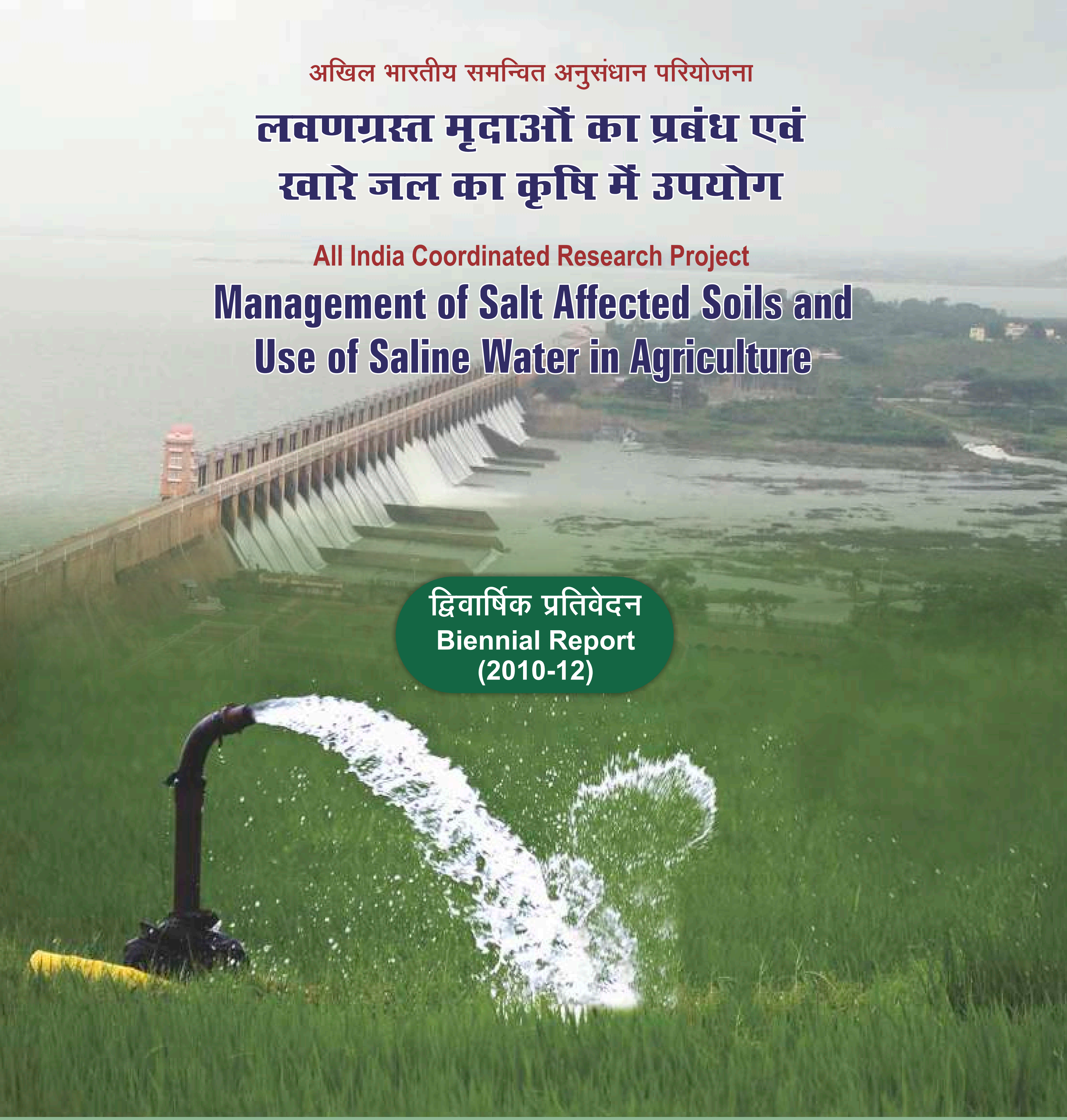
अखिल भारतीय समन्वित अनुसंधान परियोजना

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

(2010-12)

परियोजना समन्वयन इकाई

केन्द्रीय मृदा लवणता अनुसंधान संस्थान

करनाल – 132001, हरियाणा (भारत)

Project Coordinating Unit

Central Soil Salinity Research Institute

Karnal - 132001, Haryana (India)

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

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

द्विवार्षिक प्रतिवेदन
Biennial Report
2010-12

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2. Regional Research Station, Acharya N.G. Ranga Agricultural University
   Bapatla - 522 101 (Andhra Pradesh)
3. S.K. Rajasthan Agricultural University, Bikaner - 334 002 (Rajasthan)
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परियोजना समन्वयन इकाई
केन्द्रीय मृदा लवणता अनुसंधान संस्थान, करनाल - 132001 (भारत)

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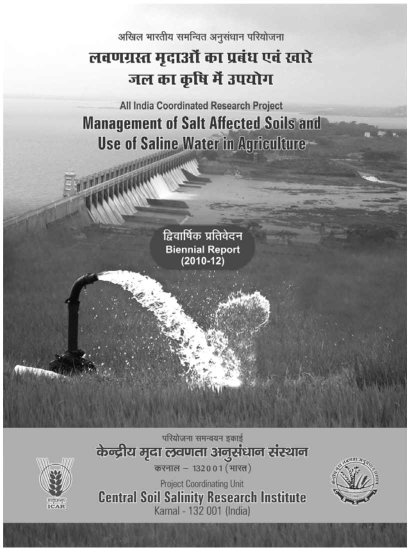

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FOREWORD

The issue of food security has been identified as a major objective to be pursued by the global community in the Rome Declaration on World Food Security and the World Food Summit Plan of Action in 1996. The projected growth in the world's population to 9.2 billion by 2050 adds an extra challenge for food security. Burgeoning populations mean more demand for food, water and land at a time when the natural resource base for agriculture is being degraded, large areas of farmland are being diverted from food crop production, and climate change threatens to further reduce agriculturally viable land. Indian agriculture and allied sectors account for 14% of the GDP in 2011-12 and about 50% of the total workforce is engaged in it. India has achieved food security at the national level but food security at the individual or the family level has not been adequate. Further, the availability of natural resources like water and land per capita at national level is declining. In the past, bulk of the allocations during different Plans has gone to irrigation and agriculture, which had significantly contributed to the Green Revolution. Water is the most-scarce natural resource and despite a viable national water policy being in place, water continues to be the most misused commodity. Further, losses in conveyance from source to the field and low water use efficiency at farm level has resulted in widespread waterlogging and salinization problems. The quality of water, both surface and underground, is increasingly degrading due to unscientific disposal of industrial pollutants and municipal effluents. Under such scenario, use of salt affected lands and naturally occurring saline/alkali and marginal quality waters can be seen as an opportunity to increase in production and productivity. Thus, knowledge driven, well tested, precision technologies are essential for achieving sustained food and nutritional security through salty lands and waters.

It is a matter of great satisfaction that the 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 1.85 million ha salt affected lands could be reclaimed adding about 12-15 million tonnes of food grains annually to the food grain basket of the nation. Recent initiatives of these organizations in the fields of digital resource inventories, alternate sources of land reclamation, salt tolerance of crops, efficient use of water etc would prove to be highly useful to increase production, enhance profitability, improve soil and water quality under climate change scenario.

The current report contains the research results of the biennium 2010-12 carried out at coordinating unit and 8 research centres covering arid, semiarid, and coastal irrigated and rain fed ecologies on alluvial, Vertisols and coastal waterlogged saline/alkali soils. The QRT chaired by Dr. S. S. Khanna, former Sr. Advisor to Planning Commission has reviewed the progress of last five years for CSSRI as well as the AICRP centres. The team has already visited the centres in this connection. 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 an innovative programme that would be able to address the current challenges of soil quality, ground water quality, declining ground water, dry land salinity, wastewater use, water logging and subsurface drainage, impact of climatic change on salinity scenario and use of remote sensing and geographical information system for resource mapping.

At the end, I record my appreciation and congratulate Dr. S.K. Ambast, Project Coordinator, Dr. R.L. Meena, Senior Scientist, Dr. B.L. Meena, Scientist and all staff of the PC unit for their concerted efforts in coordinating the activities during the last two years and in bringing out the biennial report. I have special words of appreciation to Dr. S.K. Gupta, Ex-Project Coordinator for his contribution in streamlining and coordinating the project activities. 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.

(D.K. Sharma)
Director

PREFACE

Indian agriculture has made a phenomenal growth in last four decades. Although the agricultural share in national GDP and employment has reduced from nearly 51 to 14 per cent and 72 to 52 per cent, respectively during 1951 to 2008, this is mainly owing to the expansion of industrial and service sectors. The increase in the domestic agricultural production has also made a visible impact on the national food and nutritional security but poverty and undernourishment still continue to afflict more than one fifth of our population. The Indian agriculture is dominated by small and marginal farmers with agricultural land to population ratio of about 0.3 compared to 11 ha/person in the developed countries. With a global share of 2.3% of land, 4.2% of water and 17% of population, the per capita availability of resources in India is 4-6 times less than the world average. The pressure on the limited natural resources is getting further intensified with diversion of agricultural resources to non-agricultural sectors. Our burgeoning population and rise in income level have led to increase in demand not only for basic food requirements but also for value-added food products. The increased food production has to be achieved from the limited or diminishing resources and in this scenario the role of science and technology for enhancing productivity of salt affected land and water has become crucial. In this context, several pioneering accomplishments have been made by Central Soil Salinity Research Institute and AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture that helped to revert back the productivity of barren salt affected lands and facilitated the use of saline/alkali waters for irrigation.

The AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture was established in 1972 and is being operated at 8 centers covering 7 states under the ambit of Central Soil Salinity Research Institute, Karnal. The multi-disciplinary teams of scientists at each center are engaged in developing technologies to solve local problems as well as to develop regional and national guidelines on management of salt affected soils and use of saline water in agriculture. The current report highlights the salient achievements made under the project during the biennium 2010-12. Survey of salt affected soils, characterization of ground water quality, alternate sources of land reclamation, controlled subsurface drainage, alternate land management, salt tolerance of crops, ground water quality improvement, reclamation of aqua ponds and micro-irrigation for efficient water use are some of the technologies and processes that have been included besides providing information on publications made by the scientists, budget utilized, staff strength etc.

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. A.K. Sikka, DDG (NRM), ICAR and Dr. A.K. Singh and Dr. M.M. Pandey, Ex-DDGs (NRM), ICAR for guiding the technical program and providing unstinted support to the project.

Heartfelt thanks are due to Dr. B. Mohan Kumar, ADG (A&AF) for his excellent support to the project and to Dr. P.P. Biswas and Dr. Rajbir Singh for their cooperation in all spheres. It is my bounden duty to thank Dr. D.K. Sharma, Director, CSSRI, Karnal for providing eternal support to the project as well as ensuring greater interaction between the Institute and AICRP Centers.

I wish to extend my sincere thanks to Dr. S.K. Gupta, Ex-PC for his contribution to project activities and colleagues at AICRP centers Dr. R.B. Singh, Dr. (Mrs.) G.V. Lakshmi, Dr. B.L. Kumawat/Dr. I.J. Gulati, Dr. S.L. Budihal/Dr. Vishwanath Jowkin., Dr. S.K. Sharma, Dr U.R. Khandkar, Dr Ravindra Kumar and Dr. M. Sheik Dawood/Dr. A. Saravanan for undertaking research programs and compiling centers report in time. The excellent cooperation received from Dr. R.L. Meena, Dr. B.L. Meena and Sh. A.K. Sharma for helping me in smooth running of the project and compilation and editing of the report deserves special appreciation. The staff at coordinating unit Sh. Brij Mohan, Sh. N.S. Ahlawat and Sh. Sukhbir Singh has extended willing support for project operations is thankfully acknowledged.

(S.K. Ambast)
Project Coordinator

CONTENTS

SUMMARY OF RESEARCH ACHIEVEMENTS

1. Resource Mapping and Spatio-Temporal Monitoring

Survey, characterization and mapping of ground water for irrigation – All centres

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

Andhra Pradesh	: Guntur, Krishna, Prakasam
Haryana	: Rohtak, Jhajjar
Karnataka	: Gadag, Dharwad
Madhya Pradesh	: Neemuch, Hoshangabad
Rajasthan	: Sikar
Tamil Nadu	: Namakkal
Uttar Pradesh	: Etawah, Raibareli

Delineation and mapping of salt affected soils using RS and GIS – All centres

Remote sensing and geographical information system have been found powerful tools to delineate and map salt affected soils in conjunction with limited ground truth. It is an on-going activity aiming at classifying soils according to the nature of problem so as to help in deciding the nature of interventions needed at a location. Soil mapping of the following districts was done:

Andhra Pradesh	: Guntur, Krishna, Nellore, Prakasam
Madhya Pradesh	: Mandsaur, Neemuch

Monitoring of ground water quality/soil properties at benchmark sites (Bapatla)

EC of the tube well water varied from 0.8 to 12.3 dS/m during 2010-11 and 1.0 to 9.1 dS/m during 2011-12. The EC remained more or less same at other locations and EC_e of the soils at all places varied in accordance with the variation in tube well waters. The soil SAR of Nidubrolu-I and II reached unsafe levels >10 since last six years. The variation in pH at all the sites is marginal.

2. Management of Salt Affected Soils

Reclamation of abandoned aqua ponds (Bapatla)

Rice grain yields at five locations in Gokarnamatam and Adavuladeevi ranged from 4.1 to 5.1 t/ha during 2010-11 and 4.0 to 5.7 t/ha during 2011-12. During both years the EC of the soils decreased from 54.7 to 24.5 dS/m and 20.6 to 9.6 dS/m respectively.

Prediction of long-term salinity and water table fluctuations using simulation models (Bapatla)

The DRAINMOD model was calibrated by using drain flow data, yield data and salinity levels. After calibration, it was validated by comparing the simulated and observed drain flow, yield data and salinity values over the period of 7 years.

Investigations on micro-irrigation for vegetables for saline soils (Gangawati)

Drip irrigation at 1.2 ET recorded highest yield (16.6 t/ha) of cabbage followed by 1.4 ET (16.3 t/ha), 1.0 ET (15.2 t/ha), 0.8 ET (13.9 t/ha), surface irrigation at 1.2 ET (13.0 t/ha), drip irrigation at 0.6 ET (12.0 t/ha), surface irrigation at 1.0 ET (11.5 t/ha), and surface irrigation at 0.8 ET level (10.0 t/ha). Among salinity levels, significantly higher yield (17.6 t/ha) was observed in the EC_e <4 dS/m followed by EC_e 4-8 dS/m (13.8 t/ha) and least (9.25 t/ha) in EC_e 8-12 dS/m. The highest WP (63.2 kg/ha-mm) was observed at 0.6 ET with drip and lowest (41.6 kg/ha-mm) at 1.2 ET with flood irrigation. Among salinity levels, the highest (67.2 kg/ha-mm) and lowest (32 kg/ha-mm) WP were observed in <4 and 8-12 dS/m, respectively.

Response of cotton to drip irrigation in saline soils under conservation agriculture (Gangawati)

A field study to optimize micro-irrigation for cotton in saline soils (6-8 dS/m) under conservation agriculture was carried out and results revealed that kapas yield was significantly higher in drip irrigation at 1.2 ET (3.00 t/ha) followed by drip irrigation at 1.0 ET (2.79 t/ha), drip irrigation at 0.8 ET (2.63 t/ha) and least in flood irrigation (2.43 t/ha). Water productivity was significantly higher (0.84 kg/m^3) in drip irrigation at 0.8 ET followed by (0.72 kg/m^3) at 1.0 ET, (0.64 kg/m^3) at 1.2 ET and least in flood irrigation (0.45 kg/m^3). Mulching produced significantly higher yield (2.91 t/ha) as compared to no mulch (2.52 t/ha). Significantly higher water productivity was obtained in mulching (0.71 kg/m^3) as compared to control (0.61 kg/m^3).

Monitoring salinity hazards in vegetables under drip fertigation with marginally saline water in Vertisols (Indore)

The experiment was carried out on farmer field in village Bagda Khurd, Khargone district. Soil EC increases with increase in number of irrigation in all crops. Salt accumulation was more with increased distance from drippers in all crops. Growing of horticultural crops with drip fertigation of marginally saline water in Vertisols is feasible and economically viable option. The B:C ratio of bottle gourd, tomato (Abhinav), onion and water melon grown during 2010-11 was 1.94, 2.00, 1.42 and 3.20 respectively. The WP of bottle gourd, tomato, onion and water melon were 450, 490, 470 and 600 kg/ha-cm, respectively.

Response of sunflower/cotton to chemical/organic amendments in alkali Vertisols (Gangawati)

Application of FYM 10 t/ha with 50% GR recorded significantly higher seed yield (1.79 t/ha) of sunflower as compared to 1.52, 1.48 and 1.29 t/ha with 50 and 75% GR alone and control respectively. The EC was lowest (1.50 dS/m) with application of FYM 10 t/ha with 75% GR followed by FYM 10 t/ha with 50% GR (1.53 dS/m). Application of FYM 10 t/ha with 75% GR recorded lower soil pH (8.3) and ESP (15.1%). Application of FYM 10t/ha with 75% GR recorded significantly higher kapas yield (1.44 t/ha) as compared to control (0.99 t/ha) and gypsum 50 and 75% GR alone (1.18 and 1.20 t/ha respectively). The EC (1.23 dS/m) and pH (8.3) was lowest with application of FYM 10 t/ha with 75% of GR. ESP was significantly lower with FYM 10 t/ha with 75% of GR (14.9%) indicating improvement in soil physical properties.

Land and rain water management strategies for cultivation in rainfed alkali soils of Northern Karnataka (Gangawati)

The experiment was conducted on farmer's field at village Kyarihal, Gangawati. Significant higher seed yield (1.0 t/ha) was observed in the tied ridges with 75% gypsum application, followed by tied ridges with 50% gypsum application (1.0 t/ha), compartment bunding with 75% gypsum (0.9 t/ha), deep ploughing with 75% gypsum (0.87 t/ha), compartment bunding with 50% gypsum (0.86 t/ha), deep ploughing with 50% gypsum (0.8 t/ha), flat bed with 75% gypsum (0.7 t/ha), flat bed with 50% gypsum (0.7 t/ha) and least in control (flat bed without gypsum) (0.6 t/ha).

Effect of long-term application of organic/green manures on sodic Vertisols (Indore)

The experiment was initiated in 2005-06 to observe the effect of green manuring on soil properties and crop yield in an alkali soil. Four treatments (control, FYM 10 t/ha, sunhemp and dhaincha green manuring crops) were tested at four soil ESP levels (25, 35, 45 and 50). The yield of both crops decreased with increased soil ESP during both the years. The maximum yield of paddy (2.03 and 2.06 t/ha) and wheat (2.51 and 3.39 t/ha) was recorded at soil ESP 25 during 2010-11 and 2011-12 respectively. Among various treatments incorporation of *dhaincha* gave highest yield and lowest was observed in control plot for both the crops.

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

The irrigation is yet to commence in Narmada Sagar command area. The data on area and productivity of *kharif* and *rabi* crops were collected for the pre canal irrigation period of Khandawa district. The water table in open wells in head reaches of Indira Sagar Command were also recorded and procured for the pre canal irrigation period. The soil samples were collected from 0-15 and 30-60 cm depth for physico-chemical properties of soil at Kelwa distributary and main canal, at the interval of 50, 200, 500 and 1000 m away from the canal, in the head reaches of Indira Sagar Command. The soils are non-saline and non-alkaline in nature.

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

A field experiment was initiated during 2011-12 with rice-wheat cropping sequence. Application of Lagoon Sludge 5 t/ha+Raw Spent Wash 2.5 lakh L/ha significantly increased the 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 (2.4 and 3.8 t/ha) and straw (7.3 and 4.2 t/ha) yield of rice and wheat was recorded with LS 5 t/ha + RSW 2.5 lakh L/ha application, respectively. ESP of post harvest soil was reduced significantly with different amendments. Lowest ESP (24.7 and 24.1) was observed under LS 5 t/ha + RSW 2.5 lakh L/ha after harvest of paddy and wheat, respectively.

Efficay of phospho-gypsum as an amendment for alkali soils (Kanpur)

Highest yield of rice and wheat (3.80 and 3.35 t/ha) observed under the treatment which received phosphogypsum bed. The chemical properties of soil (pH, EC, ESP and OC) showed considerable improvement under amended water passed through gypsum/phosphogypsum bed. The maximum soil pH (9.23) was recorded in RSC treated plots followed by BAW treated (9.07). Dissolution of gypsum and phosphogypsum reduced soil pH to 8.97 and 8.96 respectively. The EC_e was maximum (2.65 dS/m) in RSC treated plots followed by BAW, gypsum and phosphogypsum application. Average ESP in RSC treated plots was highest (47.2) followed by BAW (46.5), gypsum dissolution (44.1) and phosphogypsum (44.1). Organic carbon varied from 0.30-0.32% under the influence of soil amendments. Crop irrigated with RSC water (8.62 meq/l) passed through 15 cm gypsum or phosphogypsum bed showed reduction in RSC and changes in ionic composition. Initial average RSC (8.62) reduced to 4.23 and 4.05 meq/l by gypsum and phosphogypsum respectively.

Effect of management practices on resodification of reclaimed sodic lands (Kanpur)

Grain yield of paddy at farmers field varied from 1.75 to 3.95 t/ha and 2.10 to 4.30 t/ha during first and second year under partially reclaimed sodic soil. Grain yield of wheat varied from 1.88 to 3.30 t/ha. The physico-chemical properties of farmers fields under survey revealed that pH, EC, OC, ESP and infiltration rate ranged from 8.8-9.4, 2.2-2.5 dS/m, 0.1-1.5%, 40.0-55.1 and 0.3-1.3 cm/h respectively in 0-15 cm depth.

Evaluation of resource conservation technologies for rice-wheat cropping system under partially reclaimed sodic soil (Kanpur)

The average grain yield of rice and wheat ranged from 3.23 to 3.79 and 2.48 to 2.85 t/ha. Highest yield 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) in rice and conventional rice transplanting after WRI/conventional wheat sown after RRI (3.08 t/ha) followed by direct seeded rice after WRI/wheat in reduced tillage after RRI in wheat crop. The minimum yield of rice (3.23 t/ha) and wheat (2.48 t/ha) was received under direct seeded rice in zero tillage/wheat in zero tillage.

Integrated response of fly ash, gypsum and green manure to sustain the production of rice and wheat in partially reclaimed sodic soil (Kanpur)

Grain and straw yield of rice and wheat varied from 1.67-3.75 t/ha and 1.23 to 3.41 t/ha respectively. The highest grain yield of both crops were recorded with fly ash 20 t/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 (Kanpur)

Highest grain yield of rice and wheat cultivars were obtained with phosphogypsum (3.53 to 4.37 and 3.20 to 4.00 t/ha respectively) followed by gypsum, pyrites and press mud. The percentage response of various ameliorants on grain yield of various cultivars over RSC water (control) was in order phosphogypsum (7.69 t/ha) >gypsum (6.67 t/ha) >pyrite (4.87 t/ha) >press mud (3.14 t/ha) in rice and 9.21 t/ha, 7.83 t/ha, 5.96 t/ha and 3.81 with phosphogypsum, gypsum, pyrite and press mud in wheat respectively.

Identifying suitable micro-irrigation methods for vegetable crops under sodic soils (Trichy)

Results of the experiment conducted during 2012 showed that highest yield of bhindi (1.95 t/ha) and highest yield of cluster bean (2.76 t/ha) was recorded under drip method of irrigation.

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

Long term field experiment initiated during 2002 at EID Parry (I) Ltd., cane farm, Edayanvelli was continued for 10 years. The TDE was discharged @ 1.00, 0.50, 0.33, 0.25 and 0.20 lakh liters/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 DAP. The results revealed that irrigation with TDE at 1:10 dilution resulted in higher yield of sugarcane. TDE application influenced the organic carbon, available nutrients, and exchangeable cations in the soil.

3. Use of Salty and Marginal Quality Waters in Agriculture

Effect of saline water irrigation on soil properties and crop yields (Agra)

The yield of non-conventional crops, tulsi, isabgol and fennel grown under saline water irrigation reduced significantly at EC_{iw} 8 dS/m during both years whereas, the yield of isabgol reduced significantly at EC_{iw} 6 dS/m during 2010-11 and fenugreek seed yield declined significantly at 6 dS/m during both years.

Tolerance of vegetables to saline irrigation under drip/surface irrigation system (Agra)

The micro-plot study with capsicum-okra crop rotation revealed that EC_{iw} 4 and 8 dS/m reduced the average fruit yield of capsicum by 28.8 and 39.1% in drip and 30.8 and 39.9% in surface irrigation respectively. The average okra fruit yield reduced by 52.2 and 73.8% in drip irrigation and 74.6 and 99.9% in surface irrigation with EC_{iw} 4 and 8 dS/m over control respectively. The water productivity was higher in drip irrigation than surface irrigation. In okra the water productivity in control, EC_{iw} 4 and 8 dS/m was 240.4, 116.0 and 71.0 kg/ha-cm in drip and 166.7, 44.3 and 0.20 kg/ha-cm in surface irrigation respectively.

Tolerance of brinjal and onion to saline irrigation in drip/flood irrigation systems (Bikaner)

Results of two years experimentation showed that drip method was found superior over flood method by producing higher fruit yield (26.5 per cent) of brinjal. In case of onion, maximum yield was obtained under drip irrigation method with water having EC 3.0 dS/m with a significant decrease in yield at EC_{iw} 6.0 dS/m. Drip method was found superior over flood irrigation method at all the levels of EC_{iw} producing 34.9 per cent higher yield of onion.

Response of groundnut-wheat to varying salinity and moisture by sprinkler irrigation (Bikaner)

Depth of water application decreased with increase in the distance from sprinkler line and decrease in nozzle discharge. In saline and BAW alone, the total depth of irrigation applied varied from 26.8 to 61.2 cm and 27.2 to 61.9 cm respectively. In case of mixed water, the depth of water varied from 39.3 to 62.9 cm. Maximum pod yield of groundnut with BAW (EC 0.25 dS/m), saline water (EC 4.6 dS/m) and mixed waters (EC 1.56-3.24 dS/m) obtained at water depth of 60, 50 and 55 cm respectively. The salinity of BAW and saline water was 0.26 and 3.9 dS/m. Thus, gradient of irrigation water salinity across the field ranged between 0.3 to 3.9 dS/m. In saline and BAW alone, the depth of irrigation varied from 2.7 to 4.3 cm and 2.3 to 4.4 cm respectively. In case of mixed water the depth of water varied from 2.3 to 4.4 cm. For obtaining higher yield of wheat under sprinkler irrigation the depth of water applied is to be kept around 42, 33 and 38 cm for BAW, saline and mixed water, respectively.

Response of pearl millet fodder varieties to varying saline water irrigation (Bikaner)

Pearl millet fodder varieties were grown with saline water (BAW, 4.0 and 8.0 dS/m) irrigation. Variety Giant bajra observed best under all situations. However, As compared to BAW, reduction in yield due to EC 8 dS/m was lowest in RBC 2 (6.4 %) and highest in Baif Bajra (13.5 %).

Plastic low tunnels for off-season vegetables with saline water in drip irrigation (Agra)

The EC_{iw} 4 and 8 dS/m reduced the tomato fruit yield by 5.5 and 17.6% in plastic low tunnel with drip and 8.5 and 23.6% in surface irrigation, respectively. In case of bitter gourd fruit yield reduced by 3.0 and 13.7% in drip and 9.8 and 25.5% in surface irrigation at EC_{iw} 4 and 8 dS/m over control. It was observed that water productivity decreased with increased EC_{iw} levels and IW/CPE ratios.

Mitigating adverse effects of salinity by foliar application of chemicals (Bikaner)

Experiments with best available water (BAW) and saline water (EC 8.0 dS/m) with four foliar spray treatments viz. Control, Ascorbic acid-100 ppm, Thiourea 500 ppm and K_2SO_4 200 ppm was conducted to study the effect of foliar spray of different chemicals in mitigating adverse effects of saline irrigation water on pearl millet and wheat and with BAW and saline water (EC 4.0 dS/m) and four foliar sprays in ground nut and fenugreek. Results showed that reduction in the grain yield of pearl millet and wheat with saline water (EC 8.0 dS/m) and groundnut and fenugreek with saline water (EC 4.0 dS/m) was observed.

Pearl millet: All the three chemicals used for spray have shown edge over the control i.e spray of distilled water, in enhancing the grain yield of pearl millet. Thiourea and K_2SO_4 were more effective in mitigating the adverse effect of saline water than Ascorbic acid.

Wheat: Though there was no significant effect on grain yield of wheat under both the situations, but all three chemicals have shown edge over control. Thiourea and Ascorbic acid were more effective in mitigating the adverse effect of saline water than K_2SO_4.

Groundnut: Ascorbic acid and K_2SO_4 have shown edge over the control and thiourea in enhancing the grain yield of groundnut. K_2SO_4 and Ascorbic acid were more effective in mitigating the adverse effect of saline water than thiourea.

Fenugreek: All the three chemicals used for spraying have shown edge over the control in boosting the grain yield. Ascorbic acid was most effective in mitigating the adverse effect of saline water than K_2SO_4.

Mitigating adverse effects of salinity by bio-regulators/ antioxidants on wheat (Bikaner)

Grain yield of wheat was not affected significantly with irrigation water salinity up to 8.0 dS/m. Application of 12.0 dS/m EC water resulted in significantly lowest grain yield as compared to BAW, 4.0 and 8.0 dS/m. Maximum grain yield of wheat was obtained under KNO_3 spray (5000 ppm).

Performance of microbial culture on wheat irrigated with saline water (Hisar)

During 2010-11 and 2011-12, performance of microbial culture on wheat irrigated with saline water of EC 8 dS/m was studied. One parent strain and two salt tolerant microbial cultures were coated on wheat seeds at the time of sowing. During 2010-11, under saline water irrigation, the relative yield increase was 10.7, 5.6 and 3.4% by inoculation of strains such as ST-3+P-36, ST-3 and Mac-27+P-36 respectively as compared to control. During 2011-12 plant height, grains/spike increased significantly whereas earhead/metre row length and test weight was not affected due to inoculation of Azotobacter and Pseudomonas 36 and vermicompost 5 t/ha as compared to control. The grain yield of wheat (WH-711) decreased by 19.9% in saline irrigation as compared to canal water. Inoculation (*Azotobacter* and *Pseudomonas* 36) + Vermicompost 5 t/ha increased the grain yield by 6.4% over control.

Crop water/salinity production function for different crops using sprinkler irrigation (Agra)

An experiment was carried out with cluster bean-mustard crop rotation during 2010-11 and cowpea-mustard during 2011-12 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 nil), saline (EC_{iw} 10 dS/m) and RSC (10 meq/l) water for creating gradients of moisture and salinity/sodicity. In case of moisture, the grain yield increased with increase in depth of irrigation water from 0.7 to 3.6 cm per irrigation. Contrary to this, the grain yield declined with increased salinity gradient from 4.7 to 8.3 dS/m. However, in case of RSC_{iw}, the grain yield was slightly affected in the gradient range of 1.8 to 7.8 (meq/l) of water.

Salt and water dynamics in soil under drip irrigation on cole crop (Hisar)

The experimental treatment consist of frequency of irrigation (F_1: daily; F_2: alternate day) and salinity levels of irrigation water (S_1: canal; S_2: EC_{iw} 3 dS/m; S_3: EC_{iw} 6 dS/m; S_4: EC_{iw} 9 dS/m; S_5: EC_{iw} 12 dS/m). In daily irrigation, the relative yields obtained were 100.5, 90.8, 67.8, and 41.7% in F_1S_2, F_1S_3, F_1S_4 and F_1S_5 treatments respectively as compared to in canal irrigation (F_1S_1). In alternate day irrigation, the relative yields were 100.8, 86.2, 60.3 and 28.6% in F_2S_2, F_2S_3, F_2S_4 and F_2S_5 treatments respectively as compared to canal irrigation (F_2S_1).

Management of high RSC water and its effect on rice (Bapatla)

The results showed that application of gypsum based on neutralization of RSC water produced higher grain yield (5.22 and 5.42 t/ha) and harvest index (42.7 and 43.0%) than other treatments during *kharif* 2010 and 2011. Grain yield of rice increased by 43.3 per cent compared to farmers practice. Similarly, the straw yield was also significantly higher with application of gypsum based on neutralization of high RSC (>2.4 meq/l) water than other treatments.

Management of high RSC water in heavy textured soils (Bapatla)

Pyrite observed as best amendment to mitigate the adverse effect of high RSC water on cluster bean. Significant difference in pod yield was observed with the application of pyrite at varying RSC levels. Yield of cluster bean decreased with increasing levels of sodium in water, irrespective of amendment used and trend followed in case of dry matter yield.

Effect of high RSC water along with FYM and gypsum in vegetables (Hisar)

During 2010-11 the highest yield of 15.17 t/ha of okra was obtained in F_2G_2 treatment and the lowest (0.59 t/ha) was recorded in F_0G_0 treatment. The yield varied from 7.82 to 10.49 t/ha with application of FYM and with gypsum, yield varied from 1.85 to 13.39 t/ha. The highest yield of 45.70 t/ha of onion was obtained in F_2G_2 treatment and the lowest (3.74 t/ha) in F_0G_0 treatment. Yield varied from 21.73 to 29.44 t/ha with FYM and with gypsum, yield varied from 6.06 to 40.41 t/ha. The pH of the soil decreased with the addition of gypsum and FYM. In 0-15 cm layer, the highest pH 9.65 was observed in G_0F_0 and lowest 7.72 in G_2F_2 treatment. In cabbage, the mean yield increased from 4.42 t/ha under no gypsum to 13.03 t/ha under 100% GR. Maximum yield (15.93 t/ha) of cabbage was obtained in F_2G_4 treatment. In 0-15 cm layer, the highest pH 9.21 was observed in G_0F_0 and lowest 8.11 in G_4F_2 treatment. Experiment was terminated during 2011-12.

Optimization of zinc requirement of wheat irrigated with sodic water (Hisar)

The study on Zn requirement of wheat irrigated with sodic water in relation to different gypsum doses (0, 25, 50, 75 and 100% neutralization of RSC) was conducted at village Adalpur during 2010-11 and village Bhurjat during 2011-12 in Mahendragarh district. During 2010-11, the mean yield increased by 96.6, 118.5, 165.12 and 225.84% in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control. The application of Zn (25, 50 and 75 kg/ha) resulted in 26.2, 45.4 and 60.4% increase in yield respectively as compared to control. During 2011-12, the mean yield increased by 43.0, 107.1, 149.7 and 209.1% in G_{25}, G_{50}, G_{75} and G_{100} treatments respectively as compared to control irrigated with sodic water having RSC 9.6 meq/l. The application of $ZnSO_4.7H_2O$ (25, 50 and 75 kg/ha) resulted in 9.3, 17.9 and 22.5% yield increase as compared to control.

Drip irrigation to vegetables in alkali soil using amended alkali water (Trichy)

The experiment on the efficacy of ameliorated alkali water and drip irrigation on vegetable crop showed that soil application of gypsum 50% GR significantly increased the yield of okra and cluster bean. An increase of 12.7% in okra and 22.1% in cluster bean was recorded due to soil application of gypsum 50% GR. Drip irrigation of spent wash treated water recorded the highest yield in okra and drip irrigation of gypsum bed treated water recorded highest yield in cluster bean. In cluster bean, soil application of gypsum 50% GR along with drip irrigation of gypsum bed treated water recorded the highest yield which was at par with soil application of gypsum 50% GR along with drip irrigation of spent wash treated water.

Conjunctive use of saline and canal water in cotton-wheat crop rotation (Hisar)

During 2010-11, highest seed cotton yield (2.76 t/ha) was recorded in all canal irrigation followed by 2 canal (C): 1 saline (S) cyclic irrigation. The lowest yield (1.98 t/ha) was obtained under all saline. Similar trend was observed during 2011-12. During 2010-11, relative yields of wheat were 96.8, 87.2, 82.2, 81.5, 77.1, 68.8 and 65.8% in 2C:1S, 1C:1S, 1S:1C, 1C:RTS (rest with saline), 1S:RTC (rest with canal), 2S:1C, and S treatments, respectively, as compared to the yield recorded in canal irrigation. Similarly, during 2011-12, the relative yields were 97.8, 94.6, 91.4, 83.1, 81.3, 73.0 and 68.4 % in 2C:1S, 1C:1S, 1S:1C, 1C:RTS (rest with saline), 1S: RTC (rest with canal), 2S:1C, and S treatments, respectively, as compared to canal irrigation.

Conjunctive use of saline and canal water in pearl millet-mustard crop rotation (Hisar)

The experiment was terminated after pearl millet during *kharif* 2010-2011. The grain yield of pearl millet ranged from 1.9-2.9 t/ha in different irrigation treatments. Grain yields of pearl millet reduced significantly in all saline, two saline: one canal (2S: 1C), 1S: 1C and C: RTS treatments over canal irrigation. The relative yields under 2S:1C and all saline water were 83.0 and 80.0% respectively as compared to canal irrigation.

Conjunctive use of canal and alkali water in rice based cropping system (Trichy)

Grain yield under canal irrigation was 6.47 and 6.46 t/ha while grain yields under alkali water irrigation was 4.5 and 4.1 t/ha respectively during 2010-11 and 2011-12. Square method of planting registered high grain yield (6.2 and 5.5 t/ha) followed by line planting and machine planting during both years. Conjunctive use of canal and sodic water in 1:1 cyclic mode with square planting recorded around 35% and 31% enhanced yield during both years. Among the vegetables brinjal had high yield under canal irrigation (22.8 and 20.2 t/ha) and recorded highest income of Rs. 2.86 and 2.28 lakh during both years.

Effect of Sea water intrusion on ground water quality in coastal belt of Krishna zone, A.P. (Bapatla)

There is no intrusion of sea water observed during monsoon period. The pH and EC of ground water samples collected during June and December, 2010 were 7.0 to 9.1; 7.0 to 8.4 and 0.6 to 12.9; 0.2 to 16.9 dS/m respectively. During Pre-monsoon period of 2011-12, highest EC (9.8 dS/m) was observed at Machilipatnam and highest pH (8.7) at Nizampatnam. During Post monsoon no much variation in EC but pH was neutral to slightly alkaline in nature at all points.

Drain water usage and management strategies of Nallamada drain (Bapatla)

The EC of Nallamada drain water ranged from 0.6 to 1.7 dS/m (at K.B. Palem 3.4 dS/m) and slowly decreased from June 2010 to Sept. 2010 and again increased up to April 2011. pH ranged from 7.2 to 9.3. Lowest and highest pH was observed at Pedanandipadu. Highest EC (1.5 dS/m) and pH (8.0) was observed at KB Palem and Kondapaturu, respectively during March, 2012

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

Agra canal and drinking water samples were collected from different locations of Agra canal i.e. Okhla (Delhi), Palwal (Haryana), Kosi and Goverdhan (Mathura) and Bichpuri (Agra) at different intervals. Canal water used for irrigating vegetables, cereals and pulse crops has low salinity but due to contamination of industrial effluents and sewage water, the salinity was high (2.1 to 4.4 dS/m). The heavy metals such as Cu, Zn, Mn, Co, Fe, Cd, Cr and Pb showed concentration higher than permissible limit. SAR was ranged from 2.3 to 8.4 mmol/l $^{1/2}$ and no RSC in canal and ground water was observed.

Impact of irrigation with treated sewage on soil, crop and ground water quality (Agra)

The sewage and drinking water samples of STP, Dhadhupura (Agra) used for irrigation were collected and analysed. The salinity ranged from 3.6 to 4.7 dS/m in sewage water and 2.7 to 4.8 dS/m in drinking water. BOD from 27 to 224 mg/l , bicarbonate from 720 to 1074 mg/l, chloride 166 to 605 mg/l and sulphate 835 to 1931 mg/l. Among the cations Ca ranged from 86 to 150 mg/l, Mg 117- 371 mg/l, Na 319- 679 mg/l. However, K ranged from 28 to 40 mg/l, SAR ranged from 2.9 to 10.5 and RSC was nil. The heavy metals i.e. Cu, Fe, Zn, Mn, Co, Cd, Cr and Pb found in all samples and limits were higher than standard of WHO and CPCB.

Studies on long-term effect of sewage irrigation on soil and crops (Trichy)

To monitor the accumulation of heavy metals through irrigation of sewage water to paddy crops along the sewage water course of Tiruchirappalli district, eight benchmark sites were identified and OFT trials were conducted with paddy crop. The heavy metals viz., Pb, Cd and Ni in the sewage irrigated fields showed that all the heavy metals are below the standards of WHO in soil and grains.

4. Alternate Land Management in Salty Environment

Tolerance of Ber to irrigation schedules with saline water under drip irrigation system (Bikaner)

Under drip system, irrigation at 0.6 PE either with BAW (EC 0.25) or saline water (EC 8.0 dS/m) recorded higher fruit yield, fruit weight and fruit diameter as compared to irrigation at 0.4 or 0.8 PE. However, fruit yield under irrigation with saline water at 0.6 PE was found significantly lower than that recorded with BAW during all the three years.

Evaluation of medicinal and aromatic crops in saline Vertisols (Gangawati)

Evaluation of medicinal and aromatic plants on natural salinity graidient (EC_e <2 to 24 dS/m) were carried out. Results showed that threshold soil salinity (EC_t) of kamakasturi and tulsi were 4.48 (slope 2.44 kg) and 4.81 dS/m (slope 2.97 kg), 5.05 (slope 3.93 kg) and 5.1 dS/m (slope 2.16 kg) respectively. The EC_t and the slope of shatavar and citronella were 3.87 dS/m (slope 4.41 kg) and 7.54 dS/m (slope 0.74 kg) respectively, nelaberu (*Andrographis paniculata*) failed to establish reflecting sensitivity to soil salinity. In kamakasturi, per cent oil was more in leaves (0.5-1.3%) as compared to inflorescence (0.3-1.04%), in citronella (1.54-2.1%), in tulsi (0.40 to 1.25%).

Response of sugar beet to sowing dates and planting geometry in saline soils of TBP command (Gangawati)

Sugar beet being a short duration crop and requiring less water than sugarcane could perform better in the cropping programme under saline soils. Results indicated that sowing of sugar beet in 1st fortnight of August recorded significantly higher root yield (40.3 t/ha) than sowing IInd fortnight of August (35.9 t/ha), Ist fortnight (31.1 t/ha) and IInd fortnight (28.3 t/ha) of September. Among different planting geometry, there was no significant difference in root yield and TSS% in different planting geometry.

Effect of irrigation methods and water quality on fruit trees in sodic soils (Indore)

The saplings of sapota (Kalipatti), ber (Desi), pomegranate (Ganesh) and drumstick (Coimbatore-1) were transplanted on 28 July 2005, 1 August 2005, 3 September 2005 and February 2006. Three irrigation systems (viz. check basin, drip and through embedded PVC pipe of 110 mm diameter and length 40cm perforated towards roots) with two qualities of water (normal and diluted distillery waste water) were introduced in May 2006. Pomegranate and drumstick failed to survive under sodic Vertisols. The better girth and height was observed in embedded pipe and drip irrigation as compared to check basin. Changes in girth of ber (*Ziziphus zuzuba*) was 8.5, 14.1 and 13.3 cm and 11.3, 17.7 and 16.2 cm and height was 169.5, 234.9 and 202.4 cm and 198.9, 249.3 and 236.2 cm during 2010-11 in check basin, embedded pipe and drip irrigation respectively with the best available water and diluted spent wash application.

Developing multi-enterprise farming system for sodic Vertisols (Indore)

During 2010 various farming system viz. raise and sunken bed, sole crop, agro-horticulture, agro-forestry were developed. The water harvesting tank has 1890 m^3 storage capacity which was utilized to irrigate paddy and cotton crops. The stored water could manage to deliver 2170 mm depth of water for irrigating 1.73 ha paddy and 0.18 ha cotton crops during 2010 and 2500 mm depth of water for irrigating 1.28, 0.50 and 0.03 ha paddy, cotton and tomato crops, respectively. The yield of cotton (0.39 and 1.08 t/ha) and paddy (0.78 and 1.03 t/ha) grown under raised and sunken bed system were recorded. Cotton yield obtained in sole crop system was 0.22 and 1.33 t/ha during 2010 and 2011 respectively. Similarly, yield of tomato (1.81 and 1.74 t/ha) and brinjal (1.99 and 3.61 t/ha) were recorded under agro-horticulture farming system.

5. Screening of Crop Cultivars and Genotypes

Screening of mustard cultivars under saline water irrigation (Agra)

During 2010-11 in IVT, the highest yield was recorded in CSCN-10-12 (2.5 t/ha) and lowest in CSCN 10-5 and CSCN 10-9 (1.4 t/ha) and in AVT-I, the highest yield was obtained in CSCN-10-16 (2.5 t/ha) and lowest in CSCN 10-14 (1.8 t/ha). During 2011-12, in IVT highest yield was recorded in CSCN 11-5 (0.6 t/ha) and lowest in CSCN 11-6 (0.5 t/ha) and in AVT highest yield was recorded in CSCN 11-7 (0.7 t/ha) and lowest in CSCN 11-9 and CSCN 11-10 (0.4 t/ha).

Screening of maize and chick pea under saline water irrigation (Bapatla)

Among the maize hybrids, Sandhya recorded the highest yield (8.18 t/ha) which was significantly superior to DHM 117 (6.78 t/ha) but at par with 30V92 (7.57 t/ha) during *rabi* 2010-11. However, during *rabi* 2011-12, hybrid 30V92 produced significantly higher grain yield (7.62 t/ha) than other hybrids. Significant yield reduction was observed at EC 4 dS/m as compared to BAW and EC 2 dS/m. Chick pea variety KAK-2 performed well (0.68 t/ha) and produced significantly higher yield (0.36 t/ha in 2010-11 and 1.00 t/ha in 2011-12) than JG–11 and JG-130 varieties.

Screening of rice varieties to salinity tolerance under Nallamada drain (Bapatla)

During *kharif* 2010, the varieties MTU1064 performed significantly better than varieties (BPT-1768, MTU-1061, MTU-1075 and BPT-5204) at all levels of salinity. During *kharif* 2011, significantly higher grain yield (6.30 t/ha) was recorded by NLR 33892 as compared to other varieties viz., NLR3041 and NLR34449 but not comparable with NLR3042, NLR28523 at field conditions having the soil salinity of 5.96 dS/m.

Tolerance of cotton varieties to saline water irrigation under drip System (Bikaner)

Drip irrigation irrespective of quality of water was observed superior in producing higher cotton yield as compared to flood method of irrigation. With the increase in salinity of water, the yield of cotton decreased under both the methods of irrigation, but the quantum of decrease was much more in flood irrigation as compared to drip irrigation.

Response of wheat varieties under saline water irrigation in western Rajasthan (Bikaner)

The grain and straw yield of wheat decreased significantly with successive increase in EC_{iw} from 8 to 12 dS/m. Wheat variety KRL-210 performed better and followed by KRL-213, Raj-4188 and Raj-3077. Salinity build-up in soil after harvest of crop was increased in the root zone with increased salinity levels.

Screening of forage grasses in salt affected soils of TBP command area (Gangawati)

Owing to the acute shortage of green fodder in TBP command area, perennial forage grasses in degraded and marginal lands could be grown. The results revealed that the biomass yields of forage grasses ranged from 3.9 to 0.8 t/ha in Hybrid napier (DHN-6), 3.3 to 0.8 t/ha in Hybrid napier (DHN-9), 5.5 to 0.95 t/ha in Guinea grass, 6.2 to 1.3 t/ha in Grazing guinea grass, 7.6 to 1.5 t/ha in Para grass and 18.5 to 8.3 t/ha in Rhodes grass on natural soil salinity gradient varying from 3.2 to 18.1 dS/m.

Screening of elite varieties of crops for cultivation under saline water irrigation (Hisar)

During 2010-11, and 2011-12, the tolerance of cotton, wheat, mustard and sorghum genotypes was tested under saline water irrigation. Seed cotton yield of KRISHI DHAN 9810-BG-II (174.88 g/m^2) and RCH134Bt cotton genotypes and yield of P-7762 and P-7973 wheat genotypes were significantly higher than other genotypes during both the years. Under IVT trial, the genotypes CSCN-10-1 of mustard gave the highest seed yield (169 g/m^2) followed by CSCN-10-12 (164 g/m^2) at EC_{iw} of 7.5 dS/m and under AVT2 trial, the genotype CSCN-10-16 gave the maximum yield (226 g/m^2) followed by CSCN-10-13 (224 g/m^2) at EC_{iw} of 7.5 dS/m during 2010-11. During 2011-12, under IVT1 trial, the genotypes CSCN-11-3 of mustard gave the highest seed yield (269.2 g/m^2) followed by CSCN-11-4 (215.9 g/m^2) at EC_{iw} of 7.5 dS/m and under AVT2 trials, the genotype CSCN-11-10 gave the highest yield (206.6 g/m^2) followed by CSCN-11-7 (204.1 g/m^2). During 2010-11, eleven genotypes of sorghum, viz., IS 651 S, HC 171, SSG 59-3, HC 260, HC 308, HJ 513, HC 136, IS 3237, IS 2389, SGL 87and G 46 were also evaluated for fodder yield and quality under salinity conditions.

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

Screening of vegetables sodicity tolerance under sodic black clay soils was initiated during *rabi* 2011-12. The survival percentage and yield of vegetable crops decreased with increasing ESP. Maximum survival per cent and yield was observed in brinjal followed by cauliflower and bottle gourd, except yield of bottle gourd ranked second at ESP 25. The survival percentage of tomato and bitter gourd was less than 50% at ESP 35 however the survival percentage of cauliflower and brinjal was more than 50% even at ESP 55.

Performance of different mustard varieties under alkali condition (Kanpur)

Performance of 16 varieties of Indian mustard was evaluated during 2010-11 at ESP 42.5. Highest plant height 215.5 cm was observed in variety CSCN-10-01 followed by CSCN-10-02 and minimum 157.4 cm was recorded in CSCN-10-03. The seed yield varied from 0.6 to 1.6 t/ha. Highest seed yield was recorded in variety CSCN-10-01 (1.6 t/ha) followed by CSCN-10-15 (1.5 t/ha) and minimum in CSCN-10-05.

Evaluation of different crops for their tolerance to sodicity levels (Trichy)

Green gram variety CO6 recorded significantly higher yield (0.35 t/ha) than CO7 (0.30 t/ha) and VBN2 (0.24 t/ha) during 2010-2011. The maize variety CO1 and hybrid viz., COHM5, C818 under different ESP levels showed that hybrid C818 recorded highest yield (3.24 t/ha) and COHM5 recorded the lowest (1.14 t/ha) at ESP 9.5. The highest mean yield (2.19 t/ha) was obtained at ESP 9.5 which was reduced to 0.27 t/ha at ESP 34. The yield of cotton hybrids RCH-20, irrespective of the sodicity levels was 1.33 t/ha. In all the hybrids and varieties, the yield reduced significantly from 1.41 to 0.70 t/ha as the ESP level increases from 9.2 to 41.

6. Operational Research Projects

ORP on use of underground saline water at farmer's field (Agra)

In alkali water having RSC (6.2–12.0 meq/l), the pearl millet was sown with gypsum 50% GR and compared with control. The grain yield increased by 15% with the application of gypsum as compared to control. During *rabi* season the improvement in yield ranged from 7.2 to 14.0% in fields where gypsum was incorporated during *kharif* season. At recharge sites, wheat yield varied from 4.5 to 5.4 t/ha whereas on other farmers fields the yield varied from 3.9 to 4.7 t/ha and yield increase from 12.8 to 17.1 per cent.

ORP on demonstration of reclamation technologies for black alkali soils (Bapatla)

The experiment was conducted on farmers' fields at five locations during 2010-11 and four locations during 2011-12. Grain yield of rice ranged from 3.8 to 5.0 t/ha and 5.0 to 7.3 t/ha respectively during both years. pH of soil was 8.3 to 8.9 and 7.2 to 8.0, the available N was low, P was medium and K was high during both years.

ORP on performance of groundnut with saline water through drip irrigation (Bapatla)

The results of *rabi* 2011-12 revealed that plant height, dry matter accumulation, branches/plant and pods/plant decreased with increasing salinity from 2 to 8 dS/m. Test weight and pod yield significantly reduced with each increment of salinity up to 8.0 dS/m.

ORP on micro-irrigation system with saline water for different vegetables (Bapatla)

The highest mean yield of tomato, radish and spinach (16.2, 13.1 and 9.95 t/ha) was recorded with BAW through drip irrigation followed by 2 EC_{iw} (15.4, 12.6 and 7.3 t/ha), 4 EC_{iw} (11.4, 10.6 and 5.0 t/ha) and 6 EC_{iw} (8.5, 8.1 and 3.3 t/ha) irrigation water respectively.

ORP on effect of gypsum application on crop yield and soil at farmers' field (Indore)

The demonstration was carried out on farmer's fields in two villages of two districts (Indore and Khargone) of Malwa and Nimar agro-climatic zones to demonstrate the technology of reclaiming salt affected soils with soybean-wheat cropping sequence (Indore) and cotton crop (Khargone). Application of gypsum increased seed and straw yield of soybean wheat over control. Application of gypsum 75% GR results in 78 and 97% increase in seed yield of soybean and 58 and 45% grain yield of wheat over control during 2010-11 and 2011-12 respectively. The application of gypsum 50 and 75% GR increased seed cotton yield over control and 25% GR. Application of gypsum 75% GR results in 62 and 85 % increase in seed cotton yield over control during 2010-11 and 2011-12 respectively. The ESP was decreased with gypsum application as compared to untreated soil. Lowest ESP was observed under 75% GR.

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. During the Tenth Plan, the project continued with the same centers with an outlay of Rs. 1090.00 lakh. During the Eleventh Plan, Project continued with an outlay of Rs. 2125.15 lakhs with ICAR Share of Rs. 1695.63 lakhs at the following centers with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal.

Cooperating Centres with Addresses

1. Raja Balwant Singh College, Bichpuri, Agra - 283 105 (Uttar Pradesh)
2. Regional Research Station, Acharya N.G. Ranga Agricultural University
   Bapatla - 522 101 (Andhra Pradesh)
3. S.K. Rajasthan Agricultural University, Bikaner - 334 002 (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences
   Gangawati, Koppal - 583 227 (Karnataka)
5. Department of Soils, C.C.S. Haryana Agricultural University, Hisar - 125 004 (Haryana)
6. Agriculture College, R.V.S. Krishi Vishwa Vidyalaya, Indore - 452 001 (Madhya Pradesh)
7. Agriculture College, C.S. Azad University of Agriculture & Technology
   Kanpur - 208 002 (Uttar Pradesh)
8. A.D. Agricultural College and Research Institute, Tamil Nadu Agricultural University
   Tiruchirappalli - 620 009 (Tamil Nadu)

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.

XI 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 crops.
- Develop standards/guidelines for the assessment of quality of irrigation waters.

- Develop management practices to utilize 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.
- Develop alternate land use strategies for salt affected soils (Agro-forestry).
- Screen crop cultivars and tree species appropriate to salinity and alkalinity soil conditions.

Within the mandated tasks, following activities were initiated or strengthened at various centers during XI 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 Eleventh Five Year Plan (2007–2012) was sanctioned by the Council vide letter N. 9-2/2007/IA-II dated 20.10.2008 with an outlay of Rs. 2125.15 lakhs (ICAR Share Rs. 1695.63). The budget head and center wise statement of expenditure for 2010–2011 and 2011–12 is given in the annexure 7.6.

Research Accomplishments

1. Resource Mapping and Spatio-Temporal Monitoring

Survey, Characterization and Mapping of Ground Waters for Irrigation

- Etawah district (Agra)
- Guntur, Krishna and Prakasam districts (Bapatla)
- Sikar district (Bikaner)
- Gadag and Dharwad districts (Gangawati)
- Rohtak and Jhajjar districts (Hisar)
- Neemuch and Hoshangabad districts (Indore)
- Raebareli district (Kanpur)
- Namakkal district (Trichy)

Delineation and Mapping of Salt Affected Soils using RS and GIS

- Nellore, Guntur, Prakasam and Krishna districts (Bapatla)
- Mandsaur and Neemuch districts (Indore)

Monitoring of Ground Water Quality/Soil Properties at Benchmark Sites

- Guntur district (Bapatla)
- Soil and ground water quality in Sharada Sahayak canal command (Kanpur)

Survey, Characterization and Mapping of Ground Waters for Irrigation

Etawah district (Agra)

The ground water survey of Etawah district (Saifai, Jaswant Nagar, Sidhpura, Basrehar, Bharthana, Takha, Mahewa and Chakarnagar blocks) in Uttar Pradesh was initiated in 2008 and completed in 2012. A total 730 samples were collected mostly during December to March, when most of the tube wells were in use for irrigation purposes in the farmers' fields. The samples were analyzed for different parameters as per AICRP water quality guidelines. The mean and range of EC, pH, SAR and RSC are presented in Table 1.1 whereas distribution of water samples in different EC, SAR and RSC classes are presented in Table 1.2.

Table 1.1. Mean and range of ground water quality in different blocks of Etawah district

Block/Tehsil	EC (dS/m)		pH		RSC (meq/l)		SAR $(mmol/l)^{1/2}$	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Saifai	0.5-7.6	1.2	8.9-9.5	8.9	0.0-25.7	2.9	0.3-13.9	3.1
Jaswant Nagar	0.5-2.7	1.0	7.7-8.5	8.3	0.0-8.8	3.6	0.6-15.3	3.2
Badhpura	0.8-6.7	2.0	8.2-9.2	8.8	0.0-11.0	3.5	0.9-41.7	11.8
Basrehar	0.6-5.6	1.4	8.0-9.2	8.6	0.0-8.8	2.3	1.4-42.2	6.9
Bharthana	0.5-5.2	1.5	7.4-9.0	8.4	0.0-14.0	2.9	0.4-26.6	6.5
Takha	0.7-10.0	2.1	7.6-9.1	8.3	0.0-11.8	3.4	2.3-31.3	10.9
Mahewa	0.9-4.2	1.5	7.7-9.1	8.3	0.0-13.8	2.9	3.3-26.4	7.8
Chakarnagar	1.0-7.1	2.1	8.0-9.3	8.6	0.0-6.8	2.3	1.3-9.5	3.9

Table 1.2. Water quality classification in different blocks of Etawah district

Particular	Saifai (83)	J'Nagar (99)	Badhpura (93)	Basrehar (94)	Bharthana (96)	Takha (78)	Mahewa (95)	Chakrnagar (92)	Av. of Etawah
EC Classes (dS/m)									
0-1.5	94.0	96.0	52.7	74.5	68.8	42.3	60.0	42.4	66.3
1.5-3.0	3.6	4.0	30.1	23.4	24.0	44.9	36.8	41.4	26.0
3.0-5.0	-	-	12.9	1.1	6.1	10.2	3.2	10.9	5.6
5.0-10.0	2.4	-	4.3	1.1	1.0	1.3	-	5.3	1.9
>10.0	-	-	-	-	-	1.3	-	-	0.2
RSC Classes (meq/l)									
Absent	4.8	1.0	30.1	14.9	15.6	19.2	2.1	14.1	12.7
0-2.5	54.2	33.3	34.4	41.5	33.3	38.5	56.8	52.2	43.0
2.5-5.0	26.5	42.4	15.1	30.8	25.0	24.3	28.4	28.3	27.6
5.0-10.0	13.3	23.2	18.3	12.8	19.8	14.1	10.6	5.4	14.7
>10.0	1.2	-	2.1	-	6.3	3.8	2.1	-	1.9
SAR Classes $(mmol/l)^{1/2}$									
0-10	96.4	99.0	62.4	86.2	87.5	61.5	81.1	100	84.3
10-20	3.6	1.0	20.4	11.7	8.3	29.5	16.8	-	11.4
20-30	-	-	10.7	1.1	4.1	7.1	2.1	-	3.2
30-40	-	-	5.4	-	-	1.3	-	-	0.8
>40	-	-	1.1	1.1	-	-	-	-	0.3

The mean quantum of different cations and anions in relation to different EC_{iw} classes are determined and presented in Fig. 1.1. Amongst the cations, the Ca, Mg and Na increase with increases in EC_{iw} classes, whereas the K ion does not show any relation with EC_{iw} classes. Further the Ca, Mg and Na ions increase proportionately up to EC_{iw} 8 dS/m but beyond this the Na cations increases in high proportion. Similar to cations, the anions (Cl and SO_4) also increases with EC_{iw} classes. Contrarily, the CO_3 and HCO_3 anions do not have any relation with EC_{iw} and remains almost same from <1 to 15 EC_{iw} classes. Overall analysis of water samples of Etawah district showed 51.6 per cent in good quality and 48.4 per cent water samples are poor quality i.e. 8.1 per cent water samples have saline and 40.3 per cent in alkali water (Table 1.3). The major problematic waters in Jaswant Nagar block i.e. only 35.3 per cent waters are good quality and rest 65.6 per cent are alkali water. Finally, a map has been prepared to show the area wise distribution of different water quality classes in Etawah district (Fig. 1.2).

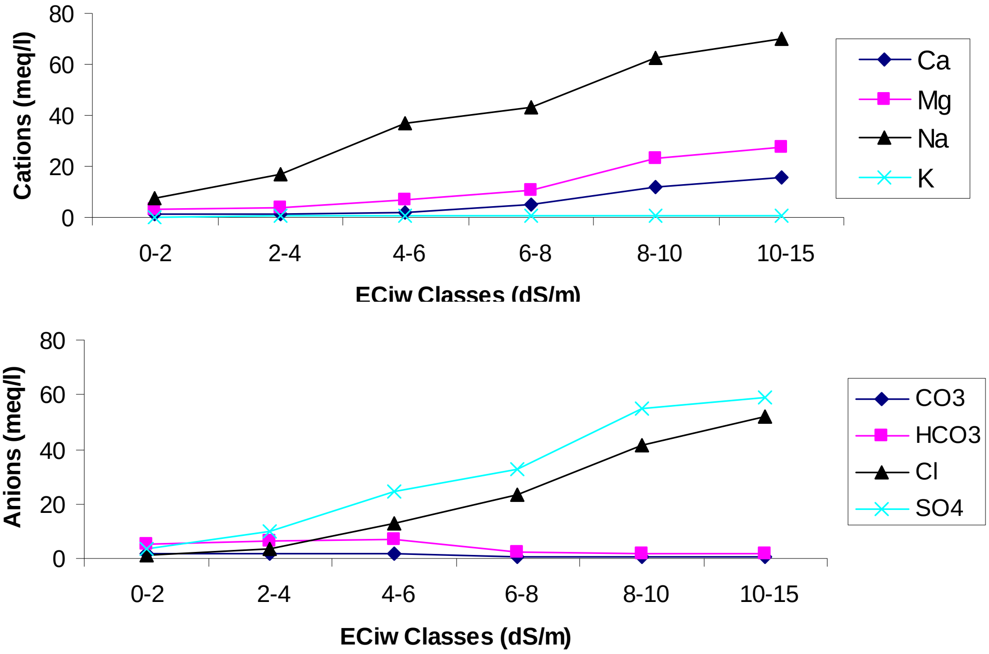


Fig. 1.1. Cations and anions with respect to EC classes in Etawah district

Table 1.3. Distribution of water samples in different water quality ratings

Quality	Saifai (83)	J'Nagar (99)	Badh pura (93)	Basrehar (94)	Bhart hana (96)	Takha (78)	Mahewa (95)	Chakar nagar (92)	Av. of Etawah
Good	57.8	35.3	55.9	54.3	49.0	42.3	55.8	62.0	51.6
Mod Saline	-	-	6.4	1.1	4.2	1.3	-	13.0	3.3
Saline	-	-	-	-	1.0	-	-	9.8	1.3
H. SAR Saline	1.2	-	2.2	1.1	1.0	19.2	3.2	-	3.5
Mod. Alkali	19.3	32.3	12.9	26.6	28.1	15.4	20.0	13.0	20.9
Alkali	-	-	1.1	4.3	1.0	2.6	8.4	-	2.2
H. Alkali	21.7	32.3	21.5	12.8	15.6	19.2	12.6	2.2	17.2

EC, SAR, RSC: Good : <2, <10, <2.5; Moderately saline:- 2-4, <10, <2.5; Saline:- >4, <10, <2.5; High SAR saline: >4, >10, <2.5; Moderately alkali : <4, <10, 2.5-4, Alkali : >4, <10, >4.0; Highly alkali: <4, >10, >4.0

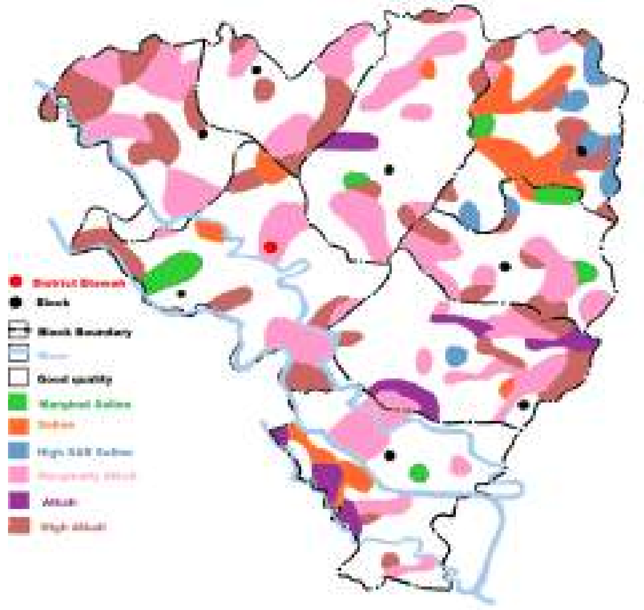


Fig. 1.2. Water quality map of Etawah district

The presence of fluoride and nitrate were analysed in ground water samples. It was found that fluoride content was less than 2.5 ppm in more than 90 per cent samples in all the blocks except Jaswant Nagar where 11 per cent samples were found with fluoride in the range of 2.5-5.0 ppm. In case of nitrate, 20 per cent samples were found with nitrate in the range of 2.5-5.0 meq/l in Mahewa whereas 25 per cent samples were found with nitrate content more than 10 meq/l in Saifai block.

Guntur, Krishna and Prakasam districts (Bapatla)

Nitrate: During 2010-11 sixteen ground water samples were collected from highly fertilized areas of Guntur district growing commercial crops, nine samples from Krishna district. The NO_3 content ranged from 0.9 to 22.3 ppm in Guntur district and 1.1 to 10.8 ppm in Krishna district. In Guntur district 44 per cent of samples are above permissible limit of 15 ppm while in Krishna district all the samples were in safer limit of below 15 ppm. In Krishna district, the pH ranged from 7.7 to 8.2, EC ranged from 0.74 to 2.41 dS/m. The SAR was with in the safer limit of 10 in both districts while RSC was nil to 4.2 meq/l in Guntur district and in some bore wells above the safer level of 2.5 meq/l while in Krishna district within the safer limt of 2.5 meq/l (Table 1.4).

Fluoride: During 2010-11 sixty two ground water samples were collected in Ongole division and analysed for pH, EC, cations, anions, SAR and RSC and fluoride. The fluoride content varied from 0.75–4.5 ppm and the highest value of 4.5 ppm recorded in Sankarapuram of Mundlamuru mandal while the lowest value 0.75 ppm was recorded in Dharmavaram of Addanki mandal. 69 per cent of ground water samples, exceeded the permissible limit of 1.5 ppm for irrigation water.

Nitrate: During 2011-12 thirty five water samples were collected in Krishna district and eleven water samples in Guntur district and in Krishna district some bore wells are above the safer level of 2.5 meq/l while NO_3 ranged from 1.68 to 33.32 ppm.

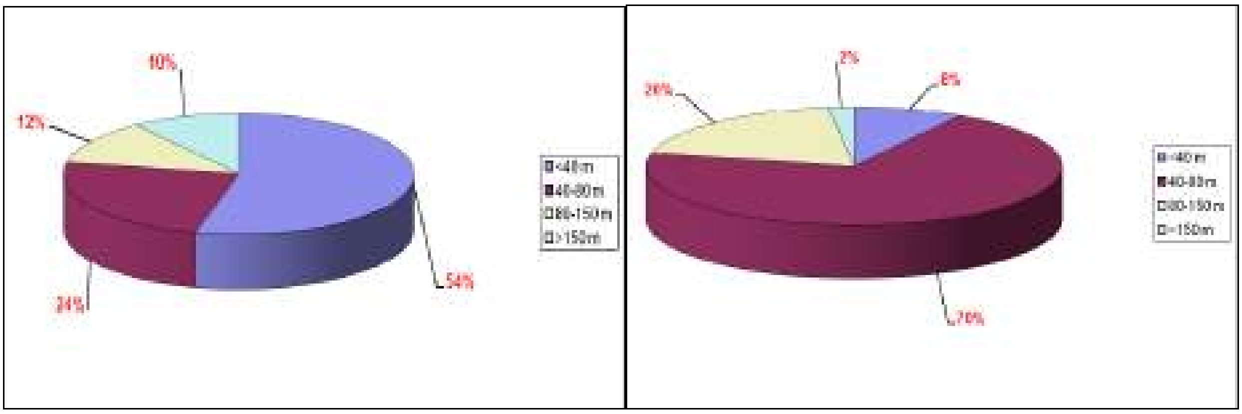
Fluoride: 185 water samples collected in Prakasam district were analysed for pH, EC, cations, anions, SAR and RSC. The fluoride content ranged from 0.15-3.10 ppm.

Table 1.4. Ground water characteristics of Guntur, Krishna and Prakasam districts

Parameter	Gutur district		Krishna district		Prakasam district	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
pH	6.9-9.7	7.2-9.5	7.7-8.2	7.1-8.2	7.1-9.1	6.6-10.5
EC (dS/m)	0.5-3.7	0.8-12.3	0.7-2.4	0.6-8.3	0.4-11.1	0.4-14.2
CO_3 (meq/l)	0.0-4.4	0.0-0.6	0-1.0	0.0-1.6	0.0-5.0	0.0-5.0
HCO_3 (meq/l)	1.2-8.0	5.3-16.5	3.3-11.3	4.7-18.2	1.3-13.6	0.3-17.6
Cl (meq/l)	1.2-16.4	0.2-101.0	2.0-10.0	1.8-64.8	1.2-68.0	0.8-102.0
SO_4 (meq/l)	1.0-6.6	1.3-16.8	0.2-1.8	0.04-6.4	0.2-26.4	0.0-12.6
Ca (meq/l)	1.2-14.8	2.0-52.0	0.8-7.6	2.4-21.2	0.8-7.2	0.1-43.3
Mg (meq/l)	0.4-12.0	0.4-56.4	1.6-7.2	0.8-11.6	1.2-16.8	0.9-108.2
Na (meq/l)	1.9-17.7	1.8-25.2	2.4-10.7	1.3-50.6	1.0-108.2	0.0-7.6
K (meq/l)	0.0-0.1	0.0-0.5	0.4-0.2	0.0-6.0	-	0.0-7.6
SAR (meq/l)	0.9-6.6	0.5-11.3	1.6-5.5	0.6-20.9	0.4-67.1	0.5-67.1
RSC (meq/l)	0.0-4.2	0.0-2.5	0.0-0.3	0.0-6.8	0.0-12.4	0.0-16.0
NO_3 (ppm)	0.9-22.3	6.9-8.4	1.1-10.8	1.7-33.3	-	-
F (ppm)	-	-	-		0.7-4.5	0.2-3.1

Sikar district (Bikaner)

Ground water quality survey of Danta Ramgarh and Sri Madhopur tehsils of Sikar district was conducted during 2010 and 2011. Water samples from 100 tube wells of Danta Ramgarh tehsil and 82 tube wells of Sri Madhopur tehsil scattered in 70 and 35 villages, respectively, were collected and analyzed for various chemical characteristics. The water table in tube wells of Danta Ramgarh tehsil varied from 20.0 to 263.6 m (Fig. 1.3a). EC and pH of water samples ranged from 0.25 to 13.4 dS/m and 7.2 to 8.9, respectively. The concentration of calcium and magnesium varied from 0.3 to 16.9 and 0.6 to 18.9 meq/l and sodium concentration ranged from 1.8 to 96.9 meq/l whereas concentration of potassium ion varied from 0.03 to 0.81 meq/l. Soluble carbonates and bicarbonates varied from 1.9 to 63.0 meq/l though the carbonates were found in traces only. The concentration of chloride and sulphate varied from 0.3 to 64.4 and 0.3 to 6.6 meq/l, respectively. Chloride was the dominant anion and sodium the dominant cation. SAR and soluble sodium percentage (SSP) of water samples ranged from 2.2 to 31.9 and 46.5 to 93.9, respectively (Table 1.5). The water table in tube wells of Sri Madhopur tehsil varied from 28.0 to 166 m (Fig. 1.3b). EC and pH of water samples ranged from 0.54 to 7.0 dS/m and 8.5 to 9.1 respectively. Concentration of calcium and magnesium varied from 0.7 to 5.6 and 1.1 to 8.2 meq/l respectively. Sodium concentration ranged from 3.0 to 56.0 meq/l whereas concentration of potassium ion varied from 0.02 to 0.84 meq/l. Soluble carbonates and bicarbonates varied from 3.9 to 37.8 meq/l though the carbonates were found in traces. The concentration of chloride and sulphate varied from 0.9 to 28.1 and 0.1 to 4.2 meq/l, respectively. Chloride and sodium was the dominant anion and cation, respectively. The SAR and SSP of water samples ranged from 1.8 to 26.3 and 33.0 to 94.2, respectively.



(a) (b)

Fig. 1.3. Water table depth of Danta Ramgarh and Sri Madhopur tehsil of Sikar district

Table 1.5. Range of chemical characteristics of tube well waters and soils of Danta Ramgarh and Sri Madhopur tehsil of Sikar district

Characteristics	Danta Ramgarh		Sri Madhopur	
	Water (100)*	Soil (70)*	Water (82)*	Soil (82)*
pH	7.2-8.9 (8.2)**	7.3-9.0 (8.1)**	8.5-9.1(8.8)**	8.0-9.0 (8.5)**
EC (dS/m)	0.25-13.4 (2.1)**	0.14-0.98 (0.52)**	0.54-7.0 (1.3)**	0.10-0.44 (0.17)**
Ca (meq/l)	0.3-16.9	0.2-1.6	0.7-5.6	0.1-0.7
Mg (meq/l)	0.6-18.9	0.3-2.4	1.1-8.2	0.2-1.0
Na (meq/l)	1.8-96.9	0.8-6.3	3.0-56.0	0.3-2.7
K (meq/l)	0.03-0.81	0.03-0.39	0.02-0.84	0.02-0.24
CO_3+ HCO_3 (meq/l)	1.9-63.0	1.1-6.2	3.9-37.8	1.0-3.7
Cl (meq/l)	0.3-64.4	0.3-4.8	0.9-28.1	0.2-1.6
SO_4 (meq/l)	0.3-6.6	0.03-0.44	0.1-4.2	0.02-0.25
RSC (meq/l)	0.5-27.2	-	1.2-24.0	-
SAR	2.2-31.9	1.0-7.0	1.8-26.3	0.4-3.0
Potential salinity (meq/l)	0.5-67.7	-	1.0-30.2	-
SSP	46.5-93.9	-	33.0-94.2	-
Mg/Ca ratio	1.0-3.8	-	1.1-3.2	-
Floride (mg/l)	0.57-2.26	-	0.53-2.96	-
Nitrate (mg/l)	110-425	-	130-381	-
Water table (m)	30.0-263.6	-	30.0-166.0	-

** Data in the parenthesis is the average value*

The distribution of water samples of Danta Ramgarh tehsil and Sri Madhopur tehsil in different ranges of EC and RSC are presented in Table 1.6. RSC of water samples of Danta Ramgarh tehsil ranged from 0.5 to 27.2 meq/l. About 21.0, 8.0, 17.0 and 54.0 per cent water samples had RSC in the range of <2.5, 2.5-5.0, 5.0-7.5 and >7.5 meq/l, respectively. Salinity of 52.0, 44.0 and 4.0 per cent water samples showed EC in the range of <2.0, 2.0-4.0 and >4.0 dS/m, respectively. The RSC of water samples of Sri Madhopur tehsil ranged from 1.2 to 24.0 meq/l. RSC of 45, 22, 21 and 12 per cent water samples ranged from <2.5, 2.5-5.0, 5.0-7.5 and >7.5 meq/l respectively. Salinity of 89, 10 and 1 per cent water samples showed EC in the range of <2.0, 2.0-4.0 and >4.0 dS/m, respectively.

Table 1.6. Distribution (per cent) of water samples in different ranges of EC and RSC

RSC (meq/l)	EC (dS/m)											
	<1		1-2		2-3		3-4		>4		Total	
	DRG	SMP	DRG	SMP	DRG	SMP	DRG	SMP	DRG	SMP	DRG	SMP
<2.5	17.0	26.0	4.0	19.0	-	-	-	-	-	-	21.0	45.0
2.5-5.0	3.0	12.0	5.0	10.0	-	-	-	-	-	-	8.0	22.0
5.0 – 7.5	-	-	15.0	20.0	2.0	1	-	-	-	-	17.0	21.0
>7.5	-	-	8.0	2.0	33.0	7	9.0	2	4.0	1.0	54.0	12.0
Total	20.0	38.0	32.0	51.0	35.0	8	9.0	2	4.0	1.0		

DRG: Danta Ramgarh, SMP: Sri Madhopur

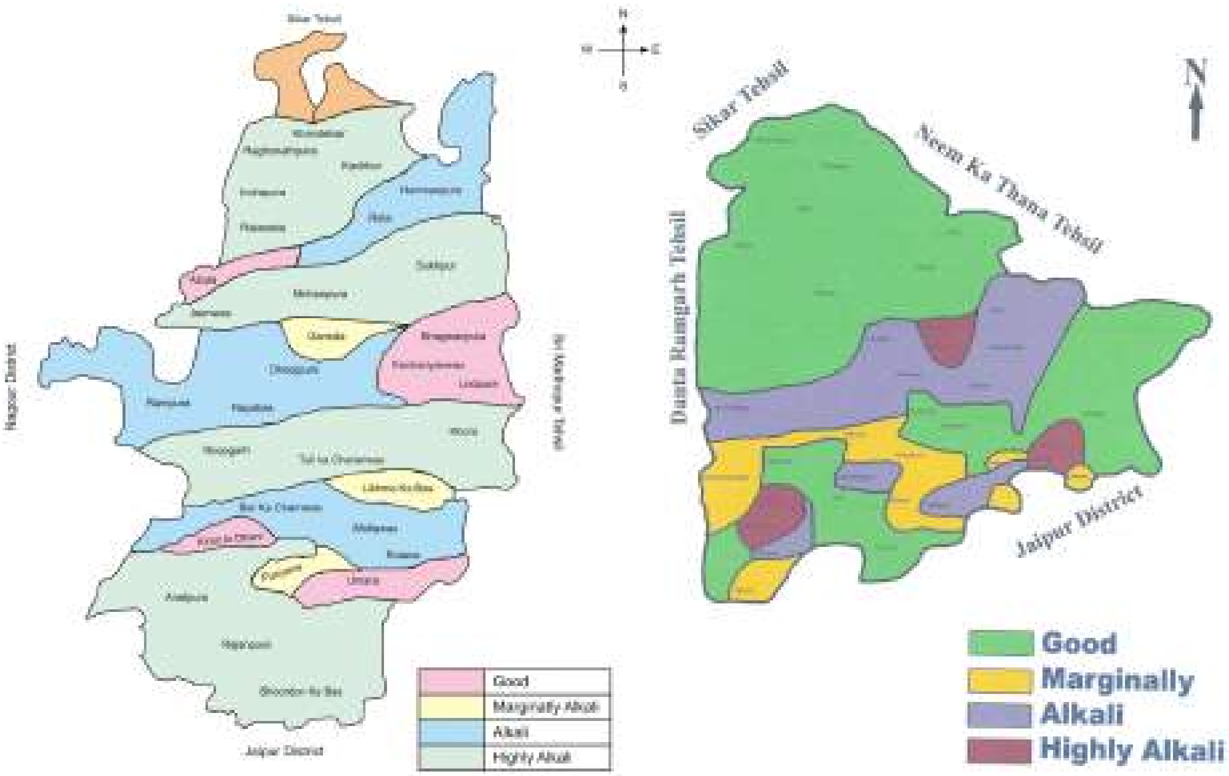
Villages of Danta Ramgarh and Sri Madhopur tehsil under different water quality categories are reported in Table 1.7. In Danta Ramgarh, about 21.0, 4.0, 25.0 and 50.0 per cent water samples are good, marginally alkali, alkali and highly alkali categories, respectively whereas in Sri Madhopur, about 45.1, 20.7, 23.2 and 11.0 per cent water samples are good, marginally alkali, alkali and highly alkali categories, respectively. The water quality maps for the tehsils are depicted in Fig. 1.4.

Table 1.7. Ground water quality in villages of Danta Ramgarh tehsil of Sikar district

Quality	Villages of Danta Ramgarh	Per cent	Villages of Sri Madhopur	Per cent
Good	Khatu, Khatu, Swaipura, Aloda, Aloda, Bhagwanpura, Ladpura, Kailash, Dhingpur, Likhma Ka Bas, Banathala, Banthala, Bai, Baloopura, Chandeli Ka Bas, Kiron Ki Dhani, Karnipura, Kachariyawas, Khachariyaswas, Pachar, Umara	21.0	Chomupurohitan,Abhawas, Baori, Dheerajpura, Sothaliya, Kasarda, Ranipura, Vijaipura, Mau, Bagariyavas, Ratanpura, Nangal, Bhim, Aspuragarh Taknet, Garh Taknet, Nathoosar, Mundru, Lisariya, Ajeetgarh, Mangarh	45.1
Marginally Saline	-	-	-	
Saline	-	-	-	
High-SAR-Saline	-	-	-	
Marginally Alkali	Punyana, Likhma Ka Bas, Ganoda, Ganoda	4.0	Chomupurohitan, Dadiyarampura, KotriLapuwa, Bhawanipura, Ratanpura, Aspura, Lisariya, Anatpura, Mangarh, Jugrajpura, Bharni,Bharni, Malakali, Jaitusar	20.7
Alkali	Hanumanpura, Kochhar, Reta, Dudhwa, Dudhwa, Dheejpura, Nayabas, Bar Ka Charnwas, Bai, Rulana, Gogawas, Ramgarh, Ramgarh, Kantiya, Motlawas, Motlawas, Gyandaspura, Punyana, Rampura, Pachar, Kuli, Dholasari, Rajanpura, Bar Ka Charanwas, Jaloond	25.0	Chomupurohitan, Abhawas, Dadiyarampura, Kotri, Tapilya, Devipura, Baori, Jalalpur, Mau, Malakali Bagariyavas, Nathoosar, Ajeetgarh, Samota Ka Bas,	23.2
Highly Alkali	Khandelsar, Khandelsar, Raghunathpura, Indrapura, Kochhar, Ralawata, Jeenwas,	50.0	Dadiyarampura, Kotri, Phootala, Tapilya, Devipura,	11.0

	Mohanpura, Basdi Kalan, Reta, Sukhpur, Nayabas, Roopgarh, Roopgarh, Tuli Ka Charanwas, Motipura, Heerwas, Neemwas, Neemwas, Amarpura, Mundiyawas, Mundiyawas, Rooppura, Khaitwas, Samer, Samer, Kerpura, Gowati, Gowati, Dukiya, Dukiya, Dhingpur, Sami Ki Dhani, Gila Ki Dhani, Khora, Maganpura, Nada, Nada Danta, Danta, Sundariya Sundariya Karad, Kuli Dholasari, Aheer Ka Bas, Anatpura, Rajanpura, Bhoordon Ka Bas.	Lapuwa, Divrala, Dhani Dera

EC, SAR, RSC: Good : <2, <10, <2.5; Moderately saline:- 2-4, <10, <2.5; Saline:- >4, <10, <2.5; High SAR saline: >4, >10, <2.5; Moderately alkali : <4, <10, 2.5-4, Alkali : >4, <10, >4.0; Highly alkali: <4, >10, >4.0



(a) (b)

Fig. 1.4. Ground water quality maps of Danta Ramgarh and Sri Madhopur tehsil of Sikar district

Percent distribution of water samples in relation to pH, EC, SAR, SSP, Mg/Ca ratio, fluoride and nitrate content pertaining to Danta Ramgarh and Sri Madhopur tehsil are presented in Table 1.8. In Data Ramgarh tehsil, about 10.0, 21.0, 47.0 and 22.0 per cent water samples showed pH in the range of 7.0 to 7.5, 7.5 to 8.0, 8.0 to 8.5 and >8.5 respectively. About 42.0 and 7.0 per cent water samples having SAR in the range of 10-20 and 20-30, respectively whereas, 28.0 per cent water samples showed SSP >80 and 10 per cent water samples had Mg/Ca ratio >3.0. In Sri Madhopur, about 5.0, and 95.0 per cent water samples showed pH from 8.0 to 8.5 and >8.5 respectively. About 89.0,7.3 and 3.7 per cent water samples having SAR in the range of 0-10, 10-20 and 20-30 respectively whereas 13.4 per cent water samples showed SSP >80 and 2.4 per cent water samples had Mg/Ca ratio >3.0.

Table 1.8. Per cent distribution of water samples in relation to pH, EC, SAR, SSP, fluoride, nitrate and Mg/Ca ratio in different blocks of Sikar district

Characteristics	Percentage		Characteristics	Percentage	
	Danta Ramgarh	Sri Madhopur		Danta Ramgarh	Sri Madhopur
pH			EC (dS/m)		
7.0-7.5	10.0	-	<2	53.0	87.8
7.5-8.0	21.0	-	2-4	43.0	11.0
8.0-8.5	47.0	5.0	4-6	2.0	1.2
> 8.5	22.0	95.0	>6	2.0	-
SAR			SSP		
0-10	50.0	89.0	< 50	3.0	9.9
10-20	42.0	7.3	50-60	20.0	24.3
20-30	7.0	3.7	60-70	14.0	37.8
> 30	1.0	-	70-80	31.0	14.6
			> 80	28.0	13.4
Mg/Ca ratio			Flouride (mg/l)		
< 1	-	-	< 1.5	73.0	61.0
1-2	49.0	63.5	1.5 -5.0	27.0	39.0
2-3	41.0	34.1	5.0 – 10.0	-	-
> 3	10.0	2.4	> 10.0	-	-
Nitrate (mg/l)					
< 20.0	-	-			
20 – 50	-	-			
50 – 100	-	-			
> 100	100.0	100.0			

In Danta Ramgarh tehsil, the fluoride and nitrate content of water samples varied from 0.57 to 2.26 and 110 to 425 mg/l, respectively. All the water samples showed nitrate content >100 mg/l. In Sri Madhopur tehsil, the fluoride and nitrate content of water samples varied from 0.53 to 2.96 and 130 to 381 mg/l, respectively. About 61 and 39 per cent flouride in water samples ranged below 1.5 and 1.5 to 5.0 mg/l, respectively. All the water samples showed nitrate content >100 mg/l.

Farmers of these tehsils are growing wheat and mustard during *rabi* with sprinkler irrigation. Soils are light to medium in texture. Pearl millet and cluster bean are being grown during *kharif* season as rain fed crop with supplemental irrigation whenever needed. Some farmers grow vegetables during *rabi* season. Farmers are using only 20-30 per cent of the recommended dose of fertilizers in wheat and mustard.

Chemical characteristics of soil samples of tube well irrigated fields in Danta Ramgarh and Sri Madhopur tehsils are given in Table 1.9. The range of chemical characteristics of soil samples as presented in Table 1.5 indicated that pH_2 of soil samples varied from 7.3 to 9.0 whereas EC_2 ranged between 0.14 to 0.98 dS/m in Data Ramgarh tehsil and it varied from 8.0 to 9.0 whereas EC_2 ranged between 0.10 to 0.44 dS/m in Sri Madhopur tehsil. Thus the problem of high alkalinity in ground water having RSC >7.5 and pH >8.5 to 9.0 indicated that the soils are deteriorated with the use of poor quality waters.

Table 1.9. Chemical characteristics of soil irrigated with tube well waters of Danta Ramgarh and Sri Madhopur tehsil of Sikar district

Name of village	pH	EC (dS/m)	Ionic composition (meq/l)							SAR
			Ca++	Mg++	Na+	K+	CO_3^{2-} + HCO_3^-	Cl^-	SO_4^{2-}	
Danta Ramgarh										
Maximum	9.00	0.98	1.6	2.4	6.3	0.39	6.2	4.8	0.44	7.01
Minimum	7.37	0.14	0.2	0.3	0.8	0.03	1.1	0.3	0.03	1.08
Average	8.14	0.52	0.81	1.12	3.16	0.18	3.12	2.04	0.19	3.16
Sri Madhopur										
Maximum	9.01	0.44	0.7	1.0	2.7	0.24	3.7	1.6	0.25	3.03
Minimum	8.03	0.10	0.1	0.2	0.3	0.02	1.0	0.2	0.02	0.42
Average	8.55	0.17	0.38	0.48	0.80	0.10	1.30	0.43	0.09	1.28

Gadag and Dharwad districts (Gangawati)

Nearly 40 per cent of total irrigated area of Gadag district in Karnataka relies on ground water resources. Village wise characterization of ground water for irrigation in the district for its optimal usage was completed during 2010-11. A total of 527 ground water samples were collected from all villages in five taluks and analyzed. Nearly 100 per cent of water samples in Gadag, Mundarigi, Ron, Shirhatti and Nargunda taluks had favorable pH (≤ 8.0) and except in Nargunda, <75 per cent of samples were found to be non-saline in other taluks (Table 1.10). However, mean Mg/Ca and Cl/SO4 ratios of majority of samples exceeded 0.63 and 2.0 which are reported to be critical for causing Mg hazard and Cl injury in sensitive crops. With regards to the overall water quality, less than 50 per cent of samples in Gadag and Mundaragi taluks and nearly 60 per cent of samples in Ron and Shirhatti taluks were of good quality. About 14 per cent each in Gadag and Mundaragi taluks were of highly alkali (SAR > 10 and RSC > 4.0 meq/l). Gadag district as a whole, <50 per cent of samples were found good followed by moderately saline (16.0 per cent). And nearly 40 per cent of samples were found to be problematic of different nature (saline, high SAR saline and alkali) requiring special attention and suitable recommendation for their use in agriculture.

During 2011-12, survey and collection of ground water samples village-wise from Dharwad and Navalgund taluks was carried out. The district Dharwad with an area of 4273 sqkm (427329 ha) lies in the northern part of Karnataka state with an annual average rainfall of 769 mm. This district has 5 taluks with net sown area accounts nearly 72.1 per cent of the total geographical area. Agriculture is the main occupation in the district using both surface water and groundwater resources. The major crops grown are sorghum, wheat and maize. A total of 103 samples (Dharwad - 69 and Navalgund - 34 samples) representing almost all the villages from these taluks were collected and analyzed. Majority of water samples in both the taluks had favourable pH in the range of 7.5-8.5. As far as EC is considered, majority of water samples in Dharwad (>85%) are of non-saline (<2 dS/m), whereas about 50 per cent of samples in Navalgund taluk had EC<2 dS/m (Table 1.10). Mean Cl content was beyond 3 meq/l and Cl/SO_4 ratio was also >2.0 in both the taluks which are considered to be not desirable. Irrespective of EC levels, mean Mg/Ca ratios were also much greater than 0.63 which is considered to be safe in both the taluks. Overall, water quality revealed that about 65% percent good quality water samples and equal percent i.e., 11.6% of moderately saline and moderately alkali samples were found in Dharwad taluk. In Navalgund taluk, <25 per cent of samples were of good quality whereas moderately saline, moderately alkali II and alkali samples constituted about 26, 21, 12 per cent of total samples.

Table 1.10. Water quality ratings of ground waters in different blocks of Gadag and Dharwad

Taluk	Sample size	Good	M. Saline	Saline	High SAR Saline	M. Alkali I	M. Alkali II	Alkali
Gadag district								
Ron	118	59.3 (70)	11.86 (14)	5.93 (7)	5.93 (7)	6.78 (8)	4.24 (5)	5.93 (7)
Shirhatti	133	59.4 (79)	14.29 (19)	0.75 (1)	5.26 (7)	11.30 (15)	3.01 (4)	6.02 (8)
Nargunda	22	22.73 (5)	18.18 (4)	18.18 (4)	22.73 (5)	18.18 (4)	-	-
Gadag	156	31.41 (49)	21.15 (33)	8.33 (13)	5.13 (8)	12.18 (19)	8.33 (13)	13.46 (21)
Mundaragi	98	45.92 (45)	14.29 (14)	1.02 (1)	4.08 (4)	8.16 (8)	12.24 (12)	14.29 (14)
District	527	43.75 (248)	15.95 (84)	6.84 (26)	8.63 (31)	11.32 (54)	5.56 (34)	7.94 (50)
Dharwad district								
Dharwad	69	65.21 (45)	11.6 (8)	--	1.44 (1)	11.6 (8)	8.7 (6)	1.45 (1)
Navalgund	34	23.53 (8)	26.47 (9)	8.82 (3)	5.88 (2)	2.94 (1)	20.6 (7)	11.76 (4)

Data in the parenthesis represents number of samples

Rohtak and Jhajjar districts (Hisar)

Survey and characterization of ground water of Rohtak and Jhajjar districts was completed during 2010-12 (Fig. 1.5). Rohtak district, located in central part of Haryana, lies between 28^0 38' 54'' to 29^0 03' 36'' N latitude and between 76^0 09' 12'' to 76^0 52' 30'' E longitude. The geographical area of Rohtak is 177500 ha and has five blocks viz, Kalanaur, Lakhan-Majra, Meham, Rohtak and Sampla. The average annual rainfall in Rohtak district is about 592 mm spread over 23 days. Out of 97900 ha irrigated area, 66900 ha is irrigated by canals and 31000 ha is irrigated by tubewells. Jawahar Lal Nehru feeder and Bhalaut sub branch are main source of canal water. Jhajjar district, located in south east of Haryana, lies between 28^0 21' 27'' to 28^0 50' 34'' N latitude and between 76^0 16' 46'' to 76^0 58' 13'' E longitude. The geographical area of Jhajjar is 189750 hectare and has five blocks namely, Bahadurgarh, Beri, Jhajjar, Matanhail, Salhawas. The average annual rainfall of the district is about 580 mm. The cultivable area in the district is 163503 hectare. About 41000 hectare land is irrigated by canals and 79794 hectare land is irrigated by tubewells. The ground water development in the district is 87 per cent.

A total of 238 ground water samples were collected from different blocks of Rohtak district (41 from Kalanaur, 33 from Lakhan Majra, 48 from Meham, 72 from Rohtak and 44 from Sampla block) whereas 384 samples were collected from different blocks of Jhajjar district (81 from Bahadurgarh, 75 from Beri, 82 from Jhajjar, 71 from Matanhail and 75 from Salhawas). The latitude, longitude and elevation of the sampling points were recorded using GPS (Fig. 1.6). Water samples were analyzed for various water quality parameters viz., pH, EC, cations (Na^+, K^+, Ca^{+2} and Mg^{+2}) and anions (CO_3^{-2}, HCO_3^-, Cl^-, SO_4^{-2}) to calculate SAR and RSC to classify as per AICRP guidelines on use of saline water.

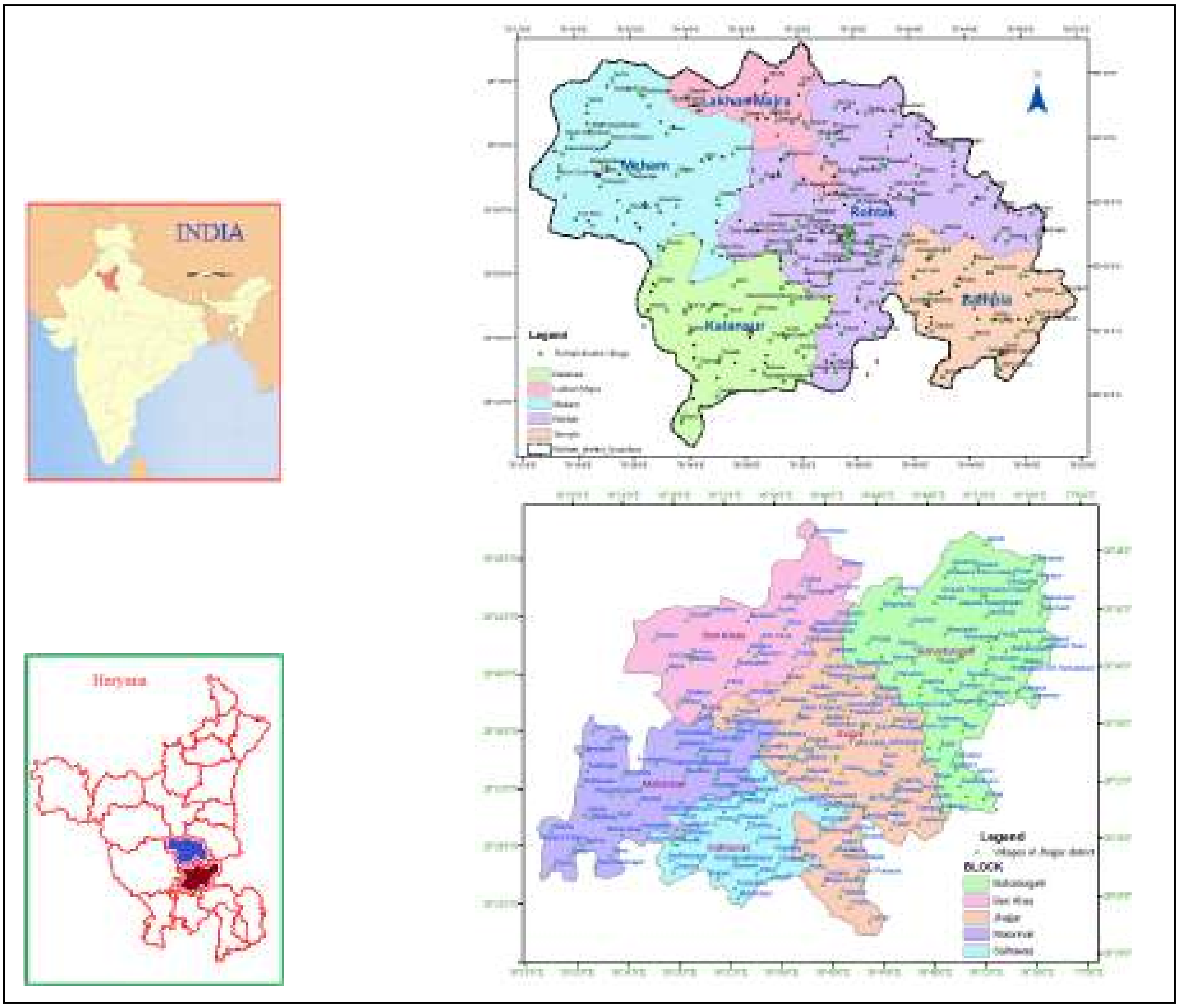


Fig. 1.5. Location map of Rohtak and Jhajjar districts in Haryana

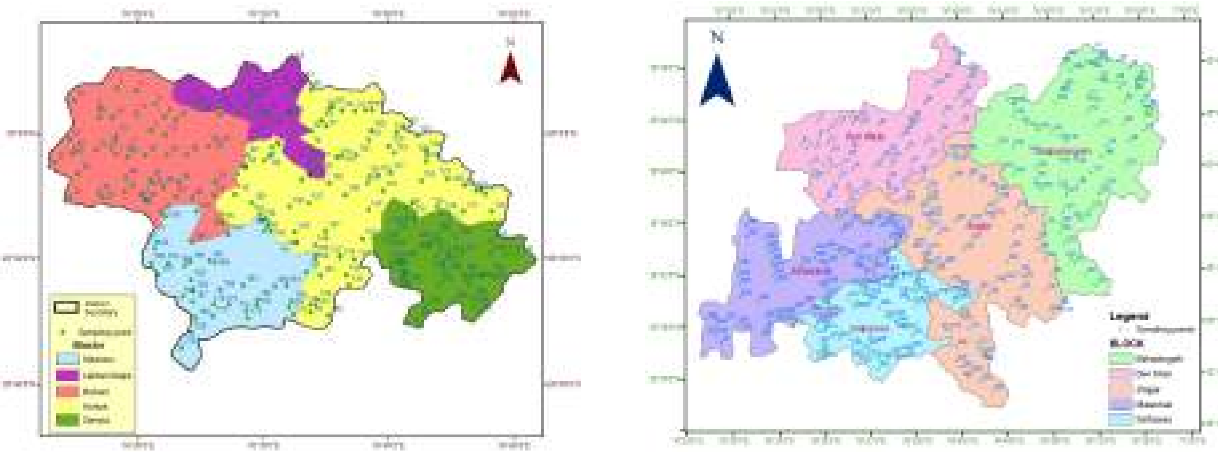


Fig. 1.6. Distribution of ground water sampling points in Rohtak and Jhajjar districts

Water quality distribution in Rohtak district: The mean and range of different water quality parameters for different blocks of Rohtak district is presented in Table 1.11 whereas district wise distribution of ground water quality is shown in Fig. 1.7. Overall in Rohtak district, 60, 57, 41, 27, 24, 17 and 12 samples were found in good, marginally saline, high SAR saline, high alkali, marginally alkali, alkali and saline, respectively. The highest percentage (25.2) of the groundwater in the district was under the good category.

Table 1.11. Water quality parameters of samples of five blocks of Rohtak district

Parameters	Kalanaur		Lakhan Majra		Meham		Rohtak		Sampla	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
EC (dS/m)	0.8-5.7	2.4	0.8-9.4	2.4	0.5-7.3	2.5	0.6-8.6	2.7	0.4-7.5	2.5
pH (-)	7.1-8.8	8.0	6.8-8.6	7.8	6.3-8.8	7.5	6.8-8.9	7.9	6.3-8.6	7.2
CO_3^{-2} (meq/l)	0.0-4.4	0.4	0.0-4.0	0.8	0-4.4	0.7	0-3.2	0.8	0.0-2.0	0.4
HCO_3^-(meq/l)	2-11.2	5.4	1.1-12.4	6.2	0.8-11.2	5.2	1.2-10.4	5.6	0.5-10.4	5.6
Cl^- (meq/l)	2.2-42.0	16.7	6.0-84.6	17.9	3.0-58.0	18.1	3.0-68.0	18.6	2.0-71.0	16.0
SO_4^{-2} (meq/l)	0.0-19.2	2.3	0.1-6.2	1.2	0.0-23.5	2.2	0.1-23.0	3.0	0.0-18.1	3.2
Ca^{+2} (meq/l)	0.2-3.8	1.8	0.3-5.7	1.7	0.2-6.4	1.8	0.0-7.5	2.1	0.3-7.5	2.0
Mg^{+2} (meq/l)	0.3-12.0	5.1	1.1-17.7	5.1	0.3-17.6	5.0	0.7-22.7	5.7	0.8-21.6	5.1
Na^+ (meq/l)	6.6-48.9	19.5	8.6-69.3	21.0	5.8-57.6	20.6	4.8-60.2	19.9	4.3-54.1	17.5
K^+ (meq/l)	0.0-4.3	0.7	0.0-1.5	0.6	0.0-2.2	0.2	0.0-11.2	1.1	0.1-7.2	0.8
RSC (meq/l)	0.0-6.0	0.9	0.0-8.5	2.6	0.0-6.3	0.9	0.0-8.7	1.2	0.0-7.0	1.2
SAR$(mmol/l)^{1/2}$	4.8-38.0	12.0	8.1-21.6	11.9	5.2-30.8	12.8	3.9-24.5	10.6	3.8-20.8	9.3

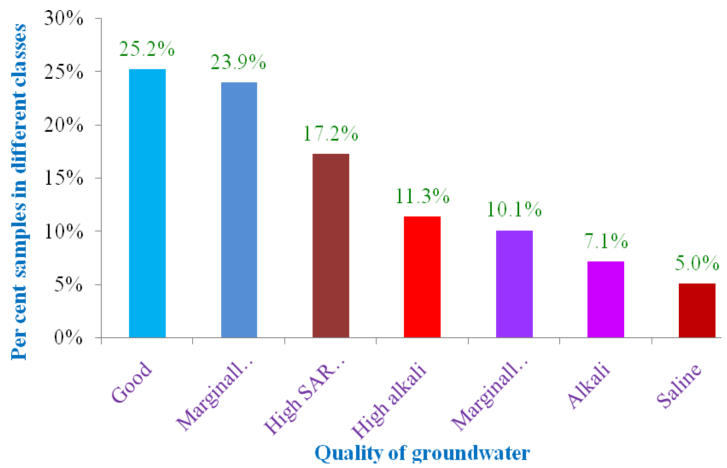


Fig. 1.7. Per cent samples of groundwater in different water quality of Rohtak district

In Rohtak district, EC ranged from 0.4 to 9.4 dS/m with a mean of 2.5 dS/m. The lowest electrical conductivity of 0.4 dS/m in water samples was observed in village Bhalout of Sampla block, whereas, the highest electrical conductivity of 9.38 dS/m is in village Lakhan Majra of Lakhan Majra block. The study revealed that 84.5 per cent of the samples showed EC values <4 dS/m. It is observed from the spatial variable map (Fig. 1.8) that the EC of groundwater is highly scattered and no particular trend is present. In the map, the EC values are divided into 10 classes and reflected by different colours. Dominance of yellow colour in the map indicates that EC of groundwater is mostly ranging between 2-3 dS/m. Next dominating colour in the map is green which shows the range of EC 1-2 dS/m. The highest range of EC 9 to 10 dS/m can be seen at one spot in Lakhan Majra block of the district.

In Rohtak district, SAR ranged from 3.8 to 34.0 $(mmol/l)^{1/2}$ with a mean of 11.2 $(mmol/l)^{1/2}$. The lowest SAR of 3.8 $(mmol/l)^{1/2}$ in water samples was observed in village Nond of Sampla block and the maximum SAR was found as 34.0 $(mmol/l)^{1/2}$ in Kherari of Kalanaur block. In the spatial variable map, the SAR values are divided into 10 classes and reflected by different colours (Fig. 1.9). Dominance of blue colour in the map indicates that SAR of groundwater is mostly ranging from 8 to 12. Next dominating colour in the map is yellow which shows the range of SAR 12-16. The highest range of SAR 36-40 $(mmol/l)^{1/2}$ can be seen at one spot in Kalanaur block.

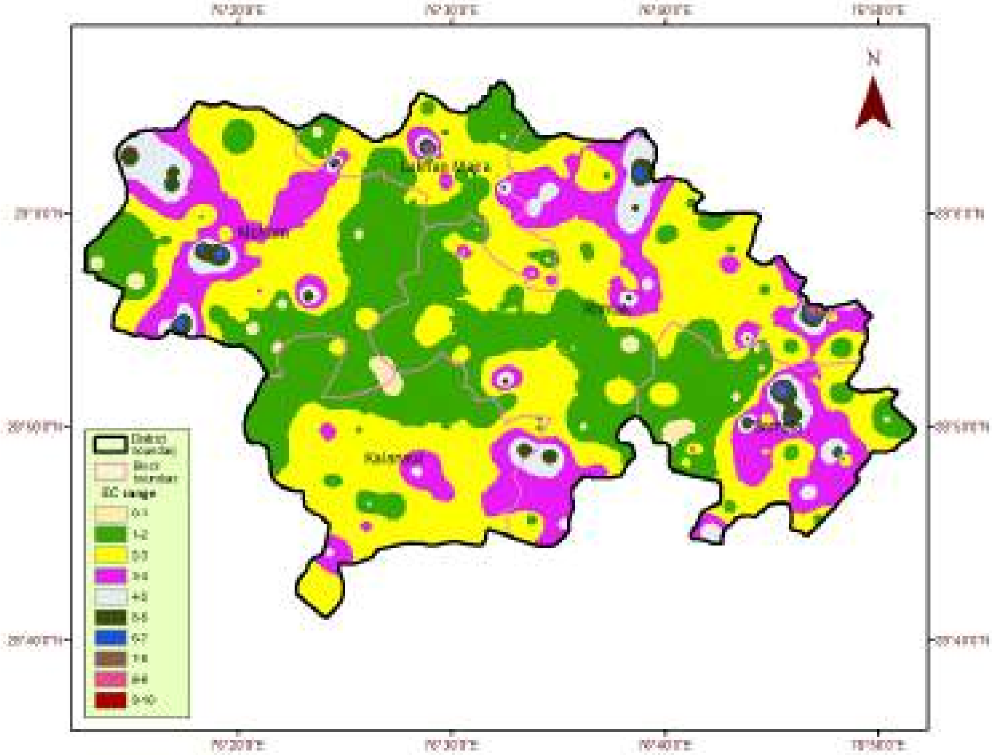


Fig. 1.8. Spatial variable map of EC of groundwater in Rohtak district

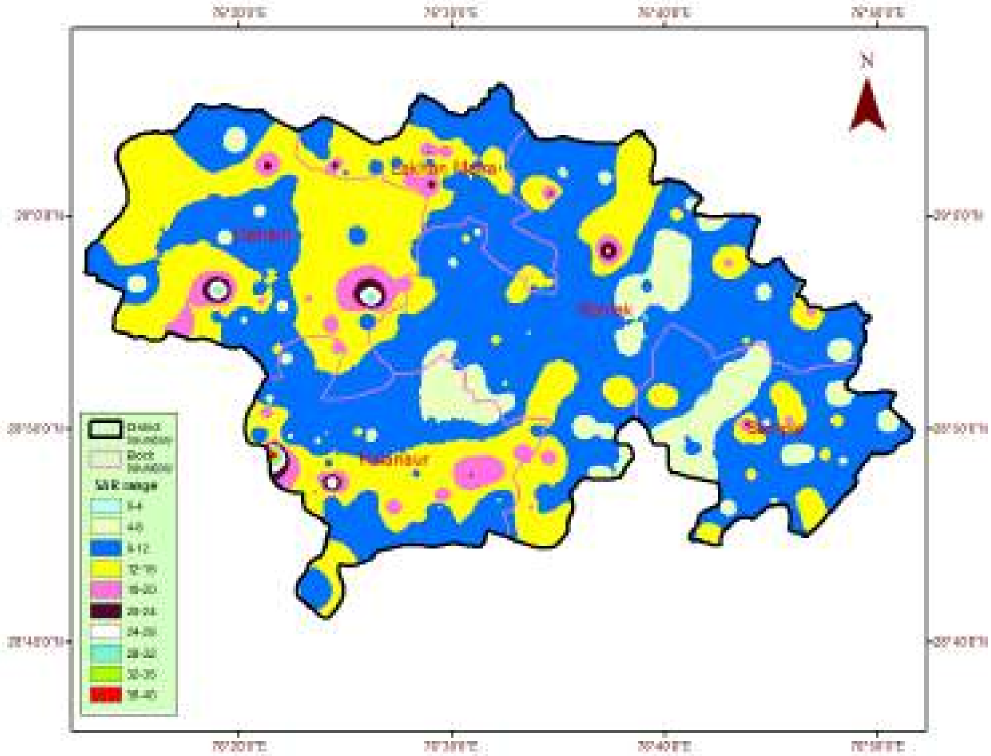


Fig. 1.9. Spatial variable map of SAR of groundwater of Rohtak district

In Rohtakh district, RSC ranged from nil to 8.7 meq/l with a mean of 1.3 meq/l. The highest RSC of 8.7 meq/l in water samples was observed in Kansala village of Rohtak block. In the spatial variable map, the RSC values are divided into 9 classes and reflected by different colours (Fig. 1.10). Dominance of sky colour in the map indicates that RSC of groundwater is mostly ranging from 0 to 1. Next dominating colour in the map is green which shows the range of RSC 1-2. The highest range of RSC 8 to 9 can be seen at different spots in Lakhan Majra block of the district.

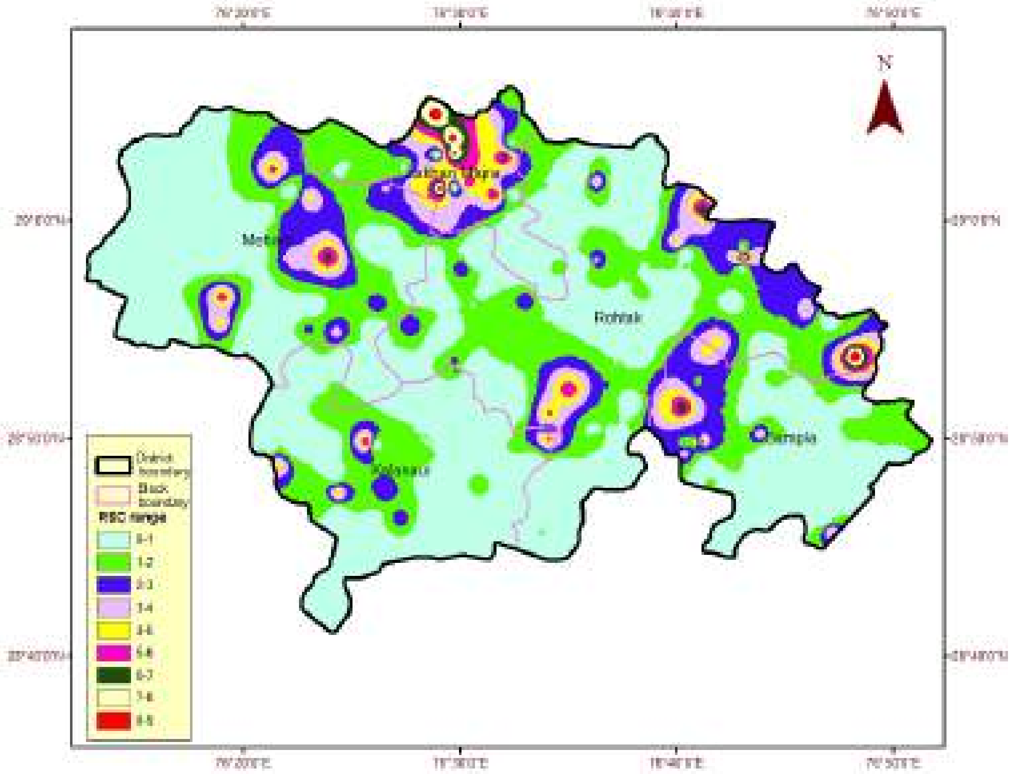


Fig. 1.10. Spatial variable map of RSC of groundwater in Rohtak district

Water quality distribution in Jhajjar district: The mean and range of different water quality parameters for different blocks of Jhajjar district is presented in Table 1.12 whereas district wise distribution of ground water quality is shown in Fig. 1.11. In Jhajjar district 132, 82, 75, 61, 16, 11 and 7 samples were found in good, high SAR saline, marginally saline, high alkali, alkali, marginally alkali and saline, respectively. The highest percentage (34.4%) of the groundwater in the district was under the good category followed by high SAR saline (21.4%). Minimum number of samples (7) was found under saline category in the whole district. On the basis of water sample analysis at block level, Bahadurgarh is severely affected by poor quality of groundwater in which 34.6 percent water samples were categorized under high SAR saline quality.

In Jhajjar district, EC ranged from 0.3 to 13.3 dS/m with a mean of 2.7 dS/m. The lowest EC of 0.3 dS/m in water samples was observed in village Lagarpur of Bahadurgarh block, whereas, the highest EC of 13.3 dS/m is in village Kheri Asara of Jhajjar block. The study revealed that 80.7% of the samples showed EC values <4 dS/m. It is observed from the spatial variable map (Fig. 1.12) that the EC of groundwater is highly scattered and no particular trend is present. In the map, the EC values are divided into 7 classes (0-2, 2-4, 4-6, 6-8, 8-10 and 10-12) and reflected by different colours. Dominance of pink colour in the map indicates that EC of groundwater is mostly ranging between 2-4 dS/m. Next dominating colour in the map is violet which shows the range of EC 0-2 dS/m. The highest range of EC 10 to 14 dS/m can be seen at two spots, one in Bahadurgarh and other in Jhajjar block of the district.

Table 1.12. Water quality parameters of samples of five blocks of Jhajjar district

Parameters	Bahadurgarh		Beri		Jhajjar		Matanhali		Salhawas	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
EC (dS/m)	0.3-12.2	3.5	0.5-8.7	2.7	0.4-13.3	2.7	0.5-9.9	2.4	0.5-6.0	2.0
CO_3^{-2}(meq/l)	0.0-3.2	0.3	0.0-3.4	0.5	0.0-3.1	0.3	0.0-3.9	0.3	0.0-1.6	0.2
HCO_3(meq/l)	0.0-10.0	4.1	1.0-8.5	4.1	0.2-12.0	5.1	0.0-9.6	3.3	0.0-20.1	3.2
Cl^-(meq/l)	2.0-112.0	26.2	1.4-76.3	20.7	2.1-130	20.5	3.6-85.5	18.3	1.3-51.1	15.5
SO_4^{-2}(meq/l)	0.0-17.5	3.9	0.0-11.0	1.9	0.0-8.2	1.1	0.0-16.2	1.9	0.0-8.9	1.3
Ca^{+2}(meq/l)	0.2-11.2	2.5	0.2-6.1	1.9	0.1-14.4	1.3	0.2-3.8	0.8	0.1-3.1	0.9
Mg^{+2}(meq/l)	0.6-33.4	7.4	0.5-19.5	5.7	0.4-42.4	4.3	0.5-11.8	2.6	0.1-9.3	2.8
Na^+(meq/l)	2.4-92.8	24.3	2.9-60.2	20.2	2.6-74.5	20.6	3.1-80.5	19.5	4.6-47.5	15.8
K^+(meq/l)	0.0-4.0	0.6	0.1-2.1	0.5	0.1-3.0	0.6	0.1-2.6	0.5	0.1-2.1	0.4
RSC(meq/l)	0.0-7.6	1.0	0.0-7.0	0.7	0.0-10.3	2.0	0.0-8.9	1.7	0.0-6.2	1.2
SAR$(mmol/l)^{1/2}$	2.5-21.9	11.1	3.1-29.0	10.7	3.2–30.0	13.5	4.6-34.5	15.0	7.3-37.1	12.5

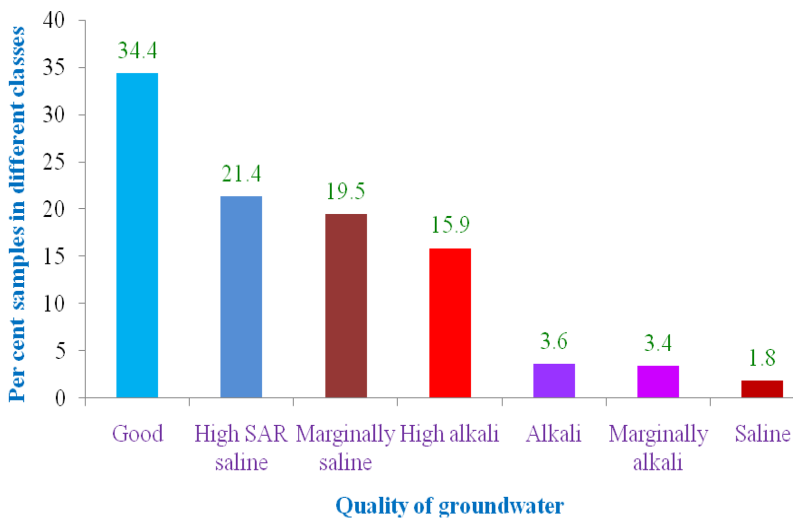


Fig. 1.11. Percent samples of groundwater in different water quality of Jhajjar district

In Jhajjar district, SAR ranged from 2.50 to 37.11 $(mmol/l)^{1/2}$ with a mean of 12.51 $(mmol/l)^{1/2}$. The lowest SAR of 2.50 $(mmol/l)^{1/2}$ in water samples was observed in village Ladrawan of Bahadurgarh block and the maximum value of SAR was found as 37.11 $(mmol/l)^{1/2}$ in village Subana of Salhawas block. In the spatial variable map, the SAR values are divided into 8 classes (0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35 and 35-40) and reflected by different colours (Fig. 1.13). Dominance of sky blue colour in the map indicates that SAR of groundwater is mostly ranging from 10 to 15. Next dominating colour in the map is light green which shows the range of SAR 5-10. The highest range of SAR 25 to 40 dS/m can be seen at ten spots in Matanhail, Salhawas and Beri blocks of the district.

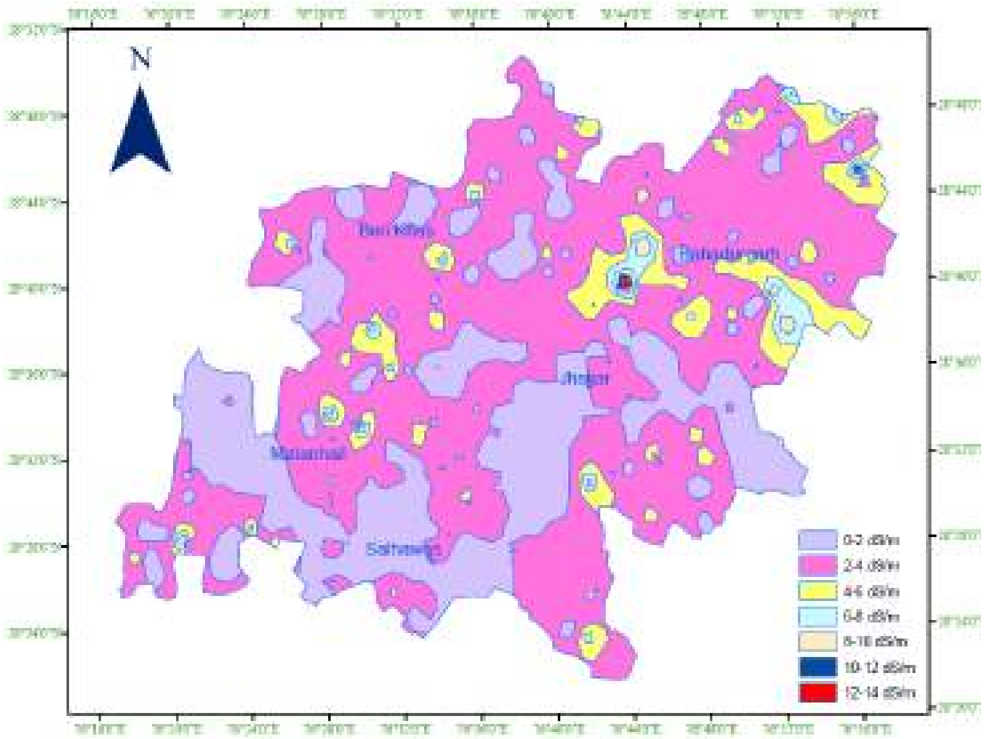


Fig. 1.12. Spatial variable map of EC of groundwater in Jhajjar district

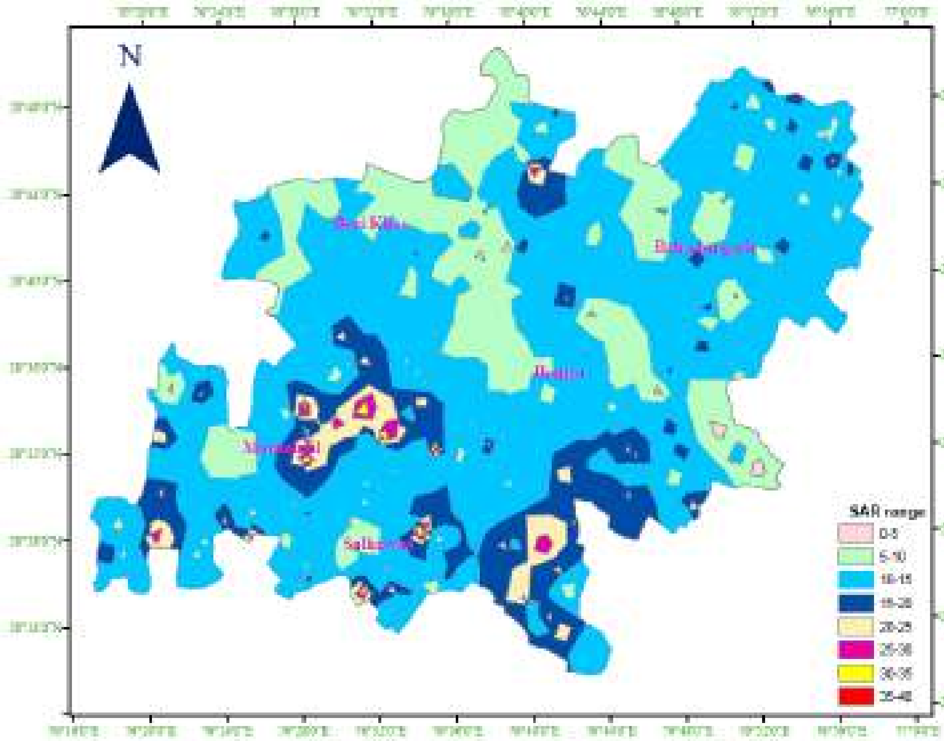


Fig. 1.13. Spatial variable map of SAR of groundwater of Jhajjar district

In Jhajjar district, RSC ranged from nil to 10.30 meq/l with a mean of 1.31 meq/l. Highest RSC of 10.30 meq/l in water samples was observed in Kheri Patuda block of Jhajjar block. In the spatial variable map, the RSC values are divided into 5 classes (0-2, 2-4, 4-6, 6-8, and 8-10) and reflected by different colours (Fig. 1.14). Dominance of sky colour in the map indicates that RSC of groundwater is mostly ranging between 0-2 meq/l. Next dominating colour in the map is yellow which shows the range of RSC is 2-4 meq/l. The highest range of RSC 6 to 10 can be seen at different spots in Jhajjar and Matanhail blocks of the district.

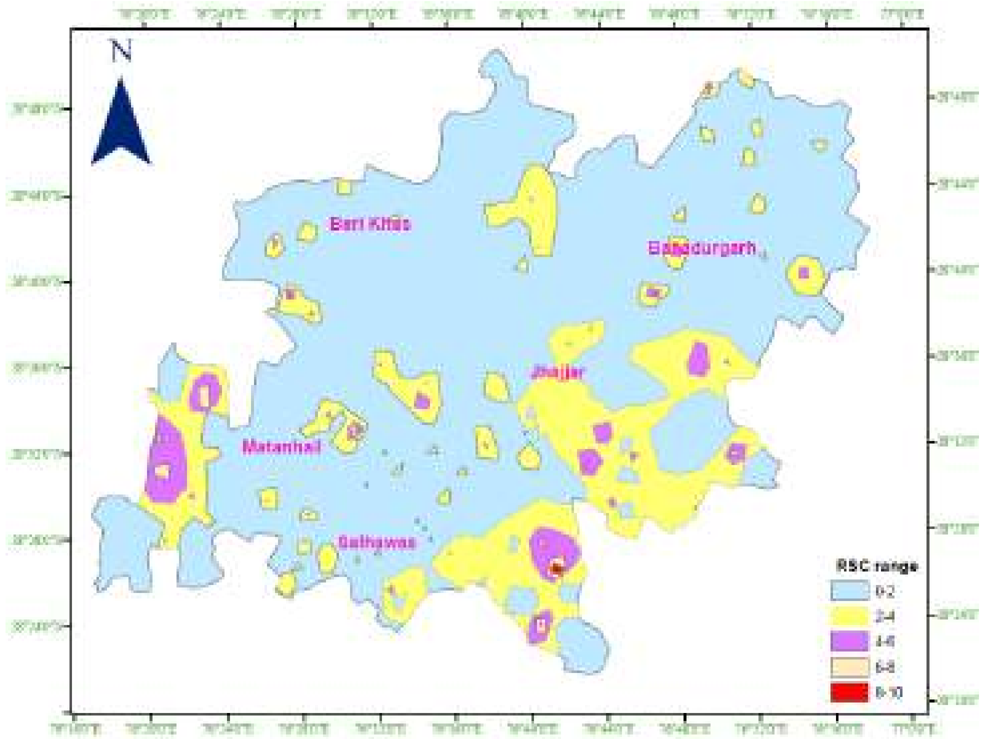


Fig. 1.14. Spatial variable map of RSC of groundwater quality in Jhajjar district

On the basis of present analysis, map for spatial distribution of groundwater quality status of Jhajjar district was prepared and is presented in Fig. 1.15. Different category of the groundwater samples are presented by different colour in the map. Dominance of sky colour represents that the good quality water is present in many parts of the district (34.4%) and next dominating colour in the map is yellow which shows high SAR saline category (21.4%). There is the least existence of saline water category which could not be represented in the map as its value was very less (1.8%) and moreover it was very scattered.

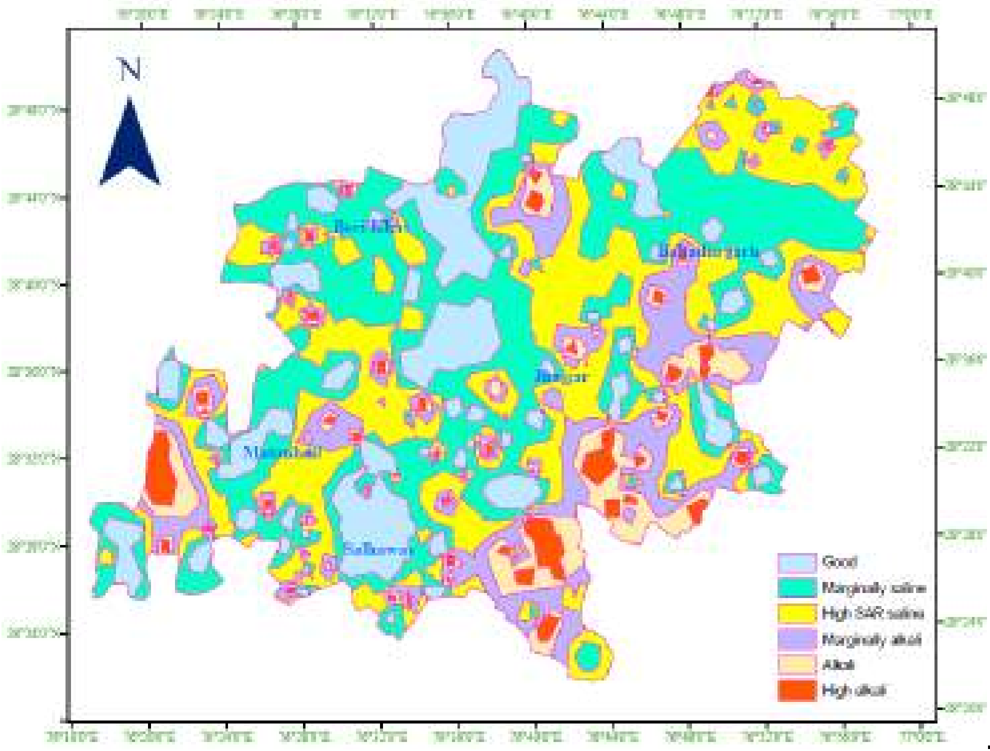


Fig. 1.15. Spatial variable map of groundwater quality in Jhajjar district

Neemuch and Hoshangabad districts (Indore)

The survey and characterisation of underground irrigation water in Manasa, Neemuch and Jawad blocks of Neemuch district in 2010-11 and Itarsi, Hoshangabad, Babai and Sivani Malwa blocks of Hoshangabad district in 2011-12 was undertaken. The Neemuch district is situated in the western part ($24^0$12′22.7″ - $25^0$02′56.3″ N and $74^0$42′32.6″ - $75^0$36′21.9″ E) whereas Hoshangabad is situated in central part ($21^0$53" to $22^0$59" N and 76^0 47" to 78^0 44" E) of the state. The climate of Neemuch district is semi-arid to arid subtropical monsoon type which receives an annual rainfall of about 700-800 mm whereas climate in Hoshangabad is hot sub-humid characterized by hot summers and mild winters which receives annual rainfall of 1300-1500 mm. In these districts, maximum and minimum temperatures are 42 ^{0}C and 9 ^{0}C, respectively. Wheat, garlic, opium poppy, mustard, citrus orchard, papaya, chillies, coriander, berseem and medicinal crops like isabgol, kalongi, chandrasur etc. are the main crops in the Neemuch district whereas soybean, rice, wheat and gram etc. are the main crops in the Hoshangabad district. Open wells and tube wells usually irrigate these crops.

In Neemuch district, a total 405 ground water samples were collected which includes samples from open wells and tube wells. The wells/tube wells vary in depth from 4 to 270 m depth. The quality of groundwater indicates that pH, EC, SAR and RSC range from 6.5 to 8.8, 0.36 to 6.10 dS/m, 0.3 to 16.0 and 0.0 to 11.1 me/l, respectively (Table 1.13). Out of 405 water samples, 294 (72.6 per cent) were classified as good quality (A), 103 (25.4 per cent) as saline (B) and 08 (2.0 per cent) as alkali (C) waters (Table 1.14). The saline waters were further categorized under marginally saline (B_1- 24.2 per cent), saline (B_2 – 0.5 per cent), and high SAR saline (B_3 – 0.7 per cent) category. The alkali waters were again sub divided into marginally alkali (C_1- 0.5 per cent), alkali (C_2 – 0.0 percent) and highly alkali (C_3 – 1.5 per cent) water categories. Manasa tehsil was most badly affected by poor quality waters (46.7 per cent) followed by Neemuch (25.9 per cent) and Jawad (11.5 per cent). Using sampling location, water quality information and ground truth, a ground water quality map for Neemuch district (Fig. 1.16) was generated with the help of remote sensing and GIS software (ERDAS IMAGINE 8.7).

Table 1.13. Salient Features of ground water samples of Neemuch district

Villages	pH	EC (dS/m)	SAR	RSC (meq/l)
Manasa	7.4 - 8.8	0.68 - 3.91	0.3 - 12.7	0.0 - 6.2
Neemuch	7.1- 8.7	0.36 - 6.1	0.6 – 16.0	0.0 – 11.1
Jawad	6.5 - 8.7	0.45 - 3.18	0.5 - 12.3	0.0 – 11.1

Table 1.14. Frequency distribution of water samples into different categories of water quality in Neemuch district

Category	Manasa	Neemuch	Jawad	Total
A	54 (52.4)	140 (74.1)	100 (88.5)	294 (72.6)
B_1	45 (43.7)	41 (21.7)	12 (10.6)	98 (24.2)
B_2	0	2 (1.1)	0	2 (0.5)
B_3	0	3 (1.6)	0	3 (0.7)
C_1	0	2 (1.1)	0	2 (0.5)
C_2	0	0	0	0
C_3	4 (3.9)	1 (0.5)	1 (0.9)	6 (1.5)
Total Samples	103	189	113	405

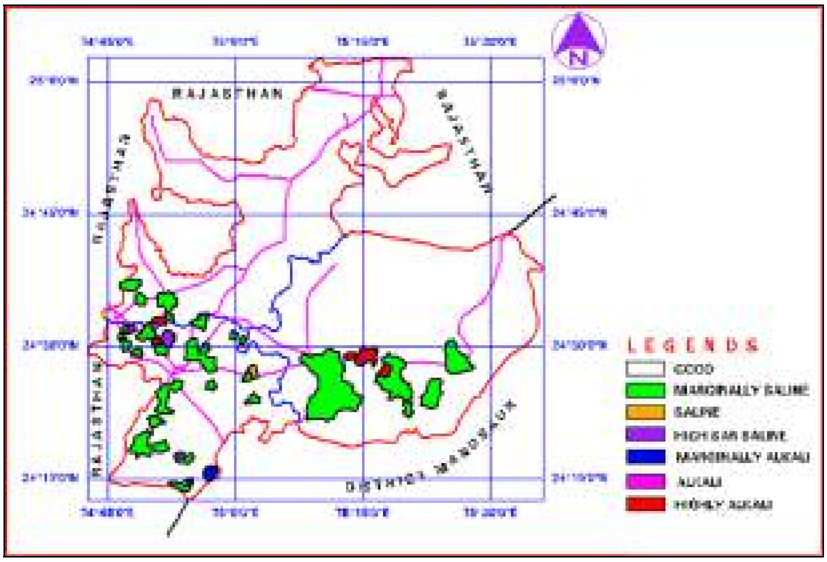


Fig. 1.16. Ground water quality of Neemuch distict of M.P.

In Hoshangabad district, a total of 372 ground water samples from open wells and tube wells of different tehsils of Hoshangabad district were collected. The wells/tube wells vary in depth from 5 to 100 m depth. The quality of groundwater samples collected from the district indicates that pH, EC, SAR and RSC range from 7.00 to 8.9, 0.20 to 3.9 dS/m, 0.0 to 11.6 and 0.0 to 3.8 meq/l respectively (Table 1.15). Out of 372 samples, 356 (95.7 per cent) samples were classified as good quality (A), 14 (3.8%) as saline (B) and 02 (0.5%) as alkali (C) waters (Table 1.16). The saline waters were further categorized under marginally saline (B_1-3.5%), saline (B_2–0.0%), and high SAR saline (B_3–0.3%) category. The alkali waters were sub divided into marginally alkali (C_1-0.5%), alkali (C_2–0.0%) and highly alkali (C_3–0.0%) categories.

Table 1.15. Salient Features of ground water samples of Hoshangabad district

Villages	pH	EC (dS/m)	SAR	RSC (meq/l)
Itarsi	7.45 - 8..85	0.29 - 3.16	0.00 - 11.64	0.00 - 3.80
Hoshangabad	7.02 - 8.52	0.20 - 2.32	0.18 -3.49	0.00 - 1.10
Babai	7.00 - 8.53	0.32 - 2.32	0.11 -7.18	0.00 - 2.60
Shivni Malwa	7.00 - 8.49	0.31 - 3.87	0.05 - 7.83	0.00 - 1.40

Table 1.16. Frequency distribution of water samples into different categories of water quality in Hoshangabad district

Category	Itarsi	Hoshangabad	Babai	Shivni Malwa	Total
A	131 (96.32)	91 (98.91)	59 (96.72)	75 (90.36)	356 (95.70)
B_1	3 (2.21)	1 (1.09)	1 (1.64)	8 (9.64)	13 (3.49)
B_2	-	-	-	-	-
B_3	1 (0.74)	-	-	-	1 (0.27)
C_1	1 (0.74)	-	1 (1.64)	-	2 (0.54)
C_2	-	-	-	--	-
C_3	-	-	-	-	-
Total	136	92	61	83	372

Raebareli district (Kanpur)

In Raebareli district, each block is classified into good, marginal and poor; three water quality aquifer zones by adopting the criteria, district soil/water testing lab and the local farmers. A total 832 groundwater samples from tube wells of each aquifer zone in different blocks (Dalmau 74, Lalganj 177, Maharajganj 103 and Tiloi 110, Raebareli 166, Unchahar 19 and Salon 112) were collected during November to December. Underground water samples were analyzed for pH, EC, ESP, SAR and ionic composition. Water quality samples were grouped in different classes on the basis of EC, SAR and RSC values. The analysis revealed that out of the 832 samples, 726 (87.3%) belongs to good, 95 (11.4%) belong to marginally saline, 02 (0.2%) samples each belongs to saline and high saline, 03 (0.4%) samples each belong to marginali alkaline and highly alkaline and 01 (0.1%) sample belongs to alkali category (Table 1.17). The groundwater quality at block level is presented in Table 1.18. The chemical analysis ground water samples revealed that Cl is the dominant anion whereas Ca followed by Na are the dominant cations in the Dalmau and Raebareli tehsil whereas Cl followed by HCO_3, SO_4 and Na followed by Ca and Mg are the dominant ions in Lalganj, Maharajganj, Tiloi, Unchahar and Salon tehsil.

Table 1.17. Ground water quality in different blocks of Raebareli district

Category	Dalmau	Lalganj	Maharajganj	Tiloi	Raebareli	Unchahar	Salon	Total
Good	69	154	84	102	142	71	104	726
M. Saline	4	20	17	7	23	17	17	95
Saline	1	1	-	-				2
High Saline	-	-	1	-		1		2
M. Alkali	-	1	1	-		1		3
Alkali	-	1	-	-				1
Highly alkali	-	-	-	1	1		1	3
Total samples	74	177	103	110	166	90	112	832

Table 1.18. Groundwater quality parameters in different blocks of Raebareli district

Tehsil	pH	EC (dS/m)	SAR	RSC (meq/l)
Dalmau	7.2-8.2	0.4-4.8	0.6-5.6	0.0-2.7
Lalganj	7.1-8.2	0.5-4.1	0.7-9.8	0.0-6.7
Maharajganj	7.1-8.3	0.5-4.0	0.6-16.0	0.0-2.8
Tiloi	7.0-8.3	0.3-3.4	0.2-10.2	0.0-10.2
Raebareli	7.1-8.2	0.3-4.8	0.5-10.2	0.0-7.2
Unchahar	7.2-8.2	0.4-4.8	0.6-10.1	0.0-2.6
Salon	7.2-8.3	0.6-3.3	0.9-10.2	0.0-7.2

Namakkal district (Trichy)

Namakkal district has 15 Blocks viz., Erumaipatti, Mohanur, Paramathi, Kabilamalai, Namakkal, Sendamangalam, Puduchatram, Namagiripet, Tiruchengodu, Pallipalayam, Kolli hills, Vennandur, Mallasamutram, Elachipalayam and Rasipuram. A total 1668 ground water samples from open and tube wells were collected from different parts of Namakkal district to characterize the ground water quality. The water samples were analyzed for pH, EC, cations (Ca, Mg, Na and K) and anions (CO_3, HCO_3, Cl and SO_4). Quality parameters like SAR and RSC were calculated. Classification of water quality is done on the basis of EC, SAR and RSC as per AICRP guidelines (Fig. 1.17).

Fig. 1.17. Ground water quality map of namakkal district

Among the 15 blocks, the distribution of good quality samples was highest in Kolli hills block (85.8%) and lowest in Rasipuram (32.5%) block (Table 1.19). The occurrence of marginally saline water (5.90 to 48.7%) was prevalent in all the blocks. Marginally alkali water is prevalent in Erumaipatti (9.5%), Mohanur (8.6%), Paramathi (4.3%), Kabilamalai (5.3%), Puduchatram (10.5%), Pallipalayam (5.9%) and Rasipuram (13.3%) blocks. Saline water was found in almost all the blocks (2.9 to 35.9%) except Namagiripet, Kolli hills and Rasipuram blocks. Marginally alkali water was found in Erumaipatti (9.5%), Mohanur (8.6%), Paramathi (4.3%), Kabilamalai (5.3%), Puduchatram (10.5%), Pallipalayam (5.9%) and Rasipuram (13.3%) blocks. Alkali water was prevalent in Erumaipatti (2.9%), Paramathi (5.1%), Namagiripet (10.7%), Pallipalayam (4.7%) and Rasipuram (8.5%) blocks. Highly alkali and high SAR saline waters were not found in any part of the district. Among the total samples collected, 62.3% is coming under good quality, 27.1 is marginally saline, 6.5% is marginally alkaline, 1.9% is alkaline and 8.5 % is saline.

Table 1.19. Water quality distribution (per cent) in Namakkal district

Name of Block	No of Samples	Good	Moderately Saline	Saline	Moderately Alkali	Alkali
Erumaipatti	136	56.6	27.9	2.9	9.5	2.9
Mohanur	104	73.0	14.4	3.8	8.6	
Paramathi	116	70.6	15.5	4.3	4.3	5.1
Kabilamalai	94	65.9	23.4	5.3	5.3	-
Namakkal	157	64.9	31.8	3.2	-	-
Sendamangalam	76	60.5	22.3	17.1	-	-
Puduchatram	123	32.5	48.7	8.1	10.5	-
Namagiripet	84	83.3	5.9	-	-	10.7
Tiruchengodu	153	46.4	47.7	5.8	-	
Pallipalayam	84	61.9	22.6	5.9	5.9	4.7
Kolli hills	99	85.8	14.1	-	-	-
Vennandur	89	62.9	11.2	35.9	-	-
Mallasamudram	111	58.5	12.6	28.8	-	-
Elachipalayam	137	43.7	43.0	13.1	-	-
Rasipuram	105	32.3	45.7	-	13.3	8.5
Total /average	1668	62.3	27.1	8.5	6.5	1.9

Chemical composition of ground waters

The relationship between EC with anionic and cationic composition of irrigation waters, SAR and RSC for different blocks of Nammakal districts are presented in Tables 1.20-1.22. In general, the distribution of cations followed the order of Ca, Mg >Na >K. However in high RSC water samples, the distribution of cations followed the order of Na >Ca, Mg >K. Similarly the distribution of anions followed the order of HCO_3 >Cl >SO_4 when the irrigation water quality is good (EC <2 dS/m). But the distribution of anions followed the order of Cl >HCO_3 >SO_4 in the EC range of 2 to 4 dS/m and Cl >SO_4 >HCO_3 in the EC range >4.0 dS/m. Water quality category for different villages of the blocks of Namakkal district are presented in Table 1.23.

Table 1.20. Quality of ground waters in different blocks of Namakkal district

Name of Block	pH			EC (dS/m)			RSC (meq/l)			SAR		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Erumaipatti	7.07	8.82	7.97	0.65	4.21	1.525	Nil	5.2	0.69	0.20	5.76	2.31
Mohanur	7.14	8.74	7.92	0.31	4.91	1.345	Nil	3.8	0.48	0.96	5.29	2.12
Paramathi	7.12	8.65	8.015	0.24	4.34	1.385	Nil	5.60	0.61	0.83	7.78	2.38
Kabilamalai	7.01	8.47	7.955	0.30	5.32	1.49	Nil	3.2	0.49	0.45	6.75	2.21
Namakkal	7.10	8.43	7.53	0.30	6.08	1.55	Nil	2.3	0.31	0.45	5.81	6.28
Sendamangalam	7.14	8.60	7.995	0.30	6.15	1.735	Nil	2.4	0.38	0.15	4.89	2.18
Puduchatram	7.01	8.70	7.89	0.32	4.83	1.875	Nil	3.8	0.71	0.26	7.25	2.49
Namagiripet	7.02	8.86	7.97	0.34	3.15	1.12	Nil	4.7	0.78	0.6	7.21	2.28
Tiruchengodu	7.09	8.43	7.875	0.30	4.33	1.63	Nil	2.4	0.21	0.39	4.39	1.79
Pallipalayam	7.13	8.90	8.035	0.37	5.62	1.415	Nil	4.2	0.56	0.26	4.39	2.2
Kolli hills	7.01	8.43	7.915	0.30	3.40	1.195	Nil	2.4	0.26	0.55	4.12	1.9
Vennandur	7.01	8.43	7.95	0.40	6.13	1.9	Nil	2.4	0.18	0.63	4.91	1.96
Mallasamudram	7.01	8.67	7.955	0.40	4.37	1.775	Nil	2.1	0.22	0.20	5.38	2.49
Elachipalayam	7.10	8.48	8.045	0.70	4.90	1.85	Nil	2.4	0.28	0.67	7.10	2.44
Rasipuram	7.21	8.73	7.965	0.10	3.75	1.685	Nil	4.6	0.76	1.10	5.76	3.17

Table 1.21. Cationic composition of ground water in different blocks of Namakkal district

Name of Block	Ca^{2+}			Mg^{2+}			Na^{+}			K^{+}		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Erumaipatti	0.3	1.8	5.73	0.2	1.6	4.33	0.1	10.7	4.8	0.01	1.5	0.09
Mohanur	1.2	20.2	5.53	1.4	18.2	3.79	1.9	8.2	4.11	0.01	0.20	0.13
Paramathi	0.30	19.2	5.45	0.5	15.2	4.07	1.9	17	4.54	0.01	1.05	0.10
Kabilamalai	0.5	25.2	6.01	0.5	20.3	4.49	1.5	15.3	4.95	0.01	0.08	0.03
Namakkal	1.2	26.3	6.66	1.2	24.8	4.63	1.0	15.3	4.91	0.01	1.08	0.15
Sendamangalam	0.5	30.5	7.08	0.4	14.9	5.09	0.1	15.5	5.08	Nil	3.02	0.40
Puduchatram	0.1	19.2	7.38	0.1	13.7	5.61	0.1	18.9	5.77	0.01	1.5	0.06
Namagiripet	0.1	14.5	3.79	0.1	12.7	3.69	0.1	10.7	3.93	0.01	0.09	0.04
Tiruchengodu	0.2	18.5	6.30	0.1	18.5	4.96	0.1	17.2	5.12	0.01	1.08	0.05
Pallipalayam	0.1	20.5	5.42	0.1	17.8	4.35	0.1	19.2	4.83	0.01	0.21	0.04
Kolli hills	0.1	14.0	4.42	0.1	13.0	3.52	0.2	10.5	2.06	0.01	0.16	0.04
Vennandur	0.1	30.5	7.95	0.1	24.8	4.40	0.2	18.9	5.66	0.02	18.9	0.23
Mallasamudram	1.0	20.5	7.07	0.2	17.8	5.28	0.1	19.2	5.46	0.01	1.8	0.23
Elachipalayam	0.2	20.2	6.60	0.1	20.3	5.14	0.3	15.3	5.25	0.01	1.5	0.09
Rasipuram	1.0	18.5	6.47	1.2	10.1	4.19	2.4	12.6	6.57	0.01	1.8	0.19

Table 1.22. Anionic composition of ground waters in different blocks of Namakkal district

Name of Block	CO_3^{2+}			HCO_3^-			Cl^-			$SO4^{2-}$		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Erumaipatti	0.1	4.3	1.45	0.3	18.6	5.70	0.3	28	6.51	0.2	4.6	1.15
Mohanur	0.1	2.3	1.04	1.3	18.6	6.1	1.8	16.2	5.02	0.1	1.8	0.55
Paramathi	0.1	16	1.90	1.2	15.3	5.85	2.2	21.9	5.92	0.1	10.4	1.06
Kabilamalai	0.1	2.9	1.09	1.3	37.3	7.05	1.3	16.5	6.79	0.1	5.2	0.98
Namakkal	0.2	1.8	0.99	1.3	39.2	6.88	1.2	26.3	7.74	0.1	6.0	1.58
Sendamangalam	0.2	30.5	1.34	0.3	30.5	7.85	0.1	30.9	7.54	Nil	5.2	1.35
Puduchatram	0.1	21.7	1.33	0.1	21.7	8.61	0.3	22.1	8.07	0.1	3.2	1.13
Namagiripet	0.1	15.5	0.99	0.2	15.5	4.85	0.2	16.2	4.55	0.1	1.6	0.8
Tiruchengodu	0.1	21.3	1.35	0.4	21.3	7.72	0.3	21.0	6.95	0.1	3.4	0.79
Pallipalayam	0.1	6.3	1.02	0.1	6.3	7.8	0.2	25.5	6.98	0.1	2.5	0.78
Kolli hills	0.1	2.5	0.76	0.1	9.8	5.19	0.1	18.1	4.65	0.1	2.9	0.65
Vennandur	0.1	1.30	1.14	0.1	39.2	8.6	0.1	30.9	8.57	0.1	6.0	1.09
Mallasamudram	0.1	6.3	1.07	0.3	25.5	8.02	2.1	25.5	6.8	0.1	1.6	0.85
Elachipalayam	0.1	1.8	1.11	3.1	37.3	8.16	2.2	18.3	8.09	0.1	10.4	1.37
Rasipuram	0.1	2.8	1.28	2.5	15.6	7.27	1.8	19.6	8.19	0.1	6.0	1.73

Table 1.23. Villages under different water quality in different blocks of Namakkal District

Water quality categories	Name of the villages
Erumaipatti block	
Good	Valavanthi, Jambumadai, Mettupatti, Vadavathur, Varatharajapuram, Pavithram, Pavithramputhur, Singalam kombi, Palaiyapalayam, Muthugapatti, Rettipatti, Valayapatti, Arur, Arusantham.
Marginally alkaline	Erumaipatti, Devarayapuram, Perumapatti.
Marginally saline	Sevanthipatti, Kavukaranpatti, Muttanchetti, Varagur, Vadagapatti, Konagipatti, Pudukombi, Alanganatham.
Alkaline	Pattireddypatti
Saline	Sivanayakkanpatti
Mohanur block	
Good	Aanda puram, Mohanur, Parali, Pettai palayam, Kumarapalayam, Senjapalli, Oidapalayam, Nanjai Edayaur, Perumamdam palayam,Ariyur, Lethuvadi, Tholur, Mudukasampatti, K.Pudhu palayam, Velur.
Marginally alkaline	Aniyuparam, Chinnapethumpatti
Marginally saline	Kumari palayam, Oruvanthur Kalipalayam
Alkaline	--
Saline	Manappalli
Paramathi block	
Good	Velur, Pilur, Nadandai, Nallur, Maniyanur, Kodur, Piranthujam, Iruttanai, Sungukaranpatti, Villipalayam, Viranam Palayam, Manikkanatham, Melsathambur, Sittampoodi.
Marginally alkaline	--
Marginally saline	Kolaram, Pillai kulathur, Kunnamalai, Paramathi
Alkaline	Kuducheri, Sirapalli
Saline	Serukkalai

Kabilamalai block	
Good	Kopalyam, Pillkal palayam, Ayyam palayam, Voda karithur, Kotha mangalam, Jamillampalli, Salasirumani, Sakku palayam, Irrukkur
Marginally alkaline	Periya Solipalayam
Marginally saline	Pothanur, Pantamangalam, Kolakkataputhur, kurumbalamahadevi, Kavuntam palayam, Kapillarmali
Alkaline	--
Saline	--
Namakkal block	
Good	Vasanthapuram, Periyapatti, Vallipuram, Thotipatti, Kirambur, Kilsathampur, Ayyampalayam, Silavampatti, Kathuplli, Yernakullam, Renjappanayakam palayam, Nalli palayam.
Marginally alkaline	--
Marginally saline	Vahurampatti, Kontisettiyapatti, Kavettipatti, Konur, Periyakovundam palayam, Thaligai, Aniur, Singlipatti, Marappanaickenpatty Thindamangulam, Kontanagakanpatti
Alkaline	--
Saline	Rasam Palayam
Sendamangalam block	
Good	Pottanam, Periyakulam, Thuthikulam, Kalappanayakanpatti, Uthirakutikaval, Narasimmankadu, Thottichikada, Pallipatti, Nadukompai, Valavan thikombai.
Marginally alkaline	--
Marginally saline	Akkiyamppatiy, Pelakurichi, Melappatti, Valayappatti.
Alkaline	--
Saline	Senthamangalam, Pachutaiyan patti, Pommasamuthiram
Puduchatram block	
Good	Elur, Kaarikurichiputhur, Minnamplli, Thalampati, A.K.samuthiram, Kathiranllur, Kannurpatti, Thathayangarpatti, Pappanayakanptti, Karatiyanur, Pachutiyanpalayam
Marginally alkaline	Udupam, Kalyani, Navani
Marginally saline	Kalagannia, Thirumalaiptti, Shellappamptti, Kartiptti, Thathathipuram, S.Nattarmangalam, Lackapuram, Puthuchathiram, Patchial, Andavargate, Mukkaliptti, Sirapalli, Thoppampatti.
Alkaline	--
Saline	Thathayangarpatti, S.Udappam
Namakiripet block	
Good	Namagiripet, Puthupatti, Mulapllipatti, Karkutalpatti, Naraikinaru, Mullukurichi, Kariyampatti, Mulakurichi, Periyakommpai, Thimmanayakanpatti, Esvaramurthipalayam, Mangalapuram, Oilaparty, Aguntampalayam, Koraiyaru.
Marginally alkaline	--
Marginally saline	Vadugam
Alkaline	Mavar.R.F, Mathurut
Saline	--

Thiruchengode block	
Good	Thannirpanthal, Akkalampatti, Kailasam palayam, Andi palayam , Pigithi, Molasi Sithulanthir, Yeraiyamangalam, patlur, yemapalli, T. Kavundam palayam, Sirumolasi Varaguram patti.
Marginally alkaline	--
Marginally saline	O. Rajapalayam, Thirumanjalam, Vattur, Animoor, Puthupalayam, Thevanam kurichi, Motamangalam, Karuveppampatti, pallioalagam.
Alkaline	--
Saline	Puthupalayam, Karamapuram.
Pallippalayam block	
Good	Pappampalayam, Kokkarayan patti, Katachanullur, Puthu Palayam, Alam pakam, Kaliyanur puthrai, Pallaku palayam, Kuppantampalyama, Thattanguttai, Kumara palayam.
Marginally alkaline	Rendanur
Marginally saline	Akraaram, Yelanthukuttai, Savuthara puram, Valayakunoore
Alkaline	Kaliyanur Akraaram
Saline	Pataiveedu
Kolli hills block	
Good	Devanor nadu, Thinnanur nadu, Valappurnadu, Valavanthinadu Puliyaensolai R.F., Valapurnadu, Ariyurnadu, Karavalikombairf, Gundurnadu, Alathurnadu, Adakampu thukombai, Thirupulinadu, Edappolinadu, Adakamputhukombai, Nayakan kombi RF, Adakampodukombai RF. Varagur.R.F Chithoor nadu,, Perakkarainadu
Marginally alkaline	--
Marginally saline	Selur Nadurf, Selurnadu, Balnadu R.F.
Alkaline	--
Saline	--
Vennandur block	
Good	K.Karalpatti,Thottypatty,Sowdapuram,Mathiyampatty, Kattanachppaty,Semmandapatty,Moolakadu,Vennandhur,Nachipatty, Alavaipaty,Anandrgoundenpalayam, Minnakkal,
Marginally alkaline	-
Marginally saline	Killur, Thiramanur R.F.
Alkaline	-
Saline	Palavanak kenpatty, Kuttaladampatty, Thottgvalasu, Ayeepalayam, Thengalpalayam, Kallankulam,
Mallasamudram block	
Good	Mangalam, Mallasamamathram, Seppaiyapuram, Sirkar Mamundi, Mamundi Agraharam, Mallasamudaram(west), Karumoonur, Kelankondal, Palamedu, Kallupalayam, Kotlaipulayam, Moramgam, muntanur, Nagarapalayam
Marginally alkaline	-
Marginally saline	Rumapuram, Avanasipatty, Vandinatham,
Alkaline	-
Saline	Ballakuli, Ballakuli Agraharm, Sambagamahadevi, Pudu palayam, Koothanatham, Pillanatham, karumanur

Elachipalayam block	
Good	Kuppachipalayam, oduvampalayam, Iluppuli, Konnaiyar, Manathi, Marukkalampaty, Elanagar, Akkalampatty, Murukalampatty, Thondipatty, Kokkalai, Periyamanali, Chinnamanali.
Marginally alkaline	--
Marginally saline	Sathiganakhenpalayam, Natagapalayam,Pokkampalayam,Lathuvadi, punjaipudupalayam, kootnampundi Agram, Puliagoundampatty, Kllapalam, Agaram,Musiri, Puthureast, Bommampatty.
Alkaline	--
Saline	Alaiyampalayam, Unjanae, Molipalli, Nallipalayam
Rasipuram block	
Good	Kumarapalayam, Ayeepalayam, Ponkurichy,Murungapatty, Anaipalayam, Kurukkapuram, Goundam palayam.
Marginally alkaline	Koonavelampatty, Muthukalipatty, Rasipuram,
Marginally saline	Molapalayam,Kanagabommanpatty,Singalanthapuram,Arasampalayam, Malayampatty Koneripatty, Bodinayakkanpatti, Vadugam, Pattanam Chandraseharapuram, muniyapan palayam,
Alkaline	Kakaveri,Pattanam,
Saline	--

Delineation and Mapping of Salt Affected Soils using RS and GIS

Nellore, Guntur, Prakasam and Krishna districts, A.P. (Bapatla)

A total 157 samples in Nellore, 220 in Guntur, 192 in Prakasam and 78 in Krishna districts were collected and anlysed to delineate and map salt affected soils using spatial techniques (Table 1.24).

Table 1.24. Soil EC_e and pH_s of different districts of Andhra Pradesh

District	Depth (cm)	pH range	EC_e range (dS/m)
Nellore	0-20	6.1 - 10.7	0.3 - 63.8
	21-50	6.9 – 13.0	0.3 - 64.3
Guntur	0-20	5.8 - 8.8	0.6 - 48.9
	21-50	6.6 - 8.5	0.9 - 30.0
Krishna	0-20	7.6 - 8.4	0.3 - 16.4
	21-50	7.2 - 8.8	0.2 - 10.8
Prakasam	0-20	6.1 - 9.0	0.1 - 37.0
	21-50	6.2 - 8.7	0.1 - 25.0
Srikakulam	0-20	6.5 - 7.9	0.3 - 10.9
	21-50	6.4 - 8.0	0.3 - 14.2
Vizianagaram	0-20	6.7 - 8.1	0.2 - 11.9
	21-50	7.0 - 8.2	0.2 - 14.9
Visakhapatnam	0-20	6.8 - 7.9	0.3 - 17.9
	21-50	7.0 - 8.0	0.2 - 9.8
	51-80	7.0 - 8.1	0.2 - 10.8
Chittoor	0-20	6.7 - 8.0	0.3 - 11.5
	21-50	6.5 - 8.0	0.3 - 12.5
	51-80	6.3 - 8.1	0.3 - 10.8

In Guntur district, out of 220 soil samples, 18.2 per cent were saline, 0.9 per cent was alkali and 0.5 per cent was saline-alkali and remaining 80.4 per cent samples were good/normal soils. In addition to EC_e, pH_s, OC, CaCO3, CaCO3 and ESP were also estimated. In Prakasam district, out of 192 soil samples, 20.3 per cent were saline, 3.7 per cent were alkali, 2.1 per cent saline–alkali and remaining 73.9 per cent were good/normal soils. In addition, water soluble Ca, Mg, Na, K., CO_3, HCO_3, Cl, SO_4 and SAR were computed. Satellite imaginaries of Vijayanagaram and Srikakulam districts were obtained from NRSC, Hyderabad and digitization work is completed. Soils samples were collected and analysed for Srikakulam, Vijayanagaram and Visakhapatnam.

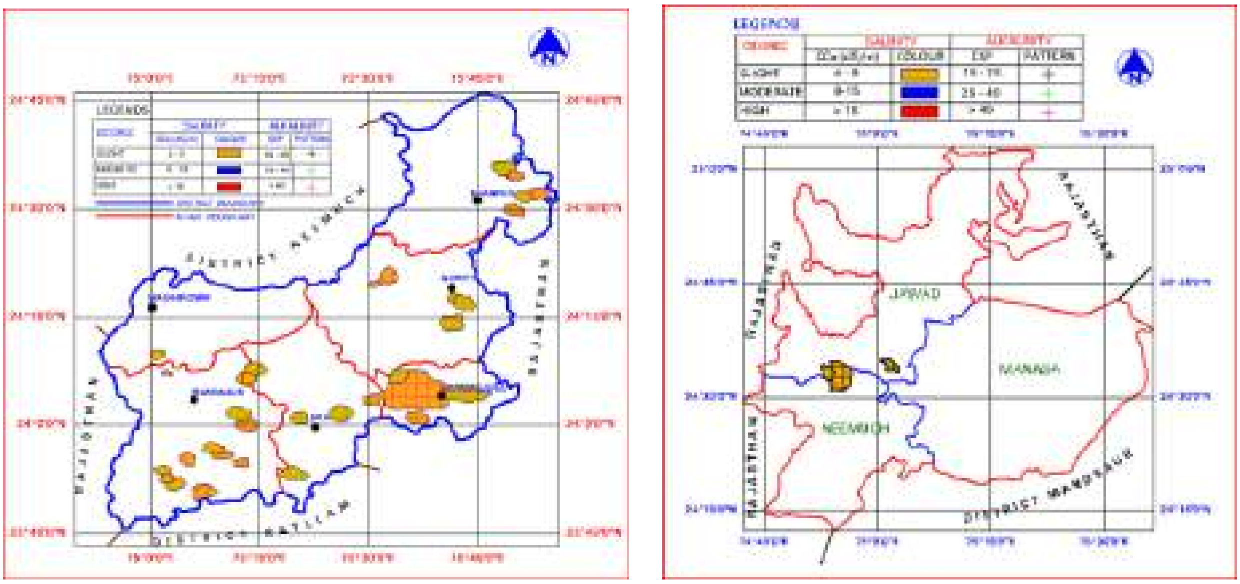
Mandsaur and Neemuch districts, M.P. (Indore)

Mandsaur district: The Detailed reconnaissance soil survey was conducted in different tehsils of Mandsaur district to find out locations, extent and nature of salt affected soil. Most of the samples are dominated by clay particles. The texture of surface soil graded in to clay loam and clay. The reaction of soil (pH) in the surface layer is alkaline. pH of the saturation extract ranged from 7.5 to 8.7. Most of the samples depicted higher pH i.e. >8.0. The EC_e of saturation extract is an important property to judge the behaviour of soil in respect of salinity/ alkalinity. EC_e ranged from 1.2 to 2.7 dS/m. Among different cations, Na was the dominant one in all the soil samples and ranged from 6.3 to 12.2 meq/l. This shows that the soils are saturated with Na followed by Ca and Mg. The SAR values ranged between 3.4 and 6.2. The exchangeable sodium percentage (ESP) varied from 14.0 to 61.6 respectively. The soils were categorized in various categories of salinity (marginal 4.0-8.0, moderate 8.0-15.0 and strong: > 15.0 EC_e dS/m) and sodicity (marginal <15.0, moderate 15.0-40.0 and strong >40.0 ESP), fall under slightly saline and highly alkali (7854 ha) followed by slightly saline and moderately alkali (7006 ha) and slightly saline and slightly alkali (577 ha) category. The salt affected soils in Mandsaur district is estimated to 15437 ha (Table 1.25).

Neemuch district: The detailed reconnaissance soil survey was carried in different tehsils of Neemuch district of Madhya Pradesh to find out locations, extent and nature of salt affected soil. The district is situated in the northern part of Madhya Pradesh. The texture of surface soil graded in to loam and clay loam. The reaction of soil (pH) in the surface layer is alkaline. pH of the saturation extract ranged from 8.3 to 8.5. Among different cations, Ca was the dominant one in all the soil samples and ranged from 5.2 to 7.8 meq/l. This shows that the soils are saturated with Ca followed by Na and Mg. The SAR values ranged between 1.06 and 1.76. The exchangeable sodium percentage (ESP) varied from 23.1 to 33.7 respectively. The soils were categorized in various categories of salinity (marginal: 4.0-8.0, moderate: 8.0-15.0 and strong: >15.0 EC_e dS/m) and sodicity (marginal: <5.0, moderate: 15.0-40.0 and strong: >40.0 ESP). The area of salt affected soils in Neemuch district is estimated to 3150 ha, mostly come under slightly saline and slightly alkali (2545 ha) followed by slightly saline and moderately alkali (605 ha) category (Table 1.25). The maps of salt affected soils for Mandsaur and Neemuch districts were prepared (Fig. 1.18)

Table 1.25. Extent of salt affected soils in Mandsaur and Neemuch district

Category	Area (ha)	
	Mandsaur	Neemuch
Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	577	2545
Slightly saline and moderately alkali (EC 4-8 dS/m and ESP 25-40)	7006	605
Slightly saline and highly alkali (EC 4-8 dS/m and ESP > 40)	7854	-
Total	15437	3150



Mandsaur Neemuch

Fig. 1.18. Distribution of salt affected soils of Mandsaur and Neemuch districts of M.P.

Monitoring of Ground Water Quality/Soil Properties at Benchmark Sites

Guntur district (Bapatla)

During 2010-11, study on monitoring the changes in properties of ground water over years at benchmark sites (Table 1.26), EC of tube well water varied from 0.79 (Angalakuduru) to 12.3 dS/m (Nidubrolu-II) followed by 11.3 dS/m (Nidubrolu I), 8.1 dS/m (Machavaram) and remained more or less same at all locations. During 2011-12, EC varied from 1.0 to 9.1 d/Sm. Out of eight locations under study, EC_{iw} of the tube well water recorded slight decrease at five locations where an increasing trend was noted in three locations.

During 2010-11, the EC_e of soils at benchmark locations varied in accordance with the variation in tube well waters with slight decrease at all the locations (Table 1.27, Fig. 1.19). The EC_e of the soils slightly decreased due to higher rainfall (821.7 mm) received than normal during 2010-11. pH_s showed not much variation though decreased slightly compared to previous year. SAR values were decreased over last year. Soils of Chiluvuru, Potharlanka, Amarthaluru and Angalakuduru were under safe limits and orchard crops like Lemon, Sapota, Turmeric, Coconut and Banana are coming up well. Further during 2011-12, SAR values of Nidubrolu-I and II reached unsafe levels of more than 10 since last six years and continued the same trend this year also. The variation in pH at all the sites is marginal. Slight increase in SAR values in profile was observed in all sites except potarlanka, Amrutaluru and Angalakuduru where SAR values are decreased with depth in a profile.

Table 1.26. Ionic composition of tube well waters at benchmark sites in Guntur district

Locations	Year	pH (-)	EC (dS/m)	SAR $(mmol/l)^{1/2}$
Nidubrolu-I	1974	7.90	1.90	7.06
	2010-11	8.08	11.25	1.75
	2011-12	7.17	9.09	0.29
Nidubrolu-II	1974	7.50	1.20	0.21
	2010-11	7.85	12.30	2.15

	2011-12	7.23	8.59	11.13
Chintalapudi	1974	7.60	1.80	5.44
	2010-11	8.90	2.65	2.03
	2011-12	7.41	2.70	5.13
Machavaram	1974	7.90	1.40	4.45
	2010-11	8.03	8.07	4.20
	2011-12	7.38	8.20	13.22
Chiluvuru	2000	8.24	1.85	10.21
	2010-11	8.53	2.54	1.71
	2011-12	7.50	2.18	2.18
Potarlanka	2000	8.42	2.00	12.04
	2010-11	8.51	2.74	1.63
	2011-12	7.94	1.93	6.98
Amrutaluru	2000	8.35	2.60	15.59
	2010-11	9.54	1.94	3.52
	2011-12	7.92	1.93	6.50
Angalakuduru	2000	8.34	0.72	4.00
	2010-11	8.96	0.79	0.44
	2011-12	7.70	0.96	0.60

Table 1.27. Ionic composition of profile soil samples at benchmark sites in Guntur district

Location	pH		EC_e (dS/m)		SAR $(mmol/l)^{1/2}$	
Depth (cm)	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Nidubrolu-I						
0-15	8.06	8.01	1.65	7.74	0.76	10.37
15-30	8.27	7.85	2.00	5.67	5.06	9.30
30-60	8.37	7.89	1.85	5.21	3.55	11.87
Nidubrolu-II						
0-15	8.15	8.37	4.91	4.98	8.17	17.31
15-30	8.13	8.14	5.10	5.18	7.97	6.94
30-60	8.21	8.26	3.60	3.71	5.06	28.60
Chintalapudi						
0-15	8.18	8.58	1.39	1.26	5.24	6.76
15-30	8.09	8.19	2.03	2.02	6.40	15.98
30-60	8.03	8.35	1.30	1.21	6.40	5.09
Machavaram						
0-15	8.20	8.29	2.15	2.08	4.08	3.17
15-30	8.14	8.28	2.67	2.63	4.88	11.65
30-60	8.05	8.28	1.15	1.11	3.25	5.26
Chiluvuru						
0-15	8.17	8.09	1.04	1.24	3.08	0.54
15-30	8.00	8.03	1.21	1.18	3.83	2.50
30-60	8.34	8.06	0.80	1.10	2.59	3.19
Potarlanka						
0-15	8.46	7.87	1.76	2.39	4.91	1.05
15-30	8.17	7.82	1.36	0.76	6.21	0.68
30-60	8.04	7.92	0.62	0.85	0.61	0.23

Amrutaluru						
0-15	8.12	7.97	0.71	0.72	3.11	0.71
15-30	8.09	8.29	0.99	0.49	4.11	0.40
30-60	8.11	8.24	0.79	0.42	2.22	0.35
Angalakuduru						
0-15	8.49	7.89	1.03	1.33	1.09	0.29
15-30	8.64	8.46	0.66	0.67	1.42	0.21
30-60	8.34	8.43	0.54	0.50	1.96	0.17

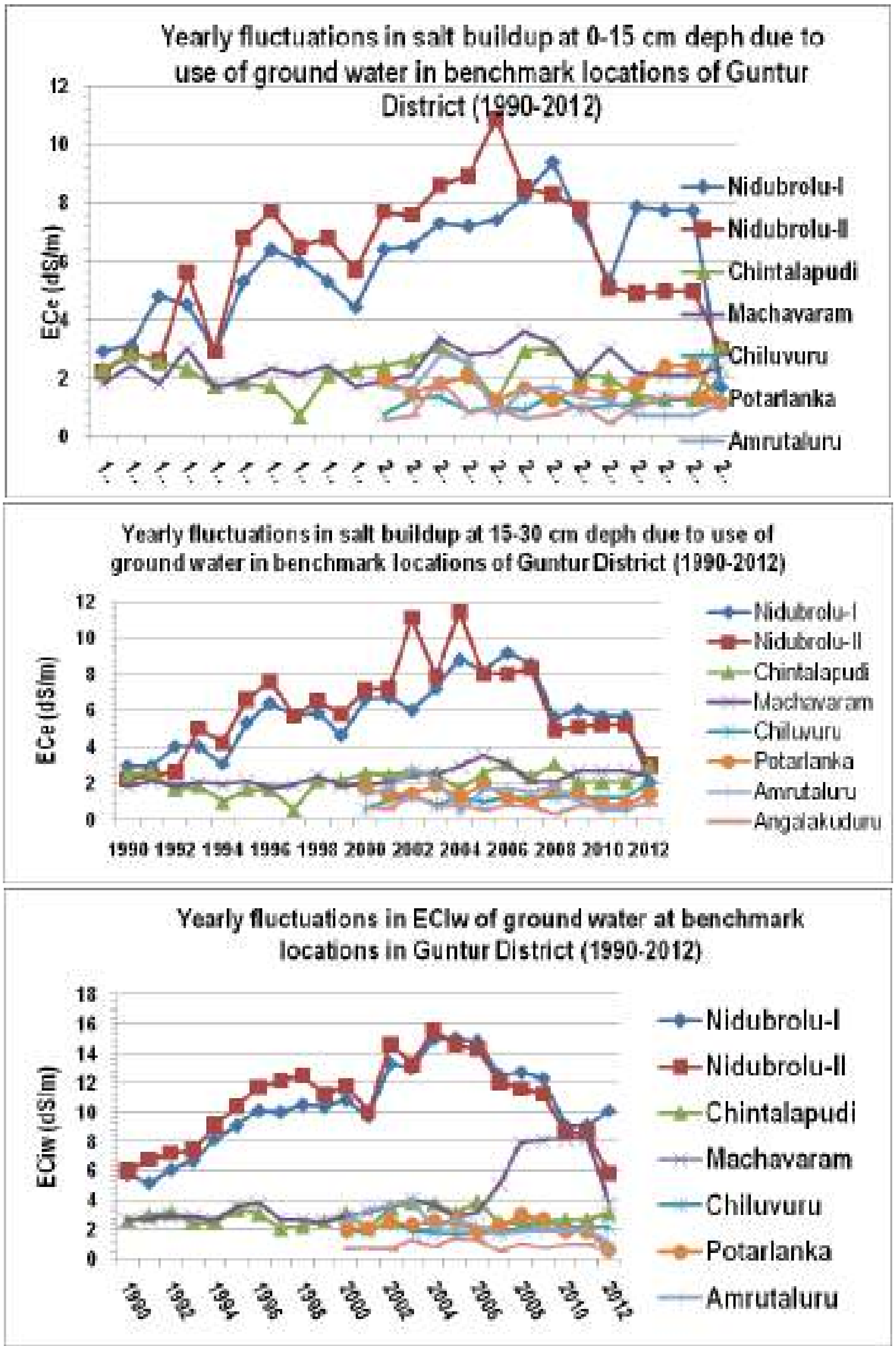


Fig. 1.19. Yearly fluctuations in salt build-up at benchmark sites in Guntur district

Soil and ground water quality in Sharada Sahayak canal command (Kanpur)

The benchmark sites of Sharda Sahayak canal area is demarcated on both sides of the canal (Fig. 1.20). Soil samples were collected at 0-20, 20-40, 40-60, 60-90, 90-120 and 120-150 cm depth. Soil samples are collected from both sides of the canal at a distance of 100, 500, 1000, 1500 and 2000 m covering a distance of 2 km on one side during pre and post monsoon period. A total 130 samples were collected on the basis of soil type and interaction of local farmers regarding the specific problem in the surveyed area.

Sites (A)					26°34'09" N 81° 06'07" E	Sites (B)				
2000 m	1500 m	1000 m	500 m	100 m		100 m	500 m	1000 m	1500 m	2000 m
•	•	•	•	•	184 km	•	•	•	•	•
•	•	•	•	•	189	•	•	•	•	•
•	•	•	•	•	195	•	•	•	•	•
•	•	•	•	•	202	•	•	•	•	•
•	•	•	•	•	207	•	•	•	•	•
•	•	•	•	•	217	•	•	•	•	•
•	•	•	•	•	224	•	•	•	•	•
•	•	•	•	•	234	•	•	•	•	•
•	•	•	•	•	241	•	•	•	•	•
•	•	•	•	•	247	•	•	•	•	•
•	•	•	•	•	254	•	•	•	•	•
•	•	•	•	•	263	•	•	•	•	•
•	•	•	•	•	271km	•	•	•	•	•
					25°35'52" N 81°20'56" E					

Fig. 1.20. Sampling sites of Sharda Sahayak canal command area, Raebareli, U.P.

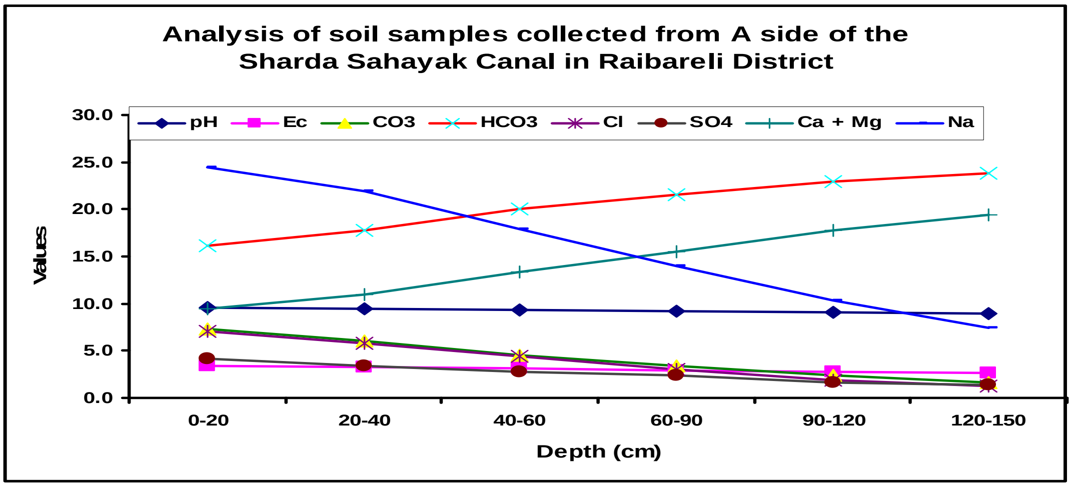
The soils samples analyzed shows variation in cationic and anionic composition at different depth (0-20 to 120-150 cm). It is obvious from the data presented in Table 1.28, Fig. 1.21 collected from "A" side of canal that the main values of pH, EC, CO_3, HCO_3, Cl, And SO_4 ranged from 8.9-9.6, 2.7-3.4, 1.7-7.3, 16.1-23.8, 1.3-7.0 and 1.4-4.2, respectively. The mean values of these characteristics determined from "B" side of canal were varied from 8.7-9.5, 2.7-3.4, 1.8-5.6, 14.5-23.1, 2.1-9.5 and 1.4-5.0 respectively. This shows that soluble salt contains are medium, bicarbonate and chloride constitutes practically the major part of the total anions and are not evenly distributed. In the cations the value of sodium is higher up to the depth of 40-60 cm while below this depth of 40-60 cm and below this depth i.e. up to 150 cm the value of calcium plus magnesium increases.

The soils are neutral in reaction with the exception of surface layer and are poor in organic matter containt. Moderate illuviation of sesquioxides is visible at lower depth. Total water soluble salts are medium and are mainly comprised bicarbonate and chloride of sodium.

At some places, soils are fertile and typically suited to paddy, pea and a number of other water loving crops during *kharif* season. At some places, kankar pan was also observed at a depth of 60 to 90 cm. The soils of Shivdeenkhera village are severely water logged. Plant roots are found at the surface and organic carbon and nitrogen is observed to be decreasing with depth.

Table 1.28. Mean values of chemical parameters of soil samples, Sarda Sahayak canal

Depth (cm)	pH	EC	CO_3	HCO_3	Cl	SO_4	Ca+Mg	Na
Side A								
0-20	9.6	3.4	7.3	16.1	7.0	4.2	9.5	24.8
20-40	9.5	3.3	6.0	17.8	5.8	3.4	11.0	21.9
40-60	9.3	3.1	4.6	20.0	4.4	2.8	13.3	17.9
60-90	9.2	2.9	3.4	21.5	3.0	2.4	15.5	14.0
90-120	9.1	2.8	2.4	22.9	1.9	1.7	17.8	10.3
120-150	8.9	2.7	1.7	23.8	1.3	1.4	19.4	7.5
Side B								
0-20	9.5	3.4	5.6	14.5	9.5	5.0	11.2	23.0
20-40	9.3	3.3	4.5	17.0	7.8	4.0	12.6	19.9
40-60	9.2	3.1	3.7	19.3	5.9	3.0	15.1	16.2
60-90	9.0	3.0	2.8	21.4	4.2	2.2	17.7	12.3
90-120	8.8	2.9	2.3	22.8	3.2	1.7	19.3	9.2
120-150	8.7	2.7	1.8	23.1	2.1	1.4	20.9	5.9



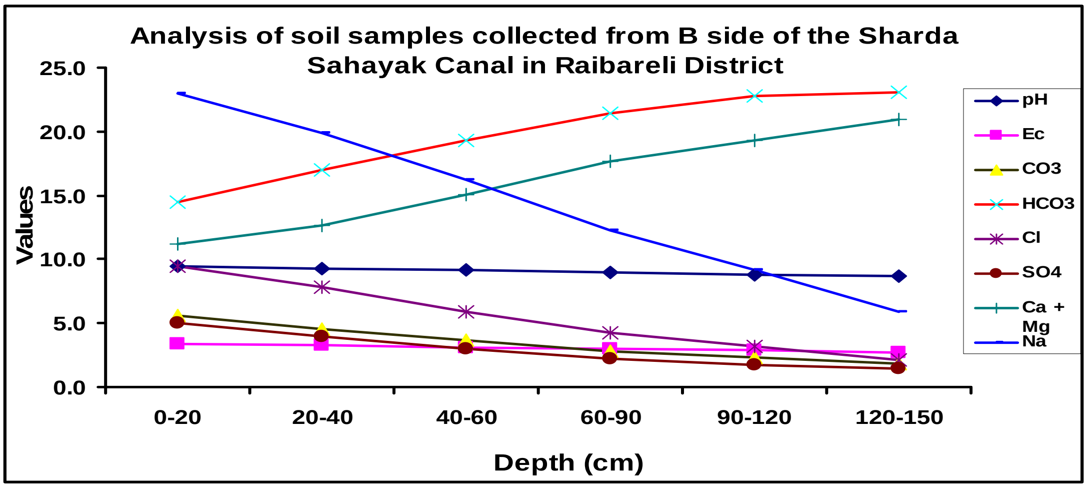


Fig. 1.21. Graphical presentation of soil chemical parameters, Sarda Sahayak canal command

Research Accomplishments
2. Management of Salt Affected Soils

Reclamation and Management of Saline Soils

- Reclamation of abandoned aqua ponds (Bapatla)
- Prediction of long-term salinity and water table fluctuations using simulation models (Bapatla)
- Investigations on micro-irrigation requirements of vegetables for saline soils (Gangawati)
- Response of cotton to drip irrigation in saline soils under conservation agriculture (Gangawati)
- Increasing agricultural productivity by amelioration of problematic soils (Gangawati)
- Monitoring of soil salinity in TBP command area under drainage project (Gangawati)
- Monitoring salinity hazards in vegetables under drip fertigation with marginally saline water in Vertisols (Indore)

Reclamation and Management of Alkali Soils

- Response of sunflower/cotton to chemical/organic amendments in alkali Vertisols (Gangawati)
- Land and rain water management strategies for cultivation in rainfed alkali soils of Northern Karnataka (Gangawati)
- Effect of long-term application of organic/green manures in sodic Vertisols (Indore)
- Assessing pre and post canal irrigation effect on soil, water and crops in Vertisols of Narmada Sagar Command (Indore)
- Relative efficacy of distillery and sugar industry waste on reclamation and crop production in sodic Vertisols (Indore)
- Efficacy of phospho-gypsum as an amendment for alkali soils (Kanpur)
- Effect of management practices on resodification of reclaimed sodic lands (Kanpur)
- Evaluation of resource conservation technologies for rice-wheat cropping system under partially reclaimed sodic soil (Kanpur)
- Integrated response of fly ash, gypsum and green manure to sustain the production of rice and wheat in partially reclaimed sodic soil (Kanpur)
- Effect of RSC water using different ameliorants on crop production and soil health of partially reclaimed sodic soil (Kanpur)
- Identifying suitable micro-irrigation methods for vegetable crops under sodic soil (Trichy)
- Long-term effects of distillery effluent on soil properties and sugarcane yield (Trichy)

Reclamation and Management of Saline Soils

Reclamation of abandoned aqua ponds (Bapatla)

During 2010-11, the initial soil EC_e of abandoned aqua lands ranged from 10.9 to 54.7 dS/m. A total 5 aqua ponds belonging to farmers were selected, levelled and open drains were formed to leach salts. Final soil EC_e ranged from 9.8 to 24.5 dS/m. Dhaincha was sown and ploughed *in-situ* at 50% flowering stage. NLR 145, MTU-2716 and BPT-5204 rice varieties were grown. 50 kg/ha $ZnSO_4$ was applied as basal and 180 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha fertilizers were applied. The grain yields ranged from 4.1 to 5.1 t/ha. Subsequently in 2011-12, initial EC_e reached to 3.0 to 20.6 dS/m and pH 7.2 to 8.0. After repeat treatment, MTU-2716 and BPT-5204 rice varieties were grown. 50 kg/ha $ZnSO_4$ applied basally whereas NPK was applied 180-40-40 kg/ha. Following recommended package of practices, 2 farmers started getting rice yield more than 5 t/ha (Table 2.1). After 2 years, EC_e reduced significantly ranging from 1.1 to 9.6 dS/m.

Table 2.1. Initial and final analysis of soils for pH_s, EC_e and yield of rice varieties (2011-12)

Name of farmer	Area (ha)	Rice variety	EC_e (dS/m)		pH_s		Yield (t/ha)
			Initial	Final	Initial	Final	
A. D. Rami Reddy*	0.40	MTU-2716	15.8	6.3	7.6	8.1	4.82
M. Narayan Rao*	0.60	NLR-145	20.6	9.6	7.5	8.0	5.66
P. Arjuna Rao#	0.48	BPT-5204	16.0	7.1	8.0	8.2	5.63
P. Gandhi Naidu#	0.16	BPT-5204	16.5	8.3	7.8	8.1	4.03
S. Nageswara Rao^	0.80	MTU-2716	3.0	1.1	7.2	7.5	4.75

*Water source:*KWD-Krishna Western Delta; #DW-Drain water (EC-4.3,pH-8.4);^BW-Bore well water (EC-3.5, pH-8.2)*

Prediction of long-term salinity and water table fluctuations using simulation models (Bapatla)

The project was initiated in 2010-11. The SALTMOD and DRAINMOD models were applied to pilot subsurface drainage project installed in 7.2 ha heavy textured soils of Krishna Western Delta, Appikatla (15^0 28′ N latitude and 80^0 28′ E longitude) in 2003-04. The SALTMOD model was run for different options such as changing leaching efficiency, influence of drainage system, drain depth, spacing and irrigation water applied in root zone using 2003-07 data of pilot project for calibration and validation. The modeled values on leaching efficiency were compared with actual salinity build-up in the root zone after rice harvest. The DRAINMOD model was calibrated using 30 m drain spacing data and validated using 60 m drain spacing data on drain flow, yield and salinity levels of the pilot area collected during 2002-09. A summary of the statistical measures used for calibration and validation are presented in Table 2.2. In general, there was good agreement between predicted and observed drain flows and depth of water table during the calibration period (Fig. 2.1, 2.2). The model slightly over-predicted drain flow in all years during the validation period whereas a close agreement between the predicted and observed water table depth during the validation years from 2007 to 2009 was observed. After calibration and validation, model was used to generate different scenarios of drainage water management for pilot area of Krishna Western Delta. In general, the model showed potential to simulate the effects of conventional and drainage water management scenarios.

Table 2.2. Statistical measures of DRAINMOD model performance during calibration period

Parameter	PE range	RMSE	CRM	EF	R
Drain flow	- 4.3	20.9	-0.043	0.57	0.88
Depth to water table	1.0	13.4	0.01	0.78	0.97
Soil salinity	2.01	6.8	0.020	0.72	0.90
Relative yield	3.7	6.5	0.037	0.30	1.00

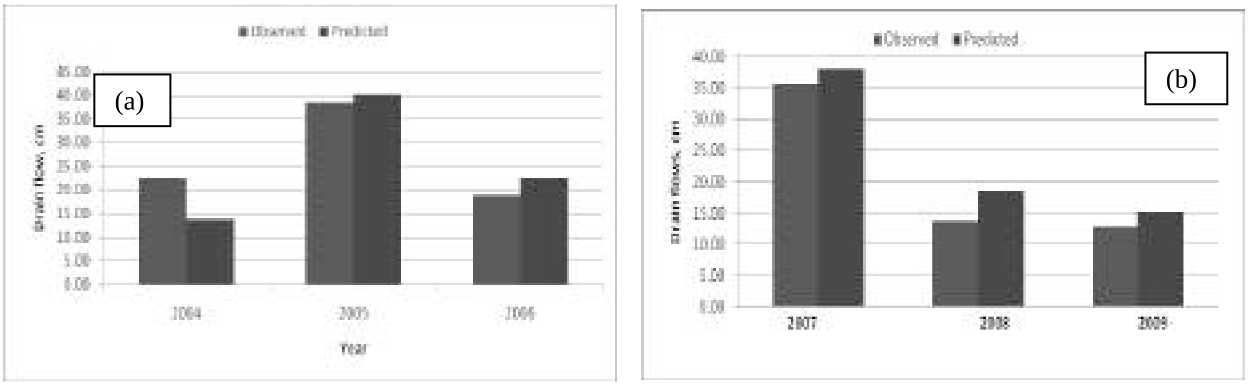


Fig. 2.1. Observed and predicted drain flows in pilot area during (a) calibration and (b) validation

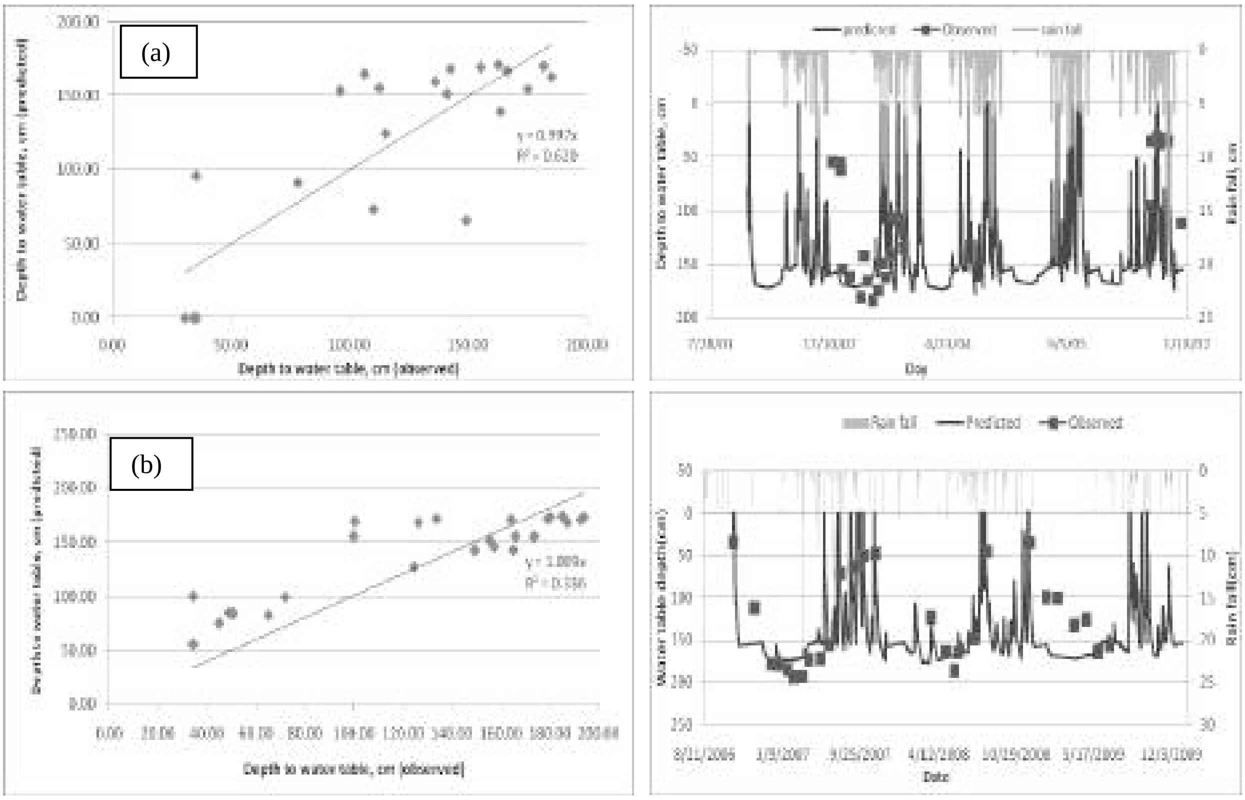


Fig. 2.2. Observed and predicted water table depths during (a) calibration and (b) validation

Sensitivity analysis of the model: Sensitivity analysis for variables like drainage, runoff, relative yields and infiltration was performed for several input parameters namely drain depth, drain spacing, distance from ground surface to impermeable layer, layer wise lateral saturated hydraulic conductivity, initial depth of water table, surface micro storage and drainage coefficient. The sensitivity was determined for four output parameters: drainage, runoff, infiltration and relative yields of paddy crop.

Scenario 1 (Reconstructing the pre-drainage scenario at the pilot area): This situation was simulated by introducing input values of wider drain spacing (500 m) and very small drainage coefficient (0.001cm/d) in the calibrated model. The variation in water table depth, soil salinity and relative yields of paddy crop were analyzed under this situation. It was noticed that for most of the period, the water table remained below 1.5 m from the ground surface in kharif season. It is observed that with drainage system the water table was maintained below the approximate root zone during the crop period. Under no drainage scenario the water table was close to the surface and more or less followed the same pattern throughout all years. This affected yields of paddy and levels of soil salinity.

Scenario II (Effect of drain spacing on drainage system performance): In this scenario the spacing between the drains was changed to 30, 40, 50, 60 and 70 m. The model predicted outputs were compared with the results obtained in actual drainage situation and the differences are discussed under the following sections. The amount of drain flow decreased as the drain spacing increased and vice versa. The average (2002-2009) annual drain flow under 30, 40, 50, 60 and 70 m drain spacing were 26.54, 25.22, 23.41, 22 and 21.13 cm respectively. As the drain spacing increased, the contributing area per unit perforated area on the drain pipes increased and hence drain flow decreased.

Scenario III (Effect of drain depth on drainage system performance): In this scenario the model was run with different drain depths such as 0.6, 0.8, 1.0, 1.2 and 1.4 m. respectively. The model predicted outputs were compared with the results obtained in actual drainage situation and the conclusions were discussed under the following sections. It was observed that, the amount of drain flow increased as the drain depth increased, this means as the drain depth increased, drained area above the drain increased which contributed more drain flow. Annual drain flows under 0.6m, 0.8m, 1.0m, 1.2m and 1.4m depths were 19.51, 20.85, 23.41, 26.12 and 28.00 cm respectively.

Investigations on micro-irrigation requirements of vegetables for saline soils (Gangawati)

A field experiment was initiated in 2008-09 and continued to optimize the micro irrigation requirements and to study the effect of different irrigation levels on soil properties and crop performance for cabbage during 2010-11. Treatments consists of three salinity levels and eight irrigation treatments Irrespective of salinity levels, significantly higher cabbage yield of 18.1 t/ha was recorded when the crop was irrigated by drip with ET level of 1.2 followed by 1.4 ET (17.8 t/ha), 1.0 ET (16.4 t/ha), drip irrigation at 0.8 ET (14.7 t/ha), surface irrigation at 1.2 ET (13.8 t/ha), drip irrigation at 0.6 ET (12.8 t/ha), surface irrigation at 1.0 ET (12.2 t/ha), and significantly least (10.3 t/ha) when the crop was irrigated with surface irrigation at 0.8 ET level (Table 2.3).

Among salinity levels, significantly higher yield (18.8 t/ha) was observed in the EC_e<4 dS/m block followed by EC_e 4-8 dS/m (15.1 t/ha) and significantly least (9.7 t/ha) in case of EC_e 8-12 dS/m. However, the interaction effect due to irrigation levels and soil salinity levels remained non-significant. Highest water productivity (WP) of 669 kg/ha-cm and 57.2 kg/ha-cm was obtained with drip irrigation level at 0.6 ET and surface irrigation in 0.8 ET, respectively (Table 2.3). Soil salinity was marginally higher in the treatment where crop was irrigated with 0.8 ET under surface method of irrigation and relatively lower where crop was drip irrigated with crop ET level of 1.4 as compared to other treatments.

Table 2.3. Yield of cabbage as influenced by different drip irrigation and soil salinity levels

Irrigation levels	Salinity levels							
	Cabbage Yield (t/ha)				WP (kg/ha-cm)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
I_1	16.56	13.18	8.57	12.77	86.8	691	449	669
I_2	18.85	15.37	9.94	14.72	80.4	656	424	628
I_3	21.07	17.29	10.93	16.43	75.8	622	393	591
I_4	23.32	19.15	11.86	18.11	72.5	595	369	563
I_5	22.92	18.95	11.54	17.81	62.8	519	316	488
I_6	13.63	9.93	7.33	10.30	75.7	552	407	572
I_7	15.99	12.41	8.19	12.20	66.6	517	341	508
I_8	17.70	14.52	9.15	13.79	59.9	484	305	463
Mean	18.75	15.10	9.69		72.6	580	376	
CD (5%)	I: 0.54; S: 0.47; IxS: NS							

(S_1: <4 dS/m; S_2: 4-8 dS/m and S_3: 8-12 dS/m) and (I_1 - Drip Irrigation at 0.6 ET; I_2 - Drip Irrigation at 0.8 ET; I_3 - Drip Irrigation at 1.0 ET; I_4 - Drip Irrigation at 1.2 ET; I_5 - Drip Irrigation at 1.4 ET; I_6 - Surface Irrigation at 0.8 ET; I_7 -Surface Irrigation at 1.0 ET and I_8 - Surface Irrigation at 1.2 ET)

Response of cotton to drip irrigation in saline soils under conservation agriculture (Gangawati)

To optimize the micro-irrigation requirement of cotton in salt affected soils (6-8 dS/m) and to study the effect of mulching on soil properties and performance of cotton in saline soils a field experiment was initiated during 2011-12. The results revealed that among ET treatments kapas yield was significantly higher (Table 2.4) in case of drip irrigated at 1.2 ET (3.00 t/ha) followed by drip irrigated at 1.0 ET (2.78 t/ha), drip irrigated at 0.8 ET (2.64 t/ha) and least in case of flood irrigation (2.43 t/ha). Among mulch treatments significantly higher yield was obtained in case of mulch treatment (2.91 t/ha) compared to without mulch treatment (2.52 t/ha). Among ET treatments, water productivity was significantly higher in drip irrigated with 0.8 ET (0.84 kg/m^3) followed by drip irrigated with 1.0 ET (0.72 kg/m^3), drip irrigated with 1.2 ET (0.64 kg/m^3) and least in flood irrigated treatment (0.45 kg/m^3). Among mulch treatments significantly higher water productivity was obtained in mulch treatment (0.71 kg/m^3) compared to without mulch treatments (0.61 kg/m^3).

Table 2.4. Cotton yield and water productivity influenced by drip irrigation and mulching

Irrigation levels	Cotton yield (t/ha)			Water productivity (kg/m^3)		
	Without mulch	With mulch	Mean	Without mulch	With mulch	Mean
	M_1	M_2		M_1	M_2	
S_1	2.46	2.81	2.64	0.79	0.90	0.84
S_2	2.54	3.04	2.78	0.65	0.78	0.72
S_3	2.74	3.26	3.00	0.59	0.70	0.64
S_4	2.32	2.54	2.43	0.43	0.47	0.45
Mean	2.52	2.91		0.61	0.71	
CD (5%)	M: 0.25; S: 0.16; MxS: NS			M: 0.05; S: 0.04; MxS: NS		

S_1: Drip irrigation at 0.8 ET; S_2: Drip irrigation at 1.0 ET; S_3: Drip irrigation at 1.2 ET; S^4 : Flood irrigation

Increasing agricultural productivity by amelioration of problematic soils (Gangawati)

To address the twin problems of water logging and soil salinity, 50 ha each in TBP and UKP areas was identified after the survey of water logged and salt affected soils in each of these command area for laying of sub-surface drainage system. In TBP command, survey was conducted and compared to Ulenur, Bargur, Hanawal, Marali, Siddapur, Hagedal villages, Hosakere block area was found suitable. This block has land slope varying from 0.4 to 1.4% in an area of 50 ha and a nala (drain) with approximate length of 1.4 km has the minimum and maximum depth of 1.3 and 1.4 m, respectively. However, reconsidering other needs of the project, a site near Mallapur of Sindhanur taluk was chosen and preliminary survey, soil sampling and analysis, digital topographic survey of the area were completed. Soil pH and EC (1:2) of the site (50 ha) varied from 7.2 to 8.4 and <2 to 23 dS/m. The hydraulic conductivity varied from 0.089 to 0.451 m/day with a mean of 0.169 m/day.

In UKP command area, among the various sites Malla-B, Shettikeri, Daryapur and Konkundi, Malla-B site was found ideal as it has good natural drainage with elevation difference of 1.4 m depth, salinity and water logging problem. Soil samples (23) up to a depth of 90 cm were collected in December 2011 and are being analyzed for various chemical parameters viz., pH, EC_e, exchangeable cations, soil water extracts for cations and anions and ESP. Soil samples were collected again in March, 2012 from the same site wherever the crop was not there (in 6 ha area). Twenty composite surface (0-15 cm) and subsurface (15-30) soil samples were collected using GPS and analyzed for soil pH and ECe. Soil pH and EC_e of surface soil varied from 7.9 to 9.0 and 2.3 to 7.7 dS/m respectively. Soil samples collected from the Malla-B site indicated that the soils are saline and the EC (1:2.5) varied from 0.2 to 27.0 dS/m with a mean of 9.6 dS/m.

Monitoring of soil salinity in TBP command area under drainage project (Gangawati)

Soil samples from the villages/block of Sidrampura (5 Nos.), Sasalamari (11 Nos.), Kurakunda (12 Nos.) of Sindhanur taluk, Wadderhatti (11 Nos.) of Gangavati taluk and Oravai (2 Nos.), Kallakamba (2 Nos.), Emmiganur (2 Nos.), Nelladi (2 Nos.), Challagudahala (3 Nos.), Honnalli (1 No), Khadanatti (5 Nos.) and Siddammanalli (5 Nos.) villages of Kurgod block were analyzed for pH and electrical conductivity. Soil pH was near neutral to alkaline and majority of the soils were saline as indicated by the EC. Soil pH varied from 7.6-8.3, 7.7-8.1, 8.0-8.4, 8.3-8.7 and 7.7-9.9 in Sidrampura, Saslamari, Kurakunda, Wadderhatti and Kurgod blocks respectively. Soil EC varied form 3.8-22.0, 4.0-20.0, 6.1-20.0, 29.0-35.0 and 0.8-77.0 dS/m in Sidrampura, Saslamari, Kurakunda, Wadderhatti and Kurgod blocks, respectively.

Monitoring salinity hazards in vegetables under drip fertigation with marginally saline water in Vertisols (Indore)

Hydraulic performance of drip fertigation system and crop performance of bottle gourd, onion, tomato and water melon planted on ridges under drip system were evaluated in a progressive farmer's field of Bagda Khurd of Khargone district during 2010-11 (Fig. 2.3). Soil samples at 15 days interval for six times from 0-5, 5-15 and 15-30 cm depths at drippers, between two consecutive drippers, side of dripper (15cm and 30 cm away from dripper) were collected. The water of two tube wells used for the purpose was marginally saline (EC 0.9 and 1.2 dS/m).

The bottle gourd, onion and tomato (Abhinav) were sown on 15th, 17th and 25th November 2010 whereas water melon was sown on 17th January 2011. The data in Table 2.5 indicates that EC increases with number of irrigations. The difference of initial and final soil salinity at different sampling locations indicates that EC increases as we move away from the drippers i.e. side of the ridge and between drippers and side of the dripper locations. The minimum and maximum soil salinity was observed at sampling point on drippers and side of the ridge, respectively.

The depth of irrigation water applied during crop period to bottle gourd crop was worked out and the details are shown in Table 2.5. The quantity of irrigation water per dripper came around 180, 92, 174 and 92 liters for bottle guard, onion, tomato and water melon crop. The depth of irrigation for bottle guard, onion, tomato and water melon was estimated to be 103, 53, 100 and 53 cm which was used to compute water productivity. The economics of different vegetable crops grown under drip fertigation with marginally saline water is shown in Table 2.6. The growing horticultural crops with drip fertigation in black soils is an economically viable venture as indicated by B:C ratio. Further, it is interesting to note that water melon is the most profitable and water economic crop.

Table 2.5. Changes in EC in bottle gourd, onion, tomato and water melon crops (2011)

Sampling points	Depth (cm)	Change in EC (dS/m)							
		Bottle gourd		Onion		Tomato		Watermelon	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final
On dripper	0-5	0.38	0.79	0.36	0.82	0.34	0.85	0.44	0.91
On dripper	15	0.48	0.84	0.35	0.91	0.41	0.91	0.36	0.86
On dripper	30	0.34	0.83	0.53	0.96	0.35	0.89	0.44	1.04
Average		0.40	0.82	0.41	0.90	0.37	0.88	0.41	0.94
Between drippers	0-5	0.37	0.92	0.42	1.01	0.34	0.98	0.56	1.20
Between drippers	15	0.41	1.04	0.39	1.11	0.42	1.01	0.53	1.30
Between drippers	30	0.34	0.89	0.29	0.96	0.41	1.08	0.36	1.06
Average		0.37	0.95	0.37	1.03	0.39	1.02	0.48	1.19
Side of ridge	0-5	0.28	0.85	0.47	1.19	0.22	0.89	0.63	1.45
Side of ridge	15	0.41	1.36	0.35	1.05	0.41	1.21	0.48	1.16
Side of ridge	30	0.41	1.25	0.39	1.21	0.40	1.17	0.50	1.21
Average		0.37	1.15	0.40	1.15	0.34	1.09	0.54	1.27
Side of Drippers	0-5	0.4	1.05	0.32	0.96	0.30	0.98	0.29	1.02
Side of Drippers	15	0.41	1.15	0.3	0.88	0.27	0.83	0.57	1.26
Side of Drippers	30	0.38	0.95	0.31	0.99	0.31	1.01	0.30	0.99
Average		0.40	1.05	0.31	0.94	0.29	0.94	0.39	1.09

Table 2.6. Economics of vegetables under drip fertigation with marginally saline water

Crop	Area (ha)	Water (cm/ha)	Yield (t/ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio	WP (kg/ha cm)
Bottle gourd	0.4	78	35	175000	85000	1.94	340
Onion	0.6	53	25	100000	30000	1.42	472
Tomato	0.4	77	38	190000	95000	2.00	380
Water melon	0.6	53	32	256000	176000	3.20	603

Fig. 2.3. Salt incrustation under drip fertigation with marginally saline water

Reclamation and Management of Alkali Soils

Response of sunflower/cotton to chemical/organic amendments in alkali Vertisols (Gangawati)

A field experiment was initiated at Kyarehal village in 2006 and continued till 2011 to find out the effect of chemical/organic amendments on crop growth, yield and properties of alkali soil.

During 2010 a significant difference in seed yield of sunflower was observed for different treatments. Application of FYM 10t/ha with 50% GR recorded significantly higher seed yield of sunflower (1.82 t/ha) when compared to control (1.23 t/ha) and application of gypsum at 50 and 75% GR alone (1.54 and 1.46 t/ha). The higher seed yield of sunflower recorded with application of FYM 10 t/ha with 50% GR remained at par with the application of FYM 10 t/ha with 75% GR (1.75 t/ha), application of vermin-compost 2.5 t/ha with 50 and 75% GR (1.68 and 1.72 t/ha) (Table 2.7). Measured soil ESP after the crop harvest was lower in treatments with amendments over control. Five years pooled data of revealed that the application of FYM @10 t/ha with 50% GR recorded significantly a higher seed yield of 1.80 t/ha when compared to 1.52, 1.48, 1.29 t/ha in case of 50% GR alone, 75% GR alone and control, respectively. The higher seed yield in case of FYM 10 t/ha with 50% GR was attributed to higher mean head diameter (11.8 cm) and higher seed yield per plant (21.1 g) which were significantly superior to 50 or 75% GR alone.

The results of 2010-11 on cotton revealed that the application of FYM 10 t/ha with 75% GR recorded significantly higher cotton yield of 1.63 t/ha as compared to control (1.07 t/ha) and application of gypsum at 50 and 75% GR alone (1.34 and 1.35 t/ha) (Table 2.8). The higher cotton yield recorded with application of FYM 10 t/ha with 75% GR remained at par with the application of FYM 10 t/ha with 50% GR (1.55 t/ha), application of vermin-compost 2.5 t/ha with 50% and 75% GR (1.52 and 1.61 t/ha). Soil ESP values observed after the harvest of crop was lower in treatments, which received amendments as compared to control. Five years pooled data (2006 to 2010) indicated that application of FYM 10 t/ha with 75% GR recorded significantly higher cotton yield (1.44 t/ha) as compared to control (0.99 t/ha) and application of gypsum at 50% and 75% GR alone (1.18 and 1.19 t/ha). The higher cotton yield obtained with application of organics along with gypsum was due to significantly higher number of branches/plant and significantly more number of bolls/plant which were significantly superior to control and 50% or 75% GR alone.

Table 2.7. Influence of chemical and organic amendments on seed yield of sunflower

Treatments	Seed yield (t/ha) of sunflower					
	2006	2007	2008	2009	2010	Pooled
T_1	1.75	1.79	1.78	1.84	1.82	1.79
T_2	1.72	1.65	1.63	1.66	1.75	1.68
T_3	1.68	1.67	1.68	1.69	1.68	1.68
T_4	1.68	1.70	1.71	1.71	1.72	1.70
T_5	1.51	1.53	1.49	1.54	1.54	1.52
T_6	1.46	1.53	1.49	1.47	1.46	1.48
T_7	1.33	1.38	1.25	1.23	1.23	1.28
CD (5%)	0.08	0.17	0.18	0.21	0.11	0.13

T_1: FYM 10 t/ha + 50% GR; T_2: FYM 10t/ha + 75% GR; T_3: Vermi-compost 2.5 t/ha + 50% GR; T_4: Vermi-compost 2.5 t/ha + 75% GR; T_5: 50% GR; T_6: 75% GR; T_7: Control (No amendments)

Table 2.8. Influence of chemical and organic amendments on cotton yield

Treatments	Cotton yield (t/ha)					
	2006	2007	2008	2009	2010	Pooled
T_1	1.13	1.27	1.40	1.53	1.55	1.37
T_2	1.19	1.30	1.44	1.62	1.63	1.44
T_3	1.14	1.26	1.39	1.52	1.52	1.37
T_4	1.21	1.29	1.42	1.59	1.61	1.42
T_5	1.01	1.09	1.14	1.31	1.34	1.18
T_6	1.03	1.12	1.18	1.32	1.35	1.19
T_7	0.91	0.94	0.98	1.06	1.07	0.99
CD (5%)	0.11	0.12	0.12	0.15	0.12	0.11

After the harvest of sunflower, a significant decrease in soil EC and ESP was observed in all treatments. The EC was lowest when FYM 10 t/ha with 75% GR (1.5 dS/m) was applied followed by FYM 10 t/ha with 50% GR (1.5 dS/m). Similarly a decrease in soil pH was also observed, though the decrease was not significant. Application of FYM 10 t/ha with 75% GR recorded lower soil pH of 8.3. The soil ESP was lowest (15.1%) in case of FYM 10 t/ha with 75% GR (Table 2.9). The gradual decrease in soil ESP indicated rather a slow replacement of sodium by calcium may be due to inadequate soil moisture under rainfed conditions.

After the harvest of cotton, a significant decrease in soil EC and ESP was observed in all treatments. The EC was lowest in the treatments with application of FYM 10 t/ha with 75% GR (1.2 dS/m). Similarly gradual decrease in soil pH in all the treatments was observed. Application of FYM 10 t/ha with 75% GR recorded lower soil pH of 8.3 (Table 2.10). At the end of fifth year, it was significantly lower in case of FYM 10 t/ha with 75% GR (14.9%) indicating improvement in soil physical conditions.

Application of FYM at 10 t/ha with 50% GR recorded higher seed yield of sunflower than 50 or 75% GR alone without organics and resulted in lowering of pH and ESP over years. However it remained on par with FYM 10 t/ha with 75%GR and vermi-compost 2.5 t/ha with 50 or 75% GR. Application of FYM 10t/ha with 75% GR recorded higher seed cotton yield than 50 or 75% GR alone without organics and resulted in lowering of pH and ESP over years. However, it remained at par at FYM 10 t/ha with 50% GR and vermi-compost 2.5 t/ha with 50 or 75% GR. The trial is concluded as ESP of 15 was attained.

Table 2.9. Influence of chemical/organic amendment on soil properties after sunflower

Treat-ments	EC (dS/m)					pH					ESP				
	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010
T_1	2.7	2.9	1.7	1.6	1.5	9.5	9.3	8.7	8.7	8.3	26.2	22.9	21.2	17.7	15.2
T_2	2.5	2.5	1.7	1.6	1.5	9.4	9.3	8.9	8.6	8.3	24.7	21.8	17.3	15.9	15.1
T_3	2.4	2.6	2.1	2.0	1.9	9.6	9.3	9.0	8.8	8.4	25.8	21.1	21.5	17.9	16.4
T_4	2.7	2.4	3.1	2.7	2.6	9.4	9.3	8.9	8.7	8.4	22.4	20.6	21.1	16.6	15.9
T_5	2.3	2.3	2.0	1.9	1.8	9.3	9.3	8.8	8.8	8.5	27.0	25.1	24.0	21.3	19.3
T_6	2.8	2.8	2.3	2.1	2.1	9.5	9.3	9.1	8.7	8.3	25.5	22.6	20.4	18.6	17.8
T_7	2.3	2.8	3.0	2.9	2.7	9.6	9.5	9.1	8.9	8.6	27.7	27.7	27.2	26.8	24.8
CD (5%)	NS	NS	0.5	0.2	0.3	NS	NS	NS	NS	NS	2.4	3.8	5.3	1.1	1.0

Table 2.10. Influence of chemical/organic amendments on soil properties after cotton

Treat-ments	EC (dS/m)					pH					ESP				
	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010
T_1	3.6	3.8	2.1	1.6	1.4	9.2	9.2	8.7	8.4	8.4	19.4	21.8	20.7	17.6	15.4
T_2	3.5	3.6	1.7	1.4	1.2	9.2	9.2	8.9	8.6	8.3	17.9	16.1	16.6	15.8	14.9
T_3	3.6	3.9	2.1	1.7	1.6	9.3	9.2	9.0	8.7	8.6	20.8	20.7	19.9	17.3	15.3
T_4	4.0	4.1	4.4	3.5	2.9	9.2	9.2	8.9	8.6	8.5	17.4	17.2	17.1	16.1	15.1
T_5	3.8	4.0	2.7	2.4	2.2	9.3	9.3	8.9	8.7	8.4	22.2	21.6	20.7	19.3	17.6
T_6	3.7	3.9	2.9	2.6	2.3	9.2	9.2	9.1	8.7	8.6	18.7	16.9	16.7	16.4	18.6
T_7	3.4	3.6	2.9	2.9	2.8	9.4	9.4	9.1	8.9	8.9	22.7	24.2	24.8	24.0	22.8
S.Em ±	0.3	0.2	0.5	0.1	0.1	0.1	0.1	0.1	1.1	0.0	19.9	1.0	0.93	0.1	0.5
CD(5%)	NS	NS	NS	0.2	0.2	NS	NS	NS	3.65	0.08	NS	3.01	NS	0.4	1.6

Land and rain water management strategies for cultivation in rainfed alkali soils of Northern Karnataka (Gangawati)

Evaluation of different rainwater harvesting practices along with gypsum applications on crop (sunflower) performance and soil alkalinity was continued during *kharif* 2010-11 as well in the rainfed sodic soils on formers field at Kyarehal near Gangawati. The results revealed that significantly higher seed yield (1.11 t/ha) was observed in the tied ridges with 75% gypsum requirement followed by ridges with 50% gypsum requirement (1.04 t/ha) (Table 2.11). The next better treatment remained compartment bunding with 75% gypsum requirement (0.96 t/ha), deep ploughing with 75% gypsum requirement (0.94 t/ha), compartment bunding with 50% gypsum requirement (0.89 t/ha), deep ploughing with 50% gypsum requirement (0.86 t/ha), flat bed with 75% gypsum requirement (0.81 t/ha), flat bed with 50% gypsum requirement (0.76 t/ha). Significantly lowest yield of 0.66 t/ha was recorded in the control (flat bed without gypsum application).

At germination stage, highest soil moisture (37.7%) was recorded in the tied ridges followed by compartment bunding (36.7%) and lowest (28%) in flat bed (Table 2.12). Soil ESP values at harvest stage ranged from 15.7 to 20.6 in different land management practices compared to highest ESP of 23.5 in control. There was decline in the ESP values in all land management practices which received amendment when compared to control. Soil salinity values (EC_e) at harvest varied from 1.1 to 1.3 dS/m among various treatments.

Table 2.11. Effect of land management practices and amendments on sunflower yield

Treatments	Yield (t/ha)	Pooled (2007-2011)
Compartment bunding with 75% GR	0.96	0.89
Compartment bunding with 50% GR	0.89	0.86
Tied Ridges with 75% GR	1.11	1.04
Tied Ridges with 50% GR	1.04	1.0
Deep ploughing with 75% GR	0.94	0.87
Deep ploughing with 50% GR	0.86	0.83
Flatbed +75% GR	0.81	0.74
Flat bed + 50% GR	0.76	0.69
Flat bed without gypsum	0.66	0.58
CD (5%)	0.12	0.07

Table 2.12. Effect of land management practices and amendments on soil moisture, ESP and salinity

Treatments	EC_e (dS/m)			ESP	Moisture content (%)	
	I	S	H	H	G	SS
Compartment bunding with 75% GR	1.4	1.3	1.2	15.8	36.7	30.9
Compartment bunding with 50% GR	1.5	1.2	1.1	17.5	35.3	31.5
Tied Ridges with 75% GR	1.5	1.3	1.2	15.7	36.7	32.8
Tied Ridges with 50% GR	1.6	1.2	1.1	17.2	37.7	32.5
Deep ploughing with 75% GR	1.5	1.3	1.1	17.0	36.2	30.5
Deep ploughing with 50% GR	1.6	1.3	1.2	18.6	36.8	30.8
Flatbed +75% GR	1.6	1.3	1.2	19.5	33.0	27.7
Flat bed + 50% GR	1.7	1.3	1.3	20.6	34.0	28.3
Flat bed without gypsum	1.7	1.4	1.2	23.5	33.2	28.0

Initial ESP: 23.1; I- At treatment imposition; S- At sowing; H- At Harvest; G-At Germination; SS- at Seed setting

The pooled data (2007-2011) revealed that, significant higher yield (1.04 t/ha) was observed in the tied ridges with 75% gypsum application followed by tied ridges with 50% gypsum application (1.0 t/ha), compartment bunding with 75% gypsum (0.89 t/ha), deep ploughing with 75% gypsum (0.87 t/ha), compartment bunding with 50% gypsum (0.86 t/ha), deep ploughing with 50% gypsum (0.83 t/ha), flat bed with 75% gypsum (0.74 t/ha), flat bed with 50% gypsum (0.69 t/ha) and least in control (flat bed without gypsum application) (0.58 t/ha).

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

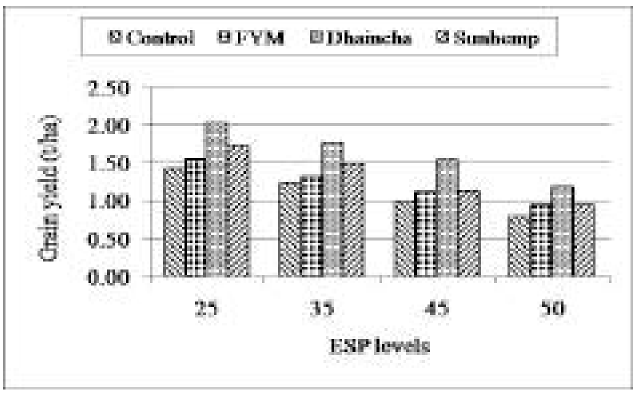
As per treatments, various green manuring crops were cultivated in gypsum-applied plots (to create different levels of soil ESP). Gypsum was applied once only before sowing of green manuring crop during April/May 2005. The green manure crop was cultivated and buried in soil at the age of 45 days well before sowing of *kharif* crop. The experiment will be carried out for atleast ten years so that impact can be identified. The paddy–wheat crop rotation, recommended for such soils is cultivated.

Paddy: Paddy yield as influenced by application of green manures and FYM at different soil ESP is presented in Table 2.13 and Fig. 2.4. The grain yield of paddy decreased significantly with increase in soil ESP. Incorporation of *dhaincha* green manure increased the paddy yield significantly over control. Highest grain yield of paddy was recorded during the years 2010-11 and 2011-12 in case of dhaincha (2.03 and 2.06 t/ha) followed by sunhemp (1.75 and 1.80 t/ha) respectively at soil ESP of 25. Lowest yield was observed in control plot.

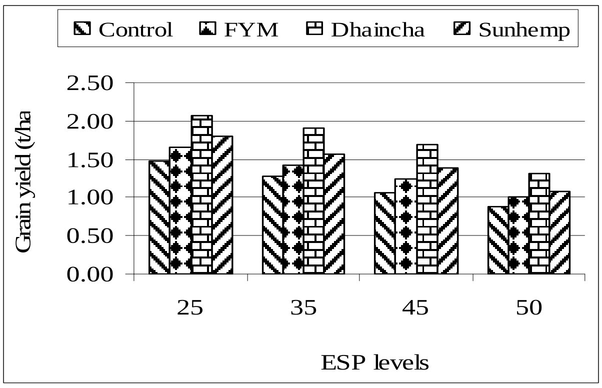
Wheat: The data in Table 2.14, Fig. 2.5 revealed that grain yield of wheat decreased significantly with increase in soil ESP. Incorporation of dhaincha green manure (Fig. 2.6) enhanced the grain yield of wheat significantly over control. Interaction effects were also significant. The highest grain yield of wheat (2.51 and 3.39 t/ha) was recorded during the year 2010-11 and 2011-12 respectively in case of dhaincha at soil ESP of 25. Incorporation of dhaincha among various treatments gave the highest yield and lowest was observed in control plot.

Table 2.13. Influence of GM/FYM on paddy grain yield at different Soil ESP levels

Green manures	Paddy grain yield (t/ha)				
	25	35	45	50	Mean
			2010-11		
Control	1.44	1.24	1.01	0.80	1.12
FYM 10 t/ha	1.56	1.33	1.13	0.95	1.24
Dhaincha	2.03	1.77	1.55	1.19	1.63
Sunhemp	1.75	1.51	1.14	0.95	1.33
Mean	1.69	1.46	1.21	0.97	
CD (5%)	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
	0.12	0.10	NS	NS	
			2011-12		
Control	1.47	1.28	1.06	0.88	1.17
FYM 10 t/ha	1.65	1.42	1.24	1.01	1.33
Dhaincha	2.06	1.91	1.68	1.31	1.74
Sunhemp	1.80	1.56	1.39	1.08	1.46
Mean	1.75	1.54	1.34	1.07	
CD (5%)	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
	0.11	0.09	NS	NS	



2010-11

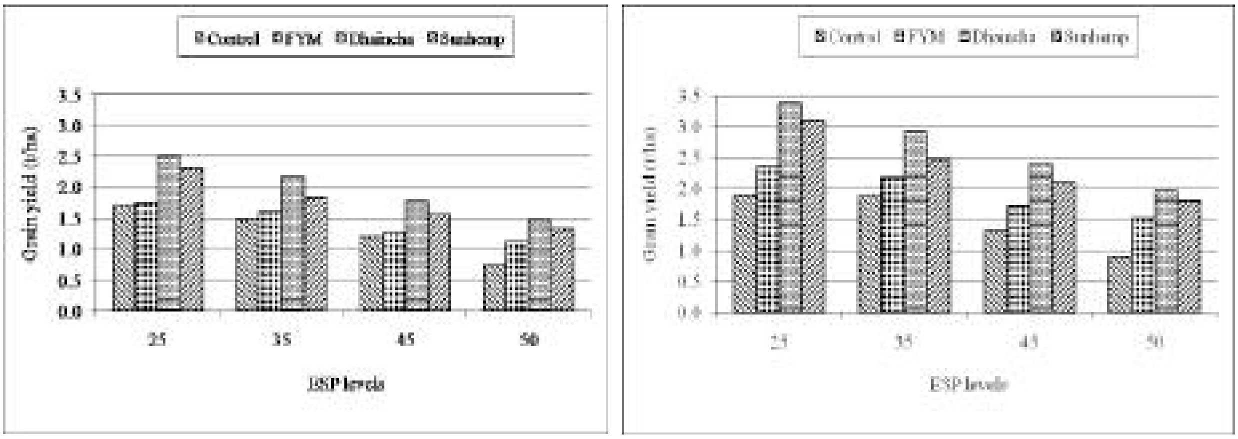


2011-12

Fig. 2.4. Effect of incorporation of green manures/ FYM on grain yield of paddy

Table 2.14. Influence of GM/FYM on wheat yield at different soil ESP levels

Green manures	Wheat grain yield (t/ha)				
	25	35	45	50	Mean
			2010-11		
Control	1.69	1.49	1.21	0.75	1.29
FYM 10 t/ha	1.75	1.62	1.27	1.13	1.44
Dhaincha	2.51	2.16	1.78	1.46	1.98
Sunhemp	2.30	1.83	1.55	1.33	1.75
Mean	2.06	1.78	1.45	1.17	
CD (5%)	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
	0.05	0.06	0.12	0.12	
			2011-12		
Control	1.90	1.88	1.32	0.90	1.50
FYM 10 t/ha	2.36	2.18	1.71	1.53	1.94
Dhaincha	3.39	2.92	2.40	1.97	2.67
Sunhemp	3.11	2.47	2.10	1.80	2.37
Mean	2.69	2.36	1.88	1.55	
CD (5%)	ESP	FYM/GM	ESP x FYM/GM	FYM/GM x ESP	
	0.07	0.08	0.15	0.16	



2010-11 2011-12

Fig. 2.5. Effect of incorporation of green manures/ FYM on grain yield of wheat

Fig. 2.6. Paddy and wheat in plots treated with dhaincha green manuring

Effect of GM/FYM on soil properties: The ESP of soil was decreased with incorporation of green manures/ FYM at all the levels. The lowest ESP was recorded in case of dhaincha followed by sunhemp (Table 2.15).

Table 2.15. Soil ESP as influenced by application of green manures/ FYM

Green manures	Soil ESP				
	25	35	45	50	Mean
	2010-11				
Control	24.2	33.4	42.7	47.4	36.9
FYM 10 t/ha	21.1	30.7	40.2	44.3	34.1
Dhaincha	18.0	27.3	35.3	40.1	30.2
Sunhemp	20.1	29.3	39.5	42.3	32.8
Mean	20.8	30.2	39.4	43.5	
	2011-12				
Control	24.23	32.95	42.32	47.01	36.63
FYM 10 t/ha	20.65	29.69	38.93	43.21	33.12
Dhaincha	17.05	25.54	32.88	37.57	28.26
Sunhemp	19.70	28.40	37.50	39.33	31.23
Mean	20.41	29.14	37.91	41.78	

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

The study was intended to generate database on impact of Narmada Sagar Irrigation Project on soil, water and crop to plan strategies for enhancing production on sustainable basis. The soils of the command area are Vertisols which generally considered problematic soils under impeded drainage conditions. During 2010, hydrologic data on annual rainfall and associated runoff for 40 years (1970-2009) were procured from the Water Resource Department, Khandwa and rainfall-runoff relationship was developed (Fig. 2.7).

Water level trend in last 10 years (1997-2006): Based on Central Ground Water Board pre and post monsoon season water levels data, a rise in water level of 3.15 m at Karoli and 9.10 m at Kelwa of Khandwa district was observed (Table 2.16).

Table 2.16. Pre-canal period water table in head reach of main canal in Indira Sagar command

Year	Village	Latitude	Longitude	Depth (m)	Water table (m)		
					May	Nov	Fluctuation
1974	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	6.9	6.0	0.9
1975	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	6.0	3.8	2.2
1976	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	6.9	2.8	4.1
1977	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	7.4	3.7	3.7
1978	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	5.8	4.4	1.4
1979	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	6.2	4.6	1.6
1980	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	6.0	2.8	3.2
1981	Punasa	$22^0$15’ 43”	76^0 20’16.7”	12.85	11.7	-	-
2005	Mohna	$22^0$09’06.5”	76^0 17’59.6”	9.6	8.0	5.2	2.8

2012	(U.S. Choukare)	22°09’06.5”	76° 17’59.6”		5.9	-	-
2005	Mohna	22°09’08.9”	76° 18’18.0”	13	11.0	6.7	4.3
2012	(Durgaram)	22°09’08.9”	76° 18’18.0”		9.1	-	-
2005	Mohna	22°08’38.5”	76° 18’48.9”	12	10.0	5.4	4.6
2012	(Shobharam)	22°08’38.5”	76° 18’48.9”		7.0	-	-
2005	Khutala	22°07’ 44.2”	76° 20’ 14.3”	10.5	8.8	4.6	4.2
2012	(Heeralal/Gopal)	22°07’ 44.2”	76° 20’ 14.3”		4.1	-	-
2005	Khutala	22° 07’44.2”	76° 20’ 12.9”	8.7	Dry	3.8	-
2012	(Krishna/Gopal)	22° 07’44.2”	76° 20’ 12.9”		3.9	-	-
2005	Khutala	22°07’ 44.2”	76° 20’ 09.0”	9.0	Dry	3.9	-
2012	Trilok/Govind	22°07’ 44.2”	76° 20’ 09.0”		4.1	-	-
2005	Khutala	22°07’ 41.5”	76° 19’ 50.0”	9.5	8.5	6.0	2.5
2012	(Baliram naral)	22°07’ 41.5”	76° 19’ 50.0”		5.8	-	-
2005	Piprad	22°08’ 50.5”	76° 19’ 24.0”	9.5	Dry	4.75	-
2012	(D. Singh)	22°08’ 50.5”	76° 19’ 24.0”		1.5	-	-
2005	Piprad	22° 04’25.0”	76° 18’23.7”	11	9.0	5.7	3.3
2012	(Kalloo Singh)	22° 04’25.0”	76° 18’23.7”		5.2	-	-
2005	Dongargaon	22° 02’05.1”	76° 16’ 23.2”	11	9.2	5.9	3.3
2012	(Ashok Puware)	22° 02’05.1”	76° 16’ 23.2”		5.2	-	-
2005	Dongargaon	22° 02’40.8”	76° 16’ 04.8”	10	8.7	4.9	3.8
2012		22° 02’40.8”	76° 16’ 04.8”		1.0	-	-
2005	Kalmukhi	22° 03’47.6”	76° 15’ 18.4”	9	8.0	2.9	5.1
2012	(Pankaj Gupta)	22° 03’47.6”	76° 15’ 18.4”		6.5	-	-
2005	KD- LHS	22° 08’10.3”	76° 19’ 44.7”	9	Dry	2.5	-
2012	(1.5-1.6 km)	22° 08’10.3”	76° 19’ 44.7”		5.0	-	-

Physico-chemical properties of soil: The soil samples collected at 0, 1.0, 2.2, 3.0 and 5.0 km from Kelwa distributary and at 9.0, 14.0, 19.4, 25.3 27.8 km from main canal were analyzed and estimated value of various soil parameters are presented in Table 2.17, 2.18.

Table 2.17. Physico-chemical properties of soil around Kelwa distributary

Symbol	Distance from canal	Depth (cm)	Latitude	Longitude	N	P	K	OC (%)	EC dS/m	pH	ESP %
					(kg/ha)						
Chainage on Kelwa Distributary – 0 km (Starting point)											
[KD1/1]0	50	00-30	22° 07’43.0”	76° 20’16.7”	162	8.0	360	0.34	0.45	7.51	2.03
[KD1/2]0	50	30-60	22° 07’43.0”	76° 20’16.7”	143	8.0	360	0.30	0.45	7.49	2.25
[KD2/1]0	200	00-30	22° 07’44.1”	76° 20’10.3”	192	9.6	400	0.46	0.59	7.44	2.09
[KD2/2]0	200	30-60	22° 07’44.1”	76° 20’10.3”	119	8.0	440	0.25	0.42	7.38	1.80
[KD3/1]0	500	00-30	22° 07’43.0”	76° 20’20.4”	119	5.6	320	0.25	0.44	7.32	2.04
[KD3/2]0	500	30-60	22° 07’43.0”	76° 20’20.4”	119	9.6	480	0.25	0.42	7.37	1.95
[KD4/1]0	1000	00-30	22° 07’42.5”	76° 19’49.2”	200	13.6	560	0.50	0.83	7.07	3.60
[KD4/2]0	1000	30-60	22° 07’42.5”	76° 19’49.2”	164	8.0	440	0.25	0.51	7.16	4.26

Chainage on Kelwa Distributary – 2.2 km											
[KD1/1]2	50	00-30	22^0 08’ 20.7”	76^0 19’20.9”	138	5.6	360	0.29	0.27	6.86	1.67
[KD1/2]2	50	30-60	22^0 08’ 20.7”	76^0 19’20.9”	156	8.0	320	0.23	0.29	6.80	1.33
[KD2/1]2	200	00-30	22^0 08’ 19.5”	76^0 19’17.2”	184	8.0	400	0.41	0.27	6.82	1.41
[KD2/2]2	200	30-60	22^0 08’ 19.5”	76^0 19’17.2”	190	9.6	440	0.45	0.28	6.81	1.46
[KD3/1]2	500	00-30	22^0 08’ 17.3”	76^0 19’10.4”	156	8.0	400	0.33	0.46	6.84	1.25
[KD3/2]2	500	30-60	22^0 08’ 17.3”	76^0 19’10.4”	156	8.0	360	0.33	0.36	6.74	1.02
[KD4/1]2	1000	00-30	22^0 08’ 16.4”	76^0 19’07.5”	138	5.6	320	0.29	0.35	6.80	1.30
[KD4/2]2	1000	30-60	22^0 08’ 16.4”	76^0 19’07.5”	156	8.0	400	0.33	0.38	6.78	1.15
Chainage on Kelwa Distributary – 5.0 km											
[KD1/1]4	50	00-30	22^0 09’ 10.4”	76^0 18’20.2”	186	8.0	400	0.42	0.33	6.91	1.99
[KD1/2]4	50	30-60	22^0 09’ 10.4”	76^0 18’20.2”	190	9.6	440	0.45	0.30	6.87	2.01
[KD2/1]4	200	00-30	22^0 09’ 07.6”	76^0 18’17.2”	200	11.2	480	0.50	0.44	7.00	1.99
[KD2/2]4	200	30-60	22^0 09’ 07.6”	76^0 18’17.2”	208	11.2	480	0.52	0.81	7.12	3.69
[KD3/1]4	500	00-30	22^0 09’ 08.8”	76^0 18’06.7”	200	11.2	440	0.50	0.41	7.10	1.92
[KD3/2]4	500	30-60	22^0 09’ 08.8”	76^0 18’06.7”	180	8.0	400	0.40	0.31	7.07	1.99
[KD4/1]4	1000	00-30	22^0 09’ 05.0”	76^0 17’52.9”	180	8.0	400	0.40	0.44	6.85	1.90
[KD4/2]4	1000	30-60	22^0 09’ 05.0”	76^0 17’52.9”	190	9.6	440	0.45	0.45	6.78	2.44

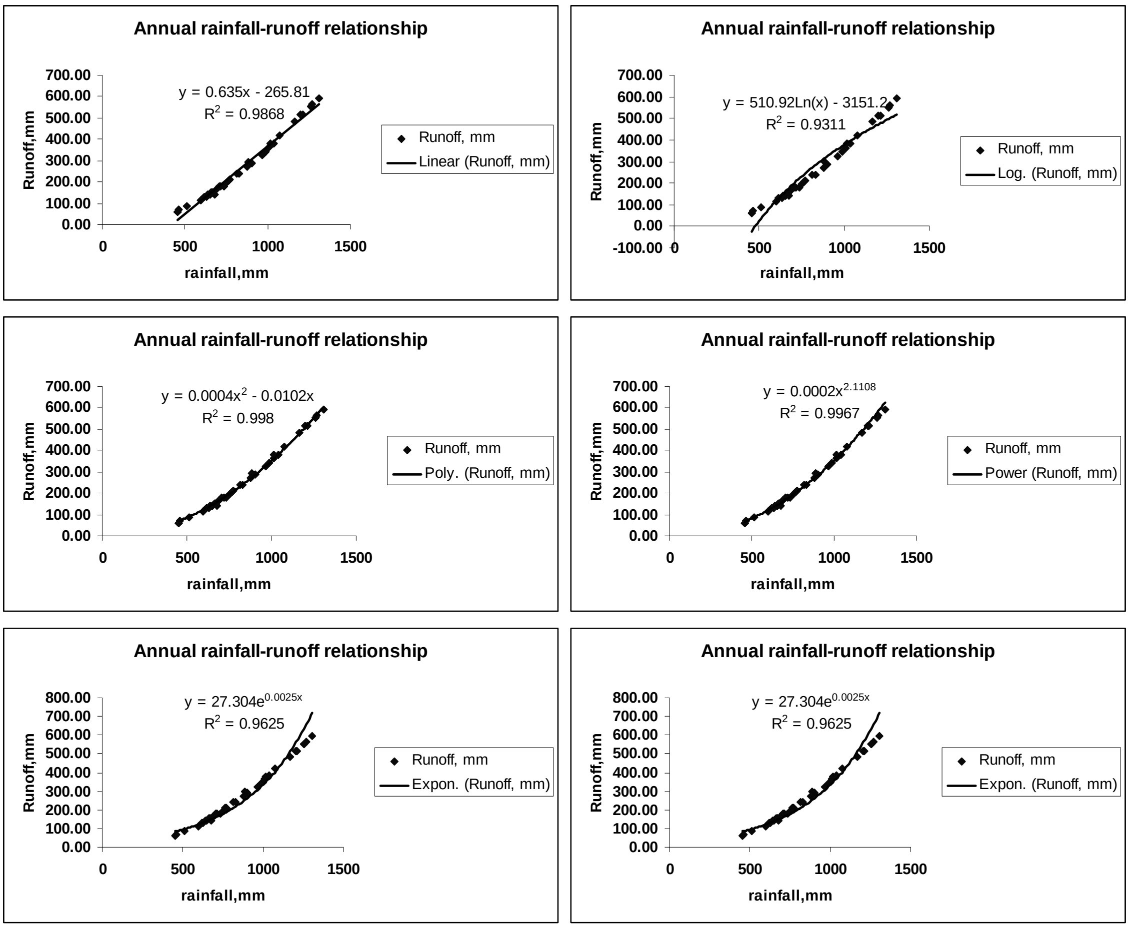


Fig. 2.7. Rainfall and runoff relationship for Khandwa district

Table 2.18. Physico-chemical properties of soil around main canal

Symbol	Distance from canal	Depth (cm)	Latitude	Longitude	N	P	K	OC	EC	pH	ESP
					(kg/ha)			(%)	(dS/m)		
Chainage on Main Canal – 9.0 km											
[MC1/1]0	50	00-30	22° 07’43.0”	76° 20’16.7”	162	8.0	360	0.34	0.45	7.51	2.01
[MC1/2]0	50	30-60	22° 07’43.0”	76° 20’16.7”	143	8.0	360	0.30	0.45	7.79	2.23
[MC2/1]0	200	00-30	22° 07’44.1”	76° 20’10.3”	208	9.6	400	0.46	0.59	7.44	2.06
[MC2/2]0	200	30-60	22° 07’44.1”	76° 20’10.3”	195	8.0	440	0.25	0.42	7.38	1.80
[MC3/1]0	500	00-30	22° 07’43.0”	76°20’20.4”	184	5.6	320	0.25	0.44	7.32	2.03
[MC3/2]0	500	30-60	22° 07’43.0”	76°20’20.4”	172	9.6	480	0.25	0.42	7.37	1.92
[MC4/1]0	1000	00-30	22° 07’58.1”	76°19’48.6”	119	8.0	440	0.25	0.45	7.42	3.45
[MC4/2]0	1000	30-60	22° 07’58.1”	76° 19’48.6”	119	8.0	400	0.25	0.47	7.53	4.19
Chainage on Main Canal – 19.4 km											
[MC1/1]1	50	00-30	22° 04’27.8”	76° 19’00.7”	248	13.6	520	0.66	0.39	7.42	2.30
[MC1/2]1	50	30-60	22° 04’27.8”	76° 19’00.7”	266	16.0	600	0.76	0.59	7.10	1.37
[MC2/1]1	200	00-30	22° 04’25.1”	76° 19’54.1”	90	5.6	320	0.14	0.52	7.30	1.17
[MC2/2]1	200	30-60	22° 04’25.1”	76° 19’54.1”	214	8.0	400	0.57	0.59	7.36	3.20
[MC3/1]1	500	00-30	22° 04’26.3”	76° 19’43.2”	274	16.0	600	0.73	0.87	7.09	1.15
[MC3/2]1	500	30-60	22° 04’26.3”	76° 19’43.2”	280	16.0	620	0.83	0.98	7.18	2.41
[MC4/1]1	1000	00-30	22° 04’26.5”	76° 18’20.5”	248	13.6	520	0.66	0.64	7.35	1.67
[MC4/2]1	1000	30-60	22° 04’26.5”	76° 18’20.5”	274	16.0	600	0.73	0.61	7.42	2.13
Chainage on Main Canal – 27.8 km											
[MC1/1]3	50	00-30	22° 03’07.1”	76° 15’09.0”	221	13.6	480	0.59	0.64	7.20	2.38
[MC1/2]3	50	30-60	22° 03’07.1”	76° 15’09.0”	214	11.2	440	0.57	0.76	7.18	1.78
[MC2/1]3	200	00-30	22° 03’15.3”	76° 15’12.5”	240	13.6	520	0.64	0.67	7.52	2.58
[MC2/2]3	200	30-60	22° 03’15.3”	76° 15’12.5”	240	13.6	520	0.64	0.64	7.55	2.69
[MC3/1]3	500	00-30	22° 03’27.2”	76° 15’12.9”	240	13.6	480	0.64	0.57	7.06	2.32
[MC3/2]3	500	30-60	22°0 3’27.2”	76° 15’12.9”	186	9.6	400	0.42	0.38	6.80	1.72
[MC4/1]3	1000	00-30	22°03’49.0”	76° 15’19.6”	180	8.0	400	0.40	0.46	7.12	2.30
[MC4/2]3	1000	30-60	22°03’49.0”	76° 15’19.6”	133	5.6	360	0.28	0.44	7.15	2.55

Water quality of canal: Analysis of water samples from main canal, kelwa distributary, minor and sub-minor indicate that canal water is of good quality. Estimated values of pH, EC, SAR and RSC are found in the range of 7.21 to 7.40, 0.36 to 0.39 dS/m, 0.82 to 0.95 and nil respectively (Table 2.19).

Table 2.19. Water quality of canal distribution system

Location	pH	EC (dS/m)	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	SAR	RSC (meq/l)
			(meq/l)									
Main canal	7.21	0.36	0.00	1.40	1.60	0.60	1.60	1.00	1.08	0.02	0.95	Nil
Kelwa Distributary	7.39	0.37	0.00	1.20	1.40	1.10	1.80	1.00	0.97	0.02	0.82	Nil
Kelwa Distr. (5km)	7.24	0.37	0.00	1.40	1.60	0.70	2.00	0.80	0.97	0.02	0.82	Nil
Kemach Distributary	7.40	0.39	0.00	1.60	1.40	0.90	2.00	0.80	1.02	0.02	0.87	Nil
Kemach Distr. (6km)	7.35	0.38	0.00	1.40	1.60	0.80	1.80	1.00	0.98	0.02	0.82	Nil
Minor of KD	7.40	0.37	0.00	1.60	1.60	0.50	2.00	0.80	0.97	0.02	0.82	Nil

Crop area and production: The area and productivity (Table 2.20) of various *kharif* and *rabi* crops grown in Khandwa district during pre-canal irrigation period (2001-11) were collected.

Soybean was major *kharif* crop grown in 103232 to 165380 ha area with average productivity of 1.15 t/ha followed by cotton (63392 to 76191 ha) with average productivity of 0.97 t/ha. Similarly wheat was major *rabi* crop grown in 49446 to 82399 ha with average productivity of 1.93 t/ha.

Table 2.20. Productivity of *kharif* and *rabi* crops in Khandwa district (2001-2011)

Crops	Productivity (kg/ha)										
	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	Mean
Kharif Crops											
Paddy	665	885	1107	1110	1115	1138	1140	1140	1145	1150	1060
Sorghum	1196	1250	1252	1255	1260	1260	1262	1265	1280	1290	1257
Maize	1353	1409	1846	1850	1855	1855	1858	1858	1900	1910	1769
Pearl millet	648	624	643	645	650	660	660	662	670	670	653
Other cereals	294	355	358	360	365	370	372	355	357	360	355
Pegion pea	931	1302	1265	1270	1275	1285	1288	1290	1305	1310	1252
Black gram	349	271	376	380	387	390	395	392	400	410	375
Green gram	306	251	328	335	350	355	355	358	370	375	338
Other pulses	361	395	395	400	425	425	425	511	549	550	444
Ground nut	583	650	800	950	952	978	978	980	1000	1000	887
Til	369	350	350	367	380	385	385	386	390	390	375
Soybean	517	1035	1155	1160	1200	1253	1258	1275	1300	1350	1150
Cotton	356	780	796	800	820	1200	1210	1225	1235	1250	967
Rabi Crops											
Wheat	1776	1780	1850	1967	1678	2149	2177	1848	2175	1971	1937
Gram	386	780	950	907	810	995	1005	850	1000	1035	872
Lentil	160	274	325	378	353	405	400	395	417	420	353
Pea	265	288	324	316	405	415	410	377	407	310	352
Other	155	265	265	0	0	315	312	315	317	0	194
Alsi	265	375	341	420	453	455	453	455	455	506	418
Muster	300	0	375	375	0	560	555	560	560	805	409
Sugarcane	42300	42500	42500	44010	45050	45000	45050	45050	45050	45000	44151

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

The experiment was conducted for rice (var. CSR 30) in *kharif* - wheat (var. HI 1077) in *rabi* cropping sequence at Barwaha district Khargone. The experimental soil belongs to fine smectitic hyperthermic family of typic heplusterts-sodic phase having ESP 38.4 cmol (p+)/kg. One time application of spent wash and other treatments (except gypsum) was done 30 days prior to transplanting of rice seedlings every year. Gypsum was applied once in three years. Recommended doses of nutrients were given as per the recommendations for sodic soils. In case of paddy, significant increase in all growth parameters was noticed due to application of amendments over control. Application of Lagoon Sludge 5 t/ha+Raw Spent Wash 2.5 lakh L/ha significantly increased the plant height, grain and straw yield of paddy as compared to gypsum 75% GR as well as LS 10 t/ha and PM 5 t/ha. Highest number of tillers/ hill (28.4), plant height (127.1 cm), length of penicle (23.4 cm), grain (2.44 t/ha) and straw (7.33 t/ha) yield was recorded in case of LS 5 t/ha + RSW 2.5 lakh L/ha application (Table 2.21). In case of wheat, grain and straw yield increased significantly with the 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 (3.77 t/ha) and straw (4.17 t/ha) yield was recorded in case of LS 5 t/ha + RSW 2.5 lakh L/ha application. It was also observed that the ESP of soil after harvest reduced significantly with the application of different amendments. Lowest ESP was observed under application of LS 5 t/ha + RSW 2.5 lakh L/ha after harvest of paddy and wheat.

Table 2.21. Grain and straw yield of crops and soil ESP as influenced by different treatments

Treatments	Paddy yield (t/ha)		ESP after harvest	Wheat yield (t/ha)		ESP after harvest
	Grain	Straw		Grain	Straw	
T_1	1.20	3.58	38.5	1.77	1.99	38.2
T_2	2.17	6.67	28.6	3.41	3.82	26.0
T_3	2.26	6.83	26.1	3.22	3.60	25.6
T_4	2.07	6.33	30.6	2.43	2.69	30.1
T_5	2.00	6.08	31.5	2.18	2.40	30.9
T_6	2.44	7.33	24.7	3.77	4.17	24.1
T_7	2.23	6.75	26.8	3.22	3.57	26.5
CD (5%)	0.24	0.58	0.59	0.26	0.25	0.70

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 : LS 5 t/ha + RSW 2.5 lakh L/ha; T_7 : PM 2.5 t/ha + RSW 2.5 lakh L/ha

Fig. 2.8. Paddy and wheat under lagoon sludge (5 t/ha) + raw spent wash (2.5 lakh L/ha)

Efficacy of phospho-gypsum as an amendment for alkali soils (Kanpur)

The dissolution of gypsum and phospho-gypsum in irrigation water through 15 cm bed during *kharif* and *rabi* are given in Table 2.22. Grain yield of rice and wheat varied from 3.04 – 3.80 t/ha and 2.62-3.48 t/ha respectively. Highest yield of both crops 3.80 and 3.48 t/ha respectively obtained under treatment T_3 which received phosphor-gypsum bed. Lowest grain yield of both crops recorded in that plot which was treated with RSC water alone (Table 2.23)

Soil Properties: The chemical properties of soil showed considerable improvement under amended water passed through gypsum/phosphor-gypsum bed. There was a remarkable change in soil pH (Table 2.24). Maximum soil pH (9.23) was recorded in RSC treated plots followed by BAW treated (9.08). Dissolution of gypsum and phosphor-gypsum reduced soil pH 8.97 and 8.96 respectively. Although, soil application of gypsum and phosphor-gypsum could not change pH variably to each other but showed more beneficial effect then BAW. EC_e was maximum (2.65 dS/m) in RSC treated plots followed by BAW, gypsum and phosphor-gypsum application. ESP in RSC treated plots remained highest (47.2) followed by BAW (44.5), gypsum dissolution (37.1) and phosphor-gypsum (34.1). Organic carbon content varied from 0.26 - 0.35 % under the influence of soil amendments.

Table 2.22. Gypsum and phospho-gypsum 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)
2009-10	Phospho-gypsum	0.59	0.99	1.58 (13.7)	1.58 (13.7)
2010-11	Phospho-gypsum	0.60	1.01	1.61 (14.0)	3.19 (27.7)
2011-12	Phospho-gypsum	0.43	1.00	1.43 (12.4)	4.62 (40.2)

Values in parentheses denotes percentage

Table 2.23. Effect treatments on yield of rice and wheat crops

Treatments	Rice (NDR-359) yield (t/ha)				Wheat (PBW-343) yield (t/ha)			
	2009	2010	2011	Mean	2009-10	2010-11	2011-12	Mean
T_1	3.02	3.03	2.97	3.04	2.61	2.63	2.61	2.62
T_2	3.26	3.33	3.50	3.36	2.84	2.95	3.12	2.97
T_3	3.64	3.79	3.97	3.80	3.28	3.42	3.75	3.48
T_4	3.42	3.53	3.75	3.57	3.01	3.16	3.42	3.20
T_5	3.46	3.61	3.90	3.66	3.16	3.31	3.58	3.35
T_6	3.28	3.38	3.60	3.42	2.85	3.07	3.24	3.05
CD (5%)	0.17	0.17	0.13	-	0.17	0.18	0.18	-

T_1: RSC water (untreated); T_2: BAW; T_3: RSCW (15cm phosphor-gypsum bed); T_4: Soil application of 15 cm phospho-gypsum; T_5: RSC water (15 cm gypsum bed); T_6: Soil application of 15 cm gypsum

Table 2.24. Effect of treatments on physic-chemical properties of soil after three years

Treatments	pH	EC	ESP	OC (%)
T_1	9.23	2.65	47.20	0.26
T_2	9.00	2.48	44.50	0.29
T_3	8.35	1.97	34.10	0.35
T_4	8.77	2.33	39.18	0.30
T_5	8.68	2.12	37.12	0.32
T_6	8.86	2.41	42.17	0.28

Change in ionic composition of RSC water: When RSC water (8.62 meq/l) was passed through 15 cm gypsum or phosphor-gypsum bed during irrigation, it showed no significant changes in pH but salt concentration increased slightly particularly in last irrigation (Table 2.25). Further, significant reduction in RSC and remarkable change in concentration of Ca and Mg were observed. Initial RSC (8.62) reduced to 4.23 and 4.05 meq/l by using gypsum and phosphor-gypsum.

Table 2.25. Change in ionic composition of RSC irrigated water as a result of gypsum and phospho-gypsum bed treatments

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)	8.1	1.1	Nil	10.5	0.6	0.5	1.62	9.83	8.62
RSC (treated with gypsum)	7.9	1.5	Nil	10.3	1.1	3.7	5.94	9.14	4.23
RSC (treated with phospho-gypsum)	7.8	1.5	Nil	10.2	1.2	3.72	6.06	9.11	4.05
BAW	7.5	0.7	Nil	4.1	3.3	0.10	6.41	1.00	Nil

Effect of management practices on resodification of reclaimed sodic lands (Kanpur)

Four benchmark sites each representing good and poorly managed reclaimed sodic lands at farmers field were identified in 2010 and soil samples were collected up to 150 cm from each sites to evaluate the cause of resodification. The kankar layer was found in between 90-125 cm depth. Physico-chemical properties of selected fields revealed that pH, EC, OC, ESP and infiltration rate ranged from 8.8-9.4, 2.2-2.5, 0.1-1.5, 40.0-55.1 and 0.3-1.3 with mean value of 8.0, 2.1 dS/m, 0.34%, 47.5% and 0.89 cm/hr, respectively from 0-15 cm depth. No definite trend was observed in anions viz., CO_3, HCO_3, SO_4, Cl and cations viz., as Ca, Mg, Na and K in relation to soil depth. The experimental results showed the yield of paddy increased from 1.92 to 4.12 t/ha under partially reclaimed sodic soil. During second year, yield potential of farmer's fields was markedly enhanced. It might be due to adoption of proper agronomical practices (Table 2.26). During *rabi s*eason, mean yield of wheat (PBW-343) ranged from 1.97 to 3.50 t/ha (Table 2.27).

Table 2.26. Details of agronomical practices used by farmers

Details	Good	Poor
Soil Condition	Reclaimed	Partially reclaimed
Organic Manures	FYM, rice straw and GM	Rice straw
Fertilizers	100:40:0 NPK	100:0:0 NPK
Micronutrients	25 kg/ha Zinc Sulphate	--
Crop Rotation	Paddy, wheat, mustard, potato and GM	Paddy and wheat
Cultivars	HYV	HYV/local land races
Water source	Tube well (owned)	Tube well (Rental)
Nos. Irrigation	More (As per requiremwnt)	Less (Critical stage)
Biocides	Used	Used
Holdings	Marginal	Small

Table 2.27. Crop yields at selected farmers fields in relation of kankar layers

Name of farmers	Grain yield of crops (t/ha)						Depth of kankar layer (cm)
	Paddy (var. Kranti)			Wheat (var. PBW 343)			
	2010	2011	Mean	2010-11	2011-12	Mean	
Deep Narayan	2.90	3.22	3.06	2.75	2.92	2.84	90
Suresh	3.73	4.15	3.94	2.80	3.08	2.94	100
Indrajeet	1.98	2.27	2.13	2.08	2.24	2.16	95
Vijai Bahadur	1.75	2.10	1.93	1.88	2.06	1.97	90
Mool Chandra	3.87	4.26	4.07	3.20	3.58	3.39	120
Radhey Lal	3.95	4.30	4.13	3.25	3.60	3.43	125
Puspendra	3.78	4.20	3.99	3.30	3.71	3.51	120
Ram Narain	3.55	4.08	3.82	2.78	3.05	2.91	100

Evaluation of resource conservation technologies for rice-wheat cropping system under partially reclaimed sodic soil (Kanpur)

The initial soil pH, EC_e, ESP and organic carbon of the experimental site was 9.2, 2.6 dS/m, 45.2 and 0.13 percent respectively. The average grain yield of rice (var. NDR-359) and wheat (var. PBW-343) ranged from 3.23 to 3.79 and 2.48 to 2.85 t/ha during *kharif* and *rabi* seasons, respectively. The highest response was observed in conventional rice transplanting after *sesbania* green manuring/wheat in zero tillage followed by conventional rice transplanting after wheat residue incorporation (WRI)/conventional wheat sowing after rice residue incorporation (RRI) in rice and conventional rice transplanting after WRI/ conventional wheat sown after RRI (3.08 t/ha) followed by direct seeded rice (DSR) after WRI/wheat in reduced tillage after RRI in wheat crop. The minimum yield of rice (3.23 t/ha) and wheat (2.48 t/ha) was observed in DSR in zero tillage/wheat in zero tillage. Similar trend was observed in experimentation conducted in 2011-12 (Table 2.28).

Table 2.28. Effect of different treatments on yield of rice and wheat

Treatments	Rice grain yield (t/ha)			Wheat grain yield (t/ha)		
	2010	2011	Mean	2010-11	2011-12	Mean
T_1	3.42	3.59	3.50	2.71	2.88	2.79
T_2	3.43	3.80	3.62	2.93	3.23	3.08
T_3	3.22	3.43	3.33	2.60	2.71	2.66
T_4	3.24	3.62	3.43	2.81	3.06	2.94
T_5	3.22	3.41	3.32	2.57	2.65	2.61
T_6	3.11	3.36	3.23	2.46	2.51	2.69
T_7	3.13	3.45	3.29	2.65	2.84	2.75
T_8	3.40	3.66	3.53	2.68	2.80	2.74
T_9	3.63	3.95	3.79	2.74	2.97	2.85
CD (5%)	0.25	0.12	-	0.18	0.19	-

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; T_9: Conservational rice transplanting after sesbania green manuring /wheat in zero tillage

Integrated response of fly ash, gypsum and green manure to sustain the production of rice and wheat in partially reclaimed sodic soil (Kanpur)

Grain yield of rice and wheat were significant due to addition of fly ash alone and in combination with various doses of gypsum and green manure. Grain and straw yield of rice varied from 1.67-3.75 t/ha with mean yield of 2.54 t/ha and wheat varied from 1.23 to 3.41 t/ha with mean yield of 2.32 t/ha. Straw yield of rice and wheat ranged from 2.08-4.60 t/ha with mean yield of 3.49 t/ha and 1.52 to 3.91 with mean yield of 2.74 t/ha respectively. The highest grain yield of both crops were recorded with application of fly ash 20 t/ha + gypsum 50% GR+GM 10 t/ha (T_{11}) followed by T_{10}, T_9 and T_{12} treatments (Table 2.29).

Table 2.29. Effect of different treatments on yield of rice and wheat (2011-12)

Treatments	Rice yield (t/ha)		Wheat yield (t/ha)	
	Grain	Straw	Grain	Straw
T_1	1.67	2.08	1.23	1.52
T_2	1.95	2.43	1.51	1.88
T_3	2.18	2.71	1.75	2.14
T_4	2.22	2.77	1.82	2.20
T_5	2.41	3.02	2.06	2.47
T_6	2.55	3.15	2.25	2.65
T_7	2.80	3.46	2.47	2.92
T_8	2.91	3.57	2.61	3.03
T_9	3.20	3.94	2.89	3.36
T_{10}	3.42	4.22	3.06	3.52
T_{11}	3.75	4.60	3.41	3.91
T_{12}	3.10	3.83	2.82	3.23
Mean	2.54	3.49	2.32	2.74
CD (5%)	0.11	0.14	0.16	0.21

T_1: Control; T_2: Fly ash 10 t/ha; T_3: Fly ash 20 t/ha; T_4: Fly ash 10 t/ha + Gypsum 25% GR; T_5: Fly ash 20 t/ha+ Gypsum 25% GR; T_6: Fly ash 10 t/ha+ Gypsum 50% GR; T_7: Fly ash 20 t/ha+ Gypsum 50% GR; T_8: Fly ash 10 t/ha + Gypsum 25% GR+ GM 10 t/ha; T_9: Fly ash 20 t/ha+Gypsum 25% GR+ GM 10 t/ha; T_{10}: Fly ash 10 t/ha+Gypsum 50% GR+ GM 10 t/ha; T_{11}: Fly ash 20t/ha + Gypsum 50% GR+GM 10 t/ha and T_{12}: Gypsum 100 % GR alone

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

The experiment was conducted in the farmers fields having waters with pH, EC, SAR and RSC ranging between 7.8-10.6, 0.8-9.5 dS/m; 0.6-18.2 mmol/l and 1.5-12.7 meq/l, respectively. The soils were clay loam to sandy clay loam with pH, EC, ESP and OC ranging between 8.1-9.7, 2.1-3.4, 48.8-60.2 and 0.2-0.5, respectively. Highest grain yield of rice (3.53 to 4.37 t/ha) and wheat (3.20 to 4.00 t/ha) cultivars were obtained from phospho-gypsum treatment followed by gypsum, pyrites and press mud in various farmers fields in different districts. The percentage response of various ameliorants on grain yield of various cultivars over RSC water (control) could be arranged as: phospho-gypsum (76.9)> gypsum (66.7)> pyrite (48.7)> Press mud (31.4) in rice and 92.1, 78.3, 59.6 and 38.1 in wheat respectively (Table 2.30).

Table 2.30. Effect of ameliorants on crop yield (t/ha) under RSC water in farmers fields

Farmers	RSC water		Press mud		Pyrites		Gypsum		Phosphogypsum	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Narendra	1.87	1.61	2.55	2.22	2.84	2.56	3.28	2.93	3.53	3.20
Ramphal	2.16	1.83	3.00	2.68	3.42	3.04	3.84	3.51	4.09	3.72
R. Yadav	2.50	2.11	3.22	2.80	3.67	3.32	4.02	3.62	4.28	3.96
Bachhu Lal	2.67	2.20	3.31	3.01	3.75	3.45	4.20	3.77	4.37	4.00

Identifying suitable micro-irrigation methods for vegetable crops under sodic soil (Trichy)

Field experiment was conducted during July-September, 2012. The pH of the soil was 9.32 with EC 0.90 dS/m. The pH of the irrigated water was 8.5 with EC_{iw} 2.02 dS/m. The initial N, P and K content of the soil was 282, 21 and 285 kg/ha respectively. Among the irrigation methods, drip irrigation has registered the highest yield (1643 kg/ha) of vegetables followed by sprinkler irrigation with yield (1166 kg/ha) of crops. Cluster bean produced the highest yield of 2037 kg/ha followed by okra 1378 kg/ha (Table 2.31). Interaction effects of irrigation methods on vegetables, cluster beans raised under sprinkler irrigation has recorded the highest yield of 2764 kg/ha followed by okra (1952 kg/ha) raised under drip irrigation (Table 2.32).

Table 2.31. Effect of irrigation methods on yield of okra and cluster bean

Treatments	Yield of vegetables (kg/ha)
Methods of irrigation	
Drip irrigation	1643
Sprinkler irrigation	1166
Farmers method	963
CD (5%)	11.0
Vegetable crops	
Okra	1378
Cluster beans	2037
Lablab	734
Vegetable cowpea	881
CD (5%)	31.0

Table 2.32. Interaction effect of irrigation methods on crop yield

Irrigation methods	Yield (kg/ha)			
	Okra	Cluster bean	Lablab	Vegetable cowpea
Drip irrigation	1952	2764	880	976
Sprinkler irrigation	1184	1835	719	925
Farmers practice	997	1511	601	742
CD (5%)		I x C	C x I	
		47.78	53.74	

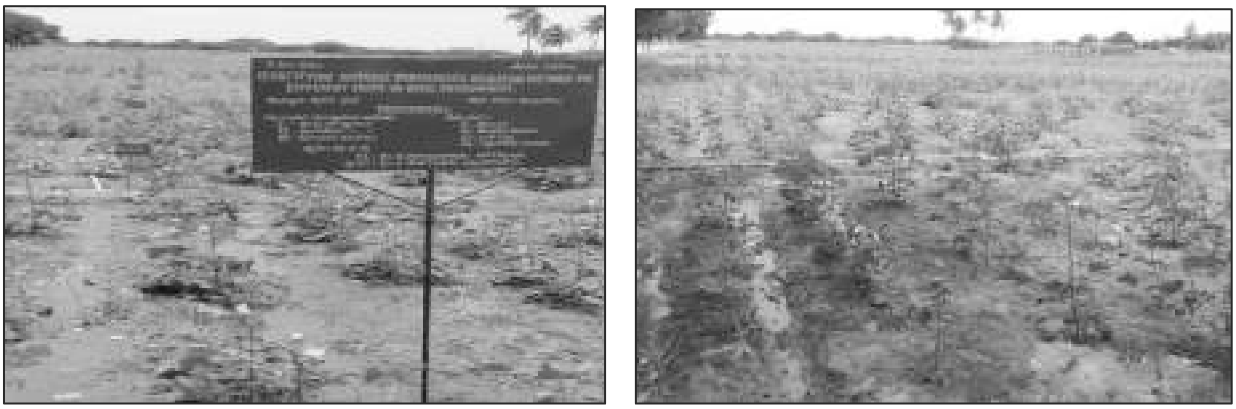


Fig. 2.9. General view of field experiments

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

Pre-plant application of post methanated effluent (PME): The experiment was initiated during 2002 and continued for 10 crop year. The treated distillery effluent (TDE) was applied as per treatment schedule. The N, P and K fertilizers were applied at 75% of the recommended doses viz., 206, 45 and 84 kg of N, P_2O_5 and K_2O/ha. The graded doses of TDE applied plots had significantly increased sugarcane yield (var. Co 86032) (Table 2.33). Yield of sugarcane increased by 23.4, 35.6, 46.7 and 57.9 per cent due to application of TDE 1.25, 2.5, 3.75 and 5.0 lakh L/ha respectively over control. Application of fertilizers significantly increased the yield of sugarcane over control at all levels of TDE. Irrespective of doses of TDE, the highest yield was recorded with the application of NPK fertilizers over control.

Table 2.33. Effect of TDE and fertilizers on yield of sugarcane

Treatments	Sugarcane yield (t/ha)						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	46.0	57.9	72.2	69.6	54.5	79.6	63.3
M_2	54.9	76.3	93.1	73.6	75.9	95.1	78.1
M_3	61.3	86.1	96.9	87.2	86.0	97.9	85.9
M_4	72.7	93.5	101.1	93.7	91.9	104.2	92.9
M_5	86.4	103.5	106.3	95.9	100.0	107.8	100.0
Mean	64.3	83.5	93.9	84.0	81.6	96.9	
CD (5%)	M: 3.7; S: 3.6; MxS: 8.1; SxM: 7.9						

M_1: No PME (control); M_2: 1.25 lakh litres/ha ; M_3: 2.5 lakh litres/ha ; M_4: 3.75 lakh litres/ha ; M_5: 5.0 lakh litres/ha ; S_1: No fertilizers (control); S_2: N alone; S_3: N and P; S_4: N and K; S_5: P and K; S_6: N, P and K

The interaction effect of NPK (S_6) fertilizers on TDE showed that the response of cane yield to combination of fertilizer nutrients and TDE was significant. Significant yield increase was observed for N and P fertilizers over control at all levels of TDE application. Application of N alone (S_2), NK (S_4), NP (S_3) and NPK (S_6) had similar effect in cane yield along with application of TDE. Application of TDE changed the pH nearer to neutral range (Table 2.34) but application of fertilizers did not affect soil pH significantly. The sub plot treatments and their interaction effect with fertilizers under graded doses of TDE were also found non-significant.

Dilution of post methanated effluent (PME): The PME was discharged 1.00, 0.50, 0.33, 0.25 and 0.20 lakh litres/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 40 days interval starting from 45 day after ratooning/planting. The N and P fertilizers were applied 75% of the recommended dose. Yield of sugarcane increased remarkably and initial soil pH changed to neutral due to use of PME in 10 years (Table 2.35).


Fig 2.10. Application of TDE as pre-plant and general view of the experimental field

Table 2.34. Effect of TDE and fertilizers on pH of post harvest soil

Treatments	Soil pH						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
M_1	8.34	8.33	8.31	8.31	8.33	8.32	8.32
M_2	8.16	8.13	8.13	8.07	8.03	8.08	8.10
M_3	7.92	7.90	7.87	7.88	7.84	7.89	7.88
M_4	7.75	7.74	7.75	7.71	7.76	7.74	7.74
M_5	7.39	7.35	7.29	7.32	7.31	7.38	7.38
Mean	7.91	7.89	7.87	7.86	7.86	7.89	
CD (5%)	M: 0.15; S: NS; MxS: NS; SxM: NS						

Table 2.35. Effect of TDE at different dilutions on on sugarcane yield and soil properties

Treatments	Yield (t/ha)	pH	EC (dS/m)	Ex. Ca	Ex. Mg	Ex. Na	Ex. K	ESP
				(cmol (p+)/kg)				
T_1	78.0	8.38	0.09	7.56	3.95	1.63	0.39	11.80
T_2	115.0	7.85	0.37	12.3	6.17	1.65	0.89	7.91
T_3	110.0	7.88	0.32	11.7	5.99	1.60	0.88	8.17
T_4	102.0	7.98	0.25	10.9	5.73	1.55	0.82	8.35
T_5	96.0	8.10	0.27	10.7	5.60	1.58	0.78	8.83
T_6	90.0	8.19	0.22	10.1	5.35	1.57	0.71	8.97
SEd	2.8	0.23	0.01	0.30	0.26	0.07	0.03	0.37
CD (5%)	6.1	NS	NS	0.70	0.56	NS	0.07	0.80

T_1 : Control (Well water); T_2 : 1:10 dilution (PME + Well water); T_3 : 1:20 dilution (PME + Well water); T_4 : 1:30 dilution (PME + Well water); T_5 : 1:40 dilution (PME + Well water); T_6 : 1:50 dilution (PME + Well water)

Research Accomplishments

3. Use of Salty and Marginal Quality Waters in Agriculture

Use of Saline Water in Agriculture

- Effect of saline water irrigation on soil properties and crop yields (Agra)
- Tolerance of vegetables to saline irrigation under drip/surface irrigation system (Agra)
- Tolerance of brinjal and onion to saline irrigation in drip/flood irigation systems (Bikaner)
- Response of groundnut-wheat to varying salinity and moisture by sprinkler irrigation (Bikaner)
- Response of pearl millet fodder varieties to varying saline water irrigation (Bikaner)
- Plastic low tunnels for off-season vegetables with saline water in drip irrigation (Agra)
- Mitigating adverse effects of salinity by foliar application of chemicals (Bikaner)
- Mitigating adverse effects of salinity by bio-regulators/antioxidants on wheat (Bikaner)
- *Performance of microbial culture on wheat irrigated with saline water (Hisar)*
- Crop water/salinity production functions for different crops using sprinkler irrigation (Agra)
- Salt and water dynamics in soil under drip irrigation on cole crop (Hisar)
- Organic input management options with saline water irrigation for sustaining productivity of high value crops (Karnal)

Use of Alkali Water in Agriculture

- Management of high RSC water and its effect on rice (Bapatla)
- Management of high RSC water in heavy textured soils (Bapatla)
- Effect of high RSC water along with FYM and gypsum in vegetables (Hisar)
- Optimization of zinc requirement of wheat irrigated with sodic water (Hisar)
- Drip irrigation to vegetables in alkali soil using amended alkali water (Trichy)

Conjunctive Use of Salty Waters with Canal/Rain Water in Agriculture

- Conjunctive use of saline and canal water in cotton-wheat crop rotation (Hisar)
- Conjunctive use of saline and canal water in pearl millet-mustard crop rotation (Hisar)
- Conjunctive use of canal and alkali water in rice based cropping system (Trichy)

Use of Marginal Quality Waters in Agriculture

- Effect of Sea water intrusion on ground water quality in coastal Krishna Zone, A.P. (Bapatla)
- Drain water usage and management strategies of Nallamada drain (Bapatla)
- Impact of Agra canal on ground water quality, soil properties and crop performance (Agra)
- Impact of irrigation with treated sewage on soil, crop and ground water quality (Agra)
- Studies on long term effect of sewage irrigation on soil and crops (Trichy)

Use of Saline Water in Agriculture

Effect of saline water irrigation on soil properties and crop yields (Agra)

The experiment was initiated in 2009 and continued during 2010-12 for Tulsi (var. Rama), Isabgal (var. Mayur), Fennel (var. Local) and Fenugreek (var. Sag Kalmi) to assess their salt tolerance. The SAR of irrigation water was 10 $(mmol/l)^{1/2}$. The results showed that biomass of tulsi and seed yield of isabgol and fennel declined significantly at EC_{iw} 8 dS/m in both the years (Tables 3.1, 3.2) whereas grain yield of fenugreek declined significantly at EC_{iw} 6 (2010-11) and 8 (2011-12) as compared to best available water. Soil salinity increased with salinity and number of irrigations whereas salinity of soil layers increased during *rabi* as compared to *kharif* season (Table 3.3).

Table 3.1. Effect of saline water irrigation on tulsi and isabgol crop yield

Treatments EC_{iw} (dS/m)	Tulsi biomass (t/ha)				Isabgol seed yield (t/ha)			
	2010-11	2011-12	Mean	RY	2010-11	2011-12	Mean	RY
BAW (2.5)	25.9	18.4	22.2	100	0.83	0.92	0.88	100
4	24.7	17.9	21.3	96	0.78	0.84	0.81	92
6	24.5	17.6	21.1	95	0.62	0.79	0.71	81
8	23.9	15.7	19.8	89	0.59	0.62	0.61	69
CD (5%)	2.0	1.7	-	-	0.17	0.14	-	-

Table 3.2. Effect of saline water irrigation on fennel and fenugreek crop yield

Treatments EC_{iw} (dS/m)	Seed yield of Fennel (t/ha)				Seed yield of Fenugreek (t/ha)			
	2010-11	2011-12	Mean	RY	2010-11	2011-12	Mean	RY
BAW (2.5)	1.25	1.17	1.21	100	1.90	2.04	1.97	100
4	1.11	1.09	1.10	91	1.80	1.93	1.87	95
6	1.08	1.03	1.06	88	1.64	1.88	1.76	89
8	0.98	0.92	0.95	79	1.53	1.53	1.56	79
CD (5%)	0.18	0.17	-	-	0.17	0.19	-	-

Table 3.3. Effect of different treatments on soil salinity at sowing (AS) and harvest (AH) of crops

Treatments EC_{iw} (dS/m)	Soil depth (cm)	Tulsi		Isabgol		Fennel		Fenugreek	
		AS	AH	AS	AH	AS	AH	AS	AH
BAW	0-15	2.3	2.6	2.7	3.7	3.1	2.8	2.7	3.1
	15-30	2.3	2.5	2.5	3.1	2.3	2.9	2.6	3.2
	30-60	2.5	2.6	2.6	2.5	3.3	2.7	2.8	3.0
4	0-15	2.9	3.3	3.7	6.4	4.5	5.8	4.0	6.2
	15-30	2.7	3.5	3.3	5.5	3.8	5.5	4.2	5.2
	30-60	3.0	3.2	3.1	4.1	3.2	4.8	3.5	4.8
6	0-15	2.9	3.9	4.9	7.9	6.2	8.9	5.8	8.5
	15-30	2.9	3.2	4.9	7.0	6.0	8.2	4.3	7.3
	30-60	2.7	3.2	4.4	4.6	5.8	7.9	4.1	6.8
8	0-15	3.4	4.0	5.9	10.1	8.2	11.2	6.2	10.2
	15-30	3.9	3.9	5.8	8.1	7.9	9.8	5.8	8.7
	30-60	3.9	3.0	3.9	6.0	6.5	7.5	4.7	6.3

Tolerance of vegetables to saline irrigation under drip/surface irrigation system (Agra)

The experiment was initiated in 2008-09 with varying saline waters (canal, 4 and 8 dS/m) and irrigation schedule (IW/CPE ratio 0.75, 1.00 and 1.25) for capsicum–okra (winter-summer) crop rotation. The irrigation interval was 4 days for drip system and depth of water at each application was 4 cm in surface irrigation. The fruit yield of capsicum and okra significantly decreased with increasing water salinity levels in both drip and surface system (Table 3.4). Based on 2 years average, capsicum yield reduced by 28.8 and 39.1 per cent in drip and 30.8 and 39.9 per cent in surface irrigation at EC_{iw} 4 and 8 (dS/m), respectively. The IW/CPE ratio was found non-significant under drip and surface irrigation. The okra yield reduced by 52.2 and 73.8 per cent in drip irrigation and 74.6 and 99.9 per cent in surface irrigation in EC_{iw} 4 and 8 dS/m over control. The okra yield increased significantly with increasing IW/CPE ratio in drip irrigation system only. The okra yield increased by 48.2 and 75.3 per cent at IW/CPE ratio 1.00 and 1.25 over 0.75. In surface irrigation, IW/CPE ratios were found non-significant. The interaction effect between EC_{iw} and IW/CPE ratio were non-significant in both crops in drip and surface irrigation system in both the years. The water productivity was observed highest in control treatments of both drip and surface irrigation (Table 3.5). The water productivity decreased with increasing EC_{iw} levels and was higher in drip than surface irrigation. The water productivity was higher at IW/CPE 1.00 in drip and 0.75 in surface irrigation as compared to other ratios.

Table 3.4. Effect of saline water and irrigation frequency on yield (Av. 2009-10 & 2010-11)

Treatments	Capsicum (t/ha)		Okra (t/ha)	
	Drip irrigation	Surface irrigation	Drip irrigation	Surface irrigation
EC_{iw} levels (dS/m)				
Canal	16.74	12.78	11.19	10.79
4	11.92	8.84	5.27	2.74
8	10.19	7.68	2.93	0.01
CD (5%)	2.37	1.37	1.26	1.14
IW/CPE ratio				
0.75	13.02	10.03	4.58	4.50
1.00	13.61	9.87	6.79	4.58
1.25	12.22	9.21	8.03	4.43
CD (5%)	NS	NS	1.26	NS
EC x IW/CPE ratio	NS	NS	3.15	NS

Table 3.5. Water use and water productivity in various treatments in okra (Av. 2010, 2011)

Treatments	Drip irrigation		Surface irrigation	
	Water use (cm)	Water productivity (kg/ha-cm)	Water use (cm)	Water productivity (kg/ha-cm)
EC_{iw} levels (dS/m)				
Canal	46.9	240.4	64.9	166.7
4	47.7	116.0	64.3	44.3
8	43.6	71.0	64.0	0.2
IW/CPE ratio				
0.75	35.9	127.5	50.5	89.3
1.00	47.8	143.4	64.7	71.5
1.25	57.6	139.4	78.4	57.7

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. 3.1). At harvest of capsicum in drip irrigation, EC_e of the surface layer ranged from 3.0 to 3.5 dS/m in control, 5.7 to 6.5 in EC_{iw} 4 and 10.3 to 10.9 (dS/m) in EC_{iw} 8 (dS/m) at 5 to 25 cm distance from the plant. Corresponding value for the lower depth (30-60 cm) are 2.8 to 3.0, 4.0 to 4.2 and 5.8 to 6.2 dS/m, respectively. In surface irrigation the salinity build-up was higher in surface layer as compared to lower depth. At harvest of capsicum crop the EC_e in surface layer (0-10 cm) were 3.9, 10.3 and 19.2 (dS/m) with canal, EC_{iw} 4 and 8 (dS/m), respectively. The EC_e in surface layer were 10.0, 11.2 and 12.3 dS/m in IW/CPE ratio 0.75, 1.00 and 1.75 respectively.

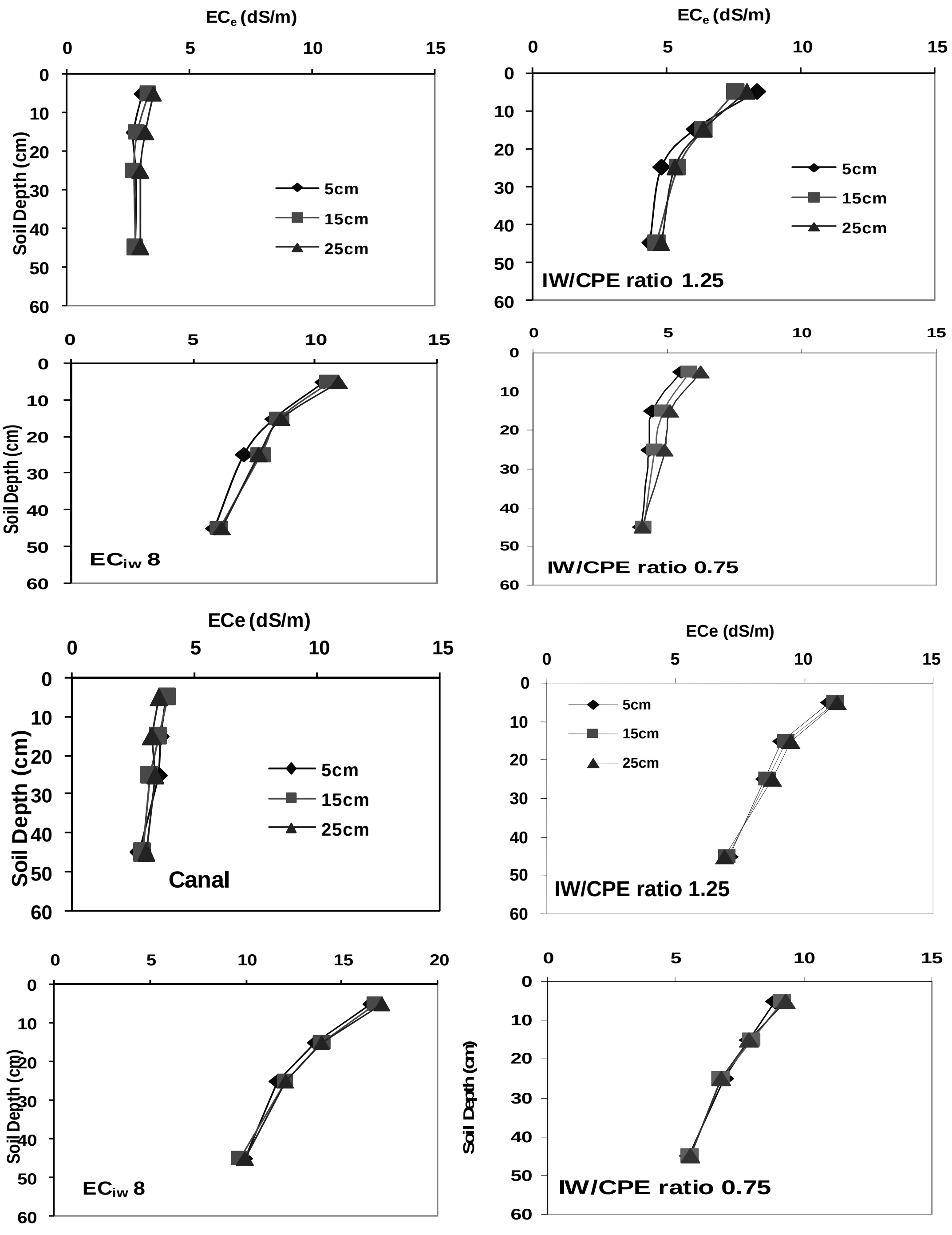


Fig. 3.1. Soil EC_e (dS/m) for different saline irrigation levels and IW/CPE ratios at harvest of (a) capsicum and (b) okra in drip irrigation (Av. 2009-10 and 2010-11)

Tolerance of brinjal and onion to saline irrigation in drip/flood irigation systems (Bikaner)

Results of two years experimentation showed that drip method was found superior over flood method by producing higher fruit yield (26.5 per cent) of brinjal (Table 3.6). In case of onion, maximum yield was obtained under drip irrigation method with water having EC 3.0 dS/m with a significant decrease in yield at EC_{iw} 6.0 dS/m (Table 3.7). Drip method was found superior over flood irrigation method at all the levels of EC_{iw} producing 34.9 per cent higher yield of onion. The analysis of soil salinity data revealed higher salinity at 30 cm distance from emitters with saline water under drip irrigation system whereas the minimum salinity was observed just below the emitters thus the zone of minimum salt concentration existed below the emitter (Table 3.8, 3.9).

Table 3.6. Effect of methods of irrigation and salinity of water on yield of brinjal

Treatments	Yield (t/ha)		
	2010-11	2011-12	Pooled
	Drip Irrigation		
BAW (EC : 0.25 dS/m)	18.78	21.53	20.15
EC : 3.0 dS/m	18.39	23.56	20.97
EC : 6.0 dS/m	15.47	18.62	17.03
	Flood Irrigation		
BAW (EC : 0.25 dS/m)	17.05	19.35	18.20
EC : 3.0 dS/m	14.10	15.68	14.89
EC : 6.0 dS/m	12.02	13.71	12.86
CD (5%)	0.89	2.60	1.29

Table 3.7. Effect of methods of irrigation and salinity of water on onion

Treatments	Weight of bulb (g)				Bulb diameter (cm)				Yield (t/ha)			
	08-09	09-10	10-11	Mean	08-09	09-10	10-11	Mean	08-09	09-10	10-11	Mean
					Drip Irrigation							
BAW	106.3	85.2	81.60	91.03	6.25	6.10	5.57	5.97	46.3	25.63	22.83	31.6
3.0 dS/m	119.9	97.7	92.10	103.23	6.58	6.29	5.82	6.23	54.3	33.24	28.65	38.7
6.0 dS/m	100.6	78.7	71.87	83.72	5.94	5.73	5.29	5.65	38.6	16.22	15.83	23.6
					Flood Irrigation							
BAW	91.1	75.3	73.50	79.97	5.90	5.88	5.45	5.74	40.1	19.43	19.83	26.5
3.0 dS/m	109.7	70.4	68.70	82.93	6.35	5.74	5.33	5.81	44.9	17.45	18.17	26.8
6.0 dS/m	79.7	62.2	60.10	67.33	5.46	4.93	5.01	5.13	30.3	9.96	9.33	16.5
CD (5%)	11.3	10.4	5.24	8.94	0.31	0.27	0.23	0.28	6.6	5.9	4.29	3.2

Fig. 3.2. View of experimental crop of brinjal

Table 3.8. Salinity build-up in the soil profile after harvest of brinjal

Dist. from emitter (cm)	Soil depth (cm)	EC_{iw} (dS/m)																	
		Kharif 2011						Kharif 2012						Mean					
		Drip			Flood			Drip			Flood			Drip			Flood		
		0.25	3.0	6.0	0.25	3.0	6.0	0.3	3.0	6.0	0.25	3.0	6.0	0.25	3.0	6.0	0.25	3.0	6.0
0±5	0-15	0.4	1.2	1.5				0.4	0.6	0.8				0.4	0.9	1.2			
	15-30	0.4	1.3	1.7				0.5	0.7	0.9				0.4	1.0	1.3			
	30-45	0.4	1.5	1.8				0.5	0.8	1.0				0.5	1.1	1.4			
15±5	0-15	0.5	1.2	1.8	0.3	1.3	1.6	0.5	0.7	1.0	0.3	0.8	1.1	0.5	0.9	1.4	0.3	1.0	1.4
	15-30	0.6	1.5	2.0	0.4	1.6	2.3	0.5	0.8	1.0	0.4	1.0	1.2	0.5	1.2	1.5	0.4	1.3	1.8
	30-45	0.6	1.7	2.3	0.4	1.8	2.9	0.6	0.9	1.1	0.6	1.2	1.3	0.6	1.3	1.7	0.5	1.5	2.1
30±5	0-15	0.5	1.3	2.3				0.5	0.8	1.0				0.5	1.0	1.7			
	15-30	0.6	1.8	2.7				0.6	0.9	1.1				0.6	1.3	1.9			
	30-45	0.7	1.8	2.7				0.6	1.0	1.2				0.7	1.4	1.9			

Table 3.9. Salinity build-up in the soil profile after harvest of onion (Av. of 3 years)

Distance from emitter (cm)	Soil depth (cm)	EC_{iw} (dS/m)					
		Drip Irrigation			Flood Irrigation		
		0.25	3.0	6.0	0.25	3.0	6.0
0	0-15	0.44	1.21	1.84	0.31	1.34	1.86
	15-30	0.47	1.24	1.91	0.39	1.36	2.04
	30-45	0.54	1.26	2.20	0.41	1.51	2.26
15	0-15	0.48	1.50	1.77	-	-	-
	15-30	0.46	1.54	2.00			
	30-45	0.46	1.66	2.25			
30	0-15	0.51	1.81	1.93	-	-	-
	15-30	0.49	1.85	2.14			
	30-45	0.50	1.87	2.29			

Response of groundnut-wheat to varying salinity and moisture by sprinkler irrigation (Bikaner)

The experiment was initiated in 2007-08 to create salinity and moisture gradient using saline water with variable discharge sprinkler nozzels. BAW (0.3 dS/m) and saline water (4.6 dS/m) was applied to create moisture and salinity gradients. Crop cuttings were taken at different locations from the laterals covering an area of 4 m^2 to correlate salinity and moisture gradient with yield. The data revealed that application of water depth decreased with increase in distance from sprinkler line and decrease in nozzle discharge. In saline and BAW alone, the total depth of irrigation varied from 26.8 to 61.2 cm and 27.2 to 61.9, respectively. In case of mixed water the depth water varied from 39.3 to 62.9 cm.

Groundnut yield was affected by amount of water applied and salinity gradients (Fig.3.3). In the zone of BAW, total depth of irrigation upto 60 cm resulted in increase of pod yield increased linearly from 0.52 to 2.02 t/ha. But, in case of saline water the increase in yield from 0.21 to 0.30 t/ha was observed only up to 50cm depth of water, thereafter, decrease in yield was found. Whereas, in mixed water zone the pod yield of groundnut increased 0.35 to 1.07 t/ha with the increase in depth of irrigation upto 55 cm. This clearly indicates that a positive relationship exists between depth of water applied and groundnut pod yield, whereas salinity of water affected negatively the pod yield of groundnut. Therefore, for obtaining the optimum yield, with increasing water salinity the depth of water applied needs to be reduced accordingly.

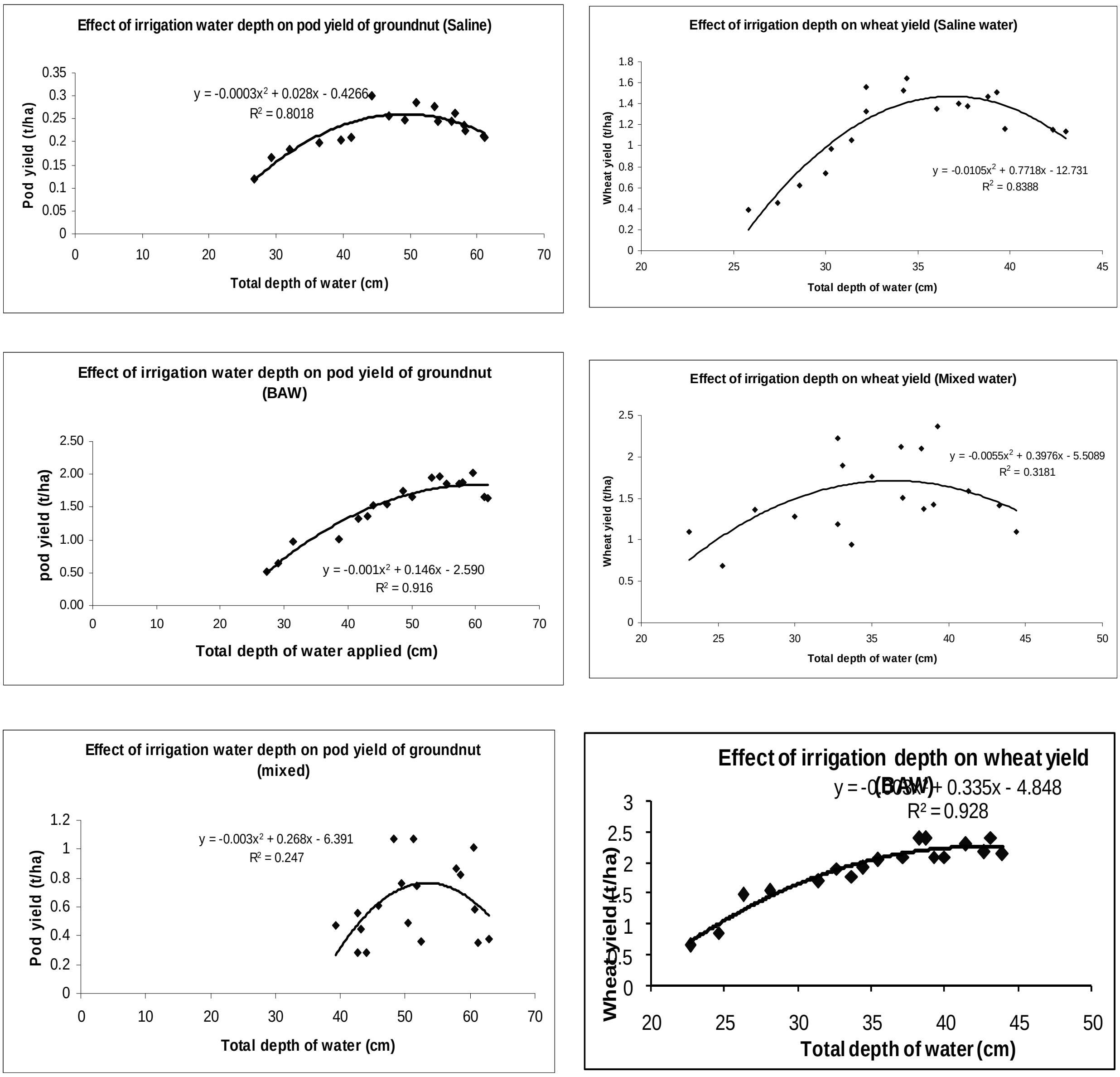


Fig. 3.3. Effect of irrigation water depth on yield of groundnut (pod) and wheat

Wheat yield was affected both by amount of water applied and salinity gradients. In case of saline water (EC_{iw} 3.9 dS/m), total depth of water applied ranged from 25.8 to 43.0 cm in seven irrigations. The grain yield of wheat ranged from 0.4 to 1.6 t/ha. It followed quadratic trend ($y = -0.0150x^2 + 0.7718x - 12.731$ (R^2=0.83). In the mixed zone, the grain yield varied from 0.7 to 2.4 t/ha. Relationship between yield and total depth of water applied obtained as $y = -0.0055x^2 + 0.3976x - 5.5089$ (R^2=0.32). In the zone of BAW (EC_{iw} 0.25 dS/m) up to total depth of irrigation of 35.0 cm the grain yield of wheat increased linearly from 0.7 to 2.0 t/ha. Thereafter it became quadratic in nature ($y = -0.0039x^2 + 0.3351x - 4.8482$ (R^2=0.93). Up to total depth of water applied i.e. 40 to 42 cm it exhibited a platue zone, indicating yield levels in between 2.2 to 2.5 t/ha. From the results it can be inferred that total depth of water applied should be around 42 cm divided in seven irrigations equally when canal water is used under sprinkler irrigation system. Irrigation water salinity was found negatively related with yield, whereas, positive correlation was observed between yield and total depth of water applied. For wheat crop the total depth of water applied should be kept around 42, 33 and 38 cm for BAW, saline and mixed water, respectively divided in seven irrigations equally under sprinkler irrigation system for getting higher yield.

Response of pearl millet fodder varieties to varying saline water irrigation (Bikaner)

An un-replicated trial was conducted for evaluation of fodder purpose varieties of pearl millet under three irrigation water qualities (BAW 0.25, 4.0 and 8.0 dS/m). The result indicated that Giant bajra variety performed better with saline water in all three situations in sandy soils of the region (Table 3.10). However, when compared for salinity with BAW, reduction in yield due to EC_{iw} 8.0 dS/m was lowest in RBC 2 (6.4 %) and highest in Baif bajra (13.5 %).

Table 3.10. Response of forage purpose varieties of pearl millet to saline irrigation water

Varieties	Green fodder yield (t/ha)		
	BAW (0.25 dS/m)	EC_{iw} (4 dS/m)	EC_{iw} (8 dS/m)
RBC 2	26.5	25.7	24.8
Giant Bajra	41.2	41.5	37.8
AVKB 19	33.0	32.8	29.8
Baif Bajra	37.8	37.3	32.7

Plastic low tunnels for off-season vegetables with saline water in drip irrigation (Agra)

The experiment was initiated in 2011 on tomato and bitter gourd. The data showed the effect of EC_{iw} differ significantly on plant height, fruit diameter, number of fruits and fruit yield/plant in both plastic low tunnels with drip and surface irrigation system. These parameters showed significant reduction at EC_{iw} 4 in surface irrigation and EC_{iw} 8 in plastic low tunnel with drip irrigation (Table 3.11). The EC_{iw} 4 and 8 dS/m reduced the tomato fruit yield by 5.5 and 17.6% in plastic low tunnel with drip and 8.5 and 23.6% in surface irrigation, respectively. In case of bitter gourd fruit yield reduced by 3.0 and 13.7% in drip and 9.8 and 25.5% in surface irrigation at EC_{iw} 4 and 8 dS/m over control. The effect of IW/CPE ratio and interactive effect of salinity levels with IW/CPE ratio were found non-significant in all growth parameters under both the treatments. The water productivity was highest in control of both plastic low tunnel with drip and surface irrigation. It was observed that water productivity decreased with increased EC_{iw} levels and IW/CPE ratios (Table 3.12).

Table 3.11. Effect of different treatments on fruit yield of tomato and bitter gourd (2011-12)

Treatments	Tomato (t/ha)		Bitter gourd (t/ha)	
	Plastic low tunnel with drip irrigation	Surface irrigation	Drip irrigation	Surface irrigation
EC_{iw} levels (dS/m)				
Canal	50.4	23.6	13.1	5.1
4	47.6	21.6	12.7	4.6
8	41.5	18.0	11.3	3.8
CD (5%)	3.7	1.7	1.3	1.2
IW/CPE ratio				
0.75	45.0	20.5	12.7	4.6
1.00	46.1	21.5	12.8	4.5
1.25	48.3	21.2	11.5	4.4
CD (5%)	NS	NS	NS	NS

Table 3.12. Water use and water productivity in different treatments in tomato (2011-12)

Treatments	Low tunnel with Drip irrigation		Surface irrigation	
	Water use (cm)	Water productivity (kg/ha-cm)	Water use (cm)	Water productivity (kg/ha-cm)
EC_{iw} levels (dS/m)				
Canal	40.5	1243.7	55.0	429.9
4	41.8	1136.4	54.7	395.1
8	41.8	992.3	54.4	331.6
IW/CPE ratio				
0.75	31.9	1410.6	42.8	480.0
1.00	42.1	1096.0	54.7	393.1
1.25	51.9	938.7	66.7	318.6

Soil salinity: The EC_e in soil profile (0-60 cm) increased with increasing levels of EC_{iw} and IW/CPE ratio (Fig. 3.4). At harvest of tomato in plastic low tunnel with drip irrigation, EC_e of the surface layer (0-10 cm) ranged from 4.0 to 4.2 dS/m in control, 8.9 to 9.3 in EC_{iw} 4 and 11.9 to 12.2 dS/m in EC_{iw} 8 dS/m at 5 to 25 cm distance from the plant. Corresponding value for the lower depth (30-60 cm) are 3.0 to 3.3, 5.2 to 5.7 and 7.0 to 7.4 dS/m, respectively. In surface irrigation the salinity build-up was higher in surface layer as compared to lower depth. At harvest of tomato EC_e in surface (0-10 cm) were 4.4, 10.8 and 16.2 dS/m with canal, EC_{iw} 4 and 8 dS/m respectively. The EC_e in surface layer were 9.3, 10.7 and 11.5 dS/m in IW/CPE ratio 0.75, 1.00 and 1.75 respectively.

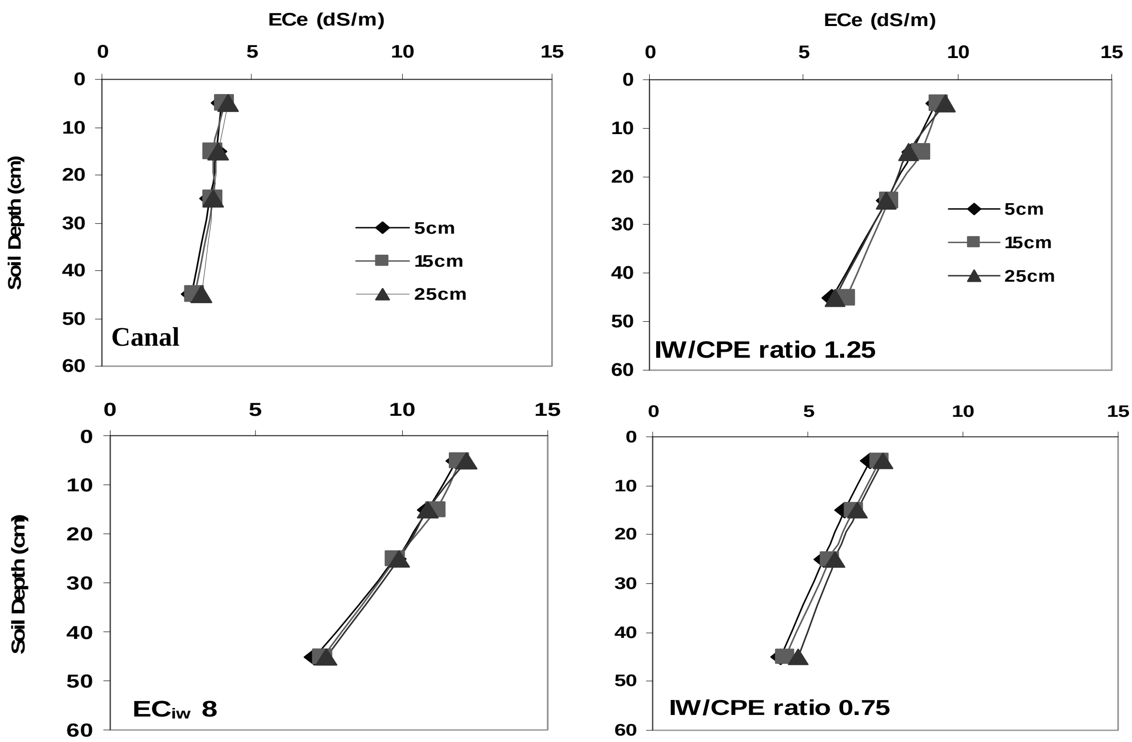


Fig. 3.4. EC_e for different EC_{iw} and IW/CPE ratios at harvest of tomato in drip irrigation (2011-12)

At harvest of bitter gourd in drip irrigation, EC_e of the surface layer (0-10 cm) ranged from 2.5 to 3.4 dS/m in control and 4.5 to 4.7 in EC_{iw} 4 and 7.4 to 8.0 dS/m in EC_{iw} 8 dS/m at 5 to 25 cm distance from the plant. Corresponding value for the lower depth (30-60 cm) are 2.5 to 2.5, 3.3 to 3.3 and 5.1 to 5.3 dS/m respectively (Fig. 3.5). In surface irrigation, the salinity build-up was higher in surface layer as compared to lower depth. At harvest of bitter gourd crop the EC_e in surface layer (0-10 cm) were 3.3, 6.4 and 8.8 dS/m with canal, EC_{iw} 4 and 8 dS/m respectively. The ECe in surface layer were 4.9, 6.3 and 7.4 dS/m in IW/CPE ratio 0.75, 1.00 and 1.75 respectively.

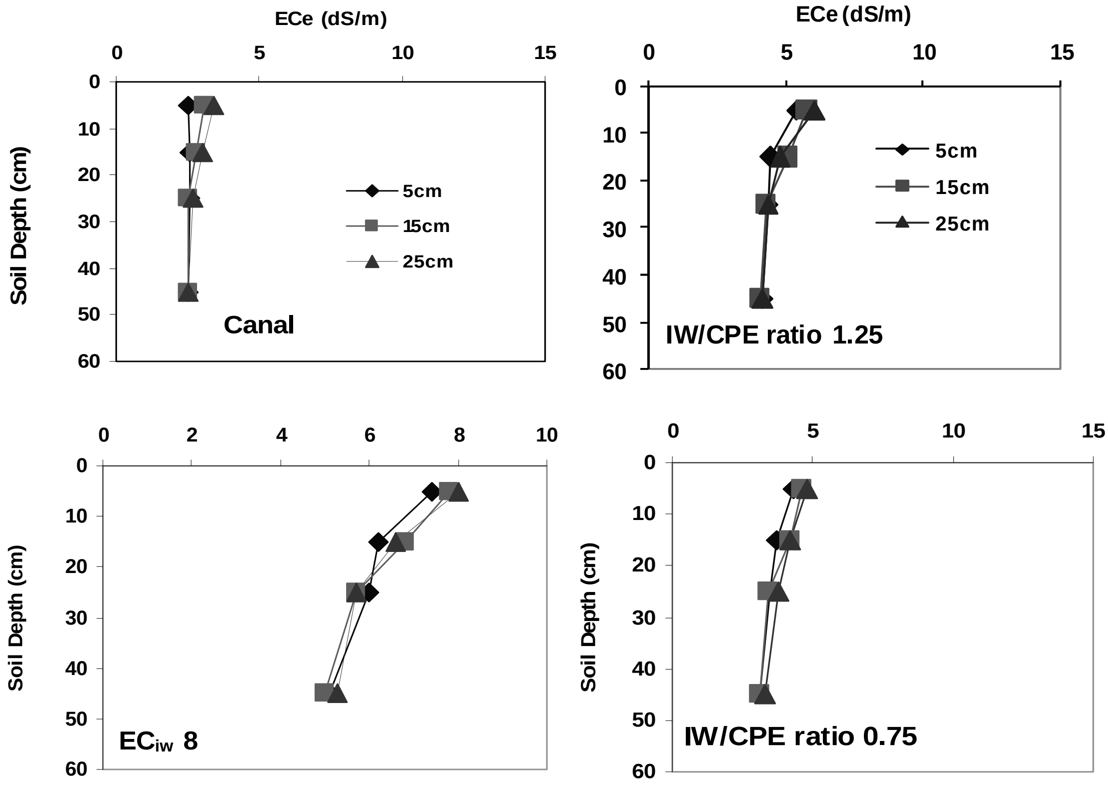


Fig. 3.5. EC_e for different EC_{iw} and IW/CPE ratios at harvest of bitter gourd in drip irrigation (2012)

Mitigating adverse effects of salinity by foliar application of chemicals (Bikaner)

Experiments in two blocks, one with BAW (EC 0.25 dS/m) and other with saline irrigation water of 8.0 dS/m for pearl millet (var. HHB 67) and wheat and 4.0 dS/m for groundnut (var. HNG 10) and fenugreek with four foliar spray treatments viz. Control, Ascorbic acid-100 ppm, Thiourea 500 ppm and K_2SO_4 200 ppm was conducted to study the effect of foliar spray of chemicals in mitigating adverse effects of saline irrigation water (Table 3.13). A reduction in the grain yield of pearl millet and wheat grown with saline irrigation water (8.0 dS/m) and fenugreek and groundnut grown with saline irrigation water (4.0 dS/m) has been observed. It has also been observed that different foliar spray treatments failed to bring any significant effect on grain yield of pearl millet, wheat, fenugreek and groundnut under both the situations i.e. irrigation with BAW and irrigation with saline water. However, all the three chemicals used for spraying have shown edge over the control i.e spray of distilled water, in enhancing the grain yield of pearl millet, wheat and fenugreek and ascorbic acid and K_2SO_4 enhanced the grain yield of groundnut. From the data it is also clear that thiourea and K_2SO_4 in pearl millet, thiourea and ascorbic acid in wheat, ascorbic acid in fenugreek and K_2SO_4 and ascorbic acid in groundnut were more effective in mitigating the adverse effect of saline water.

Table 3.13. Effect of foliar spray of chemicals on grain yield of different crops

Treatments	Yield of crops (t/ha)							
	Pearl millet		Wheat		Fenugreek		Ground nut	
	BAW	8 dS/m	BAW	8 dS/m	BAW	4 dS/m	BAW	4 dS/m
Control	1.39	1.28	2.97	2.30	0.97	0.70	2.90	2.59
Ascorbic acid (100ppm)	1.34	1.29	3.11	2.62	1.14	0.91	2.96	2.78
Thiourea (500 ppm)	1.39	1.35	3.27	2.71	1.18	0.86	2.76	2.53
K_2SO_4 (200 ppm)	1.45	1.38	3.18	2.56	1.22	0.80	2.92	2.83
S.Em. ±	0.06	0.09	0.21	0.14	0.07	0.05	0.16	0.11
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	10.1	15.9	16.7	13.1	16.2	15.0	13.1	10.3

Mitigating adverse effects of salinity by bio-regulators/antioxidants on wheat (Bikaner)

Results showed that increasing levels of irrigation water salinity upto 8.0 dS/m could not influenced the grain yield of wheat significantly (Table 3.14). Application of EC_{iw} 12.0 dS/m resulted in the lowest grain yield and differed significantly to BAW, 4.0 and 8.0 dS/m in this respective. Straw yield of wheat was not affected significantly with increasing levels of irrigation water salinity. Foliar sprays of different bio-regulators brought significant change in the grain yield of wheat over control. The highest grain yield of wheat was obtained with the spray of KNO_3 (5000 ppm), which was at par with ethaphon spray (50 ppm) but differed significantly with control, thio urea spray (500 ppm) and kinetin (10 ppm). Straw yield was not affected due to foliar sprays of different bio-regulators tried. Different levels of irrigation water salinity and bio-regulators could not influenced harvest index and test weight of wheat. Irrigation water salinity upto 8.0 dS/m could not influenced the grain yield of wheat significantly. Maximum grain yield of wheat was obtained under KNO_3 spray (5000 ppm).

Table 3.14. Effect of bio-regulators sprays and salinity levels on yield of wheat

Treatments	Wheat yield (t/ha)		Harvest Index	Test weight
	Grain	Straw	(%)	(%)
EC_{iw} levels (dS/m)				
BAW	2.24	4.16	35.13	37.53
4	2.14	4.39	33.07	36.36
8	2.12	4.45	32.21	36.31
12	1.92	4.05	33.21	36.42
S.Em.±	0.05	0.13	1.23	0.86
CD (5%)	1.81	NS	NS	NS
Bioregulators sprays				
Control	1.92	4.55	31.63	36.93
KNO_3 spray (5000 ppm)	2.25	4.26	33.74	36.87
Thio urea spray (500 ppm)	2.07	4.32	32.46	36.90
Kinetin spray (10 ppm)	2.05	4.20	33.05	35.64
Ethaphon spray (50 ppm)	2.22	4.07	35.36	36.93
S.Em.±	0.06	0.13	1.33	0.58
CD (5%)	0.16	NS	NS	NS

Performance of microbial culture on wheat irrigated with saline water (Hisar)

The study was conducted at CCS HAU, Hisar to work out the performance of microbial culture on the wheat when irrigated with saline water of during 2010-11. One parent strain and two salt tolerant microbial cultures were quoted to seed of the wheat at the time sowing. The treatments consists of two irrigation water quality (canal water EC 0.22 dS/m and saline water EC 8 dS/m and eight strains of microbial culture (control, Mac-27, ST-3, ST-24, P-36, Mac-27 + P-36, ST-3 + P-36, and ST-24 + P-36). During 2010-11, grain yield of wheat (PBW-502) decreased with saline water irrigation as compared to control (Table 3.15). The mean reduction in saline water irrigation was 11 per cent as compared to canal water. The maximum mean yield was obtained with ST-3+P-36 inoculation. Under saline water irrigation, the relative yield increase is 10.7, 5.6 and 3.4 per cent by inoculation of strains such as ST-3+P-36, ST-3 and Mac-27+P-36, respectively, as compared to control. The initial viable counts for *Azotobacter* were 9.9 x 10^5 and 10.2 x 10^5 in saline and canal water irrigation, whereas, Phosphate solublizing bacteria (PSB) were 10.6 x 10^6 and 11.4 x 10^6, respectively. At the harvesting, viable counts for *Azotobacter* and PSB were also determined in the different treatments (Table 3.16). The viable count of salinity tolerant strains of *Azotobacter* was more in saline water irrigated soils as compared to canal water. The count of Mac-27 was more in canal water irrigated fields as compared to saline water. Same was true when PSB was inoculated alongwith *Azotobacter*. The above observation were confirmed when PSB count was tested. Introduction of PSB and *Azotobacter* substantiate above findings.

Table 3.15. Effect of salinity on grain yield of wheat under inoculation of microbial culture

Microbial culture	Grain yield (t/ha) of wheat		
	Canal water	Saline water (EC 8 dS/m)	Mean
Control	4.76	4.24	4.50
Mac-27	4.88	4.42	4.65
ST-3	4.82	4.49	4.65
ST-24	4.74	4.12	4.43
P-36	4.85	4.24	4.54
Mac-27 + P-36	4.83	4.39	4.61
ST-3 + P-36	4.92	4.75	4.84
ST-24 + P-36	4.67	4.24	4.46
Mean	4.81	4.36	
CD (5%)	Salinity (S) : 0.14	Microbial culture : NS	S x M : NS

Table 3.16. Viable count of different inoculants in canal and saline water irrigated fields

Treatments	Saline water (EC 8 dS/m)		Canal water	
	Azotobacter (x10^5 cfu/g soil)	PSB (x10^6 cfu/g soil)	*Azotobacter* (x10^5 cfu/g soil)	PSB (x10^6 cfu/g soil)
Control	5.2	32	12.1	57
Mac-27	76	25	117	30
ST-3	101	102	61	65
ST-24	95	33	94	25
P-36	89	47	112	61
Mac-27 + P-36	44	27	55	36
ST-3 + P-36	122	46	79	37
ST-24 + P-36	161	50	158	32

During 2011-12, wheat seed (WH-711) was treated with the microbial cultures '*Azotobacter* and *Pseudomonas* 36' at the time of sowing. There was significant reduction in plant parameters except test weight with saline water (EC 8 dS/m) as compared to canal water irrigation. There is significant increase in plant height, number of grains per spike whereas number of ear head per metre row length and test weight remained unaffected due to inoculation (*Azotobacter* and *Pseudomonas* 36) and vermicompost 5 t/ha in comparision to no inoculation. There was significant increase in plant height and number of earhead /m row length, earhead length and number of grains/spike upto 100% RDF. The differences in these plant parameters between 100% RDF and 125% RDF were, however, non-significant. The grain yield decreased in saline irrigation as compared to control. The reduction in grain yield in saline water irrigation was 19.9 per cent as compared to canal water. Inoculation (*Azotobacter* and *Pseudomonas* 36) + Vermicompost 5 t/ha increased the grain yield by 6.4 per cent over control. Recommended dose of fertilizer (RDF) produced significantly higher grain yield as compared to 75% RDF. However, the grain yield at RDF and 125% of RDF is at par. Significantly higher straw yield was recorded with canal water irrigation than saline water irrigation. Higher straw yield was recorded in inoculation (*Azotobacter* and *Pseudomonas* 36) + Vermicompost 5 t/ha. Among fertilizer treatment 100% RDF results in significantly higher straw yield than 75% RDF but at par with 125% RDF (Table 3.17). Salinity tolerant strain of *Azotobacter chroococcum* established well in saline irrigated field. Further inoculation of salinity tolerant strain of *Azotobacter* alongwith *Pseudomonas* had more population of *Azotobacter* which probably helped in increased yield over control. Inoculation of these strains in the presence of the vermicompost further led to increased yield and increased the viable count of *Azotobacter* by 27 per cent as compared to inoculation alone (*Azotobacter* and *Pseudomonas* 36).

Table 3.17. Grain and straw yield of wheat under different treatmemts

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Viable count (x 10^5)
Canal	5.1	7.6	9.4
Saline	4.1	6.1	24.7
CD (5%)	1.9	0.3	
Inoculation and vermicompost			
No inoculation (control)	4.5	6.4	8.6
Vermicompost (5 t/ha)	4.7	7.0	37.2
Inoculation (*Azotobacter* & *Pseudomonas* 36)	4.6	6.8	98.0
Inoculation (*Azotobacter* & *Pseudomonas* 36) + VC (5 t/ha)	4.7	7.3	124.5
CD (5%)	NS	0.4	-
Fertilizers			
75% Recommended Dose	4.3	6.7	17.4
100% Recommended Dose	4.7	6.9	22.8
125% Recommended Dose	4.9	7.0	19.6
CD (5%)	0.2	0.2	

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

The experiment was initiated in 2008. The treatments included three salinity levels (BAW, EC_{iw} 9.5 dS/m and mix of the two) and three RSC levels (BAW, RSC 9.5 meq/l and mix of two). The sprinklers were set at 6 m distances in row. The data revealed that water depth decreased with increased distance from sprinkler line in case of saline/alkali and BAW alone. In saline and BAW alone, the depth of irrigation was recorded from 0.74 to 3.64 cm every irrigation at 18 different points. In case of mixing, the irrigation depth was recorded from 3.54 to 5.07 cm every irrigation. The salinity or RSC level of irrigation water remained almost same irrespective of depth in the area where single saline/alkali or BAW (EC_{iw} 3.6 dS/m and RSC_{iw} nil) were applied. In case of mixing, the EC_{iw} and RSC_{iw} plots varied with distance. In case of saline and BAW, EC_{iw} of mixed water ranged from 4.7 to 8.0 dS/m and RSC and BAW mixing plots RSC_{iw} ranged from 1.8 to 7.2 meq/l. The varying depth of irrigation water gave salinity/RSC gradients.

Cluster bean-mustard rotation: The yield data of both the sets of experiment indicate that mustard grain yield was affected by water and salinity/RSC gradients. The average yield increased with increase in depth of irrigation water away from sprinkler lines and increased by 31.4 per cent with in saline (EC_{iw} 10 dS/m) water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation, whereas in two and three nozzle plots, the increase in yield was 31.6 and 25.4 per cent with water depth 0.8 to 3.44 and 0.81 to 3.64 cm per irrigation, respectively. In mixing (BAW + EC_{iw} 10 dS/m) plots, the irrigation depth varied marginally from initial to last point. However, EC_{iw} ranged in one, two and three nozzle from 4.7 to 7.4, 4.8 to 7.9 and 4.9 to 8.0 dS/m and yield declined by 13.5, 13.4 and 14.2 per cent respectively. In RSC block also, yield increased with increase in depth of water away from sprinkler lines by 20.6 per cent with reduction in RSC_{iw} 10 meq/l water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation, whereas in two and three nozzle plots, the increase in yield was 20.6 and 22.8 per cent with depth 0.80 to 3.44 and 0.81 to 3.64 cm per irrigation respectively. In mixing (BAW + RSC_{iw} 10) plots the RSC_{iw} ranged from 1.8 to 7.1, 1.9 to 7.2 and 2.0 to 7.2 meq/l in one, two and three nozzle and yield declined by 14.5, 11.9 and 8.2 per cent respectively. In BAW (EC_{iw} 3.6 dS/m, RSC_{iw} nil), the yield increased by 24.3 per cent with reduction in water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation whereas, in two and three nozzle plots, the yield increased by 26.0 and 23.6 per cent with depth 0.80 to 3.44 and 0.81 to 3.64 cm per irrigation respectively.

Cowpea-mustard rotation: During *kharif* 2011 the crop rotation was changed to cowpea-mustard. The grain yield slightly increased under BAW irrigation. The yield under RSC was poor as compared to other treatments.

Grain yield of mustard was affected by water and salinity/RSC gradients. The yield decreased with decrease in depth of irrigation water away from sprinkler lines by 41.3 per cent with saline EC_{iw} 10 dS/m water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation, whereas in two and three nozzle plots, the decrease in yield was 45.7 and 48.5 per cent with water depth 0.8 to 3.44 and 0.81 to 3.64 cm per irrigation respectively. In mixing (BAW + EC_{iw} 10 dS/m) plots, the irrigation depth varied marginally from initial to last point. However, EC_{iw} ranged from 4.7 to 7.4, 4.8 to 7.9 and 4.9 to 8.0 dS/m and yield declined by 21.0, 23.9 and 15.8 per cent respectively. In RSC block, yield decreased with the decrease in depth of water away from sprinkler lines by 54.9 per cent with reduction in RSC_{iw} 10 meq/l water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation, whereas in two and three nozzle plots, the decrease in yield was 40.4 and 48.6

per cent with depth 0.80 to 3.44 and 0.81 to 3.64 cm per irrigation, respectively. In mixing (BAW + RSC_{iw} 10) plots the RSC_{iw} ranged from 7.1 to 1.8, 7.2 to 1.9 and 7.2 to 2.0 meq/l and yield declined by 15.8, 15.4 and 11.8 per cent respectively. In BAW (EC_{iw} 3.6 dS/m, RSC_{iw} nil), yield decreased by 41.3 per cent with reduction in water depth from 0.74 to 2.70 cm (one nozzle plot) per irrigation whereas in two and three nozzle, the yield decreased by 38.0 and 41.4 per cent with depth of water 0.80 to 3.44 and 0.81 to 3.64 cm per irrigation, respectively.

Finally, the statistical relationships were developed between depth of irrigation and grain yield (Fig. 3.6, 3.7). The quadratic relationship between yield and depth of irrigation was highly significant in BAW, saline and RSC water alone. In case of mixing (EC_{iw} 10+BAW and RSC_{iw}10 +BAW) non-significant relationship were found. In this category the depth of irrigation seems optimum.

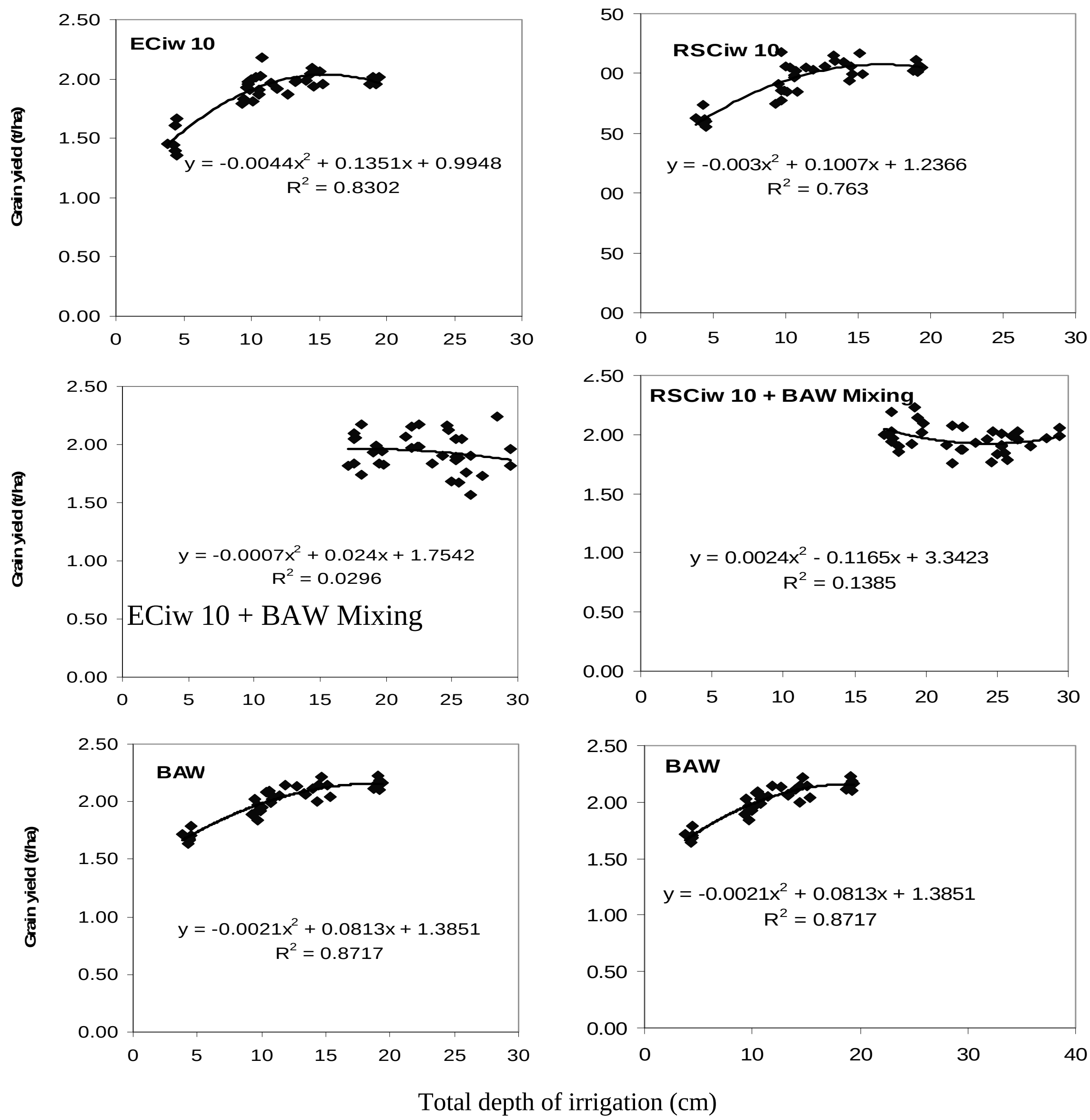


Fig. 3.6. Water production functions of mustard crop with BAW, EC and RSC water (Average 2009-10 and 2010-11)

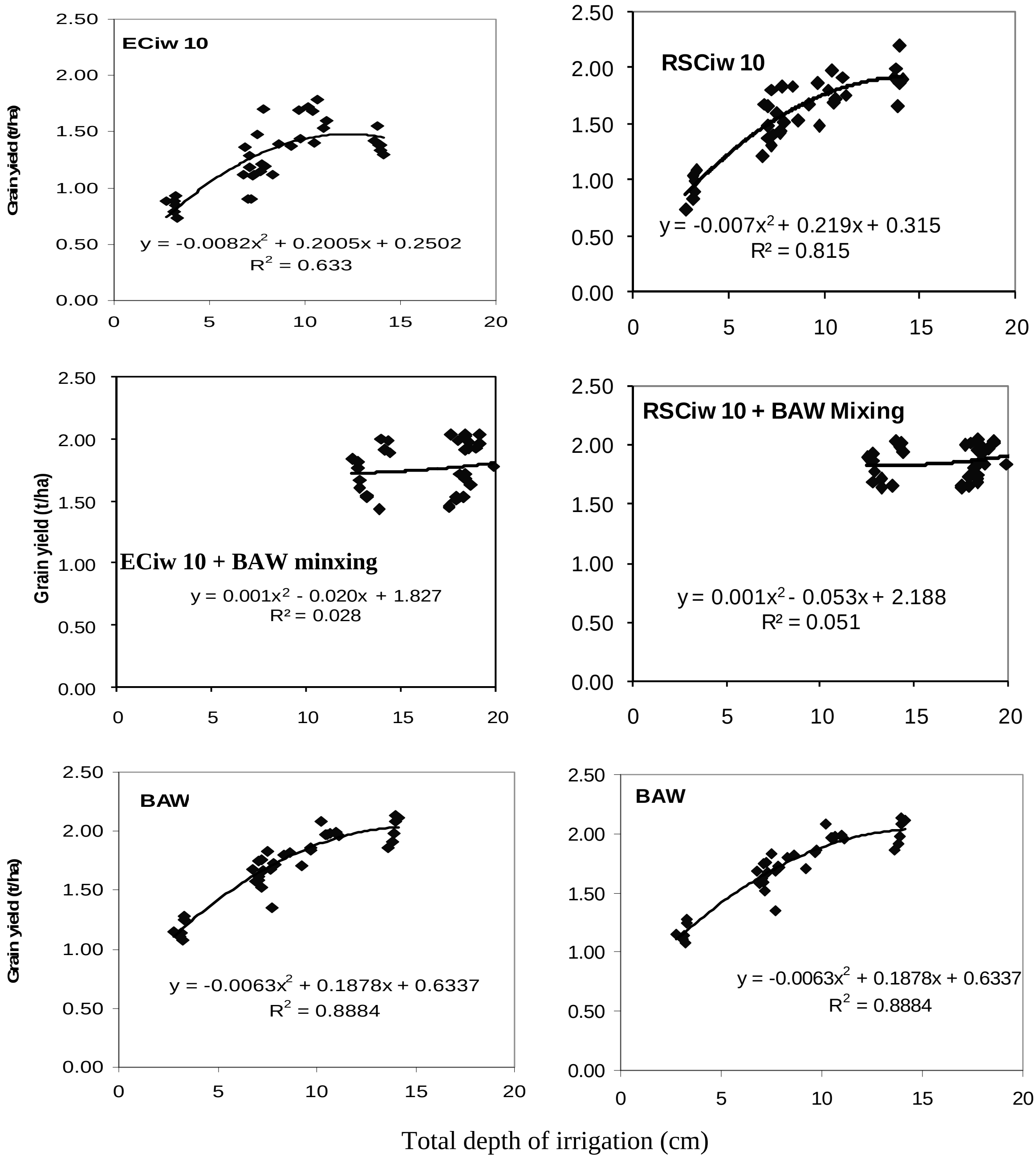


Fig. 3.7. Water production functions of mustard crop with BAW, EC and RSC water (2011-12)

Soil studies: After harvest of mustard crop (2011-12), the soil samples were collected at 4, 8 and 12 m distance from sprinkler line and analyzed. The EC_e of the 0-30 cm depth was relatively more at the adjacent point of both saline and BAW alone sprinkler line and also in mixing plots. The EC_e decreased with increase from nozzle distance due to less water applied. The EC_e (0-30 cm depth) varied from 4.6 to 9.4 dS/m in one nozzle; 4.5 to 13.0 dS/m in two nozzles and 4.4 to 12.7 dS/m in three nozzles. In case of mixing the ECe varied from 5.5 to 10.7 dS/m, 5.7 to 12.0 and 5.0 to 13.0 dS/m, respectively. The ESP varied from 23.1 to 30.7 meq/l in one nozzle, 23.2 to 33.5 meq/l in two nozzles and 24.2 to 34.8 meq/l in three nozzles. In case of mixing the ESP varied from 19.2 to 28.3 meq/l 20.9 to 26.3 meq/l and 19.7 to 27.8 meq/l, respectively.

Salt and water dynamics in soil under drip irrigation on cole crop (Hisar)

The study was initiated in 2011-12 to investigate the effect of frequency and salinity levels of irrigation water on cole crop (cabbage). The effect of irrigation frequency and salinity levels of irrigation water on water and salt dynamics and crop yield are described below:

Wetting pattern under daily irrigation treatment: The wetting pattern (moisture content) under daily irrigation with different saline water treatment i.e. F_1S_1, F_1S_2, F_1S_3, F_1S_4 and F_1S_5 at 30, 60 and 90 DAT is shown in Fig. 3.8. On comparing the contours of Fig. 3.8(a-c) for 30 DAT, it was observed that the pattern of moisture content in the rootzone is almost same in all treatments whereas contours for 90 DAT has shown more depletion in moisture content upto EC_{iw} 6 dS/m and thereafter reduced which may be due to accumulation of salts in the rootzone. The likely increase in osmotic stress due to salinity at higher EC_{iw} may restrict the water availability to the crop resulting in less depletion in moisture content.

Wetting pattern under alternate day irrigation treatment: The wetting pattern (moisture content) under alternate day irrigation with different saline water treatments i.e. F_1S_1, F_1S_2, F_1S_3, F_1S_4 and F_1S_5 at 30, 60 and 90 DAT is shown in Fig. 3.9. On comparing the contours of Fig. 3.9(a-c) for 30 DAT, it was observed that the pattern of moisture content in the rootzone was almost same in all treatments whereas contours for 90 DAt has shown similar variation as in daily irrigation frequency.

EC_e distribution under daily irrigation treatment: The EC_e distribution pattern under daily irrigation with different saline water treatments i.e. F_1S_1, F_1S_2, F_1S_3, F_1S_4 and F_1S_5, at 30, 60 and 90 DAT is shown in Fig. 3.10. On comparing the contours of these figures for 30 DAT, it was observed that the value of EC_e in the rootzone is increasing slightly with increasing levels of EC_{iw}. Whereas, contours for 90 DAT shown steep increase in EC_e of the rootzone with increasing EC_{iw}. The salt built up in the root zone 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. It is due to this reason that EC_e of the rootzone remained lower than the EC_e of the irrigation water used in respective treatments.

EC_e distribution under alternate day irrigation treatment: Fig. 3.11 showed the EC_e distribution pattern under alternate day irrigation with different saline water treatment i.e. F_2S_1, F_2S_2, F_2S_3, F_2S_4 and F_2S_5 at 30, 60 and 90 DAT. On comparing the contours of these figures for 30 DAT, it was observed that the values of EC_e in the rootzone is increasing slightly with increasing levels of EC_{iw} as in daily irrigation frequency. Similarly, contours for 90 DAT has shown steep increase in EC_e of the rootzone with increasing levels of EC_{iw}. Salt built up in the root zone under alternate day irrigation as compared to daily irrigation was higher. This higher salt build 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.

Effect of frequency and salinity of irrigation water on yield of cabbage: A significant decrease in cabbage yield was observed with decrease in irrigation frequency as well as increase in salinity of irrigation water (Table 3.18). Upto EC_{iw} 3 dS/m salinity of irrigation water, there was an increase in crop yield under both the frequencies but it is non-significant. But with further increase in EC_{iw}, a significant decrease in yield was observed. This identifies that the cabbage crop can be grown safely with saline water of EC_{iw} 3.0 dS/, may even perform a little better.

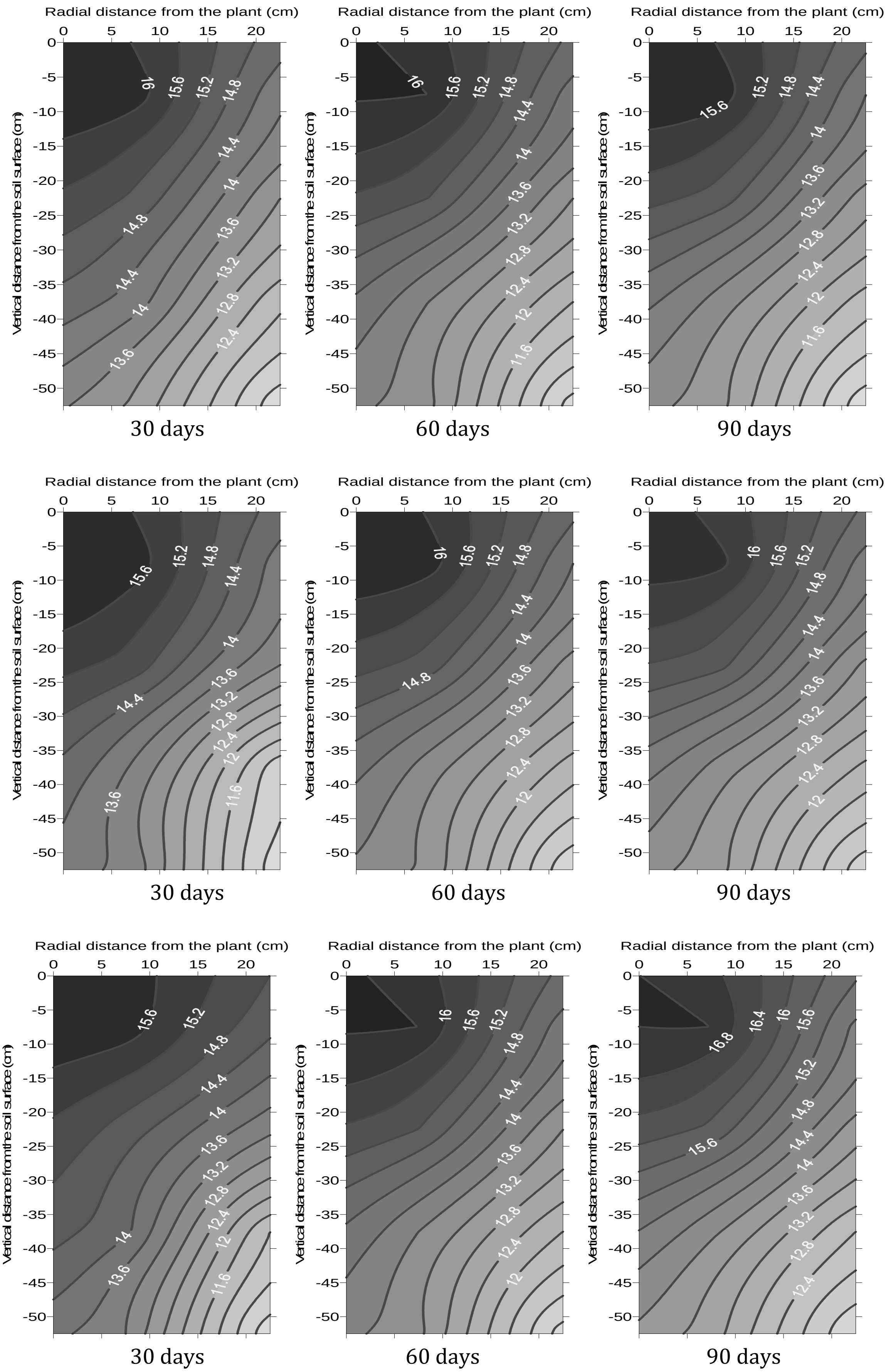


Fig. 3.8. Spatio-temporal moisture content under daily irrigation in (a) F_1S_1 (b) F_1S_3 and (c) F_1S_5 treatments

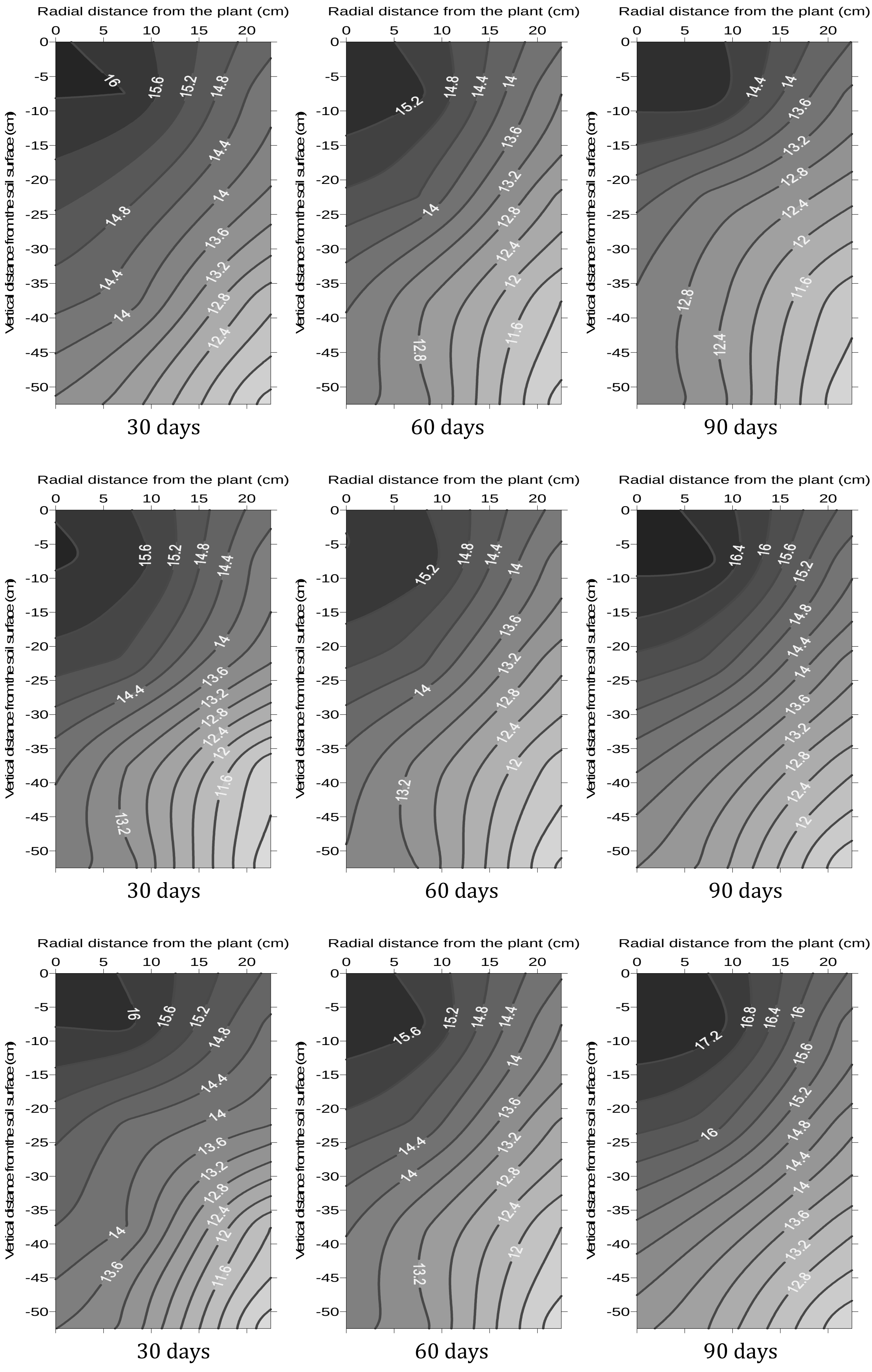


Fig. 3.9. Spatio-temporal moisture content under alternate day irrigation in (a) F_2S_1 (b) F_2S_3 and (c) F_2S_5 treatments

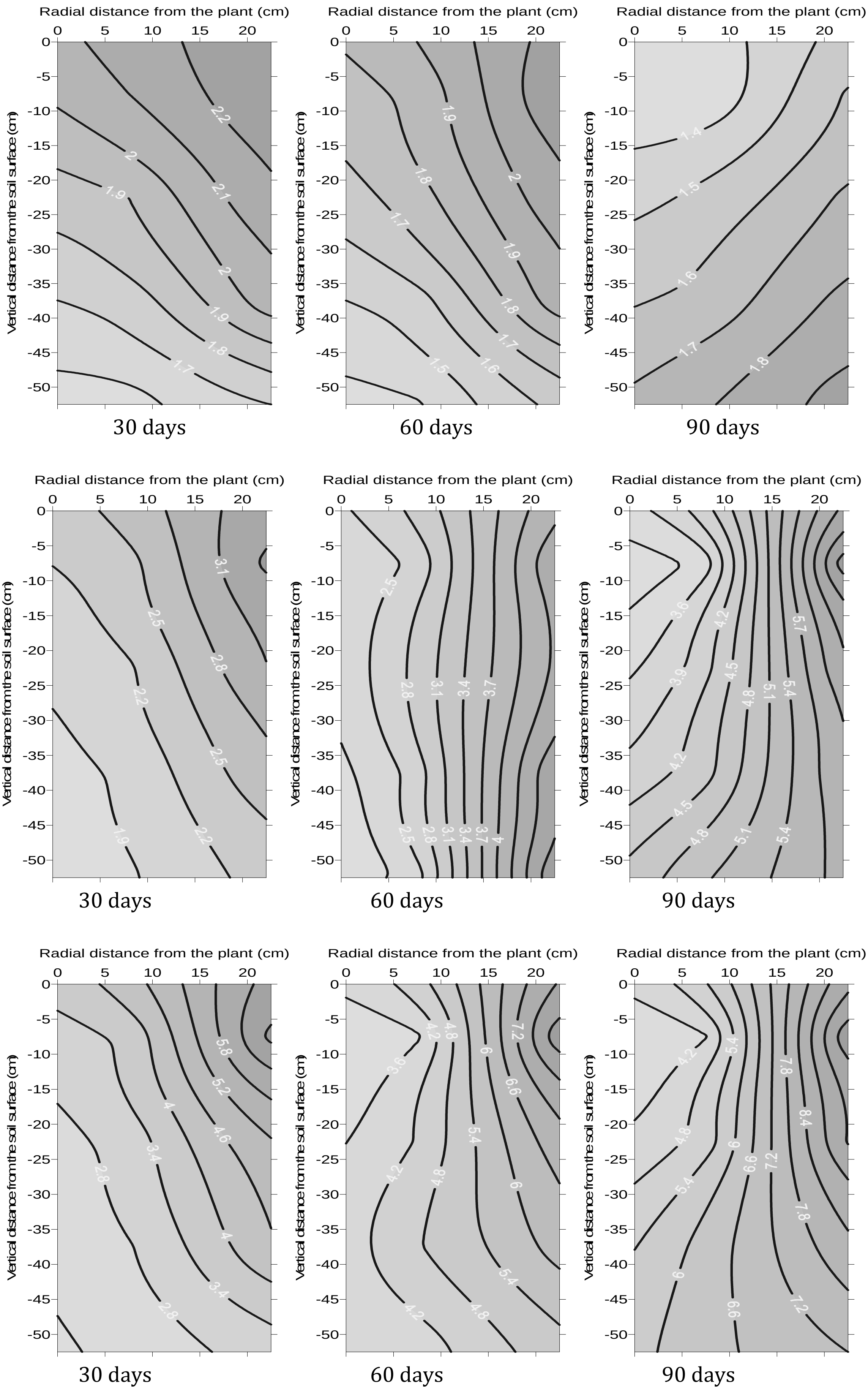


Fig. 3.10. Spatio-temporal salt movement under daily irrigation in (a) F_1S_1 (b) F_1S_3 and (c) F_1S_5 treatments

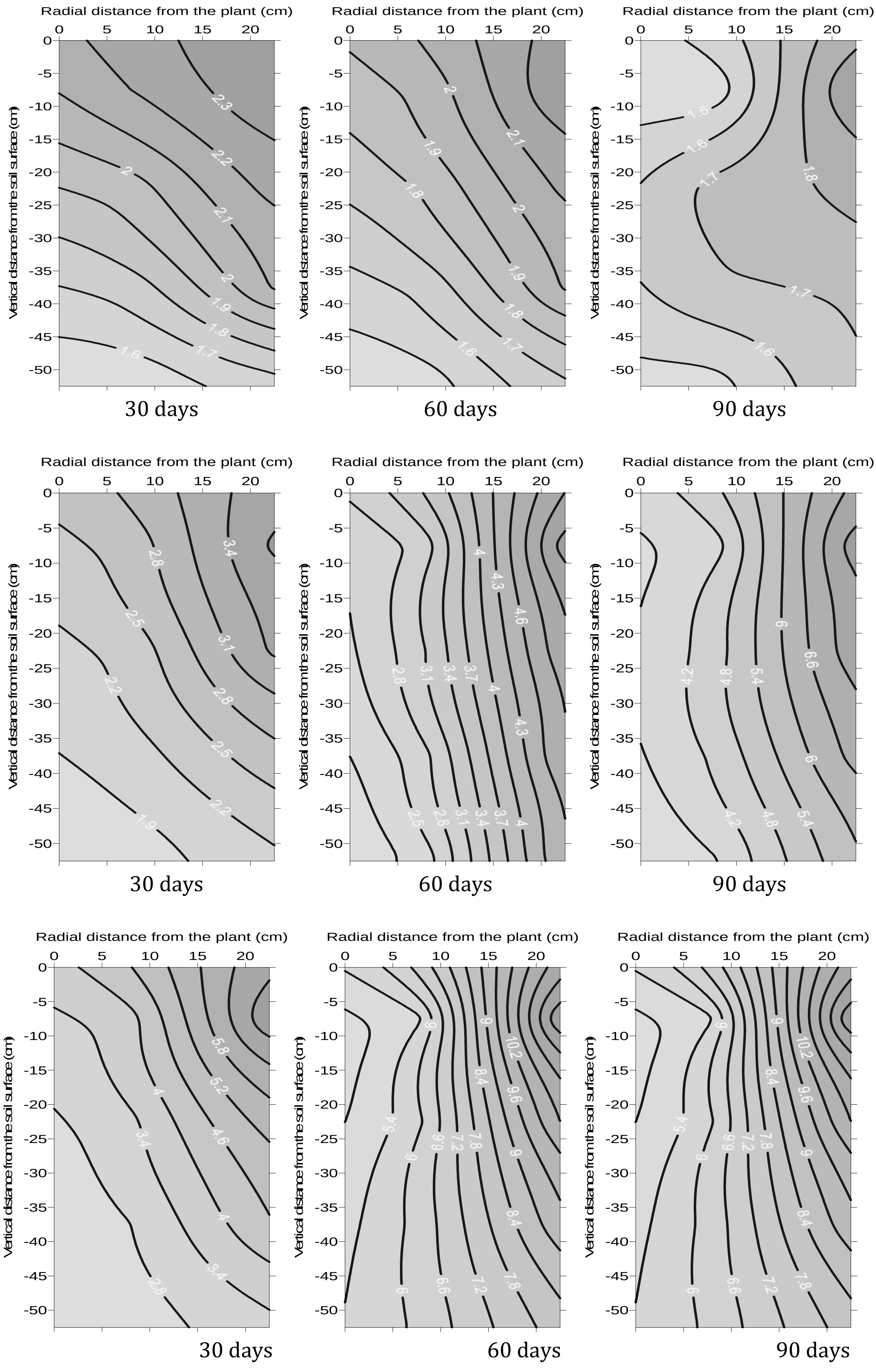


Fig. 3.11. Spatial and temporal salt movement under alternate day irrigation in (a) F_2S_1 (b) F_2S_3 and (c) F_2S_5 treatments

Table 3.18. Effect of salinity and irrigation frequency on yield of cabbage

Treatments	Crop yield (t/ha)		
EC_{iw} (dS/m)	Daily irrigation	Alternate day irrigation	Mean
Canal	74.60	72.30	73.47
3	75.00	72.90	73.97
6	67.70	62.30	65.00
9	50.60	43.60	47.10
120	31.10	20.70	25.90
Mean	59.80	54.37	
CD (5%)	Irrigation frequency (F) : 1.06; Salinity (S) : 1.67; F x S : 2.36		

Under drip irrigation frequency treatments, 3.2, 2.9, 8.7, 16.1 and 50.2 per cent higher crop yield in daily irrigation was observed as compared to alternate day irrigation (canal water, EC_{iw} 3, 6, 9, 12 dS/m) treatments. This indicates that increase in irrigation frequency can manage saline water in a better way. The cabbage yield as affected by irrigation frequency and saline water along with best fitted curves is depicted in Fig. 3.12. In daily and alternate day irrigation, the best fit curves between yield and salinity of irrigation water are obtained through the following quadratic equations in which y and x represents the yield (q/ha) and salinity levels (dS/m), respectively.

For daily irrigation $y = -3.9815 x^2 + 10.914 x + 746.62$ [R2 = 0.997]
For alternate day irrigation $y = -4.3817 x^2 + 8.581 x + 728.09$ [R2 = 0.997]

It is observed from the Fig. 3.12 that the gap between daily and alternate irrigation curves is increasing with the increase in salinity means daily frequency is performing better than alternate under increasing salinity. This concludes that if irrigation water of higher salinity has to be applied then its irrigation frequency must be increased.

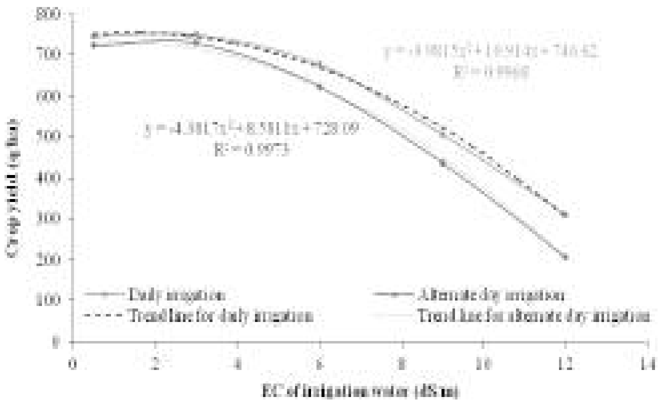


Fig. 3.12. Effect of irrigation frequency and saline water on the crop yield of cabbage

Organic input management options with saline water irrigation for sustaining productivity of high value crops (Karnal)

Increasing shortage of good quality irrigation water in arid and semi arid regions of the country is forcing the farmers to utilize saline and alkali ground water for irrigation. In order to ensure their sustainable use in combination with organic inputs management a field experiment was started during kharif 2008 at Bir Forest Experimental Farm, Hisar. During 2010-11 and 2011-12 sesame (var.HT-1) was sown during *kharif* and fennel var. Hisar Swarup (HF-33) was sown during *rabi* season with two saline water irrigation and 8 organic input management options.

Results of *kharif* 2010 showed that growth, yield attributes and yield of sesame did not differ significantly yet higher seed yield was obtained with high saline water (EC_{iw} >7 dS/m) irrigation this might be due to presence of sodicity (RSC of 4.0 to 6.2) in low saline water whereas during *kharif* 2011 plant height, 100 seed weight and seed yield are significantly higher under low saline water irrigation while plants/m row length and number of pods/plant are were at par under both saline water irrigation. Significantly higher seed yield/plant (4.9 g) was observed with the application of farmyard manure+vermicompost (50:50) as compared to inorganic fertilizer and application of inorganic and organic in equal proportion. Plant height, number of pods per plant, 100 seed weight and seed yield differed non-significantly under different organic inputs though the economically highest seed yield (0.18 t/ha) was obtained with application of 50:50 farmyard manure + vermicompost. During 2011, plant height and seed yield differ significantly under different organic input management options though the economically highest seed yield (0.09 t/ha) was obtained with the application of 50:50 farmyard manure + vermicompost (Table 3.19).

Results of rabi 2010-11 of fennel showed that the plant height was higher under EC_{iw}<4 dS/m while umbels per plant, umbellets per umbel, seed weight per umbel and 100 seed weight and seed yield/ha were higher under EC_{iw} >7 dS/m though the difference was non-significant. Different organic input application results in non-significant difference yield attributes and seed yield though the highest seed yield (1.48 t/ha) was obtained with farmyard manure+vermicompost (50:50) application. During 2011-12, plant height, 100 seed weight and seed weight per umbel was significantly higher under low saline water irrigation and seed yield was non-significantly higher under high saline water irrigation. Different organic input application results in non-significant difference in seed yield and seed yield was ranged from 1.97 to 2.21 t/ha (Table 3.19).

Table 3.19. Seed yield of Sesame and Fennel under different treatments

Treatments	Sesame yield (t/ha)		Fennel yield (t/ha)	
	2010	2011	2010-11	2011-12
Salinity of irrigation water (dS/m)				
EC_{iw} <4	0.15	0.123	1.36	2.02
EC_{iw} >7	0.18	0.064	1.45	2.13
CD (5%)	NS	0.062	NS	NS
Organic inputs				
T_1	0.11	0.052	1.28	1.78
T_2	0.14	0.058	1.32	2.16
T_3	0.18	0.090	1.48	2.10
T_4	0.16	0.081	1.31	2.17
T_5	0.17	0.120	1.40	2.01
T_6	0.18	0.147	1.53	1.97
T_7	0.17	0.097	1.48	2.17
T_8	0.17	0.101	1.41	2.21
CD (5%)	NS	0.048	NS	NS

T_1:100% Inorganic fertilizer T_2: Inorganic + organic inputs (50:50), T_3: FYM+ Vermicompost (50:50), T_4: FYM+ Non-edible Neemcake manure (50:50), T_5: FYM+ Vermicompost+Non-edible Neemcake manure (1/3rd each), T_6: FYM+Vermicompost (100: 100), T_7: FYM+Non-edible Neemcake manure (100:100), T_8: FYM+Vermicompost+Non-edible Neemcake manure (1/3rd each).

Use of Alkali Waters in Agriculture

Management of high RSC water and its effect on rice (Bapatla)

This experiment was carried out in Peramgudipalli village of Kanigiri mandal in Prakasam district during *kharif* 2010. Soil was black clay loam slightly saline in nature. The properties of soil and water at the experimental site are given in Tables 3.20, 3.21. The results indicated that significant yield increase (5.22 t/ha) was observed in gypsum applied plot based on neutralization of RSC water as compared to control (3.87 t/ha) and the yield components except test weight significantly contributed for higher yields. The other treatments followed the trend, >top dressing of gypsum thrice 3.75 t/ha at 20, 30 and 40 DATP (4.42 t/ha) passing RSC water through gypsum (4.36 t/ha) >two foliar sprays with $FeSO_4$ (4.0 t/ha) at active tillering stage.

During *kharif* 2011, RSC of ground water irrigation was 8.0 and gypsum applied as per neutralization of RSC and soil test values for EC and pH was 2.3 dS/m and 7.4. The soil properties were slightly modified by the treatments given to the crop during the end of the season. The RSC of the water increased during the season from 7.2 to 8.0 meq/l and that might be due to low precipitation (+35% and -36% rainfall received against normal rainfall of 795.5 mm during 2010 and 2011, respectively) during the crop season. The micronutrient status reduced in all the treatments except in T_1 due to foliar application of ferrous sulphate 2% twice at active tillering stage with 5 days interval. The fertility status of the soil after harvest of rice crop reduced, however, the available phosphorus improved. Yield components *i.e.* effective tillers/sqm, filled grains/panicle and test weight were significantly higher with the plot that received gypsum based on neutralization of RSC waters than other treatments during both the years of investigation, but in 2010 and 2011 the parameters *viz*. filled grains/panicle and test weight, respectively, were not comparable with other treatments (Table 3.22).

The results of the experiment conducted during *kharif*, 2011 showed that application of gypsum based on neutralization of RSC water gave higher grain yields (5.42 t/ha) and harvest index (43%) than the rest of the treatments. Grain yield increased by 43.3% over the farmer practice. Similarly, the straw yield was significantly higher with application of gypsum based on neutralization of high RSC (>2.4 meq/l) than other treatments in both the years of investigation (Table 3.23).

Table 3.20. Soil properties of the experimental site at Perungudipalli of Prakasam district

Soil	T_1		T_2		T_3		T_4		T_5	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
EC (dS/m)	4.56	1.81	3.43	1.48	3.20	1.20	4.34	1.50	3.1	2.32
pH	7.85	7.82	7.67	7.45	7.66	7.35	7.80	7.40	7.84	7.4
N (kg/ha)	138	136	138	124	138	145	125	135	152	192
P (kg/ha)	14	22	12	17	18	39	22	28	24.1	39.8
K (kg/ha)	455	405	398	353	305	285	436	358	356	382
Zn (ppm)	2.2	2.1	2.0	1.5	2.2	1.6	2.4	2.1	1.5	0.9
Fe (ppm)	15.8	18.1	18.9	13.6	18.2	14.3	21.7	18.8	16.3	15.6
Mn (ppm)	9.5	8.1	11.5	6.3	10.2	7.1	9.5	9.1	7.2	5.7
Cu (ppm)	4.9	4.4	7.6	5.7	6.6	6.4	8.2	6.9	2.4	2.3

T_1: Two foliar sprays with 2% $FeSO_4$ solution at active tillering stage at 5 days interval; T_2: Passing RSC water through gypsum; T_3: Top dressing of gypsum thrice 3.75 t/ha at 20, 30 and 40 days after top dressing; T_4: Gypsum application to soil based on neutralization of RSC water and T_5: Farmers practice.

Table 3.21. Irrigation water properties at experimental site

2010			2011		
EC_{iw}	pH	RSC (meq/l)	EC_{iw}	pH	RSC (meq/l)
2.61	7.74	7.20	2.32	7.40	8.00

Table 3.22. Yield attributes of rice as influenced by management treatments for high RSC water

Treatment	Effective tillers/sqm		Filled grains/panicle		Test weight (g)	
	2010	2011	2010	2011	2010	2011
T_1	332	264	126	134	15.3	16.9
T_2	259	240	118	140	14.8	17.2
T_3	296	366	136	149	14.8	17.4
T_4	405	449	147	150	15.3	17.5
T_5	286	251	124	130	15.0	16.8
CD (5%)	56	71	NS	8	NS	0.3
CV (%)	14.8	16.8	11.5	4.2	3.5	1.1

Table 3.23. Yield of rice as influenced by management treatments for high RSC water

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		HI (%)	
	2010	2011	2.01	2011	2010	2011
T_1	4.00	3.84	6.35	5.97	38.6	39.0
T_2	4.36	4.12	6.05	5.79	41.9	42.0
T_3	4.42	4.85	6.40	6.50	40.9	43.0
T_4	5.22	5.42	7.01	7.09	42.7	43.0
T_5	3.87	3.78	6.35	5.43	37.8	41
CD (5%)	0.41	0.47	0.50	0.63	-	-
CV (%)	6.7	8.0	6.1	7.6	-	-

Management of high RSC water in heavy textured soils (Bapatla)

During 2010-11, pot culture experiment was conducted to find out the best amendment to mitigate the effect of High RSC water on cluster bean. Pyrites and gypsum were applied twenty five days before sowing. Gypsum was found to be the best in increasing the pod yield. Phospho gypsum applied with RSC 5 meq/l water recorded highest pod yield (371.2 g/pot) while lowest yield was recorded in control. Significant differences in pod yield were observed under pyrite (S_3) treatments at varying RSC levels. Yield decreased with increasing levels of sodium in water irrespective of amendments. Similar trend followed in case of drymatter yield (Table 3.24, 3.25).

Table 3.24. Effect of RSC water on pod yield of cluster bean (g/pot)

RSC (meq/l)	Yield of cluster bean (g/pot)						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
5	231.0	371.2	323.0	287.1	271.8	255.8	290.0
10	206.0	359.4	303.6	280.3	268.4	243.6	276.9
15	142.8	338.4	297.2	275.1	261.0	239.3	259.0
Mean	193.3	356.3	307.9	280.8	267.1	246.2	
CD (5%)	Main: 5.23; Sub: 7.40; Interaction: 4.07						

S_1: Control; S_2: Gypsum; S_3: Pyrites; S_4: FYM; S_5: pressmud cake; S_6: aluminium Sulphate

Table 3.25. Effect of RSC water on cluster bean dry matter yield (g)

RSC (meq/l)	Dry matter (g) of cluster bean						
	S_1	S_2	S_3	S_4	S_5	S_6	Mean
5	20.21	33.55	29.15	27.12	25.16	23.32	26.42
10	18.31	30.32	28.64	26.47	24.76	22.90	25.23
15	16.52	29.62	28.09	25.75	24.30	22.24	24.42
Mean	18.35	31.16	28.63	26.45	24.74	22.82	
CD (5%)	Main: 0.23; Sub: 0.33; Interaction: 0.63						

S_1: Control; S_2: Gypsum; S_3: Pyrites; S_4: FYM; S_5: pressmud cake; S_6: aluminium Sulphate

Effect of high RSC water along with FYM and gypsum in vegetables (Hisar)

During 2010-11, study on use of sodic water in okra-onion and cabbage in relation to gypsum and FYM was carried out at CCS HAU, Hisar. In okra-onion, the treatments comprised of three levels of gypsum (0, 50 and 100% neutralization of RSC denoted as G_0, G_1 and G_2 respectively) and five levels in cabbage (0, 25, 50, 75 and 100% denoted as G_0, G_1, G_2, G_3, and G_4 respectively). In both experiments, three levels of FYM (0, 10 and 20 t/ha represented as F_0, F_1 and F_2, respectively). The crops were irrigated with sodic water having RSC 11.5 meq/l and SAR 14 $(mmol/l)^{1/2}$. The requisite amount of gypsum in various treatments was applied as single dose before crop sowing and mixed well in the soil. The ionic composition of irrigation water is given in Table 3.26.

Table 3.26. Ionic composition and quality parameters of irrigation water

Ion/parameter	Values
CO_3^{--} (meq/l)	0.7
HCO_3^- (meq/l)	13.3
Ca^{++} (meq/l)	1.0
Mg^{++} (meq/l)	1.5
Na^+ (meq/l)	15.8
Cl^- (meq/l)	4.0
SO_4^{--} (meq/l)	6.0
EC (dS/m)	2.4
RSC_{iw} (meq/l)	11.5
SAR_{iw} $(mmol/l)^{1/2}$	14.0

During 2010-11 the highest yield of 15.17 t/ha of okra was obtained in F_2G_2 treatment and the lowest (0.59 t/ha) was recorded in F_0G_0 treatment (Table 3.27). With the application of FYM, the mean yield varied from 7.82 to 10.49 t/ha and with gypsum, it varied from 1.85 to 13.39 t/ha. In onion, the highest yield of 45.70 t/ha was obtained in F_2G_2 treatment and the lowest (3.74 t/ha) was recorded in F_0G_0 treatment (Table 3.28). With respect to FYM, the mean yield varied from 21.73 to 29.44 t/ha and with respect to gypsum, it varied from 6.06 to 40.41 t/ha.

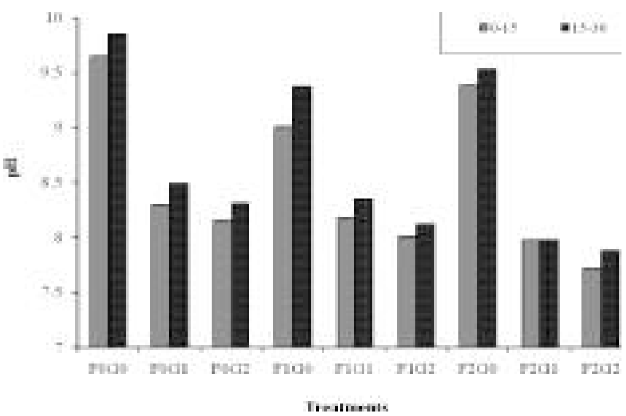
The pH of the soil decreased with the application of gypsum and FYM (Fig. 3.13). In 0-15 cm layer, the highest pH 9.65 was observed in G_0F_0 treatment and the lowest was 7.72 in G_2F_2 treatment. The value of pH decreased with the increasing level of gypsum in all the layers of the soil. The rate of decrease in pH was very in high with gypsum as compared to FYM application alone.

Table 3.27. Effect of FYM and gypsum on yield of okra under sodic water irrigation

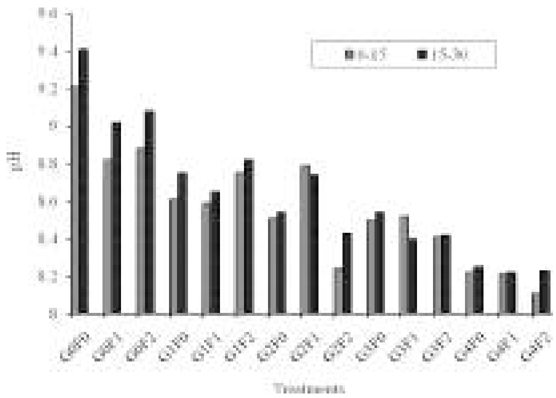
Treatments	Yield of okra (t/ha)			
	G_0	G_1	G_2	Mean
FYM (t/ha)				
F_0 : 0	0.59	11.10	11.76	7.82
F_1 : 10	2.29	12.87	13.23	9.46
F_2 : 20	2.67	13.64	15.17	10.49
Mean	1.85	12.54	13.39	
CD (5%)	Gypsum : 0.57; FYM : 0.57; G x FYM : NS			

Table 3.28. Effect of FYM and gypsum on yield of onion under sodic water irrigation

Treatment	Yield of onion (t/ha)			
	G_0	G_1	G_2	Mean
FYM (t/ha)				
F_0 : 0	3.74	29.78	31.67	21.73
F_1 : 10	8.44	38.89	43.85	30.39
F_2 : 20	6.00	36.61	45.70	29.44
Mean	6.06	35.09	40.41	
CD (5%)	Gypsum : 2.86; FYM : 2.86; G x FYM : 4.96			



Okra



Cabbage

Fig. 3.13. Effect of gypsum/FYM treatments on soil pH after crop irrigated with sodic water

Cabbage: The curd weight of cabbage increased significantly with the application of gypsum (Table 3.29). The mean yield increased from 4.42 t/ha under control to 13.03 t/ha under 100% GR. Maximum yield (15.93 t/ha) of cabbage was obtained in F_2G_4 treatment. The pH of the soil decreased with the addition of gypsum and FYM. In 0-15 cm layer, the highest pH of 9.2 was observed in G_0F_0 treatment and the lowest was 8.1 in G_4F_2 treatment.

Table 3.29. Effect of FYM and gypsum on cabbage yield under sodic water irrigation

Treatments	Yield of cabbage (t/ha)					
	G_0	G_1	G_2	G_3	G_4	Mean
FYM (t/ha)						
F_0 : 0	4.05	5.08	7.16	7.26	8.74	6.46
F_1 : 10	4.35	7.35	9.61	13.24	14.41	9.79
F_2 : 20	4.84	10.67	12.48	14.89	15.93	11.76
Mean	4.42	7.70	9.75	11.80	13.03	
CD (5%)	Gypsum : 1.06; FYM : 0.82; G x FYM : 1.84					

Optimization of zinc requirement of wheat irrigated with sodic water (Hisar)

The study on Zn requirement of wheat irrigated with sodic water in relation to levels of gypsum was conducted at village Adalpur (2010-11) and Bhuraj (2011-12) in Mahendragarh district. The treatments consist of five levels of gypsum (0, 25, 50, 75 and 100 per cent neutralization of RSC) in the main plot and three levels of Zn (0, 25, 50 and 75 kg/ha) in the sub-plots. The initial pH of the soil was 9.8, 9.8, 9.6 and 9.1, at Adalpur and 9.07, 9.20, 9.38 and 9.59 at Bhurjat in 0-15, 15-30, 30-45 and 45-60 cm soil depth respectively. The gypsum requirement of the soil was determined on the basis of exchangeable Na. The crops were irrigated with sodic water having RSC 8.5 meq/l and SAR 17.5 $(mmol/l)^{1/2}$ at Adalpur and RSC 9.6 meq/l and SAR 12.5 $(mmol/l)^{1/2}$ at Bhurjat. The ionic composition of irrigation water at Adalpur and Bhurjat are given in Table 3.30.

The results of year 2010-11 showed that significantly higher yield of wheat (PBW-502) was observed with increasing levels of gypsum as compared to control. The minimum yield (0.78 t/ha) was obtained under control whereas; the maximum yield (4.44 t/ha) was obtained with the application of 75 kg/ha Zn and 100% neutralization of RSC. The mean yield increased by 96.6, 118.5, 165.12 and 225.8 per cent respectively under G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control (Table 3.31). Application of 25, 50 and 75 kg/ha zinc resulted in 26.2, 45.4 and 60.4 per cent increase in yield respectively as compared to control**.** The soil pH at harvesting varied from 8.78 to 9.13 in 0-15 cm layer under different treatments (Table 3.32) whereas pH of soil at harvest reduced from 9.29 to 8.92 with the application of G_{100} treatment.

Table 3.30. Ionic composition and quality parameters of irrigation water

Ion/parameter	Adalpur	Bhurjat
EC (dS/m)	02.3	01.5
CO_3^{--} (meq/l)	00.0	00.0
HCO_3^- (meq/l)	11.0	12.4
Cl^- (meq/l)	09.8	01.8
Ca^{+2} (meq/l)	00.6	00.9
Mg^{+2} (meq/l)	01.9	01.9
Na^+ (meq/l)	19.5	15.8
RSC_{iw} (meq/l)	08.5	09.6
SAR_{iw} $(mmol/l)^{1/2}$	17.5	12.5

Table 3.31. Wheat yield under sodic water irrigation in relation to Zn and gypsum application

Treatments	Wheat yield (t/ha)				
	Control	25	50	75	Mean
Gypsum levels					
G_0	0.78	0.99	1.44	1.61	1.21
G_{25}	1.54	2.19	2.69	3.08	2.37
G_{50}	1.83	2.52	2.98	3.23	2.64
G_{75}	2.63	3.11	3.30	3.75	3.20
G_{100}	3.26	3.86	4.18	4.44	3.93
Mean	2.01	2.53	2.92	3.22	
CD (5%)	Gypsum (G): 0.26; Zinc (Zn): 0.13; GxZn: 0.30				

Table 3.32. Depthwise pH of soil under different levels of gypsum at harvesting of wheat

Soil depth (cm)	pH of soil under gypsum levels					
	G_0	G_{25}	G_{50}	G_{75}	G_{100}	Mean
0-15	9.13	9.03	8.98	8.89	8.78	8.96
15-30	9.15	9.07	9.02	8.97	8.91	9.02
30-45	9.34	9.27	9.15	9.04	8.97	9.15
45-60	9.55	9.38	9.23	9.11	9.01	9.26
Mean	9.29	9.19	9.10	9.00	8.92	

Perusal of the data obtained during 2011-12 showed that significantly higher yield of wheat (var. WH-711) was observed with increasing levels of gypsum as compared to control. The minimum yield (097 t/ha) was obtained under control whereas; the maximum yield (4.42 t/ha) was obtained with 75 kg/ha Zn and 100% neutralization of RSC. The mean yield increased by 43.0, 107.1, 149.7 and 209.1 per cent under G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control (Table 3.33), irrigated with sodic water having RSC 9.6 meq/l. Application of 25, 50 and 75 kg/ha zinc resulted in 9.3, 17.9 and 22.5 per cent increase in yield respectively as compared to control. The variation in yield with respect to gypsum can be expressed by quadratic equation with a coefficient of correlation (R^2) of 0.98 (Fig. 3.14). The soil pH at harvesting varied from 8.44 to 9.14 in 0-15 cm layer in different treatments (Table 3.34) whereas pH of soil at harvest reduced from 9.36 to 8.80 with the application of G_{100} treatment.

Table 3.33. Wheat yield for sodic water irrigation in relation to Zn and gypsum application

Gypsum levels	Wheat yield (t/ha) under Zn levels				
	Control	25	50	75	Mean
G_0	0.97	1.27	1.57	1.62	1.36
G_{25}	1.62	1.83	2.15	2.21	1.95
G_{50}	2.57	2.79	2.88	3.05	2.82
G_{75}	3.18	3.29	3.45	3.69	3.40
G_{100}	3.89	4.19	4.38	4.42	4.22
Mean	2.45	2.67	2.89	3.00	
CD (5%)	Gypsum (G): 036; Zinc (Zn): 0.14; GxZn: 0.31				

Table 3.34. Depthwise pH of soil under different levels of gypsum at harvesting of wheat

Soil depth (cm)	pH of soil under gypsum levels					
	G_0	G_{25}	G_{50}	G_{75}	G_{100}	Mean
0-15	9.14	8.89	8.80	8.5	8.44	8.75
15-30	9.27	9.21	9.11	8.92	8.76	9.05
30-45	9.43	9.28	9.15	9.08	8.96	9.18
45-60	9.61	9.32	9.21	9.13	9.02	9.26
Mean	9.36	9.18	9.07	8.91	8.80	

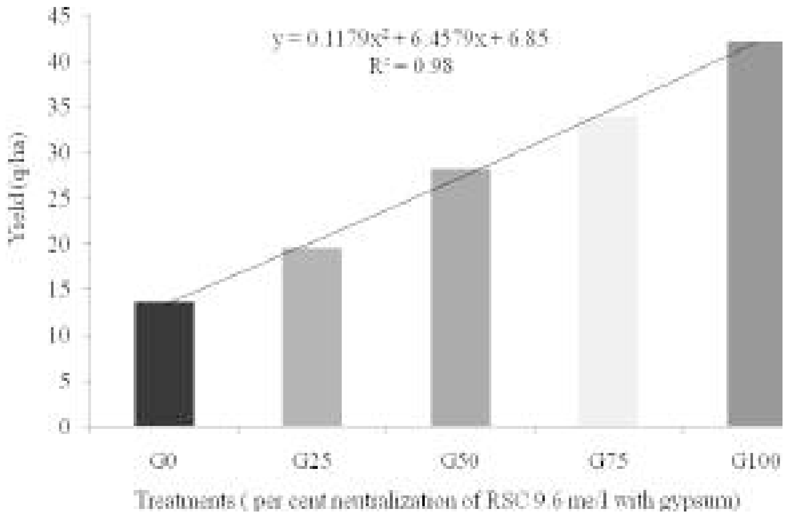


Fig. 3.14. Effect of gypsum application on the yield of the wheat

Drip irrigation to vegetables in alkali soil using amended alkali water (Trichy)

Vegetable crops viz., okra (variety *Parbani kranthi*) and cluster bean (variety *Arka anamika*) were sown in alkali soils of ADAC&RI farm under drip irrigation with initial soil pH 8.61 and EC 0.46 dS/m. The gypsum bed structure (1000 litres) was fabricated with RCC rings and a mild steel rod stand. The inlet of the irrigation water is provided below the stand and the irrigation water was treated during its upward movement though the gypsum bed kept within a gunny bag over the stand. This treated water is being collected in a storage tank from which the water is pumped into drip system through the filter. Similarly, the spent wash was mixed with irrigation water in a ratio of 1:250 through the fertigation unit to treat the alkali water. The drip irrigation is being operated thrice in a week. The recommended quantities of N and K were given through the drip system as per the schedule. The full dose of P as super phosphate was applied as basal.

In the farmer's method, the seeds were sown in ridges and furrow system and fertilizer N and K was applied in three splits. The yield of the vegetable crops was recorded in staggered manner depending upon the maturity of the crop. The soil samples were collected after harvest of the crop and analysed for pH, EC and ESP.

The results of the field experiment showed that soil application of gypsum 50% GR significantly increased the yield of okra and cluster bean (Table 3.35). An increase of 12.7 per cent in okra and 22.1 per cent in cluster bean was recorded due to soil application of gypsum 50% GR. Among the irrigation treatments, drip irrigation of spent wash treated water recorded the highest yield in okra and drip irrigation of gypsum bed treated water recorded highest yield in cluster bean crop. The interaction effect showed that soil application of gypsum 50% GR along with drip irrigation of spent wash treated water recorded the highest okra yield which was at par with soil application of gypsum 50% GR along with drip irrigation of gypsum bed treated water. In case of cluster bean, soil application of gypsum 50% GR along with drip irrigation of gypsum bed treated water recorded the highest yield which was on par with soil application of gypsum 50% GR along with drip irrigation of spent wash treated water. The lowest yield was recorded in the treatment without soil application of gypsum along with furrow irrigation of untreated alkali water in okra and cluster bean.

Table 3.35. Effect of irrigation of ameliorated alkali water on okra and cluster bean

Irrigation treatments	Yield of okra (t/ha)			Yield of cluster bean (t/ha)		
	S_1	S_2	Mean	S_1	S_2	Mean
M_1	9.40	8.60	9.00	6.16	5.21	5.69
M_2	10.30	9.60	9.95	5.86	5.33	5.60
M_3	8.60	7.30	7.95	5.01	4.21	4.61
M_4	7.80	6.50	7.15	4.72	3.25	3.99
Mean	9.03	8.00	8.51	5.44	4.50	4.97
CD (5%)	M: 0.56; S: 0.48; M x S: 1.04; S x M: 0.95			M: 0.26; S: 0.23; M x S: 0.48; S x M: 0.41		

M_1: Drip irrigation with gypsum bed treated water; M_2: Drip irrigation with spent wash treated water; M_3: Drip irrigation with untreated alkali water; M_4: Farmer's practice (furrow irrigation);
S_1: Soil application of gypsum @ 50% GR; S_2: No gypsum

The alkali water treatment (gypsum bed/spent wash) also significantly reduced the pH of the post harvest soil. However, soil application of gypsum 50% GR significantly reduced the pH of the post harvest soil below 8.5 from the initial level of 8.6 in both the crops. Interaction effect of furrow irrigation (farmer's practice) without gypsum recorded the highest soil pH (8.71 in okra and 8.72 in cluster bean) followed by drip irrigation of untreated alkali water without gypsum (Table 3.36).

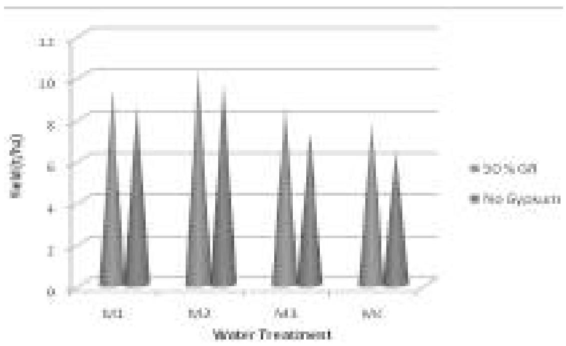
Table 3.36. Effect of irrigation of ameliorated alkali water on pH of soil after crop harvest

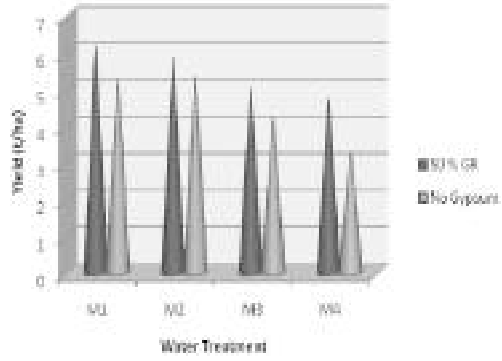
Treatments	pH after okra			pH after cluster bean		
	S_1	S_2	Mean	S_1	S_2	Mean
M_1	8.26	8.53	8.40	8.29	8.60	8.45
M_2	8.25	8.55	8.40	8.30	8.56	8.43
M_3	8.40	8.68	8.54	8.51	8.69	8.60
M_4	8.46	8.71	8.59	8.48	8.73	8.61
Mean	8.34	8.62	8.48	8.40	8.65	8.52
CD (5%)	M: 0.28; S: 0.25; M x S: 0.46; S x M: 0.43			M: 0.31; S: 0.25; M x S: 0.43; S x M: 0.39		

The treatments viz., soil application of gypsum, treatment of alkali water by gypsum/spent wash did not significantly changed the EC of post harvest soil (Table 3.37). Furrow irrigation with untreated alkali water recorded the highest ESP followed by drip irrigation with untreated alkali water. Soil application of gypsum 50% GR significantly reduced the ESP of post harvest soil to 12.9 and 13.1 respectively in okra and cluster bean fields respectively from the initial level of 26.1. The interaction effect showed that furrow irrigation of untreated alkali water with no gypsum recorded the highest ESP while soil application of gypsum with gypsum bed treated drip irrigation recorded the lowest ESP (Table 3.38).

Table 3.37. Effect of irrigation of ameliorated alkali water on Soil EC after crop harvest

Treatments	Soil EC (dS/m) after okra			Soil EC (dS/m) after cluster bean		
	S_1	S_2	Mean	S_1	S_2	Mean
M_1	0.52	0.48	0.50	0.53	0.47	0.50
M_2	0.51	0.48	0.50	0.51	0.50	0.51
M_3	0.48	0.46	0.47	0.48	0.48	0.48
M_4	0.50	0.50	0.50	0.53	0.49	0.51
Mean	0.50	0.48	0.49	0.51	0.49	0.50
CD (5%)	M: NS; S: NS; M x S: NS; S x M: NS			M: NS; S: NS; M x S: NS; S x M: NS		





Okra Cluster bean

Fig. 3.15. Influence of gypsum and irrigation of ameliorated alkali water on crop yield

Table 3.38. Effect of ameliorated alkali water by drip irrigation on ESP after crop harvest

Treatments	Soil ESP after Okra			Soil ESP after Cluster bean		
	S_1	S_2	Mean	S_1	S_2	Mean
M_1	11.5	19.6	15.6	12.1	21	16.6
M_2	11.2	20.4	15.8	11.4	21.2	16.3
M_3	13.8	24.8	19.3	13.6	23.1	18.4
M_4	14.9	29.6	22.3	15.2	29.5	22.4
Mean	12.9	23.6	18.2	13.1	23.7	18.4
CD (5%)	M: 0.71; S: 0.65; M x S: 1.11; S x M: 1.23			M: 0.65; S: 0.72; M x S: 1.03; S x M: 1.06		

Conjunctive Use of Salty Waters with Canal/Rain Water in Agriculture

Conjunctive use of saline and canal water in cotton-wheat crop rotation (Hisar)

A field experiment was conducted to evaluate the effect of conjunctive use of canal and saline water on growth, yield of cotton-wheat and pearl millet-mustard crop rotations and soil salinity build-up at CCS HAU, Hisar. The electrical conductivity of canal and tube well/saline water was 0.4 and 6.0-8.0 dS/m, respectively. The 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 to determine the salt build up. The physico-chemical properties of the soil profile (150 cm) are given in Table 3.39. The bulk density of the soil profile ranged from 1.42-1.51 Mg/m. The hydraulic conductivity decreased with soil depth and varied from 4.78 x 10^{-7}m/s to 8.54 x 10^{-7}m/s. The CEC ranged from 12.2 to 16.7 Cmol/kg soil in the profile. The organic carbon also followed a decreasing trend with depth being the maximum (0.71 per cent) in 15- 30 cm layer.

Table 3.39. Physico-chemical properties of experimental site at CCS HAU, Hisar farm

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

Cotton: During 2010-11, highest seed cotton yield (2.76 t/ha) was recorded in all canal irrigation followed by 2 canal (C):1 saline (S) cyclic irrigation (Table 3.40). The lowest yield (1.98 t/ha) was obtained under all saline irrigated plot. A reduction of 28 and 23 % were observed in all saline and 2S:1C irrigations, respectively, when compared with canal irrigation. The plant height reduced significantly in saline irrigation as compared to canal (control). The plant height varied from 139.33 to 178.67 from all saline irrigation treatment to all canal irrigation treatment and registered a 22 % reduction in plant height. However, differences among various treatments in respect of bolls weight were non-significant. The maximum boll weight of 3.11 g was recorded in 2C:1S treatment and minimum was in 2.83 gm in all saline irrigation treatment.

Similarly during 2011-12, irrigation with saline water decreased the seed cotton yield significantly. The data revealed that the highest seed cotton yield of 3.42 t/ha was recorded in all canal irrigation treatment followed by 2 canal (C):1 saline (S) cyclic irrigation. The lowest yield (1.94 t/ha) was obtained under all saline irrigated plot. A reduction of 43.3 and 40.6 % were observed in all saline and 2S:1C irrigations, respectively, when compared with canal irrigation. The differences among C and 2C:1S was, however, non-significant. The plant height reduced significantly in saline irrigation as compared to canal (control). The plant height varied from 137.3 to 155.6 from all saline irrigation treatment to all canal irrigation treatment and registered a 11.8 % reduction in plant height. However, differences among various treatments in respect of plant height were non-significant. The maximum boll/plant (27) was recorded in all canal treatment and minimum (21) was in all saline irrigation treatment. The maximum boll weight of 3.13 g was recorded in all canal treatment and minimum was 2.88 g in all saline irrigation treatment.

Table 3.40. Plant growth and yield attributes of cotton as affected by different treatments

Treat ments	Seed cotton yield (t/ha)		Plant height (cm)		Bolls/plant		Boll weight (g)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
C	2.76	3.42	178.67	155.6	25.33	27.00	3.03	3.13
1C: 1S	2.54	2.93	162.67	151.8	23.00	23.33	2.98	3.05
1S: 1C	2.33	2.80	160.67	142.7	22.00	22.66	2.92	2.97
2C:1S	2.67	3.32	178.00	154.9	24.33	26.33	3.11	3.08
2S:1C	2.13	2.03	143.67	139.7	21.00	21.67	2.81	2.98
S: RTC	2.47	3.02	168.33	149.0	22.00	22.67	2.98	3.10
C: RTS	2.41	2.79	162.00	144.7	22.00	21.67	2.93	2.92
S	1.98	1.94	139.33	137.3	20.00	21.00	2.83	2.88
CD (5%)	0.36	0.28	10.30	NS	2.30	2.49	NS	0.18

Wheat: During 2010-11, wheat yield reduced significantly in S (all saline), 2S:1C and 1C:RTS (rest with saline) treatments as compared to canal (C) irrigation (Table 3.41). The highest yield of 5.41 t/ha and the lowest 3.56 t/ha of wheat were obtained in all canal and all saline treatments, respectively. The relative yields obtained were 96.8, 87.2, 82.2, 81.5, 77.1, 68.8 and 65.8 % in 2C:1S, 1C:1S, 1S:1C, 1C:RTS, 1S:RTC (rest with canal), 2S:1C, and S treatments, respectively, as compared to the yield recorded in canal irrigation considered to be 100%. Significant differences were also obtained in case of plant height and earhead/metre row length for C, 1C:1S, 2C:1S, C:RTS treatments from S treatment, whereas earhead length were found to be significant in C, 1C:1S, 2C:1S in comparison to S treatment. The plant height ranged from 69.7 to 79.7 cm under different treatments and earhead length varied from 9.8 to 11.4 cm. Similarly during 2011-12, the wheat grain yield reduced significantly in all treatments except 2C:1S as compared to canal (C) irrigation.

The highest yield of 5.71 t/ha and the lowest 3.91 t/ha of wheat were obtained in all canal and all saline treatments respectively. The relative yields obtained were 97.8, 94.6, 91.4, 83.1, 81.3, 73.0 and 68.4% in 2C:1S, 1C:1S, 1S:1C, 1C:RTS, 1S: RTC, 2S:1C, and S treatments, respectively, as compared to the yield recorded in canal irrigation considered to be 100%. Significant differences were obtained in case of plant height for C, 1C:1S, 1S:1C, 2C:1S, S:RTC, C:RTS treatments from S treatment. In case of number of grains/earhead, significant differences were obtained for C, 1C:1S, 2C:1S, S:RTC, C:RTS treatments from S treatment, whereas, earhead length were found to be non-significant in all treatments. The plant height ranged from 66.0 to 80.0 cm under different treatments, whereas, ear head length varied from 9.7 to 11.3 cm.

Table 3.41. Plant growth and yield parameters of wheat as affected by different treatments

Treatments	Plant height (cm)		Earhead/m row length		Earhead length (cm)		Grain yield (t/ha)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
C	79.66	80.0	79.00	78.1	11.43	11.3	5.41	5.71
1C: 1S	77.00	76.7	73.66	75.2	11.16	11.0	4.72	5.40
1S: 1C	73.33	74.7	72.66	74.4	10.16	10.3	4.44	5.22
2C:1S	78.33	80.0	80.33	79.9	11.66	11.3	5.33	5.58
2S:1C	70.33	69.7	69.33	72.1	10.06	10.7	3.72	4.16
S: RTC	76.33	77.7	79.66	74.2	10.33	11.0	4.17	4.64
C: RTS	75.33	77.0	75.00	71.0	10.00	10.0	4.41	4.74
S	69.66	66.0	69.00	69.9	9.83	9.7	3.56	3.91
CD (5%)	4.49	6.67	3.92	3.67	1.18	NS	0.43	0.21

Water use and water productivity: During 2010-11, the irrigation water productivity (IWP) in cotton was highest (2.30 kg/m^3) under canal and lowest (1.65 kg/m^3) under saline water irrigation, respectively (Table 3.42). Similarly, total water productivity was highest (0.45 kg/m^3) under canal and lowest (0.33 kg/m^3) under saline water. Irrigation water productivity (IWP) in wheat was highest (1.80 kg/ m^3) under canal and lowest (1.19 kg/ m^3) under saline water irrigation, respectively. Similarly the total water productivity was highest (1.14 kg/m^3) under canal and lowest (0.77 kg/m^3) under saline water irrigation.

During 2011-12, irrigation water productivity (IWP) in cotton was highest (1.90 kg/m^3) under canal and lowest (1.08 kg/m^3) under saline water irrigation, respectively (Table 3.43). Similarly the total water productivity was the highest (0.66 kg/m^3) under canal and the lowest (0.39 kg/m^3) under saline water irrigation. In wheat, the irrigation water productivity (IWP) was observed to be highest (1.90 kg/ m^3) under canal and lowest (1.30 kg/ m^3) under saline water irrigation, respectively. Similarly, the total water productivity was highest (1.42 kg/m^3) under canal and lowest (1.00 kg/m^3) under saline water irrigation.

Salinity build up during wheat crop: During 2011-12, the salinity (EC_e) profiles at sowing and at harvest of wheat indicating the salt buildup with various modes of irrigations are presented in Fig. 3.16a & b). The average EC_e of the soil profile down to 120 cm before the sowing of wheat varied from 2.30 to 5.58 dS/m in various treatments. The mean values of EC_e at the harvest ranged from 2.43 to 7.74 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 profile distribution of ECe from surface to 120 cm depth showed decreasing trend in all the treatments being maximum in the surface layer before sowing as well as after harvesting. EC_e at the harvest of wheat during 2011-12 ranged from 2.17 (0-15cm, all canal irrigation treatment) to 9.25 dS/m (0-15cm, all saline irrigation treatment). Among the cyclic mode treatments, 2S: 1C had the highest average salinity (6.09 dS/m) followed by C:RTS (6.08 dS/m) at the time of wheat harvest. It is ascribed to the more saline irrigations in this treatment than other cyclic treatments. Major accumulation of salts at wheat harvest was observed in 0-30 cm layers.

Table 3.42. Effect of salinity on yield and water productivity of cotton and wheat (2010-11)

Treatments	Seed cotton yield (t/ha)	Relative yield (%)	Water productivity (kg/m^3)		Seed yield (t/ha)	Relative yield (%)	Water productivity (kg/m^3)	
			IW	TW			IW	TW
C	2.76	100.0	2.30	0.45	5.407	100.0	1.80	1.14
1C: 1S	2.54	92.16	2.12	0.42	4.718	87.3	1.57	1.00
1S: 1C	2.33	84.65	1.94	0.39	4.444	82.2	1.48	0.95
2C:1S	2.67	96.77	2.22	0.44	5.327	96.8	1.78	1.12
2S:1C	2.13	77.14	1.77	0.35	3.718	68.8	1.24	0.80
S: RTC	2.47	89.48	2.06	0.41	4.170	77.1	1.39	0.89
C: RTS	2.41	87.34	2.01	0.40	4.407	81.5	1.47	0.94
S	1.98	71.77	1.65	0.33	3.556	65.8	1.19	0.77
CD(5%)					0.434			

Table 3.43. Effect of salinity on yield and water productivity of cotton and wheat (2011-12)

Treatments	Seed cotton yield (t/ha)	Relative yield (%)	Water productivity (kg/m^3)		Wheat yield (t/ha)	Relative yield (%)	Water productivity (kg/m^3)	
			IW	TW			IW	TW
C	3.42	100	1.90	0.66	5.71	100.0	1.90	1.42
1C: 1S	2.93	85.7	1.63	0.57	5.40	94.6	1.80	1.36
1S: 1C	2.80	81.9	1.56	0.55	5.22	91.4	1.74	1.32
2C:1S	3.32	97.1	1.84	0.64	5.58	97.8	1.86	1.40
2S:1C	2.03	59.4	1.13	0.40	4.16	73.0	1.39	1.06
S: RTC	3.02	88.3	1.68	0.59	4.64	81.3	1.55	1.18
C: RTS	2.79	81.6	1.55	0.55	4.74	83.1	1.58	1.21
S	1.94	56.7	1.08	0.39	3.91	68.4	1.30	1.00
CD(5%)					0.21			

Modeling and Stalinization of Soil Profile: A well established model based on miscible displacement and evaporation (Kapoor and Pal, 1986), was used to predict distribution of salts in different layers of root zone after the harvest of different crops considering irrigation with canal\saline water or rain. This model included upward capillary movement of soil solution, characterizing each soil layer by its field capacity and actual moisture content of the profile at the time of irrigation.

Further, a comparison between the observed and simulated EC_e values of the soil profile (Fig. 3.17) after the harvest of wheat crop revealed a good agreement. It can also be seen from figure that when observed values of ECe were plotted against values of ECe simulated from the model for all soil layers, the points were randomly scattered about a line that was not very different from the line of perfect agreement. A linear statistical analysis of the results (y = 1.4887 x – 2.337) and values of R^2 = 0.85 suggested that predictions of the model were highly correlated with the observed ones.

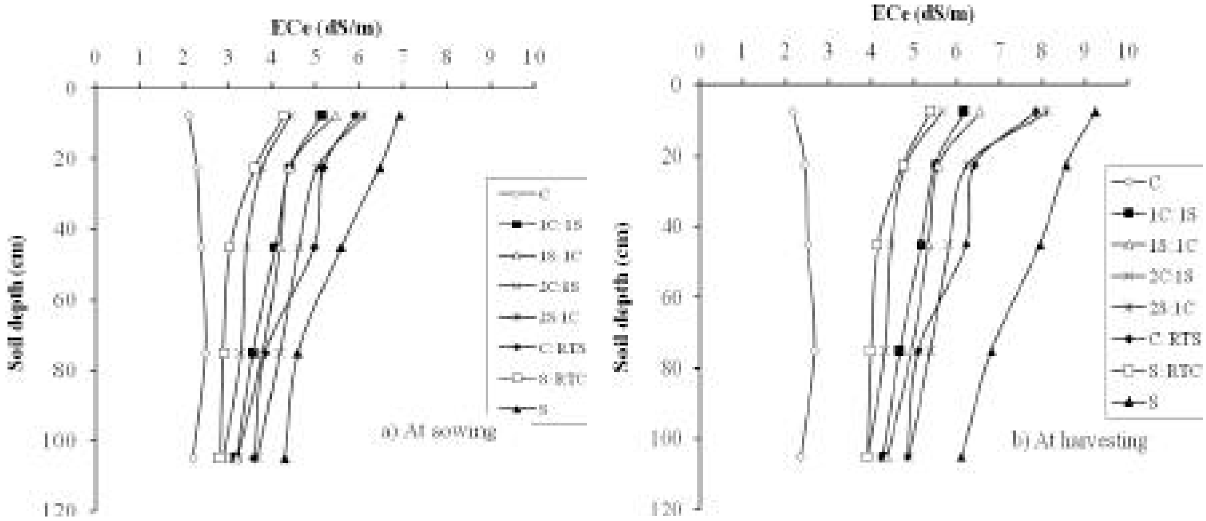


Fig. 3.16. EC_e distribution at (a) sowing and (b) harvest of wheat during 2011-12 in various treatments

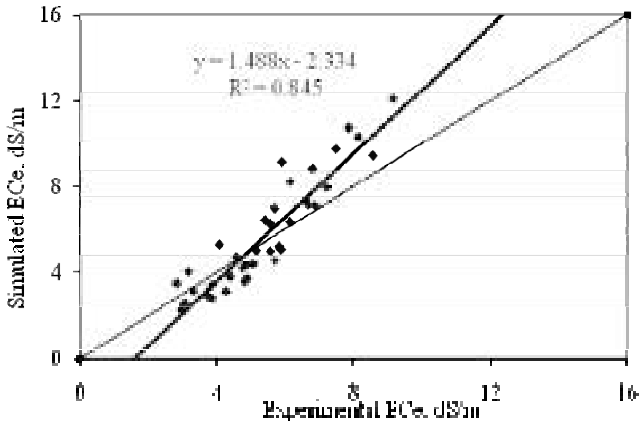


Fig. 3.17. Observed vs. simulated EC_e after harvest of wheat during 2010-11 in different treatments

Conjunctive use of saline and canal water in pearl millet-mustard crop rotation (Hisar)

During 2010-2011 in pearl millet-mustard crop rotation, application of saline water reduced the plant height, earhead per metre row length, earhead length and grain yield of pearl millet crop significantly as compared to irrigation with canal water. The grain yield of pearl millet ranged from 1.93-2.90 t/ha in different treatments. Grain yields of pearl millet reduced significantly in all saline, two saline: one canal (2S: 1C), 1S: 1C and C: RTS treatments over canal irrigation. The relative yields obtained under 2S:1C and all saline water were 83.02 and 79.97% respectively as compared to canal irrigation. Minimum plant height (139.33cm) of pearl millet crop was obtained under saline irrigation treatment which was significantly lower than other treatments except 2S:1C treatment. Maximum plant height (176.67cm) was recorded under all canal irrigation treatment. The number of earheads per mrl ranged from 21.33–27.00. The maximum earhead length (25.56cm) was recorded under all canal irrigation treatment (Table 3.44).

Distribution of EC_e in the soil profile (0-120 cm) as affected by various irrigation treatments before sowing and after harvest of pearl millet crop is presented in Table 3.45 and Fig. 3.18. The mean EC_e values ranged from 3.89 - 6.35 dS/m at the time of sowing of the crop. However, the mean post crop electrical conductivity (EC_e) values increased slightly in all the treatments and ranged from 4.06 - 6.63 dS/m at the harvest of crop. The highest EC_e (8.73 dS/m) was observed in case all saline water irrigation in the layer 0-15 cm. The electrical conductivity of soil saturation extract was higher in saline water irrigated plots then cyclic mode of irrigation. In cyclic mode treatments, 2S:1C had higher EC_e throughout the profile before sowing as well as after harvesting of the crop than other treatments. The salt deposition was maximum in the surface layer in all the treatments at the harvest which decreased with depth continuously.

Table 3.44. Growth parameters and yield of pearl millet as affected by different treatments

Treatments	Plant height (cm)	Earhead/m row length	Earhead length (cm)	Grain yield (t/ha)
C	176.67	27	25.56	2.90
1C: 1S	168.00	25	24.0	2.62
1S: 1C	153.00	24	23.0	2.42
2C:1S	173.33	24.33	24.77	2.76
2S:1C	146.00	22.33	21.22	2.13
S: RTC	168.33	24	23.00	2.37
C: RTS	163.00	24.33	23.67	2.24
S	139.33	21.33	20.44	1.93
CD (5%)	12.8	2.66	1.77	0.37

Table 3.45. Depthwise distribution of EC_e at sowing and harvesting of pearl-millet

Treatments	Soil depth (cm)					
	0-15	15-30	30-60	60-90	90-120	Mean
			EC_e (dS/m) before sowing			
C	3.7	4.28	4.14	3.76	3.59	3.89
1C: 1S	4.65	4.20	3.82	3.38	3.21	3.85
1S: 1C	6.41	5.55	4.23	3.85	3.30	4.67
2C:1S	4.05	3.95	3.8	3.18	3.02	3.60
2S:1C	6.93	7.02	5.96	5.12	4.15	5.84
S: RTC	4.56	3.88	3.53	3.23	2.95	3.63
C: RTS	5.03	4.55	4.09	3.96	3.32	4.19
S	8.44	7.35	6.31	5.28	4.38	6.35
Mean	5.47	5.10	4.49	3.97	3.49	
			EC_e (dS/m) after harvesting			
C	3.89	4.41	4.21	3.96	3.82	4.06
1C: 1S	4.83	4.32	3.98	3.66	3.69	4.10
1S: 1C	6.69	5.85	4.55	4.13	3.58	4.96
2C:1S	4.14	4.05	3.91	3.25	3.16	3.70

2S:1C	7.19	7.26	6.22	5.38	4.51	6.11
S: RTC	4.83	4.15	3.80	3.5	3.22	3.90
C: RTS	5.12	4.63	4.19	4.07	3.43	4.29
S	8.73	7.62	6.56	5.57	4.65	6.63
Mean	5.68	5.29	4.68	4.19	3.76	

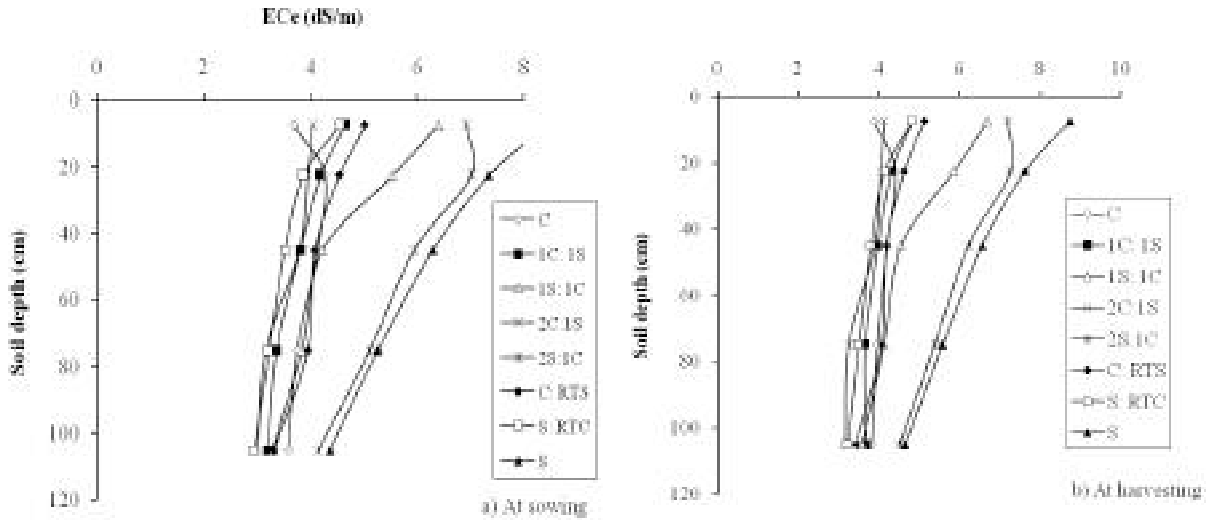


Fig. 3.18. Depthwise distribution of EC_e at (a) sowing and (b) harvesting of pearl millet crop

Conjunctive use of canal and alkali water in rice based cropping system (Trichy)

Field experiments were conducted in an alkali soil (pH 8.7, EC 0.21 dS/m, ESP 25) in rice-vegetable system for two years (2010-12). Rice (var. TRY-1) was grown as a test crop during both years under the rice crop season and vegetables were used as a test crop during May, June. Besides initial soil analysis for basic properties, post harvest stage soil samples were analysed for soil reaction, salt concentration and ESP after every crop (Table 3.46). Treatments comprised of three irrigation levels and four planting methods for rice and after rice four vegetables were grown in sub plots.

Rice grain and straw yield: Significant yield differences were observed for irrigation treatments and methods of planting in both the years of the study (Table 3.47). Canal water irrigation gave highest mean grain yields (6.47 and 5.91 t/ha respectively during 2010-11 and 2011-12). Lowest grain and straw yields were recorded for alkali water irrigation (4.51 and 4.12 t/ha grain and 5.52 and 5.05 t/ha straw yield respectively during 2010-11 and 2011-12). Among methods of planting, square planting registered highest grain yield (6.16 and 5.48 t/ha during 2010-11 and 2011-12) followed by line planting and machine planting. Conventional planting had poor yield in terms of grain and straw as compared to the other methods of planting. The interaction effect of irrigation treatment and methods of planting was found to be significant. Canal water irrigation combined with square planting had high grain yield followed by canal water and line planting combination. Conjunctive use of canal water and sodic water (1:1 in cyclic mode) with square planting recorded around 35 and 31 per cent enhanced yield during 2010-11 and 2011-12.

Table 3.46. Effect of irrigation and methods of planting on soil pH, EC and ESP at harvest

Irrigation treatment	Methods of planting										Vegetable crops				
	2010-11					2011-12					2010-11				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
							Soil pH (-)								
M_1	9.1	9.2	9.2	9.2	9.2	9.1	9.0	9.1	9.1	9.1	9.1	9.2	9.2	9.2	9.2
M_2	8.7	8.7	8.7	6.7	8.2	8.5	8.5	8.4	8.5	8.5	8.7	8.7	8.7	6.7	8.2
M_3	8.9	9.0	9.0	9.0	9.0	8.7	8.7	8.7	8.6	8.7	8.9	9.0	9.0	9.0	9.0
Mean	8.9	9.0	8.9	8.3		8.8	8.8	8.8	8.7		8.9	9.0	8.9	8.3	8.8
CD (5%)	M	S	MxS	SxM		M	S	MxS		SxM	M	S	MxS	SxM	
	0.4	NS	NS	NS		0.31	NS	NS		NS	0.4	NS	NS	NS	
							Soil EC (dS/m)								
M_1	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2
M_2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
M_3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Mean	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2
CD (5%)	M	S	MxS	SxM		M	S	MxS		SxM	M	S	MxS	SxM	
	0.08	NS	NS	NS		0.03	NS	NS		NS	0.08	NS	NS	NS	
							Soil ESP								
M_1	32.8	31.6	31.9	34.4	32.7	32.8	33.0	33.6	34.6	33.5	32.8	33.0	33.6	34.6	33.5
M_2	18.0	19.1	18.5	19.2	18.7	20.1	19.6	21.2	21.6	20.6	20.1	19.6	21.2	21.6	20.6
M_3	25.1	26.0	29.0	25.8	26.5	26.0	26.8	27.2	27.5	26.9	26.0	26.8	27.2	27.5	26.9
Mean	25.3	25.6	26.5	26.5		26.3	26.5	27.3	27.9	27.0	26.3	26.5	27.3	27.9	27.0
CD (5%)	M	S	MxS	SxM		M	S	MxS		SxM	M	S	MxS	SxM	
	1.9	NS	NS	NS		1.2	NS	NS		NS	1.2	NS	NS	NS	

Table 3.47. Effect of irrigation and planting methods on yield of rice

Irrigation treatments	Methods of planting									
	Grain yield (t/ha)					Straw yield (t/ha)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
					2010-11					
M_1	4.21	4.43	4.96	4.42	4.51	5.13	5.42	5.95	5.57	5.52
M_2	5.82	6.53	7.10	6.44	6.47	7.36	7.97	8.73	7.93	7.99
M_3	5.25	5.94	6.40	5.59	5.80	6.50	6.99	7.71	6.82	7.00
Mean	5.10	5.63	6.16	5.48		6.33	6.79	7.46	6.77	6.84
CD (5%)	M	S	MxS	SxM		M	S	MxS	SxM	
	0.33	0.22	0.46	0.38		0.28	0.23	0.45	0.40	
					2011-12					
M_1	3.89	4.01	4.38	4.21	4.12	4.66	5.04	5.44	5.05	5.05
M_2	5.27	5.86	6.46	6.03	5.91	6.36	7.2	7.75	7.35	7.17
M_3	4.36	5.20	5.61	5.12	5.07	5.18	6.29	6.73	6.26	6.12
Mean	4.51	5.02	5.48	5.12		5.40	6.18	6.64	6.22	
CD (5%)	M	S	MxS	SxM		M	S	MxS	SxM	
	0.29	0.20	0.41	0.34		0.31	0.25	0.49	0.45	

M_1: Irrigating both rice and vegetables with alkali water; M_2: Irrigating rice with canal water and vegetables with alkali water; M_3:Irrigating rice with canal and alkali water in 1:1 ratio (cyclic) and vegetables with alkali water and S_1:Conventional planting (Random); S_2: Line planting; S_3: Square planting (SRI); S_4:Machine planting

Vegetable yield and income: All the vegetables performed well under canal water (M_2) followed by M_3 (1 canal : 1 sodic water) (Table 3.48). Irrigating both rice and vegetables with high RSC water resulted in poor yield. Among the vegetables brinjal had high yield under canal irrigation (22.8 and 20.2 t/ha during 2010-11 and 2011-12) and recorded highest income of Rs. 2.86 and 2.28 lakh in 2010-11 and 2011-12. The returns were low for cluster bean and cowpea in both the years.

Table 3.48. Effect of irrigation and methods of planting on yield and income of vegetables

Treatments	Crop	Yield (t/ha)		Income (Rs/ha)	
		2010-11	2011-12	2010-11	2011-12
M_1S_1	Alkali Water + Okra	5.65	5.16	138750	128000
M_2S_1	Canal Water + Okra	9.25	8.65	117000	100772
M_3S_1	CW & AW + Okra	7.01	6.81	210340	181227
M_1S_2	AW + Brinjal	16.18	12.8	306800	286000
M_2S_2	CW + Brinjal	23.6	20.2	278200	220871
M_3S_2	CW & AW + Brinjal	21.6	15.6	32160	255608
M_1S_3	AW + Cluster bean	4.02	4.26	57120	47640
M_2S_3	CW + Cluster bean	7.14	7.94	49200	38760
M_3S_3	CW & AW + Cluster bean	6.15	6.46	52800	46800
M_1S_4	AW + Vegetable cowpea	3.30	3.12	76000	63150
M_2S_4	CW + Vegetable cowpea	4.75	4.21	69760	58350
M_3S_4	CW & AW + Vegetable cowpea	4.36	3.89		
CD (5%)	Okra	0.41	0.32		
	Brinjal	1.6	1.24		
	Cluster bean	0.26	0.21		
	Vegetable cowpea	0.12	0.15		

Use of Marginal Quality Waters in Agriculture

Effect of Sea water intrusion on ground water quality in coastal Krishna Zone, A.P. (Bapatla)

During 2010-11, a plan was prepared for collection of water samples in Krishna Zone. GPS points near the sea were fixed in following villages of Machilipatnam, Bapatla, Nizampatnam and Kanuparthi for collection of water samples:

S_1: Selected Manginapudi, Chilakalapudi, Machilipatnam, Guduru and Nidumolu
S_2: Selected Suryalanka, Muttaipalem, Bapatla, Jammulapalem, Appapuram and Kakumanu
S_3: Selected Nizampatnam, Pallepalem, Alluru, Alakapuram, Pittalavanipalem, RB Palem, Kavuru
S_4: Selected Kanuparthi, Ammanabrolu, Agraharam and Naguluppalapadu

A total 120 water samples were collected in June and December of 2010 and 2011 along the coastal region of Krishna Zone. Four points were fixed at Machilipatnam, Nizampatnam, Suryalanka and Kanuparthi and from these points samples were collected at 5, 10, 15, 20 kms distance from sea. The analysis of ground water samples revealed that there is no intrusion of sea water during monsoon period. The pH and EC values of ground water samples colleted during June and December, 2010 were 7.0 to 9.1; 7.0 to 8.4 and 0.6 to 12.9; 0.2 to 16.9, respectively. From the study it is indicating that the salt content is moderately high in majority of the samples. Intrusion of sea water in the samples collected during June, 2010 is confirmed based on the ionic ratios of the water samples (Table 3.49).

Table 3.49. Ionic ratios of good quality water 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	0.01
Cl/SO_4	0.45	9.85

During 2011-12, water samples were collected during summer and monsoon seasons to know the salinity status of the study area. A total 240 water samples were analyzed for pH, E.C, Ca^{2+} Mg^{2+} Na^{+}, K^{+}, CO_3^{--}, HCO_3^{-}, Cl^{-} and SO_4^{2-} content to measure the salinity and alkalinity. Ionic ratios of the samples were computed to find the sea water intrusion. Water samples collected during end of Decmeber, 2011 and January 2012 were analysed (Table 3.50, 3.51). During Premonsoon period, the highest EC (9.8 dS/m) was observed in Machilipatnam point, highest pH (8.7) was noticed in Nizampatnam point and highest SAR (9.2) was monitored in Kanaparthi point. During Post monsoon period EC has not showed much variation. pH values showed neutral to slightly alkaline in nature in all the points. High RSC's were observed in Nizampatnam and Kanaparthi as the pH values are high in those points. High SAR value observed (8.21) in Kanaparthi point.

Table 3.50. Sea water intrusion studies

Point		EC (dS/m)	pH	RSC (meq/l)	SAR $(mmole/l)^{1/2}$
Pre Monsoon (June 2010)					
Suryalanka	Range	0.7-10.9	6.9-9.6	-15.5-7.3	2.3-26.5
	Mean	3.2	8.3	-1.1	8.0
Machilipatnam	Range	0.7-16.5	7.3-8.5	-30.4-7.8	0.4–25.1
	Mean	4.1	7.9	-4.2	9.1
Nizampatnam	Range	0.9-6.8	6.5-7.9	-17.8-11.5	1.9-30.5
	Mean	3.3	7.2	0.3	8.7
Kanaparthi	Range	0.7-9.0	7.3-8.4	-31.4-13.6	2.0–30.0
	Mean	3.0	7.8	-3.7	8.4
Post Monsoon (December 2010)					
Suryalanka	Range	0.7–8.0	7.1–8.4	-9.4-6.1	1.3–25.6
	Mean	2.3	7.7	-0.6	5.4
Machilipatnam	Range	0.3–11.6	7.6–8.4	-19.4-5.0	0.1–20.6
	Mean	3.1	8.0	-3.9	6.6
Nizampatnam	Range	0.6–16.3	7.3–8.6	-38.2-9.7	1.0–22.9
	Mean	3.3	7.9	-2.7	7.5
Kanaparthi	Range	0.8-9.0	7.2–8.5	-17.7-7.0	0.6–31.9
	Mean	2.8	7.8	-4.0	7.0

Table 3.51. Sea water intrusion studies

Point		EC (dS/m)	pH	RSC (meq/l)	SAR $(mmole/l)^{1/2}$
		Pre Monsoon (June 2011)			
Suryalanka	Range	1.1-7.9	7.3-8.6	-1.0 to -10.9	3.6-12.4
	Mean	2.8	7.9	-2.0	6.6
Machilipatnam	Range	0.8-9.8	6.8-8.2	-0.8 to -13.5	2.7-17.1
	Mean	3.2	7.5	-2.1	8.6
Nizampatnam	Range	0.7-9.2	7.5-8.7	1.8 to –10.7	2.9-18.0
	Mean	3.1	8.1	-1.7	8.9
Kanaparthi	Range	1.0-9.6	6.9-8.4	1.2 to -22.4	4.5-21.3
	Mean	3.2	7.6	-2.0	9.6
		Post Monsoon (December 2011)			
Suryalanka	Range	0.8-8.7	6.8-7.9	-10.6 to 7.4	1.2-14.3
	Mean	2.5	7.4	0.2	3.8
Machilipatnam	Range	0.7-22.2	6.8-7.5	-63.8 to 4.6	1.1-31.2
	Mean	4.3	7.2	-7.7	7.4
Nizampatnam	Range	0.6-6.1	6.7-7.7	-3.1 to 12.8	1.7-14.5
	Mean	2.2	7.2	2.7	5.9
Kanaparthi	Range	0.9-9.3	6.7-8.1	-62.6 to 10.2	1.7-27.6
	Mean	3.1	7.4	-3.3	8.8

Drain water usage and management strategies of Nallamada drain (Bapatla)

During 2010-11, the drain water samples were collected from June, 2010 to April, 2011. The EC ranged from 0.58 to 1.68 dS/m except K.B. Palem location (3.43 dS/m). The EC slowly decreased from June, 2010 to Sept, 2010 and again increased slowly upto April, 2011. The drain water was within the safer limit of EC <2 dS/m except K.B. Palem during June, July and Sept. 2010. The pH was ranged from 7.23 to 9.29. The lowest and highest pH was noticed in Pedanandipadu location. (Table 3.52). During August 2011, EC_e levels are decreased due to rainfall and again increased during January and February 2012. During March, 2012, KB Palem has showed highest EC (1.52 dS/m) and Kondapaturu showed the highest pH (8.0). Higher values were noticed in March 2012 compared to earlier months (Table 3.53). Information on crops grown and land holdings in Nallamada drain area were collected. During 2011-12 late *Kharif* season maize, cotton, chillies, tobacco, bengal gram were under cultivation and the annual crop yield data were collected from farmers (Table 3.54).

Table 3.52. EC and pH of Nallamada drain and Appapuram canal water (2010-11)

Locations	June 2010		Aug. 2010		Oct. 2010		Dec. 2010		Feb. 2011		April 2011	
	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH
K.B. palem	3.4*	7.3	1.2	7.9	1.1	7.6	1.1	8.0	0.9	8.1	0.8	8.0
Appikatla	1.2	8.0	1.0	7.7	1.1	7.8	1.1	8.1	0.9	8.1	0.8	7.9
Returu	1.1	8.5	0.9	7.7	1.0	7.7	0.9	7.7	0.9	8.4	0.8	8.0
Kondapaturu	1.6	9.1	1.4	7.8	1.1	8.0	1.1	8.1	0.9	7.9	0.7	7.7
Pedanapadu	1.7	9.3	1.4	8.0	1.1	7.9	1.1	8.1	1.0	8.1	0.8	7.8
A'puram canal	0.6	8.0	0.6	7.6	0.8	7.6	0.6	8.1	0.7	8.2	0.7	8.4

**Backwater flow influence*

Table 3.53. EC and pH of Nallamada drain and Appapuram canal water (2011-12)

Locations	July 2011		Sep. 2011		Nov. 2011		Jan. 2012		Mar. 2012	
	EC	pH	EC	pH	EC	pH	EC	pH	EC	8.0
K.B. palem	13.4	8.0	0.9	8.0	0.5	8.1	0.6	7.7	1.5	7.9
Appikatla	6.7	8.0	1.1	7.9	0.8	8.0	0.7	7.8	1.5	7.9
Returu	2.0	7.9	0.8	7.8	0.9	8.0	1.0	7.8	1.4	8.0
Kondapaturu	1.7	8.1	0.7	7.9	0.9	8.1	0.9	7.9	1.3	7.8
Pedanapadu	1.7	8.2	0.8	8.1	0.8	7.9	0.8	7.9	1.3	7.7
A'puram canal	0.8	8.2	0.6	8.1	0.8	8.2	0.9	7.9	0.7	7.3
Nallamada Drain	1.2	8.0	0.6	8.0	0.9	8.1	1.0	8.0	1.1	8.0

Table 3.54. Crops and yields (t/ha) at Pedanandipadu (Nallamada drain command area)

Crops	2010-11	2011-12	Crops	2010-11	2011-12
Paddy	5.75	5.37	Tobacco	4.00	1.98
Green Gram	1.25	1.11	Fodder Jowar	-	5.93
Maize	10.00	9.88	White jowar	-	5.56
Blackgram	1.15	0.74	Cluster Bean	-	0.99
Chickpea	2.50	1.73	Cotton	2.25	2.47
Soyabean	-	0.99	Chillies	7.50	4.94

Based on daily data collected at Returu gauging station, the drain water flows during 2005-12 were estimated to 19.0, 48.7, 52.7, 55.0, 60.2 and 58.7 TMC with mean drain discharge of 49.0 TMC. As large quantities of good quality water flowing in the drain during different periods and if planned for better utilization, higher agricultural productivity can be achieved. The crop wise acreage and their water requirement are given in Table 3.55. It can be learnt that only 6.0 TMC of water has been used for all the LI schemes and for all the crops in a year under Nallamada command in Krishna Western Delta. The remaining 43.0 TMC of water join the Bay of Bengal. Under the Nallamada command the maximum water was utilized by Cotton crop and the minimum water was utilized by Bengal gram. Hence, it is concluded that Nallamada drain has potential to develop into an irrigation source for additional command area, which may be possible by construction of suitable checkdams and LIS. It is also suggested that it may be conjunctively used along with kommamuru canal water which is running along. It is important to note that adequate amount of water must be released into Bay of Bengal as environmental flow to maintain ecological balance.

Table 3.55. Crop wise average water requirement of LIS on Nallamada drain

Crops	Extent (ha)	Water Requirement				
		mm	ha-m	Lakh m^3	Lakh ft^3	TMC
Cotton	4528.6	743	3365	336.47	11873.38	1.187
Tobacco	4286.6	505	2165	216.47	7638.78	0.763
Chilli	3830.2	486	1862	186.15	6568.76	0.656
Maize	3884.3	374	1453	145.27	5126.27	0.512
Bengal gram	3394.7	249	845	84.53	2982.80	0.298
Total command	19924.4	Assuming conveyance efficiency 60% of total estimated water requirement				6.034

Efficiency of the Nagulapadu LI Scheme: APSIDC authority has designed and executed the LIS in Nagulapadu ayacut in the year 2005. As the authority might have considered about the cropping pattern and farming conditions, there was every need to frequently retrospect and introspect the system performance. Further for any design, it is customary to keep a FS (factor of safety) and keep the system capacity. To know, whether the Lift Irrigation Scheme was under designed or overdesigned and also to fulfill the first objective of the study, the total capacity of the LI scheme with the design capacity was worked out with practically observed reasonable assumptions with a due feedback from the beneficiary farmers. If the system's water output and farmers' actual crop consumption in the field as per their practice and as per scientific approach was known, it was easy to assess the scheme's performance which would be a prerequisite for extending irrigation benefits to the other tail end of the command.

$$\text{LI Scheme field use efficiency} = \frac{\text{Total WR of crops}}{\text{Maximum Pumped Water}} \times 100 = \frac{0.135}{0.151} \times 100 = 89.4\% \;\; (90\%)$$

It is obvious that remaining 10% of the pumped water from the scheme may be due to the ground water recharge or for deep percolation losses in all the fields or application losses within the fields. The above calculations were performed for one year duration taking reasonable practical assumptions mentioned in the above table.

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

During 2010-12, water samples of Agra canal and groundwater in its vicinity were collected seasonally (post monsoon, winter season and pre monsoon) at five locations i.e. Okhla (Delhi), Palwal (Haryana), Kosi (UP), Goverdhan (UP) and Bichpuri (UP). These water samples were analyzed using standard technique as mentioned in APHA 44 (1999) and compared with the drinking water standards as laid down by WHO (1993), IS(1991) and CPCB (1974) (Tables 3.56, 3.57, 3.58). Study revealed that several water samples have higher salinity. Among different cations, calcium, magnesium and sodium showed lower range, while anions like carbonate, chloride and sulphate showed higher concentration. Heavy metals also showed higher concentration due to contamination of domestic and industrial effluents.

Table 3.56. Agra canal and ground water analysis of Okhla (Delhi)

Particulars	Okhla Agra canal water samples			Okhla Ground water samples		
	Post monsoon	Winter season	Pre monsoon	Post monsoon	Winter season	Pre monsoon
pH	7.2	7.5	7.4	7.5	7.1	7.6
EC (µs/cm)	2150	2450	2550	2800	2400	2800
BOD (mg/l)	28	41	36	18	4	4
COD (mg/l)	33	45	28	19	17	19
CO_3 (mg/l)	-	-	-	-	36	36
HCO_3 (mg/l)	304	734	775	732	322	348
Chloride (mg/l)	196	320	313	231	231	234
Sulphate (mg/l)	735	1258	1128	1416	759	918
Nitrate (mg/l)	-	-	-	-	-	-
Calcium (mg/l)	30	84	90	88	104	106

Magnisium (mg/l)	38	194	197	192	123	127
Sodium (mg/l)	481	472	477	487	557	475
Potassium (mg/l)	26	28	29	28	28	28
Copper (mg/l)	0.057	0.037	0.043	0.152	0.196	0.027
Manganese (mg/l)	0.009	0.014	0.010	0.011	0.013	0.007
Zinc (mg/l)	0.022	0.010	0.090	0.012	0.015	0.088
Cobalt (mg/l)	0.058	0.064	0.073	0.048	0.073	0.088
Iron (mg/l)	0.080	0.073	0.099	0.083	0.099	0.101
Cadmium (mg/l)	0.010	0.009	0.011	0.010	0.010	0.011
Chromium (mg/l)	0.086	0.143	0.261	0.150	0.175	0.271
Lead (mg/l)	0.046	0.071	0.123	0.051	0.066	0.141
SAR	3.9	4.8	3.5	3.9	4.9	3.6
RSC	Nil	Nil	Nil	Nil	Nil	Nil

Table 3.57. Agra canal and ground water analysis of Kosi, Mathura (U.P)

Particulars	Kosi Agra canal water samples			Kosi Ground water samples		
	Post monsoon	Winter season	Pre monsoon	Post monsoon	Winter season	Pre monsoon
pH	7.7	7.6	7.3	7.8	7.6	7.6
EC (µs/cm)	3400	3650	3150	3300	4100	4200
BOD (mg/l)	16	28	21	3	2	2
COD (mg/l)	111	102	107	13	16	12
CO_3 (mg/l)	36	-	-	-	42	48
HCO_3 (mg/l)	409	584	616	238	663	615
Chloride (mg/l)	157	419	423	128	238	238
Sulphate (mg/l)	1368	1071	1047	917	1493	1488
Nitrate (mg/l)	-	-	-	-	-	-
Calcium (mg/l)	68	88	104	74	110	102
Magnisium (mg/l)	65	167	171	56	186	186
Sodium (mg/l)	496	537	492	504	475	516
Potassium (mg/l)	29	32	33	21	28	28
Copper (mg/l)	0.043	0.033	0.049	0.147	0.030	0.024
Manganese (mg/l)	0.013	0.012	0.013	0.010	0.014	0.020
Zinc (mg/l)	0.020	0.022	0.095	0.011	0.082	0.099
Cobalt (mg/l)	0.057	0.005	0.069	0.065	0.068	0.071
Iron (mg/l)	0.130	0.085	0.097	0.078	0.088	0.093
Cadmium (mg/l)	0.012	0.009	0.008	0.010	0.012	0.010
Chromium (mg/l)	0.104	0.165	0.260	0.131	0.196	0.279
Lead (mg/l)	0.059	0.065	0.030	0.056	0.061	0.160
SAR	3.4	5.6	3.2	3.5	4.3	5.4
RSC	Nil	Nil	Nil	Nil	Nil	Nil

Table 3.58. Agra canal and ground water analysis of Bichpuri, Agra (U.P)

Particulars	Bichpuri Agra canal water samples			Bichpuri Ground water samples		
	Post monsoon	Winter season	Pre monsoon	Post monsoon	Winter season	Pre monsoon
pH	7.1	7.8	7.8	7.9	7.9	7.9
EC (µs/cm)	2100	2750	3200	3700	3800	3800
BOD (mg/l)	28	24	30	4	4	4
COD (mg/l)	79	79	87	11	8	10
CO_3 (mg/l)	-	-	-	55	64	54
HCO_3 (mg/l)	336	482	555	319	494	574
Chloride (mg/l)	337	433	440	167	330	341
Sulphate (mg/l)	540	1190	1320	1570	1879	1785
Nitrate (mg/l)	-	-	-	-	-	-
Calcium (mg/l)	96	88	94	72	80	88
Magnisium (mg/l)	134	123	131	81	96	101
Sodium (mg/l)	506	565	512	466	550	527
Potassium (mg/l)	26	35	35	21	25	23
Copper (mg/l)	0.041	0.043	0.020	0.076	0.021	0.031
Manganese (mg/l)	0.020	0.011	0.010	0.011	0.007	0.044
Zinc (mg/l)	0.022	0.021	0.008	0.022	0.092	0.104
Cobalt (mg/l)	0.057	0.068	0.0143	0.060	0.069	0.079
Iron (mg/l)	0.092	0.097	0.024	0.087	0.099	0.095
Cadmium (mg/l)	0.010	0.010	0.089	0.013	0.0060	0.012
Chromium (mg/l)	0.133	0.189	0.174	0.150	0.217	0.028
Lead (mg/l)	0.073	0.061	0.0121	0.064	0.042	0.164
SAR	4.1	5.4	2.3	2.7	6.5	3.9
RSC	Nil	Nil	Nil	Nil	Nil	Nil

Impact of irrigation with treated sewage on soil, crop and ground water quality (Agra)

The sewage and drinking water samples were collected during 2010-11 and 2011-12 from different location of STP Dandhupura in Agra which is being used for irrigating different crops. Sewage water samples of Agra were collected from sewage station Dandhupura without treatment (at inlet) before rains, after rains and during winter season. The water showed high EC values after rains. A slight increase in pH (7.3-7.7) was observed during winter. BOD ranged from 159-224 mg/l but the highest value (224 mg/l) was observed during pre monsoon samples. The bicarbonate increased before rains, while chloride increased after rains. Calcium was the dominant cation in winter season. RSC was absent in all the samples and SAR ranged from 5.8-7.5. Heavy metals i.e. copper ranged from 0.058-0.064 mg/l , manganese 0.025-1.03 mg/l , zinc 0.014-0.037 mg/l, cobalt 0.053-0.083 mg/l, cadmium 0.008-0.045 mg/l, chromium 0.163-0.220 mg/l, lead 0.050-0.054 mg/l and iron ranged from 0.050-0.085 mg/l (Table 3.59).

The treated sewage water samples were collected from STP ponds with primary treatment. The salinity of water ranged from 3950–4750 EC µs/cm being highest in winter season. A slightly increase pH (7.3-7.5) was observed during winter season. BOD ranged from 30 to 77 mg/l with highest value (77 mg/l) during winter season. The carbonate was observed in outlet samples in winter and pre monsoon only. Range of bicarbonate 885 to 976 mg/l, chloride 415 to 605 mg/l. nitrate 277-328 mg/l, calcium 86 to 150 mg/l, magnesium 184 to 197 mg/l. Sodium content was higher 352 to 510 mg/l, potassium 31 to 39 mg/l . SAR ranged from 5.9 to 7.5, but no RSC was observed. Heavy metals i.e. copper ranged from 0.041 to 0.060 mg/l, manganese 0.013 to 0.025 mg/l, zinc 0.010 to 0.015 mg/l, cobalt 0.061 to 0.079 mg/l, iron 0.051 to 0.070 mg/l, cadmium 0.007-0.013 mg/l, chromium 0.157-0.306 mg/l and lead ranged from 0.044-0.060 mg/l.

Table 3.59. Sewage water quality at inlet and outlet of Dhadhupura STP

Particulars	At inlet of STO			At outlet of STP		
	Post monsoon	Winter season	Pre monsoon	Post monsoon	Winter season	Pre monsoon
pH	7.7	7.3	7.4	7.3	7.3	7.5
EC (µs/cm)	3650	4350	4350	3950	4750	4350
BOD (mg/l)	159	220	224	30	77	70
COD (mg/l)	378	511	530	112	1083	175
CO_3 (mg/l)	-	-	-	-	36	48
HCO_3 (mg/l)	720	947	1074	885	976	917
Chloride (mg/l)	166	532	468	479	605	415
Sulphate (mg/l)	1147	992	1008	835	1150	1195
Nitrate (mg/l)	313	313	356	277	307	328
Calcium (mg/l)	123	120	114	86	150	146
Magnisium (mg/l)	174	188	223	197	184	193
Sodium (mg/l)	488	328	486	510	352	458
Potassium (mg/l)	32	40	36	31	39	38
Copper (mg/l)	0.064	0.058	0.061	0.041	0.060	0.057
Manganese (mg/l)	0.025	0.054	01.034	0.013	0.019	0.025
Zinc (mg/l)	0.014	0.037	0.025	0.013	0.015	0.010
Cobalt (mg/l)	0.053	0.074	0.083	0.063	0.079	0.061
Iron (mg/l)	0.050	0.065	0.085	0.051	0.065	0.070
Cadmium (mg/l)	0.008	0.014	0.045	0.007	0.011	0.013
Chromium (mg/l)	0.163	0.183	0.220	0.157	0.177	0.3059
Lead (mg/l)	0.054	0.050	0.051	0.047	0.044	0.060
SAR	6.4	5.8	7.5	6.5	5.9	7.5
RSC	Nil	Nil	Nil	Nil	Nil	Nil

The treated sewage water samples were collected from 1 km distance from STP during three times a year. The water has high EC ranging from 4050 to 4500 EC µs/cm, being highest during winter season. BOD ranges from 27 to 66 mg/l highest observed in winter season. Bicarbonate observed in all samples. Nitrate ranged from 295 to 359 mg/l, calcium 88-150 mg/l, magnesium 155-371 mg/l, sodium 339-533 mg/l, potassium 32-40 mg/l. RSC was not observed but SAR ranged from 6.5 to 7.1 (Table 3.60).

Drinking water samples were collected from submersible near to sewage canal of STP village Kuankheda, district Agra. The analysis of samples shows that pH ranged from 7.4 to 7.8. The EC was very high (4050–4850 µs/cm). Amongst anions bicrbonate was the dominate ion and ranged from 525 to 640 mg/l and chloride ranged from 333 to 550 (mg/l). Sulphate ranged from 1056 to 1931 mg/l. Higher concentration of calcium, magnesium, sodium and potassium were reported as per the standard limit of WHO and CPCB. RSC of water was nil in all the samples and SAR 7.5 to 9.7. Heavy metals were also found higher; copper ranged from 0.022-0.245, manganese 0.008- 0.066 mg/l, zinc 0.013-0.015 mg/l, cobalt 0.064-0.074 mg/l , iron 0.050-0.109 mg/l, cadmium ranged from 0.008-0.012 mg/l, chromium ranged from 0.186–0.234 mg/l and lead ranged from 0.048–0.061 mg/l (Table 3.60).

Table 3.60. Sewage water quality at 1 km from STP and ground water samples for Kuankheda

Particulars	At 1 km away distance from STP			Kuankheda submersible		
	Post monsoon	Winter season	Pre monsoon	Post monsoon	Winter season	Pre monsoon
pH	7.4	7.4	7.4	7.8	7.4	7.6
EC (µs/cm)	4050	4500	4250	4050	4600	4850
BOD (mg/l)	27	66	60	8	9	6
COD (mg/l)	116	177	163	13	14	14
CO_3 (mg/l)	-	48	-	18	60	12
HCO_3 (mg/l)	939	708	921	640	592	525
Chloride (mg/l)	497	385	550	550	333	408
Sulphate (mg/l)	902	1303	970	1056	1546	1931
Nitrate (mg/l)	295	321	359	238	257	294
Calcium (mg/l)	88	150	144	106	128	92
Magnisium (mg/l)	371	155	175	161	132	150
Sodium (mg/l)	533	339	466	679	319	528
Potassium (mg/l)	32	40	36	28	28	29
Copper (mg/l)	0.037	0.018	0.066	0.245	0.022	0.024
Manganese (mg/l)	0.014	0.003	0.011	0.066	0.008	0.008
Zinc (mg/l)	0.008	0.016	0.016	0.015	0.013	0.015
Cobalt (mg/l)	0.069	0.081	0.076	0.064	0.072	0.074
Iron (mg/l)	0.046	0.064	0.083	0.057	0.050	0.109
Cadmium (mg/l)	0.008	0.012	0.011	0.008	0.008	0.012
Chromium (mg/l)	0.165	0.171	0.215	0.186	0.198	0.234
Lead (mg/l)	0.034	0.053	0.057	0.048	0.050	0.061
SAR	6.5	7.1	6.9	9.7	7.5	8.2
RSC	Nil	Nil	Nil	Nil	Nil	Nil

The drinking water samples collected from hand pump at Kuankheda revealed that pH was normal (7.6 to 7.8) whereas, EC ranged from 3550 to 4550 ECµs/cm, which was higher than the limits set by WHO and CPCB. Bicarbonate also showed higher values ranged from 385–537 mg/l similar pattern were observed in case of chloride. The sulphate content in the water ranged from 931 to 1718 mg/l and nitrate from 242 to 279 mg/l, potassium was high in drinking water and ranged from 28 to 30 mg/l. RSC of water was nil in all the samples and SAR ranged from 2.9 to 9.9. Heavy metals were also higher; copper ranged from 0.021-0.052, manganese 0.009- 0.017 mg/l, zinc 0.017-0.033 mg/l, cobalt 0.032- 0.088 mg/l , iron 0.064–0.120 mg/l, cadmium ranged from 0.011-0.026 mg/l, chromium ranged from 0.044–0.212 mg/l and lead ranged from 0.046 – 0.056 mg/l (Table 3.61).

The drinking water samples collected from tube well of Budhana village revealed that pH was normal (7.6 to 7.9) whereas, EC ranged from 2700 to 2800 µs/cm, Bicarbonate also showed higher values ranged from 262–372 mg/l. Similar pattern was observed in case of chloride (220 to 302 mg/l). The sulphate content in the water ranged from 850 to 907 mg/l and nitrate from 244 to 298 mg/l, potassium was high in drinking water and ranged from 31 to 35 mg/l. RSC of water was nil in all the samples and SAR ranged 6.8 to 10.4. Heavy metals were also found higher; copper ranged from 0.018- 0.036, manganese 0.009- 0.011 mg/l, zinc 0.022- 0.034 mg/l, cobalt 0.067- 0.072 mg/l , iron 0.025 – 0.088 mg/l, cadmium ranged from 0.008- 0.023 mg/l, chromium ranged from 0.180–0.254 mg/l and lead ranged from 0.040–0.054 mg/l (Table 3.61).

Table 3.61. Ground water analysis for STP areas

Particulars	Kuankheda hand pump			Budhana tube well		
	Post monsoon	Winter season	Pre monsoon	Post monsoon	Winter season	Pre monsoon
pH	7.8	7.6	7.8	7.7	7.6	7.9
EC (µs/cm)	3550	4550	4050	2700	2750	2800
BOD (mg/l)	3	5	5	6	8	7
COD (mg/l)	16	16	17	13	13	12
CO_3 (mg/l)	102	42	-	18	12	54
HCO_3 (mg/l)	385	537	512	318	372	262
Chloride (mg/l)	479	305	551	302	272	220
Sulphate (mg/l)	931	1718	1310	864	907	850
Nitrate (mg/l)	242	261	279	244	267	298
Calcium (mg/l)	78	146	100	128	114	42
Magnisium (mg/l)	185	117	132	138	134	137
Sodium (mg/l)	532	574	572	541	552	440
Potassium (mg/l)	28	30	28	35	34	31
Copper (mg/l)	0.034	0.021	0.052	0.033	0.036	0.018
Manganese (mg/l)	0.009	0.012	0.017	0.006	0.011	0.009
Zinc (mg/l)	0.033	0.017	0.020	0.031	0.034	0.022
Cobalt (mg/l)	0.067	0.088	0.032	0.067	0.070	0.072
Iron (mg/l)	0.065	0.064	0.120	0.066	0.025	0.088
Cadmium (mg/l)	0.011	0.026	0.011	0.008	0.023	0.010
Chromium (mg/l)	0.044	0.187	0.212	0.181	0.180	0.254
Lead (mg/l)	0.046	0.056	0.052	0.040	0.054	0.046
SAR	2.9	9.9	9.5	10.4	6.8	10.5
RSC	Nil	Nil	Nil	Nil	Nil	Nil

The soil samples were collected at sowing and at harvest of pearl millet, wheat, mustard, cauliflower, coriander and spinach at 0-15 and 15-30 cm depth. The EC_e varied from 2.5-3.0 dS/m and pH 7.4–7.8. Soil analysis showed that available nitrogen and organic carbon (%) increased with the irrigation of the crops using treated sewage water over initial available N and organic carbon content (Table 3.62). The treated sewage water irrigated crops were compared with fresh ground water. Mustard, wheat, barley and pearl millet yield increased from 6.6 to 23.8% and in vegetables yield increased from 18.2 to 75.0%. However, in other crops yield increase was 26.4-26.8% due to high organic carbon and available N status of treated sewage water (Table 3.63).

Table 3.62. Soil analysis at sowing and harvest of crops under treated sewage irrigation

Crops	Soil depth (cm)	At sowing				At harvest			
		EC_e	pH	Av. N (kg/ha)	O.C. (%)	EC_e	pH	Av. N (kg/ha)	O.C. (%)
Pearl millet	0-15	2.7	7.6	262	0.60	2.4	7.5	228	0.52
	15-30	2.4	7.5	252	0.52	2.3	7.5	222	0.48
Wheat	0-15	2.7	7.8	268	0.61	2.7	7.7	230	0.52
	15-30	2.6	7.7	258	0.52	2.5	7.5	225	0.45
Mustard	0-15	2.6	7.7	262	0.65	2.5	7.7	252	0.52
	15-30	2.7	7.6	248	0.59	2.5	7.3	232	0.47
Potato	0-15	2.7	7.6	292	0.77	2.6	7.5	265	0.61
	15-30	2.6	7.5	272	0.69	2.6	7.5	258	0.52
Cauliflower	0-15	2.5	7.8	260	0.57	2.3	7.5	241	0.48
	15-30	2.6	7.5	248	0.48	2.4	7.5	232	0.39
Coriander	0-15	2.5	7.8	262	0.58	2.5	7.7	242	0.40
	15-30	2.5	7.7	248	0.52	2.5	7.7	220	0.38
Spinach	0-15	2.7	7.9	268	0.66	2.5	7.6	257	0.60
	15-30	2.5	7.6	256	0.52	2.4	7.5	249	0.43
Sorghum	0-15	2.5	7.8	270	0.68	2.5	7.7	258	0.60
	15-30	2.4	7.6	255	0.52	2.3	7.6	240	0.47
Barley	0-15	2.6	7.7	281	0.72	2.4	7.5	262	0.65
	15-30	2.5	7.5	268	0.65	2.4	7.5	248	0.55
Cabbage	0-15	2.5	7.9	265	0.65	2.5	7.7	248	0.58
	15-30	2.6	7.7	258	0.60	2.4	7.5	232	0.42
Berseem	0-15	2.5	7.7	267	0.69	2.3	7.7	260	0.62
	15-30	2.6	7.2	258	0.52	2.3	7.2	249	0.50
Initial soil	0-15	2.4	7.9	201	0.32	2.2	7.7	195	0.29
	15-30	2.5	7.8	191	0.28	2.3	7.8	181	0.26

Table 3.63. Yield comparison of treated sewage with BAW irrigation yield at farmer's field

Crops	Treated sewage water irrigated crops yield (t/ha)	Fresh ground water irrigated crops yield (t/ha)	Per cent yield increase in treated sewage water irrigated crops
Mustard	2.9	2.4	20.8
Wheat	4.8	4.5	6.6
Pearl millet	2.8	2.3	23.8
Cauliflower	9.0(mid); 24.0(late)	6.0 (mid); 18.0 (late)	50.0 (mid);33.3 (late)
Cabbage	8.0	6.0	33.3
Carrot	26.0	22.0	18.2
Cowpea	7.0 (green pod)	4.0 (green pod)	75.0 (green pod)
	2.5 (grain)	1.8 (grain)	38.8 (grain)
Palak	9.0	7.0	28.6
Radish	7.0	4.0	75.0
Spinach	6.0	5.0	20.0
Barley	3.8	3.20	18.8
Potato	41.0	34.0	20.6
Sorghum (fodder)	28.8	22.7	26.8
Berseem (F)	22.5	17.8	26.4

Studies on long-term effect of sewage irrigation on soil and crops (Trichy)

The Trichy city corporation sewage water is stored near Panchappur and it is stored in open aerated lagoons. This sewage water has been mixed in the Koriyar River and diverted into two water ways, viz., one is directed and mixed with the river Cauvery and another water way joins with Peruvalai canal and Pullambadi canal and ends at Vallavanthankottai tank. This water course has been surveyed and benchmark sites were selected to monitor the heavy metal accumulation in soil and crops (Table 3.64). To monitor the accumulation of heavy metals under sewage irrigation to paddy crop along the sewage water course of Tiruchirappalli district, eight benchmark sites were identified to conduct on farm trials. Four farmers at Iniyannur, one at Koriyar, one farmer at Ponneripuram and two at Nathamadipatti were selected for field trials during 2012.

Table 3.64. Survey of sewage water with water ways at different locations in Trichy district

Location	Geographical co-ordinates	Water Sample			
		2010-11		2011-12	
		pH	EC	pH	EC
Panchappur	10º 45.714' N - 78º39.860' E	7.0	1.21	7.3	1.01
Edamalaipattipudur	10º 46.180' N - 78º39.755' E	7.8	1.31	7.1	1.20
Karumandapam	10º 47.729' N - 78º39.817' E	7.9	0.43	7.5	0.48
Kulumae Amman kovil	10º 47.173' N - 78º39. 378' E	8.1	0.37	8.2	0.47
Kulumae Amman kovil	10º 48.140' N - 78º39.938' E	7.8	0.41	7.3	0.31
Tennur	10º 48.603' N - 78º40.865' E	7.4	0.30	7.2	0.38
Palakarai	10º 45.584' N - 78º41.711' E	8.2	0.28	7.8	0.33
Ariyamangalam	10º 45.771' N - 78º42.972' E	8.1	0.46	8.1	0.46
Kattur Ellakkudi	10º 48.064' N - 78º44.807' E	7.8	0.42	7.2	0.32
Kattur Kailash Nagar	10º 47.679' N - 78º45.637' E	7.6	0.52	7.9	0.42
Old Thiruvarembur	10º 47.505' N - 78º45.970' E	7.8	0.74	7.8	0.64
Thiruvarembur SIT Stop	10º 47.052' N - 78º46.712'E	8.1	0.52	8.1	0.32
Ehzil Nagar	10º 46.521' N - 78º48.565' E	7.9	0.43	7.6	0.48
Ayampatti	10º 46.589' N - 78º49.430' E	8.4	0.40	8.1	0.46
Valavanthankottai	10º 45.516' N - 78º50.466' E	7.6	0.32	7.3	0.31
Thirunedunkulam	10º 46.206' N - 78º51.147' E	7.9	0.42	7.2	0.42

Analysis of the sewage water irrigated field showed that Pb content (1.98 ppm) was higher as compared to Cd (0.024 ppm) and Ni, (0.062 ppm) (Table 3.65). The rice field irrigated with sewage water during 2011, the plant samples were analyzed for grain, straw and root. Among the heavy metals, Pb recorded higher value irrespective of the plant parts tested, than Cd and Ni. The yield recorded in the OFT trial with and without sewage irrigation for paddy during 2010-11 showed that the bore well water recorded higher grain yield than sewage water irrigation (Table 3.66). In order to ascertain metal content (Pb, Cd and Ni) in the sewage water irrigated and bore well water irrigated field, an OFT experiment was conducted on selected benchmark sites using rice as a test crop. The yield was recorded in the selected benchmark sites (Table 3.67) both in the bore well water irrigated soils and sewage water irrigated soils. There were no heavy metals in the bore well water irrigated soils (Table 3.68). On the basis of the results from the on farm trials, the values of these heavy metals in the soil and paddy grains were within the permissible limits of WHO standards. These findings suggests further work taking into long term basis will provide more details regarding the accumulation of metals in soil and plant system.

Table 3.65. Heavy metal contents in soil and plant parts at sewage irrigated farmer's field

Soil parameters	Values	Heavy metals	Soil	Grain	Straw	Roots
pH	7.8	Pb (ppm)	1.98	0.004	0.006	0.005
EC (dS/m)	1.21	Cd (ppm)	0.024	BDL*	BDL*	BDL*
Available N (kg/ha)	298	Ni (ppm)	0.062	0.001	0.002	0.003
Available P (kg/ha)	14	-	-	-	-	-
Available K (kg/ha)	230	-	-	-	-	-

**Below the detection limit*

Table 3.66. Details of OFT selected for sewage water irrigation for paddy (2010-11)

Name of the farmer	Geographical Coordinates	Grain yield (t/ha)	
		Sewage water	Bore well water
R. Mani Koraiyar	10° 47.729' N - 78°39.817' E	5.92	6.25

Table 3.67. OFT on sewage water irrigation for field crops in Trichy district (2011-12)

Name of the farmer	Geographical coordinates	Grain yield (t/ha)	
		Sewage water	Bore well water
Mariyakanikai, Iniyanur	10° 48.000' N - 78° 39.135' E	5.84	6.35
M. Sabariamal, Iniyanur	10° 47.957' N - 78° 39.236' E	5.66	6.01
M. Ashok kumar, Inniyanur	10° 48.142' N - 78° 39.005' E	5.22	5.51
A. Jothimani, Iniyanur	10° 47.782' N - 78° 39.036' E	5.40	5.92
R. Mani, Koraiyar	10° 47.729' N - 78°39.817' E	5.88	6.32
V.S. Rajendran, Ponneripuram	10° 46.814' N - 78° 43.915' E	5.71	6.25
V.S. Paramasivam, N'patti	10° 46.659' N - 78° 43.673' E	5.48	5.80
M. Arokiyaraj, Ponneripuram	10° 45.645' N - 78° 44.239' E	5.62	6.04

Table 3.68. Heavy metal content (ppm) of soil of OFT trials with sewage water irrigation

Name of the farmer	Pb		Cd		Ni	
	SW	BW	SW	BW	SW	BW
Mariyakanikai Iniyanur	BDL*	BDL*	BDL*	BDL*	BDL*	BDL*
M. Sabariamal Iniyanur	0.003	BDL*	BDL*	BDL*	0.006	BDL*
M. Ashok kumar Inniyanur	0.004	BDL*	BDL*	BDL*	BDL*	BDL*
A. Jothimani Iniyanur	BDL*	BDL*	BDL*	BDL*	0.008	BDL*
R. Mani Koraiyar	0.006	BDL*	BDL*	BDL*	BDL*	BDL*
V.S. Rajendran, Ponneripuram	BDL*	BDL*	BDL*	BDL*	0.005	BDL*
V. S. Paramasivam, Npatti	0.004	BDL*	BDL*	BDL*	BDL*	BDL*

Research Accomplishments

4. Alternate Land Management in Salty Environment

Alternate Land Management for Saline Environment

- Tolerance of Ber (*Zizyphus jujuba*) to irrigation schedules with saline water under drip irrigation system (Bikaner)
- Evaluation of medicinal and aromatic crops in saline Vertisols (Gangawati)
- Response of sugar beet to sowing dates and planting geometry in saline soils of TBP command (Gangawati)

Alternate Land Management for Sodic Environment

- Effect of irrigation methods and water quality on fruit trees in sodic soils (Indore)
- Developing multi-enterprises farming system for sodic Vertisols (Indore)
- Integrated farming system suitable for problem soil areas of Tamil Nadu (Trichy)

Alternate Land Management for Saline Environment

Tolerance of Ber (*Zizyphus jujuba*) to irrigation schedules with saline water under drip irrigation system (Bikaner)

Pooled results indicated that maximum average weight of 10 fruits, fruit diameter and fruit yield per plant was obtained under 0.6 PE with BAW (EC_{iw} 0.25 dS/m) followed by 0.6 PE with saline water having EC_{iw} 8.0 dS/m over 0.4 and 0.8 PE, respectively in drip irrigation system (Table 4.1). The maximum per day requirement of water per plant was observed during the month of May and minimum in January. Further, the total water requirement in the crop season was of 6551, 5239 and 4190 litres at 0.8, 0.6 and 0.4 PE, respectively (Table 4.2). Significantly higher fruit yield of ber was obtained under 0.6 BAW which remained at par with 0.8 BAW and 0.6 saline water. It can be inferred that saline water up to 8.0 dS/m can be used successfully for ber cultivation under drip irrigation without any significant reduction in yield. The build-up of salt accumulation in soil profile determined after last picking of ber fruits indicated that higher salt concentration was observed at increasing distances from plant both laterally and vertically downwards under EC_{iw} 8.0 dS/m over BAW more so at lower levels of PE (Table 4.3).

Table 4.1. Fruit weight, diameter and yield/plant under different treatments of saline water

Treatments	Weight of 10 fruits (g)				Average diameter (cm)				Fruit yield/plant (kg)			
	2009-10	2010-11	2011-12	Pooled	2009-10	2010-11	2011-12	Pooled	2009-10	2010-11	2011-12	Pooled
0.8 BAW	329	328	349	335.33	3.51	3.45	3.48	3.48	49.67	55.88	62.62	56.06
0.6 BAW	379	383	378	380.00	3.80	3.78	3.79	3.79	55.93	65.60	72.20	64.58
0.4 BAW	297	284	284	288.33	2.97	2.83	2.85	2.88	39.66	46.00	43.90	43.19
0.8 Saline	304	305	368	325.67	3.70	3.60	3.70	3.67	45.20	53.47	58.25	52.31
0.6 Saline	310	316	374	333.33	3.72	3.68	3.75	3.72	47.30	57.82	64.96	56.69
0.4 Saline	268	267	260	265.00	2.79	2.78	2.6	2.72	34.21	41.58	41.84	39.21
S.Em±	7.8	3.9	10.6	-	0.13	0.11	0.15	-	3.17	3.56	2.52	-
CD (5%)	23.6	18.4	31.9	-	0.39	0.34	0.44	-	9.6	10.7	7.58	-

Table 4.2. Amount of water applied to ber plants

Month	Volume of water applied/day/plant (liters)			Total amount of water applied/month/plant (liters)		
	0.4 WR	0.6 WR	0.8 WR	0.4 WR	0.6 WR	0.8 WR
May 2010	26.1	32.6	40.8	809	1011	1265
June	24.2	30.3	37.9	726	909	1137
July	18.6	23.2	29.0	577	719	899
August	16.6	20.7	25.9	515	642	803
September	13.8	17.3	21.6	414	519	648
October	12.0	15.0	18.7	372	465	580
November	9.8	12.3	15.4	294	369	462
December	9.3	11.6	14.5	288	360	450
January 2011	6.3	7.9	9.9	195	245	307
Total	136.7	170.9	213.7	4190	5239	6551

Table 4.3. Salinity (EC_e) distribution in soil profile under saline water (EC_{iw} 8.0 dS/m) irrigation through drip system to ber with (2009-10)

Distance from emitter (cm)	Soil depth (cm)	2009-10			2010-11			2011-12			Pooled		
		0.4 PE	0.6 PE	0.8 PE	0.4 PE	0.6 PE	0.8 PE	0.4 PE	0.6 PE	0.8 PE	0.4 PE	0.6 PE	0.8 PE
15	0-15	2.61	2.52	2.53	2.18 (0.51)	2.15 (0.48)	2.10 (0.46)	2.16 (0.44)	2.11 (0.41)	1.90 (0.40)	2.32	2.26	2.18
	15-45	2.73	2.69	2.88	2.49 (0.57)	2.38 (0.54)	2.44 (0.51)	2.29 (0.53)	2.00 (0.49)	2.18 (0.44)	2.50	2.36	2.50
	45-75	2.69	2.73	3.17	2.60 (0.60)	2.57 (0.56)	2.69 (0.55)	2.45 (0.57)	2.37 (0.51)	2.56 (0.46)	2.58	2.56	2.81
	75-105	2.94	2.98	2.97	2.71 (0.63)	2.94 (0.58)	3.10 (0.57)	2.58 (0.59)	2.77 (0.56)	2.91 (0.52)	2.75	2.90	2.99
30	0-15	2.63	2.93	2.53	2.44 (0.57)	2.30 (0.55)	2.35 (0.52)	2.40 (0.51)	2.29 (0.47)	2.32 (0.46)	2.49	2.51	2.40
	15-45	2.84	2.98	2.69	2.89 (0.59)	2.71 (0.58)	2.77 (0.56)	2.81 (0.54)	2.66 (0.50)	2.70 (0.49)	2.85	2.78	2.72
	45-75	2.92	2.83	2.61	2.68 (0.65)	3.01 (0.62)	2.93 (0.59)	2.60 (0.60)	2.89 (0.57)	2.83 (0.53)	2.73	2.91	2.79
	75-105	3.01	2.97	2.95	2.73 (0.67)	3.19 (0.64)	3.00 (0.61)	2.69 (0.65)	2.96 (0.61)	2.88 (0.57)	2.81	3.04	2.94
60	0-15	2.79	3.00	2.69	2.79 (0.63)	2.69 (0.60)	2.76 (0.56)	2.64 (0.55)	2.56 (0.54)	2.59 (0.51)	2.74	2.75	2.68
	15-45	3.01	3.11	3.08	3.04 (0.66)	2.83 (0.62)	2.91 (0.59)	2.96 (0.59)	2.77 (0.55)	2.84 (0.53)	3.00	2.90	2.94
	45-75	3.32	3.17	3.47	2.86 (0.70)	2.97 (0.67)	3.10 (0.64)	2.80 (0.66)	2.86 (0.64)	2.96 (0.58)	2.99	3.00	3.18
	75-105	3.37	3.27	3.34	2.77 (0.74)	3.11 (0.70)	3.26 (0.67)	2.72 (0.71)	3.00 (0.68)	3.11 (0.60)	2.95	3.13	3.24
90	0-15	2.90	3.11	2.91	3.11 (0.67)	2.91 (0.63)	2.97 (0.58)	2.98 (0.60)	2.84 (0.56)	2.88 (0.52)	3.00	2.95	2.92
	15-45	3.31	2.98	3.44	3.46 (0.69)	3.34 (0.66)	3.21 (0.61)	3.21 (0.64)	3.11 (0.60)	2.90 (0.56)	3.33	3.14	3.18
	45-75	3.21	3.27	3.68	3.10 (0.74)	3.47 (0.68)	3.30 (0.66)	3.00 (0.65)	3.17 (0.63)	2.99 (0.57)	3.10	3.30	3.32
	75-105	3.62	3.82	3.96	2.80 (0.75)	3.50 (0.70)	3.33 (0.68)	2.93 (0.69)	3.10 (0.66)	3.00 (0.59)	3.12	3.47	3.43

Data in parenthesis indicate EC_e with EC_{iw} 0.25 dS/m for BAW

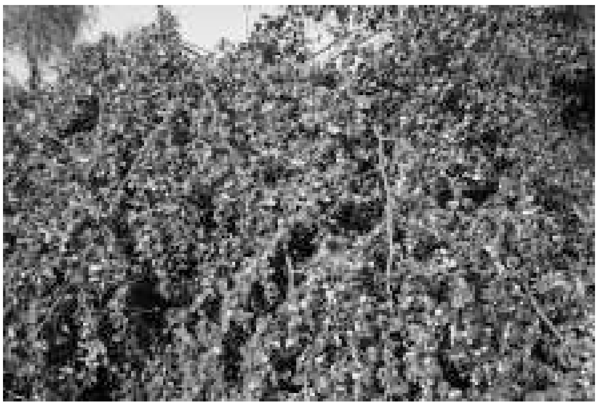


Fig. 4.1. Ber crop bearings fruits under drip irrigation

Evaluation of medicinal and aromatic crops in saline Vertisols (Gangawati)

In view of increasing shortage of water to sustain existing paddy-paddy cropping sequence and also increasing problem of water logging and salinity especially in low lying areas due to paddy, a more economic crop/cropping sequence is required to be established to convince the farmers to shift from paddy to other light irrigated crops. In this direction, field experiments to evaluate the performance of Kamaksturi (*Oscimum basilicum*), Tulsi (*Oscimum sanctum*), Shatavar (*Asparagus racemosus*) and Citronella (*Cymbopogan winterianus*) were initiated along the salinity ranging from < 2.0 to 22 dS/m. Along with these crops, nelaberu or kalmegh (*Andrographis paniculata*) was also tried during 2010-11 but failed to establish upon transplanting to the main field.

The results obtained during 2010-11 and 2011-12 revealed that the threshold soil salinity levels (EC_t) of kamakasturi and tulsi were 4.48 (slope 2.44 kg) and 4.81dS/m (slope 2.97 kg), 5.05 (slope 3.93 kg) and 5.1 dS/m (slope 2.16 kg) respectively (Table 4.4). The EC_t and the slope of shatavar and citronella were found to be 3.87 dS/m (slope 4.41 kg) and 7.54 dS/m (slope 0.74 kg) respectively during 2010-12. In kamakasturi, oil per cent was more in leaves (0.5-1.30%) as compared to inflorescence (0.30-1.04%). In citronella oil was 1.54-2.1%, tulsi 0.40 to 1.25%. In general, the relationships between soil salinity and the per cent oil in all the cases were observed to be poor as revealed by the R^2 values. However, as indicated by the trend lines, generally per cent oil appears to decline as the soil salinity increases.

Table 4.4. Economic threshold salinity and slope for different economic parts of crops

Crop/ Economic plant part	Threshold salinity (EC_t dS/m)		Slope (when x > BPx)	
	2010-11	2011-12	2010-11	2011-12
Tulsi (foliage)	5.05	5.10	-3.93 kg	2.16 kg
Kamakasturi (foliage)	4.48	4.81	- 2.44 kg	-2.97 kg
Shatavar (fresh root bulb)	3.87	nd	-4.41 kg	nd
Citronella (foliage)	7.54	nd	-0.74 kg	nd

Response of sugar beet to sowing dates and planting geometry in saline soils of TBP command (Gangawati)

Sugar beet being a short duration crop and requiring less water than sugarcane fits well in the cropping programme particularly under saline soils. However, there was no information on its agronomic requirement particularly on saline Vertisols. Hence, an experiment was conducted to work out optimum time of sowing and spacing requirements of sugar beet under saline conditions during 2010-11 and 2011-12. Results of 2011-12 indicated that among the dates of sowing, sowing of sugar beet seeds in August first fortnight recorded significantly higher root yield of sugar beet (41.3 t/ha) than sowing in August second fortnight (37.0 t/ha), September first fortnight (31.9 t/ha) and September second fortnight (28.9 t/ha) (Table 4.5). TSS % of sugar beet roots recorded significantly higher in August I fortnight (21.67%) than in other dates of sowing (Table 4.6). Among different planting geometry, there was no significant difference in root yield, number of beets/plot and TSS per cent of sugar beet. But, there was a significant difference in weight of 10 beets in different planting geometry.

Pooled data (2010 to 2011) indicated that among the dates of sowing, sowing of sugar beet seeds in August 1st fortnight recorded significantly higher root yield of sugar beet (40.3 t/ha) than sowing in August II[nd] fortnight (35.9 t/ha), September I[st] fortnight (31.1 t/ha) and September II[nd] fortnight (28.3 t/ha). TSS per cent of sugarbeet roots recorded significantly higher in August 1[st] fortnight (21.7%) than other dates of sowing (Table 4.7). Among different planting geometry, there was no significant difference in root yield and TSS per cent.

Table 4.5. Effect of dates of planting and planting geometry on root yield of sugar beet (t/ha)

Planting dates	Planting Geometry (2010)					Planting Geometry (2011)				
	45x20 cm	45x30 cm	60x20 cm	60x30 cm	Mean	45x20 cm	45x30 cm	60x20 cm	60x30 cm	Mean
D1	40.19	39.77	38.90	38.20	39.27	43.39	41.17	40.52	40.07	41.29
D2	36.55	34.83	34.13	33.52	34.76	38.86	37.06	36.46	35.55	36.98
D3	31.10	30.72	30.23	29.19	30.31	33.31	32.27	31.60	30.27	31.86
D4	28.74	28.34	27.22	26.83	27.78	29.75	29.09	28.45	28.15	28.86
Mean	34.15	33.41	32.62	31.94		36.33	34.90	34.26	33.51	
CD (5%)	Dates: 1.39; Geometry: NS; Planting dates x Geometry: NS					Planting dates: 2.58; Geometry: NS; Planting dates x Geometry: NS				

D1: August 1st fortnight; D2: August 2nd fortnight; D3: September 1st fortnight; D4: September 2nd fortnight

Table 4.6. Effect of dates of planting and planting geometry on TSS (%) of sugar beet crop

Planting dates	Planting Geometry (2010)					Planting Geometry (2011)				
	45x20 cm	45x30 cm	60x20 cm	60x30 cm	Mean	45x20 cm	45x30 cm	60x20 cm	60x30 cm	Mean
D1	22.17	22.00	21.89	21.23	21.82	22.06	21.85	21.60	21.16	21.67
D2	21.07	20.89	20.70	20.55	20.80	21.10	20.68	20.34	20.15	20.57
D3	20.23	20.17	20.07	19.91	20.09	20.08	20.05	20.00	19.89	20.01
D4	19.81	19.53	19.37	19.20	19.48	19.72	19.66	19.41	19.25	19.51
Mean	20.82	20.65	20.51	20.22		20.74	20.56	20.34	20.12	
CD (5%)	Dates: 0.60; Geometry: NS; Planting dates x Geometry: NS					Planting dates: 0.59; Geometry: NS; Planting dates x Geometry: NS				

D1: August 1st fortnight; D2: August 2nd fortnight; D3: September 1st fortnight; D4: September 2nd fortnight

Table 4.7. Pooled effect of planting dates and geometry on root yield and TSS of sugar beet

Planting dates	Root yield (t/ha)					TSS (%)				
	45x20 cm	45x30 cm	60x20 cm	60x30 cm	Mean	45x20 cm	45x30 cm	60x20 cm	60x30 cm	Mean
D1	41.79	40.47	39.71	39.14	40.28	22.11	21.93	21.74	21.20	21.74
D2	37.71	35.94	35.30	34.54	35.87	21.08	20.78	20.52	20.35	20.68
D3	32.21	31.50	30.91	29.73	31.09	20.15	20.11	20.03	19.90	20.05
D4	29.25	28.72	27.84	27.49	28.32	19.77	19.60	19.39	19.23	19.49
Mean	35.24	34.16	33.44	32.72		20.78	20.60	20.42	20.17	
CD (5%)	Dates: 0.22; Geometry: NS; Planting dates x Geometry: NS					Planting dates: 0.59; Geometry: NS; Planting dates x Geometry: NS				

D1: August 1st fortnight; D2: August 2nd fortnight; D3: September 1st fortnight; D4: September 2nd fortnight

Alternate Land Management for Sodic Environment

Effect of irrigation methods and water quality on fruit trees in Sodic soils (Indore)

The study was carried out in sodic black soils of Barwaha farm, Indore. The saplings of sapota (var. kalipatti), ber (var. deshi), pomegranate (var. ganesh) and drumstick (var. coimbatore-1) were transplanted at 3 x 3 m grid as per recommended practices in 2005/06. Different irrigation treatments were imposed. The bio-metric parameters on girth and height were recorded during 2010-11 and 2011-12. The EC, SAR and RSC of BAW and diluted spent wash (1:30 ratio) were 0.5 dS/m, 1.1 (mmol/L)½, 0.0 meq/l and 0.93 dS/m, 7.3 (mmol/l)½ and 0.0 meq/l, respectively. The pomegranate and drumstick failed to survive under sodic Vertisols.

The change in average girth and height was measured by considering average girth of plants under each treatment at the time of planting and during the years 2010-11 and 2011-12 (Table 4.8, 4.9). Better growth in terms of girth and height 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 and height was more in case of irrigation by diluted spent wash as compared to irrigation by best available irrigation water.

Table 4.8. Change in average girth (cm) of fruit trees under different methods of irrigation

Methods	Best Available Water			Diluted Spent Wash Water		
	2005-06	Change 2010-11	Change 2011-12	2005-06	Change 2010-11	Change 2011-12
			Ber			
Check basin	5.00	8.52	9.52	3.97	11.29	12.21
Embedded pipe	3.60	14.07	16.23	2.88	17.67	19.45
Drip	4.30	13.30	14.85	2.52	16.24	17.79
			Sapota			
Check basin	2.60	8.37	8.95	3.04	7.77	9.06
Embedded pipe	2.50	13.50	16.18	2.60	12.79	16.70
Drip	2.90	12.63	14.50	2.76	14.53	16.10

Table 4.9. Change in plant height (cm) up to 2010-11

Method	Best Available Water			Diluted Spent Wash Water		
	2005-06	2010-11	Change	2005-06	2010-11	Change
			Ber			
Check basin	67.3	203.67	169.47	37.9	236.77	198.87
Embedded pipe	52.7	243.67	234.92	38.3	287.62	249.32
Drip	64.5	228.50	202.40	30.7	266.90	236.20
			Sapota			
Check basin	27.1	112.17	97.13	26.0	124.23	98.23
Embedded pipe	23.4	187.50	160.30	23.0	183.7	160.70
Drip	25.9	175.00	155.30	30.0	181.2	151.20

Developing multi-enterprises farming system for sodic Vertisols (Indore)

Due to poor physico-chemical and water transmission properties, sodic vertisols has limited yield potential as crop suffers due to temporary water logged condition during kharif season and limited moisture availability in the root zone during *rabi* season. Sodic soil possesses high runoff potential and gives the scope of rainwater harvesting in dug out ponds to develop multi-enterprises farming system. Development of suitable multi-enterprises farming system may provide farmers as an alternate to enhance and provide regular farm income during the year.

The experiment was conducted with an existing tank having storage capacity of 1890 m^3, which needs to be increased up to 3000 m^3 to meet irrigation requirement of 10/hectare of 3cm/irrigation. Daily rainfall, evaporation and change in stored water in the pond were recorded during monsoon season 2010 and 2011. The average percolation loss from the pond was observed about 26.4 and 19.0 mm/day during extended spells of 25 and 38 days in 2010 and 2011, respectively. The water harvesting tank was utilized to irrigate paddy and cotton crops (Table 4.10). The stored water could manage to deliver 2170 mm depth of water for irrigating 1.73 ha paddy and 0.18 ha cotton crops during 2010-11 and 2500 mm depth of water during 2011-12 for irrigating 1.82, 0.5 and 0.03 ha paddy, cotton and tomato crops respectively.

Table 4.10. Details of life saving irrigation through pond water

Crop	Area of crop (m^2)	Number of irrigation	Area irrigated (m^2)	Depth of irrigation (mm)
		2010-11		
Paddy student	162	4	648	620
Paddy RS-III	624	3	1872	410
Paddy gm	2200	4	8800	430
Paddy RS-III, RS-I	2424	1	2424	200
Cotton RS-I	900	2	1800	200
RS-I, Paddy-Cotton	1800	2	3600	290
Total	8110		19144	2150
		2011-12		
Paddy	1440	2	2880	250
Paddy	1100	2	2200	200
Paddy	840	6	5040	970
Paddy	720	2	1440	130
Paddy	2200	3	6600	350
Tomato	300	1	300	100
Cotton	1850	2	3700	300
Cotton	450	1	450	100
Cotton	900	1	900	100
Total	9800		23510	2500

The yields of cotton and paddy under raised and sunken bed system were 0.39, 0.78 and 1.08, 1.03 t/ha during 2010-11 and 2011-12, respectively whereas yield of cotton as sole crop of farming system, was obtained 0.22 and 1.33 t/ha (Table 4.11). Similarly, yield of tomato and brinjal under agro-horticulture farming system were 1.81, 1.99 and 1.74 and 3.61 t/ha during 2010-11 and 2011-12, respectively.

Fig. 4.2. Cotton and paddy on raised and sunken bed system, Cotton under flat bed system

Table 4.11. Area, yield and returns of different crops under multi-enterprise farming system

Name of system	Crop	Area (m^2)	Yield (kg/m^2)	Yield (t/ha)	Cost of produce (Rs.)
		2010-11			
Raised bed	Cotton	180	7	0.39	236
Sunken bed	Paddy	180	14	0.78	140
Sole crop	Cotton	450	10	0.22	330
Agro-horticulture	Tomato	720	130	1.81	650
Agro-horticulture	Brinjal	360	70	1.99	350
		2011-12			
Raised bed : Kharif	Cotton	180	19.5	1.08	848
: Rabi	Sunflower	180	07.5	0.42	225
Sunken bed : Kharif	Paddy	180	18.5	1.03	92
: Rabi	Wheat	180	61.2	3.40	848
Sole crop	Cotton	450	60.0	1.33	2610
Agro-horticulture	Tomato	720	125.0	1.74	375
Agro-horticulture	Brinjal	360	130.0	3.61	390
Agroforestry	Cotton	720	28.5	0.39	1239

Integrated farming system suitable for problem soil areas of Tamil Nadu (Trichy)

An experiment was initiated in 2009 to evolve suitable farming system for sustainable income in the problem areas. The cropping pattern is presented in Table 4.12. Since there was shortage of rainfall during the year, rice fallow crops were not taken up.

The fish was harvested after four months and six months. The income from one cycle of fish grown for 6 months furnished. Similarly income from one batch of birds reared for 8 months is recorded. The birds started laying eggs from 20 weeks onwards (Table 4.13).

The analysis of expenditure components indicated expenditure of Rs 13,719 towards crops, Rs 2,000 towards fisheries and Rs 12,000 towards poultry components. The realized net profit was Rs 10,539 from crop, 1,13,360 from fisheries and 17,029 from poultry component. The total cost on capital investment including interest was Rs 24,000. The economics of cropping system without intervention in 0.4 ha was estimated at Rs 17,843 (Table 4.14).

Table 4.12. Cropping pattern (0.3 ha)

Cropping pattern			Area
Green Gram (VBN -2) (Jun–Aug)	Rice (TRY 1) (Sep-Jan)	Daincha (Feb-May)	0.10 ha
Daincha (Jul-Aug)	Rice (TRY 1) (Sep-Jan)	Okra (Feb-May)	0.10 ha
Ragi (TRY-1) (Jun-Aug)	Rice (TRY 1) (Sep-Jan)	Cucumber(Feb-May)	0.10 ha
Fisheries			Pond area
Silver carp/catla (surface feeder)	390 nos. (30%)		0.10 ha
Rohu (column feeder)	520 nos. (40%)		
Mrigal/Common carp(bottom feeder)	130 nos. (10%)		
Grass carp (Grass feeder)	260 nos. (20%)		
Poultry			
Babcock birds	40 layers		

Table 4.13. Net profit from IFS Components

Component	Income	Expenditure	Profit
Cropping (0.36 ha)	28258	13719	10539
Fisheries	115360	2000	113360
Poultry	29029	12,000	17029
Cost on capital investment		24,000	
Net profit	171647	51719	Rs. 119928

Table 4.14. Comparison of IFS with cropping alone system

Components	Profit (Rs.)	Cost (Rs.)	B/C ratio
IFS Components (0.4 ha)	119928	51719	2.3
Pure cropping (0.4 ha)	17843	17388	1.03

Fig. 4.3. Harvesting of fish from IFS pond

Research Accomplishments

5. Screening of Crop Cultivars and Genotypes

Screening of Crop Cultivars in Saline Environment

- Screening of mustard cultivars under saline water irrigation (Agra)
- Screening of maize and chickpea under saline water irrigation (Bapatla)
- Screening of rice varieties for salinity tolerance under Nallamada drain (Bapatla)
- Tolerance of cotton varieties to saline water irrigation under drip system (Bikaner)
- Response of wheat varieties to saline water irrigation in Western Rajasthan (Bikaner)
- Response of wheat varieties to saline water through sprinkler irrigation (Bikaner)
- Screening of forage grasses in salt affected soils of TBP command area (Gangawati)
- Screening of elite varieties of crops for cultivation under saline water irrigation (Hisar)

Screening of Crop Cultivars in Sodic Environment

- Screening of vegetable crops for sodicity tolerance under sodic black clay soils (Indore)
- Performance of different mustard varieties under alkali condition (Kanpur)
- Evaluation of different crops for their tolerance to sodicity levels (Trichy)

Screening of Crop Cultivars in Saline Environment

Screening of mustard cultivars under saline water irrigation (Agra)

Screening of mustard cultivars supplied by DRM, Bharatpur was carried out during 2010-11 and 2011-12. All cultivars were irrigated with saline water of EC_{iw} 12 dS/m. Highest yield of mustard cultivars under IVT was recorded in CSCN 10-12 (2.5 t/ha) and lowest was in CSCN 10-5 and CSCN 10-9 (1.4 t/ha) during 2010-11. Other cultivars showed yield between 1.5 to 2.2 t/ha. In AVT highest yield was recorded in CSCN 10-16 (2.5 t/ha) and lowest in CSCN 10-14 (1.8 t/ha). Cultivar CSCN 10-13 and CSCN 10-15 recorded the yield of 2.1 t/ha. During 2011-12, the highest yield under IVT was recorded in CSCN 11-5 (0.6 t/ha) and lowest in CSCN 11-6 (0.5 t/ha). Other cultivars showed yield 0.5 to 0.6 t/ha. In AVT highest yield was obtained in CSCN 11-7 (0.7 t/ha) and lowest in CSCN 11-9 and CSCN 11-10 (0.4 t /ha). Yield of cultivar CSCN 11-8 was 0.7 t/ha (Table 5.1).

Table 5.1. Yield of mustard cultivars on use of saline water irrigation (EC_{iw} 12 dS/m)

2010-11				2011-12	
Cultivars	Grain yield (t/ha)	Cultivars	Grain yield (t/ha)	Cultivar	Grain yield* (t/ha)
IVT		AVT		IVT	
CSCN 10-1	2.0	CSCN 10-13	2.1	CSCN 11-1	0.5
CSCN 10-2	2.2	CSCN 10-14	1.8	CSCN 11-2	0.6
CSCN 10-3	2.1	CSCN 10-15	2.1	CSCN 11-3	0.5
CSCN 10-4	1.7	CSCN 10-16	2.5	CSCN 11-4	0.6
CSCN 10-5	1.4	CD (5%)	0.11	CSCN 11-5	0.6
CSCN 10-6	1.9			CSCN 11-6	0.5
CSCN 10-7	1.5			CD (5%)	0.01
CSCN 10-8	1.9			AVT	
CSCN 10-9	1.4			CSCN 11-7	0.7
CSCN 10-10	1.8			CSCN 11-8	0.7
CSCN 10-11	2.0			CSCN 11-9	0.4
CSCN 10-12	2.5			CSCN 11-10	0.4
CD (5%)	0.23			CD (5%)	0.01

**Low yield due to aphid attack and late sowing during 2011-12*

Screening of maize and chickpea under saline water irrigation (Bapatla)

The experiment was carried out on three maize hybrids (30V92, Sandhya and ANGRAU DHM 117) at different irrigation water salinity levels (BAW, EC_{iw} 2, 4 and 6 dS/m) at Bapatla during *rabi* 2010-11 and 2011-12. The soil EC values were increased with increasing the EC level of irrigation water compared to initial values. This may be due to salt buildup in the soil due to application of different EC levels of irrigation water. During 2011-12, EC values were drastically decreased due to heavy down pour was received in the month of January (111.5 mm in two days) that's why there was no build up of salts in the soil. Available nitrogen, phosphorous and potassium values were decreased compared to initial values, it may be due to removal of nutrients from soil as it is a heavy exhaustive crop (Table 5.2).

Among hybrids, Sandhya performed significantly well across all salinity levels than other hybrids. Significant difference in grain yield was found between the hybrids as follows; Sandhya (8.18 t/ha) >30V92 (7.57 t/ha)>DHM 117 (6.78 t/ha). There was no interaction between hybrids and EC levels of irrigation water. Significant reduction in grain yield was observed at EC_{iw} 4 and 6 dS/m as compared to BAW and 2 dS/m. 30V92 hybrid recorded no reduction in yields at 4 and 6 EC_{iw} thus is suitable hybrid for salt tolerance compared to Sandhya and DHM-117 hybrids. Grain yield was on par with EC_{iw} of 4 and 6 dS/m (Table 5.3).

Table 5.2. Soil analysis at harvest of maize cultivars (2010-11)

Treatment	pH	EC	N	P_2O_5	K_2O	pH	EC	N	P_2O_5	K_2O
		(dS/m)	(kg/ha)				(dS/m)	(kg/ha)		
	2010-11					2011-12				
Initial	7.2	0.3	247	35.8	483	7.2	0.5	211	31.3	438
Sandya										
BAW	7.1	0.4	225	35.1	475	7.2	0.1	220	30	431
2 dS/m	7.1	0.7	218	34.5	462	6.7	0.1	214	35	417
4 dS/m	7.2	0.8	205	31.2	458	6.9	0.1	209	42	420
6 dS/m	7.2	0.9	194	30.3	450	7.0	0.1	199	23	411
30V92										
BAW	7.1	0.4	213	34.2	470	7.1	0.0	219	24	428
2 dS/m	7.1	0.9	201	32.6	455	6.5	0.2	205	41	408
4 dS/m	7.2	0.9	198	31.5	446	6.8	0.1	193	43	401
6 dS/m	7.0	1.1	187	31.0	438	7.2	0.1	203	39	395
DHM117										
BAW	7.1	0.5	220	35.4	468	7.0	0.0	221	39	425
2 dS/m	7.1	0.7	209	31.7	450	7.2	0.1	216	34	414
4 dS/m	7.2	0.9	195	31.3	438	7.2	0.1	202	34	406
6 dS/m	7.2	1.0	188	30.4	427	7.0	0.1	195	33	398
Bulk	7.0	1.1	173	32.5	435	7.3	0.0	210	22	419

Table 5.3. Effect of water salinity levels on yield of maize hybrids

Water salinity (dS/m)	Seed yield of maize hybrids 2010-11 (t/ha)				Seed yield of maize hybrids 2011-12 (t/ha)			
	30V92	Sandhya	DHM-117	Mean	30V92	Sandhya	DHM-117	Mean
BAW	8.23	9.44	7.85	8.51	8.59	9.37	7.55	8.81
2	8.37	9.19	7.17	8.24	8.07	6.77	5.21	6.68
4	6.84	7.34	6.31	6.83	7.29	5.47	4.69	5.81
6	6.84	6.76	5.78	6.46	6.51	4.69	3.91	5.03
Mean	7.57	8.18	6.78		7.62	6.57	5.34	
CD (5%)	Hybrids: 0.85; Salinity: 0.98; HxS: NS				Hybrids: 0.51; Salinity: 0.44; HxS: 1.05			
CV (%)	13.4				8.0			

Chickpea: The experiment on chickpea varieties was carried out on clay loam soils at farmer's field at Uppugunduru of Prakasam district during *rabi* 2010-11 and 2011-12. The treatments comprised of four chickpea varieties which were replicated five times. Slight decrease in pH and EC values were observed compared to initial values during 2010-11 but no change was observed during 2011-12. Available nitrogen was increased due to nitrogen fixation being a legume crop.

Phosphorous and potassium contents were increased in two varieties and decreased in other two varieties (Table 5.4. The grain yield indicated that the variety KAK-2 performed well and significantly higher grain yield (0.36 t/ha) was obtained than other varieties. The varieties JG-11 and JG-130 were at a par with each other (Table 5.5). KAK-2 variety showed high sodium content and lowest was recorded in JG-11. The variety which is showing high Na/K ratio resembles its salt tolerance nature.

Table 5.4. Initial and final soil analysis at sowing and harvest of chickpea

Parameter	2010-11					2011-12				
	Initial	Final				Initial	Final			
		JG-11	JG-130	KAK-2	Vihari		JG-11	JG-130	KAK-2	Vihari
pH	7.6	7.6	7.2	7.3	7.6	7.3	7.1	7.2	7.1	7.2
EC(dS/m)	5.6	5.3	5.1	5.2	5.2	5.1	5.1	5.1	5.0	5.1
N (kg/ha)	248	252	260	254	248	213	218	225	230	216
P_2O_5(kg/ha)	24.8	24.8	25.1	26.2	25.3	25.5	31.2	28.9	30.4	31.8
K_2O (kg/ha)	611	605	612	608	623	681	688	705	650	634

Table 5.5. Na and K contents in plant samples of chickpea and its seed yield

Varieties	2010-11				2011-12			
	K (%)	Na (%)	Na/K ratio	Seed yield (t/ha)	K (%)	Na (%)	Na/K ratio	Seed Yield (t/ha)
KAK-2	1.23	0.156	0.12	0.36	1.56	0.135	0.086	1.00
JG-11	2.84	0.113	0.039	0.16	2.5	0.093	0.037	0.92
JG-130	2.77	0.125	0.045	0.16	2.36	0.122	0.052	0.81
Vihari	2.36	0.138	0.058	0.21	2.47	0.130	0.053	0.79
CD (5%)	-	-	-	0.04	-	-	-	1.43
CV (%)	-	-	-	9.7	-	-	-	10.4

Screening of rice varieties for salinity tolerance under Nallamada drain (Bapatla)

Results of pot culture study during *kharif* 2010 with four salinity levels and five rice varieties showed significant yield reduction (404 g/pot) at EC_{iw} 9 dS/m as compared to BAW (575 g/pot) whereas yields obtained at 3 and 6 dS/m were at par but significant difference was noticed between EC_{iw} 6 and 9 dS/m. Higher grain yield was recorded for saline water irrigation up to EC_{iw} 6 dS/m. Among varieties MTU1064 performed significantly better than other varieties (BPT-1768, MTU-1061, MTU-1075 and BPT-5204) at all salinity levels (Table 5.6).

During *kharif* 2011, experiment was conducted under field conditions at Ramanayapalem in Prakasam district. The initial soil EC and pH were 5.9 dS/m and 7.5, respectively. NLR28523 attained maximum plant height (119.3 cm) than other varieties but at par with NLR 33892. It was observed that dry matter accumulation was higher in NLR28523 up to 60 DAT but NLR33892 recorded significantly higher dry matter accumulation at 90 DAT and at harvest as compared to other varieties (Table 5.7). The growth parameters i.e. tillers/m^2 was significantly higher in NLR34449 (596/m^2) but filled grains/panicle and test weight were significantly higher in variety NLR33892 (180 and 18.5 g) as compared to other varieties. Grain yield (6.30 t/ha) was significantly higher for NLR 33892 as compared to other varieties viz., NLR3041and NLR34449 but at par with NLR 3042 and NLR28523 (Table 5.8).

Table 5.6. Performance of rice varieties in saline water irrigation

Treatments	Filled grains/ panicle	Test weight (g)	Yield (g/pot)	
			Grain	Straw
Saline water (EC_{iw} dS/m)				
BAW	205.6	18.9	575.0	724.3
3	203.5	19.2	457.3	616.0
6	201.3	18.2	436.4	658.0
9	193.6	17.7	404.0	576.3
CD (5%)	NS	1.2	31.0	128.6
CV (%)	9.5	5.0	14.4	15.8
Rice varieties				
BPT -5204	188.6	15.3	347.3	498.8
BPT- 1768	237.9	17.1	508.2	685.4
MTU-1075	217.8	20.3	463.1	667.5
MTU-1064	194.5	19.0	523.6	685.8
MTU-1061	166.2	20.7	499.0	680.8
CD (5%)	25.4	1.1	40.6	122.5
CV (%)	10.8	5.0	20.3	16.2

Table 5.7. Growth of rice as influenced by soil salinity at Ramanayapalem

Treatment	Plant height (cm)	Dry matter accumulation (t/ha)			
		30 DAT	60 DAT	90 DAT	At harvest
Variety					
NLR3041	77.8	0.73	4.33	8.97	11.00
NLR3042	74.0	0.91	5.28	8.41	9.85
NLR28523	119.3	1.03	4.99	10.69	12.06
NLR33892	116.0	0.96	3.85	11.91	13.54
NLR34449	69.5	0.86	4.15	8.06	9.42
CD (5%)	5.5	0.12	0.81	0.78	0.74
CV (%)	3.9	8.6	11.6	5.3	4.3

Table 5.8. Rice as influenced by soil salinity at Ramanayapalem district Prakasam

Varieties	Tillers/m^2	Filled grains/ panicle	Test weight (g)	Yield (t/ha)		Harvest Index (%)
				Grain	Stover	
NLR3041	478	141	16.4	5.72	6.50	46.8
NLR3042	516	150	17.3	5.89	6.79	46.5
NLR28523	537	166	17.9	6.05	7.57	44.4
NLR33892	533	180	18.5	6.30	8.24	43.3
NLR34449	596	151	15.7	5.22	6.35	45.1
CD (5%)	42	11	0.5	0.50	0.52	NS
CV (%)	5.1	4.3	1.9	5.6	4.7	4.4

The soil salinity reduced at harvest of rice and varied from 2.06 to 2.48 dS/m. The lowest salinity was observed in variety NLR 3042 and NLR 33892 and the highest uptake of sodium at harvest (41.72 kg/ha) was observed in variety NLR3042 (Table 5.9).

Table 5.9. Soil characteristics of experimental site at Ramanayapalem district Prakasam

Parameter	Initial	Final				
		NLR3041	NLR3042	NLR28523	NLR33892	NLR34449
EC (dS/m)	5.96	2.5	2.1	2.1	2.1	3.4
pH	7.54	7.2	7.3	7.4	7.4	7.2
N (kg/ha)	210	167.0	188.0	120.0	146.0	125.0
P (kg/ha)	34	20.0	22.0	34.0	25.0	36.0
K (kg/ha)	450	499.0	458.0	479.0	480.0	480.0
Na uptake (kg/ha)		24.2	41.7	26.4	28.3	17.8

Tolerance of cotton varieties to saline water irrigation under drip system (Bikaner)

Results showed that highest plant height, number of bolls/plant, boll size and seed cotton yield was obtained under drip irrigation with water of EC_{iw} 3 dS/m. Significant decrease in yield attributes and yield was obtained at EC_{iw} 6 dS/m. Drip method was found superior with 31.7 per cent higher yield as compared to flood irrigation. Among varieties Bt cotton recorded the highest yield under both drip and flood irrigation. Interaction between methods of irrigation and salinity of water on seed cotton yield was found significant during all the four years of study (Table 5.10). Seed cotton yield decreased significantly at EC_{iw} 6 dS/m in both method of irrigation. However, better seed cotton yields recorded with 3 dS/m water under drip system as compared to BAW with flood system. Interaction between methods of irrigation and varieties indicated that Bt cotton produced significantly higher yield in both methods of irrigation. It is evident that Bt cotton responded maximum to drip irrigation and produced 45.1 per cent higher seed cotton yield over flood irrigation whereas cotton variety F-846 responded least (23.4 per cent) to drip irrigation.

Soil EC_e at harvest of cotton was affected by irrigation water salinity in 0-45 cm soil profile at 0, 15 and 30 cm lateral distances from the emitters. The maximum salinity was observed at 30 cm distance from emitters with EC_{iw} 6 dS/m saline water, whereas the minimum salinity was observed just below the emitters with canal water (0.25 dS/m). Zone of minimum salt concentration existed below the emitter. The trend indicates that the salt concentration in the soil profile increased with increase in lateral as well as vertical distances from the emitters. It can be inferred that the salts are leached away from active root zone of plant providing better growth conditions (Table 5.11).

Table 5.10. Interactive effect of various treatments on seed cotton yield (t/ha)

Treatments	Methods of Irrigation (M)							
	2008		2009		2010		2011	
	Drip	Flood	Drip	Flood	Drip	Flood	Drip	Flood
Salinity of water (S)								
0.25 ds/m	2.12	1.10	3.37	2.74	1.98	1.79	1.45	1.26
3.0 ds/m	2.04	0.94	2.87	1.82	1.96	1.53	1.44	1.07
6.0 ds/m	1.43	0.74	2.11	1.35	1.51	1.38	1.11	0.96
CD (5%)	0.16		0.23		0.12		0.10	
Varieties (V)								
F 846	1.62	1.07	2.08	2.08	1.36	1.05	1.33	0.98
RST-9	1.69	1.24	2.85	1.85	1.30	1.23	1.27	1.15
RG-8	1.47	1.23	2.57	1.55	1.24	1.19	1.21	1.11
Bt Cotton	2.67	1.63	3.62	2.42	1.55	1.24	1.52	1.16
CD (5%)	0.19		0.27		0.14		0.12	

Table 5.11. Salinity (EC_e) build-up in the soil profile after cotton (pooled over four years)

Distance from emitter (cm)	Soil depth (cm)	EC_{iw} (dS/m)					
		Drip			Flood		
		0.25	3.0	6.0	0.25	3.0	6.0
	0-15	0.34	1.08	1.59	0.37	1.19	1.49
0	15-30	0.46	1.22	1.72	0.44	1.51	2.09
	30-45	0.53	1.39	1.78	0.50	1.67	2.40
	0-15	0.52	1.23	1.76			
15	15-30	0.53	1.39	2.10			
	30-45	0.65	1.49	2.31			
	0-15	0.53	1.35	1.94			
30	15-30	0.54	1.51	2.38			
	30-45	0.70	1.71	2.57			

Drip irrigation was superior in producing higher seed cotton yield as compared to flood irrigation. With increase in water salinity, yield of cotton decreased under both methods of irrigation, but quantum of decrease in yield with increased water salinity was more in flood as compared to drip irrigation. Among varieties Bt cotton produced maximum yield with drip and flood irrigation.

Response of wheat varieties to saline water irrigation in Western Rajasthan (Bikaner)

An experiment was conducted to evaluate the response of wheat varieties under different irrigation water salinity during 2010-11 and 2011-12. Successive Increase in levels of EC_{iw} resulted into decrease in plant height, number of plants/m row length, ear length and grains/ear of wheat, significantly. However, application of BAW and EC_{iw} 4.0 dS/m remained at par for plant height, grains/ear. During both the years, successive increase in the level of salinity of water resulted in decreased grain and straw yield. A significant decrease in grain yield was observed at higher level of EC_{iw} 12.0 dS/m over lower levels of EC_{iw}. Effect of wheat varieties on grain yield was significant during 2010-11 but during 2011-12, it was non-significant. Application of different levels of EC_{iw} and wheat varieties could not increase test weight significantly during both the years (Table 5.12).

Table 5.12. Effect of saline water irrigation on wheat varieties

Treatments	Test weight (g)			Grain yield (t/ha)			Straw yield (t/ha)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
Saline water (dS/m)									
0.25 (BAW)	35.0	35.2	35.1	2.52	2.18	2.35	3.74	4.33	4.04
4	34.7	35.5	35.1	2.38	2.18	2.28	3.70	4.60	4.15
8	32.4	34.4	33.4	2.17	2.06	2.12	3.31	4.83	4.07
12	33.2	35.2	34.2	1.83	1.85	1.84	2.81	4.51	3.66
CD (5%)	NS	NS		0.20	0.16		0.29	0.45	
Varieties									
KRL-213	32.9	36.0	34.5	2.32	2.07	2.20	3.44	4.41	3.93
Raj 3077	34.2	35.0	34.6	2.14	2.01	2.07	3.31	4.31	3.81
Raj-4188	34.1	34.4	34.2	2.16	2.05	2.10	3.33	5.10	4.22
KRL-210	34.1	34.7	34.4	2.28	2.14	2.21	3.48	4.45	3.96
CD (5%)	NS	NS		0.12	NS		NS	0.49	

The grain and straw yield of wheat decreased significantly with successive increase in EC_{iw} from 8 to 12 dS/m. Wheat KRL 210 performed better followed by KRL-213, Raj-4188 and Raj-3077. Salinity build-up in soil after harvest of crop was increased in the root zone with salinity of irrigation water.

The EC_e of soil at harvest of wheat was affected by salinity levels of irrigation water in different soil layers upto 45 cm depth. The maximum salinity was observed under application of EC_{iw} 12.0 dS/m while minimum was found in BAW (EC_{iw} 0.25 dS/m) in different soil layers of 0-15, 15-30 and 30-45 cm depths, respectively (Table 5.13)

Table 5.13. Salinity (EC_e) build-up in soil after wheat harvest

Soil depth (cm)	Salinity build-up in soil (dS/m)							
	2010-11				2011-12			
	BAW	4	8	12	BAW	4	8	12
0-15	0.40	2.21	2.96	3.36	0.48	2.20	3.01	3.46
15-30	0.43	2.29	3.14	3.44	0.50	2.25	3.26	3.50
30 - 45	0.44	2.33	3.17	3.46	0.54	2.30	3.30	3.57

Response of wheat varieties to saline water through sprinkler irrigation at farmer's field (Bikaner)

Field trials were carried out at farmer's fields on performance of wheat varieties under saline irrigation (EC 6.0 dS/m) through sprinkler irrigation. Among five varieties, KRL 210 exhibited superiority in terms of grain and straw yield. However, at one location, variety KRL 213 recorded non-significantly higher grain and straw yield as compared to KRL 210. Grain yield of Raj 4188 was at par with KRL 210 at all locations, whereas, KRL 213 was at par with KRL 210 at two locations. KRL-210, Raj 4188 and KRL 213 showed salt tolerance under sprinkler irrigation (Table 5.14).

Table 5.14. Response of wheat varieties to saline irrigation (EC 6.0 dS/m) at farmers' field

Varieties	Grain yield (t/ha)			Straw yield (t/ha)		
	Mala Ram Meghwal, Thukariasar Dungargarh	Adhu Ram Meghwal, Thukariasar Dungargarh	Feth Chand Tanwar, Kanasar Kolayat	Mala Ram Meghwal, Thukariasar Dungargarh	Adhu Ram Meghwal, Thukariasar Dungargarh	Feth Chand Tanwar, Kanasar Kolayat
Raj 3077	1.80	2.00	1.90	3.31	3.70	3.47
Raj 4188	2.30	2.16	2.20	4.23	3.66	4.09
KRL-210	2.50	2.30	2.40	4.60	4.09	4.44
KRL-213	2.10	2.40	2.20	3.78	4.51	4.11
KRL-19	2.00	2.20	2.10	3.60	4.17	3.84
S.Em±	0.12	0.09	0.09	0.16	0.17	0.12
CD (5%)	0.38	0.29	0.29	0.53	0.56	0.40

Screening of forage grasses in salt affected soils of TBP command area (Gangawati)

Acute shortage of green fodder in the command area can be taken care by growing perennial forage grasses in degraded and marginal land such as saline/alkali soil in TBP command. Hence, screening of forage grasses for saline soils of TBP command was initiated with six forage grasses during 2011-12 on soil salinity gradient of EC_e 3.2 to 18.1 dS/m. The biomass of these grasses was recorded and yields of different blocks were grouped on the basis of soil salinity range i.e., <4, 4-6, 6-8, 8-10, 10-12, 12-14, 14-16 and >16 dS/m. The results revealed that at EC_e <4 dS/m, irrespective of the species highest biomass was observed. Rhodes grass yielded maximum biomass (18.5 t/ha) followed by para grass (7.6 t/ha), grazing guinea (6.2 t/ha), guinea grass (5.5 t/ha), hybrid napier 'DHN-9' (3.9 t/ha) and hybrid napier 'DHN-6' (3.3 t/ha) (Table 5.15).

Table 5.15. Biomass yield of perennial forage grasses under different soil salinity range

Soil salinity range (dS/m)	Biomass yield (t/ha)					
	Hybrid Napier (DHN-6)	Hybrid Napier (DHN-9)	Guinea grass	Grazing guinea	Para grass	Rhodes grass
<4	3.9	3.3	5.5	6.2	7.6	18.5
4-6	3.6	3.2	4.9	5.6	6.9	16.8
6-8	2.8	2.7	3.5	5.1	5.7	14.6
8-10	2.9	2.6	3.8	4.0	4.7	12.7
10-12	2.0	1.9	2.1	3.7	3.6	11.5
12-14	1.2	1.2	1.3	2.6	2.6	10.8
14-16	1.1	0.9	1.2	2.1	2.5	9.6
>16	0.8	0.8	0.9	1.3	1.5	8.3

Screening of elite varieties of crops for cultivation under saline water irrigation (Hisar)

During 2010-11 and 2011-12, tolerance of seven genotypes of cotton, fourteen genotypes of wheat, seventeen genotypes of mustard (ten in 2011-12) and eleven genotypes of sorghum were tested under different saline water irrigation treatments.

Cotton: Increasing salinity reduced the seed cotton yield by 32.8% in 2010-11 and 47.2% in 2011-12 at EC_{iw} of 7.5 dS/m as compared to control. The yield of KD 9810-BG-II (174.88 g/m^2 in 2010-11) and RCH134Bt (301.8 g/m^2 in 2011-12) were significantly higher than other genotypes (Table 5.16). Boll weight (Table 5.17), bolls/plant and number of monopod branches decreased with increasing salinity levels in all genotypes. Desi cotton varieties were highly sensitive, genotype HD-123 was the lowest yielder and seed cotton yield was 66.8 g/m^2.

Various physiological parameters (ELWL, transpiration, photosynthesis rate, chlorophyll status) and nutrient contents were also studied. No genotype showed a clear decrease in ELWL under saline conditions. Salinity of irrigation water up to 2.5 dS/m is increasing the transpiration rate (H_2O mmol/m^2/s) in all genotypes except Ajit-333-BG-II and RCH-134-BT. But after EC 2.5 dS/m of irrigation water, salinity affected adversely the transpiration rate in all genotypes. Transpiration rate is highly affected in HD-123 genotype as compared to other genotypes. Average transpiration rate varied from 5.42 to 8.25 with lowest in HD-123 genotype and highest in Ajit-333-BG-II. In H-1236, H-1098-1, KD-9810-BG-II genotypes, rate of photosynthesis increased up to EC 2.5 dS/m and thereafter, it gradually decreased with the increase in EC (Fig. 5.1). In HD-123 and RCH-134-BT genotypes, rate of photosynthesis was increased up to EC 5.0 dS/m and thereafter, it was decreased at EC 7.5 dS/m. In KD-441-BG-II and Ajit-333-BG-II genotypes, rate of photosynthesis gradually decreased with increased salinity.

Table 5.16. Effect of saline waters on seed cotton yield (g/m²) of cotton genotypes

Genotypes	Seed cotton yield (g/m²) at different EC_{iw} (dS/m) in 2010-11					Seed cotton yield (g/m²) at different EC_{iw} (dS/m) in 2011-12				
	Canal	2.5	5.0	7.5	Mean	Canal	2.5	5.0	7.5	Mean
H-1236/ SOLAR72BG-II*	170.8	114.9	67.8	66.1	104.9	95.8	90.6	88.0	82.5	89.2
H-1098-I	170.0	161.3	103.7	97.4	133.1	183.3	174.1	151.3	121.8	157.6
HD-123	91.7	90.4	64.4	22.1	67.2	103.8	90.0	47.5	25.2	66.6
KD-441-BG-II/ GRANDBG-II*	162.8	145.8	107.2	101.4	129.3	119.8	105.6	84.1	73.9	95.9
RCH-134-BT	203.4	152.4	100.5	85.8	135.5	369.7	349.0	287.3	201.4	301.9
KD-9810-BG-II	184.9	184.7	171.1	158.8	174.9	286.2	248.6	183.8	129.5	212.0
AJIT-333-BG-II/ NCS856Bt-II*	226.4	108.1	83.3	73.9	122.9	168.3	113.6	79.6	66.8	107.1
Mean	172.9	136.8	99.7	86.5		189.6	167.3	131.6	100.2	
CD (5%)	Salinity: 5.99; Variety: 7.92 SxV: 15.85					Variety (V): 10.3; Salinity (S): 7.8 VxS: 20.7				

Table 5.17. Effect of saline waters on boll weight of cotton genotypes

Genotypes	Boll weight (g) at different EC_{iw} (dS/m) in 2010-11					Boll weight (g) at different EC_{iw} (dS/m) in 2011-12				
	Canal	2.5	5.0	7.5	Mean	Canal	2.5	5.0	7.5	Mean
H-1236/ SOLAR72BG-II*	2.41	2.07	1.87	1.32	1.92	3.07	3.00	2.78	2.06	2.73
H-1098-I	2.30	2.15	2.07	1.92	2.11	2.71	2.81	2.73	2.41	2.67
HD-123	2.55	2.10	1.42	1.27	1.84	3.63	3.21	3.18	3.05	3.27
KD-441-BG-II/ GRANDBG-II*	2.92	2.52	2.32	2.15	2.48	3.52	3.62	3.32	3.01	3.37
RCH-134-BT	2.87	2.75	2.47	2.12	2.55	3.23	3.03	2.74	2.53	2.88
KD-9810-BG-II	3.52	2.86	2.80	2.10	2.82	3.31	3.42	2.93	2.69	3.09
AJIT-333-BG-II/ NCS856Bt-II*	2.75	2.65	2.17	1.82	2.35	3.58	3.36	2.90	2.86	3.18
Mean	2.76	2.44	2.16	1.81		3.29	3.21	2.94	2.66	

**During 2011-12*

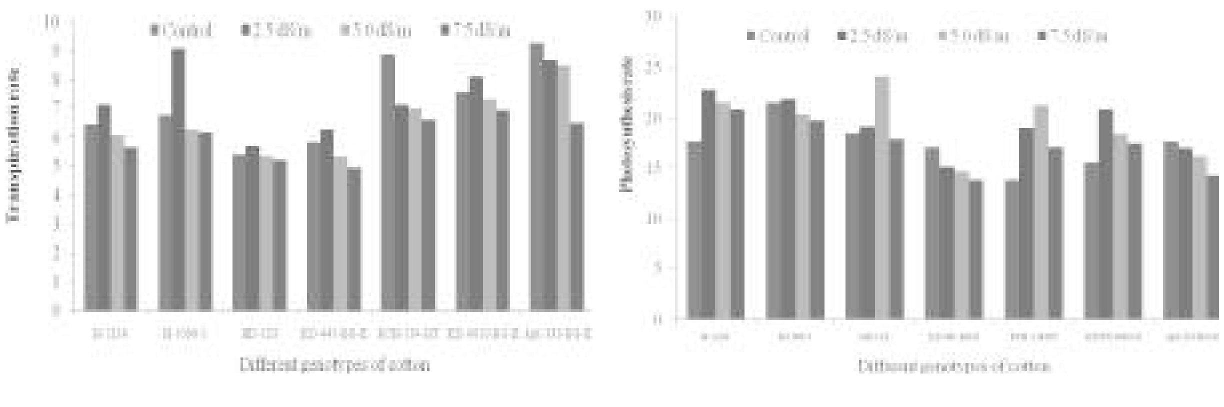


Fig. 5.1. Rate of transpiration (H_2O mmol/m²/s) and photosynthesis (µmol CO_2/m²/s) for cotton genotypes under different salinity levels

Spad reading, an indication of chlorophyll status, was generally increased at salinity of 2.5 dS/m except in RCH-134-BT and Ajit-333-BG-II genotypes, whereas, it was reduced in all genotype with further increase in salinity levels. RCH-134-BT showed maximum decrease in spad readings from canal water to EC 7.5 dS/m whereas H-1236 showed a little increase. Stomatal conductance was increased with the increase in salinity of 2.5 dS/m in all genotypes and it was reduced with further increase in the level of salinity. Mean stomatal conductance varied from 0.28 to 0.43 mmol $CO_2/m^2/s$ with minimum in H-1098-1 and maximum in H-123 genotype. Internal CO_2 concentration was reduced at the highest level of salinity in all genotypes except KD-441-BG-II. It showed an increase up to 2.5 dS/m and afterward decreased with further increase in salinity. Mean internal CO_2 concentration varied from 218 to 272 (mmol $CO_2/m^2/s$) with minimum in Ajit-333-BG-II and maximum in H-1098-1 genotypes.

Mean EC_2 in the soil profile up to 60 cm varied from 0.8 to 2.1 dS/m from control to 7.5 dS/m plots (Fig. 5.2) at the time of sowing. EC in the soil profile under 7.5 dS/m EC plot remained highest throughout the soil profile as compared to other treatments. In the upper layer (0-15 cm) of this treatment, EC was 1.9 and the bottom layer (45-60 cm) it was 2.4. In canal irrigation treatment, the highest value of EC was 1.0 in 45-60cm.

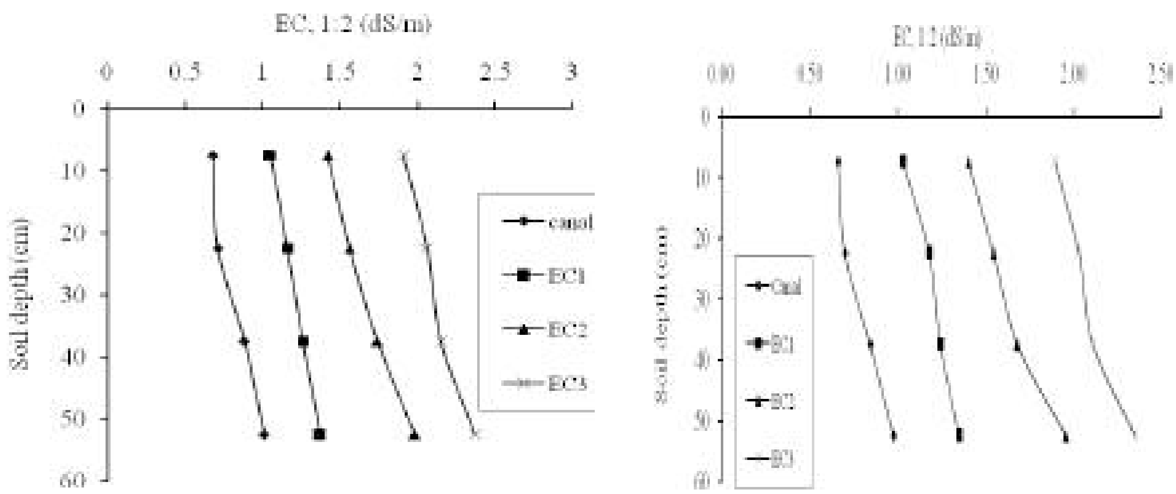


Fig. 5.2. EC in different treatments at the sowing of cotton during 2010-11 and 2011-12

Wheat: The yield of different varieties of wheat when irrigated with different quality showed that yield decreased with an increase in EC of the irrigation water (Table 5.18). Wheat genotype P-7762 performed best at the highest saline water irrigation (7.5 dS/m) and gave 51.4 per cent higher yield as compared to KRL-210 (check) followed by P-7764 which produced 43.6 per cent higher yield than KRL-210 whereas the performance of P-7871 was poorest and results in 25.8 per cent lower yield as compared to KRL-210 (check). Per cent reduction in the yield of wheat varieties was worked out under different salinity by comparing with non-saline (canal water) treatment during 2010-11 (Fig. 5.3). The highest reduction (39.8%) in the yield was observed in P-7876 under 7.5 dS/m as compared to canal irrigation water. In P-7743 and KPL-210, the increase in yield was observed when irrigated with 2.5 dS/m EC water as compared to canal and maximum value of this increase was 1.89 percent in KRL-210 variety. During 2011-12, reduction (40, 35 and 25 per cent) in the yield of P-7811 was obtained under salinity of 7.5, 5.0 and 2.5 dS/m as compared to canal water irrigation (Fig. 5.4).

Table 5.18. Grain yield of wheat varieties as influenced by different salinity waters

Genotypes	Grain yield (g/m²) at different EC_{iw} (dS/m) in 2010-11				
	Canal	2.5	5.0	7.5	Mean
P-7682	305	275	251	224	264
P-7743	470	478	448	352	437
P-7745	492	429	349	321	398
P-7749	432	422	371	376	400
P-7755	475	453	423	402	438
P-7758	472	447	398	376	423
P-7762	546	526	472	452	499
P-7764	522	503	448	428	475
P-7867	502	448	404	302	414
P-7869	498	475	421	425	455
P-7871	347	329	302	221	300
WH-1090	523	521	498	399	485
KRL-210	371	378	321	298	342
Kh-65	423	325	274	278	325
Mean	456	429	384	347	
CD (5 %)	Variety (V): 26.84; Salinity (S): 14.35; V X S : 53.68				

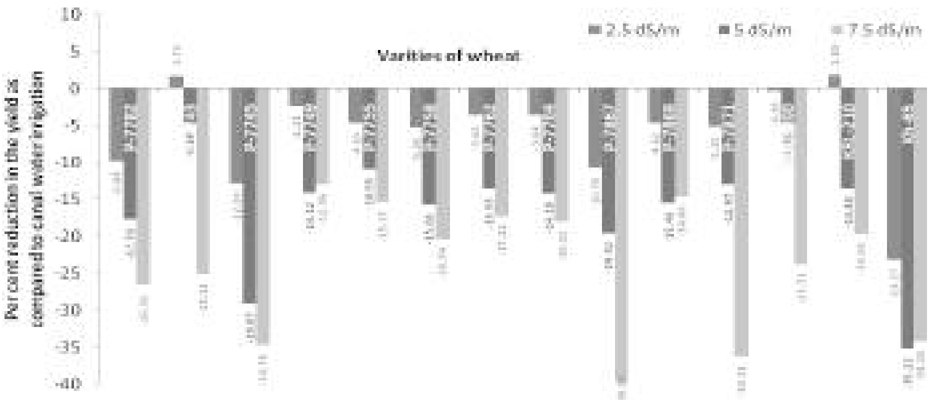


Fig. 5.3. Effect of saline and canal water irrigation on yield of wheat varieties (2010-11)

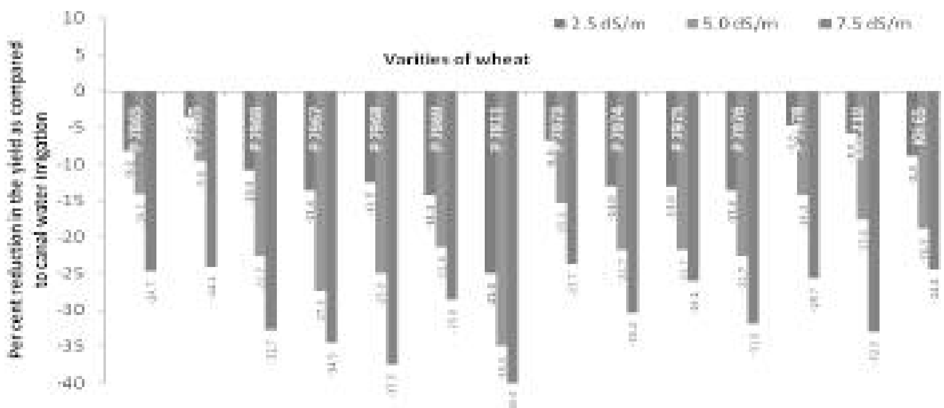


Fig. 5.4. Effect of saline and canal water irrigation on yield of wheat varieties (2011-12)

Physiological observations on osmotic potential, excised leaf water retention and SPAD chlorophyll content were recorded under different treatments. Osmotic potential recorded to test the tolerance of genotypes to salinity stress. Genotypes such as P-7745, P-7749, P-7682, P-7743 and P-7764 were found to be less sensitive to salinity stress of 7.5 dS/m on the basis of osmotic potential. The mean osmotic potential varied from 1.69 to 1.88 µmol $CO_2/m^2/s$, minimum in P-7758 and maximum in P-7682 genotypes (Table 5.19).

Table 5.19. Effect of salinity on osmotic potential of wheat varieties

Varieties	Osmotic potential (-Mpa)				
	Canal	2.5	5.0	7.5	Mean
P7682	1.97	1.92	1.84	1.78	1.88
P7743	1.92	1.83	1.79	1.77	1.82
P7745	1.86	1.84	1.83	1.83	1.84
P7749	1.85	1.84	1.80	1.78	1.82
P7755	2.05	1.88	1.67	1.66	1.82
P7758	1.85	1.78	1.67	1.45	1.69
P7762	2.01	1.89	1.77	1.59	1.81
P7764	1.89	1.80	1.76	1.71	1.79
P7867	2.00	1.79	1.71	1.61	1.78
P7869	2.24	1.81	1.75	1.53	1.83
P7871	2.06	1.85	1.80	1.39	1.77
WH1090	1.96	1.83	1.77	1.67	1.81
KRL-210	1.85	1.74	1.59	1.45	1.66
KH-65	1.87	1.81	1.76	1.69	1.78
Mean	1.95	1.83	1.75	1.64	1.79

Mustard: During 2010-11, twelve mustard genotypes were tested under IVT trials, whereas, five genotypes were tested under AVT II trials. Under IVT trial, CSCN-10-1 produced highest seed yield (169 g/m^2) followed by CSCN-10-12 (164 g/m^2) at EC_{iw} 7.5 dS/m (Table 5.20). Under AVT II trial, CSCN-10-16 produced maximum yield (226 g/m^2) followed by CSCN-10-13 (224 g/m^2) at EC_{iw} of 7.5 dS/m (Table 5.21). EC in the soil profile under 7.5 dS/m remained highest (Table 5.22).

Table 5.20. Grain yield (g/m^2) of mustard genotypes under different salinity waters

Genotypes	Grain yield of mustard genotypes under IVT at EC_{iw} (dS/m)				
	Canal	2.5	5.0	7.5	Mean
CSCN-10-1	238	196	191	169	199
CSCN-10-2	199	186	162	162	177
CSCN-10-3	164	138	130	114	136
CSCN-10-4	176	153	112	99	135
CSCN-10-5	239	196	142	112	172
CSCN-10-6	249	231	207	142	207
CSCN-10-7	139	126	113	104	120
CSCN-10-8	189	174	150	99	153
CSCN-10-9	224	178	145	127	168
CSCN-10-10	189	163	137	122	153
CSCN-10-11	169	132	117	97	129
CSCN-10-12	276	238	187	164	216
Mean	204	176	149	126	
CD (5%)	Variety (V): 15.27; Salinity(S): 8.81; VxS: 30.54				

Table 5.21. Grain yield (g/m²) of mustard genotypes under different salinity waters

Genotypes	Grain yield mustard genotypes under AVT-II at different EC_{iw} (dS/m)				
	Canal	2.5	5.0	7.5	Mean
CSCN-10-13	314	276	244	224	265
CSCN-10-14	270	257	226	212	242
CSCN-10-15	320	283	257	207	267
CSCN-10-16	296	276	256	226	264
RH-30	265	227	208	206	227
Mean	293	264	238.42	215.25	
CD (5 %)	Variety (V): 15.76; Salinity (S): 14.09; VxS: NS				

Table 5.22. Soil salinity at sowing of mustard in different saline irrigation treatments

Depth of Soil (cm)	EC_e (dS/m)			
	Canal	2.5	5.0	7.5
0-15	1.9	4.4	8.4	10.9
15-30	2.3	5.5	9.2	10.8
30-45	2.1	5.2	8.2	9.8
Mean	2.1	5.0	8.6	10.5

During 2011-12, six mustard genotypes under IVT-I trials and four genotypes under AVT-II trials were tested. The yield of mustard genotypes decreased with increase in EC of irrigation water (Fig. 5.5). Under IVT-I trial, CSCN-11-3 gave the highest seed yield (269.2 g/m²) and under AVT-II trial, CSCN-11-10 gave the highest yield (206.6 g/m²).

Salinity in the soil profile (0-45 cm) at sowing was varied from 2.1 to 10.5 dS/m. EC in the soil profile under 7.5 dS/m EC plot remained highest throughout the soil profile as compared to other treatments.

Sorghum: Eleven genotypes of sorghum were evaluated for fodder yield, component traits and quality under different salinity conditions. Significant decrease in the fodder yield and its components was observed with the increased level of salinity. The loss was maximum in EC_{iw} 12.0 followed by EC_{iw} 8.0 and EC_{iw} 4.0 dS/m. Membrane injury increased with increased salinity level in all the genotypes.

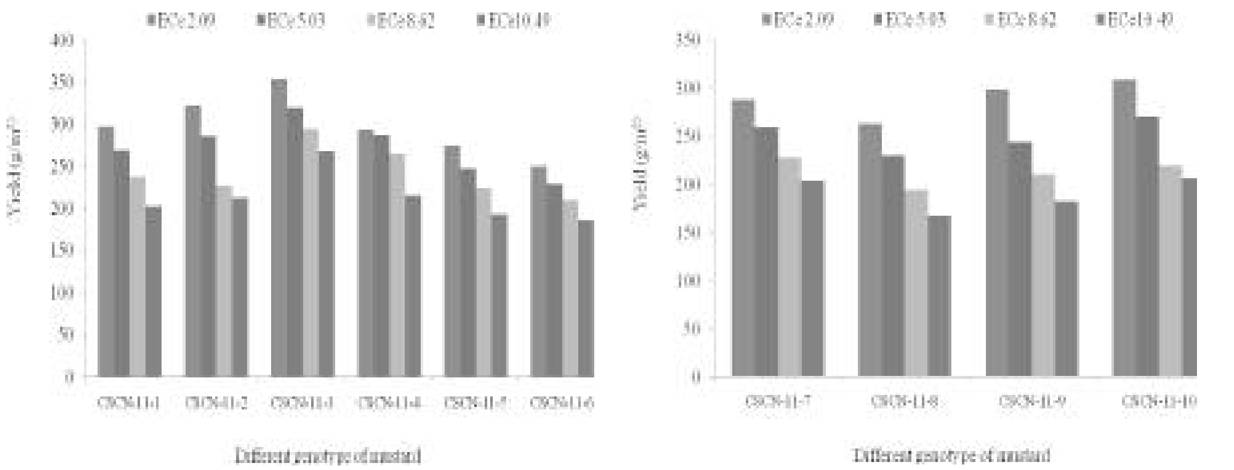


Fig. 5.5. Effect of salinity on yield of mustard genotypes under IVT and AVT2 trial during 2011-12

Screening of Crop Cultivars in Sodic Environment

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

The maximum survival percent and yield was observed in brinjal followed by cauliflower and bottle gourd, except yield of sponge gourd ranked second at ESP 25. The survival percentage of tomato and bitter gourd was <50% at ESP 35 however the survival percentage of cauliflower and brinjal was >50% even at ESP 55 (Table 5.23).

Table 5.23. Survival per cent and yield of vegetables at different ESP levels

Crops	ESP levels			
	25	35	45	55
	Survival (%)			
Cauliflower	87	72	60	51
Tomato	56	42	24	11
Brinjal	91	77	65	52
Bitter Gourd	44	24	16	06
Bottle Gourd	72	51	31	12
	Yield of vegetables (t/ha)			
Cauliflower	5.37	4.63	3.70	1.85
Tomato	2.96	1.76	1.30	0.56
Brinjal	12.96	8.33	4.63	3.70
Bitter Gourd	0.37	0.00	0.00	0.00
Bottle Gourd	11.11	3.70	1.67	1.30

Fig. 5.6. Performance of cauliflower at ESP 25 and Brinjal at ESP 55

Performance of different mustard varieties under alkali condition (Kanpur)

Sixteen varieties of Indian mustard were sown at ESP 42.5. Maximum plant population was recorded in variety CSCN-10-15 and minimum in variety CSCN-10-09. Plant height was maximum (215.5 cm) in variety CSCN-10-01 followed by CSCN-10-02. Maximum number of branches was recorded in CSCN-10-03. Maximum number of pods per plant 308.0 was obtained in CSCN-10-12. Test weight was maximum in variety CSCN-10-02. Highest seed yield was recorded in the variety CSCN-10-01 (1.6 t/ha) followed by CSCN-10-15 (1.5 t/ha) (Table 5.24).

Table 5.24. Evaluation of salinity/alkalinity tolerance lines of rapeseed mustard (2010-11)

Variety	Plant Population	Plant height (cm)	No. of branch/ plant	No. of pods/ plant	Test weight (g)	Seed yield (t/ha)
			IVT			
CSCN 10-01	141.5	215.5	7.0	590.5	5.8	1.6
CSCN 10-02	136.2	198.0	7.5	298.7	7.2	1.4
CSCN 10-03	132.0	157.4	8.2	200.0	5.1	0.8
CSCN 10-04	130.0	166.0	7.5	185.2	4.1	1.0
CSCN 10-05	120.5	186.7	6.1	265.4	5.8	0.6
CSCN 10-06	115.4	167.6	6.5	257.3	4.7	0.8
CSCN 10-07	105.6	188.0	7.2	298.4	5.2	1.2
CSCN 10-08	127.3	163.5	5.0	232.0	4.5	1.1
CSCN 10-09	98.2	162.0	6.3	180.2	6.5	1.2
CSCN 10-10	117.0	170.5	8.0	205.5	4.4	0.9
CSCN 10-11	122.5	190.4	6.2	305.4	5.3	0.8
CSCN 10-12	107.4	185.2	6.6	308.0	6.4	1.3
			AVT			
CSCN 10-13	270.5	195.0	5.5	270.5	4.8	1.1
CSCN 10-14	252.0	180.5	4.7	258.0	5.2	1.3
CSCN 10-15	288.4	175.2	7.7	250.4	6.7	1.5
CSCN 10-16	234.5	173.4	7.8	306.5	4.5	0.9

Evaluation of different crops for their tolerance to sodicity levels (Trichy)

Initial soil pH 8.6, EC 0.43 dS/m, CEC 21 cmol (p+)/kg and ESP 16 and clay loam in texture. The irrigation water was highly alkali with pH 9.0, EC 1.7, RSC 10.5 and SAR 10.7. Green gram varieties VBN2, CO6 and CO7 were tested under different ESP levels during June 2010 and maize variety (CO1) and hybrids viz., COHM5, C818 were tested during 2011.

Green gram: Significantly higher plant height (59.2 cm) and number of pods/plant (107) was recorded for CO6 as compared to VBN2 and CO7. However, as the ESP level increases all the parameters were decreased significantly. In general, all the varieties recorded lower Na as compared to K uptake. Irrespective of the varieties, higher Na/K ratio was observed in roots as compared to seed and shoot. Green gram variety CO6 recorded yield of 350 Kg/ha which was significantly higher as compared to CO7 (300 Kg/ha) and VBN2 (240 Kg/ha). The highest mean yield was recorded at ESP 9.7 (442 Kg/ha) which was reduced to 175 Kg/ha at ESP 36 (Table 5.25). Irrespective of varieties the yield was significantly reduced with increasing ESP from 9.6 to 36. Soil pH and EC was reduced after green gram as compared to initial status, might be due to leaching of salts in summer showers received during the crop growth period (Table 5.26).

Table 5.25. Green gram yield under different ESP levels (2010)

ESP levels	Green gram seed yield (kg/ha)			
	VBN2	CO6	CO7	Mean
9.6	340	527	460	442
16	270	395	307	324
27	201	278	269	249
36	145	216	163	175
Mean	240	354	300	
CD (5%)	M: 50; S: 45; MxS: 88; SxM: 90			

Table 5.26. Effect of treatments on soil pH and EC after green gram

ESP levels	Soil pH				Soil EC (dS/m)			
	VBN2	CO6	CO7	Mean	VBN2	CO6	CO7	Mean
9.6	7.97	7.99	7.88	7.95	0.08	0.08	0.08	0.08
16	8.32	8.54	8.47	8.44	0.12	0.12	0.13	0.12
27	8.88	8.86	8.85	8.86	0.17	0.17	0.17	0.17
36	9.16	9.18	9.38	9.24	0.24	0.22	0.21	0.22
Mean	8,58	8.64	8.64	--	0.15	0.15	0.15	--
CD (5%)	M: .08	S: .06	MxS:0.13	SxM:0.13	M:0.018	S:0.008	MxS:0.023	SxM:0.016

Maize: Biometric observations for maize variety/hybrids revealed that hybrid C818 recorded highest plant height (211 cm), cob length (11.8 cm) and number of grain lines/cob (12) and differ significantly as compared to CO1 and COHM5. In general, all the varieties/hybrids were recorded lower Na uptake as compared to K uptake. Na and K ratio was higher in the shoot as compared to seed and shoot. Among the maize variety and hybrids tested, hybrid C818 recorded a yield of 1.51 t/ha which was significantly higher than other variety and hybrid viz., CO1 (0.97 t/ha) and COHM5 (0.53 t/ha) respectively. At ESP 9.5, maximum yield (3.24 t/ha) was recorded in hybrid C818 and it was decreased as the ESP levels increases and yielded 0.38 t/ha at ESP 34 (Table 5.27).

Table 5.27. No. of grain lines/cob and maize yield under different ESP levels

ESP levels	Maize yield (t/ha)				Number of maize grain lines			
	(CO1)	(COHM5)	(C818)	Mean	CO1	COHM5	C818	Mean
9.5	2.19	1.13	3.23	2.19	13	12	13	13
16	0.92	0.58	1.59	1.03	12	12	13	12.5
26	0.51	0.23	0.81	0.52	11	10	12	11.4
34	0.24	0.17	0.38	0.27	9	8	10	9.4
Mean	0.97	0.53	1.51		11	10	12	
CD (5%)	M:0.13	S: 0.24	MxS: 1.19	SxM: 0.47	M:0.6	S: 0.5	MxS:0.98	SxM:0.9

Cotton: Significant difference was observed in yield attributing characters viz., monopodia, symbodia and bolls/plant under different ESP levels in all hybrids and varieties at all ESP levels. Among varieties and hybrid tested, RCH-20 performed better in producing the more monopodial, symbodial branches and more number of bolls/plant. In general the growth parameter and yield attributing parameters were decreased as the ESP level increases. Among the cotton hybrids RCH-20 recorded highest plant height (96.25 cm) and variety SVPR-2 recorded lowest plant height (63.5 cm). Cotton hybrid RCH-20 recorded the maximum seed cotton yield of 1.33 t/ha and the variety SVPR-2 recorded the lowest of 0.81 t/ha (Table 5.28). The seed cotton yields of each hybrid and variety significantly reduced with increased ESP levels. Irrespective of the hybrid and variety tested the yield was decreased from 1.41 to 0.70 t/ha for ESP level of 9.2 to 41.

Table 5.28. Seed cotton yield under different ESP levels

ESP levels	Seed cotton yield (t/ha)			
	Surabhi	RCH-20	SVPR-2	Mean
9.8	1.26	1.88	1.08	1.41
17	1.13	1.43	0.88	1.15
30	0.93	1.14	0.73	0.93
41	0.68	0.88	0.53	0.70
Mean	1.00	1.33	0.81	
CD (5%)		M: 1.66; S: 0.28		

Fig. 5.7. Green gram crop under different ESP levels

Fig. 5.8. Maize crop under different ESP levels

Research Accomplishments
6. Operational Research Projects

- ORP on use of underground saline water at farmer's field (Agra)
- ORP on low cost artificial recharge technology for dilution of saline groundwater (Agra)
- ORP on demonstration of reclamation technologies for black alkali soils (Bapatla)
- ORP on performance of groundnut with saline water through drip irrigation (Bapatla)
- ORP on micro-irrigation system with saline water for different vegetables (Bapatla)
- ORP on effect of gypsum application on crop yield and soil at farmers' fields (Indore)

ORP on use of underground saline water at farmer's field (Agra)

The field demonstrations on use of poor quality water under ORP were initiated in 1993 and implemented in Nagla Hridaya, Bhojpur, Savai of Agra district, Odara and Nagla Parasuram of Bharatpur district. 17 and 24 demonstrations were made during 2010-11 and 2011-12. On the basis of water quality, suitable management options were implemented (Tables 6.1, 6.2).

Table 6.1. Water quality of farmer's tube well

S. No	Name of farmer	EC_{iw} (dS/m)	RSC (meq/l)	SAR $(mmol/l)^{1/2}$
		Alkali water		
1	Rajesh Kumar	3.0	8.8	17.0
2	Om Prakash	4.4	7.6	23.9
3	Laxman Singh	3.0	7.8	13.5
4	Hakim Singh	5.1	6.2	24.7
5	Vijay Dixit	3.5	12.0	19.0
6	Satya Prakash	2.7	11.8	16.0
		Saline Water		
1	Subhash Chand	10.0	-	11.0
2	Dhara Singh	15.2	-	20.8
3	Amar Chand	13.5	-	12.5
4	Ram Bharosee	15.0	-	19.0
5	Hari Prasad	13.5	-	12.5
6	Lal Hans	10.9	-	16.2
7	Dinesh Chand	11.0	-	17.0
8	Mukesh Kumar	13.8	-	24.0
9	Roop Singh	23.5	-	24.9
10	Virendra Singh	19.9	-	23.5
11	Jagan Singh	12.6	-	15.5
12	Dal Chand	12.5	-	17.3
13	Munsi lal	12.0	-	13.8
14	Rohan Singh	13.2	-	23.3
15	Narayan Singh	6.0	-	13.1
16	Mukesh (NP)	15.2	-	13.2
17	Dara Singh	23.0	-	30.0
18	Mohan Singh	5.8	-	12.9
19	Gyanedra Singh	16.7	-	13.9

Table 6.2. Grouping of farmers on the basis of different categories (2010-11, 2011-12)

Group	No. of farmers		Water quality problem	Management strategy
	2010-11	2011-12		
A	-	5	Alkalinity	Gypsum application
B1	2	3	High SAR saline	Conjunctive use of saline + fresh water
B2	-	-	High SAR saline	Dhaincha GM-wheat with post sowing sprinkler irrigation
B3	9	10	High SAR saline	Dhaincha GM-sorghum fodder, bajra-wheat and mustard with rain conserved moisture and pre-sowing irrigation
C	6	6	Saline	Saline water irrigation with crop & fertilizer management

During 2010-12, gypsum was applied on the basis of soil test (50% GR) in seven farmer's field having alkali water tube wells. The yield of pearl millet revealed that the incorporation of gypsum increased the grain yield by 14.1 to 15.6 per cent and decreased soil EC, pH and ESP (Table 6.3).

Table 6.3. Pearl millet yield (t/ha) in alkali water and soil characteristics at harvest (0-30 cm)

Name of farmer	Treatments	Average of 2010-11 and 2011-12					
	Gypsum application	Yield (t/ha)	Per cent increase	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$	ESP
Rajesh Kumar	Gypsum 50%GR	1.92	15.0	1.6	8.5	10.6	13.4
	No Gypsum	1.67	-	1.7	8.8	11.6	14.3
Om Prakash	Gypsum 50%GR	2.78	14.4	2.1	8.7	9.6	15.5
	No Gypsum	2.43	-	2.8	8.9	12.1	17.5
Laxman Singh	Gypsum 50%GR	2.18	14.7	1.9	9.0	15.4	20.1
	No Gypsum	1.90	-	2.0	9.5	20..5	27.0
Hakim Singh	Gypsum 50%GR	2.37	15.6	2.7	8.6	12.6	14.6
	No Gypsum	2.05	-	2.8	8.8	14.7	18.2
Vijay Dixit	Gypsum 50%GR	2.50	15.2	2.3	8.9	11.2	17.8
	No Gypsum	2.17	-	2.4	9.2	16.7	22.4
Satya Prakash	Gypsum 50%GR	2.10	15.4	1.7	8.3	8.8	12.7
	No Gypsum	1.82	-	2.0	8.5	11.1	15.1
Krapa Shankar	Gypsum 50%GR	2.83	14.1	1.8	8.2	6.6	9.3
	No Gypsum	2.48	-	1.9	8.4	13.6	15.0

In high SAR saline water, pearl millet grain yield varied from 2.3-2.8 t/ha in ORP demonstration fields and yield was 9.2-20.4% higher as compared to traditional farming. Dhaincha produced seed yield of 0.5-0.8 t/ha whereas, fodder yield of sorghum varied from 23.1-31.0 t/ha (Table 6.4).

Table 6.4. Crop yields in saline water and soil characteristics at harvest (Av. 2 years)

Name of farmer	Crop	Yield (t/ha)		Per cent increase	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
		ORP	Farmers				
Shubhash Chand	Pearl millet	2.68	2.30	16.5	2.5	7.8	9.5
Dhara Singh	Pearl millet	2.62	2.40	9.2	2.7	7.4	11.0
Amar Chand	Sorghum F	28.12	-	-	2.5	7.6	9.2
	Dhaincha GM	-	-	-	3.2	7.5	12.3
Ram Bharose	Pearl millet	2.37	2.00	18.5	2.4	7.8	6.3
	Dhaincha S	0.77			3.9	7.6	11.8
Hari Prasad	Sorghum F	23.06	-	-	3.1	7.5	11.6
Lal Hans	Pearl millet	2.50	2.15	16.3	2.6	8.0	10.8
Dinesh Chand	Dhaincha GM	-	-	-	2.5	8.1	9.1
Mukesh Kumar	Sorghum F	29.5	-	-	3.0	7.3	12.1
	Dhaincha S	0.55	-	-	1.6	7.8	5.0
Roop Singh	Pearl millet	2.43	2.15	13.0	3.4	8.0	11.8
Jagan Singh	Pearlmillet	2.27	2.00	13.5	2.6	7.1	9.3
Dal Chand	Dhaincha S	0.52	-	-	2.8	7.6	7.7
	Dhaincha GM	-	-	-	4.5	8.0	18.9
Rohan Singh	Dhaincha S	0.48	-	-	3.2	7.9	11.3

Munsi Lal	Dhaincha GM	-	-	-	2.9	7.7	11.4
Birendra Singh	Pearl millet	2.77	2.30	20.4	3.5	7.7	11.1
Narayan Singh	Sorghum F	31.0	-	-	3.5	7.8	13.6
	Dhaincha GM	-	-	-	2.1	8.0	7.1
Mukesh (NP)	Dhaincha S	0.64	-	-	3.6	7.5	11.7
	Dhaincha GM	-	-	-	2.0	7.9	8.0
Dara Singh	Dhaincha S	0.72	-	-	4.4	7.7	16.7
	Dhaincha GM	-	-	-	1.3	7.8	11.9

S : Seed; GM : Green manure; F : Fodder

During rabi season, wheat crop was sown at 10 farmers' field, seven on flat and three on bed sowing at Savai (Mangalpur). The average increase in wheat yield varied from 7.2 to 14.0 per cent and soil pH, SAR and ESP decreased in gypsum treated fields over control (Table 6.5).

Table 6.5. Effect of gypsum on wheat yield and soil characteristics at harvest (Av. of 2 years)

Name of farmer	Treatment	ORP yield (t/ha)	% increase over control	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$	ESP
			Flat sowing				
Rajesh Kumar	Gypsum	4.5	9.7	2.7	8.8	14.5	20.7
	No gypsum	4.1	-	3.4	8.9	18.3	24.0
Om Prakash	Gypsum	4.4	7.3	3.7	8.7	18.0	26.0
	No gypsum	4.1	-	3.9	8.8	21.5	29.0
Hakim Singh	Gypsum	4.2	7.2	10.0	8.6	26.2	29.1
	No gypsum	3.9	-	10.3	8.7	28.2	31.1
Laxman Singh	Gypsum	5.0	13.6	3.6	8.9	19.7	26.3
	No gypsum	4.4	-	3.8	9.1	20.8	28.7
Satya Prakash	Gypsum	4.7	10.0	3.5	8.7	16.7	23.8
	No gypsum	4.3	-	4.1	8.8	22.2	28.6
Kripa Shanker	Gypsum	4.4	10.0	3.6	8.7	17.6	24.8
	No gypsum	4.0	-	3.8	8.9	20.7	26.3
Vijay Dixit	Gypsum	4.3	7.5	4.3	9.1	24.6	28.0
	No gypsum	4.0	-	4.8	9.2	27.2	34.0
			Bed Sowing				
Rajesh Kumar	Gypsum	4.5	9.7	2.7	8.8	14.5	20.7
	No gypsum	3.0	-	3.4	8.9	18.3	24.0
Satya Prakash	Gypsum	2.9	14.0	3.5	8.7	16.7	23.8
	No gypsum	2.7	-	4.1	8.8	22.2	28.6
Laxman Singh	Gypsum	2.9	14.0	3.6	8.9	19.7	26.3
	No gypsum	2.7	-	3.8	9.1	20.8	28.7

Conjunctive use of low salinity water/high salinity water: The combined use of low and high salinity water was demonstrated on 3 farmer's field. Almost similar wheat yield was obtained in 2 low salinity water + rest saline tube well water and one low salinity + rest saline tube well water. Whereas, in two low salinity + rest saline tube well water the slight increase in the yield (5.3 t/ha) was recorded. In demonstration fields, the average wheat yield increased by 15.2 per cent over farmer's field and soil salinity and SAR increased at farmers fields with poor quality irrigation water (Table 6.6). The demonstrations were conducted at 9 recharge sites and other farmers' field. The yield of farmers fields with high saline water varied from 3.9 to 4.7 t/ha (Table 6.7).

Table 6.6. Wheat yield and soil characteristics at harvest (0-30cm) in conjunctive water use

Name	Treatment	Crop/ variety	Yield (t/ha)		Increase in ORP (%)	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
			ORP	Farmers				
Subhash Chand	2LSW:RTS	Lok-1	5.30	4.60	15.2	14.8	7.7	17.8
Mohan Singh	1LSW:RTS	PBW 502	5.17	4.65	11.1	12.3	7.7	16.6
Gyanendra Singh	1LSW:RTS	HD 3765	5.25	4.50	16.7	16.0	7.8	21.3

LSW- Low salinity water; RTS-Rest tube well saline; C: Crop and fertilizer management

Table 6.7. Effect of saline water on yield of wheat and soil characteristics at recharge sites

Name of farmer	Yield (t/ha)		Increase in ORP (%)	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
	ORP	Farmers				
Jagan Singh	5.4	4.7	13.3	15.1	7.3	22.3
Mukesh Kumar	4.7	4.1	14.0	13.5	7.6	19.4
Birendra Singh	4.7	4.1	14.7	14.2	7.5	20.2
Lal Hans	4.7	4.2	12.8	15.8	7.8	24.4
Dinesh Chand	4.7	4.2	13.1	11.8	8.0	19.7
Dhara Singh	5.0	4.4	15.2	11.9	7.7	21.1
Ram Bharosi	4.5	3.9	15.4	17.3	7.7	27.4
Roop Singh	4.8	4.1	17.1	19.3	7.8	29.8
Hari Prasad	5.0	4.3	16.3	15.3	7.6	14.8

Wheat was sown in conserved moisture to improve the seed emergence in saline condition and afterwards saline water was applied to the crop. The wheat yield increased by 10.5 per cent over farmer's field using saline water for pre-sowing irrigations (Table 6.8). Average salinity of water at recharge sites varied from 4.1 to 6.7 at pre-sowing irrigation, 7.4 to 9.7 dS/m at 2nd irrigation, 9.6 to 16.4 at 3rd irrigation, 10.9 to 17.7 at 4th irrigation and 11.0 to 20.5 dS/m at 5th irrigation. Whereas the initial water salinity varied from 10.9 to 23.5 dS/m (Table 6.9).

Table 6.8. Effect of recharge water on wheat yield and soil characteristics at harvest

Name of farmer	Variety	Yield (t/ha)		Increase in ORP (%)	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
		ORP	Farmers				
Hari Prasad	Lok-1	5.1	4.7	9.6	16.7	7.3	25.4
Ram Bharose	„	4.9	4.4	11.5	11.1	7.8	23.5
Roop Singh	„	4.4	4.0	10.5	17.5	7.8	26.0

Table 6.9. EC_{iw} (dS/m) during different irrigations at rain water recharging sites

Name of farmer	Initial	Salinity under Irrigations					
		I	II	III	IV	V	VI
Lal Hans	10.9	5.4	9.5	10.0	11.0	10.9	10.9
Ram Bharose	15.0	*	9.2	12.5	14.1	14.4	-
Jagan Singh	12.6	4.1	8.8	10.4	11.1	10.8	11.9
Dhara Singh	15.2	6.7	9.7	11.3	13.5	13.7	14.7
Mukesh Kumar	13.8	*	9.0	11.9	12.8	13.4	-
Hari Prasad	13.5	RCM	7.8	9.6	13.1	13.5	-
Dinesh Chand	11.0	4.7	8.3	9.6	10.9	11.0	-
Birendra Singh	19.9	*	7.4	14.4	17.7	16.6	-
Roop Singh	23.5	*	9.6	16.4	20.1	20.5	-

**Ist irrigation with submersible tube well water (deep bore water)*

ORP on low cost artificial recharge technology for dilution of saline groundwater (Agra)

Agra-Bharatpur region in the states of U.P. and Rajasthan are endowed with poor quality groundwater aquifers. Shallow aquifers are relatively more saline (10-15 dS/m) relative to deeper aquifers (2-6 dS/m). The resource poor farmers of the region who cannot afford to drill deep bores are contented with exploiting the saline aquifers to give on 1-2 life saving irrigation (s) to mustard. Thus, under such a situation, yields are reduced due to high salinity. Diluting saline ground water through artificial recharge has been designed and tested on 12 farmer's fields. The technology consisted of diverting the run off to these structures for recharge. The diluted ground water is then pumped to irrigated mustard/wheat. The salinity of the ground water is reduced in most cases to less than 4 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 the case of mustard and wheat.

ORP on demonstration of reclamation technologies for black alkali soils (Bapatla)

The experiment was laid out at five locations at J.V. Palem and Gangupalem villages in Prakasam district. Gypsum was applied as per soil test value and dhaincha was grown and ploughing insitu at 50% flowering stage. $ZnSO_4$ was applied as basal kg/ha. N-P_2O_5 –K_2O was applied 180-60-40 kg/ha (N-50% extra). The initial soil analysis indicated that pH_s ranged from 8.3 to 8.9, EC_e ranged from 2.10 to 7.56 dS/m, available N was low and P was medium and K was high. The paddy variety NLR-T-145 was transplanted during *kharif*, 2010 under NSP canal area. Results showed that application of gypsum increased the yield of paddy by 35.7 to 77.1% over control (Table 6.10).

During 2011-12 experiment was laid out at 5 locations viz., Gangupalem, Kondamuru, Konidana and J.V. Palem villages of Prakasam district. The initial pH_s ranged from 7.17 to 8.02 and EC_e from 1.7 to 18.3 dS/m, available N was low, P_2O_5 was medium and high in K, the ESP ranged from 12.1 to 16.4. Final soil analysis indicated that pH_s and EC_e was decreased over initial status while available N, P_2O_5, and K_2O slightly increased. Rice variety NLR-9674 grain yield ranged from 4.95 to 7.25 t/ha in gypsum treated plots against 4.02 to 5.85 t/ha in control which was 20.9 to 23.9 per cent higher than control (Table 6.11).

The results revealed that adoption of package of practices for reclamation of alkali soils gave higher grain yields over the control (farmers practice) at all locations (Table 6.11). Per cent increase in grain yield varied from 14.8 to 55.9 across the locations. The highest gross returns (Rs.72425/-), net returns (Rs.34687/-) and BCR (1.92) was recorded in the field of K V Reddy during third year. Soil EC and pH also reduced and the fertility status improved due to incorporation of green manure crop before rice and application of gypsum.

Table 6.10. Initial soil parameters and rice yield at selected locations, Prakasam (2010-11)

Farmer	Village	Cropping system	EC_e (dS/m)	pH_s	N	P_2O_5	K_2O	Yield (t/ha)	
					(kg/ha)			Treated	Check
G.V'warlu	Gangupalem	Rice-Fallow	2.63	8.50	185	26.0	385	4.75	3.23
P'.Sriramulu	Gangupalem	Rice-Fallow	2.87	8.74	202	31.0	402	3.83	2.77
K. J. Rao	Gangupalem	Rice-Fallow	2.54	8.34	215	28.5	365	4.51	3.33
K. Ayulu	Gangupalem	Rice-Fallow	2.10	8.47	208	30.8	408	4.94	3.39
J.J. Rao	J V Palem	Rice-Fallow	7.56	8.90	188	28.5	363	4.38	2.47

Table 6.11. Rice yield as influenced by reclamation technologies, Prakasam (2011-12)

Name of farmer	Village	Grain Yield (t/ha)		Per cent increase	Gross Returns (Rs.)	Net Returns (Rs.)	BCR
		Treated	Check				
G. Venkateswarlu	Gangupalem	5.64	4.65	20.9	53825	16087	1.43
K. Sivaiah	Gangupalem	5.25	4.30	22.1	57313	19575	1.52
S. Bhoolakshmi	Kondamuru	5.63	4.60	22.3	72425	34687	1.92
K. Venkat Reddy	Kondamuru	7.25	5.85	23.9	57313	19575	1.52
V. Anjaneyulu	JV Palem	4.95	4.02	23.3	51035	13297	1.35

Cost of cultivation: Rs.37738/- per ha; Price per quintal: Rs. 1025/-

ORP on performance of groundnut with saline water through drip irrigation (Bapatla)

Plant height, dry matter accumulation, branches and pods per plant decreased with increasing salinity from 2 to 8 dS/m. Test weight and pod yield significantly reduced with each increment of salinity up to 8 dS/m. Similarly, oil content decreased with increased salinity and sodium uptake increased with increasing salinity of water (Table 6.12).

Table 6.12. Yield attributes and yield of groundnut under saline water through drip irrigation

Treatments	Pods/ plant	Test weight (g)	Pod yield (t/ha)	Stover yield (t/ha)	HI (%)	Oil (%)	Na uptake (kg/ha)
Saline water (dS/m)							
BAW	28	74.7	2.89	4.42	39.5	49.1	4.92
2	23	69.9	2.56	3.90	39.6	48.7	6.68
4	17	66.2	2.10	3.36	38.4	47.6	7.97
6	12	63.7	1.47	2.82	34.2	47.3	10.24
8	7	63.1	1.11	2.38	31.7	46.2	11.40
CD (5%)	5.0	2.7	0.33	0.52	-	-	-
CV (%)	17.4	2.6	10.6	10.0	-	-	-

ORP on micro-irrigation system with saline water for different vegetables (Bapatla)

During *rabi*, 2010-11, an experiment was laid out with four levels of irrigation i.e., BAW of horizontal skimming well (<0.5 dS/m) and saline water of 2, 4, 6 dS/m (by mixing of fresh water and sea water of 35 dS/m) to know the response of different vegetables viz., tomato, bhindi, cluster bean and radish. Cluster bean and bhindi crops failed due to prolonged water logging. The mean yield of tomato showed that drip irrigation with BAW treatment recorded highest yield of 16.18 t/ha followed by 15.44 t/ha, 11.36 t/ha , 8.46 t/ha in drip irrigation with 2, 4 and 6 dS/m which indicates 4.55%, 29.79% and 47.73% reduction in yield respectively (Table 6.13). The threshold salinity levels for 90%, 75% and 50 % yield of tomato are 2.2, 3.9 and 6.1 dS/m (Table 6.14) as against 2.4, 4.0 and 6.1 dS/m respectively during 2010-11. The mean yield of radish showed that drip irrigation with BAW recorded the highest yield of 13.14 t/ha followed by 12.61, 10.60 and 8.10 t/ha in drip irrigation with 2, 4 and 6 dS/m saline water treatments, which shows 4.02, 19.34 and 38.34% reduction in yield respectively (Table 6.13). The threshold salinity levels for 90, 75 and 50% yield of radish are 2.85, 4.73 and 6.9 dS/m respectively (Table 6.14).

During *rabi* 2011-12, the experiment consists of four levels of irrigation i.e., BAW of horizontal skimming well (<0.5 dS/m) and saline water of 2, 4, 6 dS/m (by mixing of fresh water and sea water of 35 dS/m) to know the response of different vegetable crops viz i.e radish, cluster bean and leafy vegetables. Radish is harvested during Jan. 2012. Leafy vegetables partially and cluster bean completely damaged due to heavy rains on 31 December 2011 and 1 January 2012 and waterlogged situation for 3 days in the experimental fields. Soil samples were collected in the experimental fields at the initial stage and at the harvest of crops and analysis is yet to be carried out. No clogging of pipes/drippers observed due to accumulation of salts during the crop season.

Table 6.13. Effect of irrigation water quality on yield of vegetables through drip irrigation

Drip line	Yield (t/ha) 2010-11				Yield (t/ha) 2011-12			
	BAW	2 dS/m	4 dS/m	6 dS/m	BAW	2 dS/m	4 dS/m	6 dS/m
Tomato					Radish			
1	15.67	14.89	11.22	8.11	12.8	12.6	10.5	8.2
2	15.56	15.78	11.89	8.67	12.6	12.7	10.5	8.3
3	16.11	15.44	11.22	8.44	14.4	12.3	10.6	8.0
4	16.44	15.00	11.56	8.22	14.7	11.8	10.6	8.3
5	17.11	15.11	11.33	8.33	12.7	12.7	11.4	8.3
6	15.78	15.56	11.44	8.89	12.5	12.3	10.9	8.0
7	17.00	16.22	11.56	8.67	12.7	12.6	10.8	8.5
8	15.78	15.56	10.67	8.33	13.1	12.5	10.9	8.0
Mean	16.18	15.44	11.36	8.46	13.2	12.4	10.8	8.2
Radish					Palak			
1	13.11	12.22	10.22	7.33	10.0	7.6	4.5	3.3
2	13.67	13.22	11.67	7.89	9.9	6.9	5.9	3.4
3	12.67	12.89	11.44	7.56	10.8	7.7	5.1	3.2
4	12.89	12.33	10.89	8.33	9.7	7.7	4.9	3.1
5	12.67	12.44	10.00	7.78	9.4	6.7	5.0	3.5
6	13.78	13.11	9.78	8.89	10.4	7.3	4.4	3.5
7	13.00	12.56	10.33	8.67	9.6	7.3	5.2	3.5
8	13.33	12.11	10.44	8.33	9.8	7.3	5.1	3.3
Mean	13.14	12.61	10.60	8.10	10.0	7.3	5.0	3.3

The relationship between salinity and yield for different vegetables are presented below:

$Y = - 0.0951 x^2 - 0.8674x + 16.909$ (for tomato)

$Y = - 0.1096 x^2 - 0.193x +13.282$ (r^2= 0.9999 for radish)

$Y = 0.1173 x^2 - 1.9527x + 10.853$ (r^2=0.9991 for palak)

Table 6.14. Crop-wise salinity levels for achieving 90, 75 and 50% yield levels

Yield level	90%	75%	50%
	Tomato		
Achieved quantity (t/ha)	14.56	12.14	8.09
Salinity (dS/m)	2.40	4.00	6.10
	Radish		
Achieved quantity (t/ha)	11.84	9.85	6.57
Salinity (dS/m)	2.85	4.73	6.90
	Palak		
Achieving quantity (t/ha)	9.0	7.5	5.0
Salinity (dS/m)	1.0	2.0	4.0

Soil samples were collected at the initial stage, mid season and after harvest of crop. The mean salinity build-up in 0-15 cm depth was increased from 0.19 to 0.46 dS/m after harvest in fresh water irrigation followed by 2, 4 and 6 EC with 0.2-1.01 dS/m, 0.19-1.54 dS/m and 0.21-0.41 dS/m respectively. The corresponding values of EC for 15- 30 cm depth were 0.12-0.33 dS/m, 0.06-0.31 dS/m, 0.12-0.41 dS/m and 0.07-0.67 dS/m in fresh water, 2, 4 and 6 EC irrigation, respectively and at 30-60 cm depth the salinities were 0.05-0.14, 0.04-0.17, 0.07-0.23 and 0.04-0.29 dS/m in fresh water, 2, 4 and 6 EC saline water irrigation, respectively (Table 6.15). Clogging of pipes/drippers was not observed due to salt accumulation during the entire period.

Table 6.15. Salinity buildup and pH in the soil with different saline drip treatments (2010-11)

Treatments	Depth of sample	EC_e (dS/m)			pH		
		Initial	Mid-term	Post crop	Initial	Mid-term	Post crop
BAW	0-15 cm	0.19	0.21	0.46	7.68	7.80	7.90
	15-30 cm	0.12	0.13	0.33	7.70	7.70	7.80
	30-60 cm	0.05	0.06	0.14	7.80	8.00	7.80
2 EC	0-15 cm	0.20	0.45	1.01	7.50	7.40	7.30
	15-30 cm	0.06	0.18	0.31	7.70	7.60	7.60
	30-60 cm	0.04	0.08	0.17	8.00	7.90	7.70
4 EC	0-15 cm	0.19	0.63	1.54	8.00	7.40	7.50
	15-30 cm	0.12	0.20	0.41	8.00	7.80	7.70
	30-60 cm	0.07	0.11	0.23	7.80	8.00	7.60
6 EC	0-15 cm	0.21	0.82	1.82	7.50	7.40	7.40
	15-30 cm	0.07	0.23	0.67	7.70	7.60	7.20
	30-60 cm	0.04	0.15	0.29	7.80	7.60	7.50

ORP on effect of gypsum application on crop yield and soil at farmers' fields (Indore)

Field demonstrations on gypsum application to reclaim alkali soils were carried out in 5 farmer's fields of two villages in Indore and Khargone districts of Malwa and Nimar agro-climatic zones.

Soybean-wheat crop rotation: Demonstrations on soybean (var. JS 9560) and wheat (var. Lok-1) was made at farmer's fields (20 m x 25 m) with recommended package of practices. Gypsum was applied on the basis of soil testing at laboratory. The experimental soils are clay in texture (CEC 39.4-46.8 c mol+/kg) and alkali in nature (ESP 24.9 to 27.9). The gypsum requirement of different farmer's fields were in the range of 10.3-13.8 t/ha. Application of gypsum increased the seed yield of soybean as well as grain yield of wheat over control. Application of gypsum 75% GR results in 78 and 97 per cent yield increase of soybean (Table 6.16) and 58 and 45 per cent yield increase of wheat (Table 6.17) over control during 2010-11 and 2011-12. The perusal of data on exchangeable sodium percentage (ESP) showed that ESP decreased with gypsum application as compared to untreated soil. Lowest ESP was observed under 75% GR followed by 50% GR.

The demonstrations on cotton crop (var. JK-666, Ankur-9, Mallika and RCH-2) were conducted in farmer's fields in Pipliya, Barlai and Bapalgaon villages of Khargone district. Sowing was done at farmer's field with recommended package of practices (seed rate-8 kg/ha, N -120, P-60 and K-30 kg/ha). Gypsum was applied on the basis of laboratory estimates. The experimental soils are clay in texture (CEC 38.6-50.1 c mol+/kg) and alkali in nature (ESP 24.0-30.7). The gypsum requirement of different farmer's fields were in the range of 10.3-14.0 t/ha. Application of gypsum significantly increased the seed cotton yield over control. Application of gypsum 75% GR results in 62 and 85 per cent yield increase over control during 2010-11 and 2011-12, respectively (Table 6.18). The soil ESP decreased with gypsum application as compared to untreated soil. Lowest ESP was observed under 75% GR followed by 50% GR.

Table 6.16. Effect of gypsum application on seed yield of soybean

Treatments	Seed yield of soybean (t/ha)					
	Babulal	Mangilal	Dinesh	Motiram	Badrilal	Mean
			2010-11			
Control	1.50	1.45	1.55	1.45	1.40	1.47
25 % GR	1.80	1.90	1.95	1.70	1.75	1.82
50 % GR	2.40	2.30	2.40	2.20	2.30	2.32
75 % GR	2.50	2.25	2.40	2.45	2.50	2.42
			2011-12			
Control	1.50	1.40	1.35	1.50	1.48	1.45
25 % GR	2.00	1.96	1.94	2.08	2.10	2.02
50 % GR	2.70	2.66	2.60	2.72	2.68	2.67
75 % GR	2.96	2.80	2.76	2.90	2.89	2.86

Table 6.17. Effect of gypsum application on grain yield of wheat

Treatments	Wheat grain yield (t/ha)					
	Badrilal	Motiram	Babulal	Dinesh	Mangilal	Mean
			2010-11			
Control	2.90	2.80	2.70	3.00	2.90	2.86
25 % GR	3.55	3.70	3.60	3.50	3.60	3.59
50 % GR	4.15	4.20	4.30	4.10	4.20	4.19
75 % GR	4.30	4.25	4.30	4.50	4.60	4.39
			2011-12			
Control	3.00	2.90	2.76	2.94	2.90	2.90
25 % GR	3.50	3.66	3.60	3.54	3.50	3.56
50 % GR	4.20	4.14	4.00	4.10	4.08	4.10
75 % GR	4.30	4.20	4.16	4.24	4.20	4.22

Table 6.18. Effect of different doses of gypsum application on seed cotton yield

Treatments	Seed cotton yield (t/ha)					
	Pappu	Balya	Bhagwan/ Hira	Bhagwan/ Laxman	SAS Farm	Mean
			2010-11			
Control	0.80	0.85	0.75	0.85	0.80	0.81
25 % GR	1.10	1.10	1.20	1.15	1.20	1.15
50 % GR	1.20	1.20	1.30	1.25	1.30	1.25
75 % GR	1.30	1.25	1.40	1.35	1.30	1.32
			2011-12			
Control	0.84	0.80	0.77	0.84	0.83	0.82
25 % GR	1.16	1.20	1.20	1.18	1.34	1.22
50 % GR	1.24	1.30	1.28	1.25	1.40	1.29
75 % GR	1.44	1.50	1.52	1.45	1.68	1.52

7. GENERAL

7.1: ORGANIZATION

The All India Coordinated Project on Use of Saline Water in Agriculture was first sanctioned during the IVth Five Year Plan under the aegis of Indian Council of Agricultural Research, New Delhi at four research 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. During the Tenth Plan, Project continued with an outlay of Rs. 1090.00 lakh at these centers with the Coordinating Unit at Central Soil Salinity Research Institute, Karnal. The total outlay of the XI plan has been fixed at Rs. 2125.15 lakhs including the state share of Rs. 436.52 lakhs. The center wise mandate of the project is as follows:

7.2: 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

7.3: 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 31.03.2013

Name of the post	Coordinating Unit, Karnal	Centers							
		Agra	Bapatla	Bikaner	Gangawati	Hisar	Indore	Kanpur	Trichy
Project Coordinator	1	–	–	–	–	–	–	–	–
Chief Scientist	-	–	1	1	1	–	–	–	–
Soil Chemist	1(1)	1	1	1(1)	–	1	1	1	1
Agronomist	1	–	–	–	–	–	–	–	–
Drainage Engineer	–	–	–	–	–	–	1	–	–
Soil Physicist	1(1)	–	–	–	–	–	–	1	–
Jr. Soil Chemist	1(1)	1(1)	1	1	1(1)	1	1(1)	–	1
Jr. Soil Physicist	–	1(1)	–	–	–	–	1	–	–
Jr. Drainage Eng.	–	–	1	1	1	–	–	–	–
Soil Water Eng.	–	–	1(1)	–	1	1	–	–	1
Jr. Plant Physio.	–	–	–	–	–	–	–	-	–
Jr. Agronomist	-	1	1	1	1	1	–	1	1
Jr. Soil Survey Officer	–	–	–	–	–	–	1	1	–
Tech. Officer	1	–	–	–	–	–	–	–	–
STA	–	2	1	2	–	1	2	2(1)	2
Overseer	–	–	–	–	–	–	–	-	–
Lab. Tech.	1	–	–	–	–	–	1	–	–
Tracer	--	–	–	–	–	–	–	–	–
Field Asstt.	–	2(1)	2	1	3	1	1	2(1)	1
Fieldman	–	–	–	–	–	–	1	–	–
Lab. Asstt.	1	1	2	1	1	1	-	1	1
UDC	1(1)	1	1	1	1	1	1	1	1
Jr. Steno.	1(1)	–	–	–	–	–	–	–	–
Jeep Driver	–	1	1	1	1	1	1	1	-
Lab. Attendant	3(2)	1	1(1)	1	1(1)	1	1	1	1
Messenger	-	1	1	1	1	1	1	1	1

( ) Vacant position

STAFF POSITION AS ON 31. 03. 2013

Name of the post	No.	Name of incumbent	Date of joining	Date of leaving
Coordinating Unit, CSSRI, KARNAL				
Project Coordinator	1	Dr. S.K. Gupta	07.06.2007	30.09.2011
Project Coordinator (I/c)		Dr. D.K. Sharma	01.10.2011	26.04.2012
Project Coordinator		Dr. S. K. Ambast	27.04.2012	Contd.
Pr. Scientist (Pedology)	1	Dr. Anil R. Chinchmalatpure	23.09.2010	31.03.2012
Sr. Scientist (Agronomy)	1	Dr. R. L. Meena	18.07.2007	Contd.
Scientist (Soil Science)	1	Dr. B.L. Meena	30.01.2013	Contd.
Sr. Tech. Officer	1	Sh. S.P. Gupta	03.07.2007	31.10.2011
Technical officer	2	Sh. Brij Mohan	04.10.1988	Contd.
		Sh. Anil Sharma	22.10.2011	Contd.
Technical Assistant	1	Sh. N.S. Ahlawat	08.06.2012	Contd.
Personal Assistant	1	Smt. Rita Ahuja	25.04.1992	-
		Vacant	-	-
Lab. Attendant	1	Sukhbir Singh	27.01.2009	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. P.R.K. Prasad	08.11.2008	30.09.2010
		Dr. G.V. Lakshmi	01.10.2010	Contd.
Pr. Scientist (SS)	1	Dr. G.V. Lakshmi	26.08.2008	30.09.2010
Sr. Scientist (SS)		Dr. P. Ravindra Babu	29.08.2008	08.10.2010
		Smt. K. Hema	08.08.2012	Contd.
Jr. Chemist (SS)	1	Smt. M. Latha	28.07.2011	Contd.
Scientist (Agronomy)	1	Sh. P. Venkata Rao	19.02.2010	Contd.
Scientist (SWE) –I	1	Sh. M. Raghubabu	16.10.1993	05.07.2012
		Sh. A. Sambaiah	06.02.2013	Contd.
Scientist (SWE) –II	1	Vacant	-	24.04.2008
Sr. Assistant	1	Sh. M. Raju	28.10.2005	31.03.2011
		Sh. P. Rambabu	01.04.2011	Contd.
Lab. Assistant	3	Sh. S. Baba Vali	04.09.1990	Contd.
		Sh. S.K. Mastan Vali	01.03.2011	Contd.
		Sh. S.K. Moulali	03.05.2006	31.12.2011
		Sh. P. Venkata Seshu	29.01.2013	Contd.
Field Assistant	2	Sh. Syed Khasim	19.05.2005	Contd.
		Sh. K. Siva Kumar	12.07.2006	14.08.2012
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		
Field Assistant	1	Sh. B.C. Kumawat	18.07.2001	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	Contd.
Lab. Attendant	1	Sh. Keshu Ram	17.07.1995	Contd.
Messenger	1	Sh. Ganesh Ram	25.03.1994	Contd.

GANGAWATI

Chief Scientist & OIC	1	Dr. S.L. Budihal	02.11.2009	Transferred
		Dr. Vishwanath J.	04.01.12	Contd.
Scientist (Soil Science)	1	Dr. Vishwanath J.	18.10.2009	30.08.2011
		Mr. Ravikumar D.	30.08.2011	
		Vacant		
Jr. Agronomist	1	Ms. Roopashree D.H.	02.12.2009	27.02.12
		Dr. Anand S.R.	07.11.2012	Contd.
Scientist (SWE)	1	Er. Subhas Balagnavi	15. 07. 1999	27.05.2011
		Er. Rajkumar H.	27.05.2011	Contd.
Jr. Drainage Engineer	1	Sh. 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. N. Narasimhalu	01.02.10	Contd.
		Mr. Ramappa H. Talwar	09.07.2012	Contd.
Lab. Assistant	2	Sh. B. Nagaraj	26.09.2003	21.04.2011
		Mr. Prakash Banakar	21.04.2011	Contd.
L.V. Driver	1	Mr. Basker D. Golasangi	13.08.2010	Contd.
Lab. Attendant	1	Sh. M. Srinath	14.07.2010	-
		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. Vinod K. Phogat	19.06.1997	27.04.2011
		Dr. Ramparkash	24.05.2011	Contd.
Soil Water Engineer	1	Dr. Sanjay Kumar	10.06.1997	Contd.
Agronomist	1	Dr. Satyavan	11.03.1997	Contd.
Sr. Technical Assistant	2	Dr. Rajpaul Yadav	06.06.2011	Contd
		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	Contd.
Lab. Attendant	1	Sh. Surat Singh	25.05.2010	Contd.
Messenger	1	Sh. Karan Singh	01.08.2001	26.07.2010
		Sh. Desh Raj	27.07.2010	Contd.

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. Ravindra Kumar	09.05.2008	Contd.
Soil Physicist	1	Dr. B.N.Tripathi	09.03.2011	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. N.B. Singh	01.08.2009	Contd.
		Vacant	-	-
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.

TRICHY

Soil Chemist & OIC	1	Dr. M.Sheik Dawood	04.03.2010	31.10.2011
		Dr. A. Saravanan	01.11.2011	Contd.
Jr. Soil Chemist	1	Dr. L. Chitra	27.05.2008	Contd.
Jr. Agronomist	1	Dr. S. Somasundaram	03.11.2010	31.05.2011
		Dr. S. Porpavai	01.06.2011	31.07.2011
		Dr. S. Avudaithai	01.08.2011	Contd.
Jr. Soil Water Engineer		Dr. M. Baskar	09.05.2008	Contd.
Sr. Technical Assistant	2	Sh. K. Karikalan	14.12.2000	Contd.
		Sh. S. Senthil Kumar	17.11.2008	08.06.2011
		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	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.

7.4: WEATHER DATA (2010-2012)

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				
			2010-11			
April 2010	39.3	21.3	52.3	000.0	8.8	14.6
May	41.1	26.6	53.9	005.6	9.5	14.7
June	39.3	27.5	62.5	033.2	8.5	14.8
July	33.3	28.3	84.7	075.0	4.0	12.1
August	32.0	26.8	86.2	248.7	3.0	11.8
September	30.3	24.7	78.5	226.9	3.1	11.6
October	32.8	20.1	64.8	000.0	4.0	12.2
November	27.5	15.8	70.3	027.0	2.0	12.8
December	23.9	06.7	74.2	006.0	1.0	12.7
January 2011	19.1	03.0	77.5	000.0	1.0	12.2
February	24.3	07.3	77.1	032.5	2.0	12.2
March	29.3	12.5	64.8	000.9	4.0	12.5
			2011-12			
April 2011	35.8	18.5	43.9	006.0	6.0	12.2
May	38.8	26.1	43.7	020.1	8.0	12.0
June	37.5	26.6	61.6	142.9	10.4	11.8
July	33.9	26.4	75.7	167.7	3.2	14.5
August	33.1	26.3	69.5	177.5	2.2	14.4
September	33.1	25.2	71.7	069.9	4.7	14.6
October	32.2	16.3	71.6	000.0	4.9	14.3
November	30.1	12.6	71.4	000.0	2.4	15.0
December	23.3	07.7	78.9	000.0	1.3	16.0
January 2012	19.4	06.1	48.6	033.5	2.4	15.8
February	23.5	07.2	75.5	000.0	2.1	16.0
March	27.6	10.0	70.9	000.0	3.1	14.6

BAPATLA

Latitude - 15° 54' N Longitude - 80° 28' E

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Decennial mean rainfall (mm)
	Maximum	Minimum			
			2010-2011		
April 2010	35.2	27.6	78.5	000.0	013.1
May	97.2	28.2	70.5	149.5	039.3
June	36.4	27.5	68.6	153.1	119.5
July	32.6	25.5	82.5	364.6	159.3
August	33.3	25.1	81.0	345.9	161.9
September	32.6	25.3	83.0	350.3	201.4
October	32.4	24.6	82.5	179.5	217.9
November	30.4	23.1	86.3	152.5	079.4
December	28.9	18.9	79.8	170.3	034.2
January 2011	29.8	17.2	78.4	000.0	009.3
February	31.2	18.7	75.7	029.9	016.1
March	38.6	17.0	57.5	000.0	013.1
			2011-2012		
April 2011	33.5	25.1	80.0	107.6	019.9
May	38.1	27.7	66.5	024.4	044.2
June	38.3	27.5	57.0	017.1	113.2
July	35.4	25.6	69.0	157.7	167.0
August	34.3	25.6	71.5	139.9	155.5
September	34.9	25.2	75.5	176.1	197.5
October	33.2	24.1	78.5	093.4	194.8
November	31.3	20.6	79.5	045.7	078.7
December	30.9	18.8	77.5	000.6	033.3
January 2012	29.0	17.7	81.0	111.5	013.2
February	31.6	17.7	75.0	000.0	016.1
March	33.6	23.0	84.5	000.0	013.1

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			
			2010-2011				
April 2010	41.2	26.2	37.0	10.0	000.0	7.8	12.0
May	43.3	29.6	41.0	12.0	003.5	9.5	14.6
June	40.8	29.6	55.0	26.0	075.5	10.4	12.8
July	38.2	29.5	70.0	46.0	102.3	9.2	8.2
August	36.1	27.3	81.0	50.0	080.0	6.8	5.4
September	35.2	24.8	79.0	46.0	108.0	4.7	5.0
October	36.0	22.0	67.0	28.0	000.0	4.5	5.8
November	29.4	14.2	73.0	29.0	017.0	3.1	2.8
December	23.7	06.1	75.0	29.0	003.0	3.5	2.1
January 2011	20.6	04.0	77.0	30.0	000.0	4.6	1.5
February	24.4	09.6	78.0	29.0	009.1	5.2	4.0
March	32.1	15.3	61.0	19.0	003.1	6.5	6.8
			2011-2012				
April 2011	37.0	19.9	48.0	15.0	000.5	6.0	9.3
May	43.3	27.8	52.0	16.0	011.6	12.1	15.1
June	41.9	29.0	57.0	25.0	027.0	12.0	13.6
July	38.7	27.7	67.0	39.0	082.8	9.9	8.8
August	35.6	26.3	80.0	56.0	100.6	7.4	6.5
September	34.1	25.4	84.0	50.0	065.7	7.2	5.1
October	33.9	19.1	62.0	24.0	000.0	4.5	5.6
November	31.5	13.3	66.0	27.0	000.0	2.7	4.0
December	24.7	06.5	72.0	27.0	000.0	3.1	2.4
January 2012	19.5	05.4	76.0	30.0	000.0	3.8	1.8
February	23.8	06.7	65.0	16.0	000.0	4.3	3.1
March	32.0	15.5	50.0	15.0	000.0	6.4	6.9

GANGAWATI

Latitude – 15° 00'N Longitude – 76° 00' E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation* (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2010-2011			
April 2010	38.0	22.0	84.0	67.0	008.0	-
May	38.1	23.0	81.0	62.0	101.3	-
June	34.0	22.0	89.0	69.0	051.3	-
July	31.0	21.0	84.0	79.0	110.3	-
August	30.9	21.1	82.0	77.0	259.8	-
September	30.6	20.6	83.0	81.0	067.5	-
October	30.5	19.8	82.0	80.0	038.8	-
November	29.5	19.1	85.0	80.0	085.5	-
December	29.6	19.3	77.0	79.0	-	-
January 2011	29.0	20.0	77.0	76.0	-	-
February	30.5	17.0	75.0	67.0	-	-
March	34.0	17.8	69.0	75.0	-	-
			2011-2012			
April 2011	35.0	19.0	79.0	79.0	074.0	-
May	36.7	21.9	78.0	71.0	061.3	-
June	32.9	20.8	83.0	64.0	100.5	-
July	32.0	20.3	88.0	54.0	108.0	-
August	30.6	20.4	88.0	38.0	033.0	-
September	31.2	20.1	86.0	34.0	006.3	-
October	32.0	19.2	81.0	29.0	026.3	-
November	30.4	16.5	82.0	39.0	-	-
December	29.8	12.7	77.0	61.0	-	-
January 2012	28.6	13.5	78.0	61.0	-	-
February	31.8	14.8	75.0	58.0	-	-
March	35.1	16.3	72.0	55.0	-	-

** 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		
			2010-2011			
April 2010	41.1	20.4	51.2	17.8	000.0	8.11
May	42.9	24.4	46.7	18.1	001.9	10.29
June	40.5	25.8	60.1	33.0	050.3	9.17
July	35.3	26.4	87.6	65.8	300.0	5.93
August	33.8	26.0	91.5	69.8	209.9	4.06
September	32.2	23.3	93.6	69.9	147.6	3.80
October	33.2	18.2	89.7	37.1	000.0	3.65
November	27.7	11.5	86.4	35.5	000.0	2.17
December	21.3	04.6	94.4	46.9	043.6	1.40
January 2011	16.9	04.2	94.0	53.0	000.0	1.2
February	22.7	08.1	95.0	52.0	034.8	1.9
March	28.6	11.4	92.0	45.0	012.5	3.0
			2011-2012			
April 2011	34.4	16.7	80.0	43.0	035.2	5.5
May	40.1	23.9	59.0	30.0	084.9	9.1
June	38.9	26.2	69.0	41.0	057.0	8.7
July	35.6	26.3	85.0	61.0	082.5	5.4
August	34.1	25.8	89.0	64.0	095.7	4.9
September	33.3	23.1	93.0	64.0	141.1	4.6
October	33.0	15.4	87.0	34.0	000.0	3.7
November	29.4	11.0	92.0	35.0	000.0	2.6
December	22.9	05.2	95.0	43.0	000.0	1.4
January 2012	18.4	04.8	96.0	51.0	014.4	1.4
February	21.0	05.3	87.0	41.0	000.0	2.2
March	28.5	10.3	84.0	32.0	000.0	3.8

INDORE

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

Months	Temperature* (°C)		Relative humidity* (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2010-11			
April 2010	-	-	-	-	000.0	13.6
May	-	-	-	-	007.4	17.2
June	-	-	-	-	029.8	13.0
July	-	-	-	-	221.9	4.1
August	-	-	-	-	385.1	2.0
September	-	-	-	-	092.0	2.9
October	-	-	-	-	005.2	3.5
November	-	-	-	-	083.0	2.7
December	-	-	-	-	000.0	2.1
January 2011	-	-	-	-	000.0	2.1
February	-	-	-	-	000.0	3.8
March	-	-	-	-	000.0	7.8
			2011-2012			
April 2011	-	-	-	-	000.0	12.5
May	-	-	-	-	016.3	15.8
June	-	-	-	-	138.2	9.6
July	-	-	-	-	251.6	2.4
August	-	-	-	-	334.4	1.4
September	-	-	-	-	088.4	2.6
October	-	-	-	-	000.0	3.7
November	-	-	-	-	000.0	2.9
December	-	-	-	-	000.0	2.0
January 2012	-	-	-	-	000.0	2.0
February	-	-	-	-	000.0	3.5
March	-	-	-	-	000.0	7.6

** 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		
			2010-2011			
April 2010	41.0	22.9	41.9	18.9	000.0	7.6
May	41.8	26.5	60.0	31.3	008.9	10.2
June	40.4	28.4	61.8	48.8	047.5	11.7
July	34.3	30.7	87.0	67.5	386.2	8.3
August	33.0	26.0	88.7	75.7	271.3	5.8
September	34.4	25.4	92.3	77.4	204.7	6.3
October	32.3	20.7	88.2	51.7	018.0	6.3
November	27.5	16.2	91.9	60.4	041.9	3.7
December	24.0	08.9	83.7	46.0	001.2	4.2
January 2011	19.4	06.7	89.4	51.0	000.0	1.8
February	25.1	11.3	88.7	46.8	008.0	4.1
March	31.9	16.1	76.7	45.5	000.0	6.1
			2011-2012			
April 2011	37.7	19.5	61.5	29.9	006.6	8.1
May	41.6	22.2	45.2	23.1	003.0	10.0
June	42.4	28.7	48.7	28.4	003.5	11.4
July	33.5	24.7	84.7	69.9	406.5	6.2
August	32.4	25.7	89.4	75.3	125.7	8.4
September	31.6	24.1	88.6	67.5	114.9	3.8
October	31.8	17.6	86.7	41.3	000.0	4.1
November	28.3	10.4	87.5	40.5	000.0	3.0
December	22.0	07.6	88.4	55.2	000.0	2.1
January 2012	19.4	07.0	92.7	62.0	004.6	0.9
February	23.3	10.3	91.3	64.4	121.2	1.4
March	30.5	14.2	82.4	45.5	001.9	2.8

KARNAL

Latitude – 29° 43’ N Longitude – 76° 58’ E

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
2010-2011						
April 2010	39.5	20.2	53.0	16.0	007.6	10.0
May	39.4	24.3	56.0	26.0	018.0	12.2
June	38.2	25.3	63.0	36.0	081.0	9.3
July	33.1	26.2	90.0	72.0	347.6	4.3
August	32.0	25.9	92.0	76.0	230.9	3.7
September	30.5	23.3	93.0	73.0	358.6	3.5
October	31.4	18.5	91.0	46.0	000.0	3.3
November	27.4	12.3	91.0	36.0	000.0	2.3
December	20.9	06.6	95.0	47.0	028.0	1.5
January 2011	16.2	05.6	94.0	57.0	002.2	1.5
February	22.0	09.1	93.0	55.0	037.2	2.0
March	27.7	13.1	90.0	48.0	010.9	3.6
2011-2012						
April 2011	34.0	17.0	67.0	24.0	025.0	6.4
May	38.4	23.2	67.0	32.0	058.0	7.5
June	35.0	24.9	80.0	52.0	149.9	6.6
July	33.1	26.3	91.0	71.0	179.2	4.7
August	32.1	25.7	90.0	73.0	151.7	4.1
September	32.2	23.8	93.0	69.0	093.6	3.6
October	31.9	17.1	90.0	43.0	000.0	3.9
November	28.1	12.8	93.0	40.0	000.0	2.2
December	21.8	06.9	97.0	46.0	000.0	1.6
January 2012	17.3	06.2	93.0	61.0	021.6	1.3
February	20.7	06.9	85.0	45.0	001.8	2.7
March	27.5	11.5	82.0	36.0	000.4	3.9

TRICHY

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

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2010-2011			
April 2010	-	-	-	-	-	-
May	-	-	-	-	-	-
June	37.1	24.2	83.7	60.3	103.5	6.0
July	35.5	23.5	92.6	71.3	063.0	4.1
August	31.2	25.7	85.5	64.4	105.5	5.8
September	35.2	23.1	88.5	76.5	114.2	4.6
October	35.1	26.1	89.9	74.8	108.6	6.8
November	32.9	22.6	92.2	84.9	305.9	4.2
December	30.7	23.9	95.3	82.3	097.3	3.0
January 2011	30.6	22.1	92.9	80.5	010.0	2.4
February	32.2	21.9	95.6	65.6	-	1.4
March	35.4	23.1	94.27	55.9	013.2	2.6
			2011-2012			
April 2011	37.1	25.5	91.8	51.4	036.7	3.9
May	34.8	26.4	84.2	54.3	-	7.0
June	36.7	27.3	86.2	62.2	013.0	7.9
July	36.6	26.2	91.2	68.7	013.2	8.9
August	35.2	25.4	89.4	66.0	034.4	8.3
September	35.7	23.8	92.3	76.2	152.2	7.0
October	35.5	25.1	94.4	75.5	351.4	8.0
November	35.0	19.8	91.6	80.8	130.9	5.7
December	34.6	23.8	94.8	92.3	004.1	6.8
January 2012	32.1	22.9	95.0	96.5	018.1	8.8
February	33.5	24.1	95.9	96.8	-	9.1
March	33.4	23.8	94.6	92.3	-	8.1

7.5: LIST OF PUBLICATIONS (2010-12)

AGRA

Research Papers

Chauhan, S.K. 2010. Effect of saline/alkali water on yield of cluster bean-mustard crop rotation. *Bhartiya Krishi Anushandhan Patrika.* 25(2&4): 109-112.

Chauhan, S.K. 2010. Effect of conjunctive use of alkali and canal water on oil content percent and oil production in sunflower. *Bhartiya Krishi Anushandhan Patrika.* 25 (2&3): 123-127.

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Singh, R.B. 2010. Effect of draining the rain water to mitigate the adverse effect of SAR waters on pearl millet-wheat crop. *Jornal of Rural and Agricultural Research.* 10(2): 52-55.

Chauhan, S.K., Chauhan, C.P.S. and Singh, S.K. 2011. Effect of sowing method and date of sowing on germination and yield of cotton (*Gossipium hirsutum*) irrigation with saline water. *Annals of Agricultural Research.* 32(1&2):53-54.

Chauhan, S.K., Chauhan, C.P.S. and Singh, S.K. 2011. Effect of conjunctive use of Tube well/canal water on sunflower. *Annals of Agricultural Research.* 32(1&2): 55-56.

Dayal, Bhu and Chauhan, S.K. 2011. Effect of different fertilizer levels on mustard (Brassica compestris) varieties as under saline irrigation. *Annals of Agricultural Research*. 32 (1&2): 60-61.

Singh, Y.V., Meena, R.A. and Singh, R.B. 2012. Effect of integrated nutrient management in soil physical properties and organic carbon status at the top soil horizone of a inceptisols of eastern Uttar Pradesh after 25 years of continuous cropping. *Journal Rural and Agricultural Research*. 12(2) 78-82.

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Dayal, Bhu, Singh, R.B., Chauhan, S.K., Chauhan, R.S., Shishodia, P.K. and Meena, R.L. 2011. Lavaniye avam kshariya jal dwara fasal utpadan ke safal pardarshan. *Krishi Kiran*. p 86-89.

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Ratnam, M., Lakshmi, G.V. and Satyanarayana, T.V. 2010. Influence of Sub-Surface Drainage on Rice Crop Yield in Saline and Waterlogged Soils of Konanki and Uppugunduru Pilot Areas of Andhra Pradesh. *Journal of Indian Society Coastal Agricultural Research*. 28(1): 44-47.

Ratnam, M., Reddy, K.G., Lakshmi, G.V., Radha Krishna, Y., Rao, R.S.N. and Satyanarayana, T.V. 2010 Impact of Sub-Surface Drainage on Paddy Yield and Cropping Pattern in Waterlogged Saline Soils. *Journal of Indian Society Coastal Agricultural Research.* 28 (1): 48-50.

Popular Articles

Rao, P.V. and Luther, M. 2010. Adikothpathiki varisagulo kalupumokkala yajamanyam. *Annadatha*. 42(7): 30-31.

Lakshmi, G.V. 2011. On "Bhugarbha Saguneeti Nanyata–Yajamanyam" published in *Vyvasayam–Neeti utpadhakata*. 19: 91-97.

BIKANER

Research Papers

Kumawat, B.L. and Kumawat, Arvind. 2010. Dynamics of some soil quality parameters as influenced by amendment of a loamy sand soil with different plant materials and fertilizer nitrogen. *Journal of the Indian Society of Soil Science*. 58(3): 336-340.

Kumawat, B.L., Yadav, R.L. and Kumawat, Amit. 2011. Effect of clay mixing, FYM and sulphur on soil fertility and crop productivity. *Annals of Plant and Soil Research.* 13(1): 28-32.

GANGAWATI

Research Papers

Manjunatha, M.V., Hebbara, M. and Ravishankar, G. 2010. Response of cotton (Gossypium hirsutum) to single and paired row method of sowing under drip and furrow irrigation in saline Vertisols. *Indian Journal of Agricultural Sciences.* 80(1): 38-41.

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Ramprakash, Dahiya, S.S., Singh, S., Singh, V. P. and Dudi, O.P. 2010. Effect of nitrogen and phosphorus on dry matter yield and bulb production in lilium cv. Chianti. *Haryana Journal of Horticultural Sciences*. 39(3&4):283-285.

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7.6: FINANCE

The Eleventh Five Year Plan (2007–2012) was sanctioned by the Council vide letter N. 9-2/2007/IA-II dated 20. 10. 2008 with an outlay of Rs. 2125.15 lakhs (ICAR Share Rs. 1695.63 lakhs). The budget head and center wise statement of expenditure for 2010-11 and 2011–12 is given below:

AGRA

Budget head	2010-11		2011-12	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	4100000	5545421	5480000	8466259
T.A. & P.O.L.	220000	102265	250000	126623
Contingencies				
Recurring	790000	782074	785000	655834
Non-recurring	1100000	0	0	0
Works	0	54310	0	0
Total	**6210000**	**6484070**	**7015000**	**9248716**

BAPATLA

Budget head	Expenditure (ICAR share in Rs.)	
	2010-11	2011-12
Pay & Allowances	6597068	10675859
T.A. & P.O.L.	87345	119554
Contingencies		
Recurring	349383	612008
Non-recurring	0	0
Total	7033796	11407421
ORP		
T.A.	60247	72891
Rec.contingencies	148849	436849
Total	209096	509740
Grand Total	**7242892**	**11917161**

BIKANER

Budget head	2010-11		2011-12	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	2960000	6402283	3866000	7708758
T.A. & P.O.L.	80000	67634	82000	64188
Contingencies				
Recurring	573000	472849	800000	613623
Non-recurring	0	0	0	0
Total	**3613000**	**6942766**	**47480000**	**8386569**

GANGAWATI

Budget head	2010-11			2011-12		
	Sanctioned ICAR share	Released ICAR share	Expenditure ICAR share	Sanctioned ICAR share	Released ICAR share	Expenditure ICAR share
Pay & Allowances	4590450	2000000	4544740	3010000	7400000	4426328
T.A. & P.O.L.	101250	52000	66560	55000	55000	143939
Contingencies						
Recurring	380250	380000	343785	435000	315000	414558
Non-recur.	1365000	750000	45733	300000	300000	0
Works	581250	525000	522405	0	0	0
Total	**7018200**	**3707000**	**5523222**	**3800000**	**8070000**	**4984824**

HISAR

Budget head	2010-11		2011-12	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	4063300	4067347	11186660	11227449
T.A. & P.O.L.	69300	36484	80000	61408
Contingencies				
Recurring+works	553300	254896	400000	383989
Non-recurring	522600	195974	0	0
Total	**5208500**	**4554701**	**11666660**	**11672846**
ICAR share	3906375	3416026	8750000	8754635

INDORE

Budget head	2010-11		2011-12	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	4926787	4079569	9905000	9518374
T.A. & P.O.L.	85000	74920	100000	56281
Contingencies				
Recurring	420000	419144	350000	444211
Non-recurring	1000000	0	0	0
Works	750000	750000	0	0
Total	**7181787**	**5323633**	**10355000**	**10018866**

KANPUR

Budget head	2010-11		2011-12	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	3000000	4802783	11506667	10547602
T.A. & P.O.L.	86600	62937	80000	88232
Contingencies				
Recurring	573333	550084	373333	646644
Non-recurring	1400000	1586577	1215492	1215492
Total	**5059993**	**7002381**	**13175492**	**12497970**

KARNAL

Budget head	2010-11		2011-12	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	0	0	0	0
T.A. & P.O.L.	150000	150000	50000	50000
Contingencies				
Recurring	100000	100000	200000	199000
Non-recurring	1450000	1450000	0	0
Total	**1700000**	**1700000**	**250000**	**249000**

TRICHY

Budget head	2010-11		2011-12	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	2680000	4637887	3480000	6576203
T.A. & P.O.L.	137300	122500	206600	205934
Contingencies				
Recurring	546600	546249	706600	706281
Non-recurring	622600	449316	200000	195799
Total	**3986500**	**5755952**	**4593200**	**7684217**

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