.8	4.5	-	-	13.63	-	-
Thiruppanadal	36	100		-	-	-	-	-
Thiruvaiyaru	25	56.0	4	-	-	28	12	-
Thiruvidaimarudur	47	91.5	-	-	-	-	8.5	-
Thiruvonam	27	100	-	-	-	-	-	-
Total /average	412	84.2	2.2	0.45	0.25	9.3	3.6	-

Table 2: Quality of ground water in different blocks of Thanjavur district

Name of block	pH		EC_{iw} (dS/m)		RSC (meq/l)	SAR	
	Range	Mean	Range	Mean	Range	Range	Mean
Ammapettai	8.04-8.74	8.34	0.27-4.01	0.81	Nil-4.0	1.93-8.33	3.35
Budalur	7.79-8.74	8.34	0.54-8.31	1.57	Nil-6.5	2.14-13.1	5.20
Kumpakonam	7.57-8.79	8.26	0.24-3.3	0.86	Nil-7.0	1.10-6.07	3.19
Mathukur	7.83-12.7	8.41	0.42-2.44	0.89	Nil-3.4	0.73-6.38	3.58
Orathanadu	7.96-8.81	8.24	0.32-1.3	0.65	Nil-4.1	1.11-5.09	2.95
Papanasam	7.96-8.56	8.28	0.41-0.96	0.60	Nil-3.1	1.94-5.09	3.04
Peravurani	7.15-8.16	7.91	0.69-1.56	1.03	Nil-3.4	0.58-5.32	2.43
Pattukottai	8.01-8.82	8.31	0.68-2.45	1.42	Nil-7.2	2.45-7.02	4.65
Sethubavasathiram	7.15-8.49	8.10	0.60-2.94	1.26	Nil-2.6	1.01-6.73	3.36
Thanjavur	7.42-8.42	8.16	0.2-1.84	0.84	Nil-4.5	1.18-6.82	3.13
Thiruppanadal	7.43-8.21	7.93	0.34-1.32	0.65	Nil-0.6	0.08-4.56	1.62
Thiruvaiyaru	7.69-9.46	8.28	0.52-3.51	1.00	Nil-4.5	0.97-6.11	3.81
Thiruvidaimarudur	7.05-8.82	7.87	0.4-2.45	0.80	Nil-7.4	0.59-6.63	2.06
Thiruvonam	7.65-8.35	8.09	0.45-1.56	0.80	Nil-2.4	0.37-4.98	2.82

Table 3: Cationic and anionic composition of ground water in different blocks of Thanjavur district

Name of block	Cations (Average value)				Anions (Average value)			
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
Ammapettai	2.43	1.46	4.69	0.04	1.16	4.05	3.36	0.29
Budalur	3.23	2.65	9.33	0.07	2.02	5.13	7.20	0.92
Kumpakonam	2.83	1.90	4.51	0.11	1.47	3.91	2.73	0.35
Mathukur	2.73	1.38	4.90	0.03	1.30	3.48	3.75	0.44
Orathanadu	2.22	0.98	3.71	0.03	0.77	2.72	2.82	0.36
Papanasam	1.96	1.16	3.71	0.03	0.94	2.57	3.08	0.33
Peravurani	4.46	2.60	4.19	0.03	1.39	4.35	4.28	0.43
Pattukottai	3.87	2.74	8.43	0.03	1.55	6.14	4.78	0.33
Sethubavasathiram	4.47	2.73	5.80	0.03	1.43	4.79	5.81	0.54
Thanjavur	2.48	1.54	4.41	0.02	1.17	3.66	3.00	0.33
Thiruppanadal	2.76	1.90	2.39	0.04	0.69	2.03	3.02	0.46
Thiruvaiyaru	2.74	1.85	5.45	0.02	1.35	4.48	4.23	0.56
Thiruvidaimarudur	3.23	1.76	2.92	0.02	1.17	3.35	3.32	0.51
Thiruvonam	3.00	1.54	3.76	0.03	0.97	3.24	3.73	0.34

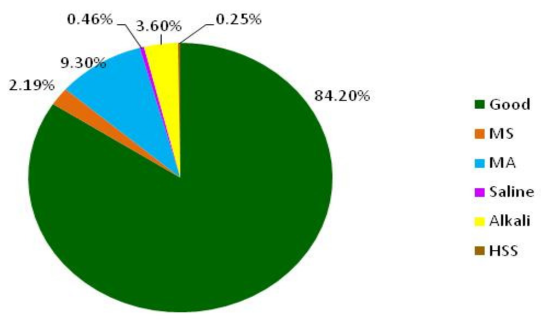


Fig. 1: Per cent distribution of ground water quality of Thanjavur district

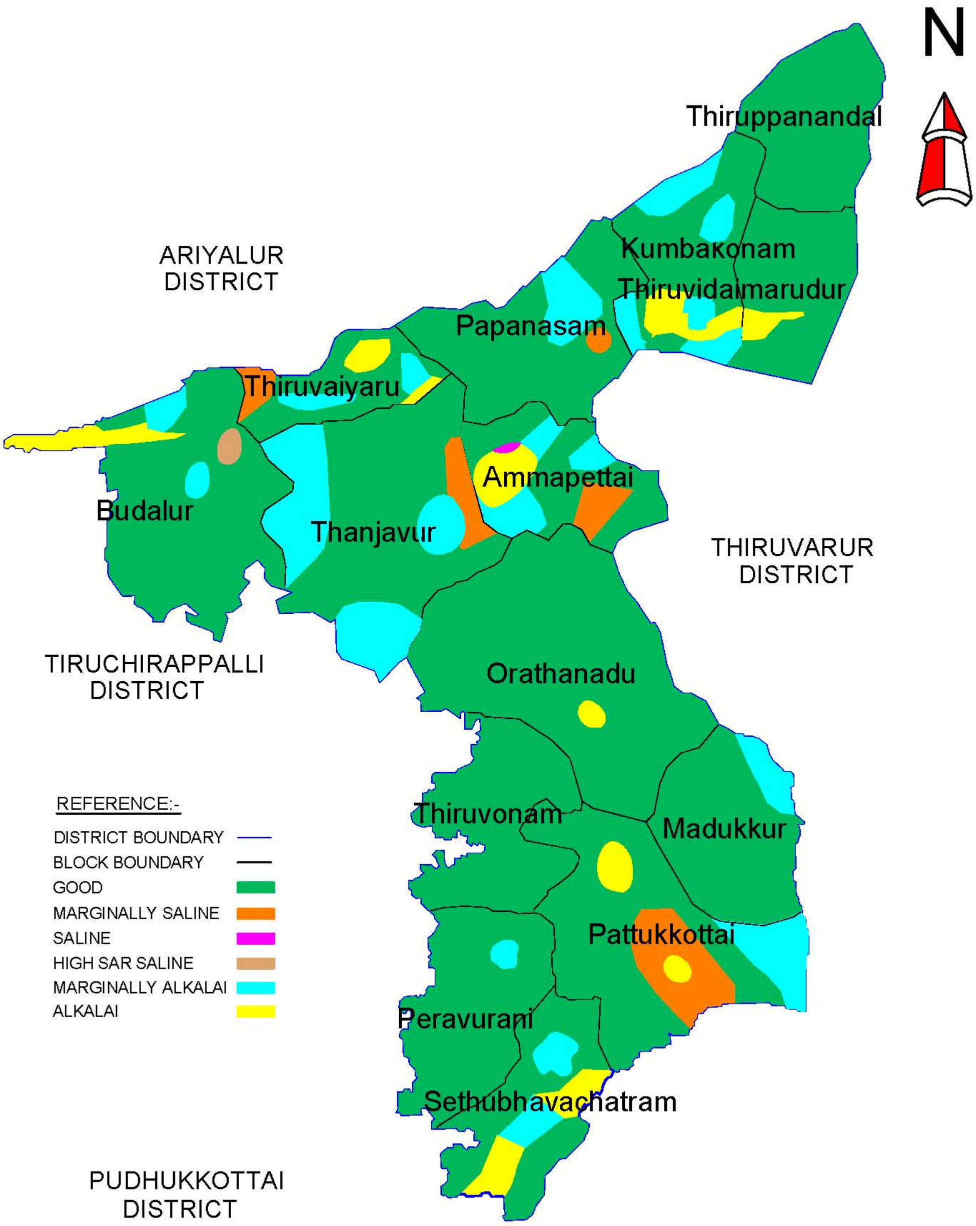


Fig. 2: Ground water quality map of Thanjavur district of Tamil Nadu

Thiruvarur district: Thiruvarur District has 10 blocks namely Koradacheri, Kottur, Kudavasal, Mannarkudi, Muthupet, Nidamangalam, Nannilam, Thiruthuraipundi, Thiruvarur and Valangaiman. Out of the total samples collected in Thiruvarur district, 83.2% are coming under good quality, 9.93% marginally saline, 3.72% marginally alkali, 1.24% alkali, 0.62% high SAR saline and 1.24% highly alkali. Among the 10 blocks, the distribution of good quality samples were the highest in Thiruthuraipundi (100%) and the lowest in Nannilam (53.3%) block (Table 4, 5, 6, Fig. 3). The occurrence of marginally saline water (5.6 to 19.0%) was prevalent in all the blocks, Marginally alkali water is prevalent in Kudavasal (10%) Nannilam (26.7%) and Valangaiman (4.8%). Alkali water was prevalent in Nannilam (13.3%) and highly alkali was found in Koradacheri (5.5%) and Kudavasal (10%) block. High SAR saline water was found in Valangaiman block only (4.8%) (Fig. 4).

Table 4: Water quality distribution (per cent) in Thiruvarur district

Name of block	No. of samples	Good	Marginally saline	Saline	High SAR saline	Marginally alkali	Alkali	Highly alkali
Koratacheri	18	77.8	16.7	-	-	-	-	5.5
Kottur	22	90.9	9.1	-	-	-	-	-
Kudavasal	10	80	-	-	-	10.0	-	10.0
Mannarkudi	16	81.2	18.8	-	-	-	-	-
Muttupet	18	94.4	5.6	-	-	-	-	-
Nannilam	15	53.3	6.7	-	-	26.7	13.3	-
Nidamangalam	11	90.9	9.1	-	-	-	-	-
Thiruthuraipundi	21	100	-	-	-	-	-	-
Thiruvarur	9	88.9	11.1	-	-	-	-	-
Valangaiman	21	71.4	19.0	-	4.8	4.8	-	-
Total	161	83.2	9.93	-	0.62	3.72	1.24	1.24

Table 5: Quality of ground waters in different blocks of Thiruvarur district

Name of block	pH		EC_{iw} (dS/m)		RSC (meq/l)	SAR	
	Range	Mean	Range	Mean	Range	Range	Mean
Koradacheri	6.65-9.80	7.03	0.77-2.85	1.52	Nil-7.3	0.45-8.59	0.53
Kottur	6.66-8.01	7.30	0.38-2.88	1.08	Nil-0.3	0.13-3.89	1.54
Kodavasal	7.30-9.05	8.01	0.40-1.10	1.03	Nil-8.2	0.77-10.40	3.77
Mannarkudi	6.70-7.71	7.22	0.46-2.67	1.14	Nil-0.60	0.65-4.78	2.88
Muttupt	6.79-8.10	7.45	0.56-1.64	1.18	Nil-0.9	0.78-5.74	1.45
Nannilam	6.99-8.70	7.05	0.53-2.59	0.93	Nil-4.2	3.31-5.60	2.00
Nidamangalam	7.17-7.50	8.01	0.39-2.32	1.10	Nil	1.19-4.64	4.24
Thiruthuraipundi	7.17-8.20	7.68	0.24-1.78	1.13	Nil-2.1	0.68-6.94	1.48
Thiruvarur	6.91-8.10	7.59	1.33-1.97	1.91	Nil-0.8	0.96-5.24	3.06
Valangaiman	6.68-8.40	7.21	0.33-8.03	1.67	Nil-3.7	0.40-13.35	12.7

Table 6: Cationic and anionic composition of ground waters in blocks of Thiruvarur district

Name of block	Cations (Average value)				Anions (Average value)			
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
Koradacheri	6.26	3.62	4.27	0.02	1.26	5.33	5.11	0.53
Kottur	5.76	2.91	3.09	0.03	1.70	2.06	84.3	0.35
Kodavasal	3.67	2.02	4.53	0.03	1.25	3.56	4.50	0.42
Mannarkudi	3.93	2.18	4.9	0.03	1.66	3.15	5.78	0.42
Muttupt	6.37	3.28	2.97	0.04	2.55	3.07	6.02	0.78
Nannilam	3.64	1.72	6.17	0.03	1.26	3.34	5.88	0.56
Nidamangalam	4.17	1.49	3.30	0.01	1.52	1.86	5.50	0.53
Thiruthuraipundi	5.87	3.24	2.75	0.03	2.76	3.40	4.26	0.96
Thiruvarur	7.13	5.09	7.84	0.03	3.03	7.26	9.00	0.41
Valangaiman	6.10	3.61	6.60	0.07	1.39	6.20	8.51	0.77

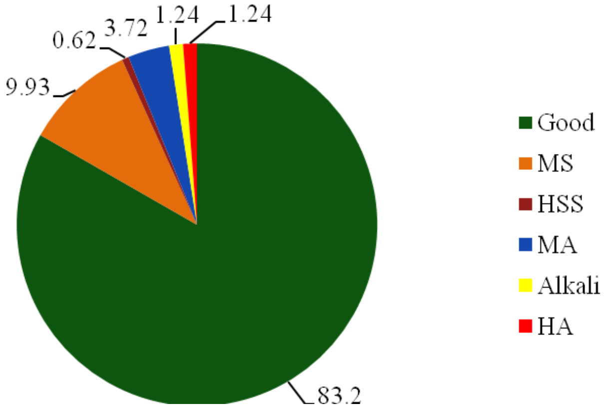


Fig. 3: Percentage distribution of ground water quality in Thiruvarur district

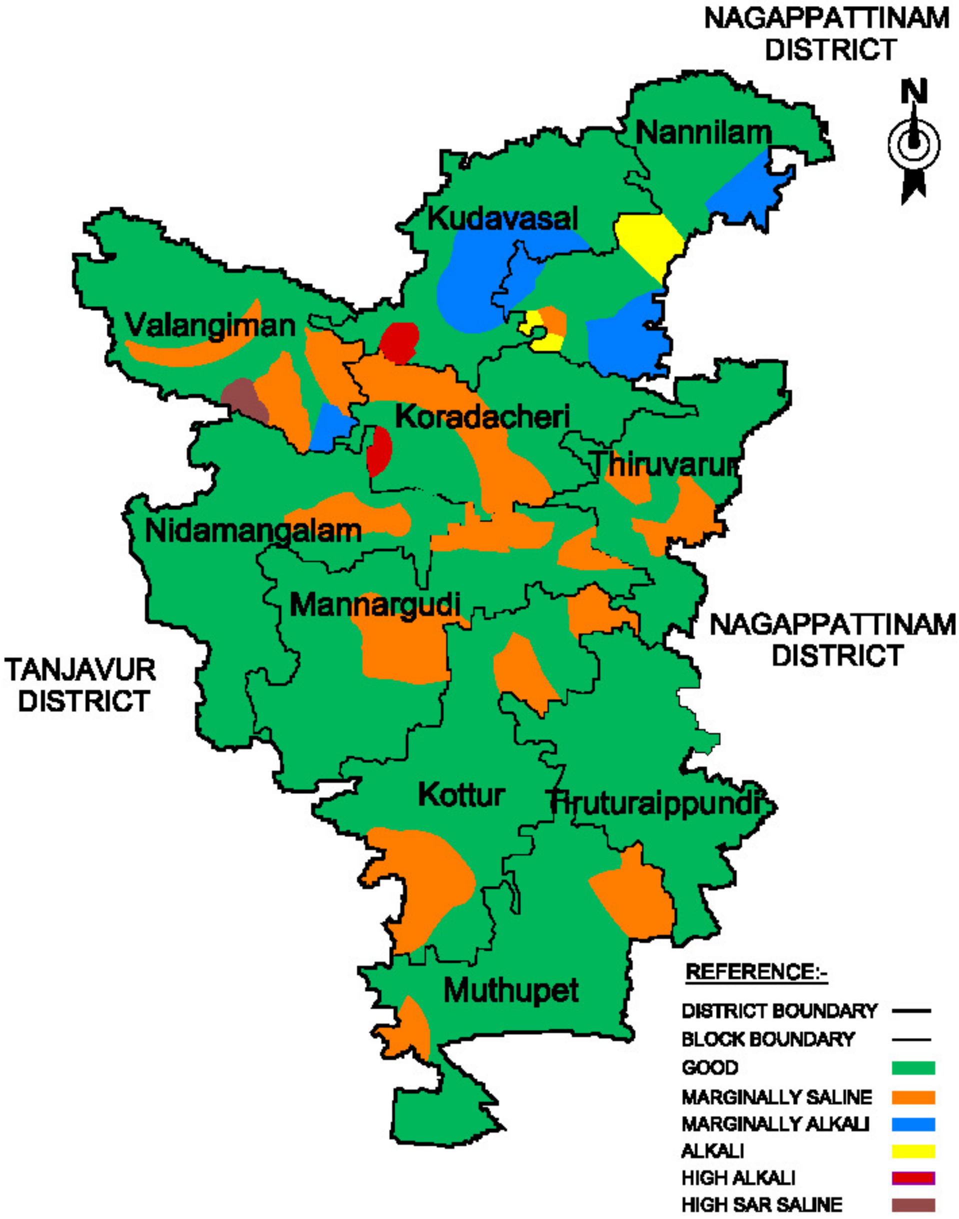


Fig. 4: Ground water quality map of Thiruvarur distrist of Tamil Nadu

Conjunctive use of canal and alkali water in rice based cropping system

The field experiment was initiated during 2008 in sodic soil of pH 8.7, EC_2 0.2 dS/m and ESP 25. Three irrigations (M1: Irrigating both rice and vegetables with alkali water; M2: Irrigating rice with canal water and vegetables with alkali water; M3: Irrigating rice with 1CW:1AW (cyclic) and vegetables with alkali water) in main plots and 4 planting methods (S1: Conventional planting; S2: Line planting; S3: Square planting (SRI); S4: Machine planting) in sub plots. After harvest of rice four vegetables (S1: Okra; S2: brinjal in 2013 and cluster bean in 2014; S3: cluster bean in 2013 and lal-lab in 2014 and S4: vegetable cowpea) was grown in sub plots and replicated thrice in strip plot design.

The experiment was continued in Oct. 2012 by raising rice cultivar TRY-1, after harvest of rice, vegetable crops were raised in 2013. Paddy (TRY 1) was transplanted during Oct. 2013 and harvested during January 2013. During summer, vegetable crops were sown in 2014.

Rice grain and straw yield: Significant yield differences were observed for irrigation treatments and methods of planting during both years (Tables 7). Canal water irrigation gave high yields (6.23 and 6.30 t/ha) during 2012-13 and 2013-14 with straw yield of 7.49 and 7.72 t/ha. Lowest grain and straw yields were recorded in alkali water irrigation (4.45 and 4.31 t/ha grain and 5.26 and 5.34 t/ha straw yield). Among methods of planting, square planting produced high grain yield (5.85 and 5.90 t/ha) during 2012-13 and 2013-14 followed by line planting and machine planting. Conventional planting had poor grain and straw yield as compared to other methods of planting. Interaction effect of irrigation and planting methods was significant.

Table 7: Effect of conjunctive mode of irrigation and method of planting on yield of rice

Irrigation treatments	Methods of planting									
	S1	S2	S3	S4	Mean	S1	S2	S3	S4	Mean
	Grain yield (t/ha) 2012-13					Straw yield (t/ha) 2012-13				
M1: Alkali water	4.16	4.31	4.65	4.68	4.45	4.82	5.17	5.49	5.56	5.26
M2: Canal water	5.62	6.10	6.92	6.26	6.23	6.68	7.32	8.44	7.52	7.49
M3: 1CW:1AW	4.85	5.46	5.98	5.61	5.48	5.82	6.44	7.11	6.61	6.50
Mean	4.88	5.29	5.85	5.52	-	5.77	6.31	7.01	6.56	-
	M	S	M at S	S at M	-	M	S	M at S	S at M	-
CD (5%)	0.23	0.16	0.34	0.28	-	0.25	0.20	0.40	0.37	-
	Grain yield (t/ha) 2012-13					Straw yield (t/ha) 2013-14				
M1: Alkali water	4.40	4.68	4.75	4.68	4.31	4.82	5.47	5.69	5.36	5.34
M2: Canal water	5.92	6.20	6.98	6.10	6.30	6.88	7.72	8.84	7.42	7.72
M3: 1CW:1AW	4.95	5.61	5.98	5.61	5.50	5.82	6.84	7.71	6.71	6.77
Mean	5.09	5.50	5.90	5.29		5.84	6.68	7.41	6.50	
	M	S	M at S	S at M	-	M	S	M at S	S at M	-
CD (5%)	0.31	0.21	0.46	0.37		0.40	0.32	0.58	0.54	-

Yield of vegetables and income (2012-13): The performance of vegetables was superior in the plots receiving canal water irrigation followed by cyclic irrigation with canal and alkali water (Table 8). Among the vegetable grown, brinjal registered the higher yield of 16.8 t/ha by canal water irrigation with maximum income of Rs. 3.0 lakhs/ha followed by okra hybrid, cluster bean and vegetable cow pea. Performance of vegetables under cyclic irrigation with 1CW:1AW ratio showed that brinjal gave highest income of Rs. 2.59 lakhs/ha followed by okra (Rs. 0.88 lakhs/ha) and vegetable cowpea (0.457 lakhs/ha). The lowest income of 0.41 lakhs/ha was recorded for cluster bean.

Table 8: Effect of irrigation and methods of planting on yield and income of vegetables

Treatments	2012-13			2013-14		
	Vegetables	Yield (t/ha)	Receipt (Rs/ha)	Vegetables	Yield (t/ha)	Receipt (Rs/ha)
M_1S_1	AW + Okra	4.21	63150	AW + Okra	3.67	73,400
M_2S_1	CW + Okra	7.26	108900	CW + Okra	6.83	136600
M_3S_1	CW & AW + Okra	5.86	87900	CW & AW + Okra	4.96	99200
M_1S_2	AW + Brinjal	10.6	190800	AW + CB	4.23	50760
M_2S_2	CW + Brinjal	16.8	302400	CW + CB	5.94	71280
M_3S_2	CW & AW+Brinjal	14.4	259200	CW & AW + CB	4.86	58320
M_1S_3	AW + CB	3.85	30800	AW + Lab lab	3.27	55590
M_2S_3	CW + CB	6.61	52880	CW + Lab lab	4.69	79730
M_3S_3	CW & AW + CB	5.18	41440	CW & AW+Lablab	4.10	69700
M_1S_4	AW + Veg. cowpea	3.01	39130	AW + Veg. cowpea	2.64	66000
M_2S_4	CW + Veg. cowpea	3.86	50180	CW + Veg. cowpea	3.79	94750
M_3S_4	CW & AW + Veg. owpea	3.52	45760	CW & AW + Veg. cowpea	3.12	78000
CD (%)	Okra	0.26	-	Okra	0.19	-
	Brinjal	1.36	-	Cluster bean	1.23	-
	Cluster bean	0.18	-	Lab lab	0.26	-
	Veg. cowpea	0.13	Veg. cowpea	0.22		

Yield of vegetables and income (2013-14): All the vegetables performed well in M_2 treatment (Irrigating rice with canal and vegetable crops with alkali water) followed by irrigating rice with 1CW:1AW ratio conjunctive mode subsequently irrigating vegetable with alkali water (M_3). Among vegetables, okra registered the highest yield of 6.83 t/ha in canal water irrigation (Table 8, Fig. 5) and also the highest income of Rs. 1.866 lakh/ha. Although the yield of cluster bean was superior over vegetable cow pea the income from the vegetable cowpea excelled due to the highest market price.

Post harvest soil properties: The post harvest soil samples were analysed for pH, EC and ESP (Table 9). The results indicated that the pH varied from 8.49 in canal to 9.16 in alkali water irrigation. EC ranged from 0.16 to 0.26 dS/m. Canal water irrigation recorded the lowest EC of 0.17 dS/m followed by cyclic mode of irrigation (EC 0.21 dS/m). Highest EC found in alkali water irrigated plots (0.25 dS/m). Irrigation with alkali water increased the ESP to 33.6 and lowest ESP 19.6 was recorded in canal irrigation. Method of rice planting had no significant effect on soil properties. The results followed the same trend in 2013-14.

Fig. 5: Vegetable crops under canal and alkali water irrigation

Table 9: Effect of conjunctive mode and methods of planting on soil properties at crop harvest

Irrig.	Methods of planting											
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
	2012-13											
	pH				EC (dS/m)				ESP			
M1	9.0	9.16	9.15	9.06	0.25	0.23	0.26	0.26	33.6	33.8	32.8	34.0
M2	8.51	8.52	8.50	8.49	0.16	0.18	0.16	0.17	19.5	18.8	19.9	20.2
M3	8.71	8.65	8.72	8.70	0.20	0.21	0.20	0.21	26.2	25.8	27.6	26.7
Mean	8.74	8.78	8.79	8.75	0.20	0.21	0.21	0.21	26.4	26.1	26.8	27.0
CD (5%)	M: 0.28				M: 0.01				M: 1.2			
	2013-14											
	pH				EC (dS/m)				ESP			
M1	8.93	9.03	9.09	9.10	0.24	0.26	0.23	0.27	31.0	32.3	32.1	33.5
M2	8.48	8.51	8.50	8.49	0.17	0.18	0.17	0.16	18.9	18.3	18.6	17.3
M3	8.63	8.65	8.72	8.70	0.18	0.19	0.19	0.20	25.2	26.0	26.8	25.1
Mean	8.68	8.73	8.77	8.76	0.20	0.21	0.20	0.21	25.03	25.53	25.83	25.30
CD (5%)	M: 0.34				M: 0.02				M: 2.1			

Identifying suitable pressurized irrigation methods for vegetable crops under sodic soils

Field experiments were conducted during 2012-13 and 2013-14. The initial pH of the soil was 9.02 and 9.1 with EC 0.90 and 0.94 dS/m respectively. The pH of irrigation water was 8.5 and 8.7 with EC 2.02 and 2.0 dS/m, respectively. The initial NPK content of soil was 282, 21, and 285 kg/ha, during 2012-13 and 270, 20 and 290 kg/ha, respectively during 2013-14.

Among the irrigation methods, drip irrigation was found superior as compared to sprinkler irrigation and farmers practice of flood irrigation in increasing the yield of vegetable crops cultivated under sodic soil environment (Table 10).

Table 10: Effect of irrigation methods on yield (q/ha) of vegetables

Irrigation methods	2012-13				2013-14			
	Okra	Cluster bean	Lab lab	Veg. cowpea	Okra	Cluster bean	Lab lab	Veg. cowpea
Drip irrigation	52.16	38.62	11.06	13.60	48.16	41.06	26.34	26.11
Sprinkler irrigation	46.55	31.25	9.10	24.93	42.39	36.40	20.16	23.14
Farmer practice	28.64	21.60	7.96	16.93	30.43	28.14	15.64	19.40
Mean	42.45	30.49	9.37	23.57	40.33	35.20	20.71	22.88
	I	C	I at C	C at I	I	C	I at C	C at I
CD (5%)	8.4	2.35	3.60	4.08	1.17	3.17	5.00	5.72

Okra yield was highest among the vegetables and recorded an yield of 52.16 q/ha under drip irrigation compared to 46.55 q/ha under sprinkler irrigation and followed by 28.64 q/ha in control (farmers practice) during 2012-13. The yield increase in okra cultivated under drip technique was 82% higher than the control (farmer's practice of irrigation). Similarly, during 2013-14, okra recorded the highest yield of 48.16 q/ha with drip irrigation as compared to 42.39 q/ha under sprinkler irrigation, followed by 30.43 q/ha in control (farmers practice). The yield increase in bhindi was 58% higher in the drip irrigation as compared to control (farmers practice). Similarly, in 2012-13, yield of cluster bean, lab lab and vegetable cow pea was 38.62, 11.06 and 13.60 q/ha respectively under drip irrigation and the yield increase over control was 78, 38 and 43%, respectively. Similarly, during 2013-14 maximum yield of cluster bean, lab lab and vegetable cowpea was 41.06, 26.34 and 26.11 q/ha respectively in drip irrigation and the yield increase over control was 46, 68 and 35 per cent, respectively.

The soil physico-chemical properties of the irrigation experiment did not have any significant effect on pH and EC due to the different irrigation treatments during 2012-13 and 2013-14 (Table 11). However, ESP of the soil was significantly increased in flood irrigation over drip and sprinkler irrigation methods.

Table 11: Effect of irrigation methods on soil pH, EC and ESP during 2012-13 and 2013-14

Irrigation methods	2012-13				2013-14			
	Okra	Cluster bean	Lab lab	Veg. cowpea	Okra	Cluster bean	Lab lab	Veg. cowpea
				Soil pH				
Drip irrigation	9.00	9.00	9.02	9.03	9.00	9.01	9.02	9.03
Sprinkler irrigation	9.03	9.07	9.05	9.05	9.04	9.07	9.05	9.05
Farmer practice	9.12	9.10	9.05	9.12	9.12	9.12	9.08	9.12
Mean	9.05	9.06	9.04	9.07	9.05	9.07	9.05	9.07
	I	C	I at C	C at I	I	C	I at C	C at I
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS
				Soil EC (dS/m)				
Drip irrigation	0.80	0.83	0.84	0.82	0.81	0.84	0.85	0.82
Sprinkler irrigation	0.87	0.86	0.90	0.81	0.87	0.86	0.90	0.81
Farmer practice	0.96	0.91	0.90	0.95	0.95	0.93	0.92	0.95
Mean	0.88	0.87	0.86	0.86	0.88	0.88	0.89	0.86
	I	C	I at C	C at I	I	C	I at C	C at I
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS
				Soil ESP				
Drip irrigation	18.0	18.6	18.5	18.7	18.2	18.7	18.4	18.6
Sprinkler irrigation	19.1	19.3	19.1	19.0	19.4	19.2	19.2	19.0
Farmer practice	19.8	20.1	20.6	20.1	19.9	20.2	20.5	20.3
Mean	19.0	19.3	19.4	19.3	19.2	19.4	19.4	19.3
	I	C	I at C	C at I	I	C	I at C	C at I
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS

Integrated farming system (IFS) suitable for problem soil areas of Tamil Nadu

The experiments were conducted during 2012-13 and 2013-14 to evolve an integrated farming system for sustainable income in the problem soil areas. The objective of this experiment was to enhance the income and employment generation. For this purpose, out of 0.80 ha, 0.40 ha has been allotted exclusively for paddy cropping alone wherein dhaincha and rice were cultivated. In the other 0.40 ha of land, cropping was done along with poultry and fisheries components (Fig. 6).

Components: Crop: Rice: 0.30 ha; **Fisheries:** Fish pond area: 0.04 ha

Poultry: To meet the feed requirement of fish fingerlings and to generate additional income, 40 and 20 layers of Babcock birds were reared in IFS program during 2012-13 and 2013-14, respectively.

Control: Normal crop rotation followed by the farmer was Paddy (TRY 1) during Sep-Jan and fallow during Feb-June.

Fingerlings	2012-13	2013-14
Silver carp/catla (surface feeder) (40%)	390 nos.	475 nos.
Rohu (column feeder) (20%)	520 nos.	500 nos.
Mirgal/Common carp (Bottom feeder)	130 nos.	175 nos.
Grass carp (Grass Feeder)	260 nos.	350 nos.

In the IFS program, under crop component of 0.30ha of land was cultivated with paddy (TRY 1). The cost of cultivation for crop component during 2012-13 and 2013-14 are given in the Table 12. The total cost of cultivation of paddy was Rs 13719 and total income generated from the paddy was Rs 28258 and Rs 19800 with net profit of Rs 14539 and Rs 6081 during 2012-13 and 2013-14, respectively.

Table 12: Cost of cultivation for crop component in IFS during 2012-13 and 2013-14 (0.30 ha)

Details	Quantity	Cost (Rs)
Seed	20 kg @ Rs 20/kg	400
Land preparation including nursery		1500
Planting	15 labours @ Rs 166/labour	2500
Intercultural operation	Two weedings	3500
Fertilizer cost	Urea 100 kg @ Rs 268/50 kg : 536	2819
	Super 150 kg @ Rs 381/50 kg : 1143	
	MOP 50 kg @ Rs 840/50 kg : 840	
	$ZnSO_4$ 10 kg @ Rs 30/kg : 300	
Foliar spray	Cost @ Rs 1000	1000
Harvest	@Rs 166/labour	2000
Total expenditure		13719

During 2012-13, the fisheries and poultry component were laid out, respectively in 0.10 ha of land. The fisheries component incurred a total expenditure of Rs 7600 and Rs 8200 and the poultry component incurred a total expenditure of Rs 14600 and Rs 7200 during 2012-13 and 2013-14, respectively. Both, fisheries and poultry component consumed a capital investment of Rs 24000 and Rs 22500 during 2012-13 and 2013-14, respectively (Table 13).

Fig. 6: General view of Integrated farming system including poultry and fisheries

Table 13: Cost on capital investment for fisheries and poultry component in IFS

Particulars	Cost (Rs)	
	2012-13	2013-14
Fish Pond digging Charge	60000	60000
Poultry shed	30000	30000
Total	90000	90000
Cost on capital investment for respective years	15000	15000
Interest on capital (1%)	9000	7500
Total	24000	22500

During 2012-13, net profit from IFS components of crop (0.30 ha), fisheries and poultry (0.10 ha) are given in Table 14. Overall profit of Rs 115328 was obtained from all three components of IFS and fisheries and poultry component yielded an income of 66 and 16 per cent, respectively. The highest net return of more than 4 times was obtained from fisheries among the IFS components. Similarly, during 2013-14 also, recorded maximum income was obtained by fisheries among three components of IFS.

Table 14: Net profit from IFS components during 2012-13 and 2013-14

Components of IFS	2012-13			2013-14		
	Expenditure (Rs)	Income (Rs)	Profit (Rs)	Expenditure (Rs)	Income (Rs)	Profit (Rs)
Crops (0.30 ha)	13719	28258	14539	13719	19800	6081
Fisheries	7600	115360	107760	8200	92000	83800
Poultry	12000	29029	14429	7200	11506	4306
Vegatables (Bund cropping)	-	-	-	400	1810	1410
Capital investment	24000	-	-	22500	-	-
Total	57319	172647	115328	52019	125116	73097

Economics of the pure cropping system (Table 15) illustrates the net profit from 0.40 ha, which is less than 0.40 ha of the IFS program (0.30 ha for crop and 0.10 ha for poultry and fisheries) has yielded high net returns and BC ratio of 3.01 and 2.41 during 2012-13 and 2013-14, respectively which was 0.98 and 1.02 per cent higher than the crop alone during 2012-13 and 2013-14 (Table 16).

Table 15: Economics of pure cropping system during 2012-13 and 2013-14 (0.40 ha)

Details	Quantity	Cost (Rs)	
		2012-13	2013-14
Seed	20 kg @ Rs 20/ kg	400	400
Land Preparation including nursery		2500	2500
Planting	20 labours @ 166	3320	3320
Intercultural operation	Two weedings	4000	4000
Fertiliser cost	Urea 150 kg @ Rs 268/50 kg : 804 Super 200 kg @ Rs 381/50 kg : 1524 MOP 50 kg @ Rs 840/50 kg : 840 $ZnSO_4$ 10 kg @ Rs 30/kg : 300	3468	3468

Foliar spray	Rs 1000	1200	1200
Harvest		2500	2000
Total expenditure		17388	16888
Income from cropping		35231	23500
Net profit		17843	6612

Table 16: Comparison of IFS with pure cropping during 2012-13 and 2013-14

Components	2012-13			2013-14		
	Income (Rs)	Cost (Rs)	B/C ratio	Income (Rs)	Cost (Rs)	B/C ratio
IFS Components (0.4 ha)	172647	57319	3.01	125116	52019	2.41
Pure cropping (0.4 ha)	35231	17388	2.03	23500	16888	1.39

Therefore, it is recommended that IFS program to be adopted in problem soils to increase the income of farmers. The government can subsidize the capital investment cost in establishing the fisheries and poultry components under IFS.

Evaluation of different crops for tolerance to sodicity levels

During 2012-13 and 2013-14, crops and varieties viz. rice (TRY 1, CO42, TRY(R)2, ADT 39, ADT 45, White Ponni), black gram (T9 and ADT 5), green gram (Pusa Bold), okra (Parbani Kranti), vegetable cowpea (VBN 37), cluster bean (Pusa Nowbahaar), sunflower (CO 4, TCSH 1), sesame (CO 1), and pearl millet (CO7, COHCu8, UCC17, ICMY221, PT1890) have been screened for sodicity tolerance and their tolerance limits have been established. The experiment continued in the same plots with four ESP gradients with cotton hybrid and varieties during 2012-13 and 2013-14.

The cotton hybrid (RCH-20) and varieties (Surabi and SVPR-2) were tested under different ESP levels during Feb. 2013 and Feb. 2014. The main plot treatments comprised of four ESP levels (8 (M1), 16 (M2), 32 (M3) and 40 (M4) created artificially by application of sodium bicarbonate. The experimental soil was clay loam in texture with initial pH 8.9, EC 0.41 dS/m, CEC 18 cmol (p+)/kg and ESP 16. The water used for irrigation was highly alkali with pH 8.8, EC 1.42, RSC 9.2.

The results of 2013 revealed that among the cotton hybrid and varieties, the cotton hybrid RCH-20 found to record the maximum seed cotton yield of 21.64 q/ha and the variety SVPR-2 recorded the lowest seed cotton yield of 5.53 q/ha (Table 17, Fig. 7). Among the ESP levels, ESP 9.2 recorded significantly higher yield of 15.54 q/ha as compared to other ESP levels. Irrespective of the hybrid and variety tested the yield significantly reduced from 15.54 to 7.37 q/ha for ESP level of 9.2 to 39.

The results of the field experiment conducted during 2014 revealed that among the cotton hybrid and varieties, cotton hybrid RCH-20 produced the maximum seed cotton yield of 29.54 q/ha and the variety SVPR-2 recorded the lowest seed cotton yield of 8.43 q/ha (Table 17). Among various ESP levels, ESP 9.2 recorded significantly higher yield (23.04 q/ha) as compared to other ESP levels.

The post harvest soil analysis during 2014, revealed soil pH increased as the ESP levels increased. However, there is no much difference in build-up of soil EC at post harvest soil analysis as compared to initial soil pH and EC during both the years. The reduction in soil EC might be due to leaching of salts and removal of salts by crop during the experiment (Table 18).

Table 17: Seed cotton yield under different ESP levels

Treatments (ESP levels)	Seed cotton yield (q/ha) (2012-13)			Seed cotton yield (q/ha) (2013-14)		
	S1 (Surabhi)	S2 (RCH-20)*	S3 (SVPR-2)	S1 (Surabhi)	S2 (RCH-20)*	S3 (SVPR-2)
M1 (9.2)	13.56	21.64	11.41	20.30	29.54	19.31
M2 (19)	12.05	15.56	9.18	14.61	21.06	14.64
M3 (28)	9.87	12.32	7.63	12.94	13.33	12.73
M4 (39)	7.15	9.44	5.53	9.31	12.34	8.43
Mean	10.66	14.74	8.44	14.29	19.06	13.77
	M	S	MxS	M	S	M x S
CD (5%)	7.9	7.1	13.9	12.17	9.10	19.16

**Cotton hybrid*

Table 18: Effect of different ESP levels on soil pH and EC at crop harvest

Treatments (ESP levels)	Cotton variety/Hybrid*			Cotton variety/Hybrid*		
	S1 (Surabhi)	S2 (RCH-20)*	S3 (SVPR-2)	S1 (Surabhi)	S2 (RCH-20)*	S3 (SVPR-2)
	Soil pH (2012-13)			Soil pH (2013-14)		
M1 (9.2)	9.62	9.58	9.65	9.53	9.51	9.51
M2 (19)	9.70	9.79	9.66	9.71	9.59	9.61
M3 (28)	9.76	9.92	9.94	9.73	9.95	9.62
M4 (39)	10.26	10.18	10.18	9.95	10.04	9.95
Mean	9.83	9.87	9.85	9.73	9.77	9.67
CD (5%)	M	S	MxS	M	S	M x S
	0.13	0.11	0.22	0.23	0.14	0.33
	Soil EC (dS/m) 2012-13			Soil EC (dS/m) 2013-14		
M1 (9.2)	0.21	0.22	0.18	0.21	0.25	0.28
M2 (19)	0.23	0.20	0.22	0.24	0.31	0.28
M3 (28)	0.28	0.22	0.20	0.22	0.36	0.27
M4 (39)	0.30	0.34	0.25	0.31	0.38	0.31
Mean	0.25	0.24	0.21	0.25	0.32	0.28
CD (5%)	M	S	M x S	M	S	M x S
	0.01	0.01	0.03	0.04	0.04	0.09

Fig. 7: Field view of cotton experiment at different growth stages

Studies on long-term effects of sewage irrigation on soil and crops

In order to assess the long-term metal accumulation (Pb, Cd and Ni) in the sewage water irrigated and ground water irrigated fields, eight benchmark sites were selected wher rice was cultivated as a test crop. The paddy seedlings were transplanted during the month of September and October, 2013. The paddy crop in the field at various growth stages were periodically monitored until crop harvest.

Soil samples were collected and analysed for pH, EC, NPK and Pb, Cd and Ni respectively, before planting rice crop and at crop harvest stage (Table 19). The pH and EC ranged from 7.15 to 8.15 and 0.31 to 0.54 dS/m, respectively. In general the soil pH and EC of the selected farmer's field showed that the neutral and salt levels are below the injurious levels. The initial soil available N content varies from low to medium status (276 to 385 kg/ha) respectively. Soil available P and K was ranged from medium to high. Heavy metals (Pd, Cd, and Ni) are concentrated in the soil upto 0-15cm depth, were below the critical level. Grain yield of paddy under borewell irrigation ranged from 43.9 to 52.0 q/ha while under sewage water irrigated was 51.0 to 62.3 q/ha (Table 20).

During 2014, the existing sewage water ways was diverted and finally it reached the river Cauvery from the city corporation storage lagoons at Panchappur. In new sewage water course ten locations were identified as sample collection points to assess the metal content in the sewage and bore well waters. (Table 19). The heavy metal content observed along the sewage water course showed that the concentration is below the toxic level prescribed by Indian standards (2000), WHO/FAO standards (1993) and EUS (2002) (Table 20).

Table 19: Soil pH, EC (dS/m), NPK (kg/ha), Pd, Cd, Ni (ppm) contents of OFT trial fields

Name of farmer	Village	Geographical Co-ordinates	pH	EC	N	P	K	Pb	Cd	Ni
M Mariyakanikkai	Inniyanur	N10° 48.000' E78° 39.135'	7.20	0.39	306	14.5	286	ND	ND	ND
A Jothimani	Inniyanur	N10° 47.957' E78° 39.236'	7.10	0.46	385	21.8	312	ND	ND	0.006
M Ashok Kumar	Inniyanur	N10° 48.142' E78° 39.005'	7.10	0.45	364	18.2	298	0.002	0.003	ND
M Sabariammal	Inniyanur	N10° 47.782' E78° 39.036'	8.15	0.31	289	16.0	312	ND	ND	ND
R Mani	Koraiyar	N10° 47.729' E78°39.817'	7.25	0.42	326	20.7	284	0.003	0.004	0.007
VS Rajendran	Ponneripuram	N10° 46.814' E78° 43.915'	7.50	0.51	358	19.2	345	0.004	ND	0.005
VS Paramasivam	Nathamadipatti	N10° 46.659' E78° 43.673'	7.40	0.46	343	18.8	320	0.003	0.005	ND
M Arokiaraj	Nathamadipatti	N10° 45.645' E78° 44.239'	7.45	0.54	276	21.5	381	ND	ND	0.006

Table 20: Guidelines for safe limit of heavy metals

Sample	Standards	Cd	Cu	Pb	Zn	Mn	Ni	Cr
Soil (μg/g)	Indian Standard (Awashthi 2000)	3-6	135-270	250-500	300-600	-	75-150	-
	WHO/FAO (2007)	-	-	-	-	-	-	-
	European Union Standards (EU 2002)	3.0	140	300	300	-	75	150
Water (μg/ml)	Indian Standard (Awashthi 2000)	0.01	0.05	0.10	5.0	0.10	-	0.05
	FAO (1985)	0.01	0.20	5.0	2.0	0.20	0.20	0.10
	European Union Standards (EU 2002)	-	-	-	-	-	-	-
Plant (μg/g)	Indian Standard (Awashthi 2000)	1.5	30.0	2.5	50.0	-	1.5	20.0
	WHO/FAO (2007)	0.2	40.0	5.0	60.0	-	-	-
	Commission regulation (EU 2006)	0.2	-	0.30	-	-	-	-

Long-term effects of distillery effluent on soil properties and yield of sugarcane

Exp. I: Pre-plant application of post methanated distillery effluent (PME) for sugarcane: Experiment on pre-plant application of PME experiment initiated during 2002 at EID Parry (I) Ltd., cane farm, Edayanvelli was continued for 11th and 12th crop with the same layout to evaluate the long-term effects of different rates of pre-plant application of PME along with different combinations of NPK on the changes in soil physico-chemical properties, fertility status, exchangeable cations and cane yield. The main plot treatments comprised of 5 PME levels (M1: No PME (control); M2: 1.25 lakh litres/ha;

M3: 2.5 lakh litres/ha; M4: 3.75 lakh litres/ha; M5: 5.0 lakh litres/ha and 6 fertlizer treatments replicated thrice in split plot design and sugarcane variety CO 86032 was planted. The treated distillery effluent was applied as per treatment schedule. The NPK fertilizers were applied at 75% of recommended dose (206-45-84 kg/ha of N, P_2O_5 and K_2O). The cane yield was recorded after harvest of the each crop. The initial properties of the experimental site are given in Table 21.

Table 21: Initial (2002) soil properties of experimental site (Exp. I)

Soil properties	Value	Soil properties	Value
Soil texture	Sandy loam	Ex. Ca (cmol (p^+)/kg)	7.40
Bulk density (g/cc)	1.41	Ex. Mg (cmol (p^+)/kg)	3.75
MWHC (%)	36.3	Ex. K (cmol (p^+)/kg)	0.30
pH	8.40	Ex. Na (cmol (p^+)kg)	1.45
EC (dS/m)	0.10	ESP (%)	11.2
OC (%)	0.50	DTPA Zn (mg/kg)	2.20
Available N (kg/ha)	139.0	DTPA Fe (mg/kg)	9.80
Available P (kg/ha)	18.0	DTPA Cu (mg/kg)	2.10
Available K (kg/ha)	240.0	DTPA Mn (mg/kg)	9.80

Cane yield: The results revealed that cane yield of sugarcane increased remarkably due to application of graded doses of treated distillery effluent (Table 22). It was found that cane yield increased by 23.2, 33.6, 44.8 and 52.5 per cent during 2013 and 27.03, 41.09, 51.56 and 60.16 per cent during 2014 with 1.25, 2.5, 3.75 and 5.0 lakh lit/ha of PME applications, respectively over control (M1). The cane yield of sugarcane also increased due to application of inorganic fertilizers. Though significant response was observed for N and P fertilizers, differences between applications of N & NK and NP & NPK fertilizers were not significant indicating that the supply of K through PME is sufficient. The effect of interelation revealed that PME application @ 1.25 lakh litres/ha with NP fertilizers was most suitable dose for harvesting appreciable yield of sugarcane.

Table 22: Effect of PME and fertilizers on yield of sugarcane

PME (LL/ha)	Sugarcane yield (t/ha)						
	Control	N	NP	NK	PK	NPK	Mean
			2013				
Control	42.5	58.2	73.4	69.5	51.2	80.2	62.5
1.25	55.4	71.0	98.2	72.3	68.2	97.1	77.0
2.50	63.1	80.2	101.5	81.4	71.5	103.1	83.5
3.75	75.4	86.4	108.1	87.2	78.2	107.6	90.5
5.00	81.2	91.2	112.2	92.4	85.4	109.6	95.3
Mean	63.5	77.4	98.7	80.6	70.9	99.5	-
CD (5%)	M	S	S x M	M x S			
	5.7	7.5	12.7	13.8			
			2014				
Control	43.9	59.1	73.0	71.2	55.2	81.4	64.0
1.25	57.2	77.2	102.5	76.5	73.6	100.5	81.3
2.50	68.5	87.4	107.2	89.1	81.2	108.4	90.3
3.75	80.2	95.2	111.5	95.4	89.5	110.2	97.0
5.00	88.4	97.6	114.1	98.0	100.5	116.2	102.5
Mean	67.6	83.3	101.7	86.0	80.0	103.3	-
CD (5%)	M	S	S x M	M x S			
	6.6	9.7	14.3	16.2			

Impact on soil properties: The application of PME at various levels changed the pH of the post harvest soils nearer to neutral range (Table 23). In fact, it was observed that the application of PME @ 5.0 lakh L/ha reduced the soil pH to 8.12 and 8.07 during 2013 and 2014 respectively from initial level of 8.42. The increases in Ca, Mg, H and release of organic acids are mainly responsible for the changes in soil pH.

Table 23: Effect of PME and fertilizers on physio-chemical properties of post harvest soils

PME (LL/ha)	pH	EC (dS/m)	EX. Ca	Ex. Mg (cmol(p+)/kg)	Ex. Na	Ex. K	ESP
			2013				
Control	8.37	0.099	7.26	3.50	1.51	0.248	12.32
1.25	8.31	0.109	7.96	4.14	1.50	0.350	10.70
2.50	8.24	0.120	8.15	4.34	1.51	0.383	10.37
3.75	8.19	0.127	8.34	4.57	1.51	0.435	10.30
5.00	8.12	0.153	8.67	4.89	1.54	0.463	10.10
CD (5%)	0.14	0.017	0.50	0.25	NS	0.032	0.58
			2014				
Control	8.38	0.101	7.26	3.51	1.50	0.25	11.99
1.25	8.24	0.113	7.93	4.16	1.50	0.35	10.73
2.50	8.19	0.127	8.12	4.35	1.49	0.39	10.37
3.75	8.13	0.133	8.30	4.59	1.51	0.45	10.17
5.00	8.07	0.156	8.66	4.93	1.54	0.47	9.89
CD (5%)	0.15	0.018	0.39	0.24	NS	0.03	0.48

The data revealed that the soluble salt content increased slightly with application of PME. Continuous application of PME increased the exchangeable cations (Table 23) of the soil viz., Ca, Mg and K. An increase of 0.70, 0.89, 1.08 and 1.41 cmol (p+)/kg of exchangeable Ca during 2013 and 0.67, 0.86, 1.04 and 1.40 cmol (p+)/kg of exchangeable Ca during 2014 were recorded due to application of distillery effluent @ 1.25, 2.50, 3.75 and 5.0 lakhs liters/ha, respectively over control. Similarly, content of exchangeable Mg, were increased due to application of distillery effluent @ 1.25, 2.50, 3.75 and 5.0 lakhs liters per ha respectively over control.

Organic carbon: The organic carbon at crop harvest increased significantly due to application of distillery effluent. Cummulative increase of 0.35, 0.43, 0.49 and 0.53 per cent was observed in 2013 and 0.36, 0.45, 0.51 and 0.55 in 2014 since 2002 was recorded in M2, M3, M4 and M5 treatments (Table 5).

The results showed that the fertility status of soil in terms of available NPK improved considerably due to continuous application of distillery effluent. An increase of 43, 53, 63 and 71 kg/ha of available N in 2013 and 43.83, 55.33, 64.83 and 71.17 kg/ha in 2014 was recorded with application of 1.25, 2.50, 3.75 and 5.00 lakh liters/ha of distillery effluent, respectively over control. Similarly, available P content increased due to distillery effluent. The highest increase of 3.77 and 3.80 kg/ha was recorded under M5 treatment over control during 2013 and 2014, respectively (Table 24).

Since the distillery effluent contains appreciable quantity of potassium, its continuous application tremendously increased the available K status of the soil (Table 24). An increase of 105, 141, 167 and 181 kg/ha during 2013 and 107, 151, 171 and 185 kg/ha during 2014 was found in M2, M3, M4 and M5 treatments as compared to control.

Table 24: Effect of PME and fertilizers on OC and and available nutrient status of post harvest soils

TDE (LL/ha)	OC (%)	Av. nutrients (kg/ha)			Av. micronutrients (mg/kg)			
		N	P	K	Zn	Fe	Cu	Mn
			2013					
Control	0.38	135.3	16.4	216	2.0	8.8	1.8	12.9
1.25	0.73	178.2	17.9	321	2.4	11.2	2.4	16.0
2.50	0.81	188.5	18.7	357	2.6	12.4	2.5	16.5
3.75	0.87	198.5	19.5	383	2.7	12.8	2.7	17.1
5.00	0.91	206.0	20.2	397	3.8	14.0	2.8	17.5
CD (5%)	0.47	7.9	0.8	14.0	0.16	0.15	0.14	0.13
			2014					
Control	0.38	137.0	16.1	215	2.03	8.7	1.8	13.0
1.25	0.74	180.8	17.7	322	2.44	11.2	2.4	16.2
2.50	0.83	192.3	18.5	366	2.61	12.4	2.6	16.8
3.75	0.89	201.8	19.2	386	2.73	12.9	2.8	17.4
5.00	0.93	208.2	19.9	400	2.91	14.1	2.8	17.7
CD (5%)	0.50	8.0	0.8	14	0.17	0.17	0.13	0.15

Available micronutrients: The data revealed that available micronutrients namely, Zn, Fe, Cu and Mn significantly increased due to the application of graded doses of PME (Table 24) being the highest with distillery effluent @ 5 lakh litres/ha. The available Zn, Fe, Cu and Mn increased to the tune of 1.83, 5.20, 0.99 and 4.59 mg/kg in 2013 and 0.88, 5.31, 1.02 and 4.78 mg/kg in 2014, respectively over control.

Microbial population dynamics: The population of fungi, bacteria and actinomycetes was increased due to application of PME over years. The microbial population also increased in the post harvest soil when different combination of NPK fertilizers was applied over control (Table 25).

Table 25: Effect of PME and fertilizers on microbial population dynamics of post harvest soil

PME (LL/ha)	Bacteria (x 10^6)		Fungi (x 10^4)		Actinomycetes (x 10^2)	
	2013	2014	2013	2014	2013	2014
Control	59.8	58.23	6.55	6.56	3.96	3.95
1.25	64.2	62.92	8.15	8.17	5.35	5.36
2.50	67.1	66.10	8.47	8.49	5.44	5.47
3.75	70.1	68.95	8.97	8.99	5.52	5.54
5.00	73.4	72.02	10.16	10.19	5.90	5.92
CD (5%)	2.97	2.86	0.37	0.37	0.24	0.22

Exp. II: Dilution of post methanated distillery effluent (PME) for standing sugarcane crop

The experiment was conducted in sandy loam soils on sugarcane (CO 86032) with 6 treatments comprised of T1: Control (Well water); T2: 1:10 dilution; T3: 1:20 dilution; T4: 1:30 dilution; T5: 1:40 dilution; T6: 1:50 dilution of PME + well water replicated four times in RBD.

PME was applied along with irrigation water. PME was discharged @ 1.00, 0.50, 0.33, 0.25 and 0.20 LL/ha to get the dilutions of 1: 10, 1:20, 1:30, 1:40 and 1:50, respectively. The diluted PME was applied four times at an interval of 40 days starting from 45 day after ratooning/planting. N and P fertilizers were applied @ 75% of recommended dose (206 kg N and 45 kg P_2O_5). The post harvest soil samples were analysed for physico-chemical properties. The initial properties of the experimental sites are given in Table 26.

Table 26: Initial properties of experimental soil (Experiment II)

Parameter	Value	Parameter	Value
Soil Texture	Sandy loam	Ex. Ca (cmol (p^+)/kg)	8.09
Bulk density (g/cc)	1.42	Ex. Mg (cmol (p^+)/kg)	3.97
MWHC (%)	35.5	Ex. K (cmol (p^+)/kg)	0.31
pH	8.35	Ex. Na (cmol (p^+)/kg)	1.54
EC (dS/m)	0.06	ESP (%)	11.00
OC (%)	0.46	DTPA Zn (mg/kg)	4.99
Available N (kg/ha)	224.0	DTPA Fe (mg/kg)	14.30
Available P (kg/ha)	17.8	DTPA Cu (mg/kg)	2.11
Available K (kg/ha)	271.0	DTPA Mn (mg/kg)	10.30

Cane yield: The sugarcane yield remarkably increased in long-term experiments with the application of PME with irrigation water at different dilutions. An increase 40, 35, 28.8, 20 and 10 per cent in 2012 and 42.1, 36.8, 27.6, 17.1 and 9.2 per cent in 2013 were recorded with dilutions of 1:10, 1:20, 1:30, 1:40 and 1:50 respectively over control. Continuous application of nutrients to the crop through distillery effluent might have increased the yield of sugarcane. The highest cane yield was obtained at 1:10 dilution. However, the increase in cane yield increased significantly upto 1:20 dilution in sandy loam soil (Table 27).

Table 27: Effect of PME at different dilutions on yield of sugarcane

PME dilution ratio	Sugarcane yield (q/ha)	
	2013	2014
Control	80	76
1:10	112	108
1:20	108	104
1:30	103	97
1:40	96	89
1:50	88	83
CD (5%)	6	9

Table 28: Effect of PME dilutions on physico-chemical properties of post harvest soils

PME dilution	pH	EC (dS/m)	Exchangeable cations (cmol(p+)/kg)				ESP
			Ex. Ca	Ex. Mg	Ex. Na	Ex. K	
			2012-13				
Control	8.38	0.09	7.55	3.97	1.62	0.37	11.99
1:10	8.14	0.36	12.10	6.19	1.63	0.89	7.83
1:20	8.19	0.31	11.80	6.00	1.58	0.89	7.79
1:30	8.19	0.24	10.10	5.75	1.53	0.84	8.40
1:40	8.23	0.27	10.90	5.62	1.56	0.80	8.26
1:50	8.20	0.22	10.30	5.37	1.55	0.71	8.64
CD (5%)	0.17	0.07	0.64	0.35	NS	0.09	0.47
			2013-14				
Control	8.37	0.11	7.57	3.99	1.60	0.35	11.84
1:10	8.15	0.38	12.14	6.21	1.61	0.91	7.71
1:20	8.20	0.32	11.85	6.04	1.56	0.88	7.67
1:30	8.19	0.25	10.12	5.77	1.52	0.86	8.32
1:40	8.24	0.29	10.94	5.64	1.54	0.83	8.13
1:50	8.20	0.24	10.36	5.39	1.53	0.75	8.49
CD (5%)	0.18	0.09	0.66	0.50	NS	0.08	0.56

Soil properties: The soil pH changed towards neutral due to use of PME over a period of 10 years. The pH of the post harvest soil reduced from initial value of 8.38 to 8.14 during 2013 and 8.37 to 8.15 during 2014 with application of PME at 1:10 dilution. The supply of Ca^{2+}, Mg^{2+} and H^+ ions through PME might have influenced the pH of soil continuously for 12 years. Though the soil EC increased with application of PME, but it was below the safer limits (<1 dS/m) (Table 28).

The supply of PME over a long period, increased the beneficial cations in soil. Highest exchangeable cations were recorded at 1:10 dilution followed by 1:20, 1:30, 1:40 and 1:50 dilutions (Table 28). The soil organic carbon significantly increased because of the supply of high organic load of PME. In the post harvest soil, organic carbon increased by 0.43, 0.34, 0.29, 0.27, and 0.26 per cent during 2012 and 0.45, 0.36, 0.31, 0.29, and 0.28 per cent during 2013 with dilutions of 1:10, 1:20, 1:30, 1:40 and 1:50, respectively over control (Table 29).

Supply of PME over a long period resulted in significant build-up in available nutrients in sandy loam soils. The highest values were observed in dilution of 1:10 and decreased with increasing dilutions. As PME contains high concentration of K (8000 ppm), requirement of K by sugarcane was fulfilled by PME. Hence, no need of additional application of inorganic K fertilizer to the sugarcane crop (Table 29).

The available micronutrients of the soil increased over years by the PME. The highest increase was observed in 1:10 dilution followed by 1:20, 1:30, 1:40 and 1:50 dilutions. The high availability might be due to direct contribution from PME as well as solubilisation and chelation effect of organic matter supplied by the effluent (Table 29).

Table 29: Effect of PME dilutions on organic carbon and available nutrient status

PME dilution	OC	Av. nutrients (kg/ha)			Av. micronutrients (mg/kg)			
	(%)	N	P	K	Zn	Fe	Cu	Mn
			2013					
Control	0.48	236	17.80	274	4.90	13.43	2.08	9.99
1:10	0.91	283	28.15	500	6.40	17.45	4.64	14.10
1:20	0.82	272	25.76	469	6.27	16.23	4.00	13.40
1:30	0.77	264	24.68	448	5.81	16.74	3.91	12.80
1:40	0.75	260	23.87	461	5.80	16.32	3.58	12.40
1:50	0.74	254	23.58	420	5.71	15.44	3.51	10.72
CD (5%)	0.06	12.10	2.31	27.50	0.41	0.99	0.24	0.06
			2014					
Control	0.47	232	17.60	276	4.91	13.45	2.09	9.98
1:10	0.92	285	28.20	501	6.41	17.46	4.65	14.12
1:20	0.83	274	25.80	472	6.29	16.25	4.01	13.41
1:30	0.78	266	24.70	451	5.83	16.75	3.93	12.84
1:40	0.76	262	23.90	464	5.81	16.34	3.59	12.44
1:50	0.75	253	23.60	424	5.73	15.45	3.53	10.78
CD (5%)	0.07	14.30	2.75	31.90	0.44	1.43	0.29	0.07

Microbial population dynamics : The application of PME enhanced the population of soil bacteria, fungi and actinomycetes. The soil microbial population increased with increased concentration of effluent. The application of organic matter to the soil through PME as fertigation increased the microbial population over the period (Table 30).

Table 30: Effect of PME dilutions on microbial population dynamics of post harvest soil

PME dilution ratio	Bacteria (x 10^5)		Fungi (x 10^3)		Actinomycetes (x 10^3)	
	2013	2014	2013	2014	2013	2014
Control	46	48	7.8	8.5	7.5	8.4
1:10	74.1	82.5	21.1	24.2	15.4	17.8
1:20	71.5	73	19.5	22.4	14.8	17
1:30	64.2	67.2	17.5	20.5	14.5	16.5
1:40	63.8	66.5	16.8	19.2	13.1	15.2
1:50	62.1	65	14.2	18.2	12.5	14.1
CD (5%)	3.63	4.51	2.86	2.09	1.32	1.87

Operational Research Project on Sodic soil reclamation technology

To demonstrate the reclamation technology of sodic soil using phosphogypsum and distillery spent wash (DSW) and other management practices, demonstrations was conducted at 20 farmers fields (10 farmers for phosphogypsum and 10 farmers for DSW technology) in different locations.

ORP I : Phospho-gypsum Reclamation Technology

The technology was demonstrated with application of 50% GR, ranged from 3.6 t/ha to 8.6 t/ha on the basis of soil test values, in comparison to farmers practice. Ten farmers (6 farmers during 2012-13 and 4 farmers during 2013-14) were selected in different locations of Trichirappalli district based on soil test. Initial and post harvest soil samples were collected and analysed for pH, EC and ESP.

The initial soil pH varied from 8.7 to 10.3 (2012-13) and 8.96 to 10.4 (2013 -14), EC varied from 0.42 to 1.36 dS/m (2012-13) and 0.76 to 1.21 dS/m (2013- 14) and ESP varied from 23 to 42 (2012-13) and 28 to 39 (2013-14).

The results of phosphogypsum reclamation technology revealed that application of phosphogypsum @ 50% GR along with package of practices increased the grain yield of rice by 16.74 to 23.00 q/ha during 2012-13 and 16.30 to 22.14 q/ha during 2013-14 as compared to control (Table 31).

The post harvest soil analysis revealed that phosphogypsum application considerably reduced the soil pH to the level of 8.3-8.7 (2012-13) and 8.36-8.52 (2013-14) and ESP reduced by 13-20 (2012-13) and 13-18 (2013-14). There is no considerable change in EC of the soils (Table 32).

Table 31: Influence of phosphogypsum technology on yield of rice at different locations

2012-13					2013-14				
Name of farmer Location	Grain yield (q/ ha)		Straw yield (q/ ha)		Name of farmer Location	Grain yield (q/ ha)		Straw yield (q/ ha)	
	Control	50% GR	Control	50%GR		Control	50%GR	Control	50%GR
M Chinnadurai Poongudi	21.41	38.15	25.47	45.78	K Veerappan Paganur	23.86	40.16	26.12	44.14
A Iruthayamary Poongudi	24.60	46.80	29.27	55.69	N Rengasamy Paganur	21.08	38.46	27.14	30.14
V Boopathy Poongudi	28.15	51.00	33.49	60.69	Subramaniyan Poongudi	19.86	37.12	24.21	44.14
S David Theras Rajan South Bhaganur	23.48	44.80	27.94	53.31	Poonusami Poongudi	27.12	49.26	31.46	54.26
A Rayappan South Bhaganur	18.90	39.20	22.49	46.69					
A Vincent South Bhaganur	29.60	52.60	35.81	62.06					

Table 32: Influence of phosphogypsum technology on physico-chemical properties of soil

Farmer name Location	pH				EC (dS/m)				ESP			
	Control		50%GR		Control		50%GR		Control		50%GR	
	I	H	I	H	I	H	I	H	I	H	I	H
					2012-13							
M Chinnadurai Poongudi	9.8	9.7	9.8	8.6	0.85	0.84	0.83	0.86	36	38	35	18
A Iruthayamary Poongudi	9.1	9.2	9.0	8.3	1.21	1.23	1.23	1.26	29	28	30	13
V Boopathy Poongudi	8.9	9.0	9.1	8.4	0.62	0.60	0.61	0.65	24	25	23	15
S David Theras SouthBhaganur	9.6	9.9	9.5	8.6	1.36	1.40	1.36	1.40	31	32	33	18
A Rayappan South Bhaganur	10.3	10.1	10.1	8.7	0.42	0.45	0.41	0.45	42	40	41	20
A Vincent SouthBhaganur	8.7	8.6	8.8	8.3	1.12	1.10	1.10	1.12	26	28	28	12

2013-14												
K Veerappan Paganur	9.12	9.14	9.14	8.41	0.76	0.77	0.77	0.79	31	32	32	13
N Rengasamy Paganur	9.46	9.45	9.47	8.40	0.91	0.90	0.90	0.96	33	34	31	14
Subramaniyan Poongudi	10.4	9.43	10.14	8.52	1.10	1.13	1.11	1.18	39	39	40	18
Poonusami Poongudi	8.96	9.50	8.93	8.36	1.21	1.19	1.20	1.29	28	27	29	15

I: Initial status; H: Harvesting

ORP II: DSW Reclamation Technology

The technology was demonstrated with application of DSW @ 5 LL/ha in comparison to farmers practice. For this demonstration 10 farmers (6 in 2012-13 and 4 in 2013-14) were selected in Tiruchirappalli district based on soil test. DSW was applied @ 5 LL/ha and DSW reclamation technology was followed. Initial and final soil samples were analysed for pH, EC and ESP.

The initial soil properties rvealed that pH varied from 8.6 to 10.0 in 2012-13 and 8.6 to 10.0 in 2013-14, EC varied from 0.68 to 1.18 dS/m (2012-13) and 0.42 to 1.21 dS/m (2013-14) and ESP varied from 24 to 32 (2012-13) and 28 to 38 (2013-14) in different location of DSW demonstrations.

The results showed that application of DSW @ 5 LL/ha along with package of practices increased the grain yield of rice by 15.60 to 24.28 q/ha during 2012-13 and 18.02 to 26.32 q/ha during 2013-14 as compared to control (Table 33).

The post harvest soil analysis revealed that DSW reduced the soil pH to the level of 8.3-8.8 during 2012-13 and 8.2-8.7 during 2013-14 and ESP reduced to the level of 14 -19% during 2012-13 and 16-21% during 2013-14. Application of DSW slightly increased the EC of post harvest soil (Table 34, Fig. 8).

Table 33: Influence of DSW reclamation technology on yield of rice at different locations

2012-13					2013-14				
Name of farmer Location	Grain yield (kg/ ha)		Straw yield (kg/ ha)		Name of farmer Location	Grain yield (kg/ ha)		Straw yield (kg/ ha)	
	Control	DSW	Control	DSW		Control	DSW	Control	DSW
P Veeramuthu Poongudi	3240	4800	3823	5568	K Jambulingam Aravakudi	2614	5246	2950	5910
V Palanisamy Poongudi	3420	5680	3967	6701	J Manikkam K Kallikudi	2341	4391	2860	4943
P Thilagavathy Poongudi	2860	5100	3432	5916	P Thavail Nadu Paganur	2214	4016	2674	5124
S Pachaiyammal Eganai patti	2180	4608	2594	5437	S Pachaiyammal Nadu Paganur	1986	3910	2461	4421
S Dharmalingam Eganai patti	2950	4960	3510	5902					
K Kannaiyan Mathur	2618	4850	2872	5723					

Table 34: Influence of DSW reclamation technology on physico-chemical properties of soil

Name of farmer Location	pH				EC (dS/m)				ESP			
	Control		50%GR		Control		50%GR		Control		50%GR	
	I	H	I	H	I	H	I	H	I	H	I	H
					2012-13							
P Veeramuthu Poongudi	8.8	8.7	8.7	8.2	0.08	0.81	0.81	0.96	26	25	27	14
V Palanisamy Poongudi	8.6	8.7	8.8	8.3	1.21	1.25	1.20	1.32	24	26	25	16
P Thilagavathy Poongudi	9.8	9.9	9.7	8.8	0.70	0.70	0.71	0.86	32	34	31	18
S Pachaiyammal Eganai patti	10.0	9.8	9.8	8.6	1.20	1.20	1.17	1.33	30	28	32	16
SDharmalingam Eganai patti	8.8	8.9	8.8	8.3	0.91	0.93	0.92	1.02	27	29	29	14
K Kannaiyan Mathur	9.6	9.7	9.5	8.7	0.68	0.70	0.67	0.80	30	32	31	19
					2013-14							
K Jambulingam Aravakudi	9.6	9.6	9.5	8.6	0.42	0.41	0.41	0.43	32	31	31	20
J Manikkam K.Kallikudi	9.1	9.0	9.2	8.4	0.96	0.95	0.95	0.99	30	32	31	21
P Thavail Nadu Paganur	8.7	8.8	8.8	8.2	1.21	1.20	1.20	1.31	28	29	29	16
S Pachaiyammal Nadu Paganur	10.3	10.2	10.2	8.7	0.94	0.95	0.95	1.03	38	38	37	19

I: Initial status; H: Harvesting

Fig. 8: Demonstrations of reclamation technology

GENERAL

1: ORGANIZATION

2: MANDATE OF COOPERATING CENTERS

3: STAFF POSITION

4: WEATHER DATA

5: LIST OF PUBLICATIONS

6: FINANCE

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 centers 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 centers. In the Sixth Five Year Plan, four centers namely Kanpur, Indore, Jobner and Pali earlier associated with AICRP on Water Management and Soil Salinity were transferred to this Project whereas the Nagpur Center was dissociated. As the mandate of the Kanpur and Indore centers 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 centers located at Dharwad and Jobner were shifted to Gangawati (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 centers at Hisar and Trichy were added. These Centers started functioning from 1 January 1995 and 1997 respectively. Futher, during Twelfth Five Year Plan, four new Volunteer Centres has been added to this AICRP and these started functioning from 2014. During XIth Plan, Project continued with an outlay of Rs 2125.15 lakh at these centers with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The total outlay of the XIIth plan has been fixed at Rs 4638.67 lakhs including the state share of Rs 963.67 lakhs. The center wise mandate of the project is as follows:

2: MANDATES FOR COOPERATING CENTERS

Centre	Mandate
Agra	1. Water quality limits in relation to cropping system
	2. Develop strategies for conjunctive use of saline and canal water
	3. Improving the nutrient use efficiency in saline environment
	4. Improved irrigation techniques and salt water management
	5. Rain water management for salinity control
	6. Alternate land use through agro-forestry and horticulture
	7. Operational research for saline water use
Bapatla	1. Water quality and soil surveys and monitoring of benchmark sites
	2. Crop-water production functions with saline water in coastal sands
	3. Water quality limits with improved irrigation technologies
	4. Improved Dorouv technology
	5. Upconing problems of sea water in coastal sandy soils
	6. Fertility management of saline coastal sandy soils.
	7. Operational research on dorouv technology/saline water use
	8. Reclamation of abandoned aqua ponds
Bikaner	1. Water quality surveys
	2. Salt and water balance in gypsiferous soils of the IGNP Command
	3. Irrigation management for saline water use
	4. Drainage for control of salinity and water logging
	5. Develop practices for use of nitrate and fluoride rich waters
	6. Nutrient management of saline gypsiferous soils
Gangawati	1. Ground water quality surveys
	2. Performance evaluation of drainage system in T.B.P. command
	3. Reuse of drainage effluents/conjunctive use

	4.	Drainage requirement of crops in saline black soils
	5.	Performance of tree species in saline black soils including bio-drainage
	6.	Organic materials for improving productivity of saline soils
	7.	Tolerance of medicinal and aromatic plants to soil salinity
	8.	Reclamation of rain fed alkali lands
Hisar	1.	Ground water quality surveys
	2.	Conjunctive use of canal and saline ground/drainage waters
	3.	Water production functions under salt stress conditions
	4.	Water quality guidelines for sprinklers/drip systems
	5.	Modelling crop yields under salt stress and strategies for mitigation
	6.	Management of alkali water for vegetable production
Indore	1.	Ground water and soil surveys
	2.	Management of heavy textured alkali soils
	3.	Crop-water production functions for alkali black soils
	4.	Develop parameters for incorporating the effect of Cl/SO_4, Mg/Ca and SAR on sodification and soil permeability
	5.	Hydrosalinity modelling in Omkeshwar Command
	6.	Alternate land use of alkali black soils for agro-forestry
	7.	Tilerance of medicinal and aromatic plants to soil alkali stress
	8.	Management of wastewaters
Kanpur	1.	Water treatment techniques for use of alkali water
	2.	Conjunctive use of alkali and canal water
	3.	Performance of tree species in alkali soils
	4.	Fertility management under conditions of alkali water use
	5.	Soil/ land/ water resource inventories in Ramganga/Sharda Sahayak Command
	6.	Resource conservation technologies for alkali soils
	7.	Salt tolerance studies on crop cultivars
Trichy	1.	Ground water quality surveys of Tamil Nadu
	2.	Mitigation strategies for adverse effects of salts on soil and crops
	3.	Conjunctive use of poor quality ground and canal waters
	4.	Survey of poor quality ground waters and salt affected soils
	5.	Alternate land use of salt-affected soils through agro-forestry
	6.	Multi-enterprise agriculture for higher income
	7.	Use of Distillery Spent wash for alkali land and water reclamation
Net work trials	1.	Identification of appropriate cultivars of crops for saline/alkali environments in different agro-ecological regions
	2.	Water quality/salt affected soil resource inventories/mapping
Coordinating Unit	1.	Developing guidelines on use of saline water
	2.	Use of saline water in agro-forestry
	3.	Modelling salt and water transport and crop response in saline environment
	4.	Generating chemical/physical parameters for computers models
	5.	Management of domestic and industrial wastewaters
	6.	Bio-drainage and wastewater disposal strategies
	7.	Management of adhoc projects approved by the council

3: STAFF POSITION

STAFF POSITION AT THE COOPERATING CENTERS

XI plan	Agra	Bapatla	Bikaner	Gang–awati	Hisar	Indore	Kanpur	Trichy	Total
Scientific	4	6	5	5	4	5	4	4	37
Technical	6	6	5	5	4	6	6	4	42
Administrative	1	1	1	1	1	1	1	1	08
Supporting	2	2	2	2	2	2	2	2	16
Total	13	15	13	13	11	14	13	11	103

POST WISE STAFF POSITION AS ON 31.03.2015

Name of the post	Coordinating Unit, Karnal	Centers							
		Indore	Kanpur	Bikaner	Agra	Bapatla	Ganga–wati	Tiruch–irapalli	Hisar
Project Coordinator	1	–	–	–	–	–	–	–	–
Soil Scientist	1(1)	–	–	1	–	1	–	–	–
Soil Chemist	-	1	1(1)	1	1(1)	–	–	1	1
Agronomist	1	–	–	–	–	–	–	–	–
Drainage Engineer	–	1	–	–	–	–	–	–	–
Soil Physicist	1	–	1	–	–	–	–	–	–
Jr. Soil Chemist	1(1)	1	–	1	1	1(1)	1	1	1
Jr. Soil Physicist	–	1	–	–	1	–	–	–	–
Jr. Drainage Eng.	–	–	–	1	–	1	1	–	–
Soil Water Eng.	–	–	–	–	–	1	1	1	1
Jr. Plant Physio.	–	–	1	–	–	–	–	–	–
Jr. Agronomist	-	–	–	1(1)	1	1	1	1	1
Jr. Soil Survey Officer	–	1	1	–	–	–	–	–	–
Tech. Officer	2	–	–	–	–	–	–	–	–
STA	–	2	3(3)	–	2	–	–	–	–
Overseer	–	–	1	–	–	–	–	–	–
Lab. Tech.	1	–	–	–	–	–	–	–	–
Tracer	--	–	–	–	–	–	–	–	–
Field Asstt.	–	1	–	1	2(1)	1	1	1	1
Fieldman	–	1	–	–	–	–	–	–	–
Lab. Asstt.	1(1)	1	1(1)	1	1	2	1	1	1
UDC	1(1)	1	1	1(1)	1	1	1	1	1
Jr. Steno.	1(1)	–	–	–	–	–	–	–	–
Jeep Driver	–	1	1	1	1	1	1(1)	1	1
Lab. Attendant	3(2)	1	1	1	1	1	1	1	1
Messenger	-	1	1	1	1	1	1	1	1

( ) Vacant position

STAFF POSITION AS ON 31. 03. 2015

Name of the post	No.	Name of incumbent	Date of joining	Date of leaving
Coordinating Unit, CSSRI, KARNAL				
Project Coordinator	1	Dr. S. K. Ambast	27.04.2012	21.01.2015
		Dr. D.K. Sharma(O/I)	22.01.2015	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	Sh. Brij Mohan	04.10.1988	31.01.2014
		Vacant		01.02.2014
		Sh. Anil Sharma	22.10.2011	Contd.
Technical Assistant	1	Sh. N.S. Ahlawat	08.06.2012	10.07.2013
		Sh. Maneesh Pandey	08.08.2013	Contd.
Sr. Technician	1	Sh. Mohinder Singh	03.07.2014	Contd.
Personal Assistant	1	Vacant	-	-
Lab. Attendent	1	Sh. Sukhbir Singh	27.01.2009	19.09.2013
		Sh. Raj Kumar	17.09.2013	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	Sh. 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	Mr. N.P. Pachauri (working against Field Assistant)		
		Vacant	-	-
Lab Assistant	1	Sh. Sarnam Singh	18.12.1989	Contd.
Driver	1	Sh. Ram Sevak (working against Jeep Driver)		
Lab. Attendant	1	Sh. Devi Singh (working against Lab. Attendent)		
Messenger	1	Sh. Kishan Singh	23.07.1980	Contd.
BAPATLA				
Pr. Scientist (SS) & Head	1	Dr. G.V. Lakshmi	01.10.2010	Contd.
Sr. Scientist (SS)	1	Smt. K. Hema	08.08.2012	Contd.
Jr. Chemist (SS)	2	Smt. M. Latha	28.07.2011	Contd.
		Dr. Sudha Rani	21.02.2014	Contd.
Scientist (Agronomy)	1	Mrs. K. Anny Mrudhula	10.12.2013	01.08.2014(Study Leave)
Scientist (SWE) –I	1	Sh. A. Sambaiah	06.02.2013	Contd.
Scientist (SWE) –II	1	Vacant	-	24.04.2008
Sr. Assistant	1	Sh. D. Bullaiah	02.09.2013	Contd.
		Sh. P. Rambabu	01.04.2011	04.07.2013
Lab. Assistant	3	Sh. S. Baba Vali	04.09.1990	Contd.
		Sh. S.K. Mastan Vali	01.03.2011	Contd.
		Sh. K. Venkateswarlu	01.02.2014	Contd.
		Sh. P. Venkata Seshu	29.01.2013	01.02.2014
Field Assistant	2	Sh. Syed Khasim	19.05.2005	Contd.
		Sh. Venkata Rao	01.01.2012	Contd.
Lab Attendent	1	Sh. D.V. Siva Rao	16.07.1992	Contd.
Driver	1	Sh. D.V. Brahmam	13.09.2007	Contd.
Messenger	1	Sh. A. Mark	29.12.1995	Contd.

BIKANER

Chief Scientist & OIC	1	Dr. I.J. Gulati	24.07.2012	Contd.
Soil Chemist	1	Vacant	-	30.04.2009
Jr. Soil Chemist	1	Dr. B.L. Kumawat	03.04.2010	Contd.
Jr. Agronomist	1	Dr. N.S.Yadava	08.07.2011	Contd.
Jr. Drainage Engineer	1	Er. A.K. Singh	10.09.2001	Contd.
Technical Assistant	2	Dr. Deepak Gupta	04.08.2010	Contd.
		Vacant		31.03.2011
Field Assistant	1	Sh. B.C. Kumawat	18.07.2001	-
		Sh. G.S. Pareek	01.06.2013	Contd.
UDC	1	Mr. Manohar Singh	02.04.2011	Contd.
Lab. Assistant	1	Sh. S.K.Bazad	14.02.1994	Contd.
Driver	1	Sh. Man Singh	03.08.1994	30.05.2013
		Vacant		-
Lab. Attendant	1	Sh. Keshu Ram	17.07.1995	Contd.
Messenger	1	Sh. Ganesh Ram	25.03.1994	Contd.

GANGAWATI

Chief Scientist & OIC Soil Scientist	1	Dr. Vishwanath J.	04.01.12	Contd.
Soil Scientist		Vacant	30.08.2011	-
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.	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	Contd
		Vacant	-	-
Messenger	1	Mr. Doddabaappa S.	01.02.1992	Contd.

HISAR

Soil Scientist & OIC	1	Dr. S.K. Sharma	08.08.2002	Contd.
Soil Chemist	1	Dr. Ramparkash	24.05.2011	Contd.
Soil Water Engineer	1	Dr. Sanjay Kumar	10.06.1997	18.05.2013
		Er. Krishan Kumar	18.05.2013	Contd.
Agronomist	1	Dr. Satyavan	11.03.1997	Contd.
Sr. Technical Assistant	2	Dr. Rajpaul Yadav	06.06.2011	25.08.2014
		Vacant	-	26.08.2014
		Vacant	-	31.03.2010
Field Assistant	1	Sh. Jagdish Chander	03.02.2001	Contd.
Lab. Assistant	1	Sh. Dhan Singh	02.03.2009	Contd.
LDC	1	Smt. Poonam Pahuja	22.09.1999	12.09.2013
		Vacant		13.09.2013
Lab. Attendant	1	Sh. Surat Singh	25.05.2010	Contd.
Messenger	1	Sh. Desh Raj	27.07.2010	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	Contd.
Jr. Soil Survey Officer	1	Sh. B. B. Parmar	02.09.2009	Contd.
Jr. Soil Chemist	1	Vacant	-	22.07.2010

Jr. Soil Physicist	1	Dr. (Mrs) S.P.K.Unni	15.09.2003	Contd.
Technical Assistant	2	Sh. S.C. Tiwari	04.03.1989	Contd.
		Sh. N.S. Tomar *	04.04.1996	Contd.
UDC	1	Mr. Dinesh Sharma	30.05.2006	Contd.
Field Assistant	1	Sh. T.L. Dhamne	01.07.2000	Contd.
Field man	1	Sh. S.R. Hirve	25.08.2003	Contd.
Lab. Assistant	1	Ms. R. Ansari	16.11.1995	Contd.
Jeep Driver	1	Sh. Dinesh Mandloi	02.02.2009	Contd.
Lab. Attendant	1	Sh. D. S. Baghel	01.04.2011	Contd.
Messenger	1	Mrs. Rama Gupta	28.08.2003	Contd.

* Agriculture Extension Officer posted against the post of Technical Assistant

KANPUR

Soil Chemist & OIC	1	Dr. Ravendra Kumar	09.05.2008	Contd.
Soil Physicist	1	Dr. B.N.Tripathi	09.03.2011	-
		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.Param Hans	15.11.2010	Contd.
Lab. Assistant	1	Sh. P.S.Katiyar	01.08.2004	Contd.
Driver	1	Sh. Vijay Kumar	15.10.2009	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. A. Saravanan	01.11.2011	21.10.2013
		Dr. P. Balasubramaniam	01.11.2013	Contd.
Jr. Soil Chemist	1	Dr. L. Chithra	27.05.2008	Contd.
Jr. Agronomist	1	Dr. S. Avudaithai	01.08.2011	15.04.2013
		Dr. P. Devgai	17.04.2013	30.08.2013
		Dr. S. Avudainayagam	02.09.2013	Contd.
Jr. Soil Water Engineer		Dr. M. Baskar	09.05.2008	Contd.
Sr. Technical Assistant	2	Sh. K. Karikalan	14.12.2000	13.06.2013
		Sh. Palanisamy	14.06.2013	08.06.2014
		Sh. K. Karikalan	09.06.2014	Contd.
		Sh. R. Mutharasan	09.06.2011	Contd.
Field Assistant	1	Sh. U. Jossephraj	01.04.2011	Contd.
Lab. Assistant	1	Sh. P. Sakthivel	01.07.2003	31.05.2013
		Sh. A. Palanivel	06.05.2013	Contd.
Lab. Attendant	1	Sh. S. Ponnan	21.08.1996	Contd.
UDC	1	Sh. C. Meenatchi	22.10.2008	Contd.
Messenger	1	Sh. V. Palaniyandi	01.04.1995	Contd.

4: WEATHER DATA (2012-2014)

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				
			2012-13			
April 2012	-	-	61.6	009.3	6.6	14.1
May	-	-	40.2	-	11.2	16.8
June	38.5	26.1	44.6	007.2	10.5	17.1
July	-	-	78.2	199.5	5.5	16.5
August	-	-	90.9	325.7	3.2	16.4
September	-	-	85.9	149.3	3.0	16.3
October	-	-	76.0	-	4.2	16.3
November	-	-	85.9	-	1.9	17.3
December	-	-	77.1	-	1.6	17.4
January 2013	21.5	05.9	86.4	012.9	1.4	17.7
February	24.4	10.8	89.2	039.3	2.1	17.2
March	33.6	15.5	80.0	005.5	3.9	17.8
			2013-14			
April 2013	38.4	19.2	57.5	-	7.0	17.0
May	-	-	43.8	002.8	8.0	16.7
June	-	-	68.0	087.1	6.0	17.2
July	34.5	26.8	81.1	302.1	3.5	16.8
August	33.7	26.1	89.1	356.3	4.4	15.9
September	36.1	24.7	82.1	129.8	4.7	16.2
October	32.5	21.4	72.7	028.4	3.2	16.4
November	28.7	12.5	59.6	-	2.2	16.4
December	24.3	01.9	63.6	013.5	1.5	16.6
January 2014	18.2	08.2	81.7	046.3	1.9	16.6
February	23.0	10.6	71.0	050.8	1.8	16.5
March	31.2	15.1	55.3	014.2	3.7	16.5

BAPATLA

Latitude - 15° 54’ N Longitude - 80° 28’ E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Decennial mean rainfall (mm)
	Maximum	Minimum			
			2012-2013		
April 2012	-	-	-	-	-
May	-	-	-	-	-
June	39.4	37.5	58.0	077.9	111.2
July	34.6	25.4	72.5	126.6	170.0
August	35.1	25.4	71.5	086.6	148.6
September	34.4	25.5	76.5	186.0	211.8
October	32.4	23.5	78.2	155.7	185.1
November	30.4	20.8	79.5	265.8	102.0
December	30.2	19.2	80.0	000.0	033.3
January, 2013	30.7	18.7	79.0	000.0	013.1
February	31.2	19.4	76.0	069.4	023.1
March	32.9	21.5	75.0	000.0	012.6
			2013-2014		
April 2013	34.7	26.3	74.5	006.9	020.7
May	38.7	28.5	69.0	036.7	035.2
June	37.2	26.1	64.0	125.3	112.0
July	33.0	25.1	72.5	193.9	170.0
August	33.6	25.1	72.5	196.1	154.2
September	33.2	24.7	81.5	335.2	230.3
October	32.0	24.5	87.0	497.9	216.8
November	30.7	21.8	84.0	062.2	106.8
December	29.9	17.9	78.5	022.8	020.9
January 2014	29.8	18.2	80.0	000.0	012.8
February	30.3	18.7	75.0	003.3	023.4
March	32.6	21.5	72.5	000.0	012.4

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			
2012-2013							
April 2012	37.1	21.6	53.0	19.0	000.0	6.6	7.9
May	41.5	25.1	45.0	15.0	065.8	8.0	10.2
June	41.6	28.9	560	22.0	021.4	12.8	12.3
July	40.6	29.5	58.0	30.0	000.0	11.8	11.0
August	35.4	26.0	79.0	50.0	105.8	8.4	5.7
September	34.7	24.2	78.0	48.0	069.0	5.7	4.3
October	34.7	16.6	54.8	22.7	000.0	3.9	5.0
November	30.1	10.1	59.0	20.0	000.0	2.9	2.7
December	24.1	10.1	59.0	20.0	0.000	3.0	2.0
January 2013	22.1	05.4	72.6	25.5	001.0	3.5	2.3
February	21.7	08.5	71.3	30.1	012.4	4.8	2.8
March	32.1	13.1	66.2	18.9	005.4	5.3	5.3
2013-2014							
April 2013	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-
June	-	-	-	-	-	-	-
July	38.2	24.5	74.7	49.0	078.9	10.3	9.6
August	35.6	22.7	82.9	53.0	117.7	8.0	7.5
September	36.4	24	72.0	38.4	006.0	7.4	9.6
October	35.1	18.9	68.3	24.3	001.0	4.7	8.4
November	28.9	10.6	62.0	30.5	000.0	3.7	5.6
December	24.4	10.7	65.0	37.9	000.0	3.4	4.8
January 2014	20.3	4.9	70.2	29.2	000.0	4.2	1.4
February	22.2	8.2	60.2	37.7	000.0	5.3	3.7
March	29.9	14.6	68.0	28.2	000.0	6.8	6.5

GANGAWATI

Latitude – 15° 00’N Longitude – 76° 00’ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation* (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2012-2013			
April 2012	37.33	20.21	74.0	42.0	017.7	-
May	36.87	23.19	83.0	73.0	000.0	-
June	36.45	26.60	73.0	73.0	008.2	-
July	32.90	23.70	81.0	73.0	029.5	-
August	31.80	22.70	87.0	82.0	078.0	-
September	30.80	22.05	84.0	84.0	078.7	-
October	30.90	20.70	74.0	65.0	063.0	-
November	28.80	17.80	71.0	60.0	097.0	-
December	30.50	15.29	68.0	55.0	000.0	-
January 2013	31.20	16.90	65.0	50.0	000.0	-
February	31.70	16.76	60.0	49.0	000.0	-
March	34.60	15.90	54.0	35.0	000.0	-
			2013-2014			
April 2013	36.9	17.6	59.0	40.0	005.5	-
May	38.0	20.7	74.0	47.0	102.0	-
June	32.5	20.3	81.0	65.0	096.5	-
July	29.2	18.8	77.0	71.0	034.5	-
August	29.7	18.3	74.0	65.0	022.5	-
September	30.1	18.0	79.0	66.0	118.5	-
October	29.8	17.1	73.0	67.0	108.5	-
November	29.2	14.7	73.0	53.0	002.0	-
December	29.0	12.2	61.0	43.0	000.0	-
January 2014	29.7	15.1	72.0	46.0	000.0	-
February	30.5	15.6	67.0	44.0	000.0	-
March	33.5	17.7	62.0	42.0	003.0	-

** Data not available*

HISAR

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

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2012-2013			
April 2012	34.2	18.0	73.0	38.0	033.3	5.6
May	39.9	22.3	51.0	24.0	029.8	8.7
June	41.6	27.8	53.0	27.0	026.5	11.1
July	38.1	28.0	76.0	51.0	076.6	7.8
August	33.5	26.1	90.0	69.0	282.5	4.6
September	33.5	23.7	87.0	57.0	032.9	4.3
October	32.4	15.1	85.0	37.0	005.4	3.6
November	27.4	9.2	92.0	38.0	000.0	1.9
December	20.8	6.0	93.0	58.0	005.5	2.1
January 2013	17.6	4.2	95.0	58.0	043.0	1.4
February	21.5	8.9	96.0	60.0	032.7	2.1
March	28.4	12.0	92.0	47.0	031.1	3.4
			2013-2014			
April 2013	35.0	17.2	68.0	27.0	023.0	5.9
May	41.5	22.7	48.0	17.0	000.0	9.2
June	39.3	27.2	69.0	44.0	097.3	7.9
July	36.6	26.9	82.0	59.0	159.3	5.7
August	33.3	25.9	90.0	71.0	288.2	4.4
September	34.4	23.9	84.0	55.0	140.4	4.7
October	31.9	20.1	91.0	48.0	006.5	2.8
November	26.6	10.4	92.0	41.0	009.4	2.0
December	21.8	7.0	94.0	51.0	000.0	1.2
January 2014	18.0	5.6	97.0	69.0	002.0	1.0
February	20.8	7.6	95.0	67.0	012.5	1.7
March	26.3	12.2	90.0	55.0	047.0	3.0

INDORE

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

Months	Temperature* (°C)		Relative humidity* (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2012-13			
April 2012	-	-	-	-	000.0	354.6
May	-	-	-	-	026.8	435.0
June	-	-	-	-	019.2	376.4
July	-	-	-	-	561.0	089.5
August	-	-	-	-	178.6	042.5
September	-	-	-	-	284.4	046.5
October	-	-	-	-	000.0	091.0
November	-	-	-	-	000.0	072.0
December	-	-	-	-	000.0	061.0
January 2013	-	-	-	-	000.0	061.5
February	-	-	-	-	056.2	054.0
March	-	-	-	-	000.0	158.0
			2013-2014			
April 2013	-	-	-	-	000.0	327.0
May	-	-	-	-	034.1	462.0
June	-	-	-	-	360.2	134.0
July	-	-	-	-	608.3	036.0
August	-	-	-	-	315.8	037.5
September	-	-	-	-	171.2	060.5
October	-	-	-	-	035.5	057.5
November	-	-	-	-	000.0	070.0
December	-	-	-	-	000.0	074.0
January 2014	-	-	-	-	014.8	073.5
February	-	-	-	-	020.9	125.0
March	-	-	-	-	000.0	275.0

** Data not available*

KANPUR

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

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
2012-2013						
April 2012	37.70	19.50	61.5	29.9	006.6	8.1
May	41.60	22.20	45.2	23.0	003.0	10.0
June	42.60	28.75	48.7	28.0	003.5	11.4
July	33.50	24.28	84.7	69.8	406.5	6.2
August	32.42	25.41	89.4	75.2	125.7	8.4
September	31.65	24.10	88.6	67.5	114.9	3.8
October	31.80	17.62	86.7	41.3	000.0	4.1
November	28.26	10.44	87.5	40.5	000.0	3.0
December	22.20	07.57	88.4	55.1	000.0	2.1
January 2013	19.40	07.08	92.7	62.0	004.6	0.9
February	23.30	10.32	91.3	64.4	121.2	1.4
March	30.54	14.20	87.4	45.5	001.9	2.8
2013-2014						
April 2013	37.2	18.8	56.2	28.6	000.0	4.8
May	41.2	23.7	54.8	28.0	000.0	8.4
June	34.8	24.3	84.1	67.9	359.8	6.3
July	32.6	32.6	91.2	78.8	326.1	4.6
August	32.2	23.6	91.7	79.8	171.3	1.0
September	33.5	22.5	83.7	67.1	095.8	3.7
October	30.7	18.2	88.8	58.8	143.2	3.3
November	27.3	09.3	88.3	42.9	000.0	2.6
December	23.4	07.2	90.2	49.4	002.0	1.7
January 2014	18.0	07.2	95.2	73.6	105.8	1.6
February	22.1	07.9	90.5	63.0	029.8	1.5
March	29.4	12.3	83.1	29.4	017.6	2.4

KARNAL

Latitude – 29° 43’ N Longitude – 76° 58’ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2012-2013			
April 2012	34.5	17.8	72.0	27.0	024.3	6.9
May	39.4	22.6	51.0	18.0	000.4	10.6
June	40.8	26.7	63.0	35.0	000.0	12.3
July	34.6	26.9	84.0	65.0	035.0	6.8
August	31.6	25.4	92.0	76.0	303.2	3.6
September	32.0	23.4	90.0	66.0	094.5	3.6
October	30.9	15.2	95.0	45.0	000.0	3.1
November	27.3	10.0	92.0	36.0	002.0	2.0
December	20.4	07.1	91.0	54.0	011.2	1.0
January 2013	16.8	04.8	96.0	63.0	064.4	1.4
February	20.7	09.1	97.0	64.0	116.4	1.9
March	27.5	12.7	90.0	49.0	005.8	3.2
			2013-2014			
April 2013	35.2	17.2	68.0	23.0	005.2	6.7
May	40.4	22.2	54.0	22.0	002.0	9.2
June	35.6	26.0	80.0	54.0	156.6	6.2
July	33.6	26.6	87.0	68.0	215.9	4.6
August	32.2	25.4	91.0	75.0	275.3	3.8
September	33.0	23.4	90.0	64.0	013.0	3.9
October	31.5	19.4	92.0	52.0	019.5	3.0
November	26.9	10.0	86.0	33.0	000.0	2.5
December	21.1	07.6	93.0	54.0	001.8	1.5
January 2014	17.1	06.7	98.0	68.0	065.8	1.1
February	20.0	07.9	95.0	58.0	049.2	1.7
March	25.5	12.2	88.0	51.0	051.6	2.7

TIRUCHIRAPPALLI

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

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2012-2013			
April 2012	-	-	-	-	-	-
May	-	-	-	-	-	-
June	34.5	24.4	93.3	90.4	000.0	8.0
July	39.8	31.0	96.1	82.0	003.4	7.3
August	44.4	32.2	78.8	71.4	078.8	7.5
September	43.3	27.4	86.5	68.2	071.2	7.6
October	34.4	25.6	86.2	80.5	131.5	8.0
November	32.7	23.5	90.5	85.3	077.0	8.5
December	29.2	22.4	86.7	83.9	002.5	7.9
January 2013	32.3	20.7	92.0	84.6	000.0	8.2
February	37.0	22.9	89.7	85.8	000.0	5.9
March	37.0	22.8	89.7	90.6	000.0	7.5
			2013-2014			
April 2013	34.5	24.0	81.8	61.0	-	7.7
May	-	-	-	-	-	-
June	46.9	26.1	88.7	83.3	-	8.3
July	38.5	27.8	88.9	85.8	-	7.9
August	36.9	27.6	86.2	81.6	097.7	6.8
September	34.0	24.9	86.8	74.1	146.9	8.6
October	35.2	25.6	85.5	81.4	174.0	8.0
November	37.2	26.9	85.4	83.5	075.2	8.3
December	33.2	25.1	85.4	82.2	028.3	8.1
January 2014	32.2	21.1	92.7	84.1	0.000	7.9
February	32.5	22.5	93.8	85.9	013.0	8.9
March	34.4	23.0	95.4	68.3	000.0	8.3

5: LIST OF PUBLICATIONS (2012-14)

AGRA

AGRA

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6: FINANCE

The Twelfth Five Year Plan (2012–2017) was sanctioned by the Council vide letter No. NRM-24-4/2013-I-II dated 28-02-2014 with an outlay of Rs 4638.67 lakhs (ICAR Share Rs 3675.00 lakh). The budget head and center wise statement of expenditure for 2012-13 and 2013–14 is given below:

AGRA

Budget head	2012-13		2013-14	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	6000000	5492368	6000000	8649026
TA & POL	100000	70501	100000	82381
Contingencies				
Recurring	500000	497624	400000	392338
Non-recurring	0	0	0	0
Works	0	0	0	0
Total	**6600000**	**6000000**	**6500000**	**9123745**

BAPATLA

Budget head	Expenditure (ICAR share Rs. in lakhs)	
	2012-13	2013-14
Pay & Allowances	6346702	7119420
TA & POL	149662	131705
Contingencies		
Recurring	598982	532542
Non-recurring	0	0
Total	7095346	7783667
ORP		
TA	58986	130683
Rec.contingencies	267042	264026
Total	326028	394709
Grand Total	**7421374**	**8178376**

BIKANER

Budget head	2012-13		2013-14	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	8000000	7642686	8000000	8826962
TA & POL	200000	85288	200000	119305
Contingencies				
Recurring	540000	441229	667000	491927
Non-recurring	0	0	0	0
Total	**8740000**	**8169273**	**8867000**	**9438194**
ICAR share	**6555000**	**6126955**	**6650000**	**7078645**

GANGAWATI

Budget head	2012-13		2013-14	
	Sanctioned ICAR share	Expenditure ICAR share	Sanctioned ICAR share	Expenditure ICAR share
Pay & Allowances	4115000	2909178	3500000	3391856
TA & POL	150000	128765	150000	102883
Contingencies				
Recurring	500000	465186	500000	485753
Non-recur.	0	0	0	0
Works	0	0	0	0
Total	**4765000**	**3503129**	**4150000**	**3980492**

HISAR

Budget head	2012-13		2013-14	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	6403000	6259458	6539000	6242531
TA & POL	20000	107265	200000	181250
Contingencies				
Recurring+works	666600	449060	666500	554395
Non-recurring	0	0	0	0
Total	**7269600**	**6815783**	**7405500**	**6978176**
ICAR share	5452200	5111837	5554125	5233632

INDORE

Budget head	2012-13		2013-14	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	6000000	6365998	6000000	6995332
TA & POL	150000	86777	150000	91556
Contingencies				
Recurring	500000	499482	500000	499234
Non-recurring	0	0	0	0
Total	**6650000**	**6952257**	**6650000**	**7586121**

KANPUR

Budget head	2012-13		2013-14	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	4000000	3639551	4000000	5023765
TA & POL	150000	71433	150000	118125
Contingencies				
Recurring	500000	262879	500000	475739
Non-recurring	0	0	0	0
Total	**4650000**	**3973863**	**4650000**	**5617629**

KARNAL

Budget head	2012-13		2013-14	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	0	0	0	0
TA & POL	275000	275000	200000	270000
Contingencies				
Recurring	125000	124000	500000	438000
NRC (Capital)	300000	300000	300000	291000
Total	**700000**	**699000**	**1000000**	**999000**

TIRUCHIRAPPALLI

Budget head	2012-13		2013-14	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	7333300	6767817	7333300	7131955
TA & POL	200000	199872	200000	98296
Contingencies				
Recurring	606600	666600	606600	1473835
Non-recurring	0	0	0	0
Total	**8139900**	**7634289**	**8139900**	**8704086**
ICAR share	**6104925**	**5725716**	**6104925**	**6528064**

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