AICRP (SWS)

All India Coordinated Research Project

MANAGEMENT OF SALT AFFECTED SOILS AND USE OF SALINE WATER IN AGRICULTURE

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BIENNIAL REPORT
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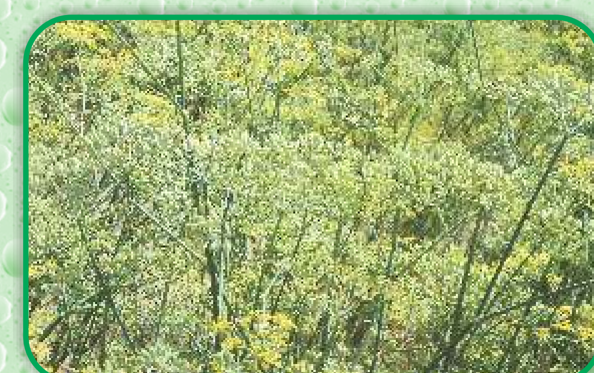

Coordinating Unit

CENTRAL SOIL SALINITY RESEARCH INSTITUTE

KARNAL - 132 001 (INDIA)

All India Coordinated Research Project

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

Biennial Report
(2006-08)

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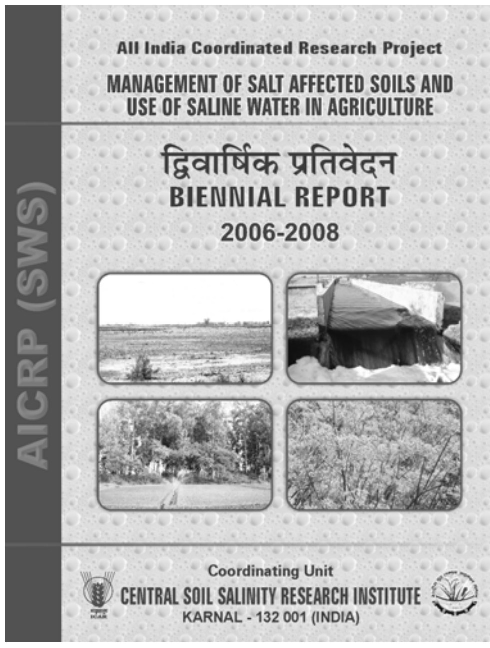

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FOREWORD

Indian agriculture is at the cross roads. While most critical resources to enhance agricultural production and productivity are becoming scarcer day-by-day, need to ensure food and nutritional security is becoming a necessity with no abatement in sight on demographic front. Besides the scarcity of natural resources, pollution of land and water has brought in another dimension, as a result of which not only land and water productivity is at peril but pollutants entering the human and animal chain are causing misery to the people dependent upon these resources. A redeeming feature however, has been that the water, a scarce and most abused resource from pollution point of view, has become a national agenda and is attracting the attention of all the politicians cutting across the party line. It is due to the foresight of peers in the Indian Council of Agricultural Research who set the agenda on he use of poor quality land and water resource since 1965 that culminated into the establishment of Central Soil Salinity Research Institute and All India Coordinated Research Project on Management of Salt Affected Soils & Use of Saline Water in Agriculture with its headquarter at Karnal.

During the intervening period between the last biennial workshop held during 13-15 September 2007 at Karnal and now, concerted efforts have been made to carry and improve upon the research agenda for which sufficient funds on upgrading laboratory facilities have been provided in the XI plan. For this, we are indebted to Dr. Mangla Rai, Honourable DG ICAR and Secretary DARE, GoI and Dr. A. K. Singh, DDG (NRM) who were quite supportive of our plans for the project. A pre-biennial workshop of the chief scientists of the project was organized to consider new areas of research such as dryland salinity, wastewater use, surface and ground water pollution, environmental degradation and climatic change. It is satisfying that first approximation maps of ground water quality of Andhra Pradesh and Tamil Nadu have been prepared and released to the stakeholders besides several district maps of other states where AICRP centers are in operation. Experiments on reclamation of abandoned aqua ponds in Andhra Pradesh have been initiated. Alternate medicinal/aromatic/flower crops are being identified and found economically viable for cultivation on wastelands or with wastewaters or as a replacement of existing crops that require too much water. Reuse of wastewater for agriculture and detoxification of heavy metal loaded soils and waters is getting due attention. As such, experiments on management of fluoride rich waters and treated wastewater have been initiated recently. Besides, the technologies developed by CSSRI with location specific testing and verification at AICRP centers facilitated the applications of such technologies at the national level.

The current report contains the research results of the biennium 2006-08 carried out at coordinating unit and 8 research centers covering arid, semi-arid, irrigated, rain fed and coastal ecologies on alluvial, vertisols and coastal water logged saline/alkali soils. Site-specific technologies developed by the coordinating and cooperating centers are being applied not only in the states but even beyond the boundaries of the state where centers are located. The technology transfer programme through on-farm testing and Operational Research Projects have yielded rich dividends and provided good insight to the scientists since application of technologies under farmer's endowment are much more difficult than at the research farms. The research results from some of the ad-hoc studies, studies on indigenous technologies and local problems have also been included in the report so that the problems/solutions suggested could be discussed at various forums to turn them into useful technologies in the long run.

The current biennial workshop is being conducted at a time when XI five-year plan is almost at mid stage providing opportunities to review the activities undertaken during the plan. With collective wisdom of invited experts, CSSRI scientific staff and scientists of AICRP centers, it should be possible to develop a programme that would be able to address the current challenges of conservation of natural resources, judicious use of drainage and wastewaters of other sectors to supplement meager fresh canal water, application of remote sensing and geographical information system in ground water quality and soil surveys, environmental degradation, climatic change and multi-enterprise agriculture etc. At the end, I record my appreciation to Dr. S.K. Gupta, Project Coordinator and entire staff of the PC Unit for their concerted efforts in compiling, editing and bringing out this publication. I have a special word of appreciation for Dr. R. L. Meena, Scientist (SS) who has single handedly compiled and brought out the biennial report. It would be happy to extend any support that may be required to achieve the targets set forth in the biennial workshop.

(Gurbachan Singh)
Director

PREFACE

Twin problem of water logging and soil salinity has been attracting the attention of the Governments since the middle of 19th century. A number of individuals and organizations have accomplished pioneering works in managing salt affected soils and water. In spite of these efforts, state of the land and water resources has been worrying all stakeholders considering precarious nature of the food security achieved so far. Considering the enormity of the problems and challenges, Central Soil Salinity Research Institute, Karnal and AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture lead from the front to develop location specific reclamation technologies and reuse of degraded water resources in an eco-friendly manner. Utilization of the so called wastelands and wastewater sources seems to be the only economically viable and technologically appropriate option to meet the increasing demand of food grains and other necessities of life.

The AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture is being operated at 8 centers in 7 states under the protective umbrella of Central Soil Salinity Research Institute, Karnal and covers arid, semi-arid, irrigated, rain fed and coastal ecologies. The mandated tasks include development of technologies to solve local problems and to participate in developing regional and national guidelines on management of salt affected soils and use of saline water in agriculture. Through this report, we have tried to showcase some of the activities being pursued to achieve the assigned tasks.

I take this opportunity to express my sincere thanks and gratitude to Dr. Mangla Rai, Director General (ICAR) & Secretary, DARE, GoI who has been kind enough to sanction whatsoever was demanded in the SFC memo for the XI plan of the project. It would help us to equip our centers with new facilities and replace old equipments. I express my deep sense of gratitude to Dr. A. K. Singh Deputy Director General (NRM) who has been taking keen interest in the project activities and providing full support to the project at various stages.

Heart felt thanks are due to Dr. P. D. Sharma, Asstt. Director General (IWM) who has actively steered the project and extended full support. His continuous guidance is a source of inspiration to the project staff. Thanks are also due to Dr. A. K. Gogoi, ADG (Agronomy) for his excellent support and to Dr. P. P. Biswas for cooperation in all spheres. Dr. Gurbachan Singh, Director, CSSRI, Karnal deserves special heartfelt thanks for providing full support and facilities to the coordinating team and staff at the project centers. His constant encouragement to ensure greater interaction between the Institute and AICRP Centers is bearing fruits and more and more avenues are being explored to achieve greater interaction.

The excellent cooperation and team spirit exhibited by my colleagues at different AICRP centres is exemplary and praise worthy. The willing cooperation extended by Drs. C.P.S. Chauhan, V. Shankra Rao, P. R. K. Prasad, B.L. Verma, M. Hebbra, S. Balganvi, S.K. Verma, U. R. Khandkar, Samir Pal, D. Jaya Kumar, R. Kavimani and S.K. Sharma in undertaking research programs as well as in compiling reports in time deserves appreciation. The staff at the coordinating unit has provided unstinted support in the smooth running of the project. For this excellent cooperation, I wish to extend thanks to Sh. S. P. Gupta, Sh. Brij Mohan, Sh. Sukhbir Singh for excellent support. Dr. R. L. Meena took upon himself the task of compiling and editing the biennial report and his efforts deserve special mention and praise. Thanks are due to Smt. Rita who has gone beyond her normal duty to type set and prepare draft and final reports.

(S. K. Gupta)
Project Coordinator

CONTENTS

RESEARCH ACCOMPLISHMENTS

A. USE OF SALINE WATER IN AGRICULTURE

B. MANAGEMENT OF SALT AFFECTED SOILS

C. ALTERNATE LAND MANAGEMENT

D. SCREENING OF CROP CULTIVARS AND GENOTYPES

E. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

F. AD-HOC STUDIES/NOTES

G : GENERAL

SUMMARY OF RESEARCH ACCOMPLISHMENTS (2006-08)

Survey and Characterization of Ground Water and Salt Affected Soils

The survey and characterization of salt affected soils and ground water is an on-going activity aiming at classifying soils and waters according to the nature of problem. The characterization of soils and water should help in deciding the nature of interventions. Ground water and/or soil quality of the following districts was surveyed

Andhra Pradesh (AP)	Visakhapatnam, Vijayanagaram
Haryana	Parts of Gurgaon, Bhiwani and Sonepat
Karnataka	Gulbarga
Madhya Pradesh (MP)	Morena, Sheopur, Bhind
Rajasthan	Bharatpur, Nagaur, Jaisalmer
Tamil Nadu (TN)	Perambalur
Uttar Pradesh (UP)	Fatehpur, Rae Bareilly

The first approximation water quality maps for the Andhra Pradesh and Tamil Nadu states were completed and distributed to stakeholders. The soil survey of North Tamil Nadu and Rae Bareilly district in UP was initiated and survey of Morena and Sheopur in MP was completed.

Changes in Ground Water Quality at Benchmark Sites

Not much change in previously reported trends was observed during the period of report at 8 benchmark sites in Andhra Pradesh. At Nidubrolu I and II, the EC increased abnormally high during 1974 to 2005 but during the study period no further change in the trend was noticed. The EC_e of surface soils at benchmark locations varied in accordance with the variation in tube well waters and reached to a level of 7.40 dS/m at Nidubrolu - I and 7.80 dS/m at Nidubrolu-II from initial level of less than 2.0. There was not much variation at other six locations. pH_s also did not show much variation. However, SAR reached unsafe limits at Nidubrolu-I and II.

Fluoride in Ground Water of Ladnu Tehsil (Nagaur district)

EC and pH of water samples of Ladnu tehsil ranged from 1.02 to 7.12 dS/m and 7.2 to 8.5, respectively. The concentration of F varied from 1.0 to 8.0 mg/l. Only 17.2% water samples are safe for drinking purpose (1.5 mg/l), whereas, 3.8, 32.8, 35.5 and 9.6% water samples are in the range of 1.5-2.5, 2.5-5.0, 5.0-7.5 and >7.5 mg/l of fluoride , respectively. Correlation between EC_{iw} and EC_{soil} & F_{iw} and F_{soil} were found positive and significant, the corresponding "r" values were +0.647** and +0.433**, respectively. The correlation between pH_{soil} and F_{soil} was positive and significant (r = +0.403**) and correlation between EC_{soil} and F_{soil} was found positive but nonsignificant (r = +0.230)

Crop Response to Poor Quality Water

Some new crops and crop rotations such as cluster bean-fennel, tulsi-isabgol, moth bean–fenugreek and cluster bean-mustard were assessed for salinity tolerance. In the cluster bean-fennel rotation, the significant yield reduction was recorded at EC_{iw} 6 dS/m in cluster bean and at EC_{iw} 4 dS/m in fennel. The average yield reduction at EC_{iw} 2, 4, 6 and 8 dS/m over canal was 2, 8, 13 and 15% in cluster bean and 4, 20, 31 and 42% in fennel, respectively. In the case of tulsi-isabgol, the average yield reduction at EC_{iw} 2, 4, 6 and 8 dS/m over canal was 3, 11, 17 and 23% in tulsi fresh biomass yield and 2, 14, 32 and 38% in isabgol grain yield, respectively. In moth bean–fenugreek rotation, the crop yields also declined with salinity to a magnitude of 5, 27, 30 and 31% in moth bean and 4, 6, 9 and 12% in fenugreek at EC_{iw} 2, 4, 6 and 8 dS/m over canal water. The cluster bean-mustard rotation was tested both for salinity and RSC tolerance. The cluster bean yield declined significantly with saline water as well as with alkali water. The alkali (RSC) water caused damage due to rainwater stagnation for longer period whereas, the saline water due to salt accumulation. The relative yield of cluster bean and mustard at EC_{iw} 4, 8 and 12 dS/m over canal were 97, 84, and 68%, and 92, 82 and 73%, respectively while at RSC 5, 10, 15 and 20 meq/l over canal were 91, 72, 54 and 05% and 92, 85, 84 and 80%, respectively.

Conjunctive Use of Alkali/Canal Waters

Potato-sunflower-green manure was grown in rotation with different conjunctive modes of canal and alkali (RSC 15 meq/l) waters, to find out the most suitable cyclic and mixing mode. The highest yield of potato tuber was recorded with canal and lowest in all alkali water. In the cyclic modes, wherever higher numbers of canal irrigations were given, higher yield was obtained compared to the modes where alkali irrigations were more. Understandably, mixing mode as 2CW+1AW gave higher yield over mixing mode as 1CW+2AW in both the crops. The pattern was similar for sunflower (summer). The sodicity in terms of exchangeable sodium percentage (ESP) increased more wherever alkali water was applied in larger qualntities in different irrigation modes.

Mitigating Adverse Effects of High SAR with Gypsum

A field experiment was carried out with pearl millet/dhaincha-wheat crop rotation irrigated with EC_{iw} 8 (dS/m) water with varying SAR_{iw} of 10, 20, 30 and 40 $(mmol/l)^{1/2}$. Gypsum was applied @ 25% GR and 25% GR + FYM to mitigate the adverse effect of SAR waters. FYM was also tested as an organic amendment. The data revealed that at SAR_{iw} 40, the relative yield of dhaincha was 47.9% without gypsum and 50.3% with gypsum addition while the respective yield of pearl millet was 33.1 and 40.9 %. The addition of gypsum @ 25 GR increased the relative yield in the pearl millet by 7.8% at SAR_{iw} 40 and 9.9 per cent in SAR_{iw} 30 $(mmol/l)^{1/2}$ over control. It showed that the addition of gypsum may not be an economic option as it resulted in only marginal increase in crop yield and soil properties. The follow-up wheat gave significantly higher yield in dhaincha-wheat rotation as compared to pearl millet-wheat rotation. The wheat grain yield declined significantly above SAR_{iw} 30. The infiltration rate after harvest of kharif and rabi crops, which comes down from 3.7 to 0.9 mm/hr improved by 0.3 mm/hr only with gypsum addition. The soil studies showed that in kharif the soil moisture reserve was low and higher salt build-up occurred after the harvest of dhaincha compared to pearl millet.

Tolerance of Vegetable Crops to Saline water with Drip and Surface Irrigation Systems

The salinity tolerance of chilli-brinjal crop rotation was assessed under drip and surface irrigation systems. While in 2006, chilli crop could not survive to maturity in 2007-08, the brinjal and chilli fruit yield declined significantly with salinity and drastic yield reduction occurred at EC_{iw} 8 dS/m in both drip and surface irrigation. The fruit yield increased with increasing IW/CPE ratio in drip irrigation, while in surface irrigation fruit yield was at par at various IW/CPE ratios. In general, yield potential was higher with drip besides saving of about 38 per cent water compared to surface irrigation.

Crop Water/ Salinity Production Functions for Different Crops using Sprinkler Irrigation

An experiment was carried out during 2007-08 with fallow-mustard crop to determine crop production function in relation to water and salinity/sodicity using sprinkler lines of BAW (EC_{iw} 3.6 dS/m and RSC nil), salinity EC_{iw} 10 dS/m and RSC 10 meq/l water for creating gradients of moisture and salinity/sodicity. The mustard grain yield was affected by moisture and salinity/sodicity gradients. In case of moisture gradient, the grain yield increased with increase in depth of irrigation water from 0.74 to 3.64 cm per irrigation. Contrary to this, the grain yield declined with increase in salinity gradient in terms of salinity of irrigation water from 4.7 to 8.3 dS/m. However, in case of RSC, the grain yield was adversely affected in the gradient range of 1.8 to 7.7 meq/l of water.

Tolerance of Fruit Trees to Saline Irrigation under Drip and Surface Irrigation

The salinity tolerance of pomegranate and guava fruits was assessed at Agra under different salinities and irrigation systems. The salinity levels were BAW, EC_{iw} 8 and 12 dS/m for both surface and drip irrigation systems. The irrigation scheduling in terms of ET were 0.5 and 1.0 for surface and 0.5, 0.75 and 1.0 for drip system. The survival %age at early stage was more for pomegranate than guava. The plant height and girth of stem were higher in drip system in both the trees. At ET 1.0, significantly higher plant height and girth was observed compared to ET 0.75 and ET 0.5 in both pomegranate and guava. The increasing salinity levels decreased the plant height and stem girth. The fruit yield of pomegranate was significantly higher (10.7%) in drip than surface system. Amongst the salinity levels, yield decreased by 34 % at EC_{iw} 12 dS/m compared to BAW.

In the case of Ber at Bikaner, maximum average yield (40.05 kg/plant) was obtained in treatment 0.8 PET + plastic mulch with BAW. Even under saline water, this treatment resulted in maximum yield (38.03 kg/plant). In general, higher yields were obtained at 0.8 as compared to 1.0 PET, both with and without plastic mulch. The average diameter and weight of fruits revealed the same trend. The total water required in the crop season in 2005-06 was 8198 and 6553 litres at 1.0 PET and 0.8 PET, respectively whereas corresponding values for the year 2006-07 and 2007-08 were 7798 and 6240 litres, and 9846 and 7890 litres at 1.0 and 0.8 PET, respectively. Comparatively, high salinity levels existed in treatments with 0.8 PET in un-mulched conditions at almost every point of observation.

Reclamation of Abandoned Aqua Ponds

A large number of marginal and poor farmers have lost their only livelihood option after the disastrous shift from agriculture to aquaculture, which could not be sustained due to many environmental and ecological reasons. Based on a survey conducted in the coastal districts of Andhra Pradesh, around 2 lakh ha lands has been found abandoned as no crop could be grown on aquaculture ponds due to high salinity. To demonstrate the technology of reclamation of aqua ponds, input package was prepared that consisted of leveling of aqua ponds, provision of open drainage system for leaching of salts periodically, a source of irrigation water, growing of green manure crop dhaincha, basal application of $ZnSO_4$ @ 50 kg/ha at time of paddy transplanting, selection of salinity tolerant paddy and nutrient management. The data indicated that the soil salinity decreased, the crop yields increased and varied from 3.8 to 5.6 t/ha in rice during *kharif*, 2007 followed by establishment of green gram crop during *rabi.*

Investigations, Design and Installation of Subsurface Drainage Systems

A subsurface drainage system (SSDS) was installed in farmer's fields at Appikatla village in Guntur district in an area of 7.5 ha. An amount of 1.99 and 1.87 tons of salts were leached during 2006-07 and 2007-08, respectively. The total amount of salts leached since installation of the system for the last 6 years was assessed at 165 tons over an area of 7.5 ha with an average of 22 t/ha. The nutrients constituted only 0.3% of the total salts leached from the area. A reduction of 82% in salt concentration was reflected in terms of rice crop productivity increase from initial yield level of 1.80 t/ha to the level of 6.64 t/ha after six years of installation which was 260% improvement over control due to subsurface drainage system. The differences in grain yield of rice due to different spacing were very marginal i.e., only 0.06 t/ha (0.91%). Similarly the differences in grain yield due to different drain materials used viz., stoneware and CPVC were very marginal i.e., only 0.21 t/ha (3.13%). Hence for the design of drainage systems in these soils, 50- 60 m spacing may be preferred to minimize cost. Any material i.e. stoneware or CPVC pipes could be used depending upon the availability. Rice-fallow cropping system was prevalent with poor yields at the time of pre-installation but after drainage, crops like sunhemp (*Crotalaria juncea*), pillipesara (*Phaseolus trilobus*), sorghum fodder (*Sorghum vulgare*) and mustard (*Brassica juncea*) could be grown with good yields showing the efficiency of the subsurface drainage system.

Drainage experiments on large scale were also installed in Haryana at Beri, Dadri, Darbakalan, Jagsi and Dhanana covering areas from 800 to 1000 ha on farmer's field in association with Haryana Operational Pilot Project being run under the Department of Agriculture, Haryana. Drainage projects were installed covering an area of about 500 ha in Maharashtra in Public-Private-Farmers association mode with technical inputs from the coordinating unit at CSSRI, Karnal. The system designs for an area of 1000 ha in Karnataka have also been finalized.

On the basis of these studies it emerged that drainage system is technically and economically viable technology and could be implemented under the farmers' endowments in various states to solve the problems of water logging and soil salinity.

Screening of Elite Genotypes of Mustard for Cultivation under Saline Water Irrigation

During 2006-07 it was observed that in IVT genotypes CSCN-11, CSCN-06 and CSCN-07 produced higher seed yield as compared to other genotypes and in AVT CSCN-17 produced higher seed yield as compared to other genotypes at EC_{iw} of 6.0 dS/m. During 2007-08 IVT genotypes CSCN-5 produced significantly higher seed yield followed by CSCN-1, whereas in AVT, CSCN-13 produced higher seed yield as compared to other genotypes at EC_{iw} 6.0 dS/m.

At Kanpur, performance of seventeen (2006-07) and fifteen (2007-08) genotypes of mustard was evaluated at sodicity level of 41 and 43 ESP respectively. The seed yield varied from 0.58 t/ha. (CSCN-06-12) to 1.08 t/ha (CSCN – 06-02) and 0.74 t/ha (CSCN 07-8) to 1.40 t/ha (CSCN-07-11) during 2006-07 and 2007-08 respectively.

The performance of three varieties of garlic (Hansa, Desi and Gatter gola) were evaluated at alkali gradients ranging between 21 to 52 ESP. The bulb yield of garlic decreased with increasing levels of alkalinity, Gatter gola yielded maximum followed by 'Hansa' and 'Desi'.

At Hisar, in year 2006-07, the tolerance of ten genotypes of cotton and wheat each was tested, whereas, in year 2007-08, the tolerance of seven genotypes of cotton, fourteen of wheat, five of mustard and twelve of oats was tested. During 2006-07, seed cotton yield/plot was maximum in H-1226 followed by H-1117. The genotype CPD-818 was the lowest yielder. In 2007-08, the mean yield of H-117 was significantly higher than other genotypes followed by H-1226. In wheat during 2006-07, the genotype WH-1043 gave the maximum yield followed by WH-1036.. However, the genotypes WH-1016, WH-1025 and WH-1012 yielded comparatively much less than other genotypes. In 2007-08, the genotype WH-1063 gave the maximum yield followed by WH-1080 at EC_{iw} of 7.5 dS/m. Genotypic responses in wheat were found variable with the salt-tolerant and sensitive lines and showed a relatively greater decline in assimilation rate (A), stomatal conductance (gs) and transpiration rate (T). Salinity also resulted in significant reduction in intracellular CO_2 concentration (Ci) but to a lesser extent than assimilation rate, stomatal conductance and transpiration rate. In mustard, genotype CSCN-15 gave the maximum yield (175.0 g/m^2) followed by CSCN-13 (170 g/m^2). The mean yield reduced by 54.8% at EC_{iw} of 7.5 dS/m as compared to canal water irrigation. In oat, with the increase in EC of irrigation water from 4 to 12 dS/m, the plant height, leaf area/plant and dry weight/plant were decreased significantly. A significant rise i.e. 0.72 to 1.22 in values of Na/K ratio was observed. Among the twelve oat genotypes tested, the genotypes NGB-6370, JHO-99-2, JHO-822 and NGB-7021 showed better tolerance against different levels of saline irrigation than others genotypes. Their better performance was based on physiological traits like high values of RWC (%) and total chlorophyll content but more '-ve' values of osmotic potential (better osmoregulation) low values of RSI (%) and MDA content (less membrane injury) and Na/K ratio.

Two experiments on screening of mustard varieties were conducted at Indore centre during 2007-08. First one was on screening of elite varieties and second one on screening of promising varieties in a sodic clay soil. All the varieties were tested at soil ESP 35±2. The yield performance of different elite varieties (IVT) was in order of CSCN 10 >CSCN 3 >CSCN 9 >CSCN 2 >CSCN 5 >CSCN 1 >CSCN 7 >CSCN 4 >CSCN 6 on the basis of seed yield. The order of performance was of CSCN 9 >CSCN 2 >CSCN 3 on the basis of seed yield, oil content and 1000 seed weight. The yield performance of different promising varieties (AVT) was in order of CSCN 13 >CSCN 14 >CSCN 15 >CSCN 11 >CSCN 12 on the basis of seed yield. The order of performance was of CSCN 14 >CSCN 15 >CSCN 11 on the basis of seed yield, oil content and 1000 seed weight.

Operational Research Project on Use of Poor Quality Ground Water at Farmer's Field

The technology transfer for saline water use based on the technologies generated by the center revealed that in alkali water having RSC 8-12 meq/l the pearl millet and cotton sown with gypsum (added on the basis of 50% GR with control) increased the pearl millet yield by 10.6% over control (without gypsum). With gypsum treatment, yield of cotton increased by 8.2 % over control. In rabi season, wheat yield increased by 6.5% with gypsum over control. In wheat crop, irrigation with low salinity water followed by high salinity water proved beneficial for getting higher yields. The fertilizer recommendations were compared for wheat, barley and mustard crops. The average per cent yield increased by 6.5 in wheat, 6.2 in barley and 16.0 in mustard with application of 120 kg N over 90 kg N level. The wheat yield increased by 9.8% in post sowing sprinkler irrigation over pre sowing saline irrigation (conventional farming). The improved seed and proper fertilizers increased the average yield by 12% in ORP over farmers' practices. In saline and alkali water, the yield was high about 7.4% in flat sowing over bed sowing, although in bed sowing, irrigation water to the tune of 25–30% could be saved over flat sowing.

Mangement of RSC Water with Organic Manures under Sprinkler Irrigation

For sustainable production of pearl millet-wheat crop sequence with waters having RSC 10.0 me/l, FYM @ 10 t/ha along with gypsum equivalent to 5.0 meq/l RSC neutralization of each irrigation should be added in sandy coarse textured soils with sprinkler irrigation. Gypsum as per GR should also be added to soil before sowing. Addition of organic matter and gypsum decreased the pH of the soil.

Tolerance of Vegetables to Saline Water under Drip/Ssurface Irrigation

Three years studies on tolerance of okra indicate that average fruit yield of okra was significantly influenced by salinity of water as well as method of irrigation. Maximum yield of okra was observed under drip irrigation with water having EC 3.0 dS/m with a significant decrease in yield with water having EC 6.0 dS/m. Drip method was superior with 49.4% higher yield compared to flood irrigation method. In case of onion maximum yield was recorded under drip irrigation with water having EC 3.0 dS/m with a significant decrease in yield with water having EC 6.0 dS/m. Drip method was superior with 24.1% higher yield compared to flood irrigation method.

Tolerance of Cotton Varieties to Saline Water Irrigation under Drip System

Drip method was found significantly superior to flood method with seed cotton yield being 44.2% higher in drip as compared to flood irrigation. Seed cotton yield decreased significantly at EC_{iw} 6.0 dS/m as compared to canal water and saline water of EC_{iw} 3.0 dS/m. The variety MH-134 of Bt cotton was found significantly superior than other varieties. Interactive effect of methods of irrigation and varieties indicate that Bt cotton produced significantly higher yield in both the methods of irrigation. Zone of minimum salt concentration existed below the emitter.

Response of Crops to Nutrients under varying Salinity of Water with Sprinkler Irrigation

Among all the treatments and almost at all levels of irrigation water salinity, treatment with 10 t/ha FYM and 125% of fertilizer dose gave higher wheat yield. Although with FYM @ 5 t/ha and 100% recommended dose of fertilizer, high yields were obtained at low salinity levels (up to 1.8 dS/m) but at EC_{iw} >1.8 dS/m, yields were more in case of 125% of recommended dose of fertilizer. Application of FYM increased the salinity tolerance of the crop. Critical limit of salinity for wheat at 0, 5 and 10 t/ha at 125% R.D was found to be 3.8, 4.1 and 4.2 dS/m, respectively under sprinkler irrigation.

In case of groundnut application of FYM at same level of NPK doses increased the salinity tolerance of the crop. There was 8.5 and 17.9% increase in pod yield of groundnut with the application of 5 and 10 t/ha FYM, respectively as compared to no FYM application. Based on average of two years, 50% yield reduction for groundnut at 0, 5 and 10 t/ha was observed to be at 2.76, 3.01 and 3.04 dS/m, respectively. Average value for 50% yield reduction for groundnut at 5 t/ha and 125% recommended dose was about 3.0 dS/m. The organic carbon content in soil increased with the incorporation of FYM as compared to control. The phosphorus and potassium contents in the soil also increased with increased doses of FYM and fertilizers i.e. 125 and 150 per cent recommended dose.

In order to ensure sustainable use of saline water in combination with organic inputs management to produce low water requiring high value crops such as oilseeds and spice crops, a field experiment was started during kharif 2008 at Bir Forest Experimental Farm, Hisar. Sesame variety HT-1 was sown. The one year experimental results showed that with organic inputs growth and yield attributes did not differ significantly yet higher seed yield of sesame was obtained as compared to 100% inorganic and inorganic and organic (50+50) input applications. The seed yield was not significantly different with irrigation water salinity although numerically higher yield was recorded under high salinity water irrigation. It could be attributed to relatively higher RSC of the low salinity water.

Skimming Well and Alternate Technologies to Develop Water Resources in Coastal Sandy Soils

A survey carried-out in the coastal belt of Guntur district, Andhra Pradesh revealed that the groundwater is being developed through various structures such as traditional *doruvu* (a conical pit) with manual pot irrigation, traditional *doruvu with* 1 HP pumping unit, radial subsurface collector well with horizontal collectors using 1-5 HP pumping units, shallow tube wells with 1 HP pumping unit and two-strainer tube wells with 1-5 HP pumping unit. The centre so far has installed 83 subsurface collector wells in coastal sandy soils of 24 villages in Guntur, Praksam and West Godavari districts covering a cultivable area of 192 ha and 6 drinking water wells. On the whole, experiences revealed that system is able to supply good quality water that is sufficient to meet crop demands of 2 ha area during rabi through use of sprinklers or 4 ha of plantation crops except oil palm through mini sprinkler/drip irrigation system. The salinity of skimming well waters varied from 0.5 – 8.9 dS/m during 2006-07. The salinity of skimming well water at Bapatla and Timmareddy Palem is less than 1dS/m.

During the recent past, innovative and progressive farmers installed shallow depth (4.5-6.0 m) low discharge tube wells and multi-strainer bore wells with varying designs in Andhra Pradesh to tap the top layer shallow fresh water. The systems performance revealed that salinity of pumped water increased with increasing pumping time. In case of multi-strainer well a moderate rise of salinity (3.5 to 13.7%) was observed. The upconing trends studied at 8 different locations indicated that with vertical pumping (tube well), safe pumping hours ranged from 0.3 to 13 hours only. The economic appraisal of the improved technologies assessed using discounting techniques revealed that skimming well with horizontal collectors had a higher benefit cost ratio (2.15) followed by multi-strainer tube well (1.96) and shallow tube well (1.35).

Drip Irrigation System for Vegetable Crops in Coastal Sandy Soils

During *rabi* 2006-07, an experiment was laid out with four levels of irrigation i.e., BAW of subsurface skimming well (<0.5 dS/m), saline water of 2, 4 qnd 6 dS/m (by mixing of fresh water and Sea water of 35 dS/m or more) to know the response on different vegetable crops viz., tomato and okra to different salinity waters under drip irrigation. The mean yield of okra with 2 EC water treatment (4.25 t/ha) was 11.74% higher than BAW treatment (3.62 t/ha) followed by drip irrigation with 4 EC (1.94 t/ha) and 6 EC (0.50 t/ha) The yield reduction at these levels of salinities was 46.1% and 86.2% respectively.

The mean yield of tomato with 2 EC (6.59 t/ha) was 16.5% less compared to the yield with BAW (7.89 t/ha) followed by drip irrigation with 4 EC (5.83 t/ha) and 6 EC (5.14 t/ha) yielding 26.1% and 34.8% less respectively.

Response of Crops to Varying Levels of Salinity and Moisture under Sprinkler Irrigation

In case of saline water the total depth of water applied ranged 19.40 to 42.91 cm in seven irrigations in wheat. The grain yield ranged between 0.49 to 1.85 t/ha and followed a quadratic trend ($Y= - 0.0044 X^2 +0.319 X- 4.241$; $R^2 =0.82^{**}$), the highest being at 34.6 cm with a declining trend later on. In the mixed zone, the grain yield varied from 0.76 to 2.42 t/ha. Relationship between yield and total depth of water applied was again quadratic but with lower R^2 value indicating influence of both salinity of irrigation water and total depth of water applied. In the zone of BAW, wheat yield ranged from 0.86 to 2.65 t/ha. Irrigation water salinity (EC_{iw}) was found negatively related with yield whereas, positive correlation was observed between yield and total depth of water applied ($Y= 0.822 -0.291 EC_{iw} + 0.473 D_{iw}$; $R^2 = 0.64$).

Pod yield of groundnut indicate that pod yield and depth of water are related quadratically ($Y= -0.0001 X^2 +0.014 X -0.170$; $R^2=0.85^{**}$) with the maxima of the curve for water depth at about 70 cm. In the zone of mixed water, total depth of water applied ranged between 39.3 to 62.9 cm and grain yield varied from 0.24 to 1.54 t/ha. The data subjected to multiple regression analysis resulted in the equation $Y= 0.222 +0.0284 X_{DW}- 0.341X_{EC}$; $R^2 =0.82^{**}$ indicating that both salinity of irrigation water and total depth of water applied are responsible for yield variation. Assuming depth of water applied at around 60 cm, the critical limit of 50% yield reduction of groundnut pod is observed to be around 3 dS/m. In the zone of BAW, quadratic equation between pod yield of groundnut and total depth of irrigation was Y= -0.001 X^2 +0.125 X- 0.2.144:R^2 =0.91 **. A maximum of the curve was found at about 62 cm.

Investigations on Micro Irrigation for Vegetables in Saline Soils

Significantly higher beet yield of 18.3 t/ha was recorded when the crop was drip irrigated at 1.2 ET followed by 1.4 ET (17.2 t/ha), 1.0 ET (16.9 t/ha), surface irrigation at 1.2 ET (16.5 t/ha), drip irrigation at 0.8 ET (15.7 t/ha), 0.6 ET (14.8 t/ha), surface irrigation at 1.0 ET (14.9 t/ha), and least (13.5 t/ha) when the crop was irrigated with surface irrigation at 0.8 ET level. Among salinity levels, significantly higher yield (19.4 t/ha) was obtained when the salinity was less than 4 dS/m followed by EC_e, 4-8 dS/m (17.1 t/ha) and least (11.4 t/ha) when the salinity was in the range of 8-12 dS/m. The interaction effect due to irrigation and soil salinity levels remained non-significant. Soil salinity was marginally higher in the treatment where the crop was irrigated with 0.8 ET under surface method of irrigation and relatively lower where the crop was drip irrigated with 1.4 ET as compared to other treatments.

Response of Crops to Chemical and Organic Amendments in Alkali Soils of Karnataka

A field experiment on sunflower was conducted in farmers' field at Kyarehal village to assess the effect of chemical/organic amendments on crop growth and yield and on soil properties in an alkali soil. Pooled data of three years indicated that application of FYM @ 10 t/ha with 50% of gypsum requirement recorded significantly high sunflower seed yield of 1.77 t/ha compared to control (1.32 t/ha) and application of gypsum at 50% and 75% of gypsum requirement alone (1.51 and 1.50 t/ha respectively). Higher seed yield was recorded with the application of FYM @ 10 t/ha with 50% of gypsum requirement and it remained at par with the application of FYM @ 10 t/ha with 75% of gypsum requirement, application of vermicompost @ 2.5 t/ha with 50% and 75% of gypsum requirement. The soil salinity values ranged between 2.15-to 2.85 dS/m and soil pH ranged from 9.12 to 9.41, being lower than the initial values except in control. Pooled data of two years (2006-2007) on cotton indicated that application of either FYM @10 t/ha or vermicompost @ 2.5 t/ha with 75 percent of gypsum requirement recorded significantly high seed cotton yield of 1.24 t/ha compared to control (0.92 t/ha) and application of gypsum @ 50% and 75% of gypsum requirement alone (1.05 and 1.07 t/ha, respectively). The higher seed cotton yield recorded with either FYM @ 10 t/ha or vermicompost @ 2.5 t/ha with 75 percent of gypsum requirement remained at par with application of FYM @ 10 t/ha and vermicompost @ 2.5 t /ha with 50% of gypsum requirement.

Land and Rain Water Management Strategies for Rainfed Alkali Soils of Karnataka

Data on yield attributing parameters showed that the crop performed better under tied ridges with application of 75% GR. Highest mean yield (2007-2009) was obtained in tied ridges with 75% GR treatment during all the three years. Highest mean seed yield was 1.13 t/ha followed by tied ridges with 50% gypsum (1.08 t/ha), deep ploughing with 75% gypsum (0.99 t/ha), deep ploughing with 50% gypsum (0.98 t/ha), compartment bunding with 75% gypsum (0.96 t/ha), compartment bunding with 50% gypsum (0.91 t/ha), flat bed (0.72 t/ha), flat bed with 75% gypsum (0.72 t/ha) and flat bed with 50% gypsum application (0.68 t/ha). Data on the effect of different moisture harvesting practices on soil salinity status and ESP indicated leaching of salts under all the practices compared to initial, being maximum under tied ridging and minimum under flat bed system (control).

Evaluation of Some Medicinal and Aromatic Crops in Saline Vertisols

During 2007-08, ashwagandha (*Withania somnifera*), stevia (*Stevia rubidiana*), adhatoda (*Adhatoda vasica*) and insulin (*Salacia oblonga*) were evaluated for their response to soil salinity in a pot culture experiment with five salinity levels. The seed and root yields of ashwagandha were maximum at 5.48 dS/m. The reduction in root yield was higher (-19.1%) than the seed yield (-11.6%) at 8.46 dS/m. In stevia, the foliage yield was maximum at 3.54 dS/m and the yield reduction was maximum (-27.2%) at 8.46 dS/m. Adhatoda was observed to have relatively higher salt-tolerance as it recorded maximum dry matter at 5.48 dS/m. In case of insulin, the highest dry matter (224 g/pot) was recorded at 1.58 dS/m, which decreased with increase in salinity. In field studies, ashwagandha, palmarosa, vetiver and lemongrass were evaluated for their salt-tolerance under natural salinity gradients. In ashwagandha, EC_t values of 5.69 and 5.48 dS/m were observed for seed and root yield respectively. Amongst the above crops, vetiver (EC_t, 6.98 dS/m) was found relatively more salt-tolerant followed by ashwagandha (EC_t, 5.69 and 5.48 dS/m for seed and root yield respectively), palmarosa (EC_t, 5.54 dS/m) and lemongrass (EC_t, 4.93 dS/m).

Response of Finger Millet and Sugar Beet Genotypes to Nitrogen under Salinity in TBP Command

Pooled data of three years (kharif 2005 – 2007) revealed that amongst the genotypes, GPU-28 recorded significantly higher grain yield of 4.28 t/ha compared to GPU-26 (3.85 t/ha), GPU-45 (2.97 t/ha), HR-374 (3.31 t/ha), PES-400 (3.21 t/ha) and VL-149 (3.47 t/ha) genotypes. Among the nitrogen levels, application of 150 % RDN recorded significantly higher grain yield of 3.84 t/ha compared to 125% RDN (3.56 t/ha) and 100% RDN (3.15 t/ha).

Screening of three sugar beet genotypes viz. Indus, Cauvery and Shubra under natural salinity gradient ranging from 2 dS/m to 20 dS/m revealed that variety Indus recorded higher yield compared to Cauvery and Shubra.

Strategies for Conjunctive use of Saline and Canal Water

Investigation on conjunctive use of canal/saline water on growth and yield of cotton-wheat and pearl millet-mustard crop rotations and on soil salinity build-up were carried out at Hisar. The data revealed that the mean (year 2006 and 2007) highest seed cotton yield of 2.48 t/ha was recorded in canal irrigation followed by 2C: 1S (2.46 t/ha) cyclic irrigation. However, the lowest yield of 1.56 t/ha was recorded in all saline treatment. The highest EC_e (8.28 dS/m) in the surface layer (0-15 cm) was observed where all saline water was used. In wheat, the highest yield of 5.00 t/ha (year 2006-07 and 2007-08) was recorded in canal irrigation followed by 2C: 1S (4.83 t/ha) cyclic irrigation. Among the cyclic mode treatments, C: RTS had the higher salinity build-up followed by 2S: 1C. In pearl millet and mustard crops also, the highest yield was recorded in canal followed by 2C: 1S treatments. Assuming the average yield obtained in canal irrigation as 100%, the relative pearl millet yields obtained under 1C : 1S, 1S : 1C, 2C : 1S, 2S : 1C, S : RTC, C : RTS and S (all saline) treatments were 89, 83, 97, 75, 85, 86 and 67%. The counter figures for mustard were 94, 88, 96, 74, 86, 85 and 71% respectively.

Effect of high RSC Water along with FYM and Gypsum in Vegetables

A study on use of sodic water in broccoli-cluster bean and knol-khol-ridge gourd vegetables with gypsum as an amendment and FYM was carried out at Hisar. The crops were irrigated with sodic water having average RSC 11.6 meq/l and SAR 14.0 $(mmol/l)^{1/2}$. Broccoli-cluster bean were grown with three levels of gypsum application (0, 50% and 100% neutralization of RSC) and three levels of FYM (0, 10 t/ha and 20 t/ha). Knol-khol-ridge gourd crops were grown with five treatments of gypsum application (0, 25%, 50%, 75% and 100% neutralization of RSC) and three levels of FYM (0, 10 t/ha and 20 t/ha). In broccoli, the highest mean yield of 10.04 t/ha was observed in F_2G_2 (FYM @ 10 t/ha and 50 % RSC neutralization) treatment and the lowest (0.09 t/ha) in F_0G_0 (no gypsum-no FYM) treatment. In cluster bean, the yield recorded in F_2G_2 and F_1G_2 were statistically at par, the highest being 11.24 t/ha in F_2G_2. The maximum pH value of 9.7 was recorded in F_0G_0 treatment, which resulted in poor yield of the crop. The mean yield of knol-khol increased significantly from 1.71 t/ha under no gypsum to 10.95 t/ha under 100% GR. Similarly, the yield of ridge gourd increased from 4.12 t/ha under no gypsum to 8.92 t/ha under 100% GR. The reduction in the ESP with gypsum application was more pronounced as compared to FYM. The maximum ESP value of 37.4 was recorded in F_0G_0 treatment. However, the lowest value of 10.4 in 0-15 cm soil depth was obtained in F_2G_4 treatment.

Performance of Crops Irrigated with Sodic Water through Sprinkler System

The study on use of sodic water through sprinkler system in pearl millet-wheat crop rotation with four levels of gypsum (0, 50%, 75% and 100% neutralization of RSC) and three irrigation depths (4, 5 and 6 cm) was carried out at Regional Research Station Bawal in 10 m x 4 m strips. The mean grain yield of pearl millet increased by 21.7, 43.5 and 47.8% with G_{50}, G_{75} and G_{100} neutralization of RSC (12.0 meq/l) over control G_0 through sprinkler system. The straw yield increased by 15.5 and 22.8% in 5 and 6 cm irrigation depths as compared to 4 cm water application. In wheat, the mean grain yield increased by 9.6, 18.3 and 21.9% in G_{50}, G_{75} and G_{100} neutralization of RSC over control. The highest pH (9.79) was obtained with 4 cm irrigation under no gypsum application.

Effect of Water Quality on Wheat under Different Methods of Irrigation

The study on effect of different saline water qualities (canal water, EC_{iw} of 2.5, 5.0, 7.5 and 10 dS/m) on wheat crop under different irrigation methods (sprinkler and flood) was carried out at Hisar in 16 m x 12 m (Sprinkler) and 6 m x 6 m (Flood) during 2006-08. In sprinkler irrigation, the maximum grain yield of 4.45 t/ha was recorded in canal water and a minimum of 3.92 t/ha in EC_{iw} of 10 dS/m, whereas, in flood irrigation the maximum grain yield of 4.25 t/ha and a minimum 3.75 t/ha were obtained with the same EC_{iw} of water. The initial average EC_e values in different soil layers varied from 3.70 to 4.26 dS/m in sprinkler irrigation system and 3.74 to 4.09 dS/m in flood irrigation system. In sprinkler irrigation, the mean EC_e values varied from 3.70 to 6.91 dS/m in the soil profile after two years while in flood irrigation, it ranged from 3.98 to 8.43 dS/m in the soil profile after two years at the time of wheat harvest.

To Optimize the Zinc Requirement of Wheat Crop Irrigated with Sodic Water

To study the application requirement of Zn to wheat crop irrigated with sodic water in relation to different gypsum amendments (0, 25, 50, 75 and 100% neutralization of RSC) was initiated at village Bhurjat, district Mahendragarh. The mean yield increased by 174.6, 292.6, 354.5 and 379.6 per cent, respectively, in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control. The application of Zn @ 25 and 50 kg/ha resulted in 11 and 19.6% increase in yield, respectively, as compared to control. At the wheat harvest, the pH in no gypsum treatment was 9.6 compared to 8.62 in 100% neutralization of RSC with gypsum.

Two technology transfer demonstration were conducted at the farmers' fields in Mahendragarh district. The requisite amount of gypsum in various treatments on the soil and water basis was applied in a single dose before sowing of crop and mixed well in the soil. The crops were irrigated with sodic water having average RSC 9.6 and 11.1 meq/l, respectively. The yield of both crops increased significantly with the addition of increasing levels of gypsum application. Mustard crop yield in G_{100} treatment increased by more than 5.5 times of the yield obtained in G_0 treatment. Similarly, wheat crop yield also increased in G_{100} treatment by 3.7 times of the yield obtained in control. Appreciable increase in yield was also obtained in other treatments. The minimum pH (8.82) was obtained in G_{100} treatment where 100% RSC of water was neutralized with gypsum.

Reclamation of Sodic Vertisols with Soil and Water Conservation Practices under Rain Fed Conditions

The experiment was carried out on sodic Vertisols at Barwaha by adopting raised and sunken bed (1:1 ratio) system with cotton (on raised beds) and paddy (in sunken beds) under rainfed conditions. The highest paddy and cotton yields were recorded by adopting bed width of 6 m. The lowest yields of these crops were recorded in 1.5 m bed width with 1:1 fixed ratio of raised to sunken bed. The yield difference decreased marginally in absence of amendment application and high soil ESP.

The experiment with different ratios (viz.1:2, 1:1, 3:2 and 2:1) of raised to sunken bed at a constant sunken bed width of 7.5 m revealed that highest seed cotton yield was obtained with raised to sunken bed ratio of 1:2 and lowest with 2:1 ratio due to better drainage and aeration. The paddy yield increased with increasing ratio of raised to sunken beds due to more water stored in sunken beds. The highest grain yield of paddy was recorded when the ratio of raised to sunken bed was 2:1 and it decreased linearly along with decreasing ratio of raised to sunken bed. The yield difference decreased marginally in absence of amendment application and high soil ESP. The results of both the experiments reveal that amendment application is a must to get good crop yields and the system is ineffective at higher soil ESP.

Land Configurations and Nutrient Management under Rain Fed Conditions in Black Soils

The maximum runoff was recorded from flat bed system and lowest in raised–sunken bed system. The soil and nutrient loss was lowest in raised–sunken bed system. The runoff potential of flat bed system was 40-80% (depending on antecedent moisture content) and it was only 5–10% under raised–sunken bed system. There was remarkable check in runoff amount, soil and nutrient loss with adoption of broad bed and furrow-BBF and ridge and furrow system. The germination percentage as well as growth of cotton crop was also better in raised–sunken bed system followed by broad bed and furrow-BBF and ridge and furrow system.

Set Furrow Methods of Gypsum Application and Soil Reclamation

A field experiment was initiated on methods of gypsum application and effect of soil texture modification in texture on growth and yield of cotton crop. Treatments include control, gypsum @ 100 % GR in plough layer, sand application @ 25 and 50 t/ha, gypsum application in strips of 60 cm wide x 30 cm deep and gypsum and sand mixed in strips. Highest seed cotton yield was recorded when 50 tons of sand along with gypsum incorporated into soil in a set furrow system followed by where only gypsum was incorporated in set furrow. The treatment came at third position in seed cotton yield where gypsum + sand @ 50 ton was applied in plough layer.

Influence of Spent Wash and Spent Wash Vermicompost on Reclamation of Sodic Soil

A field experiment was initiated during the year 2003-04 on comparative performance of gypsum, spent wash and spent wash vermicompost application on reclamation of a sodic vertisol and its effect on growth and yield of rice-wheat cropping sequence. Treatments include control, single or combined application (FYM, gypsum @ 75% of GR, vermi-compost) and spent wash (2.5, 5.0 and 10.0 cm). The rice and wheat grain and straw yield was significantly affected by different amendments. The highest grain and straw yield was recorded with the application of spent wash @ 5.0 cm. The highest Ca uptake by grain and K uptake by straw was observed at 5.0 cm spent wash application. The application of amendments decreased the pH_s, EC_e and ESP of soil after harvest of rice and wheat crop. No drastic change in soil pH_s was observed due to application of amendments.

Studies on the Performance of Crops after Tree Species in Alkali Soils

The forestry experiment was abandoned after its 15^{th} year of plantation of nine tree species (i.e. *Prosopis juliflora, Albizia lebback, Azadirachta indica, Cassia siamea, Dalbergia sisoo, Dendrocalamus strictus, Acacia auriculiformis Casuarina equisetifolia and Eucalyptus tereticornis*). to test soil improvement and other physio-chemical properties (i.e. OC, N, P, K, aggregates and infiltration rate) and observe its effect on crop production. During the year 2006-08 maximum grain yield of wheat was noticed in the plots where *Azadirachta indica* tree species was planted followed by *Prosopis juliflora*. The minimum grain yield was recorded under *Albizia lebback* plots. Non-significant changes in chemical properties of the soil were noticed after harvest of wheat as the ESP values of the soil have got stabilized.

Unconventional Methods of Irrigating Tree Plantation in Sodic Black Soils

Four varieties of aonla (Kanchan, Krishna, Narendra-10 and Narendra-7) were planted with ITK (viz. Perforated PVC pipes of 100, 75, 50 and 25 mm diameter embedded to a depth of 40 and 62.5 cm) along with conventional check basin method and tested for establishment during early stage. The observations recorded after a year of plantation in term of survival, height and thickness at stump height showed treatments effect only on survival of plant and there was no consistent difference among other parameters. The survival of all the tested varieties was significantly superior in the irrigations where PVC pipes of higher diameter were used.

Methods of Irrigation and Water Quality on Fruit Trees in Sodic Environment

Three fruit trees Ber (Banarsi Kadka), Sapota (Kalipatti) and Pomegranate (Ganesh) were transplanted during July to September 2005. Three irrigation systems (viz. Check basin, Drip and embedded 110 mm dia. perforated PVC pipe of length 40cm) with two qualities of water (normal and diluted distillery waste water) were used. Better growth in terms of thickness 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 thickness was more in case of irrigation by diluted spent wash as compared to irrigation with best available irrigation water. Better growth in terms of height was observed in case of embedded pipe and drip irrigation as compared to check basin in all the fruit plants. Change in height was more in case of irrigation by spent wash diluted water as compared to irrigation by best available irrigation water. The water use data revealed that 1610, 376 and 480 liters (2006) and 2790, 1115 and 1480 liters (2007) of irrigation water per plant per year was applied in check basin, imbedded pipe and drip respectively.

Influence of ESP on Active Ingredient of Medicinal and Aromatic Plants in Sodic Vertisols

A field experiment was conducted on sodic Vertisols at Research Station, Barwaha at 25, 35, 45 and 55 ESP. The planting/ sowing of babchi, muskdana, sadabahar, lemon grass, palmarosa, kalmegh and ashwadandh was completed at the time of onset of monsoon in last week of July. The data indicated that the survival per cent of different medicinal and aromatic plant species decreased with increasing levels of soil ESP. Most of the species failed to survive or their survival was <50% even at ESP 25 due to heavy rains and bad weather condition during the year 2006-07. The survival of babchi and sadabahar was >50% up to ESP 35 whereas other plant species survived less than 50% at ESP level of 35. Survival per cent for babchi and sadabahar was >50% during 2007-08 as well as 2008-09 at ESP 35. Ashwgandha was quite sensitive to sodic condition, as it could not survive even at ESP 25.

Effect of Long-term Application of Organic/Green Manures in Sodic Vertisols

Various green manuring crops were cultivated in gypsum-applied plots, gypsum being applied once only before sowing of green manuring crop in the month of April/May. The green manure crop was cultivated and buried in soil at the age of 45 days well before the sowing of the *kharif* crop. The paddy-wheat crop rotation was followed. Treatments combinations include four levels of ESP (25, 35, 45 and 55) and three organic/ green manures (FYM @ 10 t/ha, dhaincha and sunhemp along with control). The ESP decreased with the incorporation of green manures/FYM at all the levels. The lowest ESP was recorded in case of dhaincha followed by sunhemp. The grain yield of paddy and wheat decreased with increase in soil ESP. Comparatively, higher average yield of paddy and wheat was recorded at soil ESP of 25 and lowest at soil ESP of 55. Incorporation of dhaincha among various treatments gave the highest yield and lowest was observed in control plot for both the crops.

Frequency of Gypsum Application and Crop Performance in Sodic Soil

The initial ESP of experimental soil was around 50. Treatment combination included frequency of gypsum applications (applied once, reapplied after three years and reapplied after six years) and doses of gypsum (@ 50, 75 and 100% GR with and without FYM). FYM was applied @ 5 t/ha. The paddy-wheat crop rotation was followed. The data revealed that grain yield of paddy and wheat increased significantly with doses of gypsum application over FYM application. However frequency of application and interaction of doses and frequency had non-significant effect on grain yield of paddy as well as wheat. The maximum grain yield of paddy and wheat was recorded when gypsum was applied @ 75% GR along with FYM followed by gypsum application @ 75% GR alone. The differences between 75% GR, 75% GR + FYM and 100% GR were non-significant.

Salinity Hazards in Vegetables under Drip Fertigation with Saline Water in Vertisols

A study was carried out during 2006-07 and 2007-08 to monitor effect of drip fertigatoin with marginally saline well water on salinity and economics of horticultural crops grown in Vertisols at farmer’s field of village - Bagda khurd, of district Khargone (MP). The data indicated that the EC values increased with the number of irrigation applied. For example average values of EC were recorded (0.40, 0.38 and 0.50 dS/m) at sampling point “on drippers” in case of capsicum crop for 1^{st} 2^{nd} and 3rd sampling respectively. Similar trend was observed in all other crops and sampling points. The study revealed that higher salt accumulation was observed on sampling points on the side of ridge, side of drippers and between drippers as compared to sampling point on drippers in case of all the crops and discharge rates. The growing horticultural crops with drip fertigation in black soils is an economically viable venture as B:C ratio is greater than 1 in case of all crops grown. Water melon gave highest B:C ratio of 3.2:1. Next to it was bitter gourd with 3.11:1, followed by potato with 2.25:1. The lowest B:C ratio was obtained in case of Capsicum due to the fact that capsicum was adversely affected at later stage by salinity. The highest WUE was obtained as 8.5 q/ha-cm in case of potato followed by water melon with WUE of 6.03 q/ha-cm and lowest was with the chilli crop 0.58 q/ha-cm.

Gypsum Application, Crop Production and Soil Chemical Environment on Farmers' Field

Some of the location specific technologies for physical (leaching, drainage and mechanical), chemical (gypsum/pyrites effectivity & techniques) and biological (tolerant crops/variety, grass cultivation, forestry, agro-horticulture, agro-forestry and silvi-pastoral system) reclamation developed by the Indore center were tested at farmers' fields. Gypsum was used @ 0, 25, 50 and 75% GR, as reclaiming agent to reclaim alkali soils on 5 farmer's fields in Indore (soybean- wheat rotation) and Khargone (cotton crop) districts. The data revealed that ESP values decreased with gypsum application as compared to untreated soil. Lowest values of ESP were observed under 75% GR, which were statistically at par with 50% GR. The data also revealed that application of gypsum significantly increased seed yield of soybean, grain yield of wheat and seed cotton yield over control. Application of gypsum @ 75% GR registered significant increase in yield over 25% GR. The differences between 50% GR and 75% GR were statistically non-significant.

Use of Agro-Chemicals to Sustain Crop Yields on Alkali Water Irrigated Soils

Results of an experiment on use of high RSC (alkali) ground water passed through 15 cm gypsum bed indicated that (i) yield increased with increase in dissolution of gypsum, (ii) soil application of gypsum recorded higher yield in initial years but subsequently yielded at par with gypsum dissolution treatment, (iii) no significant enhancement in yield was recorded with higher doze of gypsum (100% GR), (iv) enhanced efficacy of dissolution of gypsum over soil application may be attributed to gradual and continuous removal of Na through repeated equilibrium that sets in with each irrigation (with calcium) and (v) re-sodification process sets in early in case of soil application of gypsum whereas the same is delayed in case of dissolution of gypsum.

Results of an experiment on rice-wheat conducted to evaluate optimal doze of soil application of various amendments to compare efficiency with gypsum bed dissolution indicated that (i) higher doses of gypsum, pyrite (100, 150%) and press mud (10, 15 t/ha) did not record significant difference in grain yield, (ii) amendments increased yield significantly over control (RSC water) best being gypsum followed by pyrites and press mud, (iii) average increase in yield due to application of amendments over control (RSCW) was higher in case of wheat (19-34%) than rice (7-20%) and (iv) gypsum bed treatment of RSC water increased yield of both rice (13%) and wheat (28%).

Evaluation of Zero Tillage System under Semi-reclaimed Sodic Soil

In an experiments to evaluate the potential of zero tillage system at varying levels of gypsum with or without incorporation of rice straw revealed that (i) application of gypsum and rice straw incorporation increased wheat yield significantly, (ii) no significant difference in yield was recorded between conventional and zero (reduce) tillage system probably due to very poor organic carbon content (0.10%) of the soil and (iii) no considerable change in soil properties was recorded between conventional and zero (reduce) tillage system.

Relative Efficiency of Method of Gypsum Application in Reclamation of Alkali Soil

Results of experiments conducted at Kanpur to evaluate the relative efficacy of gypsum dissolution through gypsum bed and soil application under best available water irrigated condition revealed that gypsum dissolution (15 cm gypsum bed) through irrigation water (0.18 t/ha/irrigation) was more beneficial than one time soil application.

Effect of Switching Over to Upland Cropping Sequence on Resodification of Sodic Soil

A field experiment was conducted to study the effect of gypsum with and without application of green manure (dhaincha) on sustainability of reclamation under paddy-wheat, fallow-wheat and sorghum-mustard cropping sequences in sodic soil. Result showed beneficial effect of gypsum application on grain yield of rice, wheat, sorghum and mustard. About 68 and 90% increase in grain yield of rice was recorded with the application of gypsum @ 50 and 100% GR respectively. Application of gypsum @ 50 and 100% GR along with green manure recorded 70 and 80% higher yield over green manure alone. Similar trend was observed in case of wheat, sorghum and mustard.

Conjunctive Use of Canal and Amended Alkali Water in Rice Based Cropping System

To minimize sodicity build-up in soils irrigated with alkali water alone or in conjunctive mode with canal water, amelioration of alkali water with gypsum bed and distillery spent wash was initiated in 2003 and their efficacy was compared with soil application of the same amendments. A significant difference in rice grain yield was observed due to different sources of irrigation. Rice irrigated with canal and alkali water in 1:1 cyclic mode recorded an increased grain yield of 24.3% and 23.4% over alkali water in both the years 2006-07 and 2007-08. Among the water treatments irrigation with gypsum bed treated alkali water recorded an increased grain yield of 1.44 t/ha and 1.45 t/ha over untreated alkali water application. Conjunctive use of canal water to rice and alkali water for green gram recorded the highest green gram yield of 0.62 t/ha and 0.69 t/ha during fourth and fifth year of the experiment respectively. In both the years amending alkali water with gypsum recorded the maximum green gram yield of 0.64 t/ha and 0.71 t/ha, which was comparable with the soil application of gypsum @ 50% GR indicating the beneficial effect of amending the alkali water. Continuous use of alkali water to both rice and green gram increased pH from 8.4 to 9.06 and ESP from 15.8 to 36.2 of the experimental soils.

Drip Irrigation to Sugarcane using Ameliorated Alkali Water

The experiment on drip irrigation to sugarcane using ameliorated alkali water was initiated in 2003. The second main crop was planted on June 2005 and the first and second ratoon was harvested in 2007 and 2008. Ameliorating alkali water through gypsum bed recorded the highest sugarcane yield of 68.66 t/ha followed by the treatment of irrigation water with distillery spent wash (DSW) at 56.88 t/ha. Drip irrigation with alkali water and farmer's practice recorded cane yield of 44.63 t/ha and 40.37 t/ha, respectively. Soil application of gypsum @ 50% GR recorded the cane yield of 56.77 t/ha. The cane yield in unamended treatment was 41.48 t/ha. Drip irrigation resulted in irrigation water saving of 26%.

Studies on the Performance of Tree Species in Alkali Environment

Results of an experiment initiated during December 1998 in a sodic soil with pH 9.2, EC 0.24 dS/m and ESP 26.4 under rainfed condition revealed that *Prosopis*, neem, tamarind, bamboo and *Acacia* were better in terms of survival (70-89%). *Leaucena, Prosopis*, *Dalbergia* and *Acacia* were tallest (6.03-7.12 m) and recorded maximum girth at stump height (GSH) and breast height (GBH).

In another experiment conducted from 2000, among the different tree species *Leaucena*, *Acacia*, silk cotton, camel foot tree and jamun, aonla, among horticultural trees recorded higher survival percentage in alkali soil under rain fed condition. Among the planting techniques the auger hole method recorded higher survival percentage and tree growth in terms of tree height and girth.

In third experiment, three planting methods with three types of amendments were tried with neem and tamarind in rain fed alkali soil. After 96 months of planting the tamarind planting in pit with auger hole (120 cm depth) recorded maximum tree girth at breast height (GBH) 36.9 cm and 39.5 cm during 2006-07 and 2007-08 respectively. Among the amendments, application of DSW @150 ml/kg of soil recorded the highest tree height of 3.40 m and 3.54 m during 2006-07 and 2007-08 respectively in tamarind. In neem, girth at stump height (GSH) and breast height (GBH) were the maximum with auger hole method of planting after 108 months of planting. Amongst the amendments, amending the excavated soil with DSW @ 75 ml/kg of soil + gypsum @ 25% of GR had significant effect on tree girth at stump height (GSH) and girth at breast height (GBH) in both the years of 2006-07 and 2007-08.

Evaluation of Different Crops for their Tolerance to Sodicity Level

The threshold ESP for sunflower was found to be 13 (TCSH1) and 16.5 (CO4) and for okra (ladies finger) it was 16 (Parbhani kranti), 15.5 (Arka anamika) and 13.5 (Hybrid No.10). The yields at threshold ESP were 1.37 and 1.06 t/ ha for the sunflower varieties TCSH1 and CO4, respectively. The ESP levels at which 50% yield reduction took place was observed to be 37.0 and 38.5, respectively for the two varieties. The highest B:C ratio of 3.1:1 was obtained at ESP 9.2 in TCSH1 sunflower hybrid. The B:C ratio for TCSH1 hybrid at ESP 24.9 was 2.3, which was equal to the B:C ratio of CO4 variety at ESP 9.2. The highest sodium and potassium uptake was recorded at ESP 9.2. At all the ESP levels, the highest Na to K ratio were found in roots of both the varieties and the ratio increased with increasing ESP levels. In okra, the hybrid No. 10 produced an average yield of 6.79 t/ha, which was at par with Arkha Anamika (5.86 t/ha). The highest mean yield was registered at ESP 9.2 (7.56 t/ha), which got reduced as the ESP increased and the lowest was at ESP 33.2 (3.43 t/ha). At ESP 9.2, the highest yield of 9.43 t/ha was obtained in okra Hybrid No.10. At ESP 33.2, the yields of Hybrid No.10 (3.76 t/ha) and Arkha Anamika (4.03 t/ha) were at par.

Impact of Tsunami on Soils and Crops of Nagapattinam District, Tamil Nadu

The bench mark sites of the tsunami affected agricultural lands were surveyed on 17.03.2007. The soil salinity due to tsunami reduced to normal at Pushpavanam, Vellapallam, Vettaikara Iruppu, Poriyar and Neithavasal. The undulating areas in Anaikovil and Manickampangu remained saline with an EC of 13.2 and 12.1 dS/m, respectively.

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. 2132.15 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. R.B.S. College of Agriculture, Bichpuri, Agra–283105 (Uttar Pradesh)
2. Regional Research Station, Acharya N.G. Ranga Agricultural University, Bapatla–522101 (Andhra Pradesh)
3. Rajasthan Agricultural University, Bikaner–334002 (Rajasthan)
4. Agricultural Research Station, University of Agricultural Sciences, Gangawati, Koppal–583227 (Karnataka)
5. Department of Soils, CCS Haryana Agricultural University, Hisar- 125004 (Haryana)
6. Agricultural College, J.N. Krishi Vishwa Vidyalaya, Indore-452001 (Madhya Pradesh)
7. Agriculture College, C.S. Azad University of Agriculture & Technology, Kanpur–208002 (Uttar Pradesh)
8. AD Agriculture College & Research Institute, Tamil Nadu Agriculture University, Navalur, Kuttapattu, Tiruchirapalli –620009 (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 for utilization of waters having high salinity/alkalinity and toxic ions.
- Develop and test technology for the conjunctive use of poor quality waters in different agro–ecological zones/major irrigation commands.

- 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 would be 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 groundwater 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. 2132.15 lakhs (ICAR Share Rs. 1695.63). The budget head and center wise statement of expenditure for 2006–2007 and 2007–08 is given in the annexure G 6.

RESEARCH ACCOMPLISHMENTS

A. USE OF SALINE WATER IN AGRICULTURE

- **Survey and Characterization of Ground Waters for Irrigation**
- **Studies at Benchmark Sites in Guntur District to Monitor the Changes in Ground Water Quality and Soil Properties**
- **Effect of Saline Irrigation on Crop Growth and Soil Properties**
- **Conjunctive Use of Alkali and Canal Waters**
- **Strategies for Conjunctive Use of Saline and Canal Water in Cotton-Wheat and Pearl Millet-Mustard Crop Rotations**
- **Conjunctive Use of Canal and Amended Alkali Water in Rice based Cropping System**
- **Neutralization of RSC Water and Application of Organic Manures for Mitigating the Adverse Effect of High RSC**
- **Effect of High RSC Water FYM and Gypsum Levels on Vegetables**
- **Use of Agro-Chemicals to Minimize Alkalinity Hazards and Sustaining Crop Yields on Alkali Water Irrigated Soils**
- **Drip Irrigation to Sugarcane Using Ameliorated Alkali Water**
- **Drip Irrigation System with Saline Water for different Vegetable Crops in Coastal Sandy Soils**
- **Tolerance of Vegetable Crops to Saline Irrigation under Drip and Surface Irrigation System**
- **Performance of Pearl Millet-Wheat Irrigated with Sodic Water through Sprinkler System with Varying Depths of Irrigation**
- **Response of Crops to Fertilizers under Varying Salinity Levels of Water with Sprinkler Irrigation**
- **Response of Wheat-Groundnut to Varying Levels of Salinity and Moisture under Sprinkler Irrigation**
- **Crop Water/Salinity Production Functions for different Crops using Sprinkler Irrigation**
- **Effect of Irrigation with Saline Water with Varying SAR Levels on Soil and Plant Growth-Mitigating SAR Effect with Gypsum**
- **Effect of Water Quality on Wheat under different Methods of Irrigation**
- **To Optimize the Zinc Requirement of Wheat Crop Irrigated with Sodic Water**
- **Status of Fluoride in Underground Irrigation Water of Ladnu in Nagaur District and its Effect on Soil Properties and Crops**
- **Organic Input Management Options with Saline Water Irrigation for Sustaining Productivity of High Value Crops**

SURVEY AND CHARACTERIZATION OF GROUND WATERS FOR IRRIGATION

This is one of the major activities of the centers. Besides monitoring the ground water quality, centers are also monitoring the adverse effects of these waters on soil quality. As per the recommendations of the Committee of Experts, the ground waters are grouped in different categories on the basis of EC, SAR and RSC as follows:

Water quality	EC (dS/m)	SAR $(mmol/l)^{1/2}$	RSC (meq/l)
A. Good	< 2	< 10	< 2.5
B. Saline waters			
Marginally saline	2- 4	< 10	< 2.5
Saline	> 4	< 10	< 2.5
High SAR saline	> 4	> 10	< 2.5
C. Alkali waters			
Marginally alkali	< 4	< 10	2.5-4.0
Alkali	< 4	< 10	> 4.0
Highly alkali	variable	> 10	> 4.0

Bharatpur district (Rajasthan)

Ground water survey of ten tehsils namely Bharatpur, Kumher, Roopvas, Nadvai, Deeg, Nagar, Kama, Pahadi, Bayana and Veir was carried out. A total of 1332 water samples were collected and analysed for different water constituents and assessed for their quality (Table 1). The maximum EC of 36.3 dS/m was recorded in Kumher tehsil followed by 31.7 dS/m in Nagar tehsil. In rest of the tehsils, it was around 20 dS/m. The highest RSC value (23.4 meq/l) was recorded in Deeg tehsil followed by 21.8 meq/l in Nadvai tehsils. The highest SAR value of 66.7 $(mmol/l)^{1/2}$ was recorded in Nagar tehsil whereas in other tehsils it ranged from 30 to 40 $(mmol/l)^{1/2}$. The average SAR in different tehsils varied between 7.2 and 16.9 $(mmol/l)^{1/2}$.

Table 1 Minimum and maximum values of different water constituents

Tehsil	EC (dS/m)		pH		RSC (meq/l)		SAR $(mmol/l)^{1/2}$	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Bharatpur	0.8-26.1	7.2	7.2-8.8	7.8	0-12.8	4.2	1.3-26.5	11.3
Kumher	0.9-36.3	10.0	7.0-9.0	8.1	0-13.6	6.1	1.1-37.4	16.1
Roopvas	0.4-18.1	4.2	7.6-9.4	8.7	0-15.6	0.8	0.3-44.4	11.5
Nadvai	0.8-19.7	6.1	8.0-9.4	8.9	0-21.8	3.5	1.2-39.0	14.9
Deeg	0.6-19.4	7.5	6.7-9.1	8.2	0-23.4	1.8	2.6-35.0	12.7
Nagar	0.9-31.7	6.1	7.2-8.9	7.9	0-18.0	2.4	1.5-66.7	15.2
Kama	0.8-18.4	5.9	7.3-9.1	8.1	0-09.6	1.6	4.0-28.2	12.5
Pahadi	1.2-30.5	8.2	7.1-8.9	8.0	0-14.2	5.4	2.7-40.5	16.9
Bayana	0.4-13.8	1.9	7.6-8.9	8.3	0-12.4	2.9	1.1-27.3	07.2
Veir	0.5-20.2	3.0	7.4-9.2	8.2	0-27.6	5.3	1.0-31.6	10.8

In all the tehsils except Roopvas, the water samples having EC<1.5 dS/m were less than 10% of the total indicating the existence of salinity problem. Samples having EC>5 dS/m were 67, 78, 31, 55, 71 and 51%, respectively, in Bharatpur, Kumher, Roopvas, Nadvai, Deeg and Nagar tehsils. Nearly 42-95% samples in different tehsils had nil RSC. The significant number of water samples having RSC>5 meq/l are in Nadvai (30%) and Nagar (20%) tehsils only. The SAR classes revealed that 20–50 % waters had SAR <10 $(mmol/l)^{1/2}$ in different tehsils. The water having SAR in the range of 10-20 $(mmol/l)^{1/2}$ ranged from 30–50% of waters in different tehsils. It showed that majority of samples in the study area have SAR up to 20 $(mmol/l)^{1/2}$. However, about 30% in

Kumher, 18% in Roopvas, 25% in Nadvai, 15% in Deeg and 28% in Nagar have SAR>30$(mmol/l)^{1/2}$ (Table 2).

Table 2 Frequency distribution of water samples in different EC, RSC and SAR classes of Bharatpur district

Particulars	Bharatpur (150)*	Kumher (123)	Roopvas (156)	Nadvai (125)	Deeg (116)	Nagar (153)	Kama (118)	Pahadi (1129)	Bayana (125)	Veir (137)
EC (dS/m) Classes										
0-1.5	6.0	3.2	34.0	9.6	8.6	7.2	10.2	5.1	60.8	35.0
1.5-3.0	10.7	8.9	22.4	20.1	12.9	25.5	32.2	15.1	22.4	34.3
3.0-5.0	16.0	9.7	12.2	14.4	16.4	16.3	17.8	18.2	8.0	14.6
5.0-10.0	45.3	30.9	20.5	35.2	32.8	34.6	25.4	24.2	8.0	13.8
>10.0	22.0	47.1	10.9	20.0	29.3	16.3	14.4	37.4	0.8	2.2
RSC (meq/l) Classes										
Nil	94.7	86.2	64.1	52.2	73.3	59.4	66.1	76.8	48.0	42.3
0-2.5	3.3	1.6	13.5	8.8	12.1	7.8	12.7	6.1	27.2	18.2
2.5-5.0	0.7	3.2	11.5	6.4	3.4	13.1	5.1	5.1	16.0	16.8
5.0-10.0	0.7	7.3	7.7	16.2	4.3	12.4	16.1	9.1	8.0	15.3
>10.0	0.7	1.6	3.2	13.6	6.9	7.2	0.0	3.0	0.8	7.3
SAR $(mmol/l)^{1/2}$ classes										
0-10	48.7	21.9	51.3	32.0	40.5	26.8	44.1	19.2	80.0	51.8
10-20	44.0	49.6	30.8	43.2	44.0	46.4	48.3	47.5	12.8	36.5
20-30	7.3	24.4	15.4	20.8	12.9	20.9	6.8	27.3	7.2	10.9
30-40	--	4.1	1.9	4.0	2.6	4.5	0.8	4.0	0.0	0.7
>40	--	--	0.6	--	--	1.3	0.0	2.0	0.0	0.0

*: Values in parentheses are no. of samples

The cationic and anionic composition revealed that cations followed the order Na>Mg>Ca>K and anions $Cl>SO_4>HCO_3>CO_3$. Its relation with different EC classes revealed that cations Na, Mg and Ca increased with the EC whereas K remained almost constant. The proportionate increase of Na ion was higher at high EC. Amongst the anions, CO_3 and HCO_3 ions had no relation with EC. The Cl and SO_4 ion increased with increase in EC and of the two Cl ion increased in higher proportion than SO_4 with EC and had dominant share amongst the anions.

The distribution of water samples in different water quality classes revealed that barring Roopvas, Nadvai, Kama, Bayana and Veir tehsils, in rest of the tehsils only <10% waters are of good quality showing severity of poor quality water problem (Table 3). In these tehsils, majority of waters had high saline-SAR problem i.e. 50% in Bharatpur, 69% in Kumher, 42% in Roopvas and Nadvai, 45% in Deeg, 55% in Nagar, 38% in Kama and 71% in Pahadi tehsils. Comparatively, lower values of this class were recorded in Bayana (9%) and in Veir (16%) tehsils. Regarding alkali problem, it was observed that few water samples had marginal alkali and alkali problems while high alkali problem was more pronounced in Nadvai (27% waters), Deeg (23% waters), Nagar (18%), Kama (14%), Pahadi (12%) and Veir (25%) tehsils. The results could be summarized as: most tehsils have the major problem of salinity (high-saline SAR) but the tehsils Nadvai, Deeg, Nagar, Kama, Pahadi and Veir have good number of sample with high alkali problem. On an average, only 17% waters are of good quality. Of the two problem classes, 63% waters have the saline problem and 20% alkali problem. Amongst the saline classes, the majority of samples i.e. 44% have high-SAR saline problem and 10% as marginally saline and 9% saline. In alkali classes, 13% have high alkali compared to only 2% as alkali and 5% as marginal alkali. A map of the district has been prepared showing distribution of different quality classes. To get higher productivity farmers are resorting to install shallow wells and use recharge techniques to dilute ground water (Fig.1a) and use it for early irrigations to wheat (Fig.1b) and mustard.

Table 3 Distribution of water samples in different water quality categories

Tehsils	No. of samples	Good	Saline			Alkali		
			Marginally saline	Saline	Highly saline	Marginally alkali	Alkali	Highly alkali
Bharatpur	150	7	14	27	50	-	-	2
Kumher	123	2	7	11	69	1	3	7
Roopvas	156	31	8	3	42	5	6	5
Nadvai	125	14	8	3	43	5	-	27
Deeg	116	8	11	21	45	2	-	13
Nagar	153	7	8	5	55	4	3	18
Kama	99	14	15	11	38	4	3	15
Pahadi	118	5	6	4	71	2	-	12
Bayana	125	55	9	1	9	19	-	7
Vair	137	25	15	5	16	12	2	25
Total	1332	17	10	9	44	5	2	13

Visakhapatnam district (Andhra Pradesh)

The survey and characterization of ground water of Visakhapatnam district was carried out. 636 water samples were collected covering 45 mandals. The analytical data indicates that 59% were good quality waters, 4% were marginally saline, 1% was saline and 4% were high SAR saline, 17% were marginally alkali, 11% were alkali and 4% were highly alkali in nature (Table 4). While the EC_{iw} of samples varied from 0.05 to 10.40 dS/m, pH varied from 5.32 to 10.32. Sodium adsorption ratio varied from 0.06 to 26.15. Nearly 86% of the samples has EC<2 dS/m (Table 5).

Table 4 Classification of groundwater of various districts of Andhra Pradesh

District	No. of Samples	Good	Marginally saline	Saline	High SAR Saline	Marginally alkali	Alkali	High alkali
Visakhapatnam	636	380	24	4	27	106	68	27
		(59)*	(4)	(1)	(4)	(17)	(11)	(4)
Vijayanagaram	600	482	8.00	0	4	49	41	16
		(80)	(1)	(0)	(1)	(8)	(7)	(3)
Srikakulam	602	487	36.00	9	5	43	15	7
		(81)	(6)	(2.0)	(1)	(7)	(3)	(1)
Nizambad	658	549	7.00	0	8	60	21	13
		(83)	(1)	(0)	(1)	(9)	(3)	(2)
Karimnagar	643	539	48	2	2	31	11	10
		(84)	(7)	(0)	(0)	(5)	(2)	(2)
Rangareddy	514	374	27	5	3	53	49	3
		(73)	(5)	(1)	(1)	(10)	(10)	(1)
Adilabad	661	577	9	0	3	47	19	6
		(87)	(1)	(0)	(0)	(7)	(3)	(1)
Warangal	607	330	43	3	1	90	135	5
		(54)	(7)	(1)	(0)	(15)	(22)	(1)
Kadapa	501	293	32	3	15	59	68	31
		(59)	(6)	(1)	(3)	(12)	(14)	(6)
Medak	622	443	15	0	0	84	77	3
		(71)	(2)	(0)	(0)	(14)	(12)	(1)

*Values in parentheses is per cent of total

VIjayanagaram district (Andhra Pradesh)

600 water samples were collected from 33 mandals in Vijayanagaram district. Majority of water samples (80%) were of good quality while 8% were marginally alkali, 7% were alkali and 3% highly alkali in nature (Table 4). SAR value ranged from 0.21 to 18.07 while pH ranged from 5.91 to 10.32. Around 4% of the samples recorded EC_{iw} values more than 2 dS/m (Table 5).

Water Quality Map of Andhra Pradesh

During 2007-08, the data previously collected by the center and secondary data collected from various sources was collated (Table 4 and Table 5) to prepare water quality map of the state (Fig. 2). The ground water quality indicates that it is more alkali in nature while salinity prevails in coastal districts except Nellore where 1/3rd of the ground water is alkali in nature. About 20% of the ground water have RSC >4 meq/l in Ananthapur, Prakasam, Nellore, Mahaboobnagar and Warangal districts. Ground water quality in coastal districts is mostly marginally saline in nature with 2 to 4 dS/m. However, in East Godavari more than 10% of the ground water has got EC_{iw} >4 dS/m. The map along with package of practices was distributed to the various extension agencies of the state.

Table 5 Per cent distribution of underground irrigation water

S.No.	District	EC_{iw} (dS/m)			RSC (meq/l)		
		0.1-2.0	2.0-4.0	>4.0	<2.5	2.5-4.0	>4.0
1	Ananthapur	92.1	6.8	1.1	51.5	21.7	26.8
2	Prakasam	76.9	17.5	5.6	59.1	18.3	22.6
3	Guntur	77.8	18.1	4.1	77.2	18.5	4.3
4	East Godavari	80.6	6.2	13.2	85.3	8.5	6.2
5	West Godavari	84.7	13.6	1.7	84.1	13.7	2.2
6	Krishna	77.6	17.9	4.5	79.8	16.7	3.5
7	Khammam	97.5	2.5	0.0	89.7	6.5	3.8
8	Kurnool	90.8	8.4	0.8	74.0	14.3	11.7
9	Nellore	86.9	9.9	3.2	49.3	20.6	30.1
10	Nalgonda	92.4	7.1	0.6	68.3	18.9	12.8
11	Mahaboobnagar	96.9	2.7	0.4	53.7	19.9	26.4
12	Chittoor	90.7	8.6	0.7	81.2	15.3	3.5
13	Vishakhapatnam	85.8	11.2	3.0	67.0	15.1	17.9
14	Vijayanagaram	96.3	3.7	0.0	81.7	9.0	9.3
15	Srikakulam	85.9	12.0	2.1	89.0	7.5	3.5
16	Nizamabad	95.6	4.1	0.3	83.7	10.5	5.8
17	Medak	97.4	2.6	0.0	73.5	15.9	10.6
18	Karimnagar	91.6	7.8	0.6	92.1	5.4	2.5
19	Kadapa	87.0	11.6	1.4	67.2	13.8	19.0
20	Rangareddi	93.0	6.0	1.0	79.6	10.9	9.5
21	Warangal	91.4	7.9	0.7	61.0	14.7	24.3
22	Adilabad	97.8	2.1	0.1	88.4	7.7	3.9

Fig.1a Shallow well

Fig.1b Wheat crop irrigated by diluted ground water

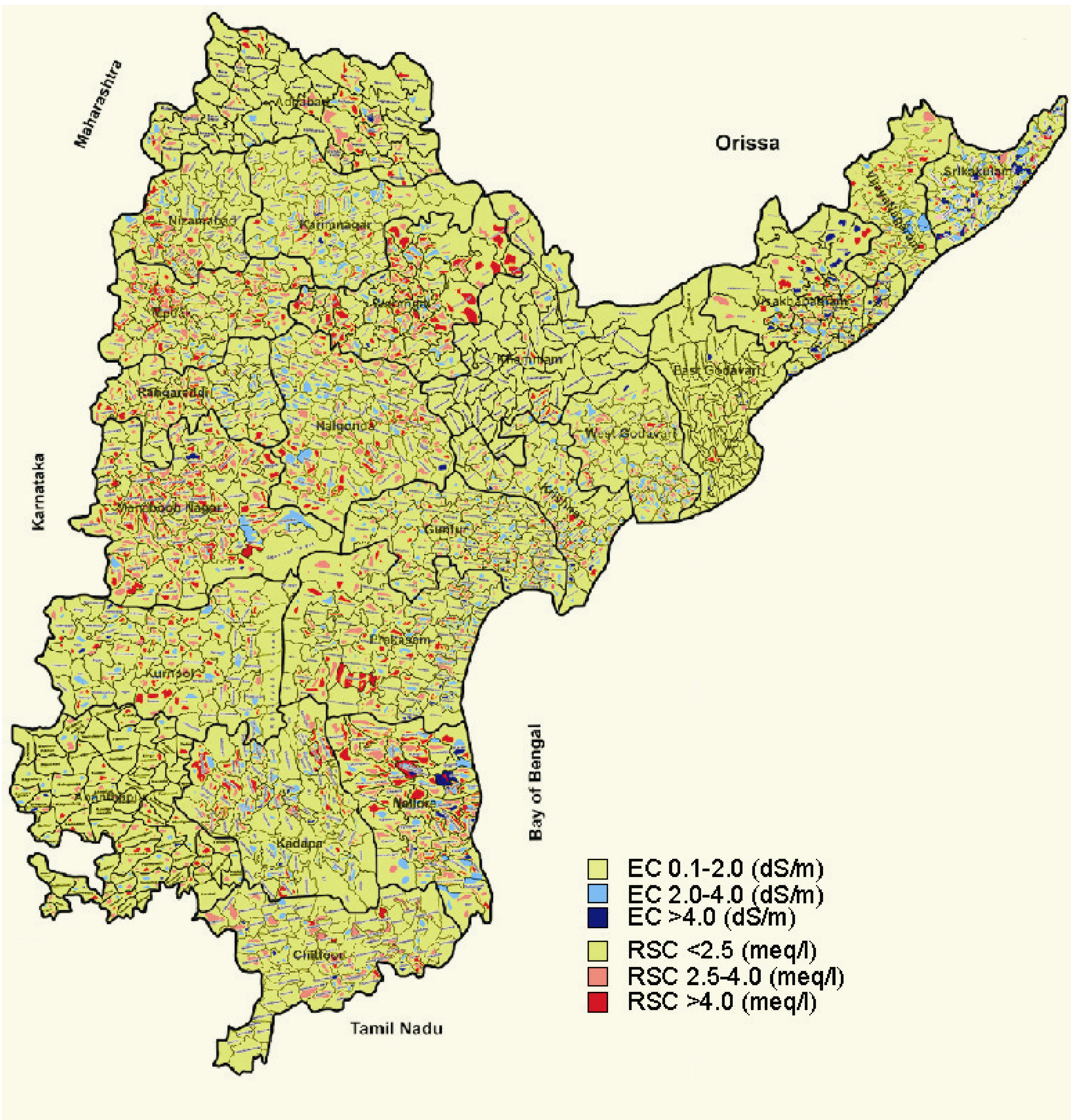


Fig. 2 Ground water quality map of Andhra Pradesh

Jaisalmer district (Rajasthan)

Survey of ground water quality of Jaisalmer district was continued. One hundred eighty eight tube well water samples were collected from three tehsils namely Pokaran, Jaisalmer and Fatehgarh and were analyzed for their chemical characteristics. EC and pH of water samples ranged from 0.7 to 20.5 dS/m and 7.1 to 8.9, respectively. The concentration of calcium and magnesium ranged from 0.4 to 6.4 and 0.5 to 44.9 meq/l, respectively (Table 6). Sodium concentration ranged from 2.8 to 110.2 meq/l, whereas concentration of potassium ion varied from traces to 2.4 meq/l. Soluble carbonates and bicarbonates varied from 3.0 to 27.6 meq/l, although the carbonate was only in traces. The concentration of chloride and sulphate varied from 2.0 to 158.2 and 0.08 to 31.3 meq/l, respectively. SAR, Adjusted SAR and soluble sodium percentage (SSP) of water samples ranged from 2.0 to 40.9, 4.2 to 120.6 and 37.1 to 92.0, respectively. Waters are of Na-Mg-Ca type with the dominance of chloride. Aquifer depth from where tube wells draw water varied from 13.3 to 166.7m (Table 6). RSC of water samples ranged from 0 to 19.2meq/l. About 53.7, 20.7, 19.1 and 6.5% water samples had RSC <2.5, 2.5-5.0, 5.0-7.5 and >7.5 meq/l, respectively. As regard salinity 39.9, 32.4 and 27.7% water samples showed EC in the range of <2.0, 2.0-4.0 and >4.0 dS/m, respectively. About 19.1,12.2, 2.7, 25.5, 10.6, 0.5 and 29.4% water samples are of good, marginally saline, saline, high SAR saline, marginally alkali, alkali and highly alkali categories, respectively (Table 7 and Fig. 3). Fluoride and nitrate content of water samples varied between 0.47 to 10.2 and 9.4 to 1193 mg/l, respectively. Only 22.9% water are safe for drinking purpose (<1.5 mg/l), whereas, fluoride content in 72.8, 2.7 and 1.6% water ranged between 1.5- 5.0, 5.0-10.0 and >10.0 mg/l. About 17.8, 33.5, 14.4 and 38.3% water samples contained nitrate content in the range <20, 20-50, 50-100 and >100 mg/l, respectively. Problem of high alkalinity is more in Jaisalmer tehsil (42.9%) followed by Fatehgarh tehsil (36.2%) and Pokaran tehsil (14.1%) whereas, problem of high SAR saline water is more in Pokaran tehsil (34.6%) followed by Fatehgarh tehsil (23.4%) and Jaisalmer tehsil (15.9%).

Table 6 Range of chemical characteristics of waters and soils of Jaisalmer district

Characteristics	Pokaran (78)*	Jaisalmer (63)	Fatehgarh (47)	Jaisalmer district (188)
pH	7.1–8.9 (7.9)**	7.8–8.9 (8.5)	7.4-8.9 (8.2)	7.1-8.9 (8.3)
EC (dS/m)	1.0-20.5 (4.4)	0.7-5.8 (2.3)	0.7-5.8 (2.6)	0.7-20.5 (3.2)
Ca (meq/l)	0.8-5.0	0.4–6.4	0.4-5.0	0.4-6.4
Mg (meq/l)	1.4-44..9	0.7–13.0	0.5-10.8	0.5-44.9
Na (meq/l)	4.3-110.2	2.8–47.2	3.7-43.2	2.8-110.2
K (meq/l)	Trace - 0.8	0.1–2.4	0.1-1.4	Trace -2.4
CO_3+ HCO_3 (meq/l)	3.0-27.6	3.0-14.4	3.6-13.8	3.0-27.6
Cl (meq/l)	3.4-158.2	2.0-48.0	2.4-50.6	2.0-158.2
SO_4 (meq/l)	0.1-31.3	0.08-12.4	0.1-5.7	0.8-31.3
RSC (meq/l)	Nil-19.2	Nil-11.5	Nil-11.0	Nil-19.2
SAR	2.7-40.9	2.0–29.6	2.7-25.8	2.0-40.9
Adj. SAR	6.1-120.6	4.2-60.7	5.7-56.8	4.2-120.6
Potential salinity (meq/l)	3.8-171.7	2.3-48.3	2.6-52.0	2.3-171.7
Fluoride (mg/l)	0.8-10.2	0.54-4.62	0.47-4.80	0.47-10.2
Nitrate (meq/l)	25-1193	9.40-472	15.2-685	9.4-1193
SSP	44.6-91.3	39.6-92.0	37.1-92	37.1-92.0
Mg/Ca ratio	0.6–2.8 (1.5)	0.8-3.8 (1.6)	0.7-3.4 (1.5)	0.6-3.8 (1.5)
Depth to Water table (m)	13.3–133.3	50.0-166.7	63.3-140.0	13.3-166.7

*: No. of samples tested; **: value in parentheses are the average values

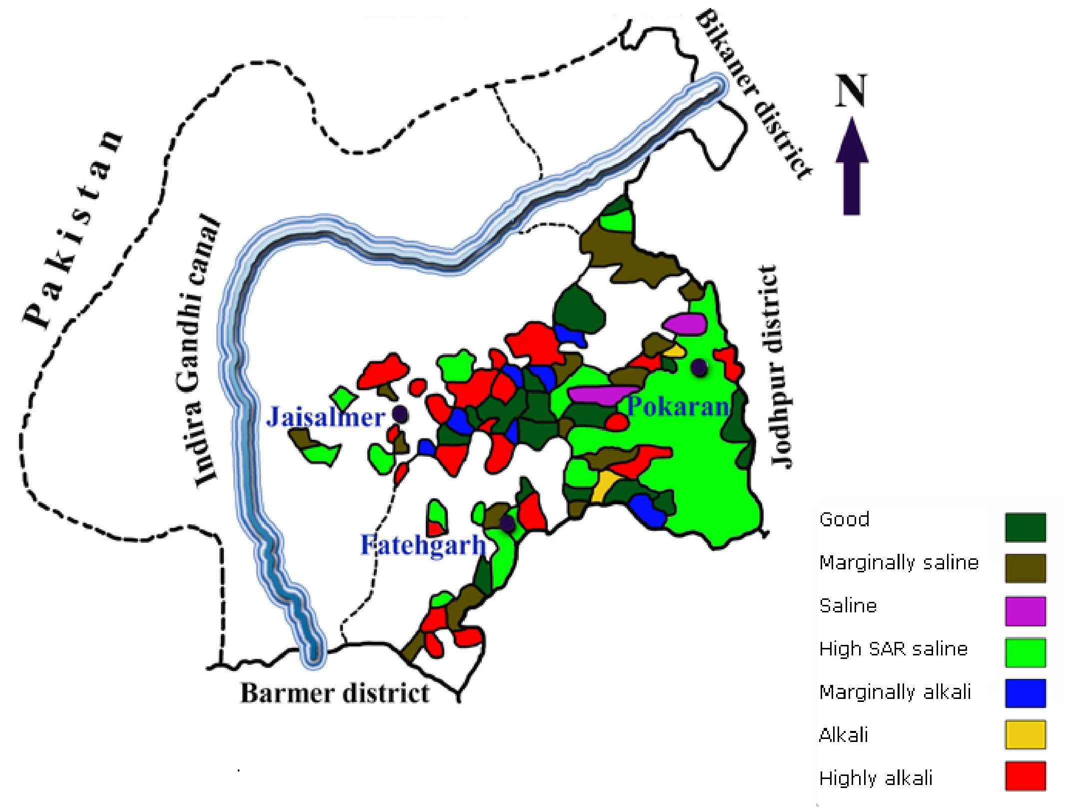


Fig. 3 Ground water quality map of Jaisalmer district

Table 7 Percent distribution of different categories of water in Jaisalmer district

Water quality	Pokaran (78)*	Jaisalmer (63)*	Fatehgarh (47)*	Jaisalmer district (188)*
Good	19.2	12.7	27.7	19.1
Marginally Saline	20.5	3.2	10.6	12.2
Saline	6.4	-	-	2.7
High SAR Saline	34.6	15.9	23.4	25.5
Marginally Alkali	3.8	25.3	2.1	10.6
Alkali	1.3	-	-	0.5
Highly Alkali	14.1	42.9	36.2	29.4

* No. of samples analysed

Percent distribution of water samples in relation to pH, EC, SAR, SSP, fluoride, nitrate and Mg/Ca ratio in the district is presented in Table 8. Percentage of water samples having pH >8.5 was found higher in Jaisalmer tehsil (52.3%) followed by Faehgarh tehsil (17.0%). Percentage of water samples having EC >4.0 dS/m was higher in Pokaran (42.3%) followed by Fatehgarh (21.2%) and Jaisalmer tehsil ((14.3%). Water samples having SAR >20 were found maximum in Pokaran tehsil (23.1%). Problem of fluoride water is more in Jaisalmer tehsil (88.9%) followed by Pokaran tehsil (82.1%). Percentage of water samples having nitrate content >100 mg/l was observed higher in Pokaran tehsil (75.6%).

Table 8 Distribution of water samples (%) in relation to pH, EC, SAR, SSP fluoride, nitrate and Mg/Ca ratio

Characteristics	Pokaran tehsil	Jaisalmer tehsil	Fatehgarh tehsil	Jaisalmer district
pH				
7.0-7.5	17.9	-	2.1	8.0
7.6-8.0	44.9	4.8	23.4	26.0
8.1-8.5	29.5	42.9	57.5	41.0
>8.5	7.7	52.3	17.0	25.0
EC (dS/m)				
<2	24.3	55.6	44.7	39.9
2-4	33.4	30.1	34.0	32.4
4-6	21.8	14.3	21.2	19.2
>6	20.5	-	-	8.5
SAR				
0-10	44.9	34.9	34.1	38.8
10-20	32.0	58.7	55.3	46.8
20-30	20.5	6.4	10.6	13.3
>30	2.6	-	-	1.1
SSP				
<50	3.7	1.6	2.1	2.7
50-60	12.8	-	2.1	5.9
60-70	24.4	3.2	12.8	14.9
70-80	28.3	30.2	29.8	19.0
>80	30.8	61.9	53.2	57.5
Fluoride (mg/l)				
<1.5	17.9	11.1	46.8	22.9
1.5-5.0	71.8	88.9	53.2	72.8
5.0-10.0	6.4	-	-	2.7
>10.0	3.9	-	-	1.6
Nitrate (mg/l)				
<20	-	38.1	4.3	13.8
20-50	10.2	44.4	57.5	33.5
50-100	14.2	11.1	19.1	14.4
>100	75.6	6.4	19.1	38.3
Mg/Ca ratio				
<1	10.3	6.3	14.9	10.1
1-2	62.8	39.7	68.1	56.4
2-3	25.6	15.9	17.0	20.2
>3	1.3	38.1	-	13.3

The range of chemical characteristics of soil samples collected from lands irrigatied with these waters in Jaisalmer district indicates that pH_2 of soil samples varied from 7.8 to 9.8 whereas, EC_2 ranged from 0.2 to 3.9 dS/m (Table 9). About 8.5 per cent soils had EC_2 greater than 0.5 dS/m and 14.5 per cent soil samples showed pH2 >9.0, which indicates that soils are deteriorating with the use of poor quality waters. The deterioration rate of Fatehgarh tehsil is less than Pokaran and Jaisalmer tehsils as most of the tube wells are operating from 2005 onward only.

Table 9 Range of chemical characteristics of soil with tube well irrigation water

Chemical Characteristics	Pokaran (38)*	Jaisalmer (53)*	Fatehgarh (19)*	Jaisalmer district (110)*
pH_2	8.1-9.7 (8.9)**	7.8-9.4 (8.8)	8.3-9.8 (8.9)	7.8-9.8 (8.9)
EC_2 (dS/m)	0.2-3.9 (0.6)	0.2-2.1 (0.47)	0.2-1.7 (0.23)	0.2-3.9 (0.48)
Ca (meq/l)	0.6-6.4	0.5-1.8	0.7-2.3	0.5-6.4
Mg (meq/l)	0.5-3.6	0.2-2.5	0.5-2.0	0.2-3.6
Na (me/l)	1.1-33.2	0.8-17.1	0.6-12.8	0.6-33.2
K (meq/l)	0-0.4	0.09-0.50	0.08-0.55	0.03-0.55
CO_3 + HCO_3 (meq/l)	1.0-4.2	0.1- 4.2	1.1-3.3	0.08-4.2
Cl (meq/l)	0.7-35.0	0.3-17.0	0.7-13.0	0.3-35.0
SO_4 (meq/l)	0.1-5.0	0.04-3.7	0.15-2.85	0.04-4.98
SAR	1.1-31.7	0.7-12.6	0.7-9.2	0.7-31.7

*:No. of samples tested; **: Figure in parenthesis are the average values

Gulbarga district (Karnataka)

The survey of ground water quality of Gulbarga district, Karnataka initiated in 2004-05 was continued during 2007-08 and 2008-09. Five more talukas of the district viz., Chittapur, Sedam, Chincholi, Afjalpur and Aland were surveyed, thus completing the survey and characterization of underground irrigation water of Gulbarga district. The data in Table 10 revealed that frequency of occurrence of good quality water in the talukas followed the order: Aland (87.3%) >Afjalpur (83.8%) >Chincholli (77.0%) >Sedam (60.8%) >Chittapur (57.50%). Except Afjalpur, the extent of occurrence of saline water with or without high SAR was considerably less in other talukas. Among the problematic waters, marginal alkali (RSC 2.5-4.0 meq/l) was predominant in Chittapur (28.1%), Sedam (19.2%) and Chincholli (17.3%). The Sedam taluka registered the highest percentage (15.40%) of highly alkali water compared to other talukas. Among the five talukas, majority of water samples in Chittapur (65.4%), Sedam (63.1%) and Chincholli (68.8%) talukas had pH >8.5. Fluoride content in water revealed fairly high content in Chittapur (1.34 ppm) compared to Sedam (0.84 ppm) and Chincholli (0.78 ppm) (Fig. 4).

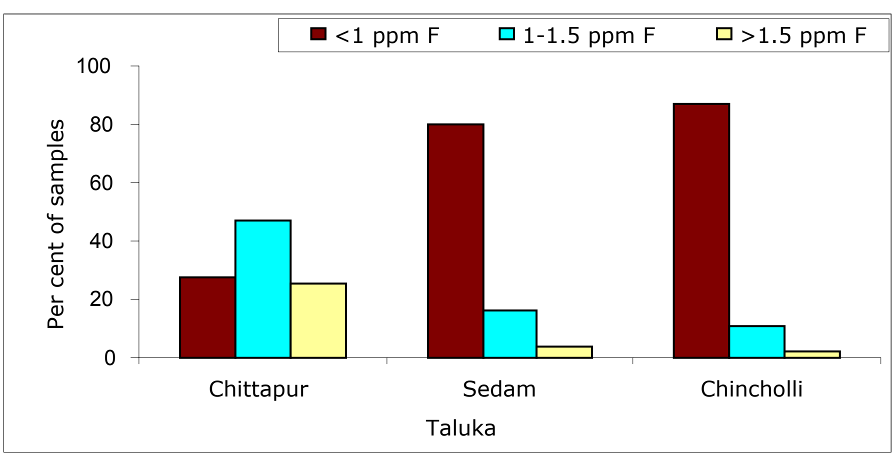


Fig. 4 Frequency distribution of ground water samples in respect of fluoride content in different talukas of Gulbarga district

Table 10 Water quality ratings (%) of ground waters of different talukas of Gulbarga

Taluka	Sample size	Good	Saline			Alkali		
			Marginal saline	Saline	High SAR saline	Marginal alkali	Alkali	Highly alkali
Afjalpur	154	83.8	4.5	-	7.8	3.9	-	-
Aland	220	87.3	3.6	-	1.4	7.7	-	-
Chittapur	188	57.5	5.9	-	2.1	28.1	0.5	5.90
Sedam	130	60.8	-	-	1.5	19.2	3.1	15.4
Chincholi	156	77.0	0.6	-	-	17.3	1.9	3.20

Morena district (Madhya Pradesh)

The survey and characterization of ground waters of Morena district of Madhya Pradesh was completed during 2006-07. The district has semi-arid to arid subtropical monsoon type climate receiving an annual rainfall of about 500-600 mm. The soils of the district are classified as Inceptisols and most of the soils have originated from deposition of alluvium. At few locations, moderately deep to shallow black soils were also encountered. A variety of crops like wheat, mustard, gram, pea, berseem, sugarcane and potato etc. are grown. Open wells and tube wells are used to irrigate the crops. However, gram and wheat are also grown on profile stored moisture. The data indicated that pH, EC, SAR and RSC ranged from 7.3-8.9, 0.4-3.2 dS/m, 0.6-10.3 $(mmol/l)^{½}$ and 0.0-13.4 meq/l respectively (Table 11). Out of the ninety groundwater samples collected from different villages of the district, 67% samples (Table 12) are of good quality, 7% samples represented saline category, whereas, 26% samples were alkali in nature (Fig. 5). Most of the poor quality water had high SAR (10.0-13.4 $(mmol/l)^{½}$ and RSC (2.5-10.3 meq/l) revealing that the amendment application might be needed in Morena, Joura, Kailaras and Porsa tehsils.

Table 11 Salient features of ground water of Morena district

Parameters	Tehsils					
	Morena	Joura	Kailaras	Sabalgarh	Ambah	Porsa
pH	7.3-8.9	7.4-8.2	7.6-8.3	7.5-7.9	7.3-8.4	7.5-8.3
EC (dS/m)	0.5-3.2	0.6-1.2	0.4-2.3	0.8-1.5	0.8-1.5	0.7-1.4
SAR $(mmol/l)^{1/2}$	1.1-10.1	1.1-3.3	0.8-10.3	1.3-3.0	0.6-1.6	1.3-5.2
RSC (meq/l)	0.0-13.4	0.0-3.6	0.0-7.8	0.0-0.9	0.0-4.8	0.0-5.0

Table 12 Frequency distribution of water samples of different categories in Morena

Tehsils	Good	Saline			Alkali		
		Moderately saline	Saline	High SAR saline	Moderately alkali	Alkali	Highly alkali
Morena	28	06	-	-	09	01	01
Joura	11	-	-	-	03	-	-
Kailaras	01	-	-	-	01	01	01
Sabalgarh	04	-	-	-	-	-	-
Ambah	08	-	-	-	01	-	-
Porsa	08	-	-	-	06	-	-
Total	60	06	-	-	20	02	02

Sheopur (Madhya Pradesh)

The survey and characterization of underground irrigation water of Sheopur district of Madhya Pradesh was undertaken during 2007-08. The district has semi-arid to arid subtropical monsoon type climate and receives an average annual rainfall of about 620 mm. The soils of the district belong to Inceptisols and Aridisols with good amount of variation in texture and colour. Most of the soils originated from deposition of alluvium. At few locations, moderately deep to shallow black soils are also encountered. A variety of crops like wheat, mustard, coriander and berseem are grown in the district. Open wells and tube wells water is used to irrigate the crops. The results revealed that pH, EC, SAR and RSC ranged from 7.0-8.1, 0.4-9.9 dS/m, 0.1-16.4 $(mmol/l)^{½}$ and 0.0-10.7 meq/l respectively (Table 13). Out of two hundred and one ground water samples collected from different villages, 86.5% samples (Table 14) are of good quality, 3.5% samples represented saline category, whereas, 10.0% samples were alkali in nature (Fig. 6). Most of the poor quality water had high RSC (2.5-0.7 meq/l) revealing that the amendment application might be needed in Sheopur and Vijaypur tehsils.

Table 13 Salient features of ground water samples of Sheopur district

Parameters	Tehsils		
	Sheopur	Karahal	Vijaypur
pH	7.0-7.8	7.1 - 7.3	7.1 - 8.1
EC (dS/m)	0.4- 3.2	0.6 - 0.9	0.5 - 9.9
SAR	0.2 - 8.4	0.1 - 2.7	1.0 - 16.4
RSC (meq/l)	0.1 - 6.1	0.0 - 0.4	0.1 - 10.7

Table 14 Frequency distribution of water samples of different categories in Sheopur

Tehsils	Good	Saline			Alkali		
		Moderately saline	Saline	High SAR saline	Moderately alkali	Alkali	Highly alkali
Sheopur	108	3	0	0	6	4	0
Karahal	11	0	0	0	0	0	0
Vijaypur	55	0	4	0	3	5	2
Total	174	3	4	0	9	9	2

Bhind district (Madhya Pradesh)

The survey and characterization of underground irrigation water of Bhind district of Madhya Pradesh was also completed during 2007-08. The district has semi-arid to arid subtropical monsoon type climate and receives an annual rainfall of about 600-700 mm. The soils of the area are classified as Inceptisols and Aridisols. Most of the soils originated from deposition of alluvium. At few locations moderately deep to shallow black soils were also encountered. A variety of crops like wheat, mustard, potato and berseem are grown in the district. The crops are irrigated with water drawn from open wells and tube wells. The quality of ground water samples indicates that pH, EC, SAR and RSC ranged from 7.1-8.4, 0.5-31.4 dS/m, 0.2-32.2 $(mmol/l)^{½}$ and 0.1-42.1 meq/l respectively (Table 15). Out of three hundred and two ground water samples collected from different villages of the district, 52.3% samples are of good quality (Table 16), 10.6% samples come under saline category, whereas, 37.1% samples represented alkali water category (Fig. 7). Most of the poor quality water had high SAR (10.0-32.1 $(mmol/l)^{½}$ and RSC (2.5-42.1 meq/l) revealing that the amendment application might be needed in district.

Table 15 Salient Features of ground water samples of Bhind district

Parameters	Gohad	Bhind	Ater	Mehgaon	Raun	Mehona	Lahar
pH	7.1-8.4	7.1-7.9	7.1-8.3	7.1-8.4	7.1-8.2	7.1-8.4	7.1-8.3
EC (dS/m)	0.5-31.4	0.6-3.5	0.9-3.6	0.7-5.4	0.8-4.3	1.2-10.2	0.5-3.4
SAR	1.2-32.2	0.2-8.8	0.2-13.4	1.1-14.5	1.5-11.0	2.6-15.2	0.8-10.1
RSC (meq/l)	0.2-42.1	0.1-7.0	0.1-8.4	0.1-14.3	0.3-11.6	0.4-8.2	0.4-5.7

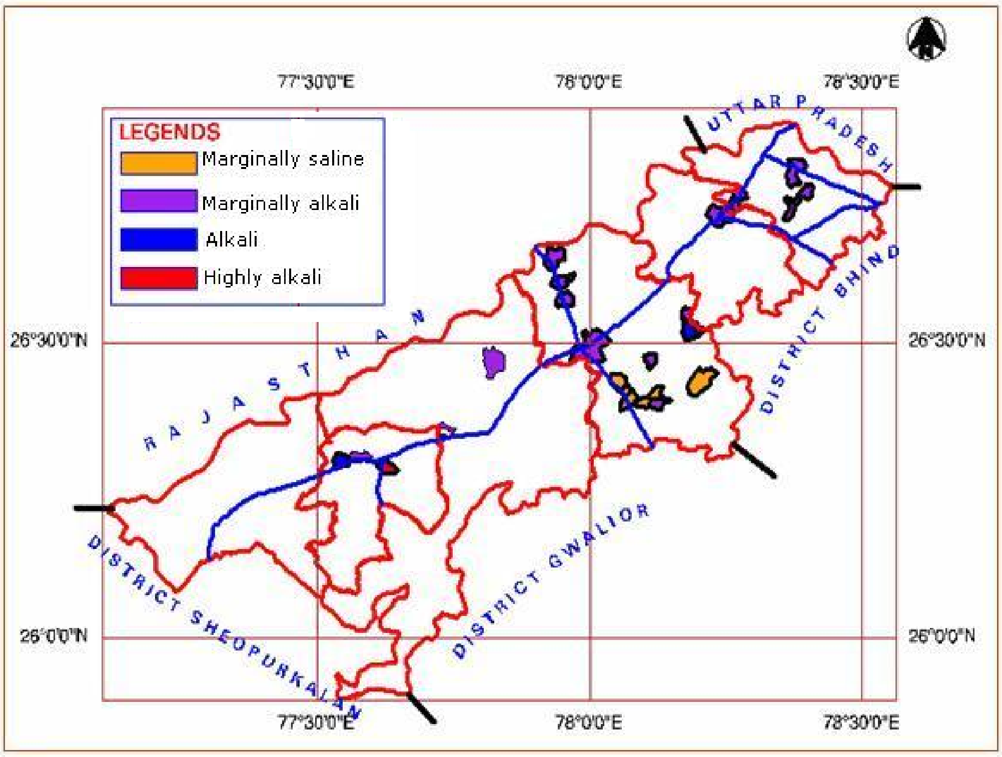


Fig. 5 Ground water quality map of Morena district

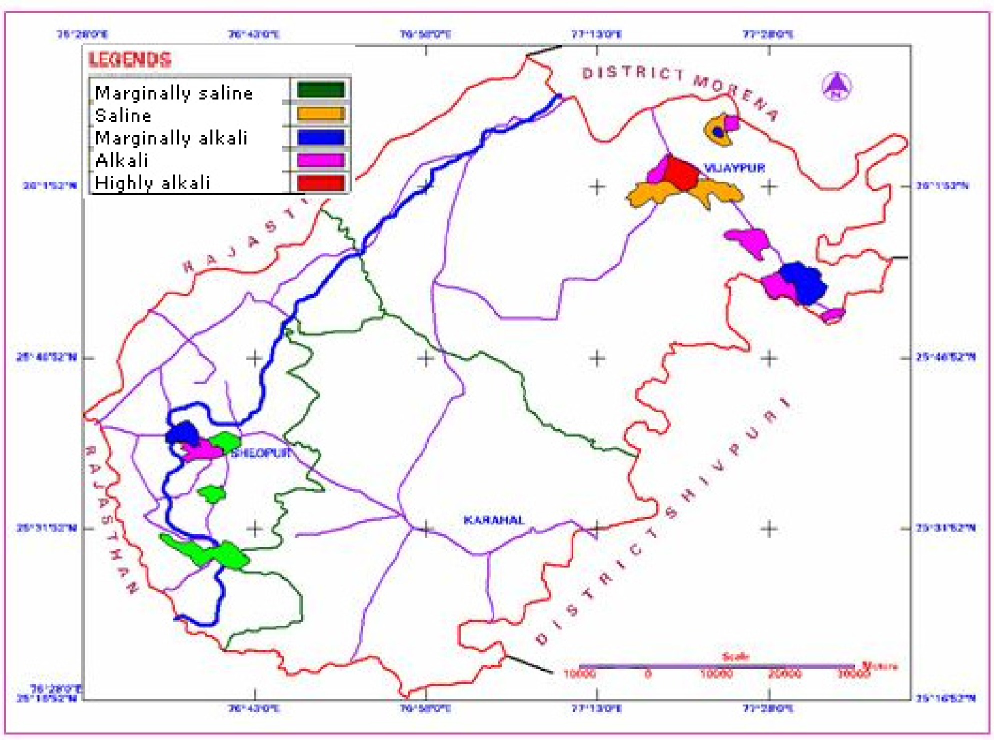


Fig. 6 Ground water quality map of Sheopur district

Table 16 Frequency distribution of water samples of different categories in Bhind

Tehsils	Good	Saline			Alkali		
		Moderately saline	Saline	Highly saline	Moderately alkali	Alkali	Highly alkali
Gohad	25	4	2	1	5	10	6
Bhind	44	4	0	0	6	8	0
Ater	26	4	0	0	10	5	2
Mehgaon	19	5	5	2	14	18	7
Raun	8	0	0	1	3	3	1
Mehona	6	3	0	1	4	3	1
Lahar	30	0	0	0	5	0	1
District over all	158	20	7	5	47	47	18

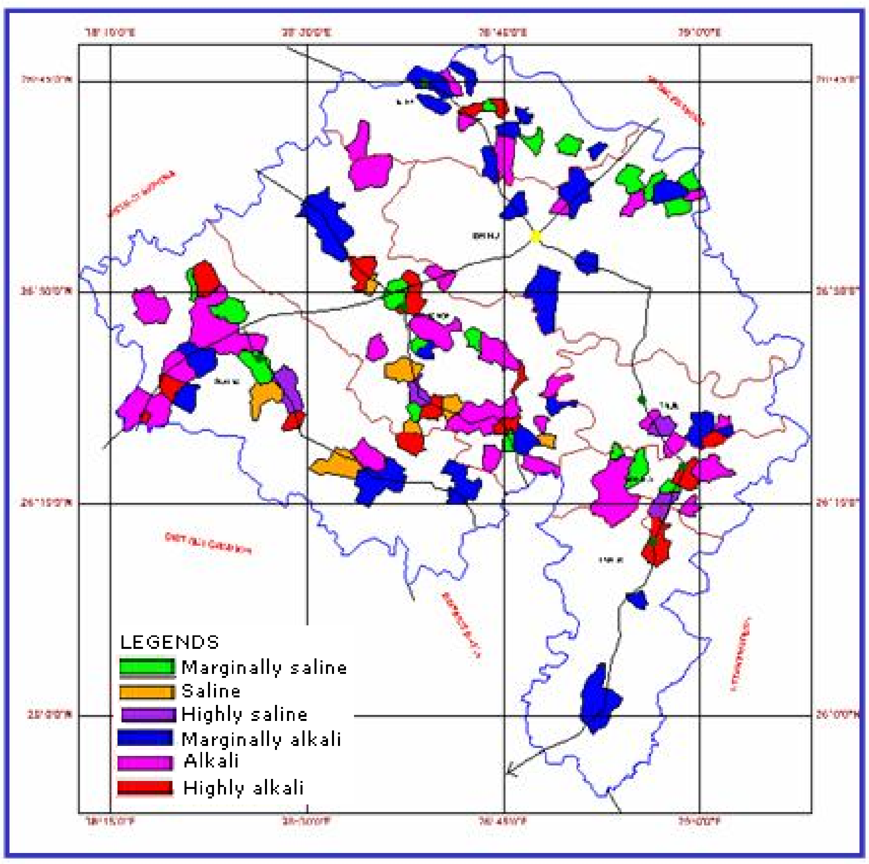


Fig. 7 Ground water quality map of Bhind district

Gurgaon district (Haryana)

In the year 2006-07, the survey and characterization of underground irrigation water of Pataudi and Farukhnagar blocks of Gurgaon district was undertaken while in the year 2007-08, Bawani Khera and Bhiwani blocks of Bhiwani district, Mundalana and Kathura blocks of Sonipat district were undertaken. Tube well water samples were collected randomly from each village of the blocks at different locations. Samples were analyzed for various water quality parameters viz., pH, EC, cations (Na, K, Ca and Mg) and anions (CO_3, HCO_3, Cl, SO_4, NO_3 and F). Subsequently, SAR and RSC were calculated and classified into various categories according to the classification approved by AICRP on Use of Saline Water.

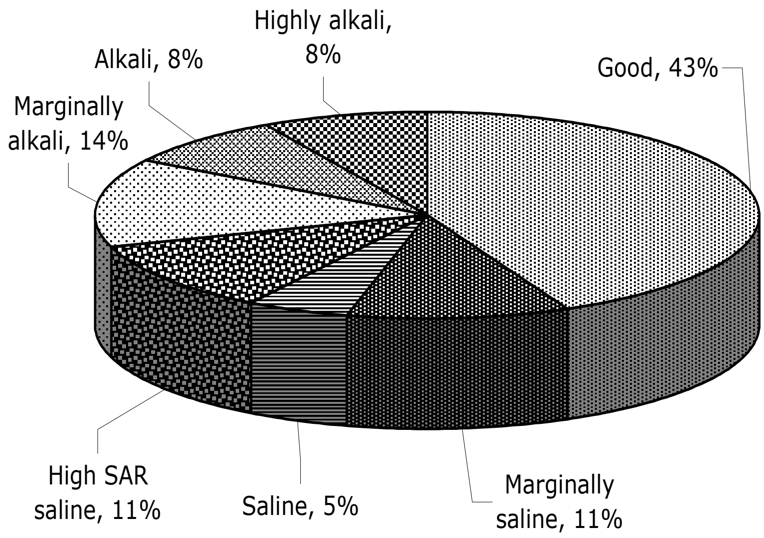
Gurgaon lies on the extreme south-east corner of Haryana state. The Gurgaon district has hot and semi-arid climate, with annual rainfall ranging from 550 mm to 760 mm with an average of 619 mm. The soils on the eastern flank of Hodal block adjoining Yamuna are sandy to fine sandy loam at the surface. Due to high water table, they are medium to poorly drained and remain saturated with water during the rainy season. The soils in some parts of Hodal and Gurgaon blocks adjoining Ballabhgarh and Delhi are heavy textured varying from sandy loam at the surface to clay loam at about 1 m depth and are mostly well drained. Of the total area, 78.2% is under cultivation and 1.1 and 2.4% is affected by salinity-alkalinity and water logging, respectively. Although soils are suitable for cultivation of a variety of crops but availability of good quality water is the main handicap. The main crops grown are pearl millet, sorghum in kharif and gram, barley, oil seeds and wheat in rabi season.

The range and mean of different water quality parameters of 261 underground water samples collected from Pataudi block and 171 samples from Farukhnagar revealed that in Pataudi block, EC values ranged from 0.52 to 10.71 dS/m with a mean of 2.34 dS/m. The SAR ranged from 0.3 to 26.62 $(mmol/l)^{1/2}$ and RSC varied from 0-15.2 meq/l (Table 17). In cations, concentration of Na, Ca and Mg and in anions, the concentration of Cl generally increased with increasing EC of the underground water. Potassium was also in appreciable amount ranging from 0.01 to 2.56 meq/l. The mean Cl content was 12.1 meq/l. The Na concentration range (0.62 to 67.7 meq/l) was the widest whereas the concentration of CO_3 varied in a narrow range (0 to 3.5meq/l). The classification of water samples of Pataudi block showed that highest per cent samples, 43% were in good quality class. The percent samples in marginally saline, saline and high SAR saline classes were 11, 5 and 11% respectively (Fig. 8). Amongst the sodic classes, marginally alkali class recorded the maximum per cent samples (14%) followed by alkali (8%) and highly alkali (8%) classes.

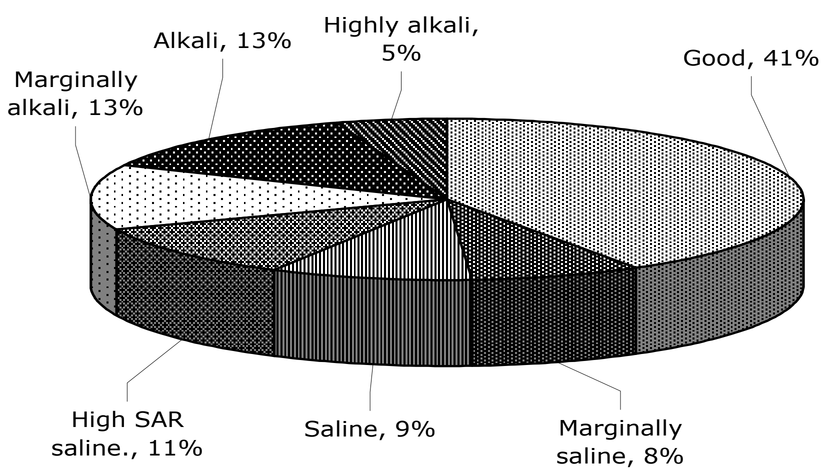
In Farukhnagar block, EC ranged from 0.45 to 14.24 dS/m with a mean value of 2.69 dS/m. The SAR ranged from 0.42 to 28.56 $(mmol/l)^{1/2}$ and RSC varied from 0 to 10.25meq/l (Table 17). The mean values of SAR and RSC were 6.28 $(mmol/l)^{1/2}$ and 1.63 meq/l, respectively. In cations, concentration of Na, Ca and Mg and in anions, concentration of Cl generally increased with increasing EC of the underground water. Potassium was in low amount ranging from 0.06 to 2.91 meq/l. The mean Cl content was 1.89 meq/l. The Na concentration ranged from 0.58 to 3.94 meq/l. The concentration of CO_3 varied in a narrow range (0 to 4.0 meq/l). Percentage of samples falling in good category was 41% while 8% were in marginally saline category (Fig. 8). Saline and high SAR saline category accounted for 9 and 11% waters. Among the sodic classes, 13, 13 and 5% samples recorded marginally alkali, alkali and high alkali classes, respectively.

Table 17 Water quality parameters of Pataudi and Farukhnagar blocks (Gurgaon)

Parameters	Pataudi block		Farukhnagar block	
	Range	Mean	Range	Mean
EC (dS/m)	0.52-10.71	2.34	0.45-14.24	2.69
pH	7.10-9.30	8.11	7.20-9.05	8.16
CO_3 (meq/l)	0.00-3.50	1.01	0.00- 4.00	0.97
HCO_3 (meq/l)	0.75-27.75	6.91	0.25-39.75	6.90
Cl (meq/l)	0.50-85.00	12.10	1.00-100.50	14.89
SO_4 (meq/l)	0.04-21.70	1.85	0.03-27.80	1.96
Na (meq/l)	0.62-67.70	14.67	0.58-103.94	14.80
Ca (meq/l)	0.67-22.93	2.71	0.67-41.87	0.70
Mg (meq/l)	0.03-45.98	5.07	0.27-45.63	4.12
K (meq/l)	0.01-2.56	0.60	0.06-2.91	6.30
SAR $(mmol/l)^{1/2}$	0.30-26.62	7.65	0.42-28.56	6.28
RSC (meq/l)	0.00-15.20	1.80	0.00-10.25	1.63



Pataudi block



Farukhnagar block

Fig. 8 Categorization of ground water of two blocks of Gurgaon district

Bhiwani district (Haryana)

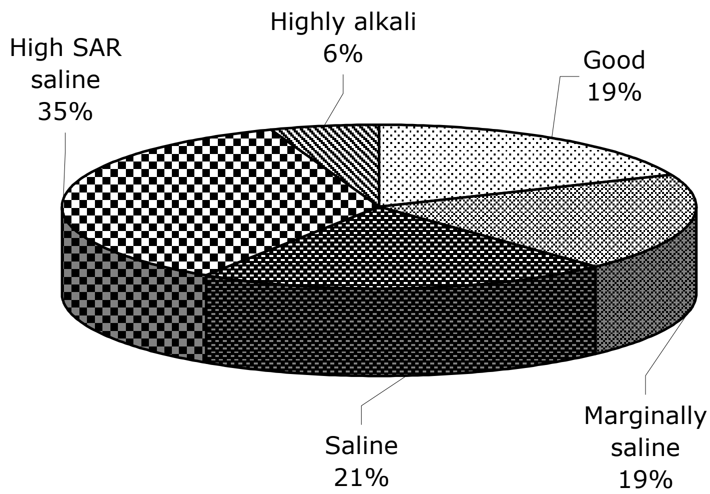
Bhiwani district has a subtropical, semi-arid and monsoonal type of climate with prolonged hot periods from March to October. A large part of the district is covered by recent to sub-recent deposits of alluvium and windblown sand. The rock exposures are very few and these are generally sporadic in nature. The eastern and north-eastern parts of the Bhiwani district, in contrast are fairly flat plain. The general physiography of the district bears the distinct imprint of the influence of both wind and water.

The range and mean values of different water quality parameters of 289 ground water samples collected from Bawani Khera block and 257 samples from Bhiwani Block are presented in Table 18. In Bawani khera, EC ranged from 0.26 to 18.49 dS/m with a mean of 5.46 dS/m. The lowest EC of 0.26 dS/m was observed in village Bandaheri and the highest value 18.49 (dS/m) was recorded in village Alekhpura. Sodium concentration in the samples varied widely (0.84 to 145 meq/l) followed by calcium (1.0 to 70.39 meq/l), magnesium (0.15 to 47.10 meq/l) and potassium (0.0 to 1.0 meq/l). It was observed that cations in ground waters of Bawani Khera block followed the order Na>Ca>Mg>K and the anions were in order of Cl >SO_4 >HCO_3 >CO_3 >F >NO_3. The values of NO_3 and F were 0.41 and 0.45 mg/l, respectively. In Bawani Khera block, 19% water samples were found in good category, 19% marginally saline and 21% saline (Fig. 9). Among the remaining 41% water samples, 6% were highly alkali and 35% were high SAR saline. Highest numbers of samples were recorded under high SAR saline category.

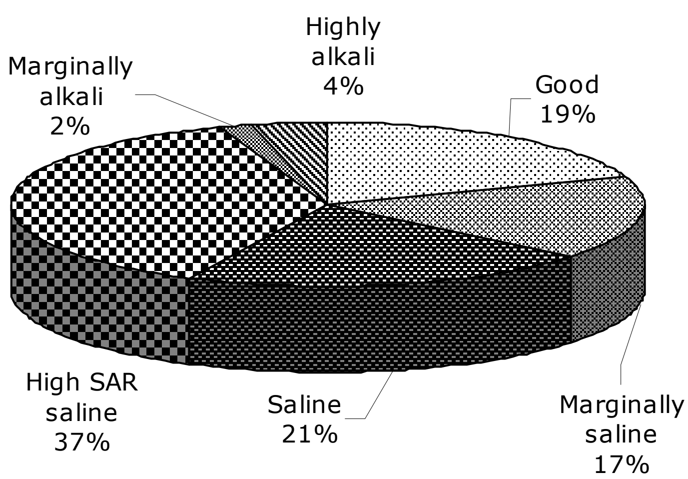
Table 18 Water quality parameters in Bawani Khera and Bhiwani blocks (Bhiwani)

Parameters	Bawani Khera block		Bhiwani block	
	Range	Mean	Range	Mean
EC (dS/m)	0.26-18.49	5.46	0.25-18.26	5.84
pH	7.56-9.23	8.53	7.43-9.67	8.31
CO_3 (meq/l)	0.00-4.20	0.79	0.00-3.52	0.64
HCO_3 (meq/l)	0.40-11.20	2.24	0.20-11.60	2.58
Cl (meq/l)	0.60-156.00	33.80	0.40-148.00	38.04
SO_4 (meq/l)	0.50-75.00	17.64	0.00-91.24	19.32
NO_3 (meq/l)	0.00-2.21	0.41	0.00-1.54	0.46
F (meq/l)	0.01-2.57	0.45	0.00-2.12	0.37
Na (meq/l)	0.12-145.00	33.27	0.37-125.10	34.21
K (meq/l)	0.00-1.00	0.28	0.00-0.93	0.19
Ca (meq/l)	1.00-70.39	11.14	1.00-55.14	11.38
Mg (meq/l)	0.15-47.10	11.08	0.17-71.78	13.81
SAR $(mmol/l)^{1/2}$	0.11-39.82	9.92	0.32-65.41	9.97
RSC (meq/l)	0.00-6.60	0.79	0.00-7.20	0.29

The EC in the Bhiwani block varied between 0.25 to 18.26 dS/m with a mean of 5.84 dS/m (Table 18). The lowest salt content (EC 0.25 dS/m) was recorded in village Kitlana. Lowest SAR was observed in village Rupgarh (0.32) and the highest was recorded in village Bamla. The highest value (7.2 meq/l) of RSC was recorded in water sample of village Rewari. Sodium concentration in the samples of Bhiwani block had a wide range (0.37 to 125.1 meq/l) followed by magnesium (0.17 to 71.78 meq/l), calcium (1.0 to 55.14 meq/l) and potassium (0.0 to 0.93 meq/l). The highest value of bicarbonate (11.6 meq/l) was found in the water sample of village Halwas. Nitrate ranged from 0.00 to 1.54 mg/l and the highest value of nitrate (1.54 mg/l) was found in the water samples of village Rupgarh. Fluoride content of water samples varied from 0.0 to 2.12mg/l with a mean value of 0.37 mg/l. The maximum concentration of fluoride was observed in the water sample of village Tigrana. Mean values for HCO_3, Cl and SO_4 were found to be 2.58, 38.04, 19.32 meq/l, respectively. It was observed that ground waters of Bhiwani block were Na>Mg>Ca>K type in respect of cations and Cl >SO_4 >HCO_3 >CO_3 type in respect of anions. Maximum number of water samples (98) was found in the EC range of 0.0-3.5 dS/m followed by 78 samples in the range of 3.5-7.0 dS/m. Only four samples were having EC greater than 17.5 dS/m (Fig. 10). According to classification criteria, in Bhiwani block 19% water samples were found under good category, 17% marginally saline, 21% saline, 2% marginally alkali, 4% highly alkali and 37% as high SAR saline waters (Fig. 9).



Bawani Khera



Bhiwani

Fig. 9 Categorization of ground water of two blocks of Bhiwani district

Sonepat district (Haryana)

Geologically, the district is a part of Indo-gangetic alluvium plain of Pluvial age, which has been laid down by the tributaries of the Indus river system and other non-existent rivers. In Mundlana and Kathura blocks, soils are heavy textured varying from sandy loam in the surface to clay loam at about 1 m depth and are mostly well drained. Annual rainfall varied from 390.8 mm to 480.1 mm in the district. The ground water samples from Mundlana (220) and Kathura (149) blocks were analysed for various chemical parameters. The range of different water quality parameters of the blocks revealed that in Mundlana block, EC ranged from 0.34 to 22.32 dS/m (Table 19).

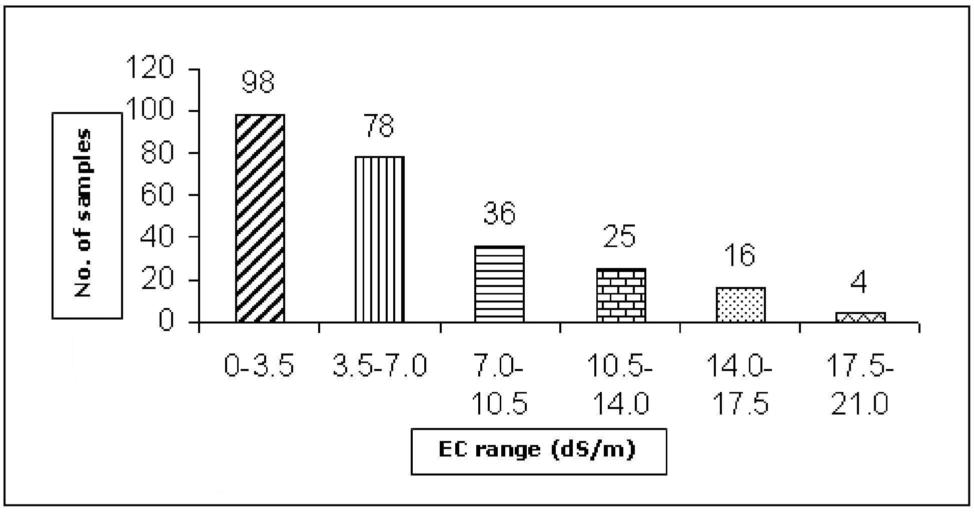


Fig. 10 Distribution of ground water samples according to EC in Bhiwani block

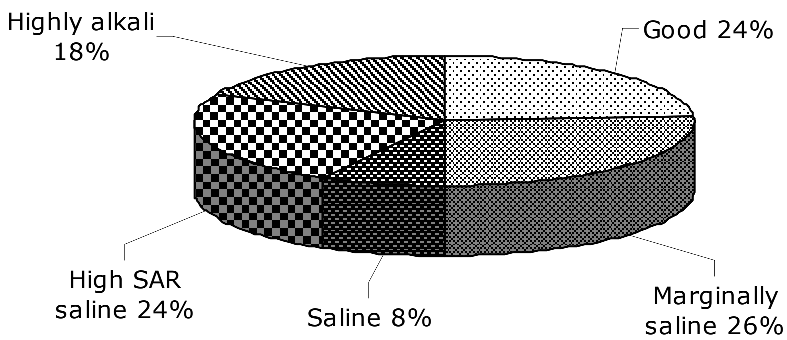
Table 19 Range of water quality parameters in Mundlana and Kathura blocks

Parameters	Mundlana	Kathura
pH	7.40-11.50	7.50-9.55
EC (dS/m)	0.34-22.32	0.48-12.13
RSC (meq/l)	0.00-9.10	0.00-14.40
SAR $(mmol/l)^{1/2}$	0.24-28.18	0.22-31.14
Ca (meq/l)	0.50-23.50	0.25-39.40
Mg (meq/l)	0.25-44.75	0.25-34.15
Na (meq/l)	0.37-155.43	0.54-83.7
K (meq/l)	0.07-1.69	0.11-1.87
Cl (meq/l)	1.20-133.60	1.00-75.00
SO_4 (meq/l)	0.67-86.76	1.01-55.16
HCO_3 (meq/l)	0.40-13.00	1.10-20.40
CO_3 (meq/l)	0.20-6.00	0.20-8.00
NO_3 (mg/l)	0.00-97.34	0.00-98.58
F^- (mg/l)	0.95-2.13	0.95-2.03

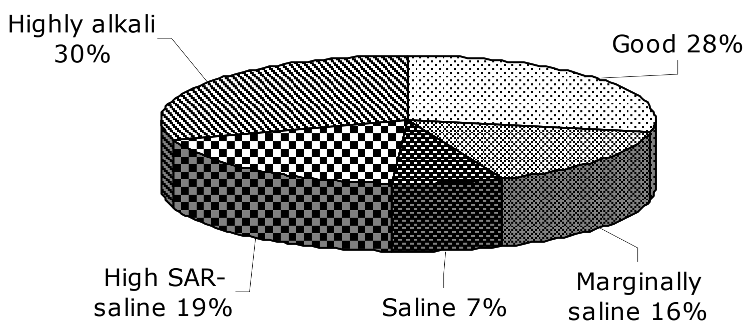
Lowest value of SAR 0.24 $(mmol/l)^{1/2}$ was observed in village Gangana and the highest 28.18 $(mmol/l)^{1/2}$ value in village Bichpuri. It was observed that ground waters of Mundlana block have the trend Na>Mg>Ca>K in respect of cations and Cl $>SO_4$ $>HCO_3$ $>CO_3$ with respect to anions. In this block, 32.1% samples had EC <2 dS/m, whereas 36.2% and 27.2% samples had EC between 2-4 and 4-8 dS/m, respectively. According to AICRP classification, 24% water samples were found in good category, 26% marginally saline, 8% under saline, 24% under high SAR-saline category and 18% samples under highly alkali (Fig. 11).

In Kathura block, EC varied between 0.48 to 12.13 dS/m (Table 19). The lowest salt content (EC 0.48 dS/m) was recorded in village Rindhana and the highest value (12.13 dS/m) in village Gharwal. Lowest SAR (0.22 $(mmol/l)^{1/2}$) was observed in Kathura and the highest being recorded in village Bhanwasa (31.14 $(mmol/l)^{1/2}$). Maximum value (14.4 meq/l) of RSC was found in village Dhanana. Sodium concentration in the samples had a wide range (0.54 to 83.7 meq/l) followed by calcium (0.25 to 39.4 meq/l), magnesium (0.25 to 34.15 meq/l) and potassium (0.11 to 1.87 meq/l). The maximum value of bicarbonate (20.4 meq/l) was found in the water samples of village Dhanana. Nitrate ranged from nil to 98.58 mg/l and the maximum nitrate (98.58 mg/l) was found in the water samples of village Kathura. Fluoride content of the water samples varied from

0.10 to 2.03 mg/l. It was observed that ground waters of Kathura block were Na > Mg >Ca >K type in respect of cations and Cl $>HCO_3 >SO_4 >CO_3 >NO_3$ type in respect of anions. In Kathura block, 28% water samples were of good quality while 16% marginally saline, 7% saline, 19% high SAR-saline and 30% were in highly alkali category (Fig. 11).



Mundlana block



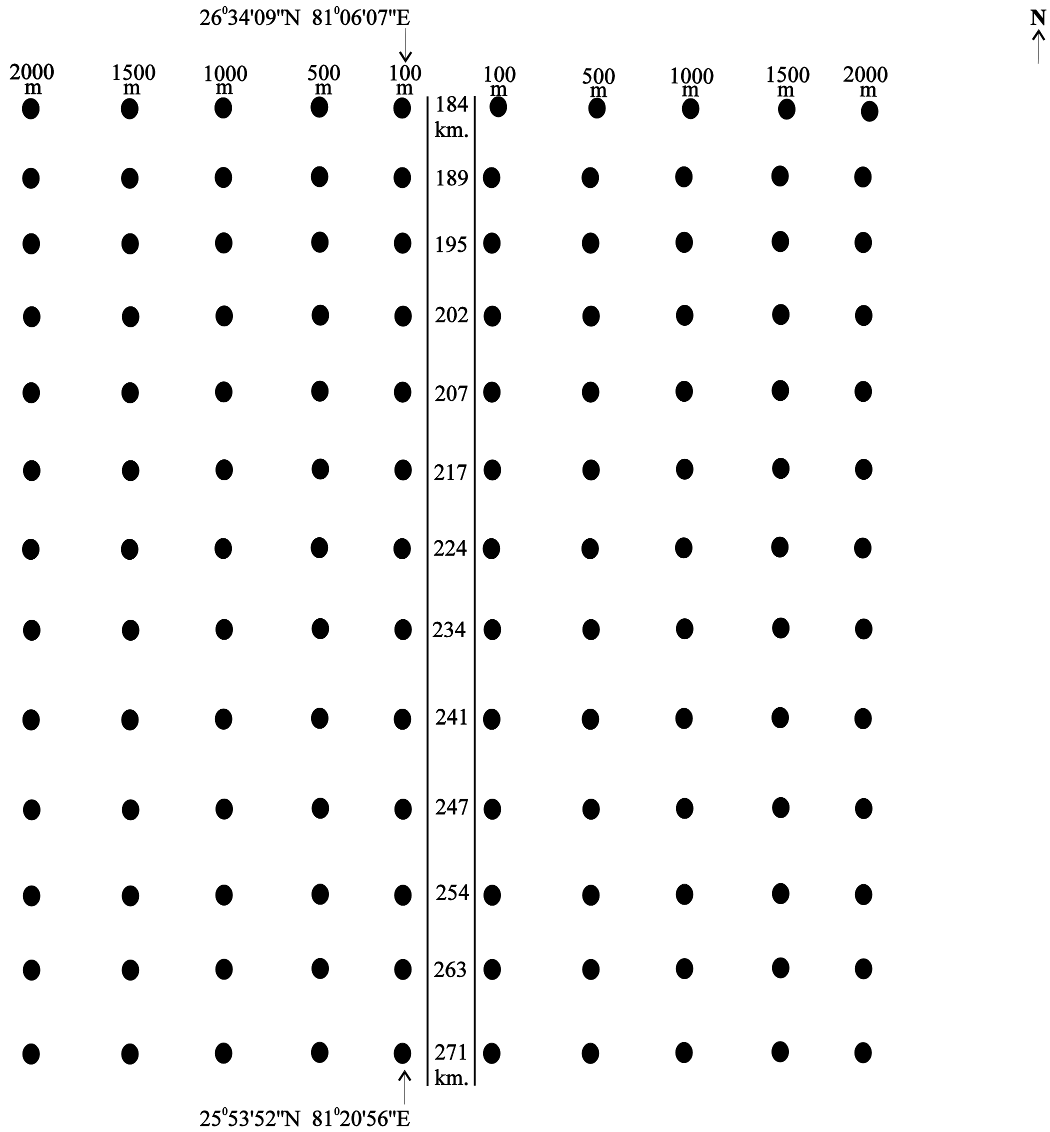
Kathura block

Fig. 11 Categorization of ground water of two blocks of Sonepat district

Sharda Sahayak Canal Area, Rae Bareilly (Uttar Pradesh)

In a joint metting of CSSRI and AICRP center on Management of Salt Affected Soils and Use of Saline Water in Agriculture it emerged that reclamation of alkali soils in Uttar Pradesh is a difficult task owing to their savior nature and pre-requisite requirement of lowering of water table. The problem is more critical in the adjoining areas of irrigation canal due to water logging. Therefore, to give impetus to the existing initiatives, survey of different canal adjoining area for soil and water table using GIS was recommended in 2007.

Keeping in view above recommendations, AICRP centre, Kanpur has been entrusted with the survey of areas adjoining to Sharda Sahayak Canal in Rae Bareilly district. Centre surveyed and collected soil and water samples using GPS, across both sides of the Sharda Sahayak canal, running (90 km) through Rae Barely district, at an interval of 100, 500, 1000, 1500 and 2000m, during February- March 2009 (pre monsoon). There are 130 sampling locations, 65 on each side of the canal (Fig. 12). Water and soil samples at each location have been collected up to 150 cm depth (0-20, 20-40, 40-60, 60-90, 90-120 and 120-150 cm) having a total of 780 samples. Post monsoon sampling will be done at the same locations during October- November 2009.



Soil and Water Samples Collected up to 150 cm depth at each location.

Total Number of Sampling Locations : 13 x 5 x 2 = 130

Number of Samples form each Location : 6 (0-20, 20-40, 40-60, 60-90, 90-120, 120-150 cm)

Total Number of Samples : 130 x 6 = 780

Fig. 12 Schematic view of sampling sites along the canal in Rae Bareilly

Fatehpur district (Uttar Pradesh)

The groundwater survey of three tehsils namely Bindaki, Fatehpur and Khaga of Fatehpur district in Uttar Pradesh initiated in 2004 was completed. A total of 1525 water samples were collected from thirteen blocks and analyzed (Table 20). The annual average rainfall of the district is 870 mm. The predominant soils are alluvial having loam to clay loam texture (Entisols and Inceptisols). Out of 1525 samples, 85% samples were found to be of good quality, 11% marginally saline, 2% each were saline and high SAR saline. The good quality samples were highest in Fatehpur (91%) and lowest in Khaga (74%) tehsil. Amongst the thirteen blocks, Amauli, Khajuha (Bindaki tehsil) and Asothar, Bahua (Fatehpur tehsil) blocks have 100% good quality water, whereas, Hathganon (55%) and Vijayipur (69%) recorded lowest. These two blocks contained 11 and 7% high SAR saline water respectively, which was maximum in the district. None of the water samples was marginally alkali, alkali and highly alkali. Average ionic composition and SAR values (Table 21) of ground water samples having EC less than 2.0 dS/m (good quality) revealed that these waters were dominated by bicarbonate (followed by chloride and sulphate) and magnesium (followed by sodium and calcium) with mean values of 4.76 (2.53, 0.12) and 3.59 (2.11 and 1.87) meq/l respectively. Carbonate was absent and SAR values varied between 1.00 and 1.49 $(mmol/l)^{1/2}$ with an average of 1.31 $(mmol/l)^{1/2}$ in this category (good) of water sample.

Water samples having EC between 2-4 dS/m (marginally saline) were dominated by chloride (followed by bicarbonate and sulphate) and sodium (followed by magnesium and calcium) with mean values of 8.24 (8.19 and 1.27) and 9.01 (7.68 and 2.96) meq/l respectively. Carbonate was present (0.10 meq/l) and SAR values varied between 3.26 and 4.23 $(mmol/l)^{1/2}$ with an average of 3.84 $(mmol/l)^{1/2}$ in this category (marginally saline). SAR values of water samples generally increased with increase in EC. Preparation of digitized groundwater quality map of the district is in progress in collaboration with RSAC-UP, Lucknow.

Table 20 Frequency distribution (%) of ground water quality in Fatehpur district

Tehsils	Samples	Good	Saline			Alkali		
			Marginally saline	Saline	High SAR saline	Marginally alkali	Alkali	Highly alkali
Bindaki	630	90	5	3	2	-	-	-
Fatehpur	470	91	9	-	-	-	-	-
Khaga	425	74	19	2	5	-	-	-
District	1525	85	11	2	2	-	-	-

Table 21 Salient features of ground water in various tehsils of Fatehpur district

Para-meters	Bindaki				Fatehpur		Khaga			
	Good	M. Saline	Saline	High SAR saline	Good	M. Saline	Good	M. Saline	Saline	High SAR saline
EC	0.80	2.10	7.2	5.9	0.77	2.12	0.78	2.14	8.4	9.2
SAR	1.43	4.23	8.4	13.8	1.00	3.26	1.49	4.02	7.1	17.2
RSC	-	-	-	-	-	-	-	-	-	-
CO_3	-	0.11	0.15	0.8	-	0.10	-	0.10	0.14	1.5
HCO_3	5.01	8.67	14.0	15.0	4.39	7.28	4.88	8.61	13.8	11.0
SO_4	0.07	1.39	15.3	13.3	0.16	1.17	0.12	1.26	20.6	36.8
Cl	2.34	9.45	41.0	29.0	2.50	8.16	2.76	7.10	49.0	40.0
Ca	1.71	3.35	5.0	8.0	1.73	2.18	2.17	3.34	18.6	11.0
Mg	3.63	7.96	29.8	10.3	3.77	6.96	3.36	8.12	29.3	16.1
Na	1.90	9.91	35.0	41.6	1.78	7.50	2.65	9.63	34.7	63.0
K	0.11	0.17	1.7	1.0	0.13	0.15	0.18	0.39	1.3	0.6

EC: dS/m, SAR: $(mmol/l)^{1/2}$, others: meq/l, M: Marginally

Ground water quality map of Uttar Pradesh

AICRP on management of salt affected soils and use of saline water in agriculture has generated substantial information on ground water quality of various districts of Uttar Pradesh through survey conducted during last one decade. The utility of this information can be enhanced by producing digital maps through GIS for widespread use by the scientists/planners/stake holders etc. The infrastructure facilities available at Remote Sensing Applications Centre, Uttar Pradesh, Lucknow would be utilized for the preparation of digitized map through strengthening intra-institutional linkages that lead to signing of MOU between CSAU, RSAC- UP and AICRP on 14.7.08. Water quality maps of ten district of U. P. are in the final stages of preparation.

Perambalur district (Tamil Nadu)

Groundwater quality survey of Perambalur District, Tamil Nadu was carried out by sampling water from open and bore wells. Out of 565 samples analyzed, 460 (80.7%), 102 (18.8%) and 3 (0.5%) recorded electrical conductivity (EC) in the range less than 2, 2 to 4 and 4 to 6 dS/m respectively. No water sample had EC more than 6 dS/m. The pH of the water samples ranged from 7.32 to 9.40 with a mean value of 8.25. The RSC of the samples ranged from 0 to 11.6 meq/l and SAR from 0.36 to 17.8 $(mmol/l)^{1/2}$.

Table 22 EC versus ionic concentration in water samples in Perambalur district

EC (dS/m)	No. of Sample	Concentration of ions (meq/l)											
		Ca			Mg			Na			K		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
0 to 2	480	0.18	11.6	2.8	0.1	13.4	2.6	0.12	32.6	9.5	0.0	4.8	0.4
2 to 4	112	0.26	26.5	4.8	0.4	27.2	9.5	1.2	28.4	13.2	0.1	10.2	1.6
4 to 6	3	0.86	30.1	12.1	0.4	27.0	11.8	6.8	56.0	24.6	0.2	16.4	3.2

EC (dS/m)	No. of Sample	Concentration of ions (meq/l)											
		HCO_3			CO_3			SO_4			Cl		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
0 to 2	480	0.2	12.4	7.2	0.0	3	0.4	0	8.2	2.4	0.2	22	5.2
2 to 4	112	0.6	17.2	8	0.0	4.2	0.4	0.2	14.4	4.6	2.0	36	14.8
4 to 6	3	1.8	20.2	8.4	0.0	4.8.	0.6	0.4	17.8	8.6	18.8	60.4	34.6

The distribution of cations followed the order of Na>Ca>Mg>K. The divalent to sum of cations ratio ranged from 0.35 to 0.46. 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 dS/m (Table 22). All the anions and cations showed a linear relationship with EC (Fig. 13).

Water Quality Map of Tamil Nadu

Several agencies are working towards assessing water quality in Tamil Nadu. These agencies use different criteria to assess the suitability of water for irrigation and other purposes. An attempt has been made to map the ground water quality of Tamil Nadu as per the criteria developed by the Committee of Experts and followed in AICRP (SAS) using the following data bases.

Source	No of samples	Remarks
AICRP on salt affected soils	2275	Tiruchirapalli and adjacent districts
SG & SWRDC, PWD, Chennai	2109	Covers the whole state at 25 sq km/sample. The 2002 (pre-monsoon) database was used. Database is available from 1972.
Soil Testing Laboratories, Department of Agriculture	2966	Bench mark water quality project for 18 districts-Mainly highlights geochemical type of waters
Total	7350	

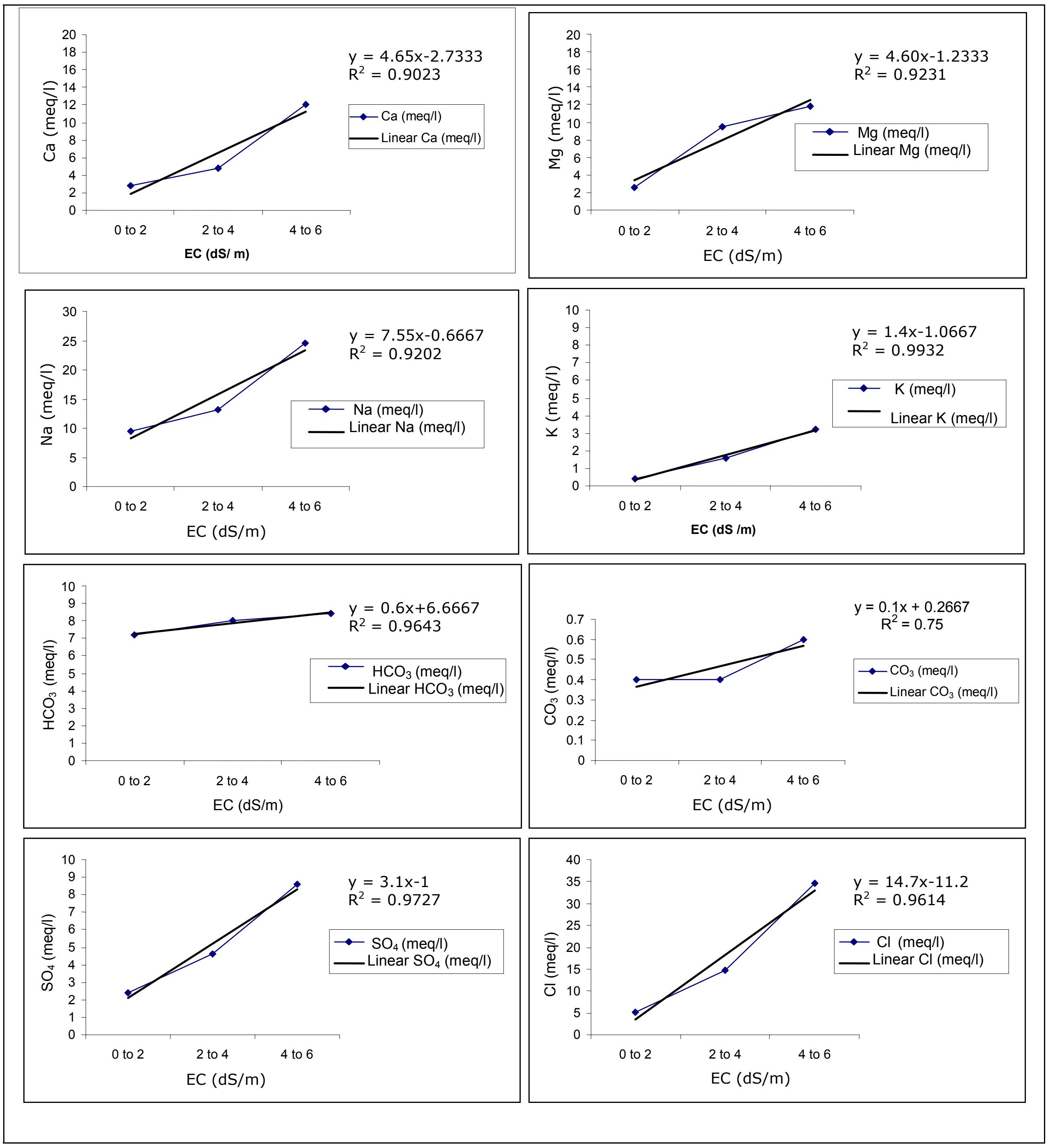


Fig. 13 Relationship between EC and ionic concentrations of ground water of Perambalur district

The ground water quality map (Fig. 14) was prepared using a base map of Tamil Nadu showing district and taluka boundaries at 1: 1,000,000 scale. The same would be updated after more data are available from the project.

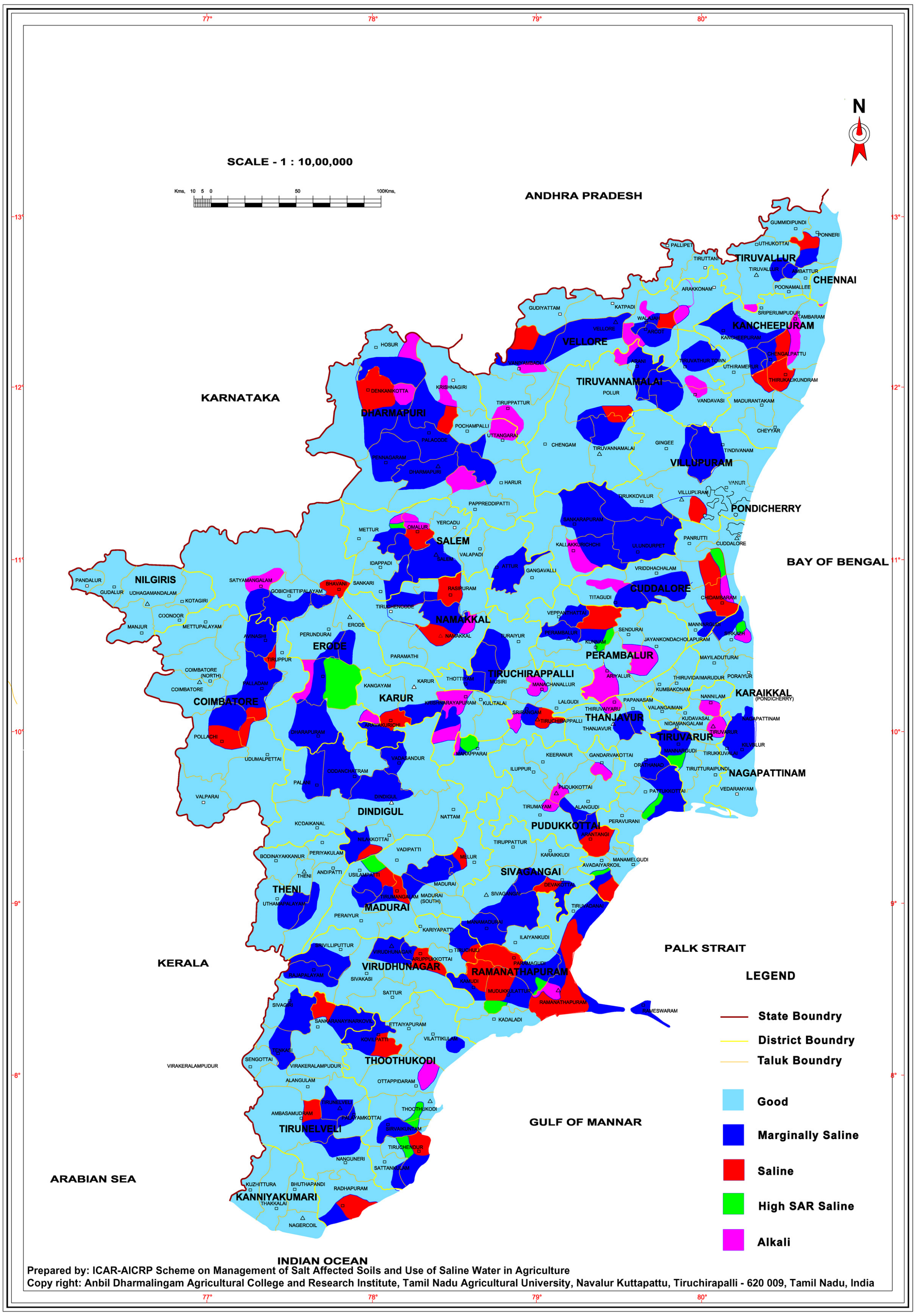


Fig. 14 First approximation ground water quality map of Tamil Nadu

STUDIES AT BENCHMARK SITES IN GUNTUR DISTRICT TO MONITOR THE CHANGES IN GROUND WATER QUALITY AND SOIL PROPERTIES

During the period 2006-07 and 2007-08, profile soil and water samples were collected from the 8 benchmark sites and analyzed.

Tube well waters

Not much change in previously reported trends was observed during the period under report at 8 benchmark sites in Guntur district (Table 23, Fig. 15).

Table 23 Ionic composition of tube well waters at benchmark sites during 2006-08

Locations	Year	pH	EC (dS/m)	SAR $(mmol/l)^{1/2}$
Nidubrolu-I	1974	7.90	1.9	7.06
	2006-07	7.40	14.8	13.72
	2007-08	7.56	12.5	14.72
Nidubrolu-II	1974	7.50	1.2	5.63
	2006-07	7.55	14.3	12.14
	2007-08	7.56	12.0	13.58
Chintalapudi	1974	7.60	1.8	5.44
	2006-07	7.51	3.9	8.13
	2007-08	8.09	2.5	7.31
Machavaram	1974	7.90	1.4	4.45
	2006-07	7.44	3.2	6.21
	2007-08	7.81	5.1	4.40
Chiluvuru	2000	8.24	1.9	10.21
	2006-07	7.66	1.8	2.41
	2007-08	8.06	1.8	2.62
Potarlanka	2000	8.42	2.0	12.04
	2006-07	7.63	1.9	2.86
	2007-08	8.26	2.3	8.62
Amrutaluru	2000	8.35	2.6	15.59
	2006-07	8.12	2.3	5.73
	2007-08	8.53	1.7	8.95
Angalakuduru	2000	8.34	0.7	4.00
	2006-07	7.46	1.3	3.43
	2007-08	8.27	0.6	1.65

Soil properties

The EC_e of surface soil at benchmark locations varied in accordance with the variation in tube well waters and reached a level of 7.4 dS/m at Nidubrolu - I and 7.8 dS/m at Nidubrolu-II from initial level of less than 2. There was not much variation at other six locations. pH_s also did not show much variation. However, SAR reached unsafe limits at Nidubrolu-I and II (Table 24 and Fig. 16).

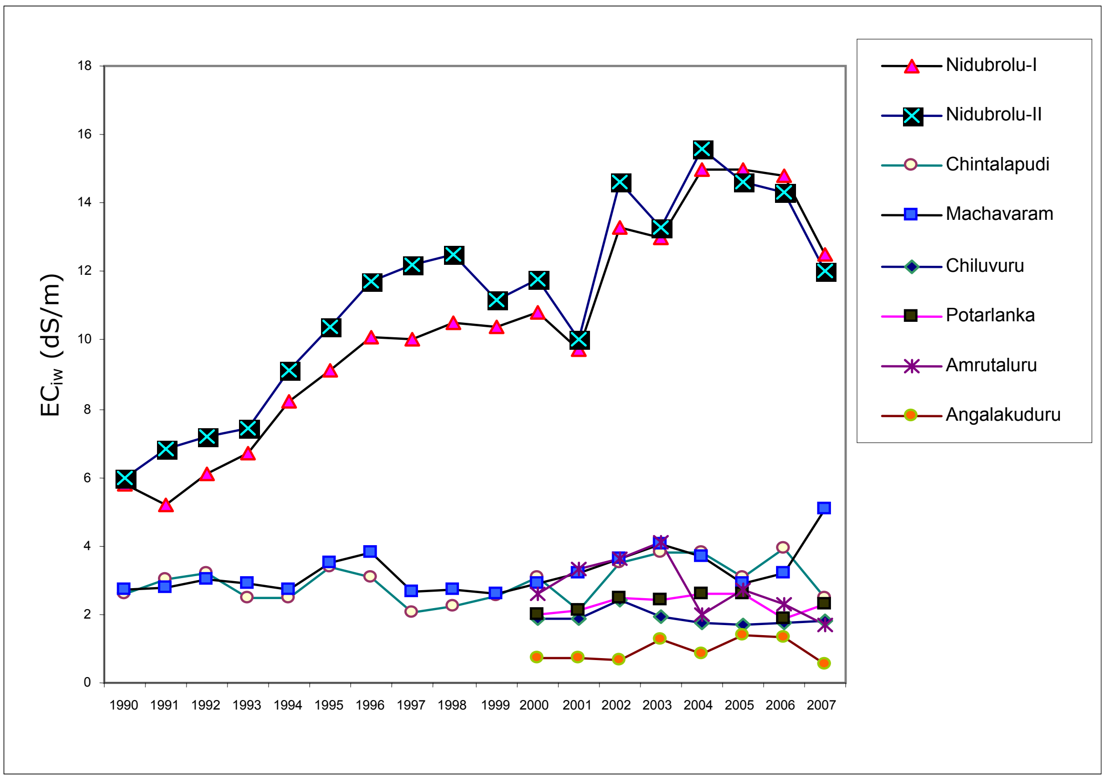


Fig. 15 Yearly fluctuations in EC_{iw} of ground water at benchmark locations in Guntur district

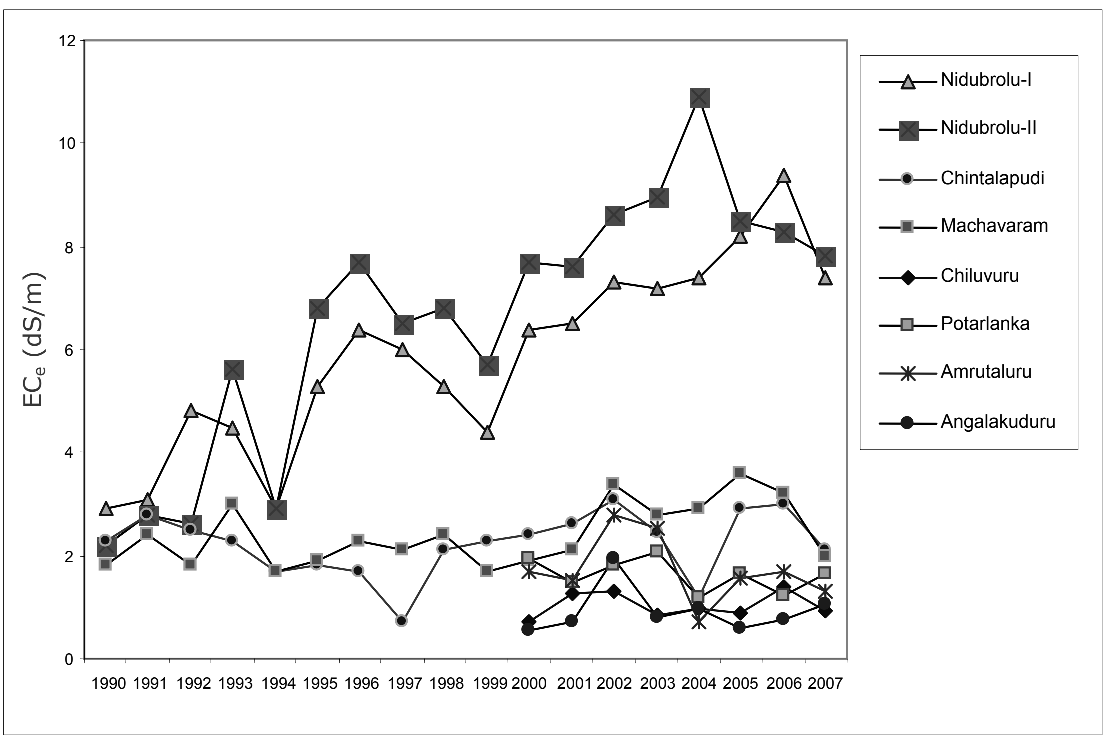


Fig. 16 Yearly fluctuations in EC_e of 0-15 cm depth due to use of ground water at benchmark locations in Guntur district

Table 24 Soils quality irrigated with tube well waters at benchmark sites during 2006-08

Location & Depth (cm)	pH_s		EC_e (dS/m)		SAR $(mmol/l)^{1/2}$	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Nidubrolu-I						
0-15	7.69	7.73	9.40	7.40	18.64	10.26
15-30	8.07	7.73	9.20	8.60	18.88	11.77
30-60	7.27	7.64	9.00	8.40	18.52	10.27
Nidubrolu-II						
0-15	7.95	7.81	8.30	7.80	13.64	10.60
15-30	8.49	7.99	8.00	8.30	14.11	10.39
30-60	8.94	7.72	7.90	8.70	15.21	10.15
Chintalapudi						
0-15	8.63	7.11	3.00	2.10	6.30	4.13
15-30	7.55	7.49	3.00	2.30	6.29	6.36
30-60	8.27	7.55	2.80	2.80	6.06	5.84
Machavaram						
0-15	7.85	7.72	3.20	2.00	6.56	5.39
15-30	7.78	7.63	3.00	2.10	6.34	4.96
30-60	7.65	7.74	3.00	2.00	5.88	5.36
Chiluvuru						
0-15	8.23	8.17	1.40	0.92	3.19	0.76
15-30	8.25	8.31	1.20	1.09	3.06	1.72
30-60	8.15	7.79	1.10	1.04	3.60	1.56
Potarlanka						
0-15	8.16	8.16	1.24	1.65	4.06	2.94
15-30	8.11	8.01	1.17	0.95	4.02	1.17
30-60	8.00	7.90	1.10	1.23	3.97	3.21
Amrutaluru						
0-15	8.30	8.28	1.70	1.32	4.50	4.14
15-30	8.10	8.12	1.68	1.47	4.72	3.90
30-60	8.00	8.00	1.37	1.10	4.03	2.67
Angalakuduru						
0-15	8.31	7.20	0.74	1.07	2.40	1.12
15-30	8.20	7.20	0.72	0.69	2.23	0.97
30-60	8.10	7.23	0.85	0.65	2.42	0.69

EFFECT OF SALINE IRRIGATION ON CROP GROWTH AND SOIL PROPERTIES

The field experiments were carried out to assess the salinity tolerance of some non-conventional crops/crop rotations of the Agra region. Salinity of the irrigation waters were Canal, EC_{iw} 2, 4, 6 and 8 dS/m. The results for different crops/crop rotations are given in the following section.

Tulsi - isabgol

The fresh biomass yield of tulsi and grain yield of isabgol declined with saline water irrigations (Table 25). The significant reduction in tulsi and isabgol yield was recorded at EC_{iw} 4 dS/m with increased yield reduction at higher salinity. The average relative yield of tulsi were 97, 89, 83 and 77% at EC_{iw} 2, 4, 6 and 8 dS/m, respectively, whereas respective values for isabgol grain were 98, 86, 68 and 62%. It may be noted that the yield reduction in the tested range of salinity was not very steep for both the crops.

Table 25 Effect of saline irrigation on seed yield of tulsi and isabgol

Treatments	Seed yield (t/ha)					
	Tulsi (Fresh biomass)			Isabgol (Grain)		
	2005	2006	Average	2005-06	2006-07	Average
Canal	20.6	17.4	19.0	1.26	0.74	1.00
EC_{iw} 2 dS/m	19.7	17.1	18.4	1.25	0.71	0.98
EC_{iw} 4 dS/m	19.0	14.9	16.9	1.22	0.50	0.86
EC_{iw} 6 dS/m	17.9	13.5	15.7	0.96	0.40	0.68
EC_{iw} 8 dS/m	17.0	12.4	14.7	0.96	0.29	0.62
CD (5%)	1.2	0.8	-	0.09	0.09	-

Soil salinity

The salinity profile at harvest of tulsi and isabgol revealed that soil salinity increased with the salinity of water but declined with soil depth (Fig. 17). Salt accumulation was more in rabi season obviously because of more irrigations and almost negligible rains compared to kharif season when rains not only substitute for irrigation but also cause the leaching of previously accumulated salts. The EC_e in surface depth (0-15 cm) at canal, EC_{iw} 2, 4, 6 and 8 dS/m were 1.7, 2.4 3.2 and 4.3 dS/m after harvest of tulsi (kharif), which increased to 2.2, 4.1, 5.0, 6.5 and 7.9 dS/m after harvest of Isabgol during 2005-06 season. During 2006-07, the salt build-up during tulsi crop was more due to less rainfall. Further, the salinity build-up during 2006-07 isabgol was quite different because of rain in the latter crop growth stages, which caused leaching of salts and accordingly it was less in surface than subsurface depth. At surface, EC_e values were similar in EC_{iw} 4, 6 and 8 dS/m where as it varied in lower depth and was higher for higher salinity of irrigation water.

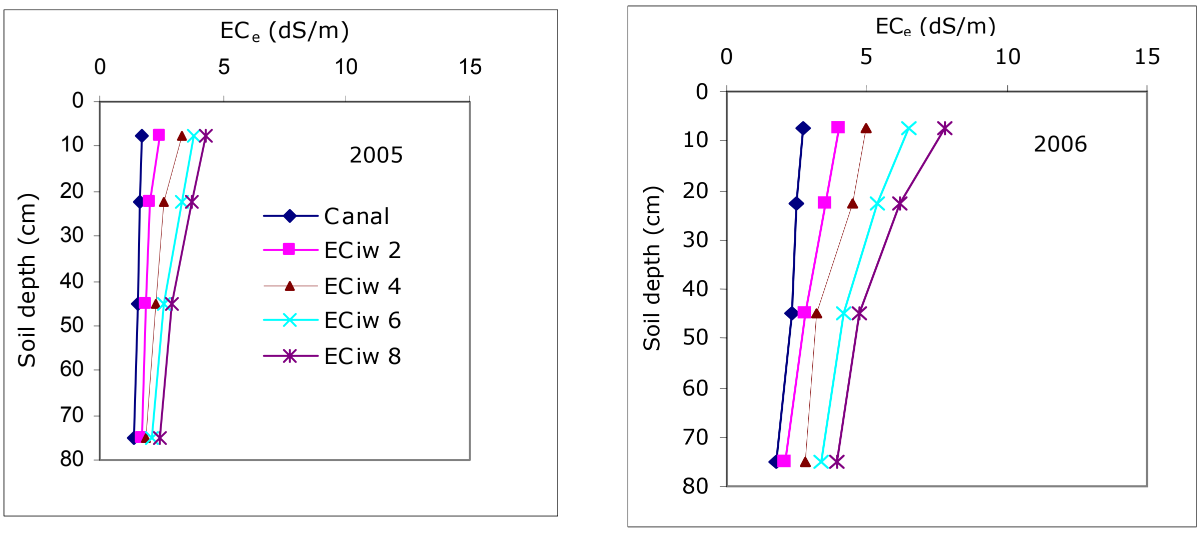
Cluster bean - fennel

In another set of experiment, cluster bean- fennel was grown with saline water. Both the crops were adversly affected by saline irrigations (Table 26). The significant yield reduction was noted at EC_{iw} 6 dS/m in cluster bean in one year and EC_{iw} 4 dS/m in fennel. The average relative yield at EC_{iw} 2, 4, 6 and 8 dS/m over canal of cluster bean were 98, 92, 87 and 85% and of fennel were 96, 80, 67 and 58%, respectively indicating that fennel is more sensitive to saline water irrigation than cluster bean.

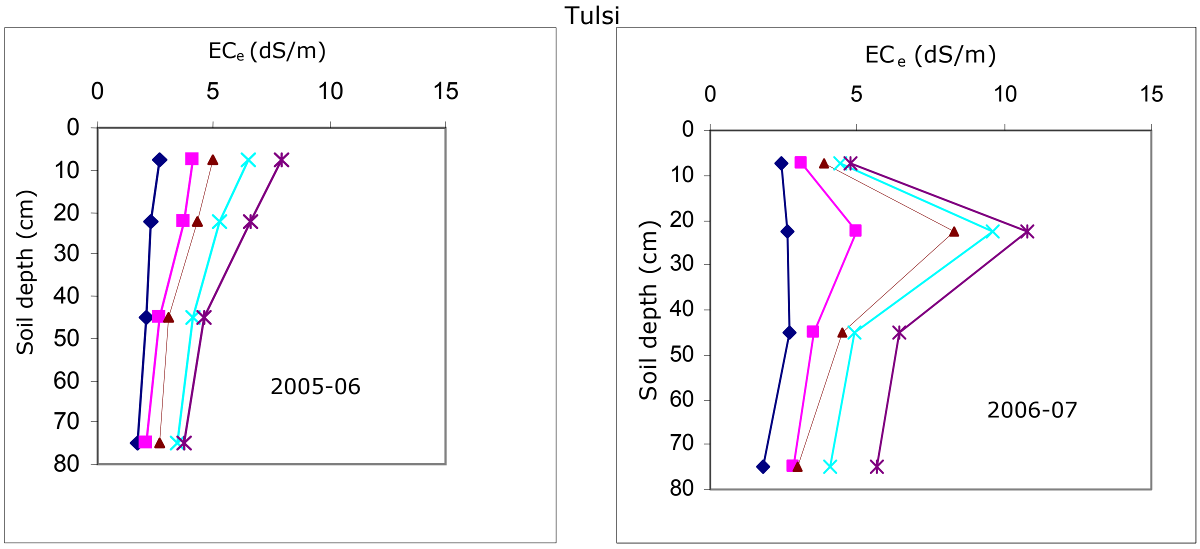
Table 26 Effect of saline irrigation on seed yield of cluster bean and fennel

Treatments	Seed yield (t/ha)					
	Cluster bean			Fennel		
	2005	2006	Average	2005-06	2006-07	Average
BAW*	2.41	2.20	2.30	1.12	0.71	0.91
EC_{iw} 2 dS/m	2.38	2.12	2.25	1.04	0.71	0.87
EC_{iw} 4 dS/m	2.18	2.07	2.12	0.87	0.58	0.72
EC_{iw} 6 dS/m	1.96	2.05	2.00	0.70	0.54	0.62
EC_{iw} 8 dS/m	1.91	2.01	1.96	0.59	0.47	0.53
CD (5%)	0.23	NS	-	0.10	0.12	-

*BAW: Best available water



Tulsi



Isabgol

Fig. 17 Salinity profile after harvest of Tulsi and Isabgol

Soil salinity

The soil salinity profiles after harvest of crops presented in Fig. 18 revealed that salinity build-up increased with salinity of water and number of irrigations. During 2005, the EC_e decreased with depth and was quite low in lower depths, whereas in 2006 the salinity was high throughout the profile probably because of less rain fall, which resulted in low leaching and also forced to provide saline irrigations to meet the crop water requirement. Since fennel was grown with bed method, EC_e status in channel and ridge was determined. The salt status at bed was higher because of movement of salt to dry zone. In channel the ECe at surface was almost same because of rains few days ahead of harvest but it increased in lower depths with the salinity of water.

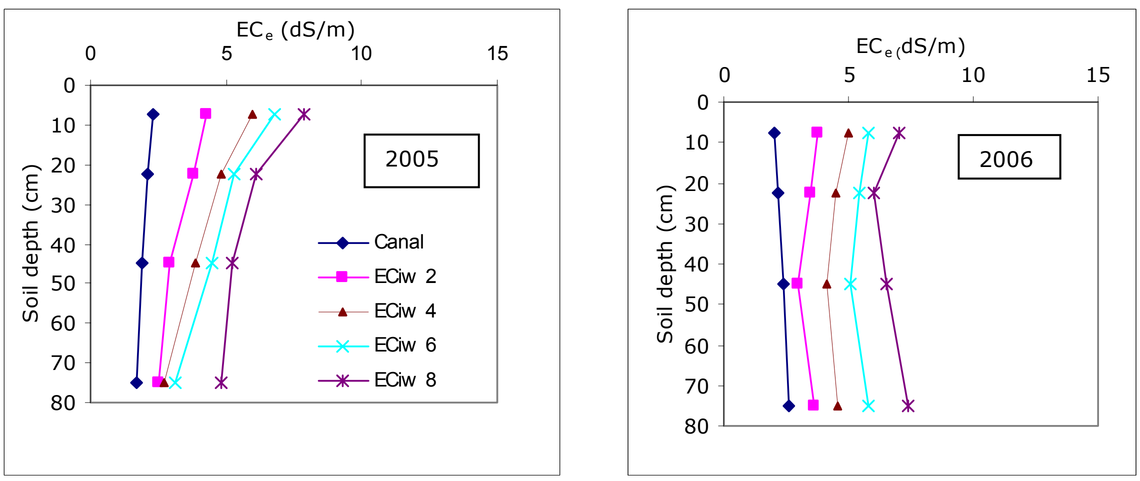
Moth bean- fenugreek

The yield of moth bean grown during kharif season, declined significantly at EC_{iw} 4 dS/m over canal but there was no significant difference between the yield when irrigated with saline water of

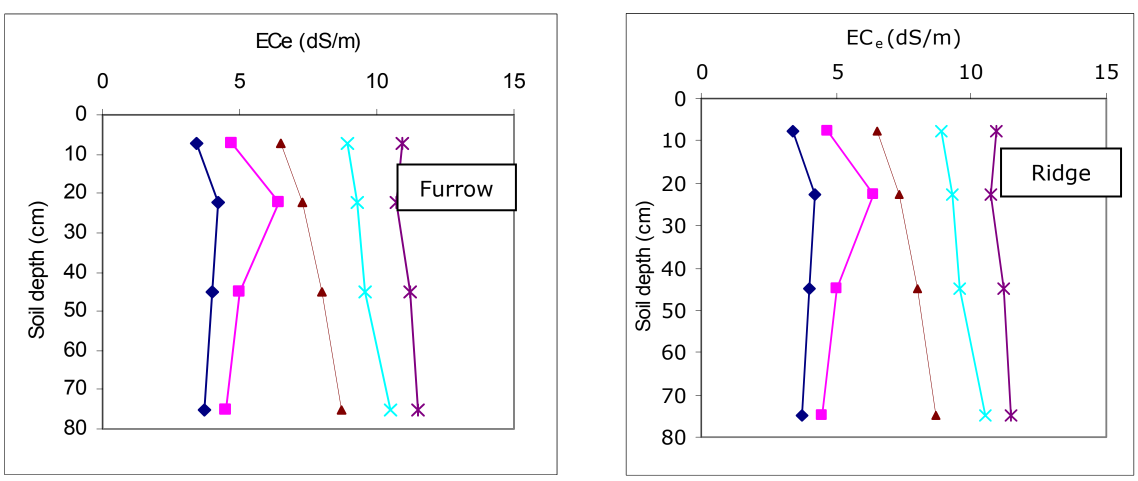
4, 6 or 8 dS/m (Table 27). The relative yield at EC_{iw} 2, 4, 6 and 8 dS/m over canal were 96, 73, 70 and 69%, respectively. The fenugreek, grown after moth bean, also showed adverse impact of salinity. The significant yield reduction was recorded at EC_{iw} 8 dS/m over canal during 2005-06 and at EC_{iw} 6 dS/m in 2006-07. The average relative yield at EC_{iw} 2, 4, 6 and 8 dS/m over canal were 96, 94, 92 and 88%, respectively.

Table 27 Effect of saline irrigation on yield of moth bean and fenugreek

Treatments	Seed yield (t/ha)			
	Moth bean	Fenugreek		
	2006	2005-06	2006-07	Average
BAW	0.90	2.14	1.71	1.93
EC_{iw} 2 dS/m	0.86	2.08	1.63	1.86
EC_{iw} 4 dS/m	0.66	2.03	1.60	1.82
EC_{iw} 6 dS/m	0.63	1.95	1.56	1.76
EC_{iw} 8 dS/m	0.62	1.84	1.55	1.69
CD (5%)	0.08	0.19	0.11	-



Cluster bean



Fennel

Fig. 18 Salinity profile after harvest of cluster bean-fennel

Soil salinity

The salinity profile after harvest of moth bean and fenugreek depicted in Fig. 19 revealed that the salt build-up increased with the increasing salinity of water and number of saline irrigations provided to the crops. It declined with depth and lowest salt content was recorded in 60-90 cm depth during 2005-06. But during 2006-07, the rains before harvest of fenugreek crop pushed the surface salt to lower depth hence EC_e status was higher in 15 - 60 cm depth.

Cluster bean - mustard

The tolerance of cluster bean – mustard rotation for saline alkali water irrigation was evaluated during 2006-08. The treatment included four levels of saline water (Best Available water (BAW), EC_{iw} 4, 8, and 12 dS/m) and five levels of alkali water (BAW, RSC 5, 10, 15 and 20 meq/l). The crop yield declined with salinity of irrigation waters in both the years. The significant reductions in grain and straw yields were recorded at EC_{iw} 8 dS/m in first and 4 dS/m in the other with further significant reduction in crop yield at EC_{iw} 12 dS/m. The average relative yield of cluster bean at EC_{iw} 4, 8 and 12 dS/m over BAW was 94, 83 and 70%, respectively. The grain yield of mustard was also adversely affected by salinity and significant reduction observed at EC_{iw} 4 in first and 8 dS/m in the second year with further reduction at EC_{iw} 12 dS/m in both the years. The adverse effects of salinity on mustard were more pronounced during 2007-08. The average relative yield at EC_{iw} 4, 8 and 12 dS/m was 94, 82 and 48 per cent over BAW, respectively.

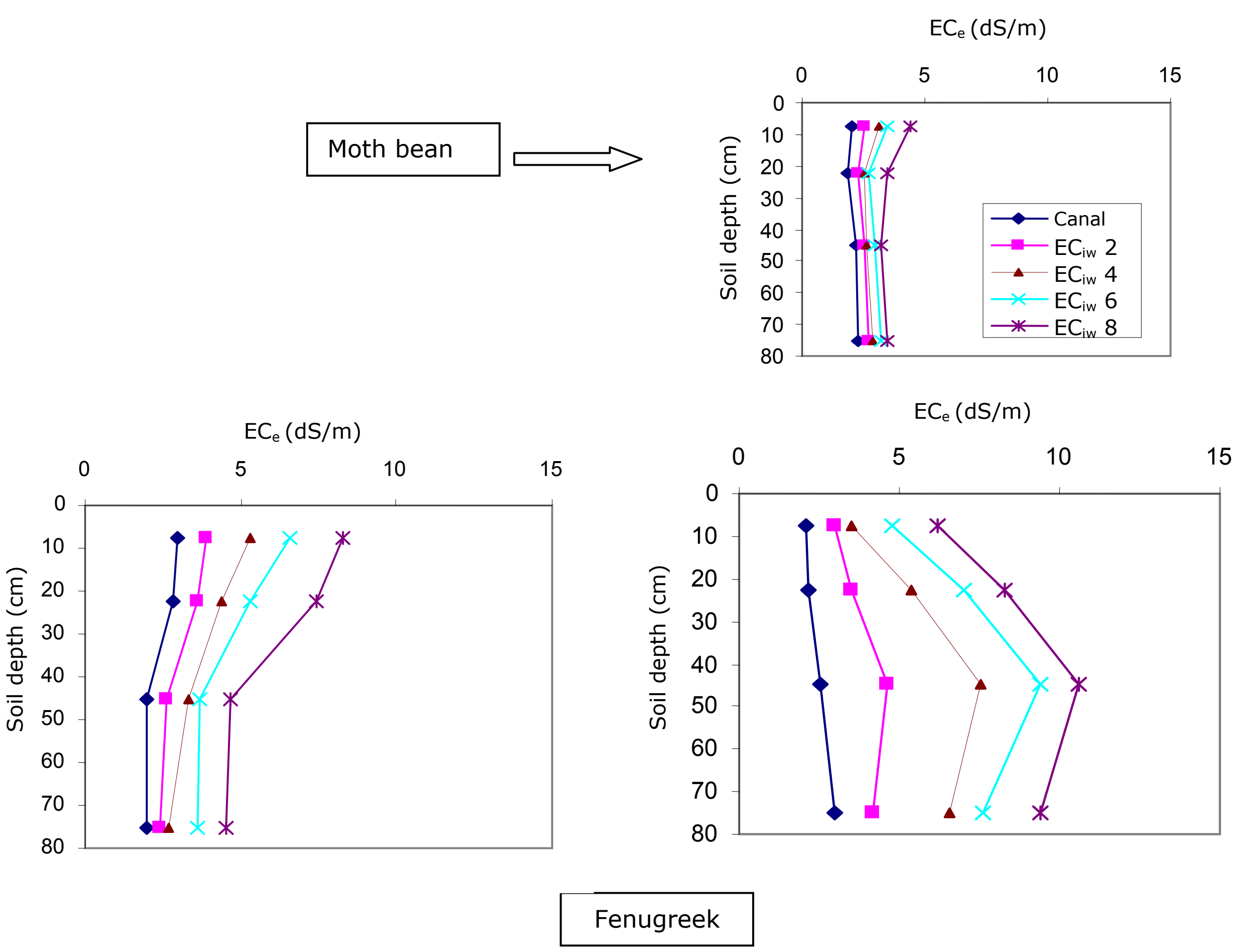


Fig. 19 Salinity profile after harvest of moth bean and fenugreek

The crop yield also declined with increasing RSC level in both the years (Table 28). However, significant reduction was recorded at RSC 10 meq/l during 2007 whereas in 2008, it occurred even at RSC 5 meq/l over BAW. Drastic yield reduction was recorded at RSC 20 meq/l in cluster bean. The average relative yield at RSC 5, 10, 15 and 20 meq/l over canal was 87, 73, 44 and 09%, respectively. The grain yield of mustard was also adversely affected by RSC levels. The significant grain yield reduction was recorded at RSC 5 meq/l over canal during both the years. Clearly at these levels crops are more affected by RSC levels than the salinity levels.

Table 28 Effect of saline waters on yield of cluster bean and mustard

Treatments	Seed yield (t/ha)					
	2006-07		2007-08		Average	
	C. bean	Mustard	C. bean	Mustard	C. bean	Mustard
BAW	2.23	2.23	2.29	2.20	2.26	2.21
EC_{iw} 4 dS/m	2.17	2.06	2.08	2.10	2.12	2.08
EC_{iw} 8 dS/m	1.86	1.82	1.91	1.80	1.88	1.81
EC_{iw} 12 dS/m	1.51	1.63	1.66	0.50	1.58	1.06
CD (5%)	0.10	0.10	0.12	0.13	0.11	0.12
BAW	2.23	2.23	2.29	2.20	2.26	2.21
RSC 5	2.04	2.06	1.88	1.90	1.92	1.98
RSC 10	1.60	1.90	1.68	1.80	1.64	1.85
RSC 15	1.21	1.87	0.78	1.60	1.00	1.74
RSC 20	0.12	1.74	0.28	0.70	0.20	1.22
CD (5%)	0.10	0.10	0.12	0.16	0.11	0.13

The soil ESP in 0-30 cm soil depth after harvest of cluster bean and mustard crops increased with RSC levels of the irrigation water. The increase was around 1.0 times of RSC level after harvest of cluster bean. The ESP in 0-30 cm soil depth further increased after harvest of mustard crop. The ESP values in 0-30 cm depth attained were 13, 17, 19 and 25 at RSC 5, 10, 15 and 20 meq/l respectively (Fig. 20).

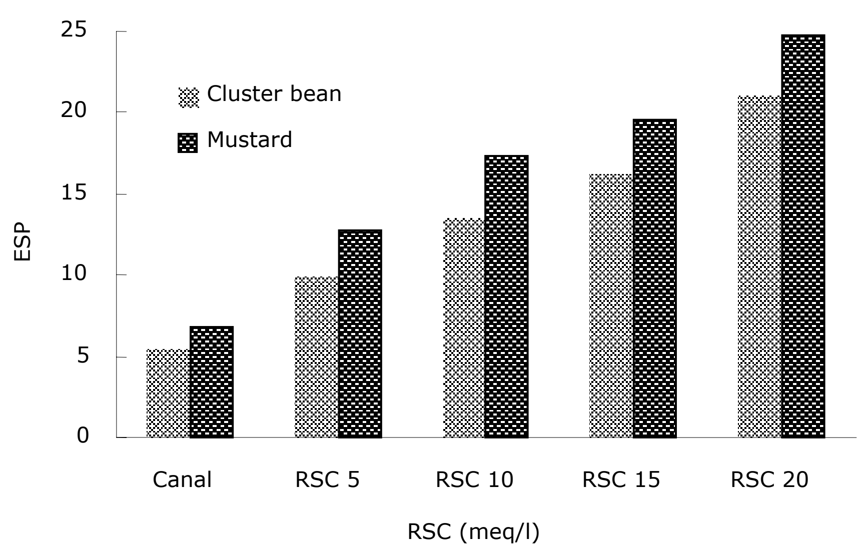


Fig. 20 ESP status after harvest of cluster bean and mustard (Average of two years)

Soil salinity

The salinity profile at harvest of both cluster bean and mustard crops with saline irrigation viz. control, EC_{iw} 4, 8 and 12 dS/m are presented in Fig. 21. The EC_e in the top layer at harvest of cluster bean ranged from 2.9 to 11.5 dS/m in the treatments EC_{iw} 4 to 12 dS/m. The pre sowing saline irrigation in mustard further increased the EC_e. The saline irrigation during mustard crop cycle further enhanced the salt build-up. But contrary to the expectation of high salinity at the soil surface at the time of harvest, it was lower to subsurface because of rains few days before the harvest of the crop during 2006-07. Because of the rains, the salts got leached down to accumulate at lower depths. As usual, the salinity was less in 90-120 cm depth. During 2007-08, the salinity build- up was higher at surface and declined with depth. At harvest of cluster bean, the EC_e build-up at surface was 3.3, 5.4 and 7.9 dS/m with EC_{iw} 4, 8, and 12 dS/m, respectively. The values at harvest of mustard increased to 8.1, 13.5 and 19.4 dS/m, respectively. As usual the lowest EC_e values were recorded at 90-120 cm depth at all salinity levels.

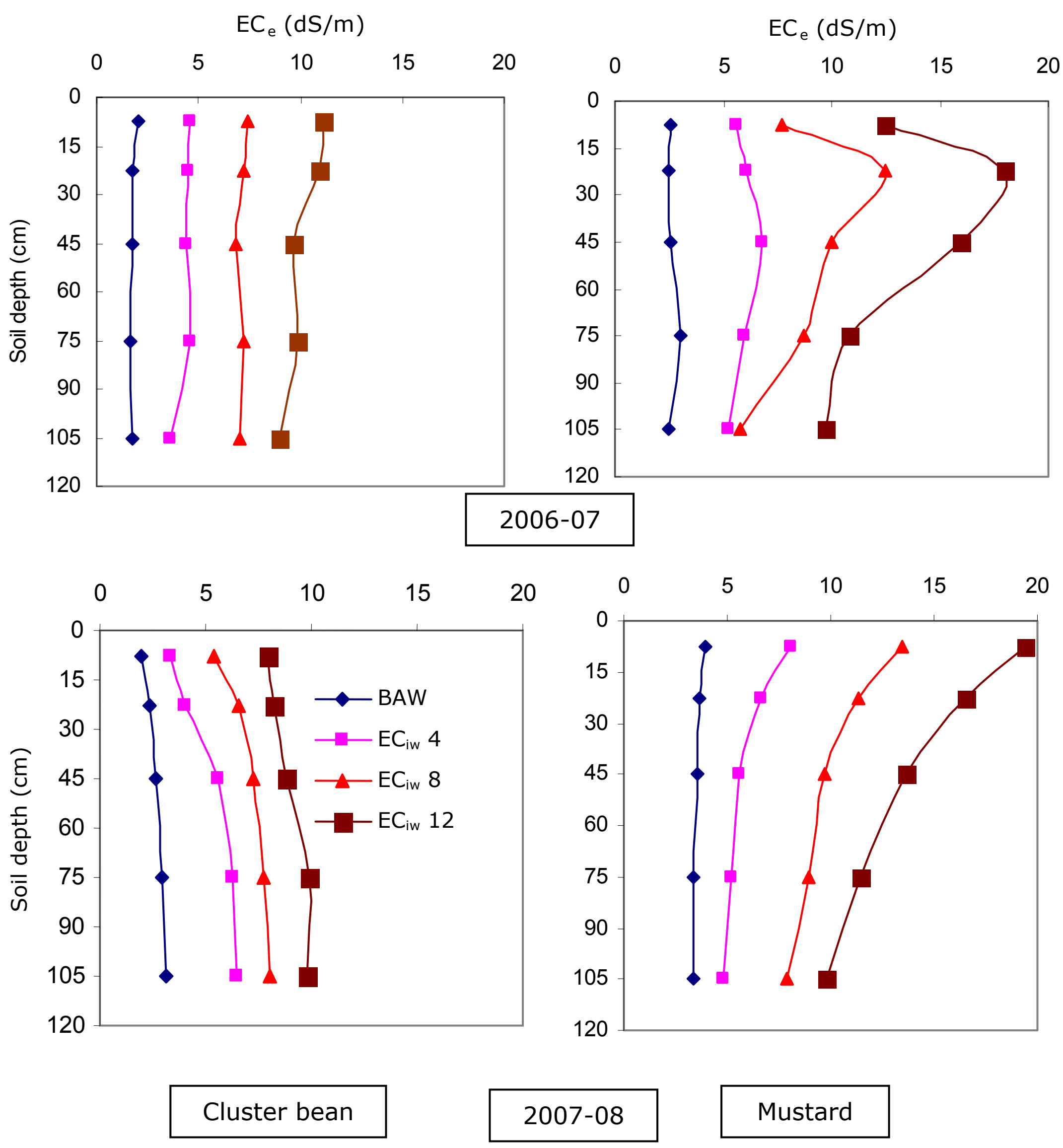


Fig. 21 Salinity status (0-120 cm) with saline irrigation in cluster bean-mustard crop rotation

CONJUNCTIVE USE OF ALKALI AND CANAL WATERS

A field experiment was initiated during 2003 to evaluate the effect of different irrigation modes for the conjunctive use of canal and alkali water (RSC 15 meq/l) under different cyclic and mixing modes for potato – sunflower crop rotation. Dhaincha was grown for green manuring (GM) during rainy season as rain fed crop in all the treatments. The treatment combination were: T_1- All canal (control), T_2- One year canal : Two year alkali, T_3- Two year alkali : One year canal, T_4 – Two year canal : One year alkali, T_5- One year alkali : Two year canal, T_6- All alkali (potato) : All canal (sunflower), T_7- Mixing (One canal + Two alkali), T_8- Mixing (Two canal + One alkali) and T_9-All alkali. The pooled data of five seasons indicated that highest yield of both potato and sunflower was recorded with canal water (Table 29). The relative yield under alkali water irrigation alone of both crops were 14 and 15% respectively compared to canal water. But when both the waters were used for irrigation in mixing mode, the yield increased significantly over all alkali. Further, the mixing mode as 2 canal + 1 alkali gave higher yield to the mixing mode (1 canal + 2 alkali) by 31%. When alkali water was used for irrigation to potato, it affected the yield of sunflower although sunflower gave about 62% relative yields. In other cyclic modes, higher yield was obtained in years when canal irrigation was given compared to the years when alkali water was used for irrigation.

Table 29 Effect of modes of irrigation with alkali and canal waters on yield of crops

Treatments	Yield (t/ha)					
	2006-2007		2007-2008		Average of 5 years	
	Potato	Sunflower	Potato	Sunflower	Potato	Sunflower
T_1	31.20	1.50	25.70	1.10	27.10	1.30
T_2	23.60	1.20	16.00	0.60	19.40	080
T_3	13.70	0.70	8.40	0.60	14.00	0.70
T_4	24.90	1.10	23.40	1.00	22.60	1.00
T_5	13.70	0.60	14.00	0.70	14.00	0.80
T_6	12.70	0.80	09.40	0.70	12.70	0.80
T_7	16.60	0.70	12.90	0.60	15.20	0.70
T_8	24.00	1.10	21.30	0.90	22.10	1.00
T_9	2.60	0.20	2.30	0.10	3.90	0.20
CD (5%)	2.1	0.12	2.30	0.40	2.0	0.2

Oil content

The percent oil content differed significantly amongst the treatments (Table 30). The maximum oil content was recorded with all canal and the minimum with alkali water being 2-3% less.

Table 30 Effect of modes of irrigation with alkali and canal waters on oil content

Treatments	Oil content (%) in sunflower grains					
	2004	2005	2006	2007	2008	Mean
T_1	42.2	42.3	41.8	42.2	42.1	42.1
T_2	41.7	40.0	39.5	39.9	38.9	40.0
T_3	40.8	39.7	39.9	39.5	38.7	39.7
T_4	41.0	41.5	40.2	39.6	38.5	40.2
T_5	39.6	40.5	38.6	38.7	37.7	39.0
T_6	40.7	40.6	39.8	39.7	38.9	39.9
T_7	41.0	40.2	39.7	39.8	38.7	39.9
T_8	41.7	41.5	40.5	40.2	39.9	40.8
T_9	38.6	38.3	37.8	36.9	35.9	37.5
CD (5%)	1.4	1.5	1.4	1.4	1.5	-

Soil alkalinity

The pooled data on soil analysis revealed that the EC_e varied in the range of 2.7 to 4.7 dS/m after harvest of potato, which remained almost at that level after harvest of sunflower (Table 31). With alkali water irrigation, ESP increased such that it was 9.8 in all canal compared to 29.9 in all alkali at surface depth after harvest of potato. In case of all alkali, ESP further increased to 36.7 after harvest of sunflower. In different modes, the ESP values were in between this range with narrow differences. The ESP was higher in 0-30 cm depth compared to surface (0-15 cm) depth.

Table 31 Effect of conjunctive modes on soil properties* at sowing of potato and harvest of potato and sunflower

Treatments	Depth (cm)	At Sowing			At Harvest					
		Potato			Potato			Sunflower		
		EC_e	pH	ESP	EC_e	pH	ESP	EC_e	pH	ESP
T_1	0-15	2.6	7.6	9.0	2.7	7.6	9.8	2.8	7.6	10.8
	15-30	2.5	7.6	9.7	2.6	7.5	10.7	2.7	7.6	11.3
T_2	0-15	3.4	8.2	12.9	3.7	8.2	15.2	3.5	8.2	16.7
	15-30	3.5	8.2	15.1	3.6	8.1	16.6	3.5	8.2	19.9
T_3	0-15	3.7	8.3	15.2	3.8	8.4	16.5	3.6	8.2	20.2
	15-30	3.6	8.3	17.7	3.6	8.3	19.5	3.5	8.2	24.0
T_4	0-15	3.4	8.1	13.4	3.4	8.2	11.2	3.6	8.4	15.5
	15-30	3.4	8.1	15.3	3.3	8.2	11.9	3.5	8.3	18.0
T_5	0-15	4.2	8.3	14.3	3.9	8.4	14.7	3.9	8.1	17.1
	15-30	4.0	8.3	16.4	3.8	8.4	16.7	3.8	8.1	20.1
T_6	0-15	3.4	8.2	13.0	3.5	8.4	15.1	3.6	8.4	14.5
	15-30	3.3	8.3	15.1	3.5	8.3	17.0	3.6	8.3	16.4
T_7	0-15	3.6	8.7	15.8	3.6	8.5	16.7	3.6	8.3	18.2
	15-30	3.5	8.5	17.5	3.5	8.4	20.2	3.4	8.2	23.8
T_8	0-15	3.4	8.5	13.4	3.4	8.3	13.7	3.5	8.1	15.5
	15-30	3.4	8.4	15.7	3.3	8.3	16.4	3.4	8.0	19.1
T_9	0-15	4.6	9.0	22.1	4.7	9.0	29.9	4.8	9.1	36.7
	15-30	4.5	8.8	25.0	4.6	8.8	32.6	4.6	9.0	42.6

* Average of 5 years

STRATEGIES FOR CONJUNCTIVE USE OF SALINE AND CANAL WATER IN COTTON - WHEAT AND PEARL MILLET - MUSTARD CROP ROTATIONS

A field experiment was conducted to evaluate the effect of conjunctive use of canal/saline water on growth, yield of cotton-wheat and pearl millet-mustard crop rotations and on soil salinity build-up at Hisar. The experiments were conducted in 4.5m x 3.0m micro-plots. Treatments were replicated thrice in the randomized block design. Each micro-plot was separated by buffer of 1 m width from all sides to arrest the horizontal movement of water and salts from the adjoining plot. Recommended cultural practices and fertilizer doses were applied in raising the crops. Uniform fertilizer applications were made in all the treatments using urea, DAP and zinc sulphate. The electrical conductivity of canal water and tube well/saline water were 0.4 and 6.0- 8.0 dS/m respectively. Growth parameters and yield attributes for each treatment were recorded. The soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm layers before sowing and after the harvest of each crop from all replications to determine the salt build-up. The mean yield of two seasons (2006 to 2008) for four crops viz., cotton, wheat, pearl millet and mustard is shown in Table 32.

In cotton, the differences among various treatments in respect of plant height, bolls/plant, boll weight (gm) and seed yield were significant. The average highest seed cotton yield of 2.48 t/ha during the year 2006 and 2007 was recorded in canal irrigation followed by 2C:1S (2.46 t/ha) cyclic irrigation. However, the lowest yield (1.56 t/ha) was obtained under saline irrigated plots, which indicated 37% reduction in seed cotton yield as compared to all canal treatment (Table 32). In the year 2007, at the time of sowing, EC_e values ranged from 3.74 - 5.45 dS/m in the 0-15 cm layer and at the harvest of crop, EC_e increased to 4.25-8.28 dS/m. The highest EC_e (8.28 dS/m) was observed in case all saline water irrigation in the layer 0-15 cm.

Table 32 Effect of conjunctive modes of irrigation on the yield* of different crops

Treatments	Cotton	Wheat	Pearl millet	Mustard
C	2.48	5.00	3.01	2.24
1C: 1S	2.23	4.49	2.68	2.10
1S: 1C	2.00	4.33	2.50	1.98
2C:1S	2.46	4.83	2.92	2.15
2S:1C	1.96	3.27	2.25	1.65
S: RTC	2.07	4.42	2.56	1.93
C: RTS	1.95	4.13	2.59	1.91
S	1.56	2.85	2.02	1.60
CD (5%)	0.35	0.60	0.33	0.25

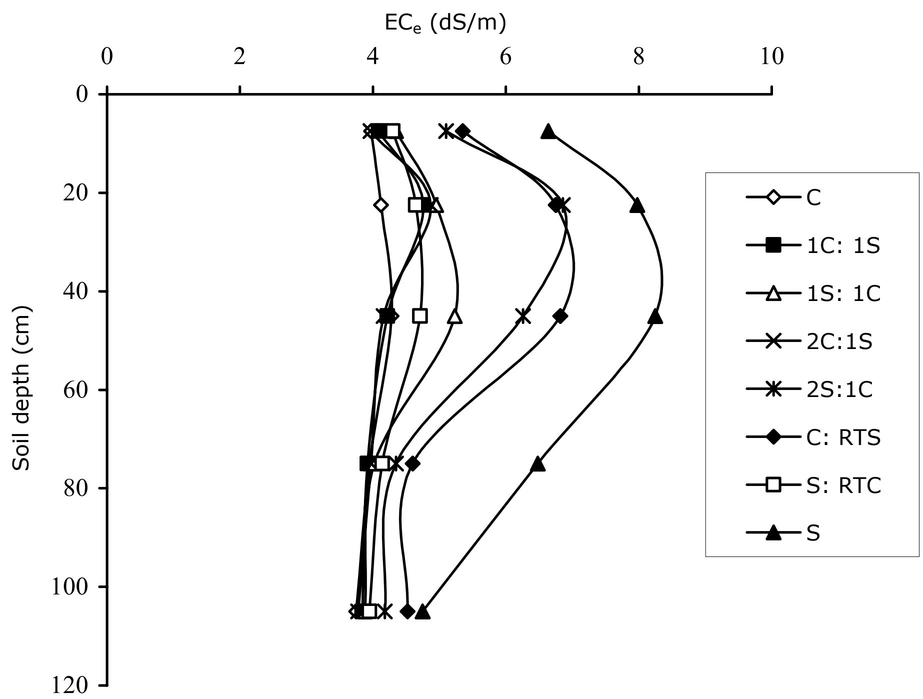
*Average of two seasons (2006-08)

In wheat, the average highest yield of 5.00 t/ha (year 2006-07 and 2007-08) was recorded in canal irrigation followed by 2C:1S (4.83 t/ha) cyclic irrigation. The lowest yield 2.85 t/ha were recorded in all saline treatments. The relative yield reduction were 10, 13, 35, 12, 17 and 43 per cent in lC:lS, 1S:1C, 2S: 1C, 1S:RTC (rest with canal), lC:RTS (rest with saline) and S (all saline) treatments (Table 32). Significant differences were also obtained in case of plant height, ear head length, ear head/metre row length and test weight. The average EC_e of the soil profile at sowing during 2007-08 varied from 3.97-6.64 dS/m in various treatments (Fig. 22). The EC_e values increased at the harvest and ranged from 4.45 to 10.52 dS/m. The highest EC_e (10.52 dS/m) was observed in case all saline water irrigation in 0-15 cm layer after the crop harvest. Amongst the cyclic mode treatments, 1C:RTS had the higher salinity build-up followed by 2S:1C. It is ascribed to more saline irrigations in these than other cyclic treatments.

In case of both pearl millet and mustard crops, the average highest yield for 2 years was recorded in canal followed by 2C:1S treatments (Table 32). Assuming the average yield obtained in canal irrigation as 100 per cent, the relative pearl millet yield obtained under lC:lS, IS:1C, 2C:lS, 2S:1C, S:RTC, C : RTS and S (all saline) treatments were 89, 83, 97, 75, 85, 86 and 67%t. The counter figures for mustard were 94, 88, 96, 74, 86, 85 and 71% respectively.

Before sowing and after harvesting of pearl millet, the EC_e in the soil profile (0-120 cm) during 2007 ranged from 6.03 to 6.33 dS/m in all saline water irrigation treatment. During year 2007-08, before sowing of mustard, the mean EC_e of the soil profile down to 120 cm varied from 3.97-6.59 dS/m in various treatments, whereas it increased to 4.01-6.69 dS/m after harvest of crop (Fig. 23). The mean EC_e values ranged from 4.54-8.52 dS/m in 0-15 cm layer and from 3.82-7.68 dS/m in 15-30 cm layer at the harvest of the crop. The highest EC_e (8.52 dS/m) was observed in case all saline water irrigation treatment in 0-15 cm layer.

For all the data sets presented in Table 32, it emerges that although 2C:1S is the next best option followed by all canal irrigations, yet the yield differences are non-significant even in 1C:1S cyclic mode compared to all canal. Moreover, in the case of wheat a single application of canal water at early growth stage could help to increase wheat yield by 45% over all saline irrigation treatment suggesting that even at tail ends of the canal irrigation system, where water for not more than 1-2 irrigation is available, if made available at early growth stage could play an important role in improving crop productivity.



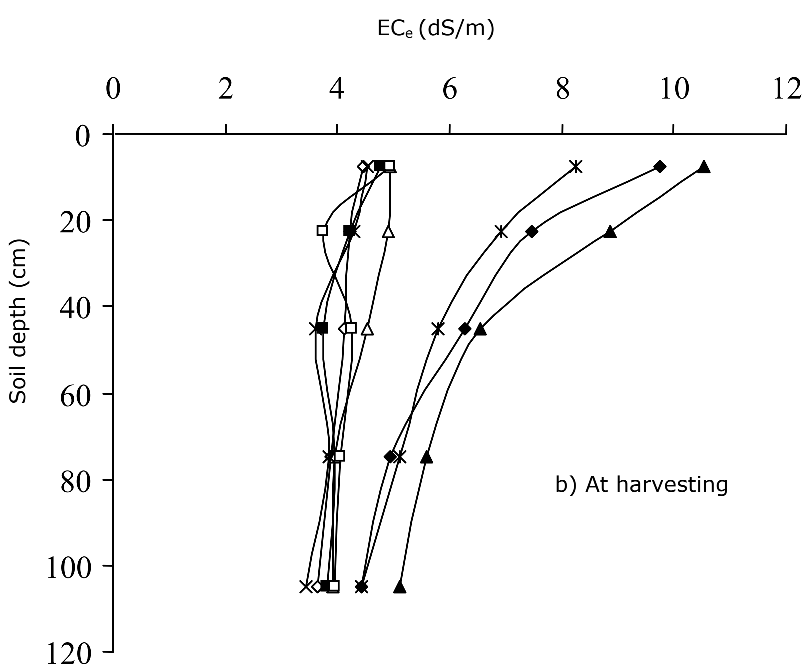


Fig. 22 Depth wise EC_e distribution in various treatments
(a) before sowing and (b) at harvest of wheat crop during 2007-08

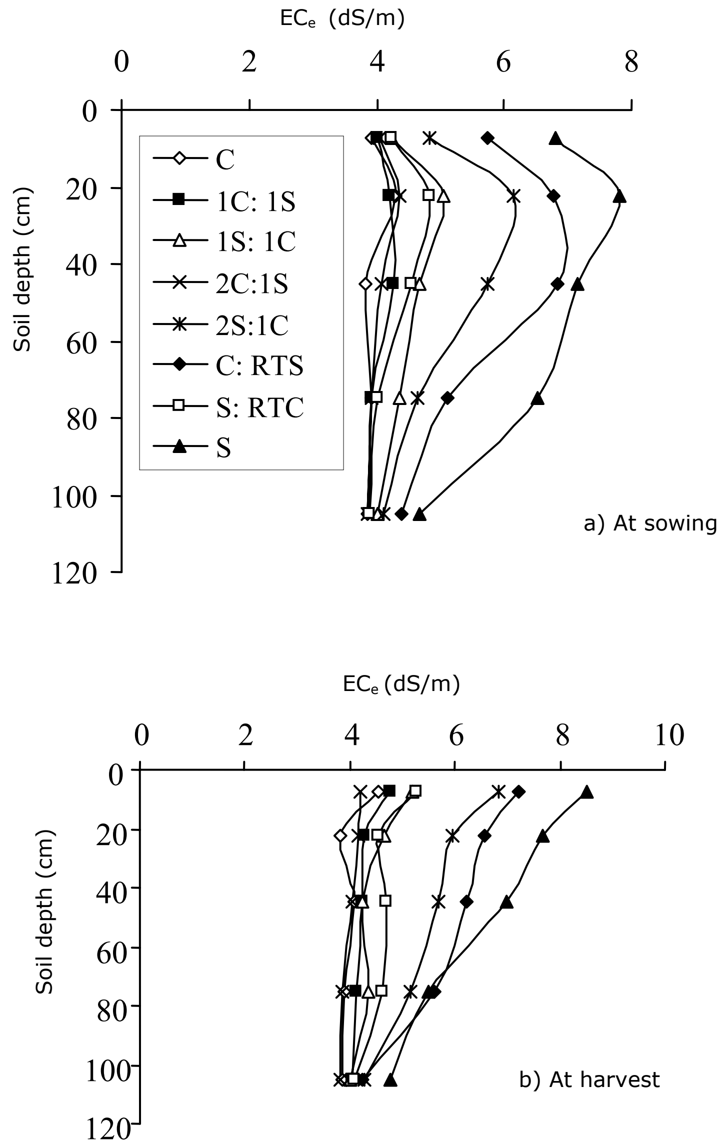


Fig. 23 Depth wise EC_e distribution in various treatments
(a) before sowing and (b) at the harvest of mustard crop during 2007-08

CONJUNCTIVE USE OF CANAL AND AMENDED ALKALI WATER IN RICE BASED CROPPING SYSTEM

An experiment to evaluate different irrigation modes for conjunctive use of canal and alkali water was initiated in 2003 in an alkali soil with pH 9.0 and ESP 16.0. The canal water (EC 0.5 dS/m, SAR 1.2 $(mmol/l)^{1/2}$ and RSC 1.2 meq/l), alkali water (EC 1.6 dS/m, SAR 7.2 $(mmol/l)^{1/2}$ and RSC 6.7 meq/l), water treated with distillery spent wash (DSW) (EC 1.9 dS/m, SAR 7.6 $(mmol/l)^{1/2}$ and RSC 7.6 meq/l) and water treated in gypsum bed (powdered gypsum was used in the gypsum bed) (EC 1.5 dS/m, SAR 6.5 $(mmol/l)^{1/2}$ and RSC 2.2 meq/l) were used to irrigate the crops. Soil application of distillery spent wash @ 5 lakhs litres per ha was carried out one month before start of the experiment and gypsum application was made before last puddling. 1:500 dilution of DSW with alkali water was found to be sufficient to neutralize the RSC value. The initial pH in the main plot treatments were 9.2, 8.4 and 8.7 and ESP 39.3, 17.6 and 25.6 in alkali water, canal water and 1:1 canal:alkali water irrigated plots respectively. The treatment details of the experiment are given as follows:

Treatment details*:

Main plot treatments: Irrigation (3)

M_1: Irrigating both rice and green gram with alkali water
M_2: Irrigating rice with canal water and green gram with alkali water
M_3: Irrigating rice with canal and alkali water in alternate mode (cyclic) and green gram with alkali water

Sub plot treatments: Amendments (5)

S_1 : No amendment
S_2 : Soil application of distillery spent wash (DSW)
S_3 : Soil application of Gypsum @ 50% GR (4.5 t/ha)
S_4 : Amending the alkali water with DSW
S_5 : Amending the alkali water with gypsum in gypsum bed

Irrigation with canal water recorded rice grain yield of 5.80 t/ha during the fourth year of experiment (2006-07), which was significantly higher than conjunctive use of canal and alkali water (CW: AW) in alternate mode. Use of alkali water recorded the lowest grain yield of 4.36 t/ha, which was 24.8 per cent lower than irrigation with canal water. Amongst the different amendments, amending alkali water with gypsum bed recorded significantly higher rice grain yield of 5.72 t/ ha (variety TRY 1) and was at par with soil application of gypsum @ 50% GR (5.54 t/ha). Lowest grain yield of 4.28 t/ha was obtained where no amendment was applied. During the fifth year of the experiment (2007-08) also, canal water irrigation for rice recorded the highest grain yield of 5.93 t/ha followed by CW: AW in alternate mode (5.54 t/ha). Amongst the water treatment methods amending alkali water with gypsum bed recorded the highest grain yield of 5.86 t/ha, which was at par with soil application of gypsum @ 50% GR (5.67 t/ha).

Conjunctive use of canal water for rice and alkali water for green gram recorded the highest green gram yield of 0.62 t/ha and 0.69 t/ha during the fourth and fifth year of the experiment respectively (Table 33). Among the amendment, amending alkali water with gypsum recorded the maximum green gram yield of 0.64 t/ha and 0.71 t/ha during 2006-07 and 2007-08, which was comparable with soil application of gypsum @ 50% GR.

Table 33 Grain yield of rice and green gram under different treatments and amendments

Irrigation treatment	2006-07						2007-08					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Grain yield of Rice (t/ha)												
M_1	3.56	4.45	4.62	4.38	4.80	4.36	3.68	4.58	4.75	4.51	4.93	4.49
M_2	4.70	5.59	6.20	5.78	6.35	5.80	4.83	6.12	6.34	5.89	6.49	5.93
M_3	4.58	5.40	5.79	5.28	6.02	5.42	4.71	5.53	5.91	5.41	6.16	5.54
Mean	4.28	5.28	5.54	5.15	5.72		4.41	5.41	5.67	5.27	5.86	
	M	S	MxS	SxM			M	S	MxS	SxM		
CD (5%)	0.20	0.24	0.40	0.42			0.20	0.25	0.40	0.48		
Grain yield of Green gram (t/ha)												
M_1	0.19	0.43	0.49	0.38	0.46	0.39	0.24	0.48	0.54	0.43	0.51	0.44
M_2	0.32	0.67	0.69	0.64	0.77	0.62	0.37	0.74	0.78	0.70	0.86	0.69
M_3	0.24	0.60	0.63	0.59	0.69	0.55	0.29	0.66	0.69	0.64	0.75	0.61
Mean	0.25	0.57	0.60	0.53	0.64		0.30	0.63	0.67	0.59	0.71	
	M	S	MxS	SxM			M	S	MxS	SxM		
CD (5%)	0.02	0.05	0.04	0.09			0.03	0.05	0.06	0.10		

Treatments as explained at *

Post harvest analysis of soil samples revealed that the highest soil pH of 8.98 and 8.64 and soil ESP built-up of 29.0 and 25.8 were in continuous use of alkali water for both rice and green gram during the year 2006-07 and 2007-08 respectively. Amongst the different amending methods, soil application of DSW recorded the lowest pH of 8.48 and 8.36 during the year 2006-07 and 2007-08, respectively. In respect of ESP values soil application of gypsum @ 50% GR recorded the lower soil ESP of 18.0 and 17.1 in the year 2006-07 and 2007-08 respectively (Table 34).

Green gram variety Pusa Bold (or) VBN 2 can be raised as a follow- up crop during summer wherever sufficient underground alkali water is available. The effect of alkali water on crop yield and soil alkalinity can be overcome by soil application of gypsum @ 50% GR or DSW @ 500,000 litres/ ha as one time application. Conjunctive use of canal water for rice and alkali water for green gram with soil application of gypsum resulted in significantly higher yield of crops in rice - green gram cropping system.

Table 34 Effect of different treatments and amendments on soil pH and ESP after the harvest of green gram

Irrigation treatment	2006-07						2007-08					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
						Soil pH						
M_1	9.06	8.98	8.63	9.22	9.01	8.98	8.86	8.52	8.27	8.98	8.59	8.64
M_2	8.61	7.82	8.75	8.50	8.66	8.47	8.25	8.21	8.48	8.25	8.43	8.32
M_3	8.67	8.65	8.86	8.73	8.74	8.73	8.42	8.36	8.48	8.47	8.47	8.44
Mean	8.80	8.48	8.75	8.82	8.78	-	8.51	8.36	8.41	8.57	8.50	-
	M	S	MxS	SxM			M	S	MxS	SxM		
CD (5%)	0.05	0.11	0.18	0.20			0.12	0.20	0.30	0.38		
						Soil ESP						
M_1	36.2	21.9	20.7	35.4	30.8	29.0	32.9	20.6	18.5	30.0	26.9	25.8
M_2	18.5	15.7	16.2	14.6	22.2	17.4	18.5	16.3	16.0	15.5	15.8	16.4
M_3	20.8	20.8	17.2	18.9	24.0	20.4	20.6	19.4	16.8	16.1	16.0	17.8
Mean	25.7	19.5	18.0	23.0	25.19	-	24.0	18.8	17.1	20.5	19.6	-
	M	S	MxS	SxM			M	S	MxS	SxM		
CD (5%)	1.77	2.81	4.68	4.87			4.23	2.31	3.89	4.12		

Treatments as explained at *

NEUTRALIZATION OF RSC WATER AND APPLICATION OF ORGANIC MANURES FOR MITIGATING THE ADVERSE EFFECT OF HIGH RSC

To evaluate the effect of high RSC water (through sprinkler irrigation) and effect of amendments on yield of wheat and pearl millet crops, an experiment was under taken in Dheerdesar village during 2006-08 at farmers field having pH_2 9.4, EC_2 0.25 dS/m and GR 1.0 t/ha. The irrigation water having pH 8.8, EC 1.44 dS/m and RSC 10.0 meq/l was used. Treatments comprised of two types of RSC water viz. untreated water (W_1) and partially neutralized water (W_2), four levels of amendments viz., No organic manure (S_1), organic manure @ 10 t/ha (S_2), gypsum equivalent to 5 meq/l RSC neutralization (S_3) and $S_4 = S_2 + S_3$. After passing through gypsum bed, RSC of water was neutralized by 2.0 to 2.5 meq/l.

There was significant effect of neutralization of RSC water and addition of soil amendments in soil on yield attributes of both the crops. The maximum yield attributes of both the crops were observed in treatment W_2S_4 (Table 35).

Table 35 Effect of RSC water and soil amendments on yield attributes of crops

Treatments	Pearl millet (Av. of three years)			Wheat (Av. of two years)		
	Plant height (cm)	Ear length (cm)	Test weight (g)	Plant height (cm)	Ear length (cm)	Test weight (g)
W_1S_1	109.5	20.3	6.28	63.2	6.9	33.50
W_1S_2	117.1	24.2	6.59	66.9	7.5	36.61
W_1S_3	134.4	28.5	6.88	70.2	7.7	38.39
W_1S_4	140.5	31.2	7.08	73.5	8.1	39.57
W_2S_1	124.9	24.0	6.50	67.2	7.4	35.89
W_2S_2	134.1	27.2	6.71	70.3	7.8	38.57
W_2S_3	139.1	32.4	7.01	76.2	8.3	39.84
W_2S_4	149.6	33.7	7.24	80.0	8.4	40.07
CD (5%)	12.6	3.5	0.54	6.9	0.9	3.39

The yield data revealed significant effect of neutralization of RSC of water and addition of soil amendments on grain yield of pearl millet and wheat. In general yield attributes and crop yields were higher for W_1 than W_2. Maximum grain yields of both the crops were recorded with the addition of FYM @ 10 t/ha along with soil application of gypsum @ 5 meq/l RSC neutralization under treated water (Table 36) but was not significantly different than W_2S_3.

Table 36 Effect of RSC neutralization and soil amendments on pearl millet and wheat

Treatments	Pearl millet (t/ha)				Wheat (t/ha)		
	2006	2007	2008	Mean	2006-07	2007-08	Mean
W_1S_1	1.11	1.49	1.21	1.27	2.04	2.32	2.18
W_1S_2	1.26	1.66	1.33	1.42	2.37	2.59	2.48
W_1S_3	1.58	1.99	1.59	1.72	2.68	2.90	2.79
W_1S_4	1.65	2.15	1.70	1.83	2.91	3.06	2.98
W_2S_1	1.26	1.62	1.33	1.40	2.26	2.44	2.35
W_2S_2	1.42	1.79	1.42	1.54	2.54	2.78	2.66
W_2S_3	1.60	2.06	1.67	1.78	2.85	3.02	2.94
W_2S_4	1.76	2.22	1.80	1.92	3.09	3.26	2.18
S Em ±	0.06	0.07	0.07	-	0.10	0.09	-
CD (5%)	0.18	0.22	0.21	-	0.29	0.29	-

Addition of organic matter and gypsum decreased the pH of soil but slightly increased the EC of the soil. After harvest of pearl millet, the decrease in EC might be due to good monsoon rains in the area. In general pH_2 and EC_2 of the soil increased after harvest of the second crop of wheat (Table 37).

Table 37 Chemical characteristics of soil after harvest of crops

Treat ments	Pearl millet		Wheat		Pearl millet		Wheat		Pearl millet	
	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)	pH_2	EC_2 (dS/m)
W_1S_1	9.44	0.24	9.30	0.17	9.44	0.18	9.42	0.22	9.45	0.14
W_1S_2	9.37	0.25	9.26	0.18	9.41	0.20	9.40	0.24	9.45	0.14
W_1S_3	9.17	0.31	9.08	0.21	9.01	0.20	9.35	0.25	9.36	0.18
W_1S_4	9.09	0.30	8.99	0.22	8.92	0.20	9.29	0.27	9.35	0.19
W_2S_1	9.37	0.28	9.21	0.20	9.38	0.19	9.38	0.24	9.41	0.15
W_2S_2	9.28	0.30	9.18	0.21	9.35	0.20	9.35	0.26	9.4	0.16
W_2S_3	9.05	0.35	8.98	0.25	8.90	0.22	9.24	0.28	9.25	0.20
W_2S_4	8.93	0.37	8.90	0.25	8.80	0.23	9.22	0.30	9.20	0.20

EFFECT OF HIGH RSC WATER, FYM AND GYPSUM LEVELS ON VEGETABLES

The study on use of sodic water in broccoli-cluster bean and knol khol-ridge gourd in relation to gypsum as an amendment and FYM was carried out at Hisar in 3.0m x 3.0m and 3.6m x 3.6m micro-plots. In broccoli-cluster bean, levels of gypsum application were 0, 50% and 100% neutralization of RSC represented as G_0, G_1 and G_2 respectively and five in knol khol-ridge gourd 0, 25%, 50%, 75% and 100% as G_0, G_1, G_2, G_3, and G_4 respectively. In both the experiments, three levels of FYM 0, 10 t/ha and 20 t/ha represented as F_0, F_1 and F_2 respectively were used. The crops were irrigated with sodic water having average RSC 11.5 meq/l and SAR 14.0 $(mmol/l)^{1/2}$. All the treatments were replicated thrice in the randomized block design. Recommended cultural practices and fertilizer doses were applied for raising the crop. Uniform fertilizer applications were made in all the treatments. The requisite amount of gypsum in various treatments was applied in a single dose before sowing of crop and mixed well in the soil. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. The ionic composition of irrigation water revealed that the water is bicarbonate type with 13.3 meq/l HCO_3^- content (Table 38).

Table 38 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 (meq/l)	11.5
SAR $(mmol/l)^{1/2}$	14.0

Broccoli-cluster bean

The mean data of two years (2006-08) showed that the yield of broccoli increased significantly both with the addition of gypsum and FYM (Table 39). However, yield obtained in F_0G_2 and F_1G_1 treatments were statistically at par. The highest yield of 10.04 t/ha was observed in F_2G_2 treatment and the lowest (0.09 t/ha) was recorded in F_0G_0 treatment.

Table 39 Effect of FYM and gypsum on the yield* of broccoli (t/ha) with sodic water

Treatments	Gypsum (% GR)			
	G_0	G_1	G_2	Mean
FYM (t/ha)				
F_0	0.09	4.88	6.43	3.80
F_1	1.51	6.83	9.38	5.90
F_2	3.26	7.64	10.04	6.98
Mean	1.62	6.45	8.61	
CD (5%)	Gypsum : 0.92	FYM : 0.92	Gypsum x FYM : NS	

*Average of two seasons 2006-08

In cluster bean also, yield increased significantly with the addition of both FYM and gypsum (Table 40). The yield recorded in F_2G_2 and F_1G_2 were statistically at par. The highest yield of 11.24 t/ha was obtained in F_2G_2 treatment.

Table 40 Effect of FYM and gypsum on the yield* of cluster bean (t/ha) with sodic water

Treatments	Gypsum (% GR)			
	G_0	G_1	G_2	Mean
FYM (t/ha)				
F_0	-	9.37	10.65	6.67
F_1	-	10.57	11.16	7.24
F_2	-	10.57	11.24	7.27
Mean	-	10.17	11.01	-
CD (5%)	Gypsum : 0.53	FYM : 0.53	Gypsum x FYM : NS	

*Average of two seasons 2006-08

The pH of soil decreased with the addition of FYM and gypsum (Fig. 24). The reduction with gypsum application was more pronounced compared to that of FYM. The maximum pH value of 9.7 was recorded in F_0G_0 treatment, which resulted in very poor yield of the crop. However, the lowest value of 8.20 was obtained in F_2G_2 treatment due to the 100 % neutralization of the RSC with gypsum.

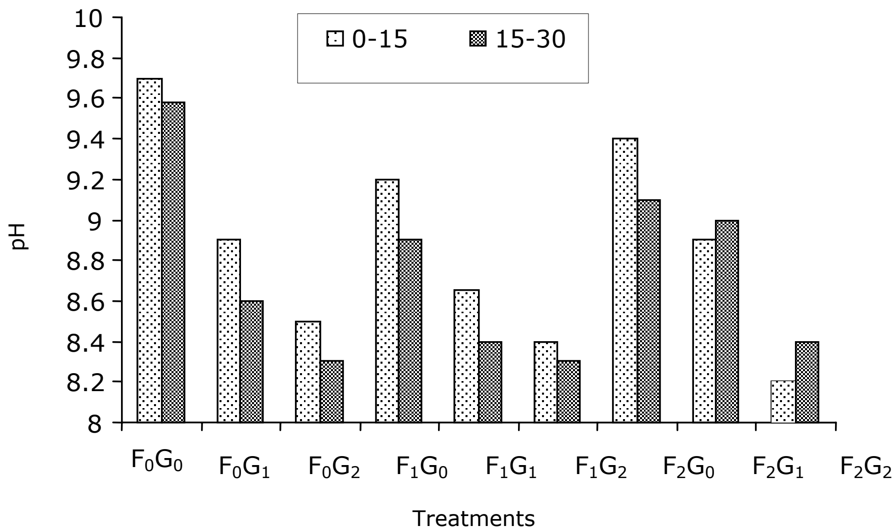


Fig. 24 Effect of different combinations of gypsum and FYM on soil pH in broccoli during 2007-08

Knol-khol - ridge gourd

The mean curd weight of knol-khol and fruit yield of ridge gourd (t/ha) increased significantly with the addition of gypsum and FYM (Table 41 and 42). However, the magnitude of increase was higher with gypsum than FYM. The mean yield of knol-khol increased from 1.71 t/ha under no gypsum to 10.95 t/ha under 100% GR (Table 54). Similarly, the yield of ridge gourd increased from 4.12 t/ha under no gypsum to 8.92 t/ha under 100% GR (Table 55). Maximum yield of these vegetables were obtained in F_2G_4 treatment.

Table 41 Effect of FYM and gypsum on the yield of knol-khol (t/ha) with sodic water

Treatments	Gypsum (% GR)					
	G_0	G_1	G_2	G_3	G_4	Mean
FYM (t/ha)						
F_0	1.50	4.98	6.47	7.90	9.53	6.07
F_1	1.64	6.18	8.97	9.46	10.73	7.39
F_2	2.00	7.26	9.82	10.56	12.60	8.45
Mean	1.71	6.14	8.42	9.30	10.95	-
CD (5%)		Gypsum : 0.57		FYM : 0.44	G X FYM : 0.7	

Table 42 Effect of FYM and gypsum on the yield of ridge gourd (t/ha) with sodic water during 2007

Treatments	Gypsum (% GR)					
	G_0	G_1	G_2	G_3	G_4	Mean
FYM (t/ha)						
F_0	3.56	4.43	6.29	7.24	8.54	6.01
F_1	4.28	4.97	6.73	7.65	8.98	6.52
F_2	4.53	5.43	7.17	8.07	9.26	6.89
Mean	4.12	4.94	6.73	7.65	8.92	-
CD (5%)	Gypsum : 0.24		FYM : 0.21	Gypsum X FYM : 0.38		

The ESP of the soil decreased with the addition of gypsum and FYM (Fig. 25). The reduction with gypsum application was more pronounced compared to FYM. The maximum ESP value of 37.4 was recorded in F_0G_0 treatment. However, the lowest value of 10.4 was obtained in F_2G_4 treatment in 0-15 cm soil depth.

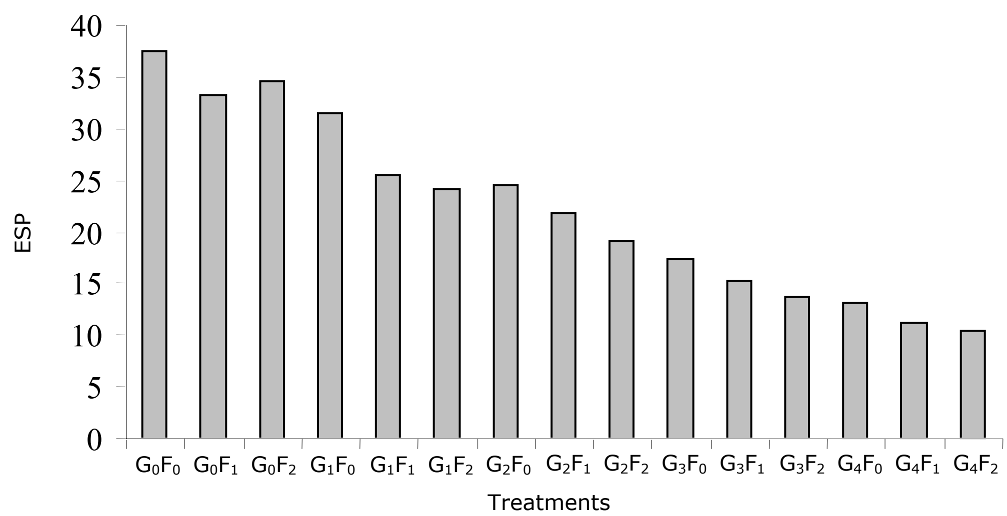


Fig. 25 Effect of different combinations of gypsum and FYM on soil ESP after knol-khol crop irrigated with sodic water during 2007-08

USE OF AGRO-CHEMICALS TO MINIMIZE ALKALINITY HAZARDS AND SUSTAINING CROP YIELDS ON ALKALI WATER IRRIGATED SOILS

Pearl millet - sunflower

A field experiment was initiated in kharif 2004 to evaluate the use of high RSC (alkali) ground water for irrigation with minimum adverse effects and higher crop productivity by comparing the efficiency of soil-applied gypsum with that of reclaimed alkali water after passing through 15 cm gypsum bed. The soil had initial pH 9.5, EC 3.7 dS/m and ESP 57. The treatments were 1) Irrigation with RSC water without soil-applied gypsum (control); 2) Irrigation with neutralized (2/3) RSC water passed through 15 cm gypsum bed without soil-applied gypsum; 3) Irrigation with RSC water with one time soil-applied gypsum (50% GR) and 4) Irrigation with RSC water with one time soil-applied gypsum (100% GR). The sunflower and pearl millet crops were cultivated with recommended package of practices.

The RSC water of 8.9 meq/l when passed through 15 cm gypsum bed showed an average reduction to 4.2 meq/l (Table 43). There was little reduction in the pH value (from 8.2 to 7.9) but with average increase in Ca and Mg (1.8 to 6.2 meq/l) and SO_4 ions (0.7 t 3.9 meq/l) in the water changes in RSC value is quite significant. The SAR of water also reduced from 10.6 to 5.4 $(mmol/l)^{1/2}$.

Table 43 Change in ionic composition of RSC due to gypsum bed treatment (Av. 4 years)

Irrigation water	pH	EC (dS/m)	Ions (meq/l)						RSC (meq/l)	SAR $(mmol/l)^{1/2}$
			CO_3	HCO_3	Cl	SO_4	(Ca+Mg)	(Na+K)		
RSC (untreated)	8.2	1.2	-	10.7	0.8	0.7	1.8	10.0	8.9	10.6
RSC (Treated)	7.9	1.5	-	10.4	1.1	3.9	6.2	9.5	4.2	5.4
BAW	7.5	0.7	-	4.1	3.3	0.1	6.4	1.0	Nil	0.6

Data pertaining to yield of sunflower and pearl millet (Table 44) showed significant improvement with the application of gypsum @ 50 and 100% GR in comparison to control in both the crops. The maximum seed yield of 2.50 and 1.34 t/ha (mean of two seasons) were recorded in treatment with gypsum @ 100% GR in pearl millet and sunflower crops respectively. The counter figures for lowest yield were 1.76 and 0.64 t/ha respectively in control. Treatment with 2/3 neutralized RSC water recorded significantly higher yield in comparison of control. Similar trend was recorded in stover yield of sunflower and pearl millet. Soil application of gypsum (50% GR) or 2/3 neutralized RSC water were found to be optimum since no significant enhancement in yield was recorded with the higher dose (100% GR) of gypsum.

Table 44 Effect of gypsum application on yield (t/ha) of crops

Treatment	Pearl millet*			Sunflower*		
	2006	2007	Mean	2006-07	2007-08	Mean
RSC water (untreated) +G_0	1.78	1.74	1.76	0.65	0.63	0.64
RSC water (2/3 Neutralized) **	2.20	2.58	2.39	1.10	1.05	1.08
RSC water +G_{50}	2.22	2.50	2.36	1.25	1.22	1.24
RSC water +G_{100}	2.40	2.59	2.50	1.36	1.31	1.34
CD (5%)	0.21	0.18	-	0.11	0.17	-

G_0, G_{50} and G_{100} represented one time soil application of gypsum @ 0, 50 and 100% GR respectively.
** Total gypsum dissolution (4.92 t/ha = 35% GR) through 15 cm gypsum bed in 3.5 years

On an average basis, the maximum seed yield of 2.44 and 1.31 t/ha (mean of four seasons) were recorded in treatment with gypsum @ 100% GR in pearl millet and sunflower crops respectively. The counter figures for lowest yield were 1.77 and 0.63 t/ha respectively in control. Treatment with 2/3 neutralized RSC water recorded significantly higher yield in comparison to control. Similar trend was recorded in stover yield of sunflower and pearl millet.

Soil properties improved under 2/3 neutralized RSC irrigation water and soil application of gypsum @ 50% GR and 100% GR (Table 45). The analytical data of soil after four years of pearl millet – sunflower cropping sequence recorded remarkable change in pH, EC_e and ESP values of the 0-15 cm layer and the decrease was 9.4-8.4, 3.7-2.2 and 55-18 in the soil samples where gypsum was applied @ 100% GR (soil application).

Rice – wheat

Another field experiment was initiated during kharif 2003 to evaluate optimal dose of soil application of various amendments and compare its efficiency with the use of neutralized RSC water through gypsum bed on deteriorated soils (pH 9.4, EC_e 3.2 dS/m and ESP 59) at Research Farm Nawabganj, Kanpur in rice-wheat cropping sequence. The treatments were 1) All irrigation with RSC water without amendments (control); 2) All irrigation with BAW without amendments; 3) 2/3 Neutralization of RSC through 15 cm gypsum bed before irrigation; 4-6) Gypsum @ 50, 100 and 150% GR; 7-9) Pyrite @ 50, 100 and 150% GR; 10-12) Press mud @ 5, 10 and 15 t/ha. Amendments were applied once in soil and treatments (4-12) irrigated with BAW. Rice and wheat crops were cultivated with recommended package of practices.

Table 45 Effect of gypsum on yield (t/ha)and chemical characteristics of surface soil

Treatment	Pearl millet*		Sunflower*		Soil Characteristics+		
	Grain	Stover	Grain	Stover	pH_s	EC_e (dS/m)	ESP
RSC water (untreated) + G_0	1.77	4.56	0.63	2.36	9.5	3.7	57
RSC water (2/3 neutralized)** + G_0	2.28	5.46	1.05	3.47	8.4	2.6	21
RSC water + G_{50}	2.36	5.99	1.22	4.24	8.5	2.4	22
RSC water + G_{100}	2.44	6.23	1.31	4.59	8.4	2.2	18
CD (5%)	0.24	0.75	0.16	0.60			
Initial values					9.4	3.6	55

* Mean yield of 4 years (2004-08)
\+ After 4 years of pearl millet-sunflower cropping sequence

The mean data of two seasons of both rice and wheat (Table 46) showed significant improvement in yield with the application of gypsum, pyrite and press mud over control. Data on grain yield of rice and wheat revealed that soil application of gypsum @ 50, 100 and 150% GR were at par. Similarly application of different doses of pyrite (50, 100 and 150% GR) as well as press mud (5, 10 and 15 t/ha) did not record any significant difference in grain yield of rice and wheat. The mean grain yield of rice (3.84, 3.71and 3.51 t/ha) and wheat (3.38, 3.34 and 2.99 t/ha) due to application of gypsum (50% GR), pyrite (50% GR) and press mud (5 t/ha) respectively were non-significant but significantly higher than control yield of rice (3.27 t/ha) and wheat (2.53 t/ha). The yield of neutralized RSC water (15 cm gypsum bed) showed beneficial effect of gypsum bed irrigation in grain yield of both crops. The straw yield also indicated similar trend.

Table 46 Effect of various amendments on yield (t/ha) of crops

Treatments		Rice			Wheat		
Amendments	Irrigation	2006	2007	Mean	2006-07	2007-08	Mean
Control	RSCW	3.27	3.28	3.28	3.56	3.50	3.53
Control	BAW	3.44	3.48	3.46	2.76	2.84	2.80
Gypsum bed **	RSCW	3.69	4.09	3.89	3.23	3.65	3.44
Gypsum 50% GR	BAW	3.77	3.90	3.84	3.31	3.44	3.38
Gypsum 100% GR	BAW	3.99	4.18	4.09	3.47	3.62	3.54
Gypsum 150% GR	BAW	4.04	4.31	4.18	3.50	3.73	3.62
Pyrite 50% GR	BAW	3.62	3.80	3.71	3.25	3.42	3.34
Pyrite 100% GR	BAW	3.71	3.89	3.80	3.36	3.55	3.46
Pyrite 150% GR	BAW	3.76	4.00	3.88	3.45	3.62	3.50
PM 5t/ha	BAW	3.46	3.55	3.51	2.96	3.02	2.99
PM 10t/ha	BAW	3.52	3.60	3.56	3.07	3.05	3.06
PM15t/ha	BAW	3.56	3.63	3.60	3.11	3.08	3.10
CD (5%)	-	0.28	0.30	-	1.78	2.40	-

PM: Press mud; RSCW: (RSC water); BAW: Best available water
** Total gypsum dissolution (7.76 t/ha = 60% GR) through 15 cm gypsum bed in five years

The pooled data of five seasons of both rice and wheat (Table 47) also showed similar results. Improvement in soil properties under gypsum amended water and soil application of gypsum, pyrite and press mud treatment was observed. The analytical data of soil after five years of rice-wheat crop rotation recorded lowest value of pH 8.0 (gypsum @ 150% GR) and highest as 9.3 (control) (Table 47). The counter values of EC_e were 1.9 and 3.3 dS/m. The highest and lowest values of ESP were 58 and 14 in control and gypsum 150% GR respectively. Effect of gypsum bed treatment on chemical properties was similar to what was obtained in the case of pearl millet-sunflower.

Table 47 Effect of various amendments on yield and chemical properties of surface soil

Treatments		Rice*	Wheat*	Soil characteristics[+]		
Amendments	Irrigation	yield (t/ha)	yield (t/ha)	pH_s	EC_e (dS/m)	ESP
Control	RSCW	3.27	2.56	9.3	3.3	58
Control	BAW	3.44	2.76	9.1	2.7	51
Gypsum bed**	RSCW	3.69	3.23	8.5	2.2	18
Gypsum 50% GR (SA0)	BAW	3.77	3.31	8.4	2.2	20
Gypsum 100%GR (SA0)	BAW	3.99	3.47	8.2	2.0	15
Gypsum 150% GR (SA0)	BAW	4.04	3.50	8.0	1.9	14
Pyrite 50% GR (SA0)	BAW	3.62	3.25	8.4	2.3	22
Pyrite 100% GR (SA0)	BAW	3.71	3.36	8.2	2.1	19
Pyrite 150% GR (SA0)	BAW	3.76	3.45	8.1	2.0	16
Press mud 5t/ha (SA0)	BAW	3.46	2.96	8.8	2.5	33
Press mud 10t/ha (SA0)	BAW	3.52	3.07	8.5	2.3	30
Press mud 15t/ha (SA0)	BAW	3.56	3.11	8.5	2.3	26
CD (5%)		0.27	0.28	-	-	-
Initial Values (2003)				9.4	3.2	59

* Mean yield of 5 seasons (2003-08); SAO: Soil application once
[+] After 5 years of rice-wheat cropping sequence

DRIP IRRIGATION TO SUGARCANE USING AMELIORATED ALKALI WATER

Sugarcane was used as test crop to evaluate the beneficial effect of drip irrigation where ameliorated alkali water was used to irrigate the crop. Drip irrigation was scheduled at 80% Pan Evaporation (PE) using alkali water (pH 9.0, EC 1.78 dS/ m and RSC 11.4) ameliorated by passing through gypsum bed and amended by application of distillery spent wash. The main crop was harvested in 2005 while ratoon crops were harvested during 2006 -08. Treatments were as follows:

Main plot (Water treatments):

- M_1 : Drip irrigation through gypsum bed treated water
- M_2 : Drip irrigation using DSW treated water
- M_3 : Drip irrigation with untreated alkali water
- M_4 : Farmer's practice (furrow irrigation)

Sub-plot (Soil treatments):

- S_1 : Soil application of gypsum @ 50% GR (Ist year)
- S_2 : No gypsum

Design : Split plot
Replications : 4
The gypsum (50% GR) was applied only once before planting.

Among the different treatments tried to ameliorate the alkali water, injection of DSW to drip system in 1:250 ratio could reduce the pH of irrigation water from 9.0 to 6.8 with complete neutralization of RSC (Table 48). Gypsum bed treatment reduced the RSC to the level of 5.0 meq/l.

Table 48 Changes in quality of ameliorated alkali water

Treatments	pH	EC (dS/m)	RSC (meq/l)
Alkali water (untreated)	9.0	1.78	11.4
Gypsum bed treated water	8.4	1.85	5.0
Distillery spent wash treated water (1:250)	6.8	1.97	Nil

Ameliorating alkali water through gypsum bed recorded the highest sugarcane yield of 64.68 t/ha followed by the treatment of irrigation water with DSW (55.06 t/ha) (Table 49). Drip irrigation with alkali water and farmer's practice recorded the cane yields of 38.69 t/ha and 41.12 t/ha, respectively. The soil application of gypsum @ 50% GR recorded the cane yield of 58.29 t/ha, whereas the cane yield in un-amended treatment was 41.48 t/ha.

Biometric observations showed that the germination was significantly higher in soil application of gypsum (55%), which was more than without gypsum (44%). Irrigation with gypsum treated alkali water with soil application of gypsum recorded the highest germination percentage (62%) than other treatments. The results revealed that irrigation with gypsum treated alkali water recorded the highest number of tillers of 2.58 lakhs/ha while the lowest 1.44 lakhs/ha were recorded in the furrow irrigation treatment (Table 49).

Table 49 Effect of drip irrigation using ameliorated alkali water on cane tillers and yield of sugarcane

Treatments	2006-07 ratoon					2007-08 ratoon				
	Irrigation water treatments					Irrigation water treatments				
	Gypsum bed	Spent wash	Un-treated	Furrow irrigation	Mean	Gypsum bed	Spent wash	Un-treated	Furrow irrigation	Mean
	Cane yield (t/ha)									
50% GR	68.90	58.07	51.59	54.61	58.29	68.57	56.26	45.27	51.48	55.54
No gypsum	60.44	52.05	25.79	27.64	41.48	60.74	52.77	30.04	32.07	43.91
Mean	64.68	55.06	38.69	41.12	-	64.66	54.52	37.66	41.78	-
	M	S	MxS	SxM	-	M	S	MxS	SxM	-
S Ed	1.27	1.41	2.37	2.83	-	1.16	1.36	2.27	2.72	-
CD (5%)	2.89	3.08	5.23	6.16	-	2.86	3.15	5.30	6.32	-
	Cane tillers (lakhs/ha)									
50% GR	2.54	2.02	2.50	1.51	2.14	2.57	2.08	2.52	1.47	2.16
No gypsum	2.62	2.62	1.56	1.38	2.04	2.66	2.26	1.49	1.38	1.95
Mean	2.58	2.32	2.03	1.44	-	2.62	2.17	2.01	1.43	-
	M	S	MxS	SxM	-	M	S	MxS	SxM	-
S Ed	0.05	0.03	0.06	0.06	-	0.05	0.03	0.06	0.06	-
CD (5%)	0.114	0.07	0.01	0.13	-	0.11	0.06	0.14	0.13	-

In ratoon crops, the furrow irrigation without gypsum recorded the highest soil pH of 9.75 followed by untreated alkali water (9.52, Table 50). Soil application of gypsum with drip irrigation recorded the lowest soil pH of 8.62. Drip irrigation with spent wash treated water with soil application of gypsum recorded the highest EC of 0.58 dS/m, while drip irrigation with alkali water recorded the lowest soil EC of 0.39 dS/m. Furrow irrigation with untreated alkali water with no gypsum recorded the highest ESP of 37.21 while soil application of gypsum with gypsum bed treated water recorded the lowest ESP of 19.75.

Amount of water used for sugarcane in drip and furrow irrigation for the second ratoon crop (2006-2007) revealed that in drip treatment, a considerable saving of 20-26% water could be made (Table 51).

In conclusion, it emerged that ameliorating alkali water through gypsum bed and soil application of gypsum @ 50% GR had significant positive effect on cane yield. Moreover, with drip irrigation as much as 25– 26% of water saving could be accomplished.

Table 50 Effect of drip irrigation using ameliorated alkali water on cane height and CCS

Treatments	2006-07 ratoon					2007-08 ratoon				
	Irrigation water treatments					Irrigation water treatments				
	Gypsum bed	Spent wash	Un-treated	Furrow irrigation	Mean	Gypsum bed	Spent wash	Un-treated	Furrow irrigation	Mean
	Cane height (m)									
50% GR	3.56	3.39	3.19	3.10	3.31	3.58	3.36	3.22	3.14	3.33
No gypsum	3.36	3.22	2.81	2.65	3.10	3.32	3.19	2.82	2.72	3.0
Mean	3.46	3.30	3.0	2.88	-	3.45	3.28	3.02	2.93	-
	M	S	MxS	SxM	-	M	S	MxS	SxM	-
S Ed	0.019	3.01	0.02	0.02	-	0.01	0.01	0.02	0.02	-
CD (5%)	0.043	0.02	0.05	0.05	-	0.03	0.02	0.05	0.04	-
	CCS (%)									
50% GR	85.71	92.79	92.23	77.97	87.18	85.30	93.54	92.12	78.79	87.44
No gypsum	97.95	74.31	94.71	82.28	87.31	97.10	74.56	95.21	89.98	89.21
Mean	91.83	83.55	93.47	80.12	-	91.20	84.05	93.67	84.39	-
	M	S	MxS	SxM	-	M	S	MxS	SxM	-
S Ed	5.62	2.44	6.60	4.88	-	5.69	2.50	6.68	4.90	-
CD (5%)	12.72	5.32	14.78	10.65	-	2.88	5.45	14.96	10.69	-

CCS: Commercial cane sugar

Table 51 Amount of water used for sugarcane in drip and furrow irrigation for the second ratoon crop (2007-2008)

Treatment	Amount of water used (mm)	Water saving (%)
Drip irrigation with gypsum treated water (M_1)	1812	26
Drip irrigation with spent wash treated water (M_2)	1830	25
Drip irrigation with untreated alkali water (M_3)	1812	26
Furrow irrigation (M_4)	2280	-

DRIP IRRIGATION SYSTEM WITH SALINE WATER FOR DIFFERENT VEGETABLE CROPS IN COASTAL SANDY SOILS

During *rabi* 2006-07, an experiment was laid out with four levels of irrigation i.e., BAW of subsurface skimming well (<0.5 dS/m), saline water of 2, 4 qnd 6 dS/m (by mixing of fresh water and seawater of 35 dS/m or more) to know the response on different vegetable crops viz., tomato and okra to different salinity waters under drip irrigation. The mean yield of okra with 2 EC water treatment (4.25 t/ha) was 11.74% higher than BAW treatment (3.62 t/ha) followed by drip irrigation with 4 EC (1.94 t/ha) and 6 EC (0.50 t/ha). The yield reduction at these levels of salinities was 46.14% and 86.19 % respectively. The mean yield of tomato with 2 EC (6.59 t/ha) was 16.48% less compared to the yield with BAW (7.89 t/ha) followed by drip irrigation with 4 EC (5.83 t/ha) and 6 EC (5.14 t/ha) yielding 26.11% and 34.85% less respectively. During 2007-08 *rabi*, experiment was laid out with three crops namely brinjal, okra and tomato. Due to heavy rains in February 2008, crops were damaged and the soil salinity build-up in the soil due to the treatments was washed away. The experiment will be repeated during 2009-10.

TOLERANCE OF VEGETABLE CROPS TO SALINE IRRIGATION UNDER DRIP AND SURFACE IRRIGATION SYSTEMS

Okra-onion

Three years studies on tolerance of okra to saline water irrigations indicate that average fruit yield was significantly influenced by salinity of water as well as method of irrigation. Plant height and number of fruits per plant were higher under treatment of water having EC 3.0 dS/m. At EC_{iw} 6.0

dS/m, yield attributes of the crop decreased significantly (Table 52). Maximum yield of okra was observed under drip irrigation with water having EC 3.0 dS/m with a significant decrease in yield with water having EC 6.0 dS/m. Drip method was superior with 49.4 % higher yield compared to flood irrigation method.

The most significant observation that emerged from this study is that with drip irrigation maximum yield of okra was obtained with a saline water of 3 dS/m while with flood irrigation, it was obtained with BAW although it was not significantly different than the yield obtained with saline water of 3 dS/m.

Table 52 Effect of irrigation water salinity on yield and yield attributes of okra

Treatments	Yield (t/ha)				Plant height (cm)	Fruits/ plant
	2006	2007	2008	Mean		
Drip irrigation						
BAW	3.36	4.92	4.15	4.14	70.0	19.7
3.0 dS/m	3.78	6.18	4.44	4.80	73.5	21.9
6.0 dS/m	2.45	3.79	2.69	2.97	62.2	15.5
Flood irrigation						
BAW	1.70	4.26	3.08	3.01	63.5	15.7
3.0 dS/m	1.88	4.00	2.72	2.87	62.6	15.0
6.0 dS/m	1.49	3.02	1.81	2.11	46.9	12.7
S Em ±	0.17	0.27	0.28	-	-	-
CD (5%)	0.55	0.85	0.89	-	-	-

In the case of onion, maximum yield was recorded under drip irrigation with water having EC 3.0 dS/m with a significant decrease in yield at EC 6.0 dS/m. Drip method was superior with 24.1% higher yield compared to flood irrigation method. Bulb diameter and weight of bulb were also higher under treatment with water having EC 3.0 dS/m. At EC_{iw} 6.0 dS/m yield attributes of the crop decreased significantly (Table 53).

Table 53 Effect of salinity levels on yield and yield attributes of onion (2007-08)

Treatments	Yield (t/ha)	Bulb diameter (cm)	Weight of bulb (g)
Drip irrigation			
BAW	13.2	5.6	70.3
3.0 dS/m	14.9	6.5	83.1
6.0 dS/m	11.1	4.6	60.0
Flood irrigation			
BAW	11.6	5.2	60.9
3.0 dS/m	12.6	6.1	71.5
6.0 dS/m	7.4	3.8	40.8
S Em ±	0.9	0.4	3.2
CD (5%)	2.7	1.2	9.6

In general, soil salinity increased with increase in salinity of the irrigation water at all depths and locations. Zone of minimum salt concentration existed below the emitter. The trend indicated that the salt concentration in the soil profile increased with increase in lateral as well as vertical distance from the emitters. It can be inferred that the salts are leached away from the active root zone of plant providing better growing conditions. Salt concentration was highest at 30 cm distance from emitter (Table 54).

Table 54 Salinity (EC_e) build-up in the soil profile after harvest of okra and onion

Distance from emitter (cm)	Soil depth (cm)	EC_{iw} (dS/m)					
		Drip irrigation			Flood irrigation		
		0.25	3.00	6.00	0.25	3.0	6.00
		Okra					
	0-15	0.54	1.00	1.40	0.58	1.18	1.54
0	15-30	0.60	1.32	1.80	0.60	1.44	1.95
	30-60	0.61	1.40	2.10	0.62	1.60	2.20
	0-15	0.60	1.16	1.76	-	-	-
15	15-30	0.64	1.48	2.16	-	-	-
	30-60	0.64	1.60	2.24	-	-	-
	0-15	0.69	1.32	2.16	-	-	-
30	15-30	0.71	1.75	2.50	-	-	-
	30-60	0.72	1.80	2.52	-	-	-
		Onion					
	0-15	0.36	1.13	1.87	0.30	1.28	1.75
0	15-30	0.41	1.19	1.96	0.39	1.56	2.00
	30-60	0.42	1.47	2.21	0.41	1.64	2.13
	0-15	0.37	1.29	1.79	-	-	-
15	15-30	0.43	1.43	2.03	-	-	-
	30-60	0.46	1.58	2.39	-	-	-
	0-15	0.43	1.73	1.98	-	-	-
30	15-30	0.49	1.94	2.17	-	-	-
	30-60	0.51	1.99	2.30	-	-	-

Chilli-brinjal

An experiment was conducted to assess the tolerance of chilli-brinjal rotation under drip and surface irrigation method with different irrigation schedules during 2005-08. The treatments included a combination of saline irrigation waters (Canal, 4 and 8 dS/m) and irrigation schedule (IW/CPE ratio 0.75, 1.00 and 1.25). While the irrigation interval for drip irrigation was 4 days, in surface irrigation, 4 cm of water was applied in each irrigation. The fruit yield of chilli decreased significantly with increasing EC_{iw} in both drip and surface irrigation system (Table 55). With EC_{iw} 4 and 8 dS/m, on an average the chilli fruit yield reduced by 41.2 and 51.7 per cent in drip irrigation and 45.0 and 64.4 per cent in surface irrigation system. In case of brinjal these reductions were 16.3 and 46.4 in drip and 60.5 and 86.2 per cent in surface irrigation respectively. On an average, the IW/CPE ratio treatments were observed to be non-significant in both drip and surface irrigation.

Water use in chilli

On an average, total water use by the chilli crop varied from 28.4 to 40.9 cm in drip and 36.9 to 55.7 cm in surface irrigation system (Table 56). Water use efficiency was highest in control treatments of both drip and surface irrigation being 390.2 and 256.8 kg/ha-cm. The water use efficiency decreased with increasing EC_{iw} levels. At EC_{iw} 4 and 8 (dS/m) the water use efficiency was 264.6 and 234.7 kg/ha-cm in drip and 156.4 and 101.8 kg/ha-cm in surface irrigation system, respectively. The water use efficiency was higher in IW/CPE 0.75 in both drip and surface irrigation as compared to other IW/CPE ratios.

Soil salinity

The EC_e in the soil profile (0-60 cm) increased with increasing levels of EC_{iw} and IW/CPE ratios in the whole profile (Fig. 26). At harvest of chilli, the average, EC_e of the surface layer in drip irrigation ranged from 3.1 to 3.5 dS/m in control, 7.1 to 7.5 in EC_{iw} 4 and 14.1 to 14.8 dS/m in

EC_{iw} 8 dS/m at 5 to 25 cm distance from the plant. Corresponding values for the lower depth (30-60 cm) are 2.4 to 2.6, 3.6 to 3.9 and 6.8 to 6.9 dS/m, respectively.

Table 55 Effect of different treatments on fruit yield (t/ha) of chilli and brinjal in drip and surface irrigation systems

Treatments	Drip irrigation		Surface irrigation		Drip irrigation		Surface irrigation	
	Chilli	Brinjal	Chilli	Brinjal	Chilli*	Brinjal	Chilli*	Brinjal
	2005-06				2006-07			
EC_{iw} levels (dS/m)								
Canal	15.21	7.64	10.30	11.10	-	5.21	-	4.21
4	9.74	5.88	6.13	4.99	-	4.75	-	3.05
8	9.10	3.43	4.74	1.42	-	2.76	-	2.15
CD (5%)	0.69	1.07	0.57	1.07	-	1.00	-	0.62
IW/CPE ratio								
0.75	11.51	4.56	7.41	5.93	-	4.14	-	3.05
1.00	11.57	5.68	7.01	5.87	-	4.12	-	3.27
1.25	10.97	6.71	5.61	5.61	-	4.46	-	3.08
CD at 5%	NS	NS	NS	NS	-	NS	-	NS
S x I	NS	NS	NS	NS	-	NS	-	NS
	2007-08				Average			
EC_{iw} levels (dS/m)								
Canal	14.55	9.00	14.46	8.75	14.88	7.28	12.38	8.02
4	7.77	7.65	7.50	2.00	8.75	6.09	6.81	3.35
8	5.26	5.51	4.09	0.10	7.18	3.90	4.41	1.11
CD (5%)	0.81	1.73	1.35	0.97	0.75	1.27	0.96	0.89
IW/CPE ratio								
0.75	8.20	3.86	9.25	3.55	9.85	4.19	8.33	4.18
1.00	9.40	7.44	8.57	3.66	10.48	5.75	7.79	4.27
1.25	9.98	10.86	8.22	3.64	10.47	7.34	6.91	4.11
CD (5%)	0.81	1.73	NS	NS	NS	NS	NS	NS
S x I	NS	NS	NS	NS	NS	NS	NS	NS

*Chilli crop could not survive during 2006

Table 56 Water use (WU) and water use efficiency (WUE) in different treatments in chilli

Treatments	2005-06				2007-08				Average			
	Drip irrigation		Surface irrigation		Drip irrigation		Surface irrigation		Drip irrigation		Surface irrigation	
	WU	WUE	WU	WUE	WU	WUE	WU	WUE	WU	WUE	WU	WUE
EC_{iw} levels (dS/m)												
Canal	33.7	451.3	50.8	202.7	44.2	329.1	46.5	310.9	38.9	390.2	48.6	256.8
4	30.9	315.2	50.5	121.3	36.3	214.0	40.4	185.5	33.6	264.6	45.4	156.4
8	30.4	299.3	50.4	94.0	30.9	170.2	37.3	109.6	30.6	234.7	43.8	101.8
IW/CPE ratio												
0.75	28.5	403.8	40.4	183.4	28.4	288.6	33.5	276.6	28.4	346.2	36.9	230.0
1.00	31.4	368.5	50.0	140.2	35.7	263.2	43.0	199.2	33.5	315.8	46.5	169.7
1.25	33.9	323.5	62.4	108.0	48.0	207.9	49.1	167.4	40.9	265.7	55.7	137.7

At harvest of brinjal crop in drip irrigation, EC_e of the surface layer (0-10 cm) ranged between 2.7 to 2.9 dS/m in control, 7.5 to 8.3 in EC_{iw} 4 and 12.4 to 13.0 dS/m in EC_{iw} 8 dS/m at 5 to 25 cm from the plants. Corresponding values for the lower depth (30 to 60 cm) were 2.5 to 2.7, 5.1 to 5.7 and 9.1 to 9.2 dS/m, respectively (Fig. 27).

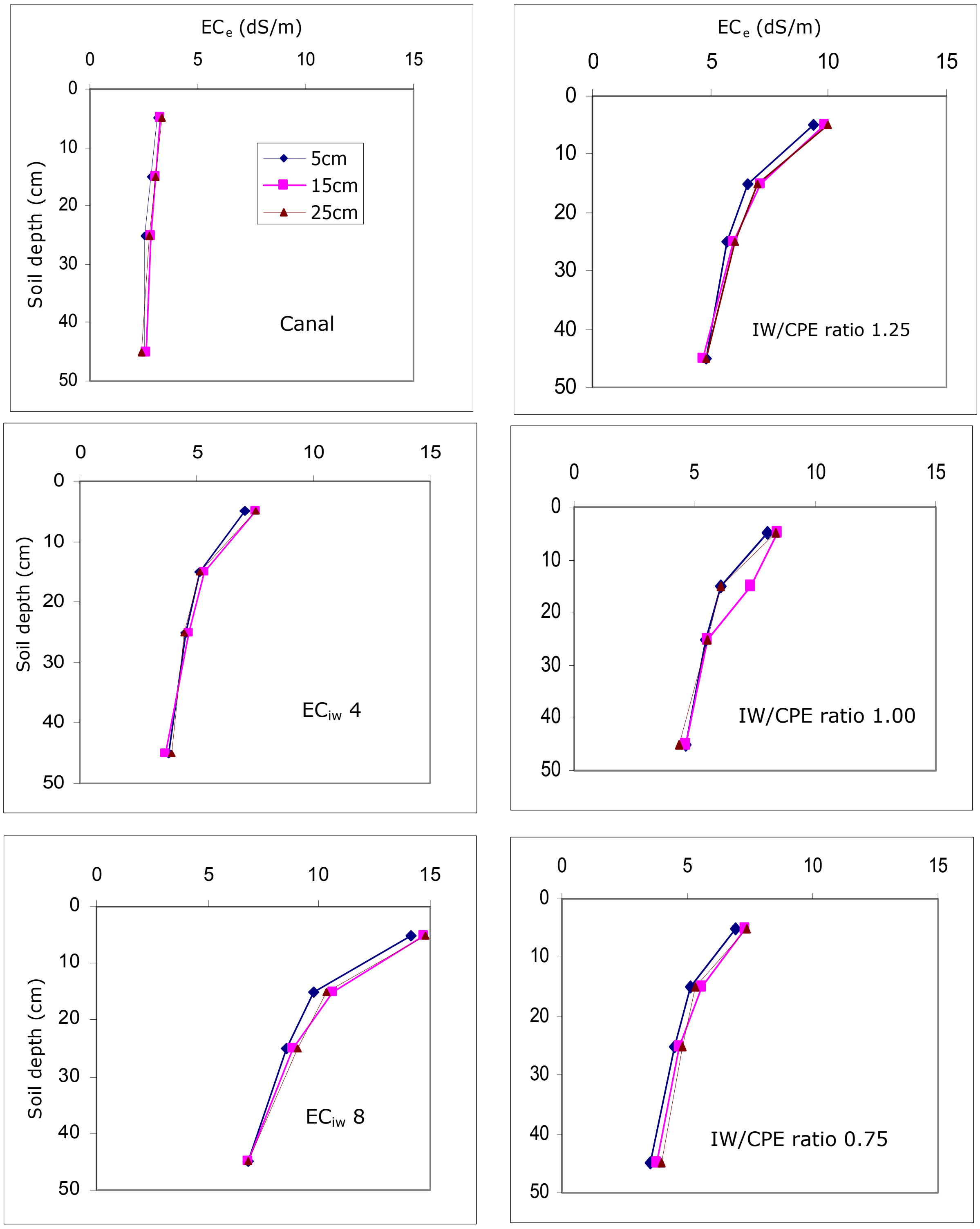


Fig. 26 EC_e (dS/m) in different EC_{iw} levels and IW/CPE ratios at harvest of chilli (2005-06 to 2007-08)

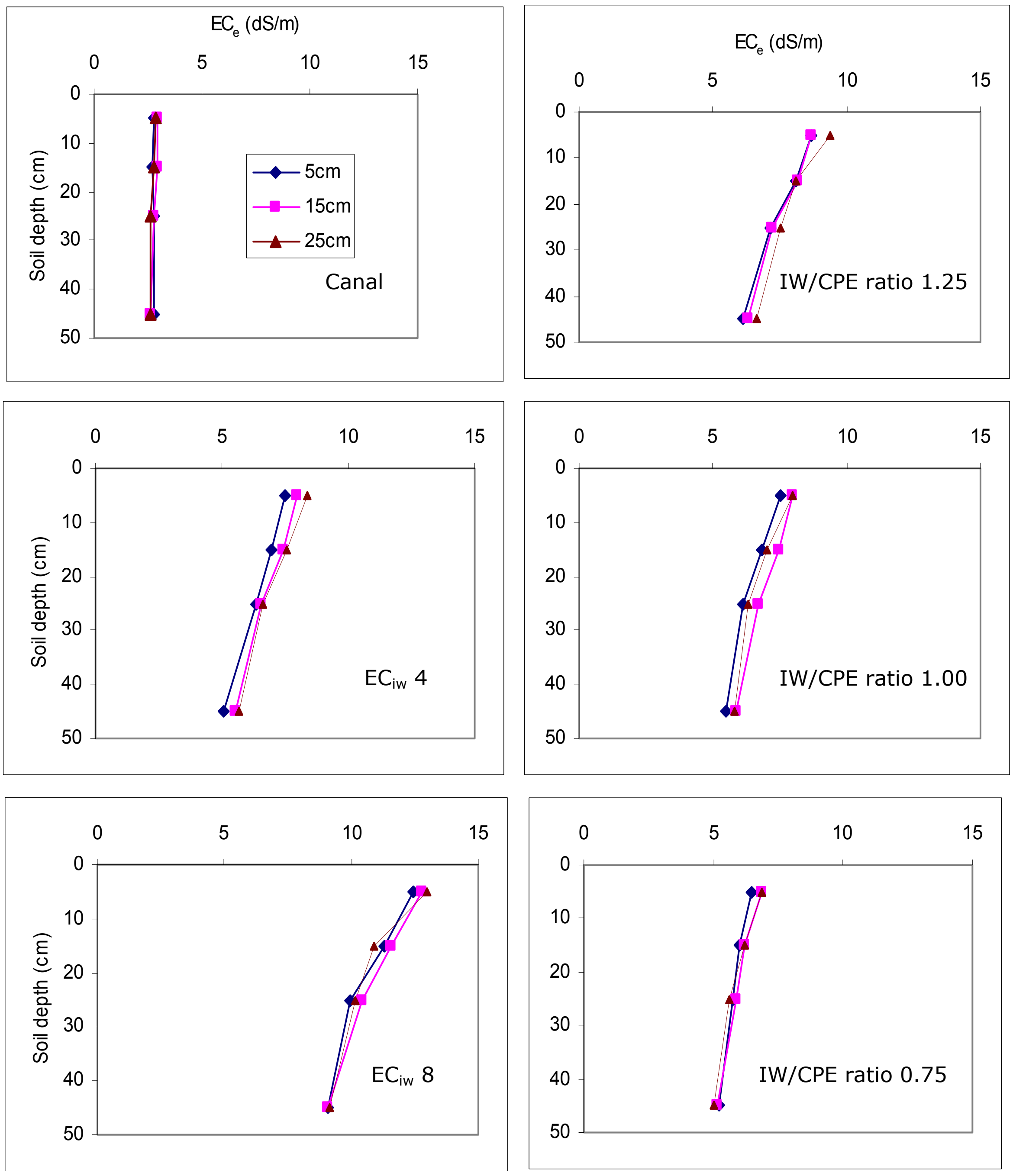


Fig. 27 EC_e (dS/m) at different EC_{iw} levels and IW/CPE ratios at harvest of brinjal (2005-06 to 2007-08)

In surface irrigation, the salinity build-up was higher in surface layer as compared to lower depth (Table 57). At harvest of chilli crop EC_e in surface layer (0-10 cm) was 3.5, 8.9 and 15.9 dS/m with canal, EC_{iw} 4 and 8 dS/m, respectively. The EC_e in surface layer were 10.4, 9.3 and 8.4 dS/m in IW/CPE ratios of 1.25, 1.00 and 0.75, respectively. At harvest of brinjal crop the EC_e trend was similar to the chilli crop.

Table 57 Salinity build-up at harvest of chilli and brinjal in surface irrigation

Treatments	Soil depth (cm)	EC_e *(dS/m)	
		Chilli	Brinjal
Salinity levels (dS/m)			
Control	0-10	3.5	3.1
	10-20	3.4	3.2
	20-30	3.2	3.1
	30-60	2.7	3.0
EC_{iw} 4	0-10	8.9	7.2
	10-20	6.4	7.4
	20-30	5.6	6.5
	30-60	4.8	6.4
EC_{iw} 8	0-10	15.9	12.5
	10-20	11.0	10.9
	20-30	8.4	9.7
	30-60	7.5	8.9
IW/CPE ratio			
1.25	0-10	10.4	8.4
	10-20	7.4	7.8
	20-30	6.3	7.0
	30-60	5.3	6.6
1.00	0-10	9.3	7.6
	10-20	7.0	7.0
	20-30	5.7	6.4
	30-60	4.9	6.2
0.75	0-10	8.4	7.0
	10-20	6.3	7.1
	20-30	5.2	6.3
	30-60	4.8	5.9

* After harvest of 2007-08

PERFORMANCE OF PEARL MILLET-WHEAT IRRIGATED WITH SODIC WATER THROUGH SPRINKLER SYSTEM WITH VARYING DEPTHS OF IRRIGATION

The study on pearl millet-wheat crop rotation with different doses of gypsum as an amendment was started at Regional Research Station, CCS HAU at Bawal during rabi 2002 which is situated at 28º 40' N latitude and 76º 35' E longitude at an altitude of about 266 m above mean sea level. The area in the Bawal zone is undulating in nature. The topography varies from leveled to stabilized sand dunes. Three irrigation depths (4, 5, 6 cm) in main plots and four gypsum treatments (0, 50%, 75% and 100 % neutralization of RSC represented as G_0, G_1, G_2, G_3 and G_4 respectively) in sub plots were replicated thrice in a split plot design. The plot size was 10 m x 4 m. The crop was irrigated with sodic water of average RSC 12.0 meq/l and SAR 19.3 $(mmol/l)^{1/2}$ (Table 58). The water is bicarbonate type with 14.0 meq/l HCO_3 content. The requisite amount of gypsum in various treatments was applied in a single dose before sowing of the crop and mixed well in the upper 10 cm soil.

The texture of the experimental site is loamy sand with 17-21% silt + clay content and remaining (79-83%) sand (Table 59). The soil is non-calcareous and non-gypsiferrous with low organic carbon (0.06-0.13%) having cation exchange capacity of 3.9 Cmol (P^+)/kg soil. The pH of the soil profile increased from surface to 45 cm and then remained almost at the same level up to 150 cm depth (Table 60). The soil of the experimental area up to a depth of 150 cm was non-saline, the salinity varying from 0.38-0.53 dS/m with an increasing trend with depth.

Table 58 Ionic composition and quality parameters of irrigation water

Ion/parameter	Values
CO_3 (meq/l)	Nil
HCO_3 (meq/l)	14.0
Ca (meq/l)	0.4
Mg (meq/l)	1.6
Cl (meq/l)	5.6
EC (dS/m)	1.93
RSC (meq/l)	12.0
SAR $(mmol/l)^{1/2}$	19.3

Table 59 Physico-chemical characteristics of experimental soil

Property	Soil depth (cm)	
	0-15	15-30
Silt + clay (%)	17	21
Sand (%)	83	79
Textural class	ls	ls
pH (1:2)	9.25	9.30
$CaCO_3$ (%)	traces	traces
CEC (Cmol (P^+)/kg)	3.9	4.0
Organic Carbon (%)	0.13	0.06

Table 60 pH and EC (1:2) of soil profile before start of experiment in the year 2006

Soil depth (cm)	pH	EC_2 (dS/m)
0-15	9.35	0.38
15-30	9.52	0.41
30-45	9.55	0.39
45-60	9.42	0.39
60-90	9.38	0.48
90-120	9.41	0.53
Mean	9.44	0.43

Pearl millet

The grain and straw yield data averaged for two years revealed that grain and straw yield of pearl millet increased significantly with increase in depth of irrigation water and gypsum application. The mean grain yield of pearl millet increased by 21.7, 43.5 and 47.8% with G_{50}, G_{75} and G_{100} neutralization of RSC (12.0 meq/l) over control G_0 with sprinkler system (Table 61). The mean straw yield of pearl millet increased by 27.2, 52.3 and 57.4 percent with G_{50}, G_{75} and G_{100} neutralization of RSC (12.0 meq/l) over control G_0 (Table 62). The straw yield in 5 cm and 6 cm irrigation depth increased by 15.5 and 22.8% respectively as compared to 4 cm irrigation depth.

Wheat

The yield data averaged for two years showed that the grain yield in 6 cm depth was significantly higher than 4 cm and 5 cm depth of irrigation (Table 63), the overall increase in 5 cm and 6 cm depth of irrigation being 8.3 and 12.8 per cent, respectively as compared to 4 cm depth. Grain yield of wheat increased significantly with successive increase in the neutralization of RSC. Mean grain yield increased by 9.6, 18.3 and 21.9 per cent in G_{50}, G_{75} and G_{100} neutralization of RSC over control. Similar trend was observed in straw yield of wheat also (Table 64). The interaction between depth of irrigation and RSC neutralization was found non-significant for both grain and straw yield.

Table 61 Pearl millet yield (t/ha) irrigated with sodic water through sprinkler irrigation

Gypsum levels	Depth of irrigation (cm)			Mean
	4	5	6	
G_0	1.03	1.17	1.25	1.15
G_{50}	1.20	1.47	1.54	1.40
G_{75}	1.48	1.69	1.78	1.65
G_{100}	1.53	1.75	1.82	1.70
Mean	1.31	1.52	1.60	-
CD (5%)	Gypsum (G): 0.08, Depth of irrigation (D): 0.09, G x D: NS			

Table 62 Straw yield (t/ha) of pearl millet under sodic water through sprinkler irrigation

Gypsum levels	Depth of irrigation (cm)			Mean
	4	5	6	
G_0	1.74	1.96	2.14	1.95
G_{50}	2.15	2.57	2.73	2.48
G_{75}	2.66	3.04	3.22	2.97
G_{100}	2.75	3.16	3.30	3.07
Mean	2.32	2.68	2.85	
CD (5%)	Gypsum (G): 0.12, Depth of irrigation (D): 0.09, G x D: NS			

Table 63 Wheat yield (t/ha) irrigated with sodic water through sprinkler irrigation

Gypsum levels	Depth of irrigation (cm)			Mean
	4	5	6	
G_0	2.92	3.16	3.26	3.11
G_{50}	3.19	3.46	3.59	3.41
G_{75}	3.43	3.71	3.90	3.68
G_{100}	3.54	3.83	4.00	3.79
Mean	3.27	3.54	3.69	-
CD (5%)	Gypsum (G): 0.11, Depth of irrigation (D): 0.10, G x D: NS			

Table 64 Straw yield of wheat (t/ha) irrigated with sodic water through sprinkler irrigation

Gypsum levels	Depth of irrigation (cm)			Mean
	4	5	6	
G_0	3.57	3.89	4.07	3.84
G_{50}	3.90	4.58	4.47	4.31
G_{75}	4.21	4.61	4.84	4.55
G_{100}	4.36	4.70	4.95	4.67
Mean	4.01	4.44	4.58	-
CD (5%)	Gypsum (G): 0.12, Depth of irrigation (D): 0.10, G x D: NS			

The pH of the soil at wheat harvest during 2007-08 decreased with the addition of increasing level of RSC neutralization through increasing levels of gypsum for all irrigation depths (Fig. 28). The highest pH (9.79) was obtained with 6 cm irrigation under no gypsum application. However, a sharp decrease in pH was obtained under 6 cm irrigation depths with 75 % RSC neutralization. The magnitude of decrease was higher with 50 % RSC neutralization in all the irrigation treatments.

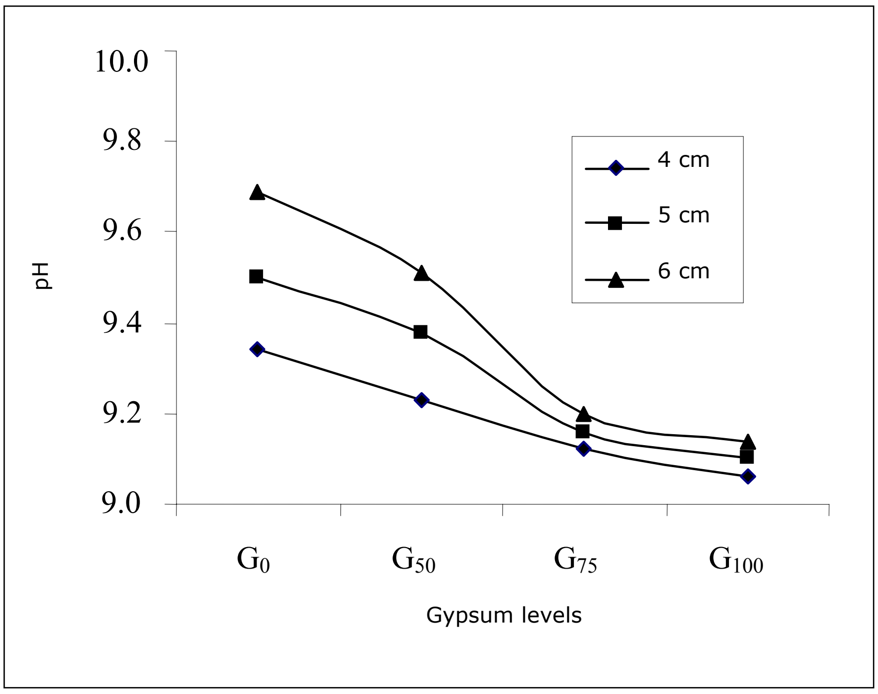


Fig.28 Effect of gypsum levels on soil pH after wheat harvest in 2007-08

RESPONSE OF CROPS TO FERTILIZERS UNDER VARYING SALINITY LEVELS OF WATER WITH SPRINKLER IRRIGATION

Wheat-groundnut

An experiment was conducted to evaluate the response of wheat and groundnut to irrigation water salinity and fertilizer doses during 2005-06 and 2006-07. The treatments included three levels of FYM i.e. 0, 5 and 10 t/ha each with 100, 125 and 150 per cent of recommended dose (RD) of fertilizer. Sprinkler lateral lines supplying BAW and saline water created the irrigation water salinity gradient, ranging from 0.20 to 4.56 dS/m.

In case of wheat, almost at all levels of irrigation water salinity, treatment with 10 t/ha FYM and 125 per cent of fertilizer dose gave higher yield followed by the treatment of 5 t/ha FYM and 150 per cent of recommended dose of fertilizer. At low salinity levels (up to 1.8 dS/m) treatment with FYM @ 5 t/ha with 100 per cent of recommended dose of fertilizer gave higher yields. At all salinity levels, comparatively lower yields were obtained in treatments with no FYM application (Table 65). Apparently the integrated nutrient management helps in getting higher yields.

Application of FYM increased the crop adaptation to salinity stress. The critical limits for various yield reduction levels showed higher values due to FYM application up to 125% of the recommended fertilizer dose beyond which, no benefits were noticed. Critical limits of salinity for wheat at 0, 5.0 and 10.0 t/ha at 125% of the recommended dose were found to be 3.8, 4.1 and 4.2 dS/m, respectively under sprinkler irrigation (Table 66).

Table 65 Effect of irrigation water salinity and fertilizer levels on wheat yield (t/ha)

EC_{iw}	FYM (10 t/ha)			FYM (5 t/ha)			No FYM		
	100% NPK	125% NPK	150% NPK	100% NPK	125% NPK	150% NPK	100% NPK	125% NPK	150% NPK
				2005-06					
0.20	2.43	2.87	2.77	2.45	2.35	2.49	2.19	2.32	2.25
0.50	2.40	2.67	2.70	2.33	2.29	2.35	2.11	2.25	2.14
0.60	2.35	2.61	2.59	2.22	2.12	2.27	2.03	2.17	2.09
0.75	2.27	2.67	2.61	2.14	2.07	2.14	1.95	2.10	2.00
1.01	2.15	2.54	2.50	2.06	1.80	2.08	1.88	1.95	1.95
1.45	2.10	2.24	2.33	1.95	1.85	1.94	1.81	1.90	1.88
1.60	2.05	2.20	2.28	1.91	1.80	1.92	1.73	1.84	1.82
1.80	1.94	2.26	2.20	1.86	1.73	1.88	1.67	1.77	1.71
2.07	2.00	2.17	2.10	1.70	1.79	1.82	1.60	1.69	1.65
2.34	1.96	2.05	1.99	1.64	1.70	1.79	1.52	1.61	1.57
2.56	1.85	1.94	1.94	1.60	1.62	1.72	1.48	1.53	1.49
2.67	1.67	1.85	1.76	1.50	1.56	1.63	1.31	1.40	1.28
2.70	1.41	1.80	1.82	1.38	1.41	1.51	1.23	1.32	1.18
2.91	1.36	1.66	1.70	1.20	1.22	1.38	1.14	1.21	1.05
3.23	1.23	1.54	1.44	1.15	1.24	1.35	1.07	1.14	1.00
3.71	1.17	1.40	1.41	1.07	1.17	1.26	1.01	1.08	0.93
3.91	1.10	1.34	1.21	0.96	1.03	1.20	0.96	1.02	0.90
4.51	1.07	1.30	1.17	0.90	0.98	1.07	0.90	0.99	0.87
4.56	0.98	1.28	1.14	0.85	0.90	0.97	0.87	0.94	0.80
Mean	1.76	2.02	1.98	1.63	1.61	1.72	1.50	1.59	1.50
				2006-07					
0.25	2.54	2.62	2.45	2.65	2.81	2.86	2.14	2.32	2.65
0.25	2.51	2.55	2.82	2.62	2.75	2.82	2.10	2.30	2.35
0.27	2.44	2.50	2.42	2.65	2.73	2.75	2.04	2.27	2.20
0.33	2.35	2.44	2.35	2.53	2.66	2.70	2.06	2.22	2.25
0.33	2.29	2.39	2.46	2.44	2.56	2.75	2.00	2.15	2.27
0.40	2.31	2.38	2.38	2.39	2.52	2.72	1.94	2.15	2.01
1.00	2.31	2.42	2.47	2.34	2.46	2.79	1.74	1.94	2.04
1.40	2.12	2.20	2.31	2.16	2.27	2.56	1.58	1.75	1.87
2.01	1.93	2.02	2.10	1.91	2.03	2.38	1.34	1.53	1.66
2.42	1.72	1.84	1.88	1.68	1.83	2.13	1.22	1.36	1.45
2.80	1.66	1.72	1.79	1.66	1.78	2.02	1.18	1.30	1.38
3.20	1.52	1.60	1.69	1.58	1.65	1.80	1.10	1.30	1.40
3.70	1.57	1.61	1.61	1.70	1.90	1.82	1.10	1.27	1.40
3.87	1.32	1.51	1.50	1.46	1.73	1.75	1.10	1.25	1.27
3.90	1.30	1.44	1.38	1.38	1.64	1.71	1.06	1.21	1.30
4.20	1.27	1.40	1.37	1.36	1.56	1.66	1.02	1.09	1.18
4.33	1.26	1.32	1.25	1.29	1.21	1.60	1.01	1.10	1.14
4.55	1.24	1.30	1.24	1.27	1.31	1.55	1.01	1.13	1.13
Mean	1.87	1.96	1.97	1.95	2.08	2.24	1.49	1.65	1.72

Table 66 Yield functions and EC at different % yield reduction of wheat (Av. of 2 years)

Treatments	Yield function	EC_{iw} (dS/m) at different per cent of yield reduction		
		20	40	50
No FYM				
NPK 100% RD	Y= -0.283x + 2.124 (R^2 =0.94)	1.50	3.01	3.76
NPK 125% RD	Y= -0.301x + 2.288 (R^2 =0.95)	1.52	3.04	3.80
NPK 150% RD	Y= -0.311x + 2.303 (R^2 =0.89)	1.48	2.96	3.70
FYM 5 t/ha				
NPK 100% RD	Y= -0.312x + 2.472 (R^2 =0.87)	1.58	3.17	3.96
NPK 125% RD	Y= -0.313x + 2.536 (R^2 =0.78)	1.62	3.24	4.05
NPK 150% RD	Y= -0.313x + 2.674 (R^2 =0.77)	1.71	3.42	4.27
FYM 10 t /ha				
NPK 100% RD	Y= -0.317x + 2.522 (R^2 =0.94)	1.59	3.18	3.98
NPK 125% RD	Y= -0.320x + 2.703 (R^2 =0.95)	1.69	3.38	4.22
NPK 150% RD	Y= -0.335x + 2.723 (R^2 =0.95)	1.62	3.25	4.06

x: Water salinity (dS/m)

Groundnut

In case of groundnut, application of FYM at same level of NPK doses helped the crop to tolerate higher salinity. Average values for 50% yield reduction for groundnut at 0, 5 and 10 t/ha was observed to be 2.7, 3.0 and 3.0 dS/m, respectively. Average value for 50% yield reduction for groundnut at 5 t/ha at 125% recommended dose was 3.0 dS/m. There was 8.5 and 17.9% increase in pod yield of groundnut with the application of 5 and 10 t/ha FYM, respectively as compared to no FYM application (Table 67). Based on average of two years data, values for 50% yield reduction for groundnut at FYM application of 0, 5 and 10 t/ha were 2.8, 3.0 and 3.0 dS/m, respectively (Table 68).

Table 67 Effect of EC_{iw}, FYM and fertilizers on groundnut yield (Average of 2 years)

EC_{iw} (dS/m)	EC_e (dS/m)	FYM (10 t/ha)			FYM (5 t/ha)			No FYM		
		100% NPK	125% NPK	150% NPK	100% NPK	125% NPK	150% NPK	100% NPK	125% NPK	150% NPK
0.30	0.49	1.86	1.96	2.00	1.77	1.71	1.81	1.59	1.68	1.72
0.31	0.53	1.72	1.94	1.91	1.68	1.76	1.83	1.61	1.69	1.66
0.33	0.58	1.70	1.84	1.92	1.62	1.78	1.74	1.53	1.63	1.70
0.35	0.61	1.65	1.77	1.88	1.56	1.64	1.67	1.50	1.47	1.55
0.38	0.67	1.58	1.71	1.75	1.49	1.61	1.59	1.43	1.46	1.54
0.89	0.74	1.50	1.63	1.73	1.51	1.57	1.36	1.41	1.53	1.51
1.10	0.89	1.26	1.50	1.52	1.23	1.31	1.41	1.22	1.31	1.34
1.30	1.12	1.18	1.37	1.48	1.11	1.23	1.33	1.13	1.19	1.22
1.67	1.27	1.08	1.28	1.31	0.99	1.07	1.25	1.05	1.10	1.15
1.91	1.43	1.02	1.12	1.36	0.91	1.03	1.18	0.96	1.00	1.05
2.47	1.69	0.99	1.13	1.15	0.83	1.01	1.10	0.94	1.01	1.07
2.80	1.97	0.96	1.07	1.12	0.81	0.98	1.04	0.80	0.86	0.90
3.42	2.11	0.73	0.93	0.99	0.73	0.82	0.88	0.63	0.71	0.80
3.59	2.43	0.69	0.84	0.92	0.68	0.75	0.85	0.53	0.62	0.68
3.73	2.50	0.63	0.77	0.84	0.57	0.73	0.77	0.45	0.53	0.56
4.01	2.61	0.48	0.62	0.68	0.48	0.58	0.60	0.32	0.42	0.47
4.21	2.79	0.46	0.53	0.56	0.40	0.53	0.47	0.24	0.37	0.43
4.32	2.86	0.43	0.49	0.51	0.37	0.50	0.44	0.13	0.26	0.29
Mean		1.11	1.25	1.31	1.04	1.15	1.18	0.97	1.05	1.09

Table 68 Yield functions and EC at different per cent yield reduction of groundnut (Average of 2 years data)

Treatments	Yield function	EC_{iw} (dS/m) at different percent of yield reduction		
		20	40	50
No FYM				
NPK 100% RD	Y = -0.333x + 1.738 (R^2 = 0.98)	1.04	2.09	2.61
NPK 125% RD	Y = -0.323x + 1.800 (R^2 = 0.98)	1.12	2.23	2.79
NPK 150% RD	Y = -0.320x + 1.840 (R^2 = 0.98)	1.15	2.30	2.87
FYM 5 t/ha				
NPK 100% RD	Y = -0.313x + 1.769 (R^2 = 0.96)	1.13	2.26	2.82
NPK 125% RD	Y= -0.302x + 1.859 (R^2 = 0.97)	1.23	2.47	3.08
NPK 150% RD	Y= -0.303x + 1.904 (R^2 = 0.95)	1.26	2.52	3.14
FYM 10 t /ha				
NPK 100% RD	Y= -0.319x + 1.864 (R^2 = 0.96)	1.17	2.34	2.92
NPK 125% RD	Y= -0.332x + 2.035 (R^2 = 0.97)	1.22	2.45	3.06
NPK 150% RD	Y = -0.334x + 2.108 (R^2 =0.97)	1.26	2.52	3.15

x: Water salinity (dS/m)

The organic carbon content, P_2P_5 and K_2O were measured: The organic carbon content in soil increased with the incorporation of FYM. The increased fertilizer doses i.e. at 125 and 150 % RD, also slightly increased the OC in the soil. The phosphorus and potassium contents also increased with increased doses of fertilizer and incorporation of FYM in the soil as FYM also contained P and K (Table 69).

Table 69 Soil chemical characteristics after groundnut-wheat crop rotation

Treatments	Soil depth (cm)	Organic carbon (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)
No FYM				
NPK 100% RD	0-15	0.12	25	253
	15-30	0.10	22	240
NPK 125% RD	0-15	0.15	32	275
	15-30	0.11	28	264
NPK 150% RD	0-15	0.16	40	282
	15-30	0.12	37	261
FYM @ 5 t/ha				
NPK 100% RD	0-15	0.18	31	271
	15-30	0.15	29	244
NPK 125% RD	0-15	0.23	41	287
	15-30	0.17	30	252
NPK 150% RD	0-15	0.27	46	298
	15-30	0.21	41	274
FYM @ 10 t/ha				
NPK 100% RD	0-15	0.24	34	281
	15-30	0.18	30	261
NPK 125% RD	0-15	0.28	46	305
	15-30	0.19	38	266
NPK 150% RD	0-15	0.28	46	310
	15-30	0.21	41	288
Initial (2005-06)	0-30	0.11	14	224

RESPONSE OF WHEAT-GROUNDNUT TO VARYING LEVELS OF SALINITY AND MOISTURE UNDER SPRINKLER IRRIGATION

An experiment was initiated during 2007-08 to create salinity and moisture gradient using saline water with variable discharge sprinkler nozzles. Sprinkler lateral lines supplied BAW (0.25 dS/m) and saline water (4.50 dS/m) to create moisture and salinity gradients. The salinity gradient ranged between 0.25 to 4.56 dS/m. 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.

Applied water depth decreased with increase in distance from the sprinkler line and decrease in nozzle discharge. In case of saline water, total depth of water applied ranged from 19.40 to 42.91 cm in seven irrigations. The grain yield of wheat ranged between 0.49 to 1.85 t/ha. A quadratic relation ($Y = - 0.0044x^2 +0.319x- 4.241$; $R^2 =0.82$**) could be established between the wheat yield (Y) and depth of water applied (x). The highest grain yield was obtained with an application of 34.6 cm. In the mixed zone, the grain yield varied from 0.76 to 2.42 t/ha. Relationship between yield and total depth of water applied was established ($Y = - 0.0041x^2 +0.3064x- 3.8507$; $R^2 =0.43$**). Lower R^2 value in mixed zone clearly indicates that both salinity of irrigation water and total depth of water applied were responsible for yield variation. In the zone of BAW, wheat yield ranged from 0.86 to 2.65 t/ha and a quadratic relation could be established ($Y = - 0.0025X^2 +0.2387x- 3.1567$; $R^2 =0.95$**). While the yield was negatively correlated with irrigation water salinity (EC_{iw}), positive correlation was observed between yield and total depth of water applied ($Y= 0.822 -0.291\ EC_{iw} + 0.473x$; $R^2 = 0.64$) (Table 70 and Table 71).

Groundnut

Pod yield was affected both by amount of water applied and salinity gradients. In case of saline water, total depth of water applied ranged from 26.8 to 61.2 cm in ten irrigations. The pod yield (Y) ranged between 0.12 to 0.33 t/ha. The graph clearly indicate that pod yield and depth of water (x) are related quadratically ($Y = -0.0001x^2 +0.014x -0.170$; $R^2=0.85$**) with maxima of the curve at about 70 cm (Fig. 29).

In the mixed zone, total depth of water applied ranged between 39.3 to 62.9 cm and grain yield varied from 0.24 to 1.54 t/ha. The data subjected to multiple regression revealed that the equation ("$Y = 0.222 +0.0284x- 0.341\ EC_{iw}$" $R^2 =0.82$**) fitted well to the data sets. Assuming depth of water applied around 60 cm, the critical limit for 50% yield reduction of ground nut is observed to be around 3.0 dS/m.

In the zone of BAW, quadratic equation between pod yield of ground nut to total depth of irrigation was ("$Y= -0.001X^2 +0.125X- 0.2.144$" :$R^2 =0.91$**). It exhibited a plateau zone until 60 cm depth of water applied (Fig. 29). The maxima of the curve as found to be around 62 cm (Table 70 and Table 71).

Table 70 Yield functions for wheat and groundnut as affected by EC and water depth

Zone	EC (dS/m)	Range of applied water depth (cm)	Yield range (t/ha)	Yield function	R^2	Maxima at water depth (cm)
				Wheat		
Saline	4.5	19.40-44.03	0.49-1.85	$Y=-0.0044X^2 +0.319X- 4.241$	0.82	34.6
Mixed	1.27-4.10	20.79-44.38	0.76-2.42	$Y=-0.0041X^2+0.306X-3.851$	0.43	37.3
				$Y=0.822-0.291EC_{iw}+0.473D_{iw}$	0.64	
BAW	0.25	22.19-45.50	0.86-2.65	$Y=-0.0025X^2 +0.239X-3.157$	0.95	47.8
				Groundnut		
Saline	4.5	26.8-61.2	0.117-0.326	$Y=-0.0001X^2 +0.014X- 0.170$	0.85	70.0
Mixed	1.62-4.57	39.3-61.3	0.241-1.540	$Y=-0.002X^2 +0.222X- 5.439$	0.16	55.6
				$Y=0.227+0.0284X_{DW} -0.341X_{EC}$	0.82	
BAW	0.25	27.2-61.9	0.647-1.963	$Y=-0.001X^2 +0.125X - 0.214$	0.91	62.3

Table 71 Effect of depth of irrigation and water salinity on wheat and groundnut yields

Zone	Nozzle size (mm)	Sampling location (m)	Wheat			Groundnut		
			EC_{iw} (dS/m)	Depth of water applied (cm)	Yield (t/ha)	EC_{iw} (dS/m)	Depth of water applied (cm)	Yield (t/ha)
Saline	5.10	0-2	4.5	42.9	1.29	4.5	61.2	0.307
		2-4	4.5	44.0	1.27	4.5	61.0	0.310
		4-6	4.5	41.1	1.31	4.5	58.3	0.294
		6-8	4.5	36.9	1.47	4.5	56.2	0.326
		8-10	4.5	34.6	1.85	4.5	56.2	0.278
		10-12	4.5	33.5	1.79	4.5	54.1	0.253
	4.13	0-2	4.5	38.0	1.70	4.5	56.7	0.269
		2-4	4.5	35.3	1.64	4.5	53.6	0.297
		4-6	4.5	35.7	1.54	4.5	51.0	0.281
		6-8	4.5	35.0	1.51	4.5	49.3	0.253
		8-10	4.5	34.4	1.70	4.5	46.9	0.267
		10-12	4.5	31.9	1.50	4.5	44.3	0.310
	3.17	0-2	4.5	28.4	1.12	4.5	41.3	0.200
		2-4	4.5	28.0	1.01	4.5	39.6	0.218
		4-6	4.5	27.5	0.90	4.5	36.4	0.194
		6-8	4.5	23.9	0.70	4.5	32.1	0.170
		8-10	4.5	20.7	0.59	4.5	29.3	0.169
		10-12	4.5	19.4	0.49	4.5	26.8	0.117
Mixed	5.10	0-2	4.1	42.0	1.20	4.48	61.3	0.370
		2-4	3.5	44.4	1.54	4.10	62.9	0.351
		4-6	2.8	41.6	1.73	3.62	60.7	0.592
		6-8	2.1	37.1	2.24	2.70	58.6	0.832
		8-10	2.0	37.5	2.38	1.98	57.9	1.274
		10-12	1.3	42.6	2.42	1.65	60.6	1.540
	4.13	0-2	4.2	35.1	1.47	4.57	51.7	0.290
		2-4	3.6	39.4	1.50	4.21	52.7	0.339
		4-6	2.5	36.9	1.69	3.82	50.4	0.479
		6-8	2.0	35.0	1.85	2.61	49.4	0.763
		8-10	2.0	32.9	2.03	2.24	48.2	1.127
		10-12	1.5	34.5	2.32	1.56	51.3	1.370
	3.17	0-2	4.3	29.3	1.12	4.00	44.1	0.241
		2-4	3.5	29.9	1.36	3.94	45.8	0.293
		4-6	3.0	28.0	1.44	3.01	42.7	0.318
		6-8	2.0	26.3	1.54	2.65	43.1	0.416
		8-10	1.9	23.6	1.23	2.17	39.3	0.463
		10-12	1.3	20.8	0.76	1.62	42.6	0.541
BAW	5.10	0-2	0.25	45.5	2.54	0.25	61.3	1.674
		2-4	0.25	44.6	2.65	0.25	61.9	1.661
		4-6	0.25	42.1	2.59	0.25	59.6	1.963
		6-8	0.25	39.7	2.64	0.25	57.4	1.824
		8-10	0.25	41.7	2.44	0.25	54.3	1.994
		10-12	0.25	42.9	2.37	0.25	53.1	1.901
	4.13	0-2	0.25	36.7	2.22	0.25	58.0	1.837
		2-4	0.25	39.1	2.58	0.25	55.4	1.910
		4-6	0.25	36.9	2.14	0.25	50.1	1.701
		6-8	0.25	39.3	2.55	0.25	48.7	1.670
		8-10	0.25	34.8	2.03	0.25	46.1	1.500
		10-12	0.25	33.7	1.94	0.25	43.9	1.467
	3.17	0-2	0.25	30.2	1.90	0.25	43.1	1.457
		2-4	0.25	28.3	1.76	0.25	41.7	1.200
		4-6	0.25	27.0	1.40	0.25	38.6	0.953
		6-8	0.25	25.0	1.27	0.25	31.4	0.780
		8-10	0.25	22.7	1.05	0.25	29.1	0.739
		10-12	0.25	22.2	0.86	0.25	27.2	0.647

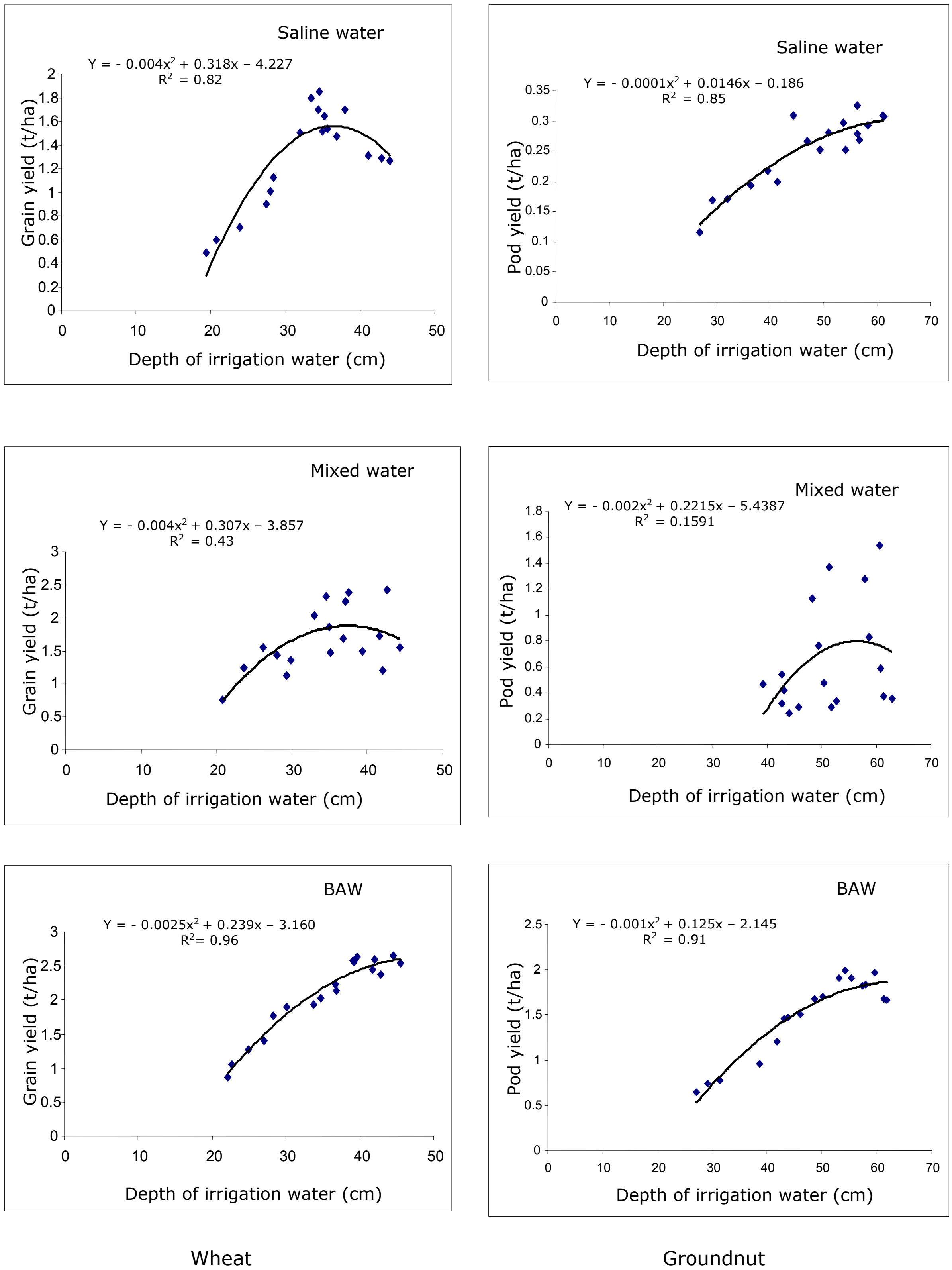


Fig. 29 Effect of irrigation water depth on yield of wheat and groundnut

CROP WATER/SALINITY PRODUCTION FUNCTIONS FOR DIFFERENT CROPS USING SPRINKLER IRRIGATION

A study was conducted during 2006-08 to develop crop water production function of mustard by creating salinity/alkalinity gradients though sprinkler line source. The plot size was 12 m x 12 m with three plots in a row. The treatments included three salinity levels (BAW, saline water 9.5 dS/m and mixture of the two) and three RSC levels (BAW, RSC 9.5 meq/l and mixture of the two). The sprinklers were set at 6 m distances in row (Fig. 30). The data revealed (Table 72 and 73) that water depth decreased with increasing distance from sprinkler line in case of saline/alkali and BAW alone. In saline and BAW alone, the depth of irrigation at 18 different points was recorded as 0.74 to 3.64 cm in each irrigation.

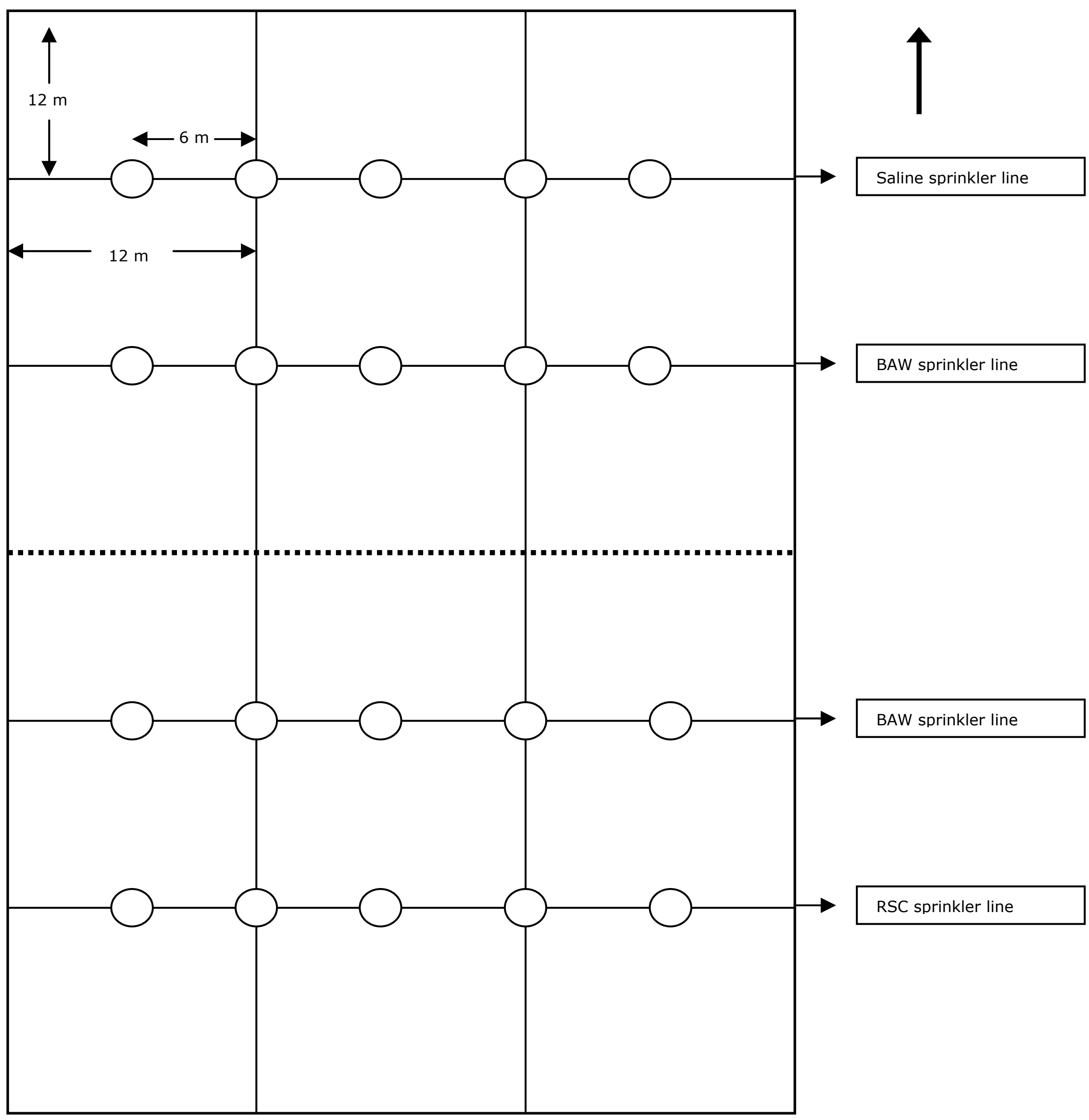


Fig. 30 Experimental layout of sprinklers for assessing crop production function

In case of mixing, the irrigation depth was recorded from 3.38 to 5.35 cm in each irrigation. The salinity or RSC level of irrigation water remained almost same irrespective of depth in the area where only 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} varied with distance. EC_{iw} of mixed water ranged from 4.7 to 8.4 dS/m, and RSCiw ranged from 1.8 to 7.7 meq/l. the varying depth of irrigation water gave salinity/RSC gradients. The yield data of both the sets of experiment indicate that the mustard yield was affected by salinity/RSC gradients. In single sprinkler line, the grain yield significantly decreased with decreasing irrigation depths in saline/sodic and BAW plots.

Table 72 Effect of depth of irrigation water on yield, and water use efficiency of mustard

Distance (cm)	Depth of each irrigation (cm)	Total depth of irrigation (cm)	EC_{iw} (dS/m)	Mustard grain yield (t/ha)			EC_e (dS/m)*	WUE (kg/ha-cm)
				2006-07	2007-08	Average	Average 2 years	Average 2 years
EC_{iw} 10 (dS/m)								
One nozzle								
4	2.70	16.20	10.0	1.82	1.74	1.78	9.15	309.1
8	1.85	11.10	10.0	1.77	1.74	1.75	8.39	333.3
12	0.74	4.44	10.0	1.27	1.30	1.29	4.27	369.7
Two nozzle								
4	3.44	20.64	10.0	179	1.50	1.65	9.74	252.1
8	1.87	11.22	10.0	1.73	1.76	1.74	8.84	327.9
12	0.80	4.80	10.0	1.29	1.30	1.30	4.56	355.1
Three nozzle								
4	3.64	21.84	10.0	1.83	1.77	1.80	9.70	257.9
8	1.96	11.76	10.0	1.70	1.71	1.70	8.14	354.3
12	0.81	4.86	10.0	1.29	1.32	1.31	4.66	352.6
Mixing (EC_{iw} 10 + BAW)								
One nozzle								
4	3.55	21.30	7.4	1.84	1.76	1.80	9.75	281.3
8	3.55	21.30	6.1	1.89	1.95	1.92	8.73	293.9
12	3.54	21.05	4.7	2.07	2.18	2.13	5.54	311.8
Two nozzle								
4	4.58	27.48	7.9	1.87	1.75	1.31	10.20	231.7
8	5.07	30.42	6.3	2.0	1.88	1.94	3.89	224.5
12	4.46	26.76	4.8	2.12	2.14	2.13	5.50	262.9
Three nozzle								
4	4.60	27.60	8.0	1.88	1.79	1.94	10.50	237.8
8	4.84	29.04	6.4	1.95	1.94	1.95	9.57	241.3
12	4.60	27.60	4.9	2.12	2.18	2.15	6.34	248.8
BAW								
One nozzle								
4	2.70	16.20	BAW	2.22	2.13	2.18	3.13	360.2
8	1.85	11.10	BAW	2.17	2.01	2.09	3.03	373.8
12	0.74	4.44	BAW	1.66	1.69	1.68	2.50	380.5
Two nozzle								
4	3.44	20.64	BAW	2.17	2.01	2.09	3.80	305.5
8	1.87	11.22	BAW	2.08	2.20	2.14	3.61	293.3
12	0.80	4.80	BAW	1.74	1.59	1.67	3.22	421.0
Three nozzle								
4	3.64	21.84	BAW	2.22	2.20	2.21	3.89	315.4
8	1.96	11.76	BAW	2.10	2.01	2.04	3.58	400.9
12	0.81	4.86	BAW	1.70	1.58	1.64	3.19	431.4

* After harvest of mustard (0-15 cm depth)

Table 73 Effect of depth of irrigation water on yield, and water use efficiency of mustard

Distance (cm)	Depth of each irrigation (cm)	Total depth of irrigation (cm)	RSC_{iw} (dS/m)	Mustard grain yield (t/ha)			ESP*	WUE (kg/ha-cm)
				2006-07	2007-08	Average	Average 2 years	Average 2 years
RSC_{iw} 10 (meq/l)								
One nozzle								
4	2.70	16.20	10.0	1.93	1.97	1.95	17.8	352.5
8	1.85	11.10	10.0	1.92	2.14	2.03	15.8	380.3
12	0.74	4.44	10.0	1.60	1.55	1.57	12.8	390.7
Two nozzle								
4	3.44	20.64	10.0	1.96	1.88	1.91	18.3	345.0
8	1.87	11.22	10.0	1.90	2.01	1.96	17.2	389.0
12	0.80	4.80	10.0	1.61	1.55	1.58	13.9	418.9
Three nozzle								
4	3.64	21.84	10.0	2.01	2.05	2.03	19.2	297.4
8	1.96	11.76	10.0	1.82	2.15	1.99	15.3	412.2
12	0.81	4.86	10.0	1.55	1.56	1.56	12.0	416.4
Mixing (RSC_{iw} 10 + BAW)								
One nozzle								
4	3.55	21.30	7.1	1.87	2.04	1.95	12.0	301.5
8	3.55	21.30	5.1	1.92	2.12	2.02	11.2	301.3
12	3.54	21.05	1.8	2.10	2.15	2.13	9.7	329.2
Two nozzle								
4	4.58	27.48	7.2	1.84	2.07	1.95	14.3	247.9
8	5.07	30.42	5.2	1.99	2.14	2.07	13.7	242.3
12	4.46	26.76	1.9	2.11	2.14	2.13	10.1	280.8
Three nozzle								
4	4.60	27.60	7.2	190	2.09	2.00	14.7	238.7
8	4.84	29.04	5.4	2.05	2.09	2.07	12.6	245.3
12	4.60	27.60	2.0	2.12	2.21	2.17	11.0	257.9
BAW								
One nozzle								
4	2.70	16.20	BAW	2.22	2.13	2.18	7.7	360.2
8	1.85	11.10	BAW	2.17	2.01	2.09	7.5	373.8
12	0.74	4.44	BAW	1.66	1.69	1.68	6.6	380.5
Two nozzle								
4	3.44	20.64	BAW	2.17	2.01	2.09	8.3	305.5
8	1.87	11.22	BAW	2.08	2.20	2.14	7.5	293.3
12	0.80	4.80	BAW	1.74	1.59	1.67	6.9	421.0
Three nozzle								
4	3.64	21.84	BAW	2.22	2.20	2.21	8.5	315.4
8	1.96	11.76	BAW	2.10	2.01	2.04	7.7	400.9
12	0.81	4.86	BAW	1.70	1.58	1.64	7.1	431.4

* After harvest of mustard (0-15 cm depth)

In saline block, grain yield decreased by 30.2% in 2006-07 and 25.3% in 2007-08 with 0.74 cm IW depth compared to 2.70 cm IW depth in each irrigation. For RSC water grain yield declined by 17.1 and 21.3 per cent for similar depth range. In the mixed water plots, the yield did not vary much with irrigation depth of RSC water. However, mixing with saline water resulted in decreasing trend with increase in salinity. A quadratic type statistical relationship was worked out with depth of irrigation and grain yield of the crop (Fig. 31). It revealed that grain yield increased with depth of saline/RSC and BAW waters but decreased at moisture content less than threshold moisture levels.

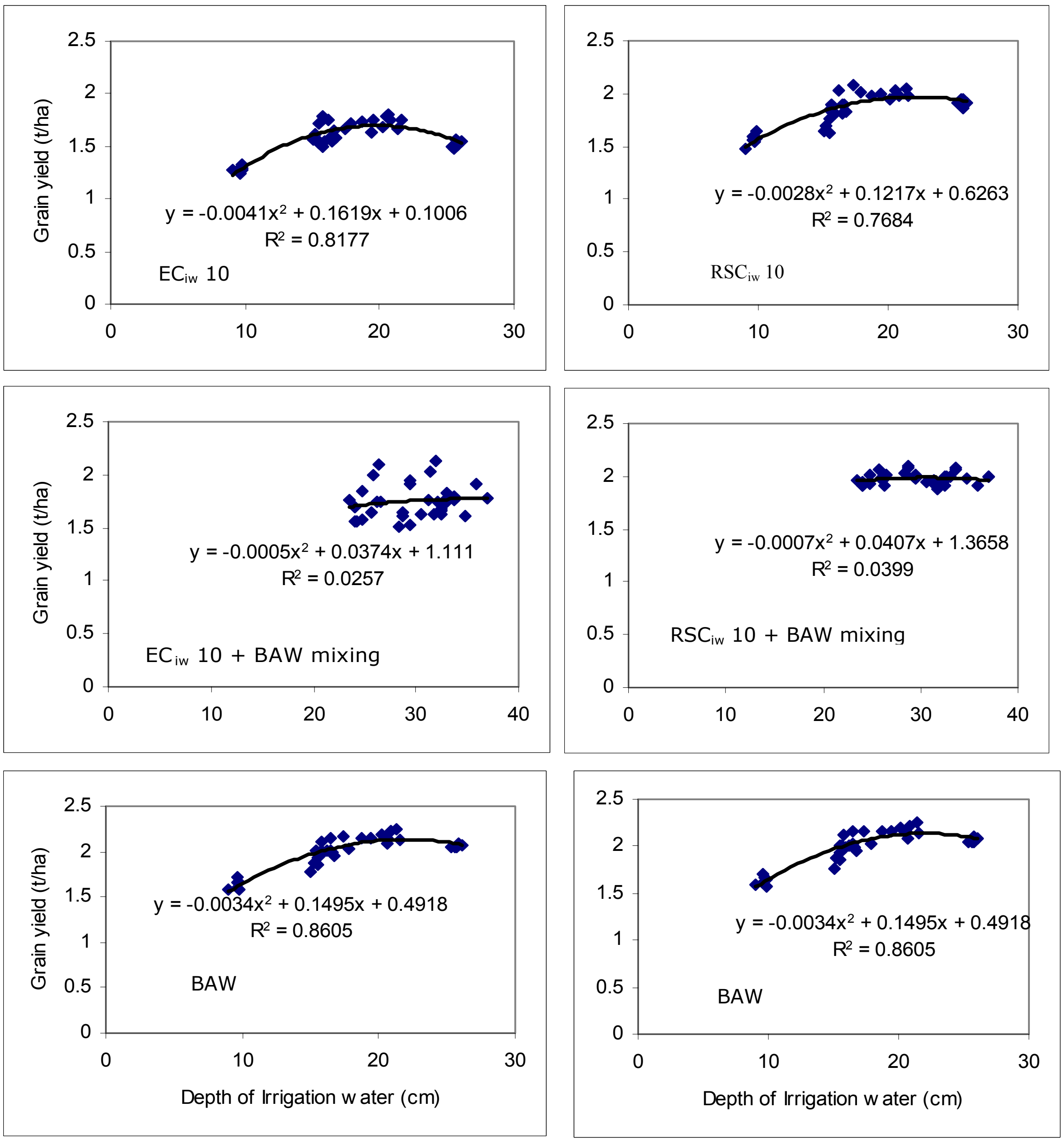


Fig. 31 Water production functions of mustard crop (Average of 2006-07 and 2007-08)

After harvest of mustard crop, the soil sample were collected from 0-15 cm depth at 2, 4, 6, 8, 10 and 12 m distance from sprinkler line and analyzed for EC_e of the 0-15 cm depth. The EC_e decreased with increasing distance from nozzle due to less amount of water applied. The EC_e varied from 4.27 to 9.15 dS/m in one nozzle; 4.56 to 9.74 dS/m in two nozzle and 4.66 to 9.70 dS/m in three nozzles. In case of mixing, the EC_e varied from 5.54 to 9.75, 5.50 to 10.20 and 6.34 to 10.50 dS/m, respectively.

In RSC block, the ESP was higher with increasing depth of RSC water. The RSC value was higher in RSC_{iw} alone while in the mixed zone it was relatively less. The ESP value ranged from 12.0-19.2 in RSC alone, 9.7-14.7 in mixed plots and 6.6-8.5 in BAW plots.

EFFECT OF IRRIGATION WITH SALINE WATER WITH VARYING SAR LEVELS ON SOIL AND PLANT GROWTH-MITIGATING SAR EFFECT WITH GYPSUM

An experiment was conducted during 2003-07 for the management of high SAR saline water using amendment and salt tolerant crop (s). The treatments included:

1. SAR_{iw} 10 and 20 and EC_{iw} 8 dS/m

a) Pearl millet: Without gypsum and gypsum @ 25% GR
b) Dhaincha: Without gypsum and gypsum @ 25% GR

2. SAR_{iw} 30 and 40 and EC_{iw} 8 dS/m

a) Pearl millet: Without gypsum, gypsum @ 25% GR and gypsum @ 25% GR + FYM @ 5 t/ha
b) Dhaincha: Without gypsum, gypsum @ 25% GR and gypsum @ 25% GR + FYM @ 5 t/ha

The pooled data of four years (2003-07) for pearl millet-wheat and dhaincha-wheat crop (Table 74) revealed that the yield of all the crops decreased significantly with increasing SAR_{iw} levels. A reduction of 20.4, 49.7 and 65.6 percent in pearl millet grain yield and 7.1, 12.5 and 18.1 percent in dhaincha grain yield at SAR_{iw} 20, 30 and 40 $(mmol/l)^{1/2}$ over SAR_{iw} 10 $(mmol/l)^{1/2}$ was recorded. The pear millet crop was observed to be more sensitive to water stagnation as compared to dhaincha crop. An increase of 43 and 37 percent in grain yield was noted at SAR_{iw} 30 and 40 by the application of gypsum over without gypsum. The counter figures in dhaincha were only 3.3 and 6.2 percent respectively.

Table 74 Yield of crops in different treatments (mean of 2003-07)

Treatments		Pearl millet-wheat (t/ha)		Dhaincha-wheat (t/ha)	
SAR_{iw}	GR (%GR)	Pearl millet	Wheat	Dhaincha	Wheat
Control	GR 0	3.03	4.14	2.09	3.69
SAR_{iw} 10	GR 0	1.94	3.78	1.79	3.36
SAR_{iw} 10	GR 25	2.08	3.71	1.84	3.50
SAR_{iw} 20	GR 0	1.53	3.52	1.67	3.12
SAR_{iw} 20	GR 25	1.68	3.54	1.70	3.13
SAR_{iw} 30	GR 0	0.81	2.92	1.58	2.43
SAR_{iw} 30	GR 25	1.16	2.82	.63	2.60
SAR_{iw} 30	GR 25+FYM	1.06	2.87	1.63	2.65
SAR_{iw} 40	GR 0	0.56	2.58	1.44	2.10
SAR_{iw} 40	GR 25	0.77	2.77	1.53	2.33
SAR_{iw} 40	GR 25+FYM	0.74	2.84	1.52	2.24
CD (5%)		0.27	0.32	0.27	0.32

The pooled data of 2007-09 revealed slightly different trend because of introduction of pre-sowing irrigation to wheat where 3 cm irrigation water was applied in the case of dhaincha-wheat rotation. The data on grain yield of wheat revealed that in the dhaincha-wheat rotation, the grain yield was higher by 6.2% over pearl millet -wheat rotation (Table 75). Dhaincha-wheat crop rotation was superior due to 3 cm extra pre-sowing irrigation in wheat. The SAR_{iw} levels also significantly affected the grain yield of wheat. The yield reduction was 4.9, 15.6 and 27.4% in SAR_{iw} 20, 30 and 40 over SAR_{iw} 10 $(mmol/l)^{1/2}$ in pearl millet-wheat rotation, whereas in dhaincha-wheat rotation it was 5.4, 17.7 and 27.4%, respectively. The addition of gypsum before kharif season did not enhance the grain yield significantly.

Table 75 Yield of crops in different treatments (mean of 2007-09)

Treatments		Pearl millet-wheat (t/ha)		Dhaincha-wheat (t/ha)	
SAR_{iw}	GR (% GR)	Pearl millet	Wheat	Dhaincha	Wheat
Control	GR 0	3.22	4..06	1.44	4.12
SAR_{iw} 10	GR 0	2.46	3.28	1.05	3.66
SAR_{iw} 10	GR 25	2.64	3.66	1.24	3.70
SAR_{iw} 20	GR 0	2.14	3.10	1.01	3.43
SAR_{iw} 20	GR 25	2.25	3.31	1.0	3.72
SAR_{iw} 30	GR 0	0.60	2.9	0.8	3.03
SAR_{iw} 30	GR 25	0.81	2.95	0.87	3.03
SAR_{iw} 30	GR 25+FYM	0.87	3.20	0.87	3.23
SAR_{iw} 40	GR 0	0.53	2.35	0.70	2.57
SAR_{iw} 40	GR 25	0.65	2.69	0.77	2.76
SAR_{iw} 40	GR 25+FYM	0.64	2.70	0.80	2.80
CD (5%)		0.28	0.32	0.28	0.32

The interaction effects between SAR x GR, SAR x crop rotation and GR x crop rotation were non-significant.

The infiltration rate after harvest of pearl millet/dhaincha and wheat (Fig. 32) decreased with increase in SAR_{iw} levels in all the crops. The value was 0.92 mm/hr in pearl millet and 1.22 mm/hr at dhaincha harvest in SAR_{iw} 40 $(mmol/l)^{1/2}$ with out gypsum as compared to 3.35 mm/hr and 3.62 mm/hr in SAR_{iw} 10 with out gypsum. The same trend was also found in wheat crop. The addition of gypsum to pearl millet resulted in increased infiltration rate by 0.32 and 0.37 mm/hr in SAR_{iw} 30 and 40 $(mmol/l)^{1/2}$ only, while in dhaincha the increase was 0.31 and 0.45 mm/hr respectively.

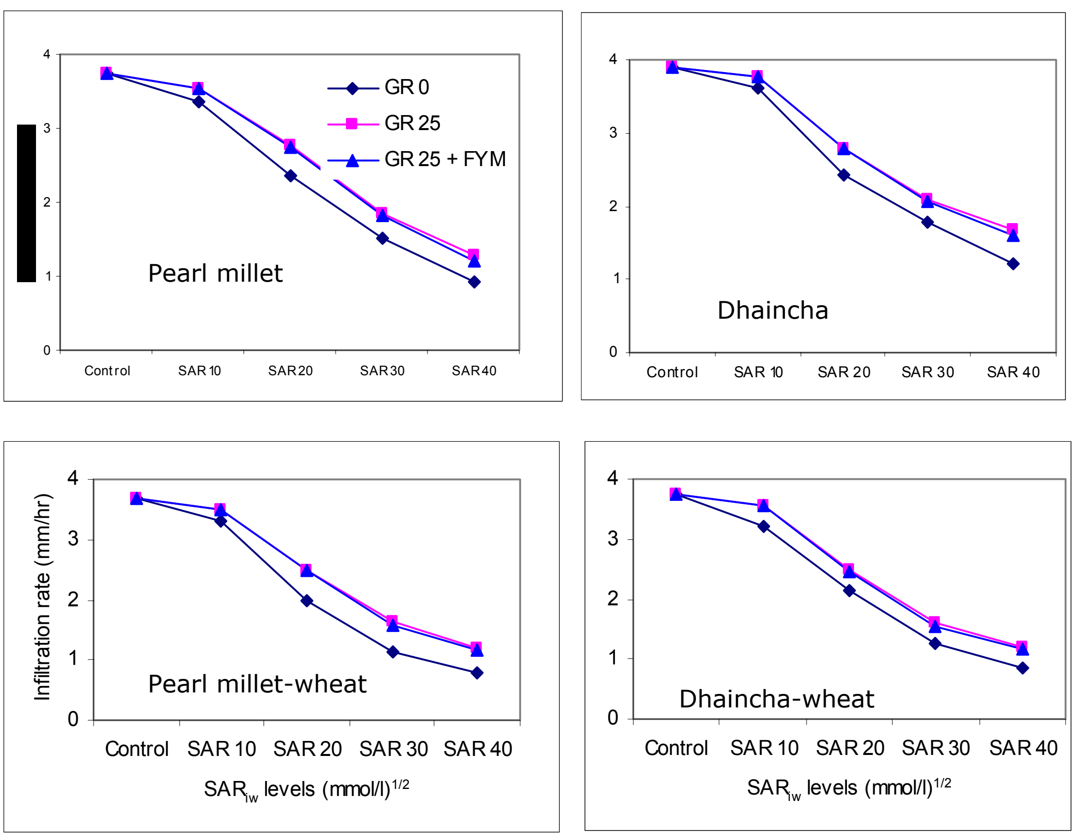


Fig.32 Infiltration rate after harvest of pearl millet/dhaincha and wheat (Av.2003-04 to 2007-08)

The SAR_{iw} of soil profile (0-120 cm) under different treatment at harvest of pearl millet and dhaincha depicted in Fig. 33 revealed that the SAR_e after harvest of pearl millet was 12.7 in SAR_{iw} 10 and 38.8 in SAR_{iw} 40. In case of dhaincha, SAR_e slightly increased as compared to pearl millet i.e. 13.1 and 39.0 $(mmol/l)^{1/2}$ respectively in surface 0-15 cm. corresponding values at lower depth (90-120 cm) were 14.8 and 44.5 in pearl millet and 14.9 and 45.1 in dhaincha crops respectively. At harvest of wheat crop SAR_e was 14.9 in SAR_{iw} 10 $(mmol/l)^{1/2}$ and 44.6 in SAR_{iw} 40 $(mmol/l)^{1/2}$ in pearl millet-wheat crop rotation (Fig. 34). While in dhaincha-wheat crop rotation SAR_e slightly increased i.e. 15.5 and 45.6 respectively in surface layer 0-15 cm corresponding values for lower depth (0-120 cm) were 13.8 and 35.3 $(mmol/l)^{1/2}$ in pearl millet-wheat rotation and 14.1 and 35.7 $(mmol/l)^{1/2}$ in dhaincha-wheat rotation.

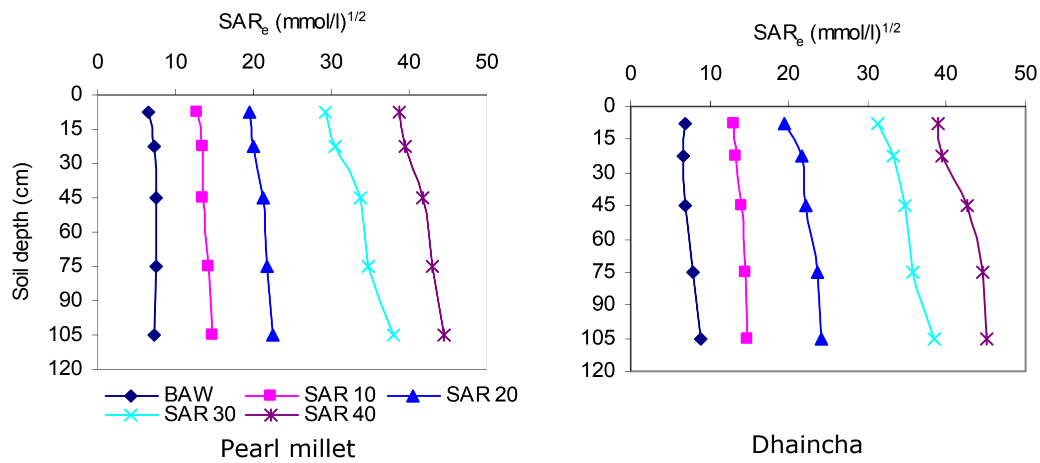


Fig. 33 SAR_e $(mmol/l)^{1/2}$ in soil profile at harvest of pearl millet crop (2007)

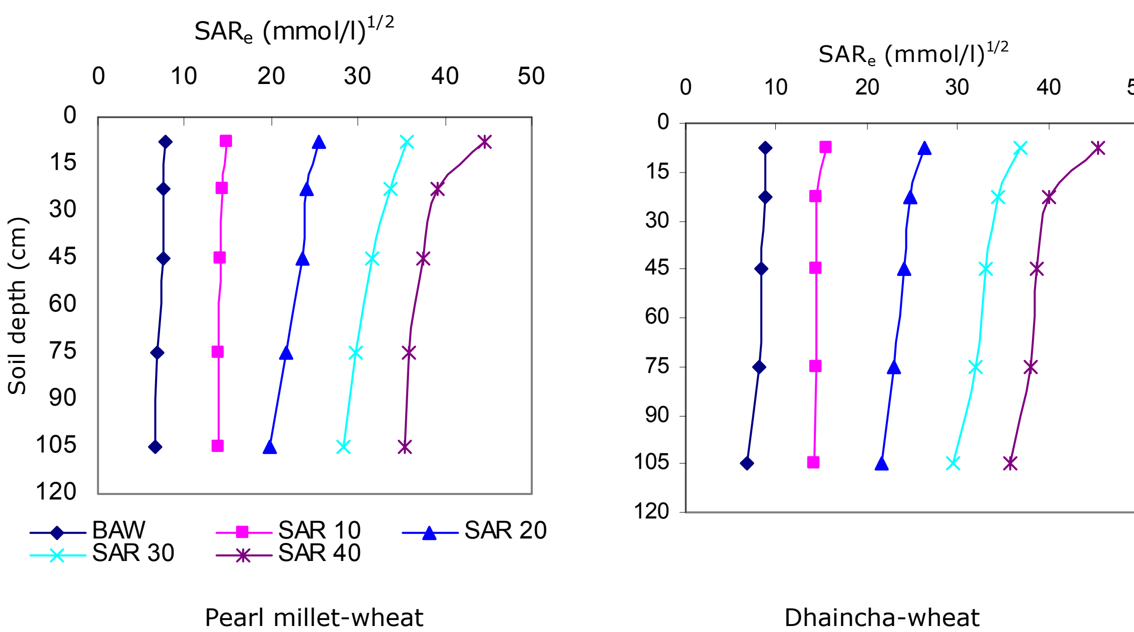


Fig. 34 SAR_e $(mmol/l)^{1/2}$ in soil profile at harvest of wheat crop (2007-08)

Overall it could be concluded that the pearl millet-wheat crop rotation is superior to dhaincha-wheat. The yield reduction in wheat was 5.9, 23.5 and 27.2% in pearl millet-wheat rotation and 8.7, 25.3 and 35.3% in dhaincha-wheat rotation with SAR_{iw} 20, 30 and 40 $(mmol/l)^{1/2}$ over SAR_{iw} 10 $(mmol/l)^{1/2}$. The grain yield of wheat did not vary significantly with the addition of gypsum only once before the kharif season. In the dhaincha-wheat rotation, wheat yield is reduced due to initial low soil moisture content. Thus, if this rotation is practiced, a pre-sowing irrigation (3 cm) to wheat would be necessary as compared to pearl millet-wheat.

EFFECT OF WATER QUALITY ON WHEAT UNDER DIFFERENT METHODS OF IRRIGATION

In order to study the effect of water quality and irrigation methods on grain yield of wheat, a study was conducted with different saline water qualities (canal water, EC_{iw} of 2.5, 5.0, 7.5 and 10 dS/m) under different irrigation methods (sprinkler and flood) at research farm of CCS HAU Hisar in 16m x 12 m (Sprinkler) and 6m x 6m (Flood) plots during 2006-08. All the treatments were replicated thrice in a split plot design. Recommended cultural practices and fertilizer doses were applied in raising the crops. Uniform fertilizer applications were made in all the treatments using urea, DAP and zinc sulphate. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. The soils are sandy loam throughout the profile. The clay content varied from 13.2-17.8% and sand particles ranged from 65.4-73.4%. The soil is non-calcareous and non-gypsiferrous having cation exchange capacity of 3.9 Cmol (P^+)/kg soil. The pH of the soil profile varied from 8.15-8.25 in the soil profile (Table 76). The organic content in the soil profile varied from 0.12-0.63% and decreased with depth. The crop was irrigated with saline waters prepared by mixing highly saline ground water (EC_{iw} = 23-27 dS/m) with good quality water (EC_{iw} = 0.4 dS/m) in different ratios to get the water of EC_{iw} 2.5, 5.0, 7.5 and 10 dS/m. The soil samples were collected from 0-15, 15-30, 30-60 and 60-90 cm layers before sowing and after the harvest of crop from all replications.

Table 76 Physico-chemical properties of the soil at Experimental site, HAU, Hisar

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Textural class	Db (Mg/m^3)	Ks (10^{-7} m/s)	pH	CEC (Cmol/kg)	OC (%)
0-15	15.2	17.4	65.4	Sandy loam	1.42	9.82	8.15	12.45	0.48
15-30	16.0	17.5	66.5	Sandy loam	1.50	5.62	8.22	13.22	0.63
30-60	17.8	14.0	68.2	Sandy loam	1.52	6.14	8.20	16.14	0.32
60-90	14.8	13.6	71.6	Sandy loam	1.48	5.60	8.25	16.86	0.19
90-120	13.2	13.4	73.4	Sandy loam	1.52	4.54	8.23	16.75	0.16
120-150	15.7	15.0	68.1	Sandy loam	1.46	4.24	8.16	16.28	0.12

Db: Bulk density; Ks: saturated hydraulic conductivity; OC: Organic carbon;
CEC: Cation exchange capacity

The mean wheat grain yield of two years under sprinkler was higher than flood irrigation at all salinity levels (Fig. 35). The maximum yield of 4.45 and 4.25 t/ha was recorded in canal water, and minimum 3.92 and 3.75 t/ha at EC_{iw} of 10 dS/m, respectively, in sprinkler and flood irrigation system. Difference in yield may be due to better micro-environment and utilization of water under sprinkler system than flood method. The initial average EC_e values in different soil layers varied from 3.70 to 4.26 dS/m in sprinkler irrigation system and 3.74 to 4.09 dS/m in flood irrigation system (Fig. 36). The EC_e distribution showed similar trend depth wise in both irrigation systems. The EC_e values decreased with depth in all the treatments in both systems. In sprinkler irrigation, the EC_e varied from 3.93 to 8.70 dS/m in 0-15 cm layer while the mean EC_e values varied from 3.70 to 6.91 dS/m in the soil profile after two years at the time of wheat harvest (Fig. 37). However, in flood irrigation, the EC_e varied from 4.22 to 10.36 dS/m in 0-15 cm layer while the mean EC_e values varied from 3.98 to 8.43 dS/m in the soil profile after two years at the time of wheat harvest (Fig. 38). Higher EC_e values were recorded in all the treatments in the upper layer (0-15 cm) which decreased gradually with depth in all the treatments in both the systems.

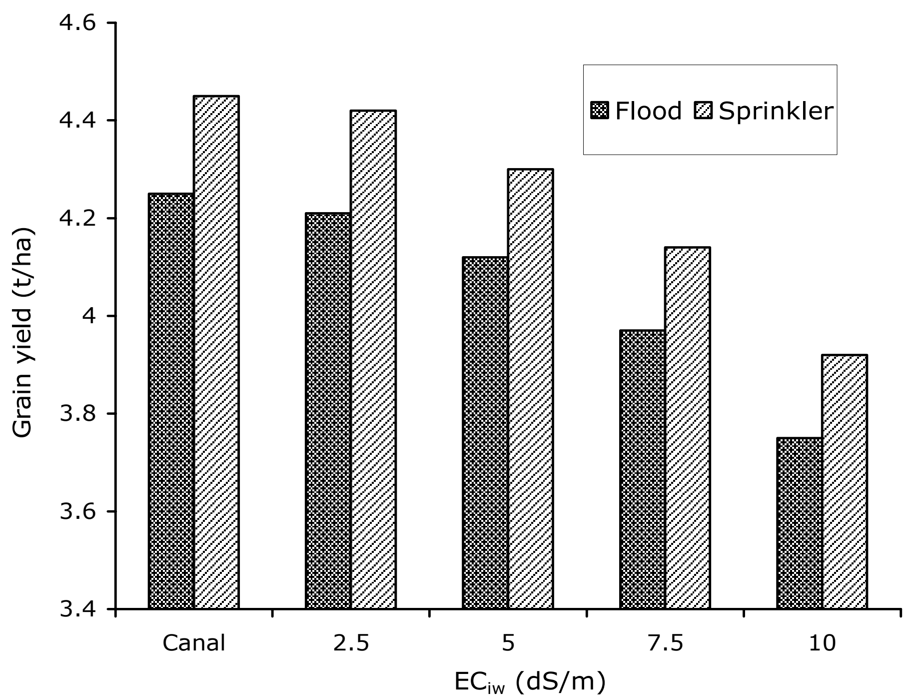


Fig. 35 The grain yield of wheat in relation to different irrigation method and water quality

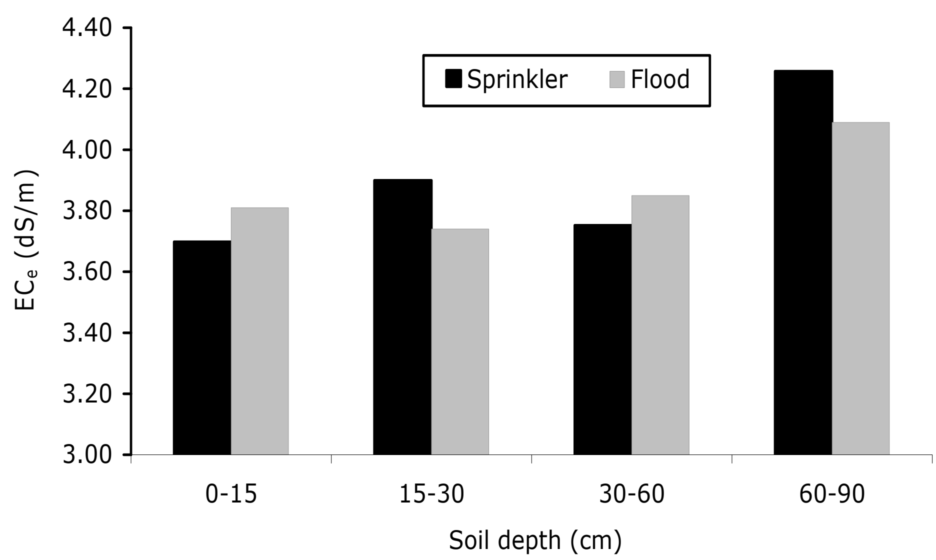


Fig. 36 Average EC_e in the soil profile at the time of sowing of wheat crop in 2006

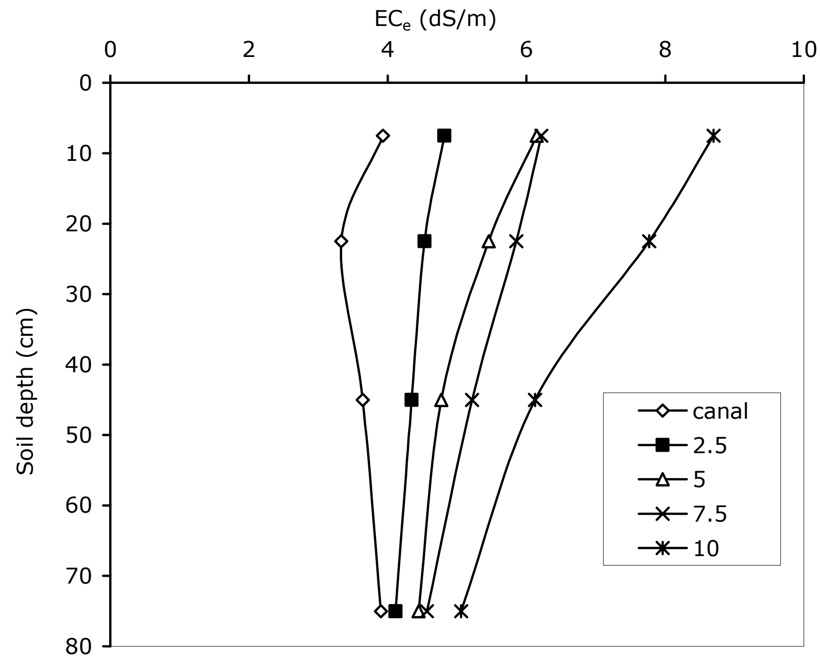


Fig. 37 Depth wise EC_e distribution at the time of harvest of wheat crop under canal and different EC_{iw} (dS/m) through sprinkler irrigation system in 2008

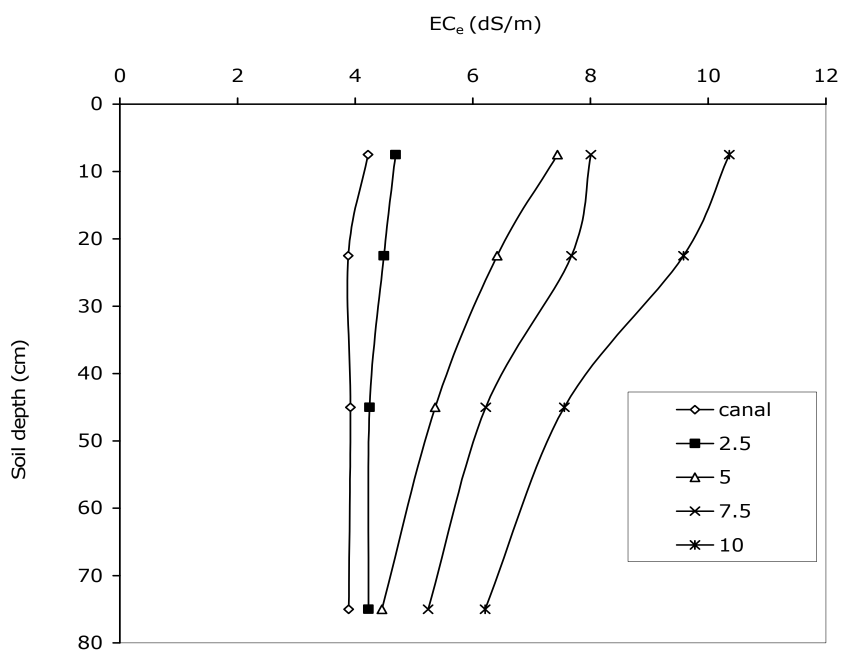


Fig. 38 Depth wise EC_e distribution at the time of harvest of wheat crop under canal and different EC_{iw} (dS/m) throughflood irrigation system in 2008

TO OPTIMIZE THE ZINC REQUIREMENT OF WHEAT CROP IRRIGATED WITH SODIC WATER

To evaluate the zinc requirement of wheat crop under irrigation with sodic water, a study on the requirement of Zn of wheat crop was carried out in relation to different gypsum amendments (0, 25, 50, 75 and 100% neutralization of RSC) at Village Bhurjat, District Mahendragarh in 2007-08. The experiment was conducted in plots of size 12.0 m x 12.0 m. Treatments consisted of three levels of gypsum application (0, 50 % and 100 % neutralization of RSC) in the main plot and three levels of Zn (0, 25 and 50 kg/ha) in the sub-plot. All the treatments were replicated thrice. The initial pH of the soil was 9.6, 9.6, 9.4 and 8.9 respectively in 0-15, 15-30, 30-45 and 45-60 cm soil depth. The gypsum requirement of the soil was determined on the basis of exchangeable Na. The requisite amount of gypsum in various treatments on the soil and water basis was applied in a single dose before sowing of crop and mixed well in the soil. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. The crops were irrigated with sodic water having average RSC 9.6 meq/l and SAR 12.5 $(mmol/l)^{1/2}$. The ionic composition of irrigation water revealed that the water is bicarbonate type with 12.4 meq/l HCO_3 content (Table 77).

Table 77 Ionic composition and quality parameters of irrigation water

Ion/parameter	Values
CO_3 (meq/l)	Nil
HCO_3 (meq/l)	12.40
Ca (meq/l)	0.90
Mg (meq/l)	1.90
Na (meq/l)	15.80
Cl (meq/l)	1.80
EC (dS/m)	1.45
RSC (meq/l)	9.60
SAR $(mmol/l)^{1/2}$	12.50

The data showed that significantly higher yield was obtained with increasing levels of gypsum as compared to control. The mean yield increased by 174.6, 292.6, 354.5 and 379.6%, respectively, in G_{25}, G_{50}, G_{75} and G_{100} treatments as compared to control (Table 78). The application of Zn @ 25 and 50 kg/ha resulted in 11 and 19.6 % increase in yield, respectively, as compared to control. The initial pH of the field was 9.6 in 0-15 cm layer which decreased with depth of soil and lowest pH of 8.9 was observed in 45-60 cm layer and (Fig. 39). At the wheat harvest, the pH in no gypsum treatment was 9.6 while it was 8.62 in 100% neutralization of RSC with gypsum.

STATUS OF FLUORIDE IN UNDERGROUND IRRIGATION WATER OF LADNU IN NAGAUR DISTRICT AND ITS EFFECT ON SOIL PROPERTIES AND CROPS

In the present study, ground water samples from 52 tube wells distributed in 29 villages of Ladnu tehsil of Nagaur district were collected during November-December, 2007. Surface soil samples were also collected from the fields irrigated with corresponding waters. These water and soil samples were analyzed for their chemical characteristics and fluoride contents.

The water table in tube wells of Ladnu tehsil varied from 53.3 to 200.0 m. EC and pH of water samples ranged from 1.02 to 7.12 dS/m and 7.2 to 8.5, respectively. The concentration of fluoride varied from 1.0 to 8.0 mg/l. EC_2 and pH_2 and fluoride content of soil samples ranged between 0.18 to 2.93 dS/m, 8.0 to 8.7 and 0.47 to 3.8 mg/l, respectively.

Percent distribution of fluoride (F) content in water samples w.r.t. pH and EC indicated that 17.2 percent water samples are safe for drinking purpose (1.5 mg/l), whereas 3.8, 32.8, 35.5 and 9.6 per cent water samples are in the range of 1.5-2.5, 2.5-5.0, 5.0-7.5 and >7.5 mg/l, respectively. About 25 and 75 per cent water samples showed pH in the range 7.5-8.0 and 8.0-8.5, respectively. As regard salinity about 19.2, 44.3, 24.9 and 11.5 percent water samples had EC <2.0, 2.0-4.0, 4.0-6.0 and >6.0 dS/m, respectively (Table 79).

Table 78 Effect of Zn and gypsum application on grain yield of wheat (t/ha) irrigated with sodic water

Gypsum levels	Levels of Zn (kg/ha)			Mean
	Control	25	50	
G_0	4.53	6.53	8.73	6.60
G_{25}	15.90	18.50	20.00	18.13
G_{50}	23.70	26.23	27.80	25.91
G_{75}	28.05	30.10	31.90	30.01
G_{100}	29.70	31.80	33.50	31.66
Mean	20.38	22.63	24.39	
CD (5%)	Gypsum level (G) : 1.22	Levels of Zn : 0.94	G x D : NS	

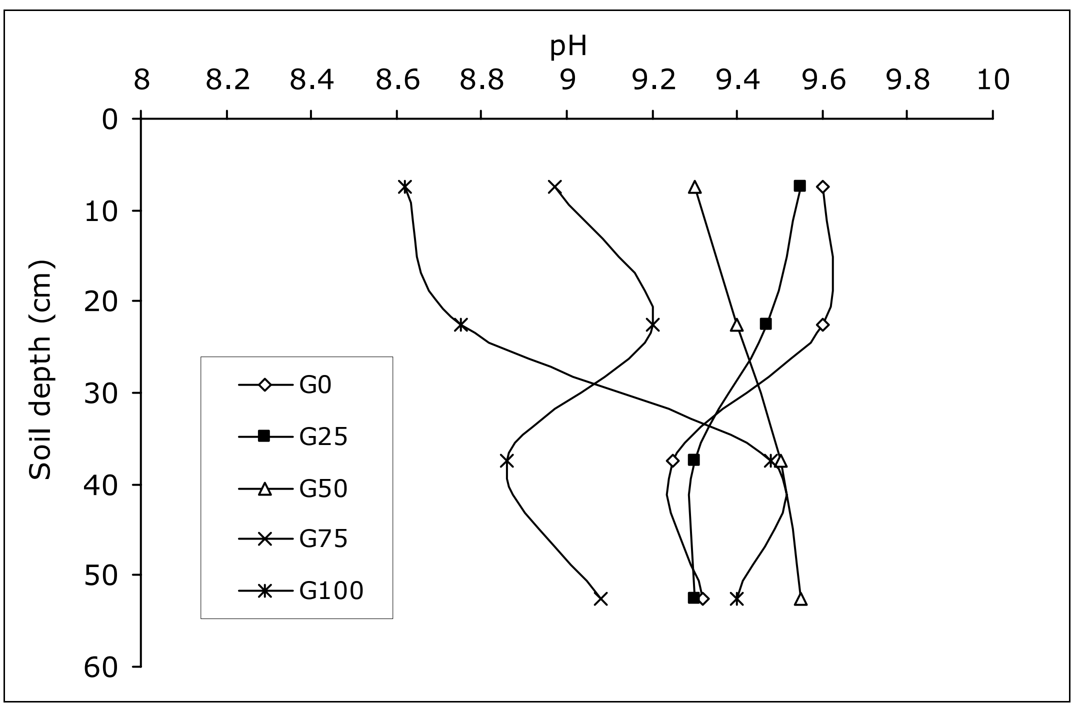


Fig. 39 Effect of gypsum level on pH of soil after the harvest of the wheat

Correlation between EC_{iw} and EC_{soil} & F_w and F_{soil} were found positive and significant, the corresponding "r" values were +0.647** and +0.433**, respectively. Correlation between pH_{soil}

and F_{soil} was positive and significant (r = +0.403**) and correlation between EC_{soil} and F_{soil} was found positive but non significant (r = +0.230)

Table 79 Percent distribution of fluoride in water samples in relation to pH and EC

Characteristics	Fluoride content (mg/l)					
	<1.5	1.5-2.5	2.5-5.0	5.0-7.5	>7.5	Total
pH						
7.5-8.0	3.8	-	9.7	8.6	1.9	25.0
8.0-8.5	13.5	3.8	23.1	26.9	7.7	75.0
EC (dS/m)						
<2.0	9.6	-	5.8	1.9	1.9	19.2
2.0-4.0	1.9	1.9	17.4	23.1	-	44.3
4.0-6.0	3.8	1.9	9.6	7.7	1.9	24.9
>6.0	1.9	-	-	3.8	5.8	11.5
Total for EC	17.2	3.8	32.8	35.5	9.6	

ORGANIC INPUT MANAGEMENT OPTIONS WITH SALINE WATER IRRIGATION FOR SUSTAINING PRODUCTIVITY OF HIGH VALUE CROPS

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 to produce low water requiring high value crops such as oilseeds and spice crops. A field experiment was started during kharif 2008 at Bir Forest Experimental Farm, Hisar. Sesame variety HT-1 (demonstration) was sown in kharif season. Experiment was laid out in split plot design with two main plot treatments (Salinty levels of irrigation water, EC_{iw} <4, EC_{iw} >7) and 8 sub-plot treatments (organic input management options) viz., (T_1) 100% Inorganic fertilizer RD (60:30:30 NPK), (T_2) Inorganic fertilizer (50% of RD) : organic inputs (50% of RD) (FYM + Non-edible oilcake manure + Vermicompost), (T_3) FYM +Vermicompost (50%+50%), (T_4) FYM + Non-edible oilcake manure (50%+50%), (T_5) FYM +Vermicompost + Non-edible oilcake manure (33.3+33.3+33.3%), (T_6) FYM + Vermicompost (100%+100%), (T_7) FYM + Non-edible oilcake manure (100+100%), (T_8) FYM + Vermicompost + Non-edible oilcake manure (66.6+66.6+66.6%). The nutrient contents in different organic materials used are reported in Table 1. Accordingly on N equivalent basis, the amount of FYM, VC and Neem Cake comes out to be 12 t/ha, 2.6 t/ha and 2.4 t/ha respectively.

Initial soil sample analyzed from depth of 0-30 cm revealed that EC_e, pH, and available nitrogen analyzed before start of the experiment were initial EC_e was 0.80-0.86, and pH_s was 8.2-8.5 and available N was 98 kg/ha. Salinity of irrigation water was analyzed during crop growth period along with RSC of the water of two tube wells of the Bir Forest Experimental Farm, Hisar. Sesame was sown after pre sowing irrigation and afterwards irrigated with saline water irrigation at, 35 DAS and 60 DAS. Water analysis showed that pH of tube well 1 ranged from 8.2 to 9.0, EC_{iw} from 1.1 to 2.2 and RSC from 4.3 to 6.5 whereas the pH of tube well 2 varied from 6.8 to 8.9, EC_{iw} from 7.8 to 9.8 and no RSC has been found in tube well 2. Changes in soil properties (Table 80) were recorded under different organic inputs with different salinity waters. The one year experimental results showed that with organic inputs growth and yield attributes did not differ significantly yet higher seed yield of sesame (Table 80) was obtained as compared to 100 % inorganic and inorganic and organic (50+50) input applications. The seed yield was not significantly different with irrigation water salinity although numerically higher yield was recorded under high salinity water irrigation. It could be attributed to relatively higher RSC of the low salinity water.

Table 80 Soil pH_S and EC_e, yield attributes and yields at the harvest of *kharif* crop under different treatments

Treatments	pH_s (0-30 cm)	EC_e (dS/m) (0-30 cm)	No. of plants/m row length	No. of capsules/plant	Seed yield (t/ha)
EC_{iw}<4	8.3	1.05	8.6	29.0	0.38
EC_{iw}>7	8.2	1.27	7.6	30.5	0.40
CD (5%)	NS	NS	0.6	NS	NS
T_1	8.4	1.19	7.5	30.9	0.25
T_2	8.5	0.90	7.5	31.1	0.30
T_3	8.3	1.17	9.0	28.0	0.49
T_4	8.3	1.36	7.8	30.7	0.40
T_5	8.3	1.19	8.5	28.1	0.46
T_6	8.2	1.09	8.2	30.0	0.43
T_7	8.3	1.13	8.0	28.5	0.39
T_8	8.2	1.25	8.2	30.4	0.40
CD (5%)	NS	NS	NS	NS	0.08

Initial values: pH_s: 8.2-8.5; EC_e : 0.80-0.86

B. MANAGEMENT OF SALT AFFECTED SOILS

- **Characterization and Delineation of Salt Affected Soils**
- **Reclamation of Sodic Vertisols in Conjunction with Soil and Water Conservation Practices under Rain Fed Conditions**
- **Investigations on Micro Irrigation for Vegetables Crops in Saline Soils**
- **Reclamation of Abandoned Aqua Ponds**
- **Land Configuration and Water, Soil and Nutrient Management at different Soil ESP under Rain Fed Conditions in Black Soils**
- **Evaluation of Zero Tillage under Semi-Reclaimed Sodic Soil**
- **Effect of Set Furrow Method of Gypsum Application and Textural Modification on Soil Reclamation and Crop Performance**
- **Influence of Spent Wash and Spent Wash Vermicompost on Reclamation of Sodic Soils**
- **Relative Efficiency of Method of Gypsum Application in Reclamation of Alkali Soil**
- **Evaluation of different Crops for Their Tolerance to Sodicity**
- **Effect of Switching Over to Upland Cropping Sequence on Resodification and Sustainability of Crop Yield in Reclaimed Sodic Soil under Water Supply Constraint**
- **Drainage Investigation, Design and Installation of Sub-Surface Drainage Systems and Monitoring for Control of Water Logging and Salinity in Heavy Textured Soils of Appikatla, Krishna Western Delta**
- **Monitoring and Evaluation of Large Scale Drainage Projects in Haryana**
- **Subsurface Drainage for Heavy Soils of Maharashtra and Karnataka under Public- Private Industry Partnership**
- **Response of Crops to Chemical and Organic Amendments in Alkali Soils of Northern Karnataka**
- **Land and Rain Water Management Strategies for Cultivation in Rain Fed Alkali Soils of Northern Karnataka**
- **Effect of Long-Term Application of Organic/Green Manures at different Soil ESP in Sodic Vertisols**
- **Effect of Doses and Frequency of Gypsum Application on Soil Properties and Crop Performance in Sodic Soil on Long-Term Basis**
- **Impact of Tsunami on Agricultural Lands and Crops of Nagapattinam District of Tamil Nadu**

CHARACTERIZATION AND DELINEATION OF SALT AFFECTED SOILS

Morena (Madhya Pradesh)

The detailed reconnaissance soil survey was undertaken in different tehsils of Morena district of Madhya Pradesh to find out the extent and nature of salt affected soil. Most samples were dominated by silt particles followed by sand and belonged to category of loam. The texture of surface soil could be graded in to loam, silty loam, silty clay loam, clay loam and sandy loam. The soils are dominated by exchangeable Ca followed by Mg, Na and K. The ESP values ranged from 19.2 to 46.2. The soils were categorized in various categories of salinity (marginal 4-8, moderate 8-15 and strong >15 EC_e dS/m) and sodicity (marginal <15, moderate 15-40 and strong >40 ESP). The presence of salinity and sodicity were sporadic but spread was in large areas covering a number of villages. The total area of salt affected soils was about 22592 ha (Table 81). The district maps at various scales (1:50000 and 1: 125000) were prepared (Fig. 40).

Table 81 Extent of salt affected soils in Morena and Sheopur district

Category	Area (ha)	
	Morena	Sheopur
Slightly saline and slightly alkali (EC 4-8 dS/m and ESP 15-25)	9920	7761
Slightly saline and moderately alkali (EC 4-8 dS/m and ESP 25-40)	1263	7788
Slightly saline and highly alkali (EC 4-8 dS/m and ESP >40)	1647	3641
Moderately saline and slightly alkali (EC 8-15 dS/m and ESP 15-25)	5548	-
Moderately saline and moderately alkali (EC 8-15 dS/m and ESP 25-40)	4106	-
Moderately saline and highly alkali (EC 8-15 dS/m and ESP >40)	108	123
Highly saline and moderately alkali (EC >15 dS/m and ESP 25- 40)	-	0
Highly saline and highly alkali (EC >15 dS/m and ESP >40)	-	234
Total	22592	19547

Sheopur (Madhya Pradesh)

Most samples in the district dominated by silt particles could be graded in to loam, silty loam and clay loam. The soils are dominated by exchangeable Na followed by Ca, Mg and K. The exchangeable sodium percentage (ESP) varied from 19.8 to 61.6. The profile study indicated that ESP was much higher in surface horizons and reached as high as 82.2. Soils are classified as a member of coarse loamy, mixed, hyperthermic family of Typic Natrargids. Based on classification explained in the previous section, salinity and sodicity area covered about 19547 ha (Table 82). About 39 % of affected area (7761 ha) was slightly saline and slightly alkali in nature. The district maps at various scales (1:50000 and 1: 125000) were prepared (Fig. 41).

North Tamil Nadu

In order to identify, delineate and characterize salt affected soils of Northern Tamil Nadu using remote sensing, satellite data and topo sheets of the study area were procured. After delineation of salt affected area and ground truth verifications, salt affected soil map will be prepared.

RECLAMATION OF SODIC VERTISOLS IN CONJUNCTION WITH SOIL AND WATER CONSERVATION PRACTICES UNDER RAIN FED CONDITIONS

The experiment on reclamation of sodic Vertisols under rain fed condition was conducted at Barwaha Research Farm with raised and sunken bed system. Different beds width (1.5, 3.0, 4.5, 6.0 and 7.0 m) in 1:1 ratio of raised to sunken beds with vertical difference of 40 cm were prepared. While the paddy was cultivated in sunken beds, cotton was shown on raised beds with standard package of practices. The experiment was modified later on to accommodate different ratios (1:2, 1:1, 3:2 & 2:1) of raised to sunken beds by fixing width of sunken bed as 7.5 m.

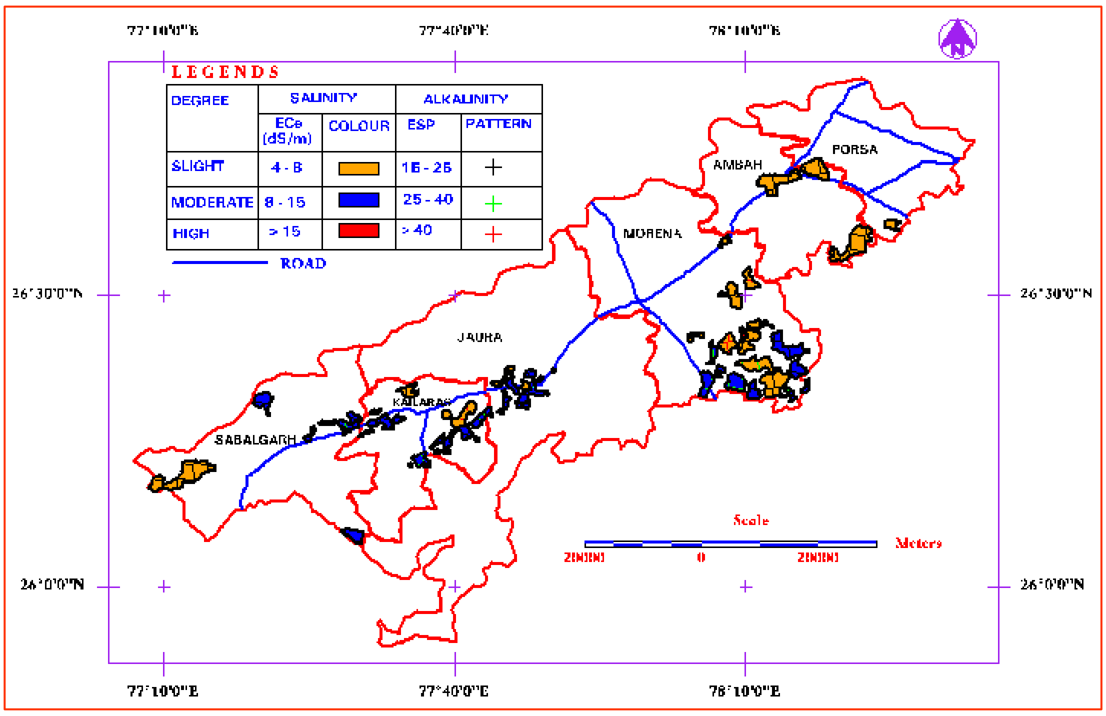


Fig. 40 Map of salt affected soils of Morena district

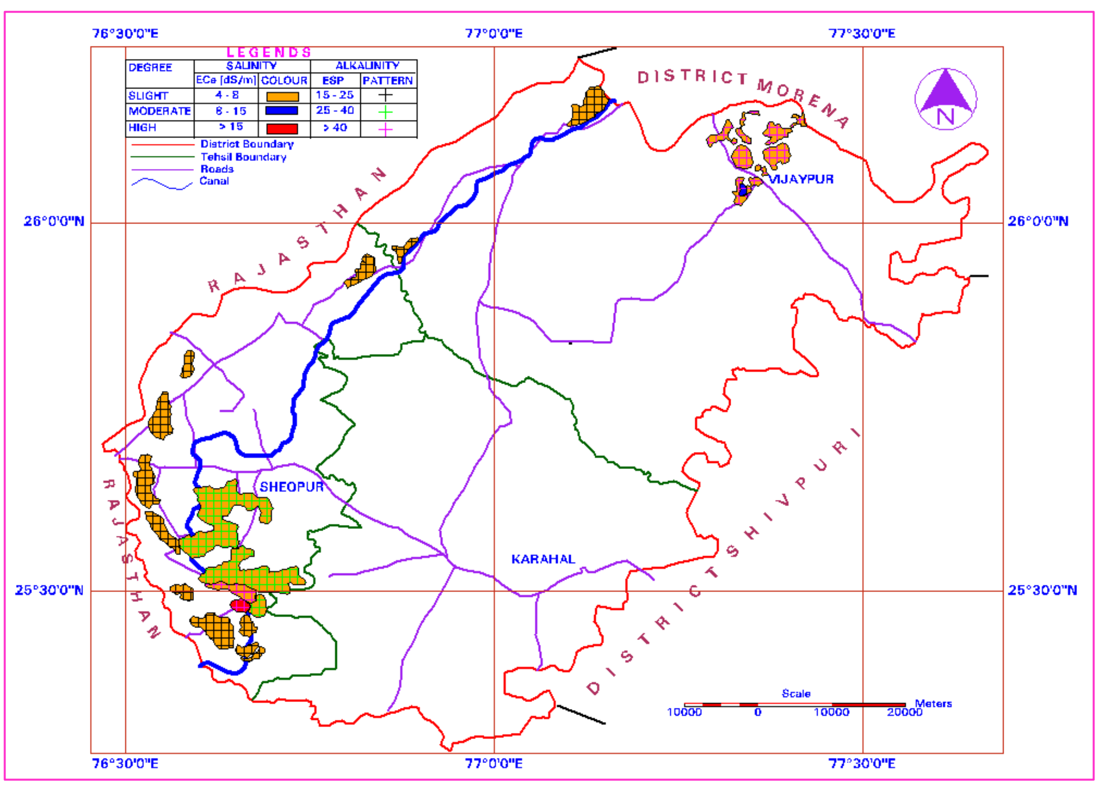


Fig. 41 Map of the salt affected soils of Sheopur district

Water balance was computed to estimate crop water use, assuming that the difference in inflow and outflow is available for plant growth. The measurement were carried out only for one bed width of 7.5 m sunken bed with three different ratios of raised beds considering that this would provide enough evidence of water balance for the system as a whole. Only a little change in data was expected with various widths of raised and sunken beds. The data for the year 2006-2007 were computed for various raised to sunken bed ratios (Table 82). The sunken bed with the ratio of 3:2 was able to collect slightly more water (1909 mm) as compared to 1:1 and 1:2. Cotton crop was able to utilize 563 mm of water during its growth period.

Table 82 Soil water balance (mm) in raised and sunken bed system of different ratios

Parameters	2006-07		
	1:2	1:1	3:2
A. Inflow parameters			
a. Precipitation	1113	1113	1113
b. Soil moisture storage	76	76	76
c. Irrigation to paddy	300	300	300
Total	1489	1489	1489
B. Outflow parameters			
a. Disposal of excess water			
Before transplanting	50	100	150
Runoff	200	400	600
b. Changes in moisture storage	230	230	230
Total	480	730	980
C. Water available for crops (inflow – outflow)	1009	759	509
a. Cotton crop	333	333	333
b. Water stored in sunken bed from raised beds	390	780	1170
c. Total water stored in sunken bed	1399	1539	1679
Cotton	563	563	563
Paddy	1629	1769	1909
D. Water disposed off from the field	250	500	750

The highest grain yield of paddy was recorded when the ratio of raised to sunken bed was 1:1 in 2006 and 2:1 in 2007. The average yield of paddy was 3.16 and 2.99 t/ha during 2006-07 and 2007-08 respectively. Maximum seed cotton yield (2.24 t/ha) was recorded in case of raised to sunken bed ratio 1:2, whereas, minimum seed cotton yield (1.18 t/ha) was noticed under 2:1 ratio during 2007-08. The average seed cotton yield during the year 2007 and 2008 were 1.7 t/ha and 1.4 t/ha (Table 83).

Table 83 Yield of paddy and cotton from various raised: sunken bed ratios

Ratio of raised to sunken beds	Paddy (t/ha)			Seed cotton (t/ha)		
	2006	2007	2008	2006	2007	2008
1:2	3.31	2.88	1.70	0.36	2.24	1.67
1:1	3.43	2.94	1.99	0.00	1.71	1.41
3:2	3.22	3.04	2.12	0.10	1.68	1.29
2:1	2.87	3.11	2.28	0.13	1.18	1.21
Mean	3.16	2.99	2.04	0.15	1.70	1.40

The chemical properties of soil (2006-2008) with varying depths revealed that the salts accumulated in surface layer and decreased with depth. The Soil ESP was higher on raised as compared to sunken beds because of the movement of salt from sunken to raised bed. The soil pH_s and EC_e reduced due to continuous cropping under raised and sunken bed system (Table 84). ESP build-up in later years showed that in the absence of gypsum application, the biological efficiency of reclamation with the help of paddy crop and rainwater is minimal in black alkali soils.

Table 84 Changes in average chemical properties in raised and sunken beds

Depth (cm)	Initial	2006-07		2007-08	
		Raised bed	Sunken bed	Raised bed	Sunken bed
		EC_e (dS/m)			
0-15	3.5	1.8	1.8	1.6	1.7
15-30	3.3	1.6	1.7	1.6	1.9
30-45	2.7	2.1	2.0	2.2	2.4
45-60	2.6	2.5	2.6	2.4	2.6
60-90	2.2	2.5	2.7	2.6	2.7
		pH_s			
0-15	8.2	8.2	8.2	8.1	8.1
15-30	8.2	8.2	8.3	8.2	8.1
30-45	8.3	8.3	8.3	8.2	8.3
45-60	8.3	8.4	8.5	8.3	8.2
60-90	8.3	8.3	8.6	8.3	8.4
		ESP			
0-15	37.0	48.6	38.2	49.2	40.1
15-30	41.0	49.0	39.1	50.1	40.8
30-45	48.0	51.2	46.2	51.6	47.0
45-60	50.0	54.2	52.6	54.4	52.8
60-90	52.0	55.2	54.8	55.2	54.6

INVESTIGATIONS ON MICRO IRRIGATION FOR VEGETABLES CROPS IN SALINE SOILS

The present study was conducted to assess the effect of different drip irrigation levels on growth and yield of vegetable crops in saline soils of Tungabhdra project command. The investigation was initiated during the year 2007-08. Beet root and cabbage were selected as test crops. The experiment was conducted at Agricultural Research Station, Gangawati with the following treatments.

Main treatments:

S_1 - Salinity level (<4 dS/m)
S_2 - Salinity level (4-8 dS/m)
S_3 - Salinity level (8-12 dS/m)

Sub treatments:

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
I_8 - Surface Irrigation at 1.2 ET

Design : Strip plot
Replications : 3

Beet root

The results indicated that irrespective of salinity levels, significantly high beet yield of 18.3 t/ha was recorded when the crop was drip irrigated with ET level of 1.2 followed by 1.4 ET (17.2 t/ha), 1.0 ET (16.9 t/ha), surface irrigation at 1.2 ET (16.6 t/ha), drip irrigation at 0.8 ET (15.7 t/ha), drip irrigation at 0.6 ET (14.8 t/ha), surface irrigation at 1.0 ET (14.9 t/ha) and least (13.5 t/ha) when the crop was irrigated with surface irrigation at 0.8 ET level. Among salinity levels, significantly high yield (19.4 t/ha) was observed in the EC_e <4 dS/m block followed by EC_e 4-8 dS/m (17.1 t/ha) and least (11.4 t/ha) in case of EC_e 8-12 dS/m (Table 85). However, the interaction effect due to irrigation levels and soil salinity levels remained non-significant. The higher yield in case of crop irrigated with drip irrigation at 1.2 ET may be attributed to the higher tuber girth, length and fresh weight.

Table 85 Fresh tuber weight and yield of beet root as affected by drip irrigation and soil salinity

Irrigation levels	Salinity				Salinity			
	Fresh tuber weight (gm)*				Yield (t/ha)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
I_1	352.7	267.0	124.7	248.1	18.4	15.7	10.2	14.8
I_2	416.3	319.7	170.0	302.0	19.3	16.7	11.2	15.7
I_3	420.0	365.3	218.7	334.7	20.5	17.9	12.4	16.9
I_4	501.7	407.0	258.0	388.9	21.6	19.4	13.8	18.3
I_5	480.3	384.3	264.0	376.2	20.8	18.2	12.7	17.2
I_6	318.7	220.0	93.0	210.6	17.1	14.7	8.7	13.5
I_7	366.7	269.3	128.0	254.7	18.4	16.1	10.3	14.9
I_8	421.7	323.3	177.0	307.3	19.7	17.6	12.4	16.6
Mean	409.8	319.5	179.2	-	19.5	17.0	11.5	-
	I	S	I x S		I	S	I x S	
S Em ±	0.885	0.393	-		0.35	0.11	-	
CD (5%)	22.03	11.83	NS		0.87	0.33	NS	

* Average of 10 tubers

Soil salinity was marginally higher in the treatment where crop was irrigated at 0.8 ET under surface method of irrigation and relatively lower where the crop was drip irrigated with ET level of 1.4 as compared to other treatments (Table 86).

Table 86 Soil salinity as influenced by drip irrigation and soil salinity levels

Treatments	EC_e (dS/m)		Treatments	EC_e (dS/m)		Treatments	EC_e (dS/m)	
	0-30*	30-60*		0-30*	30-60*		0-30*	30-60*
$S_1 I_1$	2.6	2.8	$S_2 I_1$	5.7	5.4	$S_3 I_1$	9.3	9.1
$S_1 I_2$	2.2	2.4	$S_2 I_2$	5.2	5.0	$S_3 I_2$	8.7	8.4
$S_1 I_3$	2.1	2.3	$S_2 I_3$	4.7	4.4	$S_3 I_3$	8.4	8.2
$S_1 I_4$	1.9	2.2	$S_2 I_4$	4.3	4.2	$S_3 I_4$	8.2	8.0
$S_1 I_5$	2.1	2.3	$S_2 I_5$	4.2	4.1	$S_3 I_5$	8.1	8.0
$S_1 I_6$	3.7	3.5	$S_2 I_6$	7.4	6.7	$S_3 I_6$	11.5	11.1
$S_1 I_7$	3.5	3.3	$S_2 I_7$	6.7	6.5	$S_3 I_7$	10.1	9.7
$S_1 I_8$	2.8	2.6	$S_2 I_8$	6.8	6.2	$S_3 I_8$	9.4	8.7

*: Soil depths (cm)

Cabbage

A field experiment was conducted during Kharif-2008-09 at ARS, Gangawati. The crop was sown with the same treatments as for beet root. The experiment was vitiated due to poor plant stand mainly due to incessant rains and high incidence of pest and disease.

RECLAMATION OF ABANDONED AQUA PONDS

A large number of marginal and poor farmers have lost their only livelihood option after the disastrous shift from agriculture to aquaculture, which could not be sustained due to many environmental and ecological reasons. Based on a survey conducted in the coastal districts of Andhra Pradesh, around 2 lakh ha lands has been found abandoned as no crop could be grown on aquaculture ponds due to high salinity. Although the aquaculture farmers are inclined to shift to cultivation of agricultural crops they lack in technological information and resources. To demonstrate the technology of reclamation of aqua ponds, four farmers' fields were selected in the village of Kothapalem of Nizampatnam mandal in Guntur district. The input package consisted of the following:

- Leveling of aqua ponds
- Provision of open drainage system for leaching of salts periodically
- The source of irrigation water (EC 2.1 dS/m and pH 7.67).

- Growing of green manure crop dhaincha and *in-situ* incorporation at 50% flowering stage for green manuring
- Basal application of $ZnSO_4$ @ 50 kg/ha at time of paddy transplanting
- Cultivation of salinity tolerant paddy variety NLR-145
- Application of chemical fertilizers at 180 kg N, 40 kg P_2O_5, 40 kg K_2O/ha (N 50% extra)

The data indicated that the soil salinity decreased over the initial level of salinity due to leaching. The crop yields varied from 3.8 to 5.6 t/ha in rice during *kharif*, 2007 followed by establishment of green gram crop during *rabi.* However, the green gram crop was damaged due to untimely heavy rains during 1st fortnight of February, 2008 (Table 87). The uptake of nitrogen ranged from 34.6 to 50.4 kg/ha, phosphorus from 11.0 to 16.8 kg/ha and potassium ranged from 16.0 to 25.0 kg/ha.

For the year 2008-09 in addition to these farmers, 11 more farmers were identified and the paddy variety CSR-23 @ 62.5 kg/ha was distributed, which was multiplied at Bapatla Centre during 2006-07.

Table 87 Changes in soil pH_s, EC_e and grain yield of rice and NPK uptake by rice in abandoned aqua ponds brought under paddy cultivation

Name of the farmer	Area (ha)	pH_s		EC_e (dS/m)		Uptake (kg/ha)			Grain yield (t/ha)
		Initial	Final	Initial	Final	N	P	K	
Sh Ch. Srinivasa Rao	1.2	8.77	8.48	6.50	2.00	40.3	11.8	19.5	4.7
Sh N. Venkata Subbaiah	0.6	8.59	8.54	14.00	4.80	34.6	11.0	16.0	3.8
Sh N. Nagendram	0.8	9.00	8.20	7.90	2.27	40.0	12.0	19.3	4.6
Sh B. Pedabalaramaiah	0.4	9.00	8.54	1.20	0.87	50.4	16.8	25.0	5.6

LAND CONFIGURATION AND WATER, SOIL AND NUTRIENT MANAGEMENT AT DIFFERENT SOIL ESP UNDER RAINFED CONDITIONS IN BLACK SOILS

Four land configurations namely raised-sunken bed (1:1) - RSB, broad bed and furrow (100 cm beds with 30 cm furrow in alternate)-BBF, ridge and furrow (30 cm each)- R&F and flat bed-F with general slope of 0.3% were prepared in plots measuring 30 m x 4.5 m in the month of June 2002. Mould board plough and chiseler were used to establish the configurations. Cotton crop was planted on different configurations while paddy was planted in sunken bed only. Runoff potential was quantified for various land configurations with the help of multi-slot divisors. Multi-slot divisors having 11 slots were installed at lower end on ground level in the plots of BBF, R&F and flat bed configurations. In case of RBS, the multi-slot divisor was installed at the height of 30 cm so as to store water up to 30 cm for growing paddy crop. Runoff, sediment loss and loss of nutrients (nitrogen and potassium) were measured during monsoon season.

Although the experiment was carried out at four ESP levels, multi-slot divisors could only be installed in the field having soil ESP 25. Total 19 runoff events were observed after sowing of crop during 2006-07. Runoff yield was 51.6%, 69.4%, 73.70% and 77.8% in RSB, BBF, RF and F respectively, the maximum being in the flat system (Table 88). Raised and sunken land configuration was more effective in controlling runoff amongst other land configurations.

The highest loss of sediments was observed in flat bed (26.09 t/ha) system whereas, the lowest (3.85 t/ha) was in RSB. Among different land configurations RSB was markedly effective in controlling sediment loss. The order of suitability to control sediments was RSB > BBF > R&F >F. During study period (2006-07), maximum loss of nitrogen was 32.85 kg/ha in R&F and minimum in RSB as 4.24 kg/ha (Table 88). The potassium loss recorded under F was 48.93 kg/ha and it was only 6.30 kg/ha under RSB.

Table 88 Effect of land configuration on runoff and nutrient loss from sodic soil (2006)

Losses	Rainfall (mm)	Land configurations			
		RS	BBF	R&F	F
Runoff (%)	586.8	51.6	69.4	73.7	77.8
Sediment loss (t/ha)		3.85	18.90	22.37	26.09
Nitrogen loss kg/ha)		4.24	23.79	28.30	32.85
Potash loss (kg/ha)		6.30	38.60	44.47	48.93

RSB: Raised and sunken bed; BBF: Broad bed and furrow
R&F: Ridge and furrow; F: Flat bed

The yield data at different ESP levels revealed that highest seed cotton yield (0.90 t/ha) was obtained in RSB at 25 ESP with 2.75 t/ha paddy yield in sunken bed (Table 90). Similarly, at 35 ESP, cotton and paddy yield were 0.68 t/ha and 3.04 t/ha in RSB land configuration. The lowest yield levels were obtained in flat bed (F). However, crop yields were very low beyond soil ESP of 35.

Table 89 Cotton and paddy yield under different land configurations at various ESP levels

ESP	Seed cotton (t/ha)				Paddy (t/ha)
	RSB	BBF	R&F	F	RSB
25	0.90	0.75	0.82	0.05	2.75
35	0.68	0.43	0.55	0.32	3.04
45	0.00	0.14	0.07	0.07	1.58
55	0.00	0.28	0.74	0.23	1.58

EVALUATION OF ZERO TILLAGE UNDER SEMI-RECLAIMED SODIC SOIL

A field study was initiated during kharif 2003 at Dalip Nagar Farm, Kanpur to evaluate the potential of zero tillage system at varying levels of sodicity and role of rice straw incorporation in the system. The treatment included:

Main plots: (1) Conventional tillage and (2) Zero tillage

Sub plots: Gypsum application @ 0, 25, 50 and 100% GR (G_0, G_{25}, G_{50} and G_{100}) with and without rice straw incorporation (RSI)

The sodic soil had initial pH 10.0, EC 4.6 dS/m and ESP 72. Rice and wheat crops were cultivated with recommended dose of fertilizers (120:60:60). Data revealed significant increase in grain and straw yield of both rice and wheat with the application of different doses of gypsum being highest with the application of gypsum @ 100% GR and lowest in no gypsum, control (Table 90). Application of rice straw in general increased the grain yield but the increase was non-significant. Conventional tillage and zero tillage practices showed marginal yield differences at all levels of gypsum application. The conventional tilled plots recorded higher grain yield of wheat in comparison to zero till but yield differences were non-significant. Clearly, a significant saving in expenditure on rice-wheat cultivation could be made by adopting zero tillage.

Changes in soil properties after five years (2003-08) revealed the beneficial effect of gypsum application (Table 91). Initial soil pH value (10.0) dropped to 8.6-9.0 and 8.1-8.5 with gypsum and gypsum along with rice straw incorporation respectively both under conventional as well as zero tillage system. Changes of similar magnitude were also observed in regard to ESP and EC_e. ESP dropped from initial values of 72 to 29-44 and 23-40 in the above treatments. The counter figures for EC_e were 4.6 to 3.1-3.5 and 2.9-3.5 dS/m respectively. No marked difference in soil pH, EC_e and ESP values were recorded between conventional and zero tilled plots after 5 years.

Table 90 Effect of gypsum application and rice straw incorporation on yield under conventional and zero tillage system in sodic soil

Treatment	Conventional tillage						Zero tillage					
	Rice yield (t/ha)			Wheat yield (t/ha)			Rice yield (t/ha)			Wheat yield (t/ha)		
	2006	2007	Mean	2006-07	2007-08	Mean	2006	2007	Mean	2006-07	2007-08	Mean
G_0	1.45	1.40	1.43	1.27	1.31	1.49	1.45	1.47	1.46	1.21	1.24	1.23
G_{25}	2.27	2.26	2.27	1.80	1.85	1.83	2.23	2.30	2.27	1.70	1.77	1.74
G_{50}	3.12	3.20	3.16	2.51	2.56	2.54	3.08	3.25	3.17	2.40	2.45	2.43
G_{100}	3.70	3.73	3.72	2.87	2.96	2.92	3.65	3.78	3.72	2.75	2.81	2.78
G_0 +RSI	1.56	1.52	1.54	1.35	1.37	1.36	1.61	1.61	1.61	1.29	1.36	1.33
G_{25} +RSI	2.42	2.43	2.43	1.93	1.96	1.95	2.31	2.53	2.42	1.84	1.88	1.86
G_{50} +RSI	3.32	3.48	3.40	2.72	2.81	2.77	3.26	3.52	3.39	2.64	2.66	2.65
G_{100} +RSI	3.87	3.97	3.92	3.10	3.18	3.14	3.80	8.02	3.91	2.95	2.98	2.97
CD (5%)												
Gypsum	0.14	0.20	-	0.10	0.13	-	-	-	-	-	-	-
RSI	0.18	0.12	-	0.07	0.09	-	-	-	-	-	-	-

Table 91 Effect of gypsum application and rice straw incorporation on soil properties* under conventional and zero tillage system

Treatments	Conventional tillage			Zero tillage		
	pH	EC_e (dS/m)	ESP	pH	EC_e (dS/m)	ESP
Gypsum (0%GR)	9.7	4.7	62	9.8	4.7	63
Gypsum (25%GR)	9.0	3.2	44	9.0	3.2	46
Gypsum (50%GR)	8.9	3.3	32	8.7	3.5	37
Gypsum (100%GR)	8.6	3.1	29	8.7	3.1	33
Gypsum (0%GR) + RSI	9.1	4.2	45	9.1	4.1	44
Gypsum (25%GR) + RSI	8.5	2.9	38	8.5	3.1	40
Gypsum (50%GR) + RSI	8.4	3.5	28	8.5	3.5	27
Gypsum (100%GR)+ RSI	8.1	2.9	22	8.1	3.0	23
Initial value (2003)	10.0	4.6	72	-	-	-

*After 5 years (Post rabi 2007-08)

EFFECT OF SET FURROW METHOD OF GYPSUM APPLICATION AND TEXTURAL MODIFICATION ON SOIL RECLAMATION AND CROP PERFORMANCE

A field experiment was conducted during 2006-07 to 2008-09 on black alkali soil at Barwaha having initial soil ESP of 55 to 60 to assess the effectiveness of method of gypsum application and effect of modification in texture on growth and yield of cotton crop. The treatments included control, gypsum @ 100% of GR in plough layer, sand application @ 25 and 50 t/ha, gypsum application in strips (60 cm wide x 30 cm depth) and gypsum and sand mixed in strips along with control.

The data in respect of the soil properties revealed that the application of gypsum reduced soil ESP whereas, application of sand at any rate was not able to show any considerable reduction in soil ESP as expected due to change in texture of the soil (Table 92). The maximum seed cotton yield was recorded in treatment T_6 - 50 tons of sand along with gypsum incorporated to soil in a set furrow (0.97, 1.49 and 1.03 t/ha) and followed by T_5 - gypsum incorporated in set furrow (0.95, 1.42 and 0.99 t/ha). The lowest seed cotton yield 0.26, 0.50 and 0.34 t/ha was recorded in control plots. The gypsum application in soil layer (0-15 cm) along with sand also produced equally good result but significantly lower than set furrow applications. The seed cotton yield decreased with increasing ESP of the soil. The results revealed that the addition of amendment to soil along with sand significantly increased the yield of cotton.

Table 92 Soil properties and seed cotton yield under different treatments

Treatments	EC_e (dS/m)	pH_s	ESP	Seed cotton yield (t/ha)		
				2006-07	2007-08	2008-09
Initial	3.12	8.6	60.5	-	-	-
T_1 : Control	1.28	8.4	53.2	0.26	0.50	0.34
T_2 : Surface mixing of gypsum @ 100% of GR	1.25	8.2	47.8	0.41	1.14	0.74
T_3 : Surface mixing of sand @ 25 t/ha+gypsum @ 100% of GR	1.32	8.3	42.2	1.06	1.20	0.82
T_4 : Surface mixing of sand @ 50 t/ha+gypsum @ 100% of GR	1.28	8.3	41.4	0.94	1.26	0.91
T_5: Mixing of gypsum in set furrow of 60 X 30 cm	1.22	8.2	31.4	0.95	1.42	0.99
T_6 : Mixing of sand + gypsum in set furrow of 60 X 30cm	1.20	8.4	30.8	0.97	1.49	1.03

INFLUENCE OF SPENT WASH AND SPENT WASH VERMICOMPOST ON RECLAMATION OF SODIC SOILS

In India about 257 distilleries, generate 40.72 million-kilo liters of spent wash annually. Disposal of such a huge quantity on land poses severe problems of soil, water and environmental pollution because of its high BOD and COD. Spent wash is acidic in nature and contains Ca, Mg, K and S and organic carbon and some other micronutrients in high amount (Table 93). Being an organic material, it improves physical condition of the soil and it can be utilized as an amendment for reclaiming sodic soil. Owing to the high cost of reclamation, use of such locally available waste may economize the reclamation cost. In this experiment, spent wash had been tested along with other organic amendments in paddy and wheat crop grown on sodic soils.

The experiment was initiated during 2003-04 on comparative performance of gypsum, spent wash and spent wash vermicompost on reclamation of a sodic Vertisol and its effect on growth and yield of rice and wheat cropping sequence. Treatments included control, single or combined application (FYM, gypsum @ 75% GR, vermcompost) and spent wash (2.5, 5.0 and 10.0 cm/ha). The treatments were applied only once in the year during summer. Wheat crop was grown in the same plots after harvesting of rice for evaluating the residual effect of amendments. The crop was fertilized with 120:60:40 NPK kg/ha.

The data revealed that the addition of amendments significantly increased yield of rice and wheat over control (Table 94). The highest grain yield was recorded with the application of spent wash @ 10 cm but it was statistically at par with 5 cm. The uptake of Ca, Mg and K by grain and straw of paddy increased significantly by the application of different amendments in comparison to control. However, uptake of Na by grain and straw decreased significantly with application of different amendments as compared to control.

The data pertaining to physico-chemical properties of the soil revealed that application of amendments decreased pH_s, EC_e and ESP of soil after harvest of rice and wheat crop (Table 95). Although no major change in pH_s and EC_e of post harvest soil was observed due to treatments, ESP levels of post harvest soil decreased with the application of amendments. The lowest ESP was noticed with 5.0 cm spent wash application, which showed the efficiency of spent wash in reclaiming sodic soils.

Table 93 Physico-chemical properties of spent wash, spent wash vermicompost and Farmyard manure (FYM)

Organic amendments	pH (1:4)	EC (dS/m)	Ca	Mg	K	S
		2006-07				
Spent wash	4.8	13.4	1580 mg/l	962 mg/l	8900 mg/l	1280 mg/l
Spent wash vermicompost	8.7	4.5	0.9%	0.36%	1.0%	0.68%
FYM	8.0	2.0	0.4%	0.15%	0.6%	0.26%
		2007-08				
Spent wash	4.9	11.6	1522 mg/l	886 mg/l	8675 mg/l	1160 mg/l
Spent wash vermicompost	8.6	3.9	0.8%	0.42%	1.12%	0.58%
FYM	8.0	1.9	0.5%	0.18%	0.65%	0.22%

Table 94 Yield (t/ha) of rice and wheat as influenced by amendments

Treatments	Rice			Wheat	
	2006	2007	2008	2006-07	2007-08
Control	3.08	4.00	3.46	3.17	2.95
FYM @ 5 t/ha	3.25	4.55	3.58	3.26	3.03
Vermicompost @ 5 t/ha	3.42	4.67	3.66	3.50	3.20
Gypsum @75% GR	3.75	4.93	4.05	3.90	3.57
Gypsum@ 75% GR+FYM @5 t/ha	3.91	5.13	4.26	4.07	3.65
Gypsum @75% GR+VC @ 5 t/ha	4.00	5.42	4.35	4.20	3.72
SW 2.5 cm	4.08	5.43	4.38	4.37	3.90
SW 5.0 cm	4.58	5.75	4.85	4.94	4.27
SW 10.0 cm	4.75	5.78	5.01	5.13	4.35
CD (5%)	0.41	0.31	0.42	0.57	0.24

Table 95 Effect of amendments on soil properties after the harvest of wheat

Treatments	2006-07			2007-08		
	pH_s	EC_e (dS/m)	ESP	pH_s	EC_e (dS/m)	ESP
Control	8.4	1.2	37.0	8.3	1.36	36.0
FYM @ 5 t/ha	8.3	1.3	36.5	8.1	1.30	35.5
Spent wash vermicompost @ 5 t/ha	8.3	1.2	36.0	8.1	1.25	34.4
Gypsum @ 75% GR	8.2	1.3	24.2	8.1	1.22	23.0
Gypsum @ 75% GR+FYM @ 5 t/ha	8.2	1.2	22.8	8.0	1.20	22.0
Gypsum @ 75% GR+SWVC@ 5 t/ha	8.2	1.2	21.6	8.0	1.18	21.3
SW 2.5 cm	8.1	1.2	20.0	8.0	1.16	19.4
SW 5.0 cm	8.1	1.2	19.4	8.0	1.15	17.8
SW 10.0 cm	8.0	1.1	19.2	8.0	1.15	17.2

RELATIVE EFFICIENCY OF METHOD OF GYPSUM APPLICATION IN RECLAMATION OF ALKALI SOIL

A field study was conducted at Dalip Nagar Farm; Kanpur to compare the efficiency of gypsum application through irrigation water and soil application with best available water (BAW) irrigated conditions. The treatment comprised of T_1) control (without gypsum); T_2) water treatment passed through 15 cm gypsum bed (GB); T_3) Gypsum @ 25% GR (soil application once); T_4) Gypsum @

50% GR (soil application once); T_5) Gypsum @ 25% GR + GB; T_6) Gypsum @ 50% GR + GB; and T_7) Gypsum @ 100% GR (soil application once). The initial pH, EC_e, ESP, organic carbon and calcite content of soil were 10.8, 6.0 dS/m, 77, 0.08% and 2.6% respectively. Rice and wheat crops were cultivated with recommended package of practices.

The mean yield of two years of rice and one year wheat revealed a significant enhancement in grain yield with combined use of gypsum through soil (one time application) and irrigation water (gypsum bed) (Table 96). Highest mean grain yield in both crops (rice 4.72 and wheat 3.85 t/ha) was observed with sole soil application of gypsum @ 100% GR which remained statistically at par (rice 4.60 and wheat 3.77 t/ha) with combined use of gypsum @ 75% GR (50% GR through soil application and quantity equivalent to 25% GR through gypsum bed dissolution).

Table 96 Crop yields and soil properties due to amendments in alkali water irrigated lands

Treatments	Rice (t/ha)			Wheat (t/ha)			Soil characteristics+		
	2006	2007	Mean	2006-07	07-08⊗	Mean	pH	EC_e (dS/m)	ESP
T_1	2.26	2.27	2.27	1.50	-	1.50	9.7	5.0	64
T_2 **	3.00	3.03	3.01	2.46	-	2.46	8.4	4.4	34
T_3	2.80	3.85	3.33	2.19	-	2.19	8.7	4.5	49
T_4	3.22	3.27	3.25	3.09	-	3.09	8.6	4.2	34
T_5	3.39	3.44	3.42	3.30	-	3.30	8.3	3.8	23
T_6	4.60	4.59	4.60	3.77	-	3.77	8.0	3.4	19
T_7	4.59	4.84	4.72	3.85	-	3.85	8.2	3.7	24
CD (5%)	0.26	0.16	-	0.14	-	-	-	-	-
Initial value (2002)							10.8	6.0	77

* Mean yield of 2 seasons (2006-08); + After 5 years of rice-wheat crop rotation, ⊗ Experiment concluded after kharif 2007; ** Total gypsum dissolution (7.74 t/ha = 48% GR) through 15 cm gypsum bed in 5 years

The pooled data of five seasons of both rice and wheat revealed similar results (Table 97).

Table 97 Crop yield and soil properties due to amendment application in alkali water irrigated lands

Treatments	Rice (t/ha)*		Wheat (t/ha)*		Soil characteristics+		
	Grain	Straw	Grain	Straw	pH	EC_e (dS/m)	ESP
T_1	2.28	2.85	1.51	1.82	9.7	5.0	64
T_2 **	2.86	3.44	2.05	2.42	8.4	4.4	34
T_3	2.70	3.31	2.01	2.34	8.7	4.5	49
T_4	3.24	3.82	2.79	3.35	8.6	4.2	34
T_5	3.26	3.70	2.81	3.30	8.3	3.8	23
T_6	4.42	4.93	3.34	3.73	8.0	3.4	19
T_7	4.51	4.93	3.50	3.99	8.2	3.7	24
CD (5%)	0.23	0.27	0.18	0.25	-	-	-
Initial Values (2002)					10.8	6.0	77

* Mean yield of 5 seasons (2002-07); + After 5 years of rice-wheat crop rotation
** Total gypsum dissolution (7.74 t/ha = 48% GR) through 15 cm gypsum bed in 5 years

Changes in soil characteristics showed considerable reduction in pH, EC_e and ESP values with the application of gypsum. Maximum reduction in pH (10.8 to 8.0), EC_e (6.0 to 3.4 dS/m) and ESP (77 to 19) were recorded with the combined use of gypsum (50% GR soil application and 25% GR

through irrigation water). This sustained the earlier observation that gypsum application through dissolution is better than one time soil application.
On the basis of results it could be concluded that 1) Partial one time application and gypsum dissolution (15 cm gypsum bed) through irrigation water (0.18 t/ha/irrigation) is more beneficial than one time soil application, 2) It reduces the cost of soil reclamation and 3) Investment on gypsum could be spread over the years.

EVALUATION OF DIFFERENT CROPS FOR THEIR TOLERANCE TO SODICITY

So far ten crops and varieties *viz*. rice (TRY 1, CO 42, TRY(R)2, ADT 39, ADT 45, White Ponni), black gram (T9 and ADT 5), green gram (Pusa Bold), okra (Parbani Kranti), vegetable cowpea (VBN 3), cluster bean (Pusa Nowbuhar), maize (COHM 4), sunflower (CO4, TCSH 1), sesame (CO1), and pearl millet (CO7, COHCu8, UCC23, UCC17, ICMY221, PT1890) have been screened for sodicity tolerance and their tolerance limits have been established. The experiment is being continued in the same experimental plot with four ESP gradients and new varieties are being evaluated for sodicity tolerance.

The experimental soil is clay loam in texture with initial pH of 8.6, EC 0.43 dS/m, CEC 21 cmol (p+)/kg and an ESP of 16. The water used for irrigation is highly alkali with pH of 9.0, EC 1.65 dS/m, RSC 10.5 meq/l and SAR 10.7 $(mmol/l)^{1/2}$. Taxonomically the soil of the experimental field belongs to fine, mixed, calcareous isohyperthemic Vertic Ustropept. The sodicity tolerance of crops and varieties was analysed using Mass-Hoffman equation and benefit-cost ratio.

Experimental details:

Crop : Okra (2007–08)

Design : Split plot

Main plots: ESP levels (4) (M_1:9.8; M_2:17.3; M_3:25.5; M_4:35.3)

Sub plots: Okra varieties (3): S_1: Parbhani Kranti; S_2: Arkha Anamika; S_3: Hybrid No.10

Among the okra varieties, hybrid No.10 produced an average yield of 6.79 t/ha, followed by Arkha Anamika 5.86 t/ha. The highest mean yield was registered at ESP 9.8 (7.56 t/ha), which got reduced to 3.43 t/ha at an ESP 35.3 (Table 98).

Table 98 Yield of okra varieties (t/ha) at different ESP levels (2007-08)

Cultivars	ESP levels				Mean
	9.8	17.3	25.5	35.3	
Parbani Kranti	6.02	5.51	3.01	2.49	4.26
Arkha Anamika	7.22	6.89	5.29	4.03	5.86
Hybrid No.10	9.43	8.43	5.53	3.76	6.79
Mean	7.56	6.94	4.61	3.43	-
CD (5%)	Cultivars: 1.28, ESP levels: 0.54, Cultivars x ESP levels: 0.88				

At low ESP of 9.8 and 17.3, the yield of all the three varieties differed significantly. However, when the ESP level was higher (25.5 and 35.3) the yield of Arkha Anamika and hybrid No. 10 were at par. Pre-sowing and post harvest soil samples were collected and analyzed for pH, EC_e and ESP**.** The results revealed that there was an increase in the average pH of soil from 8.69 to 8.79 due to one season of alkali water irrigation (Fig. 42). The results revealed that there was a reduction of 0.07 dS/m in the mean EC_e after one irrigation with alkali water for one season (Fig. 43). The slight reduction in EC_e may be attributed to the leaching of salts due to summer showers received during May. The mean soil ESP increased by 0.7 per cent in the post harvest soil samples. The highest increase of 1.1 per cent was observed in M_4 (Fig. 44).

Overall, the thresholds ESP for okra varieties were 13.5, 15.5 and 16.0 for hybrid No. 10, Arkha anamika and Parbhani kranti, respectively.

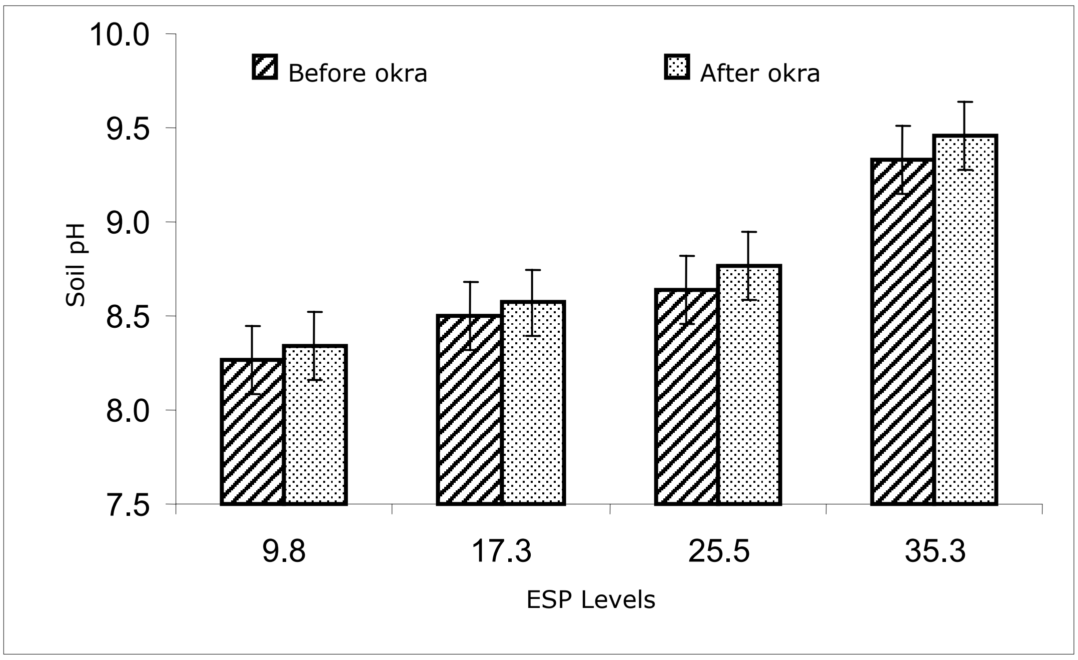


Fig. 42 Effect of treatments on soil pH before and after okra crop

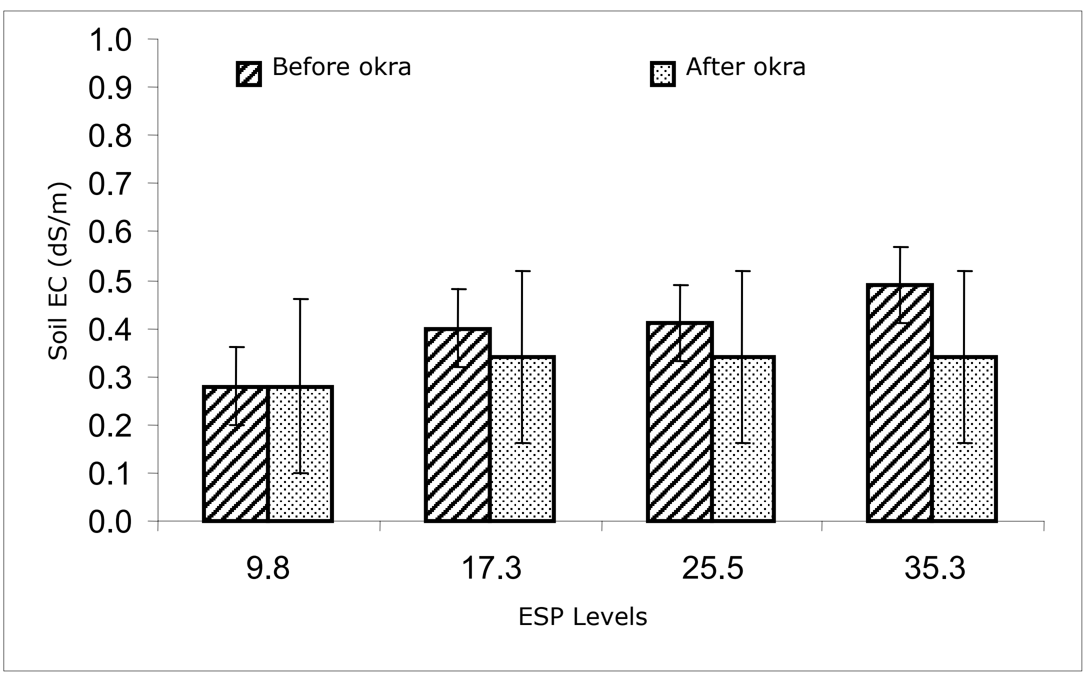


Fig. 43 Effect of treatments on soil EC_e (dS/ m) before and after okra crop

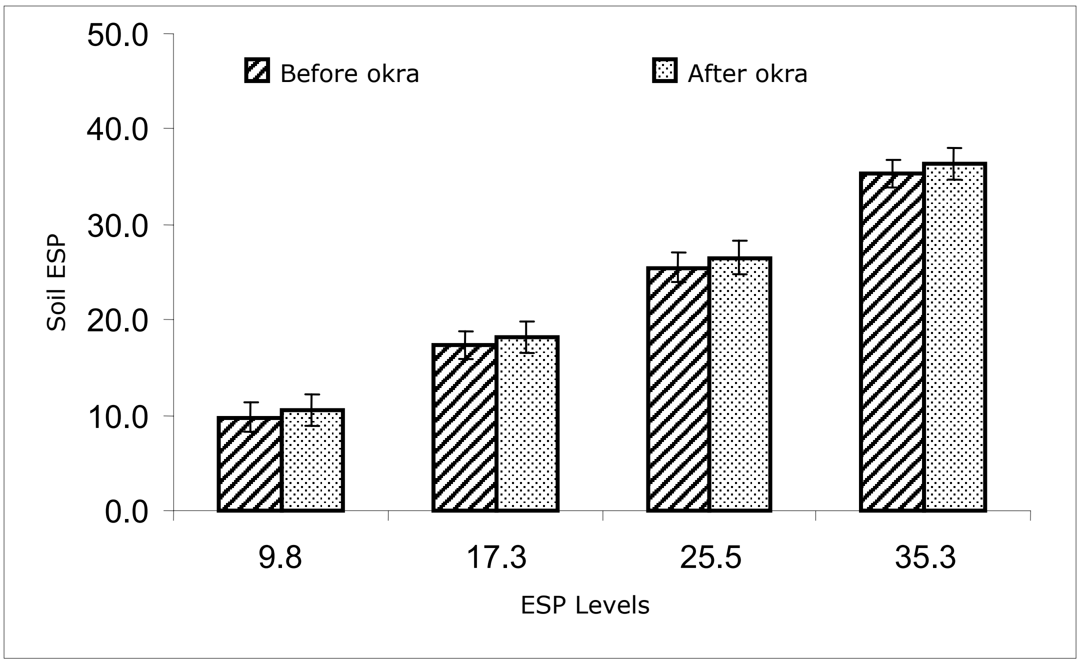


Fig. 44 Effect of treatments on soil ESP before and after okra crop

EFFECT OF SWITCHING OVER TO UPLAND CROPPING SEQUENCE ON RESODIFICATION AND SUSTAINABILITY OF CROP YIELD IN RECLAIMED SODIC SOIL UNDER WATER SUPPLY CONSTRAINT

An experiment was conducted at NARP Research Farm, Dalipnager, Kanpur to study the effect of gypsum with and without application of green manure Dhaincha (*Sesbania aculeata*) on sustainability of reclamation with paddy-wheat, fallow-wheat and sorghum mustard cropping sequences in sodic soil. The initial pH, EC_e and ESP values of soil were 10.2, 6.5 dS/m and 83 respectively. The treatment included 1) Gypsum @ 0% GR; 2) Gypsum @ 50% GR; 3) Gypsum @ 100% GR; 4) Gypsum @ 0% GR + Dhaincha; 5) Gypsum @ 50% GR + Dhaincha; 6) Gypsum @ 100% GR + Dhaincha. Dhaincha was grown in main plots and was ploughed after seven weeks before transplanting. The best available water (pH 7.4, EC 0.8 dS/m and SAR 0.7) was used for irrigation. The mean yield data of two years (2006-08) showed beneficial effect of gypsum application on grain yield of rice, wheat, sorghum and mustard (Table 99). About 68 and 90% increase in yield of rice was recorded with application of gypsum @ 50 and 100% GR respectively.

Table 99 Effect of gypsum and green manuring on grain yield (t/ha) of Kharif crops under different cropping sequence

Treatments	Rice-wheat			Sorghum-mustard			
	Rice			Sorghum			REY*
	2006	2007	Mean	2006	2007	Mean	
Gypsum 0% GR	2.62	2.58	2.60	0.94	0.96	0.95	0.80
Gypsum 50% GR	4.35	4.39	4.37	1.90	1.99	1.95	1.65
Gypsum 100% GR	4.90	4.95	4.93	2.14	2.25	2.20	1.86
Gypsum 0% GR+GM	2.81	2.83	2.82	1.04	1.06	1.05	0.89
Gypsum 50% GR+GM	4.60	4.66	4.63	2.03	2.08	2.06	1.74
Gypsum 100% GR+GM	5.05	5.07	5.06	2.27	2.33	2.30	1.95

CD (5%) 2006- Gypsum: 0.13; GM: 0.11; Interaction: NS
2007- Gypsum: 0.18; GM: 0.15; Interaction: NS

GM denotes green manuring @ 1.5 t/ha (Fresh weight), * Mean rice equivalent yield

Application of gypsum @ 50 and 100% GR along with green manure recorded 70% and 87% higher yield over green manuring alone. Thus, it was observed that application of gypsum @ 100% GR with green manuring, recorded maximum yield. Similar trend was recorded for sorghum yield. In rabi 2006-07 and 2007-08, application of different doses of gypsum showed significant increase in grain yield of wheat and mustard in the cropping sequences paddy-wheat, fallow-wheat and sorghum-mustard (Table 100). It was noted that fallow-wheat cropping sequence recorded higher grain and straw yield of wheat in comparison to paddy-wheat cropping sequence but yield differences were marginal. The application of green manuring in combination with different doses of gypsum increased the grain yield of wheat and mustard.

Table 100 Effect of gypsum and green manuring on grain yields (t/ha) of rabi crops under different cropping sequence

Treatments	Rice-wheat			Fallow-wheat			Sorghum-mustard			
	Wheat			Wheat			Mustard			
	2006-07	2007-08	Mean	2006-07	2007-08	Mean	2006-07	2007-08	Mean	WEY*
Gypsum 0% GR	1.68	1.72	1.70	1.73	1.75	1.74	0.81	0.83	0.82	1.23
Gypsum 50% GR	3.21	3.30	3.26	3.26	3.29	3.28	1.39	1.42	1.41	2.2
Gypsum 100% GR	3.70	3.75	3.73	3.83	3.80	3.82	1.66	1.69	1.68	2.52
Gypsum 0% GR +GM	1.75	1.83	1.79	1.82	1.86	1.83	0.87	0.89	0.88	1.41
Gypsum 50% GR+GM	3.36	3.53	3.43	3.41	3.47	3.42	1.49	1.47	1.48	2.34
Gypsum 100% GR+GM	3.89	3.95	3.92	3.99	4.02	4.01	1.76	1.76	1.76	2.75
CD (5%) 2006- Gypsum : 0.15, GM : 0.12, Interaction : NS										
2007- Gypsum : 0.15, GM : 0.12, Interaction : NS										

* Mean wheat equivalent yield

Changes in soil characteristics as a result of treatments showed the beneficial effect of gypsum application on chemical properties (Table 101). pH values dropped drastically from 10.2 to 8.2 and from 10.2 to 8.1 in plots treated with gypsum @ 50% and 100% GR along with green manuring. Changes of similar magnitude were also observed in regard to ESP and EC_e. ESP dropped from initial value of 83 to 15 and 10 and EC_e from 6.5 to 2.1 and 1.0 dS/m in the above treatment respectively under different rotations.

Table 101 Effect of gypsum and green manuring on chemical properties in reclaimed sodic soil under upland cropping sequences (after 5 years)

Treatments	Rice-wheat			Fallow-wheat			Sorghum-mustard		
	pH_s	EC_e dS/m	ESP	pH_s	EC_e dS/m	ESP	pH_s	EC_e dS/m	ESP
Gypsum 0% GR	9.1	4.5	40	9.2	4.6	50	9.1	4.6	47
Gypsum 50% GR	8.3	2.3	15	8.6	2.4	18	8.5	2.4	17
Gypsum 100% GR	8.1	1.0	12	8.2	1.0	13	8.3	1.0	14
Gypsum 0%GR+GM	8.7	4.4	36	8.8	4.5	41	8.8	4.5	42
Gypsum 50%GR+GM	8.1	2.0	13	8.3	2.1	16	8.2	2.1	15
Gypsum 100%GR+GM	7.9	0.9	9	8.1	1.0	11	8.1	1.0	11
Initial soil values (Kharif 2003) pH_s :10.2; EC_e : 6.5; ESP : 83									

DRAINAGE INVESTIGATION, DESIGN AND INSTALLATION OF SUB-SURFACE DRAINAGE SYSTEMS AND MONITORING FOR CONTROL OF WATER LOGGING AND SALINITY IN HEAVY TEXTURED SOILS OF APPIKATLA, KRISHNA WESTERN DELTA

A Subsurface drainage system (SSDS) was installed in farmer's fields at Appikatla village in Guntur district covering an area of 7.5 ha. The soils are heavy textured clayey saline waterlogged with low rice productivity. The system was installed in the year 2002 at an average drain depth of 1 m using stoneware and corrugated PVC material for pipe line with two different lateral spacing of 30 and 60 m.

The pumping from the main sump was continued during the reporting period and samples of leachates were collected on daily basis, analysed for cations and anions besides pH and EC. An amount of 2.0 and 1.9 tons of salts were leached during 2006-07 and 2007-08, respectively (Table 102). The total amount of salts leached since installation of the system for the last 6 years was assessed at 165 tons over an area of 7.5 ha with an average of about 22 t/ha. The ionic composition indicated that sodium was dominant cation followed by calcium, magnesium and potassium while chlorides were dominant anions followed by sulphate, bicarbonate and carbonate (Fig. 45). The SAR values were less than 10 showing that leachate is within the safer limit during both the years.

Table 102 Quantity of water, salts and nutrients pumped from SSDS

Year	Volume of water pumped (m^3)	Amount of salts leached (t/ha)	Nutrients (kg/ha)		
			N	P	K
2002-03	27448	7.3	-	-	-
2003-04	19377	3.1	5.30	2.91	11.2
2004-05	27327	4.0	5.40	2.30	8.5
2005-06	26784	3.2	3.10	1.71	5.9
2006-07	14374	2.0	9.70	2.31	3.9
2007-08	10493	1.9	1.77	0.23	3.3
Total	125803	21.5	25.27	9.46	32.8

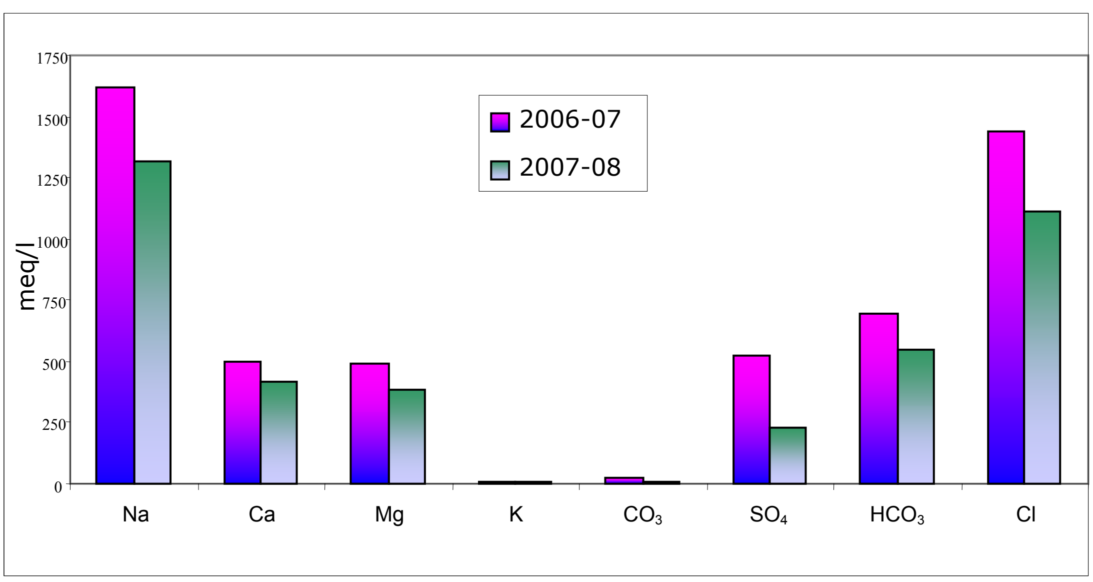


Fig. 45 Ionic composition of leachates (2006-08)

The NPK nutrients were also lost through leachates to the extent of 11.47 Kg N, 2.54 kg P, 7.2 kg K during both the years of 2006-2008. Thus, the nutrients constituted only 0.3% of the total salts leached from the area. The average water table in post drainage remained at 139 cm and 139.7 cm during March 2007 and 2008 respectively, which is nearly the same as for pre-drainage (Table 103).

Table 103 Ground water table in Pre and post drainage situations

Location	Depth to water table (cm)		
	Pre-drainage (March, 2002)	Post drainage (March, 2007)	Post drainage (March, 2008)
L-1	128	129	130
L-2	138	120	143
L-3	138	130	140
L-4	142	145	109
L-5	145	142	124
R-1	146	137	159
R-2	145	136	132
R-3	140	161	158
R-4	143	148	162
R-5	140	145	140
Average	142	139	139.7

Stoneware pipes drained more water than CPVC drains and 30 m spaced drains were more effective in controlling water table than 60 m spacing. The IC-1, IC-9R and IC-9L laterals drained more water compared to other laterals as they are at the drained field boundaries. Moreover IC-1 is also influenced by a drain carrying drainage effluents and IC-9R and IC- 9L by upstream surplus flow. The mean salinity build-up in 30 m spaced fields was 2.17 dS/m, which in case of 60 m spaced drain area was 4.09 dS/m during 2008 summer. The drain discharge rate with 60 m spacing drains is 1.76 to 1.85 during 2007-08, which is less than the design discharge rate, whereas with 30 m spacing drains, the drain discharge ranged from 2.76 to 3.55 during 2007-08, which is higher than the design discharge rate. The rice yield during 2007-08 in 30 m spaced drains averaged 6.75 t/ha while in 60 m spacing it was 6.54 t/ha (Table 104 and 105).

Table 104 Drain discharge from the subsurface laterals of Appikatla drainage area

Lateral	Drain Material	Envelope Material used	Average drain discharge (mm/day)	
			2006-07	2007-08
60 m drain spacing				
IC-1	Stone ware	Sand	4.38	3.98 *
IC-3	Stone ware	Sand	1.92	1.85
IC-5	Stone ware	Sand	1.88	1.97
IC-2	Corrugated PVC	Nylon mesh	1.87	1.84
IC-4	Corrugated PVC	Nylon mesh	1.34	1.76
IC-6	Corrugated PVC	Nylon mesh	1.42	1.38
30 m drain spacing				
IC-7 R	Stone ware	Sand	3.26	3.29
IC-8 R	Stoneware	Sand	3.52	3.55
IC-9 R	Stone ware	Sand	3.84	3.76
IC-7 L	Corrugated PVC	Nylon mesh	1.76	1.89
IC-8 L	Corrugated PVC	Nylon mesh	2.87	2.76
IC-9 L	Corrugated PVC	Nylon mesh	3.65	3.48

* Breakage of pipe (near IC- I) caused low drainage discharge compared to previous years

Table 105 Drain performance during 2006-08

Performance Indicator	CPVC drainage system with different spacing		Stoneware pipe drainage system with different spacing	
	30 m	60 m	30 m	60 m
		2006-2007		
Soil salinity (dS/m) (March/April 2007)	2.30	3.23	2.12	2.98
Paddy yield (t/ha) (Jan 2007)*	2.10*	2.28*	2.09*	1.86*
Drain discharge rate (mm/day)	2.87	1.34	3.52	1.92
		2007-2008		
Soil salinity (dS/m) (March/April 2008)	2.75	4.51	1.58	3.66
Paddy yield (t/ha) (Jan 2008)	6.63	6.57	6.86	6.51
Drain discharge rate (mm/day)	2.76	1.76	3.55	1.85

* Due to Ogni cyclone, crops were under submerged condition for a week and hence poor yield

The analysis of soil extract for EC_e (Fig. 46, Table 106 and Table 107) after six years of installation revealed a decrease from initial mean value of 16.2 dS/m to 3.0 dS/m, while pH was nearly neutral and SAR within the safer limit at the end of 2007-08 cropping season. It showed a reduction of 82% in salt concentration, which was reflected in terms of rice crop productivity increase from initial yield level of 1.80 t/ha at time of pre-installation to the level of 6.64 t/ha (mean of 35 grids) after six years of installation which was 260% improvement over control due to subsurface drainage system (Table 108). The differences in grain yield of rice due to different spacing were very marginal i.e., only 0.06 t/ha (0.91%). Similarly the differences in grain yield due to different drain materials used viz., stoneware and CPVC were very marginal i.e., only 0.21 t/ha (3.13%). Hence for the design of drainage systems in these soils, 50- 60 m spacing may be preferred to minimize cost. Any material i.e. stoneware or CPVC pipes could be used depending upon the availability.

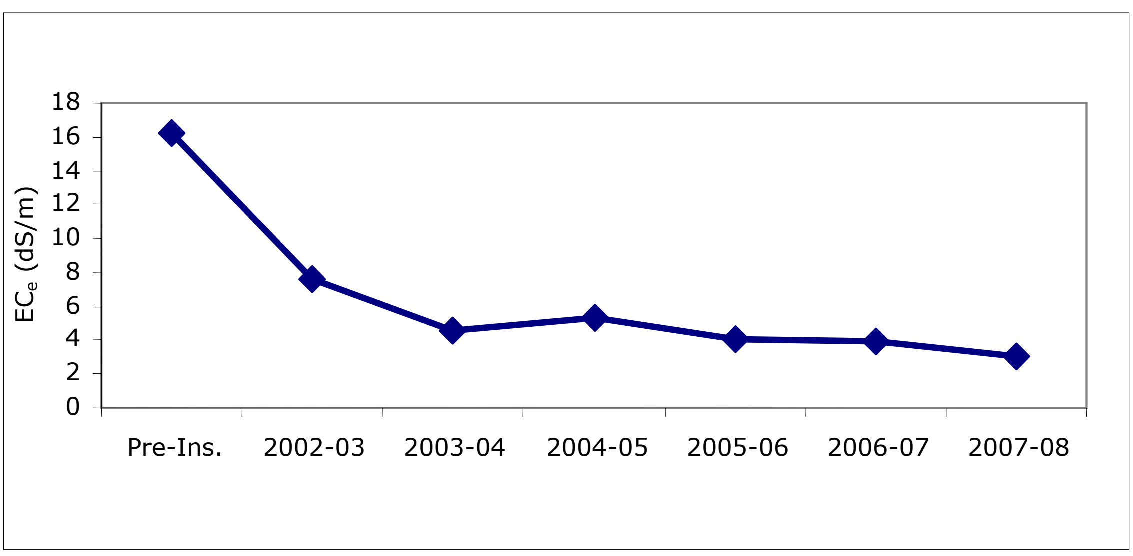


Fig. 46 Changes in soil EC_e (0-20cm) in SSDS, Appikatla

Table 106 pH_s, EC_e and ionic composition of soil (0-20cm) after harvest of paddy

Grid No.	EC_e (dS/m)	pH	Ionic composition (meq/l)								SAR $(mmole/l)^{1/2}$
			CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	
						2006-07					
Mean	2.60	7.69	0.00	1.71	18.46	6.47	5.62	8.61	14.14	0.36	4.83
Min	0.50	6.27	0.00	0.60	2.60	1.00	0.80	1.40	2.60	0.24	2.37
Max	9.50	8.19	0.00	4.50	76.00	20.50	20.20	28.40	38.20	0.92	9.11
						2007-08					
Mean	2.33	7.54	0.00	2.18	12.80	8.47	7.87	7.70	7.51	1.50	2.25
Min	1.00	6.80	0.00	0.20	4.00	2.00	1.60	1.60	2.00	0.08	0.69
Max	8.50	7.90	0.00	3.40	44.00	74.60	48.80	25.60	22.00	2.55	5.10

Table 107 pH, EC and ionic composition of soil (0-20cm) after harvest of second crop

Grid No.	EC_e (dS/m)	pH	Ionic composition (meq/l)								SAR $(mmole/l)^{1/2}$
			CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	
						2006-07					
Mean	3.96	7.69	0.00	3.55	26.63	10.14	11.77	7.59	20.94	0.36	6.47
Min	0.80	6.27	0.00	2.20	4.00	2.00	2.80	1.60	4.20	0.24	1.75
Max	11.10	8.19	0.00	5.00	86.00	28.50	37.20	22.60	52.00	0.92	16.35
						2007-08					
Mean	3.00	7.67	0.00	2.47	18.07	9.29	11.98	5.56	12.48	1.32	3.24
Min	1.16	6.70	0.00	1.40	2.40	4.50	4.40	0.40	1.70	0.80	0.46
Max	8.60	8.19	0.00	5.32	74.00	20.00	35.60	15.20	37.80	1.70	7.72

Table 108 Paddy yield in subsurface drainage system at Appikatla

Year	Grain yield (t/ha)	Straw yield (t/ha)
2002-03	4.10	5.50
2003-04	4.24	5.90
2004-05	6.40	7.40
2005-06	5.78	7.32
2006-07	2.09	4.94
2007-08	6.64	7.43

Note: During 2006-07 due to Oogny cyclone at flowering stage of the crop, the yield of paddy was very low

Rice-fallow cropping system was prevalent with poor yields at the time of pre-installation but after drainage, crops like sunhemp (*Crotalaria juncea*), pillipesara (*Phaseolus trilobus*), sorghum fodder (*Sorghum vulgare*), mustard (*Brassica juncea*) could be grown with good yields showing the efficiency of the subsurface drainage system (Table 109).

Table 109 Influence of SSDS on yield of different crops after paddy

Year	Fodder sorghum (t/ha)	Pillipesara (t/ha)	Sunhemp (t/ha)	Mustard (t/ha)
2002-03	Germinated but failed			
2003-04	27.20	18.50	19.30	0.27
2004-05	25.40	19.00	20.60	0.28
2005-06	26.10	17.40	20.30	0.29
2006-07	25.20	17.85	18.70	0.67
2007-08	Germinated but failed due to heavy rains during Feb and Mar, 2008			
Mean	26.05	17.85	19.75	0.38

In conclusion, it could be inferred that the soil EC_e in Appikatla subsurface drainage project decreased from 16.2 dS/m at pre installation to 3.0 dS/m at the end of 6 years showing a reduction of 82%. The rice yield increased from 1.80 t/ha at pre-installation to 6.48 t/ha after 6 years of installation which showed improvement of more than 260%. Establishment of sunhemp

(*Crotalaria juncea*), pillipesara (*Phaseolus trilobus*), sorghumfodder (*Sorghum vulgare*) and mustard (*Brassica juncea*) made possible during fallow period raising the cropping intensity.

MONITORING AND EVALUATION OF LARGE SCALE DRAINAGE PROJECTS IN HARYANA

Effect of subsurface drainage on soil salinity and crop yield

The Department of Agriculture (DoA), Government of Haryana, is implementing four large-scale drainage projects in the state. This institute is associated with monitoring and evaluation of these projects. Monitoring of soil and crop improvement in a drainage project provides a convenient way for impact assessment of subsurface drainage systems for waterlogged saline lands. To achieve this objective, monitoring and evaluation of drainage project at Charkhi Dadri (Bhiwani district) was continued during the year. The soil samples were analyzed for soil EC and pH in 1: 2 soil: water suspension. The range and mean values of EC (1:2), pH (1:2) and paddy yield obtained during the kharif 2007 and wheat grain yield obtained during the rabi 2007-08 are summarized in Table 110 and Table 111, respectively.

Table 110 Soil salinity, alkalinity and paddy grain yield in the Charkhi Dadri project

Variables	No. of observations (Kharif, 2007)	Range	Mean
	Village Khatiwas		
EC (1:2) (dS/m)	17	0.30 – 2.32	0.94
pH (1:2)	17	7.80 – 8.20	8.00
Paddy yield (t/ha)	16	1.67 – 3.58	3.00
	Village Jhinjhar		
EC (1:2) (dS/m)	11	0.74 – 1.60	0.96
pH (1:2)	11	7.80 – 8.20	8.00
Paddy Yield (t/ha)	09	2.00 – 3.33	2.59
	Village Achina		
EC (1:2) (dS/m)	07	0.67 – 1.64	1.32
pH (1:2)	07	7.80 – 8.10	7.90
Paddy yield (t/ha)	05	1.67 – 3.50	2.91
	Village Loharwara		
EC (1:2) (dS/m)	29	0.32 – 1.78	1.00
pH (1:2)	29	7.80 – 8.30	8.10
Paddy yield (t/ha)	26	0.96 – 3.71	2.23
	Overall mean		
EC (1:2) (dS/m)	64	0.30 – 2.33	1.00
pH (1:2)	64	7.80 – 8.30	8.00
Paddy yield (t/ha)	56	0.96 – 3.71	2.57

Impact of SSD on soil salinity and paddy and wheat yield

The impact of SSD was evaluated by analyzing the soil salinity and paddy yield data of Kharif, 2007 and compared with 2005 Kharif data (Table 112). Data revealed that there was overall 31% decrease in soil salinity in Kharif 2007 compared to Kharif 2005 and paddy yield increased by 25%.

Similarly impact of SSD was evaluated by analyzing the soil salinity ($EC_{1:2}$, dS/m), wheat yield (t/ha) data of rabi 2007-08 and compared with the rabi data of 2004-05. The data revealed that as compared to 2006-07, there was small decrease in salinity but no improvement in wheat yield. Over 2004-05, the yield increased from 33 to 67% with average of about 56% (Table 113).

Table 111 Soil salinity, alkalinity and wheat grain yield in the Charkhi Dadri Project

Variables	No. of observations (Rabi, 2007-08)	Range	Mean
	Village Khatiwas		
EC (1:2), dS/m	17	0.54 – 2.05	0.84
pH (1:2)	17	7.80 – 8.20	8.00
Wheat grain yield (t/ha)	17	1.66 – 3.61	2.83
	Village Jhinjhar		
EC (1:2), dS/m	11	0.21 – 1.92	0.93
pH (1:2)	11	7.80 – 8.20	8.00
Wheat grain Yield (t/ha)	10	1.29 – 3.86	2.59
	Village Achina		
EC (1:2), dS/m	06	0.42 – 2.04	0.84
pH (1:2)	06	7.80 – 8.10	8.00
Wheat grain yield (t/ha)	05	2.08 – 3.57	2.98
	Village Loharwara		
EC (1:2), dS/m	29	0.17 – 1.84	0.65
pH (1:2)	29	7.80 – 8.30	8.00
Wheat grain yield (t/ha)	28	2.07 – 4.15	3.10
	Overall mean		
EC (1:2), dS/m	63	0.17 – 2.05	0.77
pH (1:2)	63	7.80 – 8.30	8.00
Wheat grain yield (t/ha)	60	1.29 – 4.15	2.91

Table 112 Impact of SSDS on soil salinity and paddy crop yield

Variable	2005	2007	Per cent increase (+)/ decrease (-)
		Village Khatiwas	
EC (1:2) (dS/m)	1.41	0.91	(-) 35.46
Paddy yield (t/ha)	2.06	3.00	(+) 45.63
		Village Jhinjhar	
EC (1:2) (dS/m)	1.22	0.96	(-) 21.31
Paddy yield (t/ha)	2.17	2.59	(+) 19.35
		Village Achina	
EC (1:2) (dS/m)	1.74	1.32	(-) 24.13
Paddy yield (t/ha)	1.86	2.91	(+) 56.45
		Village Loharwara	
EC (1:2) (dS/m)	1.51	1.00	(-) 33.77
Paddy yield (t/ha)	2.03	2.23	(+) 9.85
		Overall Charkhi Dadri Project	
EC (1:2) (dS/m)	1.45	1.00	(-) 31.03
Paddy yield (t/ha)	2.05	2.57	(+) 25.36

Table 113 Impact of subsurface drainage system on soil salinity and wheat yield

Variable	2004-2005	2007-08	Per cent increase (+)/ decrease (-)
	Village Khatiwas		
EC (1:2), dS/m	1.72	0.84	(-) 51.16
Wheat yield (t/ha)	1.76	2.83	(+) 60.80
	Village Jhinjhar		
EC (1:2), dS/m	1.68	0.93	(-) 44.64
Wheat yield (t/ha)	1.94	2.59	(+) 33.51
	Village Achina		
EC (1:2), dS/m	3.24	0.84	(-) 74.07
Wheat yield (t/ha)	2.01	2.98	(+) 48.26
	Village Loharwara		
EC (1:2), dS/m	2.12	0.65	(-) 69.34
Wheat yield (t/ha)	1.85	3.10	(+) 67.57
	Overall Charkhi Dadri Project		
EC (1:2), dS/m	2.03	0.77	(-) 62.07
Wheat yield (t/ha)	1.86	2.91	(+) 56.45

Economic performance of paddy and wheat

The basmati type varieties of rice namely Basmati 19, Basmati 30 and Pusa 1121 were grown extensively in the area under study. In the selected HOPP plots also, Basmati 19, Basmati 30 and Pusa 1121 covered almost all the area during Kharif 2007 with a few exceptions of sorghum fodder and sugarcane crops. The economic analysis for paddy crop revealed that benefit cost ratio on operational cost was 2.91. These ratios were comparatively better for Achina and Khatiwas villages mainly due to less operational cost of cultivation. The benefit cost ratio was 1.81 on the basis of total cost. The economic analysis for wheat crop showed that benefit cost ratio on operational cost was 1.93 on an average and it ranged from 1.69 in Jhinjhar and Achina to 2.28 in Loharawara village. The benefit cost ratio on the basis of total cost was 1.24.

Analysis of drainage water samples from Achina, Charkhi Dadri

Thirteen samples from various manholes were obtained and analyzed for EC, SAR and RSC (Fig. 47). RSC for all the samples was nil. Since the EC and SAR of all the samples except two were within reasonable limits, it was concluded that water from all places except that of CD2 and CD3 could be used directly and of CD2 and CD3 in conjunctive mode with canal water without any major problem to soil resource and crops grown in the area.

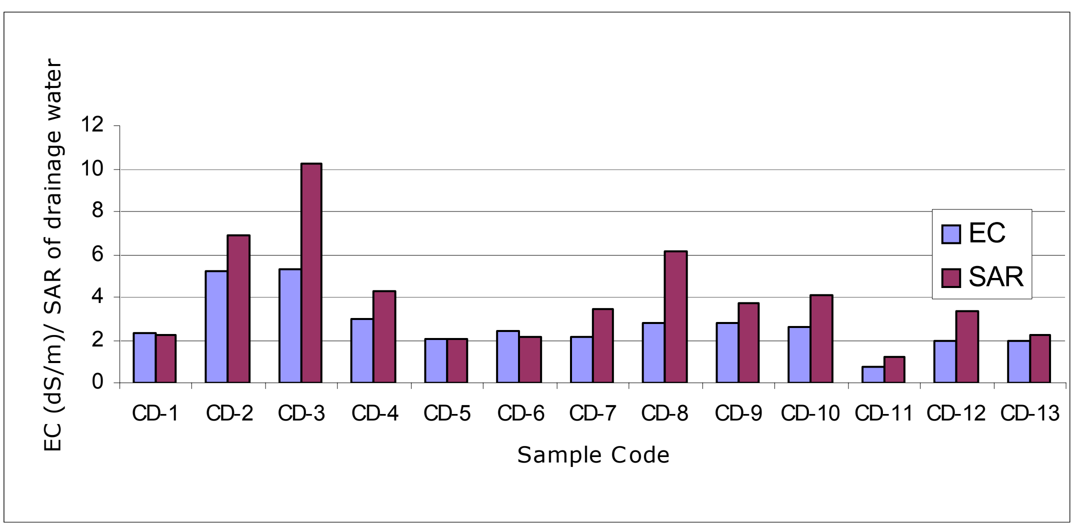


Fig. 47 Drainage water quality at different manholes of SSDS at Achina, Charkhi Dadri

SUBSURFACE DRAINAGE FOR HEAVY SOILS OF MAHARASHTRA AND KARNATAKA UNDER PUBLIC- PRIVATE INDUSTRY PARTNERSHIP

The MOU between CSSRI and Rex Group of Industries, Sangli was renewed for 2008-09 on the same terms and conditions as previous years. The CSSRI is to provide technical inputs in drainage investigations and designs of new projects, capacity building of Rex staff and organizing training programmes for farmers. Besides, CSSRI is also expected to provide technical advice in monitoring and evaluation of large-scale drainage projects. CSSRI worked in close collaboration with Rex staff while they undertook subsurface drainage of 1100 ha area in RECLAIM – I project at village Dhdhgaon and 1065 ha RECLAIM-II project at village Kasabe Digraj. The efforts during the period under report were more focused towards the finalization of designs and layouts of the 1100 ha Ugar subsurface drainage project at Ugar, District Belgaum (Karnataka). The scientists visited the area for the purpose of drainage investigations (Fig. 48) and later on to sort out layout related issues.

Fig. 48 Water logging and weed growth in agricultural fields at Ugar (Karnataka)

These fields are infested with lift irrigation pipelines. Hence, it was difficult to prepare layout for laterals and collectors while keeping the damages to lift irrigation pipelines at minimum level. Considering this background, micro level modifications/adjustments in the layout were incorporated in consultation with Rex staff and farmers. Considering undulating topography of the area, sufficient natural slope was available for laterals. The actual lengths of laterals (or maximum areas drained by laterals) and maximum areas drained by collectors were kept within permissible limits. The elevation levels of different outlets were verified with reference to formation levels of the surface drain. It was confirmed that that there would be sufficient outfall at each outlet and subsurface drainage system could work with gravity. The layout for subsurface drainage project at Ugar was technically approved to undertake installation activity in the project.

The Rex also adopted CSSRI's wheat variety KRL-19 on its Trail Farm. The farm is under subsurface drainage and reclamation process is proceeding normally. The yield even under the saline environment surpassed the average yield in Maharashtra. The subsurface drainage system in combination with salt tolerant wheat variety KRL-19 seems to be a promising technological package for saline vertisols of Maharashtra, which are under subsurface drainage and yet to be reclaimed fully.

RESPONSE OF CROPS TO CHEMICAL AND ORGANIC AMENDMENTS IN ALKALI SOILS OF NORTHERN KARNATAKA

Sunflower

A field experiment was initiated during 2006 and continued during 2007 and 2008 in farmer's field at Kyarehal village to assess the effect of chemical/organic amendments on growth and yield of sunflower and soil properties in an alkali soil. Pooled data of three years indicated that application of FYM @ 10 t/ha with 50% GR recorded significantly higher sunflower seed yield of 1.77 t/ha compared to 1.32 t/ha in control and 1.51 and 1.50 t/ha respectively with application of gypsum at 50% and 75% GR alone. Seed yield recorded with application of FYM @ 10 t/ha with 50% GR was at par with the application of FYM @ 10 t/ha with 75% GR and application of vermicompost @ 2.5 t/ha with 50% and 75% GR. Sunflower seed yield obtained with the application of FYM @ 10 t/ha with 50% GR was higher to the extent of 34, 18, 17, 7, 6 and 5% when compared to control, application of gypsum at 50% GR alone, 75% GR alone, FYM @ 10 t/ha with 75% GR, vermicompost @ 2.5 t/ha with 50% GR and vermicompost @ 2.5 t/ha with 75% GR respectively (Table 114). The soil salinity values ranged between 2.15 - 2.85 dS/m and soil pH ranged between 9.12 - 9.41 (Table 115). The soil pH values recorded after the harvest of crop were slightly lower than the initial values except the control.

Table 114 Effect of chemical and organic amendments on sunflower yield

Treatments	Sunflower seed yield (t/ha)			
	2006	2007	2008	Pooled
T_1: FYM @ 10 t/ha with 50% GR	1.75	1.78	1.78	1.77
T_2: FYM @ 10 t/ha with 75% GR	1.72	1.65	1.63	1.66
T_3: Vermicompost @ 2.5 t/ha with 50% GR	1.67	1.66	1.68	1.67
T_4: Vermicompost @ 2.5 t/ha with 75% GR	1.68	1.70	1.71	1.69
T_5: 50% GR	1.51	1.53	1.49	1.51
T_6: 75% GR	1.49	1.52	1.49	1.50
T_7: Control (No organics/No gypsum)	1.33	1.37	1.25	1.32
S Em ±	0.03	0.05	0.06	0.04
CD (5%)	0.09	0.17	0.18	0.14

Cotton

Pooled data of two years (2006-07 and 2007-08) indicated that application of either FYM @ 10 t/ha or vermicompost @ 2.5 t/ha with 75% GR recorded significantly higher seed cotton yield of 1.24 t/ha compared to control (0.92 t/ha) and application of gypsum @ 50% and 75% GR alone (1.05 and 1.07 t/ha, respectively) (Table 116). The seed cotton yield recorded with either FYM @ 10 t/ha or vermicompost @ 2.5 t/ha with 75% GR was at par with application of FYM @ 10 t/ha and vermicompost @ 2.5 t/ha with 50% GR. The pooled number of branches/plant and bolls/plant also followed a similar trend. The soil salinity values ranged between 3.53-4.07 dS/m. Soil ESP values recorded after the harvest of crop were lower in the treatments, which received amendments when compared to control. The experiment is being continued during 2008-09 and the crop is yet to be harvested.

Table 115 Effect of chemical and organic amendments on soil properties*

Treatments	Soil EC_e (dS/m)	Soil pH
T_1: FYM @ 10 t/ha with 50% GR	2.52	9.23
T_2: FYM @ 10 t/ha with 75% GR	2.15	9.12
T_3: Vermicompost @ 2.5 t/ha with 50% GR	2.33	9.27
T_4: Vermicompost @ 2.5 t/ha with 75% GR	2.44	9.23
T_5: 50% GR	2.29	9.21
T_6: 75% GR	2.51	9.26
T_7: Control (No organics/No gypsum)	2.85	9.41
CD (5%)	NS	NS

*pooled data of 3 years, Initial soil EC_e : 2.5 dS/m, Initial soil pH: 9.6

Table 116 Growth and yield of cotton as influenced by amendments in alkali soil*

Treatments	Seed cotton yield (t/ha)	Branches per plant	Bolls per plant	Soil EC_e (dS/m)	Soil ESP
T_1: FYM @ 10 t/ha with 50% GR	1.19	19	26	3.72	19.1
T_2: FYM @ 10 t/ha with 75% GR	1.24	18	26	3.55	17.0
T_3: Vermicompost @ 2.5 t/ha with 50% GR	1.19	17	27	3.73	20.2
T_4: Vermicompost @ 2.5 t/ha with 75% GR	1.24	20	28	4.07	16.8
T_5: 50% GR	1.05	16	21	3.86	21.9
T_6: 75% GR	1.07	16	22	3.80	17.8
T_7: Control (No organics/No gypsum)	0.92	14	18	3.53	23.4
S Em ±	0.034	0.667	1.364	0.273	1.099
CD (5%)	0.1	2.055	4.203	NS	3.389

*pooled data of two years; Initial soil salinity: 2.5 dS/m, Initial soil ESP: 24.6

LAND AND RAIN WATER MANAGEMENT STRATEGIES FOR CULTIVATION IN RAIN FED ALKALI SOILS OF NORTHERN KARNATAKA

The experiment comprising different rainwater harvesting practices namely deep ploughing, tied ridges, compartment bunding and flat bed along with gypsum application all with 75% and 50% gypsum requirement (GR) was conducted on farmers' field. The treatments were initiated during 2005-06 to study the effect on crop (sunflower) performance and soil chemical parameters and continued during 2007, 2008 and 2009 in a rain fed sodic soil (Table 117). Treatments were imposed at the beginning of the monsoon, so that sufficient rainwater could be harvested to leach down the salts before the crop is sown. Data on sunflower yield showed that the crop performed better under tied ridges with 75% gypsum. Highest mean seed yield (1.13 t/ha) was obtained under this treatment followed by tied ridges with 50% gypsum (1.08 t/ha), deep ploughing with 75% gypsum (0.99 t/ha), deep ploughing with 50% gypsum (0.98 t/ha), compartment bunding with 75% gypsum (0.96 t/ha), compartment bunding with 50% gypsum (0.91 t/ha), flat bed (0.72 t/ha), flat bed with 75% gypsum (0.72 t/ha) and least in case of flat bed with 50% gypsum application (0.68 t/ha).

Data depicted in Table 118 on the effect of different moisture harvesting practices on soil salinity status and ESP indicated leaching of salts under all the practices compared to initial. Leaching of salts was maximum under tied ridging and minimum under flat bed system (control).

Table 117 Effect of moisture harvesting practices and amendments on sunflower

Treatments	Sunflower seed yield (t/ha)			
	2007	2008	2009	Mean
Deep ploughing with 75% gypsum	1.23	0.99	0.76	0.99
Deep ploughing with 50% gypsum	1.21	0.97	0.75	0.98
Tied ridges with 75% gypsum	1.35	1.15	0.89	1.13
Tied ridges with 50% gypsum	1.26	1.12	0.86	1.08
Compartment bunding with 75% gypsum	1.18	0.97	0.74	0.96
Compartment bunding with 50% gypsum	1.1	0.93	0.71	0.91
Control (Flat bed)	1.05	0.65	0.48	0.73
Flat bed with 75% gypsum	-	0.81	0.62	0.72
Flat bed with 50% gypsum	-	0.78	0.58	0.68
CD (5%)	1.23	0.99	0.76	-

Table 118 Effect of moisture harvesting practices and amendments on soil properties

Treatments	EC_e (dS/m)				ESP		
	2007	2008	2009	Mean	2008	2009	Mean
Deep ploughing with 75% gypsum	3.1	2.9	1.6	2.5	16.4	16.1	16.2
Deep ploughing with 50% gypsum	3.4	2.6	1.2	2.4	19.4	18.5	18.9
Tied ridges with 75% gypsum	3.3	2.7	1.2	2.4	17.7	16.3	17.0
Tied ridges with 50% gypsum	3.0	2.7	1.2	2.3	20.6	19.3	19.9
Compartment bunding with 75% gypsum	2.7	2.9	1.6	2.4	18.8	17.5	18.1
Compartment bunding with 50% gypsum	3.0	2.6	1.7	2.4	21.7	19.6	20.6
Control (Flat bed)	3.2	2.8	1.2	2.4	23.4	23.2	23.3
Flat bed with 75% gypsum	-	2.8	1.3	2.0	23.2	20.6	22.4
Flat bed with 50% gypsum	-	3.0	1.1	2.1	20.4	22.1	21.2

EFFECT OF LONG-TERM APPLICATION OF ORGANIC/GREEN MANURES AT DIFFERENT SOIL ESP IN SODIC VERTISOLS

The various green manuring crops were cultivated in gypsum-applied plots (to create different levels of soil ESP) as per the treatments. The application of gypsum was done only once before sowing of green manuring crop in the month of April/May. The green manure crop was buried in the soil at the age of 45 days well before the sowing of the kharif crop. The paddy-wheat crop rotation was followed. Treatment combinations included four levels of ESP (25, 35, 45 and 55) and three organic/green manures (FYM @ 10 t/ha, dhaincha and sunhemp along with control).

The grain yield of paddy and wheat decreased with increase in soil ESP (Table 119). Comparatively higher average yield of paddy and wheat was recorded at soil ESP of 25 and lowest at 55. Incorporation of dhaincha among various treatments gave the highest yield and lowest was observed in control plot for both the crops. The data revealed that the ESP values decreased with the incorporation of green manures/ FYM at all the levels. The lowest ESP was recorded in case of dhaincha followed by sunhemp (Table 120).

Table 119 Grain yield of paddy and wheat as influenced by green manure and FYM

Treatments	Paddy (t/ha)					Wheat (t/ha)				
	Soil ESP					Soil ESP				
	25	35	45	55	Mean	25	35	45	55	Mean
2006-07										
Control	3.15	2.65	2.35	2.15	2.58	1.73	2.05	1.32	1.38	1.62
FYM @ 10 t/ha	3.27	3.19	2.77	2.42	2.91	2.56	2.48	1.75	1.41	2.05
Sunhemp	3.12	2.54	2.46	2.12	2.56	2.81	2.91	2.60	2.51	2.71
Dhaincha	3.69	3.42	2.39	2.12	2.90	3.19	3.12	3.29	3.19	3.20
Mean	3.31	2.95	2.49	2.20	-	2.57	2.64	2.24	2.12	-
2007-08										
Control	3.9	3.2	3.1	2.4	3.2	3.0	2.9	2.2	1.8	2.5
FYM @ 10 t/ha	4.0	3.5	3.2	2.5	3.3	3.7	3.0	2.5	2.1	2.8
Dhaincha	4.9	4.5	3.5	2.9	3.9	4.3	3.9	3.1	2.8	3.5
Sunhemp	4.8	3.8	3.2	2.7	3.6	3.7	3.5	2.8	2.6	3.1
Mean	4.4	3.7	3.2	2.6	-	3.6	3.3	2.7	2.3	-
	M	S	MxS	SxM		M	S	MxS	SxM	
CD (5 %)	0.81	0.67	NS	NS		0.15	0.11	0.25	0.23	

M: Main; S: Sub

Table 120 Soil properties as influenced by green manures/FYM after wheat (2007-08)

Green manures	Soil ESP				Mean
	25	35	45	50	
Control	24.8	34.6	44.2	49.5	38.3
FYM @ 10 t/ha	23.6	33.4	43.6	48.1	37.2
Dhaincha	22.1	31.4	41.6	47.2	35.6
Sunhemp	22.4	31.9	42.0	47.6	36.0
Mean	23.2	32.8	42.9	48.1	

EFFECT OF DOSES AND FREQUENCY OF GYPSUM APPLICATION ON SOIL PROPERTIES AND CROP PERFORMANCE IN SODIC SOIL ON LONG-TERM BASIS

Application of gypsum for amelioration of alkali soil is an old and effective practice. It was experienced from past experimentations that ESP of soil increases after few years. Therefore, need for the repeat application was to be confirmed by field experiments. The initial ESP of experimental soil was around 50. Treatment combinations included frequency of gypsum applications (applied once, reapplied after three years and reapplied after six years) and doses of gypsum @ 50, 75 and 100% GR with and without FYM. FYM was applied @ 5 t/ha. The paddy-wheat crop rotation was followed. The data indicated that ESP of the soil reduced drastically due to application of gypsum. The minimum ESP was recorded in gypsum application @ 100% GR. Very little difference was noticed in soil ESP between gypsum application @ 75% GR along with FYM @ 5 t/ha and 100% GR (Table 121).

The data revealed that grain yield of paddy and wheat increased significantly with doses of gypsum application over FYM application (Table 122). However, frequency of application and interaction of doses and frequency were non-significant on grain yield of paddy as well as wheat. The maximum grain yield of paddy and wheat was recorded when gypsum was applied @ 75% GR along with FYM followed by gypsum application @ 75% GR alone. The differences between 75% GR, 75% GR + FYM and 100% GR were non-significant.

Table 121 Effect of frequency and doses of gypsum on ESP of the soil after wheat

Doses of Gypsum	Frequency of gypsum applications			
	Applied once	Reapplied after 3 years	Reapplied after 6 years	Mean
FYM @ 5 t/ha	46.0	48.1	47.6	47.2
GR 50% + FYM @ 5 t/ha	41.3	39.1	43.2	41.2
GR 75%	34.1	37.5	38.3	36.6
GR 75% + FYM @ 5 t/ha	33.3	33.8	35.4	34.1
GR 100%	32.8	33.8	30.3	32.3
Mean	37.5	38.4	38.9	38.3

IMPACT OF TSUNAMI ON AGRICULTURAL LANDS AND CROPS OF NAGAPATTINAM DISTRICT OF TAMIL NADU

To study the impact of tsunami on agricultural lands, a coastal length of about 160 km from Sirkazhi to Vedharanyam of Nagapattinam district (Tamil Nadu) was surveyed by a team of scientists from AICRP on Use of Saline Water, Tiruchirapalli in two spells on 22nd January 2005 and 2nd and 3rd February 2005. Four transects from Sea to the farther most point of the inundated area were surveyed to assess the nature of crop damage, soil salinity build-up and surface and ground water contamination within one month after the impact of tsunami during January 2005. Thirteen benchmark sites were fixed and the quality of soil and ground water were monitored periodically.

The bench mark sites were surveyed on 17.03.2007. Data revealed that the soil salinity has reduced to normal at Pushpavanam, Vellapallam, Vettaikaran Iruppu, Poriyar and Neithavasal (Table 123). The undulating areas in Anaikovil and Manickampangu remained saline with an EC_e of 12.1 and 13.2 dS/m, respectively.

Table 122 Effect of frequency and doses of gypsum on grain yield of paddy and wheat

Doses of Gypsum	Paddy (t/ha)				Wheat (t/ha)			
	Frequency of application			Mean	Frequency of application			Mean
	Applied once	Reapplied after 3 years	Reapplied after 6 years		Applied once	Reapplied after 3 years	Reapplied after 6 years	
			2007-08					
FYM	2.67	2.63	2.67	2.65	2.54	2.58	2.58	2.57
GR 50% + FYM	3.69	3.63	3.63	3.65	3.79	3.79	3.75	3.78
GR 75%	4.50	4.63	4.54	4.56	4.25	4.21	4.25	4.24
GR 75 % + FYM	4.75	4.75	4.79	4.76	4.38	4.42	4.38	4.39
GR 100%	4.46	4.54	4.54	4.51	4.33	4.33	4.33	4.33
Mean	4.06	4.10	4.09	4.09	3.86	3.87	3.86	3.86
	F	D	F x D	D x F	F	D	F x D	D x F
CD (5%)	NS	0.52	NS	NS	NS	0.17	NS	NS
			2008-09					
FYM	1.21	1.46	1.25	1.21	-	-	-	-
GR 50% + FYM	1.58	1.83	1.54	1.58	-	-	-	-
GR 75%	1.63	2.13	1.58	1.63	-	-	-	-
GR 75% + FYM	1.67	2.17	1.63	1.67	-	-	-	-
GR 100%	1.71	2.04	1.67	1.71	-	-	-	-
Mean	1.56	1.93	1.53	1.56	-	-	-	-
	F	D	F x D	D x F	-	-	-	-
CD (5%)	0.15	0.20	NS	NS	-	-	-	-

F: Frequency of gypsum application; D: Doses of gypsum

Table 123 Impact of tsunami on soil pH and soil salinity in Nagapattinam district

S.No.	Location	Soil Depth	pH_s	EC_e (dS/m)
1	Pushpavanam	0-15 cm	7.82	0.15
		15-30 cm	7.45	0.40
2	Pushpavanam	0-15 cm	7.12	0.58
		15-30 cm	7.70	0.90
3	Pushpavanam	0-15 cm	7.05	0.87
		15-30 cm	7.15	1.10
4	Vellapallam	0-15 cm	7.30	2.15
		15-30 cm	7.68	2.85
5	Vellapallam	0-15 cm	7.65	1.25
		15-30 cm	7.86	1.82
6	Vettaikaran Iruppu	0-15 cm	7.90	0.84
		15-30 cm	7.55	1.10
7	Prathamaramapuram	0-15 cm	7.22	1.12
		15-30 cm	7.80	1.80
8	Poraiyar	0-15 cm	7.50	1.78
		15-30 cm	7.12	2.01
9	Manikkampangu	0-15 cm	7.97	13.20
		15-30 cm	8.14	14.25
10	Anaikovil	0-15 cm	7.94	12.12
		15-30 cm	8.21	13.17
11	Neithavasal	0-15 cm	7.28	1.41
		15-30 cm	7.65	1.28
12	Neithavasal	0-15 cm	6.84	0.45
		15-30 cm	6.55	0.77
13	Thirumullaivasal	0-15 cm	7.18	1.14
		15-30 cm	7.54	1.86

C. ALTERNATE LAND MANAGEMENT

- **Tolerance of Ber to Saline Irrigation under Drip Irrigation System**
- **Tolerance of Fruit Trees to Saline Irrigation under Drip and Surface Irrigation System**
- **Studies on Performance of Tree/Fruit Species in Saline and Alkali Soil Environments**
- **Studies on Performance of Tree Species in Alkali Environment**
- **Performance of Unconventional Methods to Irrigate Tree Plantations in Sodic Black Soils**
- **Effect of different Methods of Irrigation and Quality of Water on Performance of Some Fruit Trees in A Sodic Environment**
- **Effect of Salinity on Growth and Yield of Medicinal Plants**
- **Influence of different ESP Levels on Performance, Nutrient Uptake and Active Ingredient of Some Medicinal and Aromatic Plants Grown in Sodic Vertisols**
- **Evaluation of the Performance of Some Medicinal And Aromatic Plants in Saline Vertisols**
- **Evaluation of Jatropha Curcas in Alkali Soils under Irrigated Condition**

TOLERANCE OF BER TO SALINE IRRIGATION UNDER DRIP IRRIGATION SYSTEM

An experiment was conducted to study the tolerance of ber (*Zizyphus spp*) under saline irrigation. The treatments included:

Two water application rates at 1.0 to 0.8 times of the PET
Two qualities of water: BAW and EC 8.0 dS/m
Two mulch treatments i.e. mulch and no mulch

The maximum average yield (40.05 kg/plant) was obtained in treatment 0.8 PET + plastic mulch with BAW. Even under saline water, this treatment yielded 38.03 kg/plant. In general, higher yields were obtained in treatment of 0.8 PET as compared to 1.0 PET, both with and without plastic mulch. The average fruit diameter varied from 2.82 to 3.76 cm in different treatments highest being in 0.8 PET BAW with mulch and lowest in 1.0 PET BAW without mulch (Table 124).

Table 124 Average fruit weight, diameter and yield/plant under different treatments of water application and mulching

Treatments	Average fruit diameter (cm)				Fruit yield/plant (g)			
	2005-06	2006-07	2007-08	Mean	2005-06	2006-07	2007-08	Mean
1.0 BAW	2.71	2.84	2.92	2.82	27.90	28.12	32.47	29.50
0.8 BAW	3.51	3.72	3.45	3.56	31.10	34.93	44.18	36.74
1.0 Saline	2.60	2.71	3.27	2.86	26.40	27.00	41.20	31.53
0.8 Saline	3.40	3.60	3.90	3.63	30.40	32.16	49.97	37.51
1.0 BAW+M	3.10	3.30	2.77	3.06	30.00	31.63	39.44	33.69
0.8 BAW+M	3.90	4.01	3.37	3.76	35.87	39.49	46.80	40.05
1.0 Saline+M	2.83	2.94	3.27	3.01	28.70	29.86	39.39	32.65
0.8 Saline+M	3.65	3.84	3.73	3.74	32.63	38.17	43.30	38.03
CD (5%)	0.50	0.54	0.61	-	4.3	5.1	3.9	-

The monthly water requirement presented in Table 125 revealed that maximum per day water requirement was in the month of May and minimum in the month of January. The total water required in the crop season was 8198 and 6553 litres at 1.0 PET and 0.8 PET, respectively, during 2005-06, whereas during 2007-08, the total water required in the crop season was 9846 and 7890 litres at 1.0 PET and 0.8 PET, respectively.

Table 125 Total water applied to ber crop (litres/month/plant)

Months	2005-06		2006-07		2007-08		Average	
	1.0 PET	0.8 PET	1.0 PET	0.8 PET	1.0 PET	0.8 PET	1.0 PET	0.8 PET
May	1581	1265	1516	1213	1881	1506	1659	1327
June	1422	1138	1506	1205	1946	1548	1625	1300
July	1135	900	1128	903	1508	1237	1257	1006
August	1004	804	967	774	1328	1062	1100	880
September	810	648	732	586	1085	867	876	701
October	725	580	660	528	851	679	745	596
November	576	461	486	389	512	408	525	420
December	561	449	453	362	348	276	454	363
January	384	308	350	280	387	307	374	299
Total	8198	6553	7798	6240	9846	7890	8615	6892

The distribution of salts in the soil profile at harvest during 2007-08 revealed that application of saline water resulted in salt accumulation in lower depth of the soil profile. The salts leached from the upper layers are being piled up in the lower depths. Comparatively, high salinity levels existed in treatments with 0.8 PET in un-mulched conditions at almost every point of observation. This could be attributed to lower moisture level in soil profile as compared to 1.0 PET, thereby, increasing the salinity status. Treatment with plastic mulch resulted in higher salinity in shallow soil depths as compared to previous years. This may be due to puncturing of mulch film by the "Dachab" grass (*Cyperus spp*.), which consequently increased the rate of evaporation as well as transpiration by the weed plants resulting lesser moisture status in top of the soil profile (Table 126).

Table 126 Soil profile salinity (EC_e) under drip irrigation with EC_{iw} 8.0 dS/m (2007-08)

Distance from the plant (cm)	Soil depth (cm)	1.0 PET	0.8 PET	1.0 PET + M	0.8 PET + M
15	0-15	2.23	2.01	2.03	1.83
	15-45	2.60	2.62	2.37	2.39
	45-75	2.83	2.75	2.69	2.50
	75-105	3.10	3.15	2.90	2.87
30	0-15	2.83	2.61	2.63	2.23
	15-45	2.97	3.01	2.89	2.74
	45-75	3.22	3.30	3.17	3.00
	75-105	3.10	3.20	3.00	2.92
60	0-15	2.84	2.98	2.79	2.61
	15-45	3.30	3.29	3.21	2.98
	45-75	3.52	3.51	3.37	2.83
	75-105	3.41	3.54	3.10	3.01
90	0-15	3.20	3.01	2.91	2.42
	15-45	3.72	3.80	3.51	2.74
	45-75	3.70	3.94	3.63	3.19
	75-105	3.87	3.69	3.81	3.45

TOLERANCE OF FRUIT TREES TO SALINE IRRIGATION UNDER DRIP AND SURFACE IRRIGATION SYSTEM

A field experiment was initiated in 2003 to assess the tolerance of guava and pomegranate using saline water. The treatments included two irrigation methods i.e. drip and surface irrigation. In drip irrigation system, 3 salinity levels of BAW, 8 and 12 dS/m were used with 3 IW/CPE ratios of 0.5, 0.75 and 1.0. In surface irrigation system, salinity levels were BAW, 8 and 12 dS/m but only 2 IW/CPE ratios of 0.5 and 1.0 were used. The plantation was completed in August 2003. In case of pomegranate, the survival was 100% after four year of experimentation. The fruit yield/plant and t/ha of pomegranate declined with salinity of irrigation water in both the irrigation methods. The pooled yield data of two years revealed that under the drip irrigation system, significantly higher yield (10.3%) was obtained as compared to surface irrigation system. The BAW and EC_{iw} 8 were not differing significantly but 12 EC_{iw} declined the yield by 34% in comparison to BAW. The ET levels were also found significant both in yield /plant and yield t/ha. The highest yield was recorded with ET 1.0. In ET 0.75 and 0.5, the yield declined over ET 1.0 by 16.8 and 57.7% (Table 127).

Soil salinity was monitored in February and June in surface irrigation system (Table 128). In February EC_e was maximum in ET 1.0 at all salinity levels. In the month of June (pooled basis), rainfall at soil sampling time reduced soil EC_e in upper layers (0-15 cm) and it caused in increased salinity in lower layers.

In drip irrigation system, maximum EC_e was recorded in ET 1.0 with EC_{iw} 12 dS/m at 45 cm distance away from tree. EC_e was less in (0-15 cm) depth and higher in lower layers in month of June i.e. 5.2 to 5.7 in BAW 11.1 to 13.2 in EC_{iw} 8 and 14.8 to 17.9 dS/m in EC_{iw} 12 in ET 0.5 and

ET 1.0 respectively. The EC_e was higher in whole profile under ET 1.0 as compared with ET 0.5. Same trend of the EC_e was observed at 15 cm and 30 cm distance away from the plant.

Table 127 Yield and yield attributes as affected by different treatments

Treatments	Fruits per plant	Fruit diameter (cm)	Fruit yield (kg/plant)	Fruit yield (t/ha)
Method of irrigation				
Surface	40.9	17.1	13.9	11.3
Drip	47.0	17.7	15.4	12.6
CD (5%)	1.2	0.5	0.1	0.4
Salinity levels				
BAW	48.3	18.4	16.9	13.7
8 dS/m	49.7	18.1	16.5	13.4
12 dS/m	34.6	15.3	10.7	09.9
CD (5%)	1.4	0.5	0.5	0.5
ET				
0.5	40.4	16.4	12.7	05.8
0.75	45.6	17.1	14.6	11.4
1.0	47.4	18.4	16.8	13.7
CD (5%)	1.2	0.6	0.6	0.4
Ineractions: M X EC_{iw}; EC_{iw} x ET; M x ET : Non-significant				

Table 128 Effect of different treatments on soil salinity

Treatments	Depth (cm)	Surface		Drip					
		February	June	February			June		
				Distance* (cm)			Distance (cm)		
				15	30	45	15	30	45
BAW									
0.5	0-15	4.4	5.1	4.3	4.4	4.4	4.5	5.0	5.2
	15-30	4.3	5.1	4.1	4.1	4.3	4.9	5.2	5.4
1.0	0-15	4.9	5.5	4.9	4.9	5.1	5.2	5.1	5.7
	15-30	4.6	5.4	4.6	4.8	4.9	5.7	5.4	5.8
EC_{iw} 8 dS/m									
0.5	0-15	8.4	11.1	8.3	8.9	9.7	10.2	10.5	11.1
	15-30	7.9	10.2	8.8	9.3	9.9	11.3	10.9	11.8
1.0	0-15	9.1	11.9	9.4	9.9	10.1	11.8	12.5	13.2
	15-30	8.7	12.1	9.8	10.2	10.1	12.2	13.1	13.9
EC_{iw} 12 dS/m									
0.5	0-15	10.9	14.5	10.3	10.9	11.2	12.9	13.2	14.8
	15-30	10.8	15.6	10.5	11.3	11.0	14.3	14.0	15.4
1.0	0-15	11.4	19.2	11.1	11.9	11.8	14.6	17.2	17.9
	15-30	11.2	18.7	11.1	11.7	11.4	17.0	17.4	18.3

*Distance from the plant

STUDIES ON THE PERFORMANCE OF TREE/FRUIT SPECIES IN SALINE AND ALKALI SOIL ENVIRONMENTS

A field experiment based on the findings of preliminary screening was planned in split plot design with 9 tree species in main plots and 2 methods of planting in subplots. The methods of planting comprised of i) conventional pits of 45 x 45 x 45 cm (T_1) and ii) pit auger hole of 45cm x

45cm x 45 cm pit followed by auger hole of 30 cm diameter and 30 cm depth (T_2). The pits were made to keep row-to-row distance 2.5 m and plant to plant 2 m. The required quantity of amendment @ 50% GR (10.3 and 16 meq/100 g for 0-45 and 45-75 cm depth, respectively) was mixed with basaltic murrum (6 kg for T_1 and 8.5 kg for T_2) and sodic soil. The tree saplings of 12 months age were planted in between 23rd July and 7th August 1990. The tree species were removed from the plots by JCB in the year 2005. The plot wise soils samples were collected and analyzed for physico-chemical properties of the soil before sowing of wheat crop. Physico-chemical properties of the soil after 14 years of plantation and after removal of tree species are presented in Table 129.

The data on crop yield in the cleared area revealed that the maximum grain yield of sorghum and wheat was obtained in plots where *Azadirachta indica* was planted followed by *Prosopis juliflora* as the low ESP was observed after 14 years of tree plantation. The minimum grain yield was recorded under *Albizia lebback* plots (Table 130 and 131). Non-significant changes in chemical properties of the soil were noticed after harvest of wheat as the ESP values of the soil are getting stabilized (Table 132).

Table 129 Physico-chemical properties of soil

Particulars	After 14 years of plantation (2004)			After removal of trees (2005)		
	pH_s	EC_e (dS/m)	ESP	pH_s	EC_e (dS/m)	ESP
Initial (1990)	8.8	4.00	35.0	-	-	-
Cassia siamea	8.2	1.29	15.0	8.0	1.12	19.0
Albizia lebback	8.0	0.95	18.8	8.0	1.10	19.6
Casuarina equisetifolia	8.1	0.75	16.6	8.2	0.85	20.2
Azadirachta indica	8.3	0.62	12.6	8.0	0.92	19.6
Acacia nilotica 1994	8.3	1.52	22.4	8.3	1.32	24.1
Hardwickea binnata 1993	8.0	0.96	21.0	8.1	1.16	23.0
Prosopis juliflora	8.1	0.81	8.4	8.1	1.11	23.6
Acacia catechu 1993	8.3	0.62	18.4	8.2	0.92	23.9
Eucalyptus tereticornis	8.3	0.94	19.2	8.3	1.24	23.4

Table 130 Effect of planting of tree species for 14 years on grain yield (t/ha) of sorghum

Tree Species planted	2007			2008		
	T1*	T2*	Mean	T1	T2	Mean
Cassia siamea	1.56	1.64	1.60	0.81	0.87	0.84
Albizia lebback	1.34	1.64	1.52	0.71	0.82	0.76
Casuarina equisetifolia	1.44	1.69	1.56	0.76	0.85	0.81
Azadirachta indica	1.69	1.94	1.81	1.68	1.77	1.73
Acacia auriculiformisa	Data not available as crop failed due to heavy rains			1.07	1.21	1.14
Dalbergia sisoo				0.87	0.95	0.91
Prosopis juliflora				1.60	1.66	1.63
Dendrocalamus strictus				1.30	1.48	1.39
Eucalyptus tereticornis				1.24	1.38	1.31
				Main	Sub	Interaction
CD (5%)				0.07	0.20	0.28

*****original treatments for plants

Table 131 Effect of planting of tree species for 14 years on yield of wheat

Tree Species	Grain yield of wheat (t/ha)					
	2006-07			2007-08		
	T1*	T2*	Mean	T1	T2	Mean
Cassia siamea	1.88	1.93	1.90	3.19	3.81	3.50
Albizia lebback	1.67	1.70	1.68	2.69	3.38	3.03
Casuarina equisetifolia	1.68	1.70	1.69	3.06	3.56	3.31
Azadirachta indica	2.89	2.97	2.93	4.13	4.84	4.48
Acacia auriculiformisa	2.28	2.34	2.31	3.22	3.91	3.56
Dalbergia sisoo	1.54	1.58	1.56	2.50	3.00	2.75
Prosopis juliflora	2.64	2.73	2.69	3.78	4.50	4.14
Dendrocalamus strictus	2.38	2.42	2.40	3.53	4.31	3.92
Eucalyptus tereticornis	2.30	2.35	2.33	3.31	4.13	3.72
	Main	Sub	Interaction	Main	Sub	Interaction
CD (5%)	0.11	0.19	NS	0.19	0.26	NS

*original treatments for plants

Table 132 Chemical properties of soil after harvest of wheat

Tree Species	pH_s		EC_e (dS/m)		ESP	
	T1	T2	T1	T2	T1	T2
Cassia siamea	8.5	8.4	0.64	0.59	22.4	23.4
Albizia lebback	8.4	8.6	0.36	0.58	23.0	22.8
Casuarina equisetifolia	8.6	8.3	0.42	0.53	22.9	22.6
Azadirachta indica	8.6	85	0.46	0.60	19.6	19.2
Acacia nilotica 1994	8.7	8.6	0.54	0.66	22.0	22.4
Hardwickea binnata 1993	8.3	8.4	0.52	0.52	24.6	24.4
Prosopis juliflora	8.4	8.5	0.56	0.54	20.0	20.8
Acacia catechu 1993	8.5	8.3	0.64	0.42	21.6	22.6
Eucalyptus tereticornis	8.4	8.3	0.59	0.58	21.6	22.0

STUDIES ON THE PERFORMANCE OF TREE SPECIES IN ALKALI ENVIRONMENT

Experiments were initiated during December 1998 in a sodic soil (pH 9.2, EC 0.24 dS/m) under rain fed conditions to evaluate different tree species for their performance under different planting techniques and to study the effect of amendments to grow tree crops on sodic soils.

Treatment details:

Main plot : Planting techniques (3)

- M_1 : Pit system (60 cm x 60 cm x 60 cm)
- M_2 : Pit with auger hole (60 cm depth)
- M_3 : Pit with auger hole (120 cm depth)

Sub plot : Soil Amendments (3)

- S_1 : Gypsum @ 50% GR
- S_2 : Spent wash @ 150 ml/kg of soil
- S_3 : Gypsum @ 25% GR +50% spent wash (75 ml/kg of soil)

Out of the ten tree species tested, neem and tamarind established well. These species are being continuously monitored and biometric observations were taken during the reporting period of 2006–07 and 2007-08. Biometric observations on neem, 108 months old, revealed that the girth at stump height (GSH) and girth at breast height (GBH) were highest in pit with auger hole method of planting (M3) during 2006–07 (42.2 and 35.5 cm) and 2007–08 (43.2 and 36.4 cm respectively) (Table 134). Among the amendments, the maximum girth at stump height (GSH) and girth at breast height (GBH) were in application of DSW @ 75 ml/kg soil + gypsum @ 25% of GR/ kg of the excavated soil (S3) during 2006-07 (41.7 and 35.1 cm) and 2007–08 (41.4 and 35.9 cm) respectively (Table 133).

Table 133 Effect of planting techniques and amendments on GSH and GBH of neem

Treatment	2006 – 07				2007 – 08			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
				GSH (cm)				
M_1	31.3	35.5	37.5	34.8	32.2	36.9	38.6	35.9
M_2	36.9	37.3	43.1	39.1	38.3	38.5	44.5	40.4
M_3	42.5	39.7	44.4	42.2	43.8	40.5	45.3	43.2
Mean	36.9	37.5	41.7	-	38.3	39.8	41.4	-
	M	S	M x S	S x M	M	S	M x S	S x M
S Ed	1.06	0.44	0.99	0.68	1.09	0.45	1.02	0.70
CD (5%)	2.59	0.87	2.34	1.39	2.66	0.89	2.41	1.43
				GBH (cm)				
M_1	25.8	29.1	31.3	28.7	26.5	30.2	32.2	29.6
M_2	30.3	30.5	36.0	32.3	31.2	31.2	36.7	33.0
M_3	33.0	35.4	38.0	35.5	33.7	36.5	38.9	36.4
Mean	29.7	31.7	35.1	-	30.5	32.6	35.1	-
	M	S	M x S	S x M	M	S	M x S	S x M
S Ed	1.13	0.39	1.09	0.67	1.16	0.40	1.12	0.69
CD (5%)	2.76	0.79	2.15	1.32	2.84	0.81	2.21	1.36

In case of 8 years old tamarind, pit with auger hole (120 cm) method (M3) recorded a plant height of 3.24 and 3.42 m during 2006-07 and 2007-08 respectively which was at par with other planting methods (Table 135). A GBH of 36.9 and 29.5 cm was recorded in M_3 during the reporting period. Amongst the amendments, the highest tree height of 3.40 and 3.54 m were in application of DSW @150 ml/kg of soil during 2006–07 and 2007-08 respectively. Amendments had no effect on GBH during later periods of crop growth (Table 134).

Overall, pit with auger hole (120 cm) was the best method of planting for establishment and growth. Amendment with DSW @ 75 ml/kg of soil with gypsum @ 25% GR for neem and DSW @ 150 ml/kg of soil for tamarind were found to be better for establishment and tree growth.

PERFORMANCE OF SOME UNCONVENTIONAL METHODS TO IRRIGATE TREE PLANTATIONS IN SODIC BLACK SOILS

Four varieties of aonla (Kanchan, Krishna, NA-10 and NA-7) were planted with some unconventional methods of irrigation (Perforated PVC pipes of 100, 75, 50 and 25 mm diameter embedded to a depth of 40 and 62.5 cm) along with conventional method and tested for establishment of plants during early stage.

The amounts of irrigation water season wise during the years 2006 are abstracted in Table 135. While 1050 liters of irrigation water per plant per year was required during 2006 in unconventional (T_1), in case of conventional (C) it was 1470 liters. It implies that there was around 28.6% saving of irrigation water in T_1 over CB.

Table 134 Effect of planting techniques and amendments on tree height and GBH of Tamarind

Treatment	2006 – 07				2007 – 08			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
				Tree height (m)				
M_1	3.20	3.32	2.75	3.09	3.36	3.45	2.80	3.20
M_2	2.83	3.38	2.87	3.03	2.89	3.53	2.92	3.11
M_3	3.13	3.51	3.24	3.29	3.26	3.65	3.36	3.42
Mean	3.05	3.40	2.95	-	3.17	3.54	3.03	-
	M	S	M x S	S x M	M	S	M x S	S x M
S Ed	0.10	0.11	0.19	0.16	0.10	0.11	0.19	0.17
CD (5%)	NS	0.23	NS	NS	NS	0.23	NS	NS
				GBH (cm)				
M_1	25.6	26.4	32.3	28.1	27.4	28.0	35.8	30.4
M_2	29.2	33.5	27.8	30.2	31.2	36.5	29.6	32.4
M_3	36.5	38.4	35.8	36.9	39.7	42.3	36.6	39.5
Mean	30.4	32.8	32.0	-	32.8	35.6	34.0	-
	M	S	M x S	S x M	M	S	M x S	S x M
S Ed	0.98	0.82	1.31	1.18	1.05	0.88	1.41	1.27
CD (5%)	2.39	NS	NS	NS	2.58	NS	NS	NS

Table 135 Yearly and seasonal water requirement per plant under embedded pipe and check basin method of irrigation

Season	Months	No. of irrigations	Quantity of water Per irrigation (litre)		Total quantity of water applied		Saving %
			C	T1	C	T1	
Winter	Jan-Mar	7	70	50	490	350	-
Summer	Apr-Jun	12	70	50	840	600	-
Rainy	Jul-Dec	2	70	50	140	100	-
Total 2006		21	-	-	1470	1050	28.6

The biometric parameter i.e. circumference at stump height was recorded during the year 2006-07 for all the 4 varieties of Aonla (Table 136). The circumference was 4.92, 3.90, 6.68 and 5.22 cm in case of Krishna, Kanchan and NA-10 and NA-7 respectively when irrigated by method T_1. However, it was 2.18, 1.60, 2.70 and 4.14 cm in case of check basin method of irrigation. The data on survival percentage revealed that survival percentage was 100 % in case of T_1 in Krishna, Kanchan and NA -10 except NA-7 with 60% while in case of CB survival was around 40 %, which was the lowest.

Table 136 Change in thickness and survival during the year 2006-07

Length (mm)	ID	Thickness (cm)				Survival (%)			
		K_1	K_2	NA-10	NA-7	K_1	K_2	NA-10	NA-7
40.0	100	4.92	3.90	6.68	5.22	100	100	100	60
62.5	100	3.10	2.80	7.42	1.82	80	80	100	80
40.0	75	3.62	2.66	2.52	2.72	80	80	60	80
62.5	75	3.38	3.56	1.96	4.42	100	80	40	80
40.0	50	3.64	2.96	2.40	1.92	100	60	60	60
62.5	50	4.00	4.32	4.10	2.26	60	60	80	40
40.0	25	0.22	1.64	0.58	4.20	40	60	40	60
62.5	25	1.30	2.02	1.80	4.44	40	60	40	60
Basin (C)		2.18	1.60	2.70	4.14	40	40	40	40

EFFECT OF DIFFERENT METHODS OF IRRIGATION AND QUALITY OF WATER ON PERFORMANCE OF SOME FRUIT TREES IN A SODIC ENVIRONMENT

Three fruit trees Ber (Banarsi Kadka), Sapota (Kalipatti) and Pomegranate (Ganesh) were transplanted during July to September 2005. Three irrigation systems (viz. Check basin, Drip and through embedded 110 mm diameter perforated vertical PVC pipe of length 40 cm) were used to irrigate the plants. Two qualities of water (normal and diluted distillery waste water) were introduced only in the month of May, 2006. The data revealed that 1610, 376 and 480 liters (2006) and 2790, 1115 and 1480 liters (2007) of irrigation water per plant per year was applied during the study period in check basin, imbedded pipe and drip methods respectively (Table 137). The change in average thickness was worked out by considering average thickness of plants under each treatment at the time of planting and after 1 and 2 year of planting (Table 138). Better growth in terms of thickness 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 thickness was more in case of irrigation by diluted spent wash as compared to irrigation by best available irrigation water.

Table 137 Water requirement (litre/plant/year) under different methods of irrigation

Year	Check basin		Embedded pipe		Drip	
	No. of irrigations	Quantity of water (litre)	No. of irrigations	Quantity of water (litre)	No. of irrigations	Quantity of water (litre)
2006	23	1610	120	376	120	480
2007	31	2790	120	1115	120	1480

Table 138 Change in average girth of fruit trees under different methods of irrigation

Method	Change in thickness (cm)			Change in height (cm)		
	Ber	Sapota	Pomegranate	Ber	Sapota	Pomegranate
Best available water -2006						
Check basin	0.81	0.42	0.52	33.0	13.3	25.4
Embedded pipe	1.21	0.83	0.67	51.9	22.5	26.3
Drip	1.21	0.81	1.05	51.9	20.8	43.9
Diluted spent wash (Spent wash : Water - 1:30)- 2006						
Check basin	0.65	0.50	0.48	19.0	21.0	26.0
Embedded pipe	0.95	0.87	0.94	38.0	23.0	34.0
Drip	0.71	0.78	0.76	25.0	25.0	28.0
Best available water -2007						
Check basin	2.8	3.0	0.7	115.8	52.3	45.4
Embedded pipe	6.4	3.9	4.3	144.8	79.6	113.7
Drip	6.7	4.4	1.5	122.2	86.1	79.8
Diluted spent wash (Spent wash : Water - 1:30)- 2007						
Check basin	4.6	2.6	2.5	143.7	86.0	51.4
Embedded pipe	9.2	4.3	3.7	178.6	101.0	105.1
Drip	8.2	5.2	3.1	173.3	102.0	104.7

EFFECT OF SALINITY ON GROWTH AND YIELD OF MEDICINAL PLANTS

A study on the cultivation of some medicinal plants with saline water was initiated. The initial soil analysis indicated that the EC_e was 0.10 dS/m, pH was 7.5, organic carbon was 0.2%, available N was 84 kg/ha., P_2O_5 was kg/ha, K_2O was 205 kg/ha and the soil type was sandy in nature. The yield of *Aloe vera* grown with different levels of saline water ranging from BAW (2.0 dS/m) to 10.0 dS/m indicated that significantly higher yield was recorded in T_2, i.e. saline water of 2 dS/m (13.13 t/ha) over BAW and was at par with T3, where saline water of 4 dS/m was used. The treatments T_1, T_3 and T_4 were also at par while significantly lower yields were recorded with T_5 and T6. The salt build-up during the growth stage of the crop was very marginal, there being no change in case of BAW (T_1) to 0.75 dS/m in T_6 where saline water of 10 dS/m was used. The variation in soil pH was very marginal. The available N at harvest ranged from 76.0 to 83.0 kg/ha while P_2O_5 ranged from 20.0 to 22.0 kg/ha and available K_2O ranged from 200 to 210.0 kg/ha (Table 139). Kamanchi (*Solanam nigram)* and mint (*Mentha arvensis*) crops in addition to Aloe vera (*Aloe barbadensis*) have been included in the study from second year onwards

Table 139 Yield and changes in soil EC_e, pH and nutrients at harvest of *Aloe Vera*

Treatments	EC_e (dS/m)	pH	Available nutrients (kg/ha)			Yield (t/ha)
			N	P_2O_5	K_2O	
T_1 : BAW	0.10	7.5	80	22.0	204	11.13
T_2 : 2 EC_{iw}	0.35	7.4	81	20.5	210	13.13
T_3 : 4 EC_{iw}	0.40	7.5	79	20.8	208	12.25
T_4 : 6 EC_{iw}	0.56	7.4	82	21.0	205	10.50
T_5 : 8 EC_{iw}	0.68	7.5	76	20.2	200	9.75
T_6 :10 EC_{iw}	0.75	7.5	83	20.0	203	4.63
S Em ±	-	-	-	-	-	0.44
CD (5%)	-	-	-	-	-	1.31
CV (%)	-	-	-	-	-	8.53

INFLUENCE OF DIFFERENT ESP LEVELS ON PERFORMANCE, NUTRIENT UPTAKE AND ACTIVE INGREDIENT OF SOME MEDICINAL AND AROMATIC PLANTS GROWN IN SODIC VERTISOLS

A field experiment was conducted on sodic vertisols at Research Station, Barwaha (three replications at 25, 35, 45 and 55 ESP). The planting/ sowing of babchi, muskdana, sadabahar, lemon grass, palmarosa, kalmegh and ashwagandha was completed at the time of onset of monsoon in last week of July.

The data presented indicated that the survival percentage of different medicinal and aromatic plant species decreased with increasing levels of soil ESP (Table 140). Most of the species failed to survive or their survival was <50% even at ESP 25 due to heavy rains and bad weather condition during the year 2006-07. The survival of babchi and sadabahar was >50% up to ESP 35. Survival per cent for babchi and sadabahar was >50% during 2007-08 as well as 2008-09 at ESP 35. Ashwgandha was quite sensitive to sodic condition, as it could not survive even at ESP 25.

The yield data of medicinal crops showed that the seed yield of isabgol and chandrasur decreased with increasing levels of soil ESP (Table 141). Maximum seed yield (0.68 and 0.74 t/ha of isabgol) and (1.16 and 1.00 t/ha of chandrasur) was recorded at 25 ESP during the year 2006-07 and 2007-08 respectively. The lowest seed yield of isabgol and chandrasur was obtained at 55 ESP. The reduction in the seed yield of isabgol was more than 50% beyond ESP 35, whereas, chandrasur produced satisfactory yield up to ESP 45.

Table 140 Survival of medicinal and aromatic plant species under different ESP levels

Plant species	Survival (%) at ESP levels			
	25	35	45	55
		2006-07		
Babchi	63.0	32.0	20.0	Nil
Muskdana	40.0	20.0	Nil	Nil
Sadabahar	42.0	28.0	11.0	Nil
Kalmegh	9.0	3.0	Nil	Nil
Ashwgandh	Nil	Nil	Nil	Nil
Lemon grass	21.0	12.0	Nil	Nil
Palma rosa	15.0	9.0	Nil	Nil
		2007-08		
Babchi	87.0	70.0	32.0	6.0
Muskdana	43.0	28.0	10.0	2.0
Sadabahar	62.0	51.0	21.0	4.0
Kalmegh	18.0	10.0	2.0	Nil
Palma rosa	6.0	2.0	Nil	Nil

Table 141 Effect of different ESP levels on seed yield of isabgol and chandrasur

ESP levels	Isabgol				Chandrasur			
	2006-07		2007-08		2006-07		2007-08	
	Yield (t/ha)	Per cent reduction	Yield (t/ha)	Per cent reduction	Yield (t/ha)	Per cent reduction	Yield (t/ha)	Per cent reduction
25	0.680	-	0.741	-	1.160	-	1.033	-
35	0.429	36.9	0.500	32.5	0.925	20.3	0.859	17.0
45	0.149	78.1	0.167	77.4	0.748	35.5	0.678	34.3
55	0.080	88.2	0.107	85.5	0.287	75.3	0.292	72.0

EVALUATION OF THE PERFORMANCE OF SOME MEDICINAL AND AROMATIC PLANTS IN SALINE VERTISOLS

Earlier attempts to replace the existing paddy-paddy could not succeed because this cropping pattern gave highest economic benefits. On the other hand, increasing shortage of water failed to sustain this cropping sequence and also caused increasing problems of water logging and soil salinity in low-lying areas. Thus, need to have a more economic crop/cropping sequence is needed to convince the farmers to shift from paddy to other light irrigated crops. Thus, pot culture experiments (2005-06, 06-07 and 07-08) with natural saline soils having salinity values of 2, 4, 6, 8 and 10 dS/m and field trials (2006-07, 07-08 and 08-09) under natural salinity gradients were initiated with some medicinal and aromatic plants to evaluate their salt tolerance.

The pot culture experiment (CRD with four replications) was conducted in cement cisterns (30 cm diameter and 70 cm height) filled with known graded levels (2, 4, 6, 8 and 10 dS/m) of natural saline soils (*Salic chromousterts*). The test plants during 2007-08 included ashwagandha (*Withania somnifera*), stevia (*Stevia rubidiana*), adathoda (*Adhatoda vasica*) and insulin (*Salacia oblonga*).

Field experiment under natural salinity gradient included ashwagandha and palmarosa (*Cymbopogon martini*) during 2006-07 and ashwagandha, palmarosa, vetiver (*Vetiveria zizanioides*) and lemon grass (*Cymbopogon citrates*) during 2007-08. Each crop was planted in three rows of 5 m length in each salinity block along the salinity gradient, which ranged from 0.63 to 9.1 dS/m (2006-07) and <1.0 dS/m to around 16 dS/m (2007-08). Soil salinity (0-30 cm depth) in each salinity block was estimated by drawing representative samples at regular time intervals for computing Time Weighted Mean Salinity (TWMS). The yield of economic part (seed/ root/ foliage yield) in each block was related to TWMS using SEGREG programme.

Pot culture experiment

Effect of soil salinity on the seed and root yields of ashwagandha (g/plant) was maximum at EC_e 5.48 dS/m (Table 142). The reduction in root yield was more (-19.1%) than seed yield (-11.6%) at 8.46 dS/m indicating that root growth was relatively more sensitive to salinity than seed. In stevia, the foliage yield was maximum (36.7 g/pot) at 3.54 dS/m and the maximum yield reduction (-21.8%) occurred at 8.46 dS/m. Adhatoda was observed to have relatively higher salt-tolerance as it recorded maximum dry matter (58.7 g/pot) at 5.48 dS/m. In case of insulin plant, the highest dry matter (224 g/pot) was recorded at 1.58 dS/m, which decreased with increasing salinity. Based on these results, ashwagandha and adhatoda could be categorized relatively more salt-tolerant than stevia and insulin.

Table 142 Effect of salinity on the yield (g/plant) of economic plant parts

Crop (Economic plant part)	Soil salinity levels - TWMS (EC_e, dS/m)					CD (5%)
	1.58	3.54	5.48	7.12	8.46	
Ashwaganda (root)	3.20 (-8.60)	3.23 (-7.7)	3.50 (0.0)	3.33 (-4.8)	2.33 (-19.1)	0.33
Ashwaganda (seed)	21.7 (-15.9)	23.7 (-8.1)	25.8 (0.0)	25.7 (-0.4)	22.8 (-11.6)	1.2
Stevia (foliage)	36.5 (-0.5)	36.7 (0.0)	36.0 (-1.9)	30.2 (-17.7)	28.7 (-21.8)	2.40
Adhatoda (foliage)	54.7 (-6.8)	56.6 (-3.6)	58.7 (0.0)	48.3 (-17.7)	46 (-21.6)	3.60
Insulin (foliage)	224 (0.0)	200 (-10.2)	192 (-14.3)	186 (-17.0)	162 (-27.6)	8.20

Field experiment

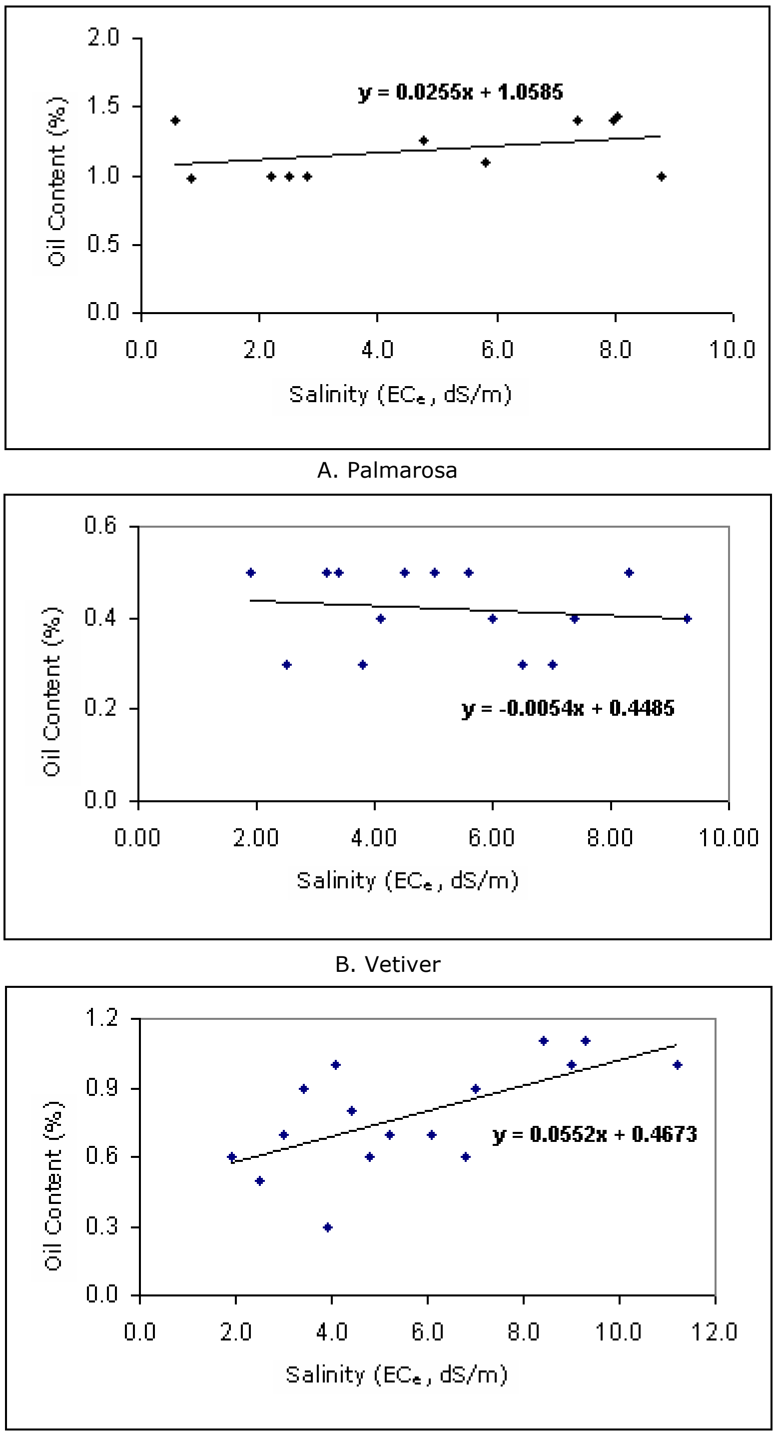
The threshold salinity for various crops was estimated using SEGREG. Results revealed that the threshold salinity for seed yield of ashwagandha was higher compared to root yield in both the years of testing (6.41 dS/m versus 5.87 dS/m and 5.69 dS/m versus 5.48 dS/m during 2006-07 and 2007-08 respectively). The higher EC_t values for seed yield compared to root yield indicated the lesser tolerance of root to salinity (Table 143). Palmarosa was also found to be relatively more salt-tolerant recording EC_t of 6.46 dS/m during 2006-07. Though the trend was similar during 2007-08, EC_t levels of ashwagandha and palmarosa were lower compared to 2006-07.

Table 143 Threshold salinity (EC_t) level of medicinal and aromatic plants

Crop (Economic plant part)	Threshold salinity (EC_t, dS/m)	
	2006-07	2007-08
Ashwaganda (seed)	6.41	5.69
Ashwaganda (root)	5.87	5.48
Palmarosa (foliage)	6.46	5.54
Vetiver (root)	-	6.98
Lemon grass (foliage)	-	4.93

Among all the crops tested during 2007-08, vetiver (EC_t, 6.98 dS/m) was relatively more salt-tolerant followed by ashwagandha (EC_t, 5.69 and 5.48 dS/m), palmarosa (EC_t, 5.54 dS/m) and lemon grass (EC_t, 4.93 dS/m).

The oil content of aromatic grasses viz; palmarosa (foliage), vetiver (root) and lemon grass (foliage) was estimated during 2007-08 (Fig. 49). In case of palmarosa, the oil content marginally increased with increasing salinity up to around 9 dS/m. The oil content in vetiver nearly remained almost constant up to 9 dS/m. Interestingly, the oil content showed a remarkable increasing trend with increasing salinity in lemon grass till 11 dS/m.



C. Lemon grass

Fig. 49 Effect of soil salinity on oil content of some aromatic grasses

EVALUATION OF *JATROPHA CURCAS* IN ALKALI SOILS UNDER IRRIGATED CONDITION

This experiment was conducted to evaluate the cultivation of *Jatropha Curcas* in alkali soils under irrigated conditions. The main objectives are to develop suitable spacing and amendments for *Jatropha* cultivation by assessing the effect of amendments on plant growth and yield.

Treatment details:

Main plot: Spacing (3)

M_1 : 2.5 m x 2.5 m
M_2 : 3.0 m x 3.0 m
M_3 : 3.5 m x 3.5 m

Subplot: Amendments (5)

S_1 : Native soil with gypsum @ 50 % GR
S_2 : Native soil with DSW @ 150 ml/kg of excavated soil from the pit
S_3 : Native soil with gypsum @ 25% GR + DSW@ 75ml/kg of excavated soil from the pit
S_4 : Composted coir pith @ 15 t/ha
S_5 : No amendment

Design : Split plot
Replications : Three

The experiment was laid out and planting completed in the month of October 2008. The experiment is in progress.

D. SCREENING OF CROP CULTIVARS AND GENOTYPES

- **Screening of Elite Varities of Crops for Cultivation under Irrigation with Poor Quality Water**
- **Screening of Elite Mustard Cultivars for Saline Irrigation**
- **Screening of Elite Varieties of Mustard for Sodicity Tolerance in Sodic Vertisol (IVTt and AVT)**
- **Screening of Crop Genotypes for Salt Tolerance**
- **Screening of Elite Varieties of Crops for Cultivation on Saline and Alkali Soils**
- **Response of Finger Millet Genotypes to Nitrogen Levels under Saline Conditions of TBP Irrigation Command**
- **Tolerance of Cotton Varieties to Saline Water Irrigation under Drip System**

SCREENING OF ELITE VARIETIES OF CROPS FOR CULTIVATION UNDER IRRIGATION WITH POOR QUALITY WATER

In year 2006-07, salt tolerance of ten genotypes of cotton (NH-130, RAH-205, GTHV-205, H-1226, CPD-818, GTHV-01/124, HAG-811, KH-144, H-1117 and LH-2076) and ten genotypes of wheat (WH-1025, WH-1016, WH-1021 , WH-1012, WH-1043, WH-1015, WH-157, WH-1036, WH-1040 and KRL-19) were tested. In year 2007-08, the tolerance of seven genotypes of cotton (NH-130, RAH-205, H-1117, KH-144, H-1226, CPD-818 and HAG-811), five genotypes of Mustard (CSCN-13, CSCN-14, CSCN-15, CSCN-16 and CSCN-17), fourteen genotypes of wheat (WH-1045, WH-1051, WH-1052, WH-1053, WH-1054, WH-1058, WH-1061, WH-1062, WH-1063, WH-1076, WH-1077, WH-1078, WH-1080 and KRL-19) and twelve genotypes of oats (JHO-99-2, NGB-4871, NGB-6370, NGB-7253, NGB-7022, NGB-7021, NGB-7245, JHO-851, JHO-822, NGB-4462, OS-6 and HJ-8) were tested. The tolerance of crops was evaluated in lined micro-plots of 2 m x 2 m in size. For cotton, wheat and mustard, the levels of irrigation water were canal water, EC_{iw} 2.5, 5.0 and 7.5 dS/m, whereas, for oats levels were canal water, EC_{iw} 4, 8 and 12 dS/m.

Cotton

In year 2006, the maximum plant stand was recorded in H-1117 and H-1226 at the highest salinity level but number of plants/plot decreased with increase in salinity (Table 144). The differences in plant population were statistically significant amongst the genotype tested at every level of salinity. Maximum numbers of opened bolls were recorded in H-1226 followed by GTHV-01/124 in the control as well as at the highest level of salinity. Decrease in seed cotton yield/plant was recorded with the increase in salinity levels. Cotton plant height decreased significantly with the increasing levels of salinity. Seed cotton yield/plot was maximum in H-1226 followed by H-1117. The lowest yield was obtained with genotype CPD-818.

In year 2007, increasing salinity led to a gradual decrease in cotton production (Table 145). The mean yield of H-1117 was significantly higher than other genotypes followed by H-1226. Amongst the seven genotypes, RAH-205 was the lowest yielder. Logrithmic equations developed for cotton yields as affected by salinity had R^2 values ranging from 0.85 in HAG 811 to 0.98 in RAH 205 (Table 146). The coefficient of Ln in the equations ranged from -38.328 in H-1226 to -22.659 in NH-130. The constant term in the equations ranged from 80.333 in H-1117 to 137.47 in H-1226. Amongst the various physiological parameters studied excised leaf water level (ELWL %) an indication of rate of transpiration (Table 147) showed r^2 of 0.5. The two better performing genotypes showed least effect of salinity on this parameter even at the highest level of salinity where all the other genotypes showed a steep reduction at the highest level or even below that. Spad readings (Table 148), an indication of the chlorophyll content in the leaves did not show any consistent pattern of effects with a poor –ve correlation with cotton yield.

Table 144 Effect of mean salinity on growth and yield of cotton genotypes (2006)

Genotypes	Plant population	Plant height (cm)	No. of opened bolls / plant	Seed cotton yield (g/m^2)
NH -130	8.38	96.39	4.50	91.52
RAH-205	8.38	99.67	5.66	92.50
GTHV-205	10.75	79.63	3.79	92.78
H-1226	11.88	99.88	6.50	143.77
CPD-818	7.25	92.92	5.41	86.23
GTHV-01/124	10.63	87.38	5.91	123.75
HAG-811	11.13	84.63	4.71	115.97
KH-144	8.75	82.96	3.50	87.27
H-1117	12.75	64.04	5.41	131.62
LH-2076	11.25	83.29	3.92	103.55
CD (5%) Salinity	0.39	1.02	0.23	2.57
Variety	0.24	0.65	0.14	1.63
S x V	0.77	2.05	0.46	5.14

Table 145 Effect of saline water (EC_{iw} dS/m) on yield of cotton genotypes (2007)

Genotypes	Seed cotton yield (g/m^2)				
	Control	2.5	5.0	7.5	Mean
NH -130	103.53	80.37	57.23	39.13	70.07
RAH-205	98.67	53.13	44.97	28.63	56.35
H-1117	156.20	106.50	75.17	93.90	107.94
KH-144	124.93	97.83	59.13	72.93	88.71
H-1226	166.03	100.87	66.53	69.00	100.61
CPD-818	129.30	79.73	65.23	32.97	76.81
HAG-811	114.17	98.00	52.53	41.23	76.48
Mean	127.55	88.06	60.11	53.97	-
CD (5%)	Salinity (S) : 2.17	Variety (V) : 2.88	S x V : 5.75		

Table 146 Values of logarithmic equations developed for different cotton genotypes

Genotype	Logarithmic equations	R^2
NH 130	y = -22.659Ln(x) + 91.86	0.93
RAH 205	y = -24.934Ln(x) + 80.333	0.98
H 1117	y = -27.126Ln(x) + 134.03	0.87
KH 144	y = -22.517Ln(x) + 110.36	0.86
H 1226	y = -38.328Ln(x) + 137.47	0.97
CPD 818	y = -32.984Ln(x) + 108.50	0.96
HAG 811	y = -27.167Ln(x) + 102.61	0.85

Table 147 Effect of salinity on ELWL per cent shown by different cotton Genotypes

Genotypes	EC_{iw} (dS/m)			
	0.5	2.5	5.0	7.5
NH 130	23.60	24.30	27.55	15.85
RAH 205	28.75	29.75	18.65	19.45
H 1117	25.20	28.20	26.95	29.40
KH 144	22.20	37.95	26.35	18.45
H 1226	28.25	32.80	27.35	26.65
CPD 818	29.40	19.05	18.45	16.60
HAG 811	36.30	22.20	18.80	19.80

Table 148 Effect of salinity on spad readings shown by first fully expanded leaf from the top of cotton genotypes

Genotypes	EC_{iw} (dS/m)			
	0.5	2.5	5.0	7.5
NH 130	33.9	28.7	32.2	20.8
RAH 205	23.2	29.2	44.2	33.1
H 1117	55.4	55.1	45.5	48.9
KH 144	30.6	28.8	32.0	34.5
H 1226	29.5	36.4	37.6	46.8
CPD 818	37.0	45.5	42.6	34.0
HAG 811	29.2	34.8	41.1	42.2

Wheat

In year 2006-07, the data on tolerance of wheat genotypes showed that the yield of different varieties of wheat decreased with an increase in EC of the irrigation water (Table 149). Genotype WH-1043 gave the maximum yield followed by WH-1036. However, the genotypes WH- 1016, WH-1025, and WH-1012 yielded comparatively much less than other genotypes.

Table 149 Grain yield of wheat genotypes affected by different saline waters (2006-07)

Genotypes	Grain yield (g/m^2)				
	Canal	2.5	5.0	7.5	Mean
WH-1025	383.33	316.67	275.00	166.67	285.42
WH-1016	375.00	262.33	208.33	175.00	255.17
WH-1021	412.33	350.00	308.33	241.67	328.08
WH-1012	350.00	291.67	241.67	225.00	277.08
WH-1043	475.00	400.00	308.33	300.00	370.83
WH-1015	412.33	291.67	316.67	266.67	321.83
WH-157	350.00	333.33	283.33	275.00	310.42
WH-1036	437.33	341.67	325.00	283.33	346.83
WH-1040	450.00	300.00	285.00	241.67	319.17
KRL-19	341.67	308.33	291.67	258.33	300.00
Mean	398.70	319.57	284.33	243.33	-
CD (5%)	Variety : 36.72	Salinity : 23.22	V x S : NS		

In year 2007-08, The genotype WH-1063 gave the maximum yield followed by WH-1080 at EC_{iw} of 7.5 dS/m. However, the genotypes WH-1076, WH-1053, and WH-1052 yielded comparatively much less than other genotypes (Table 150). The physiological data of genotypes was recorded for assimilation rate, stomatal conductance, intracellular CO_2 concentration and transpiration rate and tolerant entries were identified on the basis of mean performance (numerical superiority) over the best check KRL 19 (Table 151). Entries viz. WH-1063, WH-1054 and WH-1078 were identified as tolerant genotypes on the basis of physiological parameters.

Table 150 Grain yield of wheat genotypes as affected by saline waters during 2007-08

Genotypes	Grain yield (g/m^2)				Mean
	Canal	2.5	5.0	7.5	
WH-1045	375	300	250	180	276.2
WH-1051	250	225	200	170	211.2
WH-1052	350	300	200	150	250.0
WH-1053	350	225	175	100	212.5
WH-1054	425	300	250	200	293.7
WH-1058	300	250	225	175	237.5
WH-1061	315	265	235	210	256.2
WH-1062	300	275	250	215	260.0
WH-1063	360	305	265	235	291.2
WH-1076	250	225	150	100	181.2
WH-1077	335	290	240	200	266.2
WH-1078	450	300	250	175	293.7
WH-1080	300	265	250	225	260.0
KRL-19	350	285	200	175	252.5
Mean	336.43	272.14	224.29	179.29	
CD (5 %)	Variety: 21.79	Salinity: 11.65	V X S : 43.59		

Table 151 Physiological parameters measured on the flag leaf of wheat genotypes during the grain filling stage under control and salt stress of 5 and 7.5 dS/m (mean)

Genotypes	Assimilation rate ($\mu mol/m^2/s$)	Stomatal conductance ($mol/m^2/s$)	Transpiration rate ($mmol/m^2/s$)	Intercellular CO_2 Concentration (ppm)
WH1045	7.49	0.192	4.77	231.2
WH1051	5.26	0.085	2.56	276.0
WH1052	5.71	0.107	2.84	265.7
WH1053	8.23	0.190	5.88	281.7
WH1054	9.77	0.280	6.93	217.2
WH1058	6.99	0.120	3.77	282.5
WH1061	6.30	0.125	3.70	288.0
WH1062	7.80	0.195	4.53	278.0
WH1063	10.42	0.382	8.06	195.0
WH1076	7.32	0.152	4.61	284.5
WH1077	6.07	0.097	3.46	235.5
WH1078	8.75	0.285	5.70	230.5
WH1080	8.47	0.197	5.35	233.2

Mustard

In mustard, genotype CSCN-13 had significantly higher mean yield (268.8 g/m^2) than other genotypes tested (Table 152). However at the highest salinity level (7.5 dS/m) the genotype CSCN-15 gave the maximum yield (175.0 g/m^2) followed by CSCN-13 (170.8 g/m^2). The mean yield reduced by 54.8% at EC_{iw} of 7.5 dS/m as compared to canal water irrigation.

Table 152 Effect of saline waters (EC_{iw} dS/m) on seed yield of mustard genotypes

Genotypes	Seed yield (g/m^2)				
	Control	2.5	5.0	7.5	Mean
CSCN-13	358.3	329.2	216.7	170.8	268.8
CSCN-14	400.0	283.3	216.7	133.3	258.3
CSCN-15	316.7	308.3	195.8	175.0	249.0
CSCN-16	325.0	216.7	183.3	158.3	220.8
CSCN-17	266.7	229.2	166.7	116.7	194.8
Mean	333.3	273.3	195.8	150.8	-
CD (5%)	Salinity : 25.78	Variety : 28.83	S x V : NS		

Oat

The mean values of all the treatments indicated that genotype NGB-6370 produced the maximum yield followed by JHO-99-2, JHO-822, NGB-7021 and OS-6 (Table 153). The lowest yielder genotype was JHO-851.

Among the genotypes, except NGB-4871 (84.64%) and NGB-4462 (84.42%) rest of the genotypes maintained above the 86% RWC values (Table 154). The highest values was noticed in NGB-7022 (89.64%) followed by NGB-6370 (88.61%), JHO-822 (88.18%) and JHO-99-2 (81.85%). The osmotic potential (ψ_S) of leaves were most '–ve' value of ψ_S was noticed in NGB-6370 (-2.26) followed by JHO-822 (-2.09), NGB-7022 (-2.04), JHO-99-2 and NGB-7021(-2.01) while low '-ve' values were in NGB-4462 (-1.76), JHO-851 (-1.86) OS-6 and NGB-4871 (-1.87). More '-ve' values of ψS help in the process of osmoregulation i.e. improve the physiological efficiency of plants under adverse conditions by maintaining better RWC.

The maximum relative stress injury (RSI %) varied from 46.13 to 48.85% observed in genotypes NGB-4462, NGB-4871, JHO-851, OS-6, HJ-8, NGB-7245 and NGB-7253. The minimum RSI (%) was noticed in NGB-6370 (42.43%) followed by NGB-7022 (42.23%), NGB-7021 (44.11%), JHO-99-2 (44.47%) and JHO-822 (44.50%). Almost a similar trend was followed by these genotypes with regards to MDA content (Malondialdehyde – a product of Lipid peroxidation, which is generally measured for membrane injury).

Table 153 Grain yield of oat genotypes at different salinity levels EC_{iw} (dS/m)

Genotypes	Grain yield (g/m^2)				Mean
	Canal	4	8	12	
JHO-99-2	297	186	176	142	200.25
NGB-4871	74	58	49	20	50.25
NGB-6370	347	288	232	184	262.75
NGB-7253	160	127	129	66	120.50
NGB-7022	179	163	123	94	139.75
NGB-7021	224	204	174	132	183.50
NGB-7245	154	142	134	94	131.00
JHO-851	56	48	22	18	36.00
JHO-822	318	216	153	109	199.00
NGB-4462	130	90	66	45	82.75
OS-6	208	201	153	132	173.50
HJ-8	157	130	102	92	120.25
Mean	192	154.42	126.08	94.0	-
CD (5%)	Variety : 9.34	Salinity : 5.39	V X S : 18.68		

Genotype JHO-99-2 maintained the maximum total chlorophyll content (2.42) followed by NGB-7022, NGB-6370, JHO_822 and NGB-7021 (2.00). The lowest amount of chlorophyll was estimated in NGB-4871 (1.59) followed by NGB-4462 (1.66). Among the genotypes Na^+/K^+ ratio was maximum in NGB-4462 (1.08) followed by NGB-4871 (0.92), NGB-7022 (0.89) and HJ-8 (0.89) (Table 154). Exceptionally the lowest values were noticed in NGB-7245 (0.62) and JHO-851 (0.70), showing the avoidance mechanism by roots and needs further investigations.

Table 154 Effect of salinity stress on growth, water relations, membrane injury, ionic content, chlorophyll and yield of oat genotypes

Genotypes	Plant height (cm)	Leaf area per plant (cm^2)	Dry weight (g/plant)	RWC (%)	ψ_S (-M Pa)	RSI (%)	MDA content (µg/g dw)	Total Chlorophyll (µg/gdw)	Na^+/K^+ ratio	Grain yield (g/m^2)
JHO-99-2	62.58	369.53	4.57	87.85	2.01	44.12	342.80	2.42	0.83	200.25
NGB-4871	55.92	212.46	2.95	84.64	1.87	48.13	488.48	1.59	0.92	50.25
NGB-6370	60.25	525.68	4.63	88.61	2.26	42.43	363.40	2.19	0.88	262.25
NGB-7253	48.08	334.69	3.15	87.64	1.98	46.92	403.61	1.97	0.86	120.50
NGB-7022	58.58	396.16	4.21	89.64	2.04	42.23	323.66	2.32	0.89	139.75
NGB-7021	63.25	467.14	4.63	87.11	2.01	44.11	303.83	2.00	0.84	183.50
NGB-7245	58.25	302.85	3.49	86.07	1.99	46.23	364.71	1.99	0.62	131.00
JHO-851	38.75	225.82	1.85	86.07	1.86	46.88	397.46	1.85	0.70	36.00
JHO-822	70.83	387.87	3.36	88.18	2.09	44.50	290.97	2.08	0.81	199.00
NGB-4462	53.92	171.15	1.98	84.42	1.76	48.85	567.28	1.66	1.08	82.75
OS-6	70.42	258.30	3.03	86.63	1.87	46.63	408.90	1.75	0.84	173.50
HJ-8	79.58	330.33	3.15	87.65	1.94	46.13	393.90	1.87	0.89	120.25
Mean	60.04	315.16	3.58	87.05	1.97	45.51	387.48	1.82	0.85	141.62
CD (5%)	2.11	3.46	0.90	1.45	0.11	1.64	13.50	0.14	0.012	9.34

SCREENING OF ELITE VARITIES OF MUSTARD FOR SALINE IRRIGATION

An experiment was carried out to screen mustard cultivars supplied by NRC on Rapeseed-Mustard, Bharatpur during 2006-07 to 2007-08. The cultivars were different in different years with their code names. The crop was irrigated with saline water of 12 dS/m.

The different cultivars had different yield potential under saline (EC_{iw} 12 dS/m) irrigation (Table 155). During 2006-07, CSCN-06 series produced grain yield in the range of 1.69 to 1.27 t/ha. The highest yield of 1.69 t/ha was obtained for CSCN-06-3 while the lowest yield of 1.27 t/ha with CSCN-06-7. However, during 2007-08, the series CSCN-08 produced grain yield in the range of 1.34 t/ha to 0.67 t/ha. The highest yield was recorded with CSCN-08-1 (1.34 t/ha) followed by CSCN-08-5 (1.22 t/ha). The cultivars CSCN-08-6, CSCN-08-7 and CSCN-08-8 produced lowest grain yield (0.67 t/ha).

Table 155 Effect of saline water irrigation on seed yield of mustard

2006-07		2007-08	
Genotypes	Seed yield (t/ha)	Genotypes	Seed yield (t/ha)
CSCN-06-1	1.56	CSCN-08-1	1.34
CSCN-06-2	1.35	CSCN-08-2	1.12
CSCN-06-3	1.59	CSCN-08-3	0.83
CSCN-06-4	1.69	CSCN-08-4	0.90
CSCN-06-5	1.41	CSCN-08-5	1.22
CSCN-06-6	1.55	CSCN-08-6	0.67
CSCN-06-7	1.27	CSCN-08-7	0.67
CSCN-06-8	1.37	CSCN-08-8	0.67
CSCN-06-9	1.34	CSCN-08-9	1.06
CSCN-06-10	1.25	CSCN-08-10	1.09
CSCN-06-11	1.41	CSCN-08-11	0.88
CSCN-06-12	1.34	CSCN-08-12	0.77
CSCN-06-13	1.46	CSCN-08-13	0.98
CSCN-06-14	1.36	CSCN-08-14	0.98
CSCN-06-15	1.31	CSCN-08-15	0.86
CSCN-06-16	1.49	-	-
CSCN-06-17	1.64	-	-

During 2006-07 twelve genotypes under Initial Varietal Trial (IVT) and five genotypes under Advanced Varietal Trial (AVT) at EC_{iw} of 6.0 dS/m were tested for their salt tolerance. It was observed that in IVT genotypes CSCN-11, CSCN-06 and CSCN-07 produced higher seed yield as compared to other genotypes and in AVT CSCN-17 produced higher seed yield as compared to other genotypes. During 2007-08 ten genotypes under Initial Varietal Trial (IVT) and five genotypes under Advanced Varietal Trial (AVT) were tested for salt tolerance at EC_{iw} 6.0 dS/m. In IVT significantly higher seed yield was produced by the genotype CSCN-5 followed by CSCN-1, whereas in AVT, CSCN-13 produced higher seed yield as compared to other genotypes (Table 156).

SCREENING OF ELITE VARIETIES OF MUSTARD FOR SODICITY TOLERANCE IN A SODIC VERTISOL (IVT AND AVT)

The experiment was conducted with 10 elite varieties (CSCN 1 to CSCN 10) supplied by the Project Coordinator, AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture, CSSRI, Karnal at Barwaha Research Farm during 2007-08 at soil ESP 35±2. The yield of varieties tested under IVT was in order of CSCN 10 >CSCN 3 >CSCN 9 >CSCN 2 >CSCN 5 >CSCN 1 >CSCN 7 >CSCN 4 >CSCN 6 on the basis of seed yield. The order of performance was of CSCN 9 >CSCN 2 >CSCN 3 on the basis of seed yield, oil content and 1000 seed weight.

The experiment was carried out with 5 promising varieties (CSCN 11 to CSCN 15) supplied by the Project Coordinator, AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture, CSSRI, Karnal at Barwaha Research Farm during 2007-08 at soil ESP 35±2. The varieties tested under AVT trial showed outstanding performance. The yield performance of different varieties was in order of CSCN 13 >CSCN 14 >CSCN 15 >CSCN 11 >CSCN 12 on the basis of seed yield. The order of performance was of CSCN 14 >CSCN 15 >CSCN 11 on the basis of seed yield, oil content and 1000 seed weight.

Table 156 Effect of saline water irrigation on seed yield of mustard

2006-07		2007-08	
Genotypes	Seed yield (t/ha)	Genotypes	Seed yield (t/ha)
	IVT		
CSCN- 1	1.60	CSCN- 1	2.56
CSCN- 2	1.94	CSCN- 2	2.28
CSCN- 3	2.20	CSCN- 3	2.31
CSCN- 4	1.67	CSCN- 4	2.18
CSCN- 5	1.99	CSCN- 5	2.62
CSCN- 6	2.37	CSCN- 6	1.48
CSCN- 7	2.32	CSCN- 7	2.42
CSCN- 8	1.98	CSCN- 8	2.16
CSCN-9	2.13	CSCN-9	2.09
CSCN-10	2.08	CSCN-10	2.44
CSCN-11	2.46	CD (5%)	0.49
CSCN-12	1.96		
CD (5%)	0.22		
	AVT		
CSCN-13	1.82	CSCN-11	0.93
CSCN-14	1.79	CSCN-12	1.54
CSCN-15	1.92	CSCN-13	1.87
CSCN-16	1.89	CSCN-14	1.65
CSCN-17	2.04	CSCN-15	1.27
CD (5%)	0.25	CD (5%)	0.30

SCREENING OF CROP GENOTYPES FOR SALT TOLERANCE

Sugar beet

Screening of three sugar beet genotypes viz. Indus, Cauvery and Shubra was continued at ARS, Gangawati under natural salinity gradient ranging from 2 dS/m to 20 dS/m during the year 2007 and 2008. Shubra genotype was included in screening trial during the year 2007. The yield levels obtained during 2007 ranged between 30.7 to 38.0 t/ha in Indus, between 27.3 to 36.5 t/ha in Cauvery and between 27.4 to 37.1 t/ha in Shubra variety under different soil salinity levels (Table 158). Amongst the varieties Indus recorded higher yield when compared to Cauvery and Shubra (Table 157 and 158).

The soil salinity values recorded after harvest of crop ranged between 1.26 to 18.30 dS/m. The experiment was continued during 2008-09 and crop is yet to be harvested.

Table 157 Yield and No. of beets/block of sugar beet genotypes at various salinity levels

Block No. (10 m)	Yield (t/ha)			No. of beets/block		
	Indus	Cauvery	Shubra	Indus	Cauvery	Shubra
1	37.5	35.2	36.4	44	40	39
2	38.0	36.5	37.1	45	42	43
3	36.6	33.4	35.5	42	38	41
4	36.2	34.7	35.7	40	43	42
5	34.7	32.8	33.6	38	40	40
6	35.0	33.4	34.1	35	36	37
7	34.6	31.7	33.8	35	33	34
8	33.8	31.0	33.0	33	32	30
9	33.7	32.5	32.5	36	30	35
10	31.0	27.3	29.5	32	35	33
11	31.6	28.7	27.4	30	34	32
12	30.7	28.4	28.3	29	30	31

Table 158 Test weight of beets and soil salinity under different salinity blocks (2007)

Block No. (10 m)	Test weight of 10 beets (kg)			Soil salinity (dS/m)	
	Indus	Cauvery	Shubra	Before sowing	After harvest
1	14.5	14.1	14.0	1.22	1.26
2	14.0	13.7	14.1	1.55	1.67
3	14.2	14.1	13.5	1.60	1.75
4	13.8	13.6	13.3	3.80	4.10
5	13.6	13.3	13.0	4.50	5.32
6	13.5	13.1	13.2	4.20	5.60
7	13.0	12.6	12.9	6.50	7.00
8	12.5	12.0	12.2	7.20	7.70
9	12.7	12.4	12.5	7.00	7.60
10	12.2	11.9	12.1	12.50	13.00
11	11.5	11.0	11.3	13.30	15.20
12	10.3	10.2	10.5	17.10	18.30

Safflower

This study was undertaken in collaboration with Directorate of Oilseeds Research, Hyderabad. The experimental conditions were:

Soil salinity: Range: 5.32-7.58 dS/m; Mean: 6.16 dS/m

Soil pH: Range: 8.14-8.38; Mean: 8.25
No. of entries tested: 140

The performance of promising entries of safflower, yielding higher than or equal to best check are reported in Table 159.

Table 159 Comparative yield of safflower accessions and best check in saline soil

Accessions	Seed yield (kg/ha)	Plant height (cm)	No. of effective capitula/plant	100 seed weight (g)
GMU-3126	708	46.4	11	3.9
GMU-3133	704	55.8	18	4.6
GMU-3201	700	44.0	14	4.2
GMU-3164	681	47.6	11	4.0
GMU-3138	678	56.8	14	5.0
GMU-3111	674	51.6	10	4.5
GMU-3112	645	46.2	11	3.4
GMU-3136	637	53.0	14	4.9
GMU-3123	630	48.4	11	3.9
GMU-3106	601	52.8	17	3.8
GMU-3124	582	60.0	18	3.1
GMU-3109	534	48.4	11	3.3
GMU-3203	518	47.6	14	3.4
GMU-3105	515	51.2	14	5.1
GMU-3117	496	53.2	13	3.2
GMU-3130	493	51.8	10	4.1
GMU-3208	493	51.2	15	4.6
GMU-3110	482	50.0	13	2.6
GMU-3144	482	46.4	11	2.7
GMU-3108	474	44.6	11	3.9
GMU-3134	474	49.4	15	5.1
GMU-3171	459	47.4	12	4.8
GMU-3207	459	53.0	21	5.4
Best check (Bhima)	459	50.2	13	4.3

SCREENING OF ELITE VARIETIES OF CROPS FOR CULTIVATION ON SALINE AND ALKALI SOILS

Mustard

The performance of seventeen (2006-07) and fifteen (2007-08) genotypes of mustard was evaluated at sodicity level of 41 and 43 ESP respectively. The seed yield of genotypes varied from 0.58 t/ha (CSCN-06-12) to 1.08 t/ha (CSCN-06-2) and 0.74 t/ha (CSCN-07-8) to 1.40 t/ha (CSCN-07-11) during 2006-07 and 2007-08 respectively (Table 160).

Garlic

The performance of three varieties of garlic (Hansa, Desi and Gatter gola) were evaluated at different alkali gradients (ESP levels of 51.9, 42.0, 32.2 and 21.5) under field condition during 2006-07. The bulb yield of garlic decreased with increasing levels of alkalinity. Percent yield reduction due to sodicity (Table 161) as compared to average normal soil yield (15 t/ha) indicated that maximum reduction in yield (46%) was recorded with variety 'Desi' followed by 'Hansa' (44%) and 'Gatter gola' (39%).

Table 160 Performance of mustard genotypes under sodic conditions

2006-07			2007-08		
Genotypes	Seed yield (t/ha)	Test weight (gm)	Genotypes	Seed yield (t/ha)	Test weight (gm)
CSCN-06-1	0.78	4.98	CSCN-07-1	1.00	7.00
CSCN-06-2	1.08	4.37	CSCN-07-2	0.83	7.23
CSCN-06-3	0.73	4.79	CSCN-07-3	0.81	7.59
CSCN-06-4	0.69	4.57	CSCN-07-4	0.92	6.80
CSCN-06-5	0.83	3.87	CSCN-07-5	1.05	7.15
CSCN-06-6	0.89	3.98	CSCN-07-6	0.91	3.33
CSCN-06-7	0.82	4.04	CSCN-07-7	0.94	5.54
CSCN-06-8	0.73	4.20	CSCN-07-8	0.74	4.85
CSCN-06-9	0.70	4.68	CSCN-07-9	0.88	6.69
CSCN-06-10	0.77	4.20	CSCN-07-10	1.16	8.15
CSCN-06-11	0.81	4.17	CSCN-07-11	1.40	8.50
CSCN-06-12	0.58	3.35	CSCN-07-12	1.06	8.00
CSCN-06-13	0.69	2.52	CSCN-07-13	0.84	6.20
CSCN-06-14	0.69	4.44	CSCN-07-14	0.80	8.30
CSCN-06-15	0.76	6.61	CSCN-07-15	0.75	7.30
CSCN-06-16	0.71	4.71	-	-	-
CSCN-06-17	0.77	4.49	-	-	-
CD (5%)	0.18	0.21	CD (5%)	0.22	0.19

The figures for test weight (gm/1000 seeds) were 2.52 (CSCN-06-13) to 6.61 (CSCN-06-15) and 3.33 (CSCN-07-6) to 8.50 (CSCN-07-11) during 2006-07 and 2007-08 respectively.

Table 161 Effect of varying levels of alkalinity on yield loss* of garlic

Varities	Sodium saturation (%)				Mean
	51.9	42.0	32.2	21.5	
Hansa	63.9	51.0	33.1	28.6	44.2
Desi	66.7	52.0	37.1	29.7	46.4
Gatteer Gola	62.5	44.9	28.0	19.9	38.8

* Yield loss in per cent assuming a yield of 15 t/ha in normal soil

RESPONSE OF FINGER MILLET GENOTYPES TO NITROGEN LEVELS UNDER SALINE CONDITIONS OF TBP IRRIGATION COMMAND

A field experiment was conducted at ARS, Gangawati during 2005-2007 to find out the response of finger millet genotypes to nitrogen levels under saline conditions (EC_e 6.5 dS/m). Results of 2007 indicated that among the genotypes GPU-28 recorded significantly higher grain yield of 4.39 t/ha when compared to GPU-26 (4.08 t/ha), GPU-45 (3.73 t/ha), HR-374 (3.81 t/ha), PES-400 (3.98 t/ha) and VL-149 (3.83 t/ha) genotypes. Amongst the nitrogen levels, application of 150% RDN recorded significantly higher grain yield of 4.16 t/ha as compared to 125% RDN (4.02 t/ha) and 100% RDN (3.72 t/ha). The interaction remained non-significant (Table 162).

Pooled data of three years (kharif 2005-2007) revealed that amongst the genotypes, GPU-28 recorded significantly higher grain yield of 4.28 t/ha (Table 163) when compared to GPU-26 (3.85 t/ha), GPU-45 (2.97 t/ha), HR-374 (3.31 t/ha), PES-400 (3.21 t/ha) and VL-149 (3.47 t/ha) genotypes. Among the nitrogen levels, application of 150% RDN recorded significantly higher grain yield of 3.84 t/ha as compared to 125% RDN (3.56 t/ha) and 100% RDN (3.15 t/ha). The interaction remained significant. The genotype GPU-28 with 150% RDN recorded a higher grain yield of 4.59 t/ha when compared to other treatment combinations.

There was not much variation in soil salinity when compared to initial values. The soil salinity values ranged between 6.00 to 6.80 dS/m (Table 164).

Table 162 Finger millet yield as influenced by genotypes and nitrogen (2007)

Genotypes / Nitrogen levels	Yield (t/ha)			
	RDF	125% N	150% N	Mean
V1 : GPU-26	3.83	4.16	4.25	4.08
V2 : GPU-28	4.19	4.38	4.58	4.39
V3 : GPU-45	3.44	3.79	3.94	3.73
V4 : HR-374	3.68	3.78	3.95	3.81
V5 : PES-400	3.61	4.09	4.23	3.98
V6 : VL-149	3.55	3.91	4.04	3.83
Mean	3.72	4.02	4.16	-
		S Em ±		CD (5%)
Between genotypes		0.07		0.24
Between nitrogen levels		0.03		0.10
Genotypes x Nitrogen levels		0.09		NS

Table 163 Finger millet yield as influenced by genotypes and levels of nitrogen

Genotypes / Nitrogen levels	Pooled yield (t/ha) 2005-07			
	RDF	125% N	150% N	Mean
V1 : GPU-26	3.39	3.88	4.29	3.85
V2 : GPU-28	3.89	4.37	4.59	4.28
V3 : GPU-45	2.67	3.04	3.22	2.97
V4 : HR-374	3.02	3.25	3.67	3.31
V5 : PES-400	2.70	3.32	3.61	3.21
V6 : VL-149	3.23	3.53	3.65	3.47
Mean	3.15	3.56	3.84	-
		S Em ±		CD (5%)
Between genotypes		0.05		0.16
Between nitrogen levels		0.03		0.09
Genotypes x Nitrogen levels		0.07		0.21

Table 164 Soil salinity as influenced by genotypes and nitrogen

Genotypes / Nitrogen levels	Soil salinity (dS/m) after kharif, 2007			
	RDF	125% N	150% N	Mean
V1 : GPU-26	6.00	6.23	6.53	6.26
V2 : GPU-28	6.57	6.46	6.27	6.43
V3 : GPU-45	6.47	6.16	6.07	6.23
V4 : HR-374	6.36	6.07	6.56	6.33
V5 : PES-400	6.46	6.80	6.13	6.47
V6 : VL-149	6.40	6.20	6.13	6.24
Mean	6.38	6.32	6.28	-
		S Em ±		CD (5%)
Between genotypes		0.17		NS
Between nitrogen levels		0.10		NS
Genotypes x Nitrogen levels		0.23		NS

Initial soil salinity: 6.5 dS/m

TOLERANCE OF COTTON VARIETIES TO SALINE WATER IRRIGATION UNDER DRIP SYSTEM

An experiment was conducted to study the tolerance of cotton varieties to saline water irrigation under drip system. Treatment comprised of two methods of irrigations (Drip and Flood), three levels of water salinity (EC 0.25, 3.0 and 6.0 dS/m) and four varieties of cotton (F-846, RST-9, RG-8 and Bt cotton Mh-134). Results indicated that methods of irrigation, salinity of irrigation water and varieties showed significant effect on seed cotton yield. Drip method was found significantly superior to flood method in increasing seed cotton yield, which was 44.2 per cent higher in drip as compared to flood method. As regard salinity of water, seed cotton yield decreased significantly at EC_{iw} 6.0 dS/m as compared to canal water and saline water having EC_{iw} 3.0 dS/m. However, differences in seed cotton yield with canal water and saline water of EC_{iw} 3.0 dS/m were non-significant. The variety MH-134 of Bt cotton was significantly superior to other varieties (Table 165).

Interaction between methods of irrigation and salinity of water on seed cotton yield was significant (Table 166). Seed cotton yield decreased significantly at EC_{iw} 6.0 dS/m in both the method of irrigation, the minimum being in EC_{iw} 6.0 dS/m with flood method of irrigation. Interactive effect of methods of irrigation and varieties indicate that Bt cotton produced significantly higher yield in both the method of irrigations. Variety RST-9 gave significantly higher yield than RG-8 in drip method of irrigation. F-846 produced minimum seed cotton yield in flood method of irrigation.

Table 165 Effect of irrigation methods, salinity of water and varieties on cotton

Treatments	Seed cotton yield (t/ha)	Plant height (cm)	Bolls per plant	Boll size (cm)
Methods of irrigation				
M_1-Drip	1.86	149.5	50.3	4.15
M_2-flood	1.29	107.0	44.0	3.87
S Em ±	0.03	2.2	0.9	0.05
CD (5%)	0.10	6.2	2.5	0.14
Salinity of water				
S_1- 0.25 dS/m	1.78	135.5	54.0	4.26
S_2- 3.0 dS/m	1.69	129.4	48.0	4.11
S_3- 6.0 dS/m	1.27	120.1	39.0	3.66
S Em ±	0.04	2.7	1.1	0.06
CD (5%)	0.12	7.6	3.0	0.17
Varieties				
V_1- F 846	1.35	124.3	46.1	4.07
V_2- RST-9	1.46	133.6	49.5	4.23
V_3-RG-8	1.35	120.2	41.7	3.45
V_4- Bt Cotton (MH-134)	2.15	135.3	51.2	4.28
S Em ±	0.05	3.1	1.2	0.07
CD (5%)	0.13	8.8	3.5	0.20
CV (%)	12.7	10.3	11.1	7.4

Zone of minimum salt concentration existed below the emitter. The salt concentration in soil profile increased with increase in lateral as well as vertical distance from the emitters (Table 167).

Table 166 Interactive effect of irrigation methods, salinity of water and varieties on seed cotton yield (t/ha)

Treatments	Drip irrigation (M_1)	Flood irrigation (M_2)
Salinity of water		
S_1- 0.25 dS/m	2.12	1.10
S_2- 3.00 dS/m	2.04	0.94
S_3- 6.00 dS/m	1.43	0.74
S Em ± (M X S)	0.06	
CD (5%)	0.16	
Varieties		
V_1- F 846	1.62	1.07
V_2- RST-9	1.69	1.24
V_3-RG-8	1.47	1.23
V_4- Bt Cotton	2.67	1.63
S Em ± (M X V)	0.07	
CD (5%)	0.19	

Table 167 Salinity (EC_e) build-up in the soil profile at harvest of cotton

Distance from emitter (cm)	Soil depth (cm)	EC_{iw} (dS/m)					
		Drip irrigation			Flood irrigation		
		0.25	3.00	6.00	0.25	3.0	6.00
0	0-15	0.39	1.04	1.61	0.43	1.17	1.54
	15-30	0.45	1.27	1.75	0.49	1.49	1.97
	30-60	0.53	1.39	1.77	0.58	1.63	2.40
15	0-15	0.55	1.21	1.81	-	-	-
	15-30	0.50	1.37	2.01	-	-	-
	30-60	0.61	1.43	2.23	-	-	-
30	0-15	0.50	1.36	2.00	-	-	-
	15-30	0.46	1.49	2.37	-	-	-
	30-60	0.67	1.70	2.52	-	-	-

E. ON-FARM TRIALS AND OPERATIONAL RESEARCH PROJECTS

- **An Operational Research Project on Improvisation and Demonstration of Reclamation Technologies for Black Alkali Soils**
- **Operational Research Project on the Use of Poor Quality Ground Water at Farmer's Field**
- **Low Cost Technology for Dilution of Saline Groundwater through Artificial Recharge (Agra Centre)**
- **Study of Skimming Well and other Alternative Technologies for Development of Water Resources in Coastal Sandy Soils**
- **Effect of Gypsum Application on Crop Production and Soil Chemical Environment on Farmer's Fields**
- **Study on Monitoring Salinity Hazards in Vegetable Crops Grown under Drip Fertigation with Marginally Saline Water in Vertisols**
- **Field Trails on Farmer's Field on Alkali Water Irrigation**

AN OPERATIONAL RESEARCH PROJECT ORP ON IMPROVISATION AND DEMONSTRATION OF RECLAMATION TECHNOLOGIES FOR BLACK ALKALI SOILS

During the first year, reclamation technology was adopted in five locations at JV Palem, Kondamuru and Swarna villages of Panguluru and Karamchedu mandals of Prakasam district with the following technological inputs:

- Powdered gypsum application based on pH @ 50% gypsum requirement
- Green manuring by growing dhaincha @ 50 kg/ha seed rate and *in-situ* incorporation at 50% flowering stage
- Application of $ZnSO_4$ @ 50 kg/ha as basal application
- Fertilizer application @ 180 kg N-40 kg P_2O_5–40 kg K_2O/ha, N through urea in 3 equal splits 1/3 at basal, 1/3 at maximum tillering and 1/3 at panicle initiation stage, entire P as SSP at basal at the time of incorporating green manure and ½ of K at basal along with urea and remaining ½ at panicle initiation stage as MOP
- Growing salt tolerant variety of NLR-145 of 145 days medium duration
- Planting 35 days old seedlings @ 4/hill and 44 hills/m^2 at a spacing of 15cm x 15cm to increase the plant density by 25%

The grain yield of 3.52 t/ha was recorded in treated plots as compared to 2.95 t/ha in control. The soil pH_s, EC_e and ESP after harvest of paddy were 8.97, 1.32 dS/m and 17.41 respectively at JV Palem and the same trend was maintained at other locations as well. The grain yields recorded were 3.83, 3.64, 3.40 and 3.58 t/ha at Kondamuru-I, Kondamuru-II, Swarna-I and Swarna-II respectively whereas yields recorded in the control plots at the same locations were 3.25, 3.08, 2.89 and 3.00 t/ha, respectively (Table 168). There was decrease in soil pH_s, EC_e and ESP in the treated plots over control. The uptake of NPK by grain increased in gypsum treated plots over no gypsum at all the five locations (Table 169). The economic analysis revealed that farmers could get an additional income of Rs. 2000-3000 (Table 170).

Table 168 Effect of gypsum application on yield and NPK uptake by paddy in alkali soils

Location	Grain yield* (t/ha)		Uptake* (kg/ha)					
			N		P		K	
	Control	Treated	Control	Treated	Control	Treated	Control	Treated
JV Palem	2.95	3.52	20.7	24.7	9.3	10.7	6.8	11.3
Kondamuru-I	3.25	3.83	21.5	29.5	8.6	11.6	7.8	10.7
Kondamuru-II	3.08	3.64	23.7	28.0	6.6	7.8	9.5	11.7
Swarna-I	2.89	3.40	22.3	26.5	6.9	8.5	6.7	10.2
Swarna-II	3.00	3.58	21.9	29.0	9.0	11.4	7.2	11.1

* During 2006-07

Table 169 Influence of gypsum (50% GR)* on Soil pH_s, EC_e and ESP in alkali soils

Location	pH_s		EC_e (dS/m)		ESP	
	Initial	At harvest	Initial	At harvest	Initial	At harvest
JV Palem	10.31	8.97	1.75	1.32	20.51	17.41
Kondamuru-I	9.78	9.06	2.49	2.30	20.71	18.26
Kondamuru-II	9.94	8.72	2.14	1.41	20.00	17.65
Swarna-I	9.60	8.21	3.26	2.92	20.61	17.65
Swarna-II	9.81	8.35	3.30	3.00	20.81	17.71

* During 2006-07

During the second year, the technology was demonstrated at eight locations namely Kondamuru-I & II, JV Palem-I and II, Kasyapuram, Renangivaram and Swarna-I and II of Pangaluru and Karamchedu mandals of Prakasam district. It showed that application of gypsum to alkali soils based on the soil test value, $ZnSO_4$ @ 50 kg/ha and *in-situ* green manuring with dhaincha (*Sesbania* *aculeata*) increased the grain and straw yields of paddy and uptake of NPK by grain and decreased the soil pH_s, EC_e and ESP during kharif, 2007 (Table 171 and Table 172).

Table 170 Economic returns from rice paddy in reclaimed alkali (2006-07)

Location*	pH_s	Gypsum applied (t/ha)	Yield gap (t/ha)	Sale price (Rs/ton)	Gross returns (Rs./ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)
JV Palem	10.31	8.15	0.57	10000	5700	3668	2032
Kondamuru-I	9.78	7.20	0.58	10000	5800	3240	2560
Kondamuru-II	9.84	7.80	0.56	10000	5600	3510	2090
Swarna-I	9.60	6.25	0.51	10000	5100	2813	2887
Swarna-II	9.81	7.20	0.58	10000	5800	3240	2560

* One demonstration at each location

Table 171 Effect of gypsum application on yields of paddy in alkali soils (2007-08)

Location	Control		Gypsum applied		Per cent yield increase over control
	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	
Kondamuru-I	4.5	5.0	5.2	5.8	13.5
Kondamuru-II	4.7	5.2	5.4	6.0	13.0
J.V. Palem-I	3.8	4.2	4.5	5.0	15.6
J.V. Palem-II	4.2	4.7	5.0	5.6	16.0
Kasyapuram	4.7	5.2	5.4	6.0	13.0
Renangivaram	4.8	5.3	5.3	5.9	9.5
Swarna-I	4.5	5.1	5.2	5.7	13.5
Swarna-II	4.4	4.9	5.4	5.9	18.5

Table 172 Influence of gypsum on soil pH_s, EC_e and ESP in alkali soils (2007-08)

Location	Soil pH_s		Soil EC_e (dS/m)		ESP	
	Initial	At harvest	Initial	At harvest	Initial	At harvest
Kondamuru-I	9.9	8.6	2.1	1.6	25.6	18.5
Kondamuru-II	9.8	8.5	2.0	1.4	22.5	16.4
J.V Palem -I	9.5	8.4	3.8	2.5	28.2	19.2
J.V Palem -II	9.4	8.2	2.5	1.8	26.8	17.5
Kasyapuram	9.5	8.2	2.8	2.0	21.5	15.0
Renangivaram	9.3	8.3	2.4	1.7	20.5	14.6
Swarna-I	9.5	8.5	3.1	2.2	23.0	15.8
Swarna-II	9.6	8.6	3.2	2.3	25.0	16.6

ORP ON THE USE OF POOR QUALITY GROUND WATER AT FARMER'S FIELD

Field demonstrations in Operational Research Project for the use of poor quality water were initiated in kharif 1993 in Karanpur village of Mathura district. The village is located at Fareh-Achhnera road only 6 kms away from Fareh town. In 1999 the program was extended to two other villages' i.e. Nagla Hridaya and Bhojpur. At these sites, medium and high SAR saline water was available. In the year 2000 the program was further extended to Savai village of Agra district to demonstrate the technologies on the use of alkali water. In kharif 2004, ORP was also initiated at Odara village of Bharatpur district in medium and high saline water (EC_{iw} 6.0 to 14 dS/m and SAR 10-18 $(mmol/l)^{1/2}$. In 2006, one other site was also selected for dry land salinity demonstrations at Nagla Parasram in Bharatpur district. The selected farmers were grouped on the basis of most suitable management options to be implemented at their farms (Table 173).

Table 173 Grouping of farmers on the basis of management options

Group	No. of farmers		Water Quality Problem	Strategy for management
	2007	2008		
A	6	6	Alkalinity	RSC management with gypsum
B1	3	3	High Salinity	Conjunctive use of low and high salinity water
B2	-	1	High Salinity	Pearl millet-wheat/barley With post sowing sprinkler irrigation or
B3	2	4	High Salinity	Dhaincha green manure/sorghum fodder/ mustard with rain conserved moisture
C	17	11	Saline- alkali	Crop and fertilizer management

The water quality parameters pertaining to tube well water of the selected farmers given in Table 174 revealed that during the study period salinity of RSC water varied from 2.1 to 3.9 dS/m, RSC from 7.8 to 12.0 meq/l and SAR from 13.1 to 25.8 $(mmol/l)^{1/2}$. In saline water at Odara and Nagala Parasuram EC_{iw} varied from 6.0 to 15.0 dS/m and SAR from 10.1 to 24.0 $(mmol/l)^{1/2}$. During 2006-07 and 2007-08, demonstrations were conducted on 28 and 25 farmer's fields at Savai, Odara and Nagala Parasram villages.

Table 174 Water quality at farmer's tube well

S.No.	Water quality problem	EC_{iw} (dS/m)	RSC (meq/l)	SAR $(mmol/l)^{1/2}$
1.	RSC water (Savai)	2.1-3.9	7.8-12.0	13.1-25.8
2.	Saline water (Odara)	6.3-15.0	-	10.1-24.0
3.	Saline water (Nagla Parasram)	6.0-13.2	-	13.1-23.3

a. Alkali water: Gypsum application

In 2006-08, gypsum was incorporated in 3 farmer's field having alkali water tube wells. Gypsum was applied on the basis of 50% GR and pearl millet crop was cultivated on flat beds. The yield data revealed that incorporation of gypsum increased the yield by 8.8 to 11.6% with decrease in pH, SAR and ESP (Table 175).

Table 175 Effect of gypsum on pearl millet yield and soil characteristics in alkali water

Name of the farmer	Treatment	Average yield (t/ha)	Per cent increase over control	Soil characteristics at harvest (0-30 cm)			
				EC_e (dS/m)	pH_2	SAR	ESP
Sh. Krapa Shankar	50% GR	2.07	11.3	2.5	8.7	12.6	17.7
	No gypsum	1.86	-	2.6	8.9	14.0	19.5
Sh. Om Prakash	50% GR	2.11	11.6	2.3	8.7	12.6	17.6
	No gypsum	1.89	-	2.2	8.9	13.6	19.3
Sh. Raj Kumar	50% GR	1.60	8.8	2.1	8.8	12.6	17.3
	No gypsum	1.47	-	2.0	9.0	15.8	21.8
Overall	-	-	10.6	-	-	-	-

During 2006-07 and 2007-08, the benefits of adding gypsum to mitigate the adverse effect of residual alkalinity were demonstrated (Table 176). The demonstrations were conducted for wheat on 4 farmer's fields. The improvement in yield ranged between 6.1-6.7% with an average increase of 6.5%. The pH_2, SAR and ESP at harvest were comparatively low in gypsum treated fields over no gypsum (control).

Table 176 Effect of gypsum on average yield of wheat

Name of the farmer	Treatments	Yield (t/ha)	Increase over control (%)	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$	ESP
Mr Krapa Shankar	50% GR	3.20	6.7	3.3	8.8	17.2	24.2
	No gypsum	3.00	-	3.2	8.9	18.2	25.6
Mr Hari Shankar	50% GR	3.00	6.7	4.0	8.7	18.6	25.9
	No gypsum	2.80	-	4.1	8.8	20.7	28.7
Mr Om Prakash	50% GR	3.43	6.5	3.8	8.8	17.6	24.3
	No gypsum	3.22	-	4.1	8.9	19.3	26.4
Mr Raj Kumar	50% GR	3.45	6.1	4.5	9.0	18.5	25.8
	No gypsum	3.25	-	4.1	9.1	19.2	27.0
OverAll	-	-	6.5	-	-	-	-

Sowing technique

In 2006-07, cotton crop was cultivated with bed sowing technique in 2 farmers' fields. Gypsum was applied @ 50% GR. The yield data revealed that the incorporation of gypsum increased the average yield by 8.2 % and resulted in decreased pH, SAR and ESP of the soil (Table 177).

Table 177 Effect of gypsum on cotton (RG-8) yield with alkali water (2006-07)

Name of the farmer	Treatment	Seed cotton yield (t/ha)	Per cent increase over control	Soil characteristics at harvest (0-30 cm)			
				EC_e (dS/m)	pH_2	SAR	ESP
Sh. Bhawani Shankar	50% GR	1.13	8.6	3.0	8.9	12.8	17.5
	No gypsum	1.04	-	2.9	9.0	13.6	18.8
Sh. Rajessh	50% GR	1.37	7.9	2.2	8.7	12.4	17.1
	No gypsum	1.27	-	2.2	8.9	13.3	18.7
Overall	-	-	8.2	-	-	-	-

In 2007-08 pearl millet crop was cultivated in 4 fields in alkali water region and 2 fields in saline water region. The yield varied from 1.72 -3.12 t/ha in alkali water while the yield varied from 1.37-1.53 t/ha in saline water (Table 178).

Table 178 Yield of pearl millet in alkali/saline water with bed sowing (2007-08)

Name of the farmer	Water quality	Variety	Yield (t/ha)	Soil characteristics at harvest (0-30 cm)		
				EC_e (dS/m)	pH_2	SAR
Mr Jagdish	Alkali	MRB 2210	1.90	2.7	8.6	14.0
Mr Devendra	Alkali	MRB 204	1.73	4.0	9.3	15.2
Mr Rajesh Kumar	Alkali	JK-BH -26	1.72	2.0	8.6	13.3
Mr Girish Chand	Alkali	MRB 2210	3.12	3.1	8.6	15.8
Mr Nirapat Singh	Saline	MRB 204	1.53	6.7	8.3	22.6
Mr Ved Prakash	Saline	MRB 2210	1.37	5.4	8.5	15.9

b. Saline water

The pearl millet (grain) and sorghum fodder were grown on different farmer's fields during two years. Pearl millet yield varied from 1.46-2.26 t/ha while sorghum fodder yield varied from 14.98 - 22.0 t/ha. Due to low rainfall, none of the farmer had grown these crops on their fields. As a result the yields were not compared with flat and conventional sowing.

Conjunctive use of low salinity/high salinity water

The conjunctive use of low salinity water with high salinity water was demonstrated on three farmer's fields in different irrigation modes i.e. 1 LSW+RTS and 2LSW+RTS (Table 179). The average yield improvement ranged between 10.7-17.8 percent when compared with conventional farming. The soil salinity and SAR varied from 12.6 to 20.1 dS/m and 18.1 to 20.7 $(mmol/l)^{1/2}$.

Table 179 Wheat yield under different irrigation management strategies

Name of farmer	Treatments		Wheat variety	ORP yield (t/ha)	Conv-entional yield (t/ha)	Per cent increase in ORP	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
	2006-07	2007-08							
Jagan Singh	1LSW+ RTS	2LSW+ RTS	PBW 343	3.52	3.16	11.4	16.4	7.2	19.8
Balveer Singh	1LSW+ RTS	2LSW+ RTS	PBW 343	3.18	2.70	17.8	20.1	7.6	18.1
Subhash Chand	2LSW+ RTS	2LSW+ RTS	PBW 373	3.93	3.55	10.7	12.6	7.5	20.7

LSW: Low salinity water (EC_{iw} 4-6 dS/m) ; RTS : Rest tube well saline water

Post sowing sprinkler and conventional pre-sowing saline irrigation

On one farmer's field wheat crop was sown in dry soil and after that sprinkler irrigation was applied to improve the seed emergence with saline water (Table 180). The wheat yield increased by 9.8% in post sowing sprinkler irrigation over pre-sowing saline irrigation (conventional farming).

Table 180 Comparison of post sowing sprinkler and conventional pre-sowing saline irrigation

Name of farmer	Wheat variety	ORP yield (t/ha)	Conventional yield (t/ha)	Per cent increase	EC_e dS/m	pH_2	SAR $(mmol/l)^{1/2}$
Amar Chand	PBW-343	3.57	3.25	9.8	15.5	7.5	16.5

Crops and fertilizer management

Assessment of N fertilization for wheat, barley and mustard reported in Table 181 reveal that application of 120 kg N/ha on an average increased yield by 6.5% in wheat , 6.2% in barley and 16% in mustard compared to application of 90 kg N/ha.

Saline water recharge

Due to limited rainfall, studies on rainwater recharge could not be taken up. While farmer's applied all saline irrigations in 1st year, four of the five farmers could apply one pre sowing irrigation with low salinity water (4-6 dS/m) in second year. The improved seed and proper fertilizers increased the average yield by 12.2% in ORP demonstrations over farmer's fields (Table 182).

Comparison of flat sowing with bed sowing technique

The bed sowing technique was compared with flat sowing for wheat at 4 farmers fields (Table 183). The yield was higher by about 7.4% in flat sowing on 3 farmer's field while yield at one farmer field was slightly higher in bed sowing. In bed sowing, irrigation water to the tune of 25 to 30% could be saved over flat sowing.

Table 181 Assessment of N fertilization for wheat, barley and mustard crops

Name of farmer	Treatment	Crop	ORP yield (t/ha)	Per cent increase over 90 kg	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
Mr. Ram	90 kg N	Wheat	3.11	-	14.4	7.5	18.7
Bharosee	120 kg N		3.34	7.4	14.2	7.5	19.9
Mr. Shiv Kumar	90 kg N	Wheat	2.55	-	15.2	7.7	28.1
	120 kg N		2.80	9.8	16.7	7.5	29.0
Mr. Mukesh	90 kg N	Wheat	3.42	-	14.7	7.5	20.1
	120 kg N		3.60	5.3	16.5	7.7	20.5
Mr. Dal Chand	90 kg N	Wheat	3.35	-	14.7	8.0	20.2
	120 kg N		3.50	4.5	15.0	8.1	21.0
Mr. Mohan Singh	90 kg N	Barley	3.29	-	12.0	7.1	20.6
	120 kg N		3.40	6.2	12.5	7.0	22.0
Mr.Mukesh	90 kg N	Mustard	1.87	-	12.7	7.1	21.1
	120 kg N		2.25	20.3	13.7	7.6	21.7
Mr.Dal Chand	90 kg N	Mustard	1.32	-	15.0	7.7	23.5
	120 kg N		1.55	17.4	15.5	7.2	24.3
Mr. Munsi Lal	90 Kg N	Mustard	1.65	-	10.2	7.5	15.4
	120 kg N		1.92	16.4	11.0	7.5	17.6
Mr.Gangoo Singh	90 kg N	Mustard	1.72	-	11.2	8.1	16.3
	120 Kg N		2.00	14.0	11.7	8.2	16.5
Mr Narayan	90 kg N	Mustard	1.70	-	6.5	7.6	13.6
Singh	120 Kg N		1.90	11.8	6.5	7.7	13.7

Table 182 Effect of saline water on yield of wheat and soil characteristics (0-30 cm) at harvest at water recharge sites

Name of the farmer	Treatments		ORP yield (t/ha)*	Farmers yield (t/ha)*	Per cent increase	EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
	2006-07	2007-08						
Lal Hans	S	1LSW+S	3.38	3.05	10.8	14.6	7.8	25.0
Mukesh Kumar	S	1LSW+S	3.77	3.37	11.9	10.8	7.3	14.5
Hari Prasad	S	1LSW+S	3.43	3.06	12.1	14.1	7.2	18.7
Ranveer Singh	S	1LSW+S	3.57	3.13	13.9	17.0	7.4	20.9
Dinesh Chand	S	S	3.43	3.05	12.4	11.8	8.0	19.1
Overall					12.2			

S: Saline water; LSW: Low salinity water; *Average grain yield of 2 years

Table 183 Comparison of flat sowing with bed sowing technique for wheat

Name of the farmer	Hours of irrigation/ha	ORP bed sowing Yield (t/ha)	Farmers flat sowing yield (t/ha)	Per cent increase on farmers field	Soil characteristics at harvest (0-30 cm)		
					EC_e (dS/m)	pH_2	SAR $(mmol/l)^{1/2}$
Alkali water							
Mr. Rajesh	F-20.5	2.85	3.05	7.0	4.5	8.7	19.0
Kumar	B-16.1	-	-				
Mr. Shiv	F-23.1	2.07	2.20	6.3	2.7	8.9	15.0
Naryan	B-18.5	-	-				
Saline water							
Mr.Nirpat	F-20.8	2.54	2.77	9.0	11.9	8.0	22.1
Singh	B-16.1	-	-				
Mr. Ved	F-19.7	2.50	2.35	-	11.4	7.6	23.1
Prakash	B-15.2	-	-				

F: Flat sowing; B: Bed sowing

LOW COST TECHNOLOGY FOR DILUTION OF SALINE GROUNDWATER THROUGH ARTIFICIAL RECHARGE (AGRA CENTER)

Agra-Bharatpur region in the states of Uttar Pradesh and Rajasthan are endowed with poor quality groundwater aquifers. Shallow aquifers are relatively more saline (10-15 dSm-1) 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 one/two life saving irrigation(s) to mustard. Thus, under such a situation, yields are reduced due to high salinity of the irrigation water. In order to improve crop productivity, a low cost technology based on diluting saline groundwater through artificial recharge has been designed and tested on 8 farmer's fields. The technology consisted of diverting the runoff to these structures for recharge (Fig. 50). The diluted groundwater is then pumped to irrigate mustard/wheat The salinity of the groundwater 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. On the contrary, farmers' over enthusiasm to switch over from mustard to wheat calls for increased withdrawal from the aquifers. Also, to earn hard cash, these farmers are now selling the water to their neighbors thus, loosing the benefits of dilution at their own farms particularly in the case of wheat.

Fig. 50 Rainwater recharge to dilute groundwater

Some resourceful farmers' of the region have installed deep submersible pumps at their farms A cost comparison of the two alternatives is shown in Table 184. A visual comparison of a crop irrigated with diluted saline water of a shallow pump and a deep submersible pump reveals that there is not much difference and ultimately the yield from both the fields might be similar.

Table 184 Initial investments and per hour cost of pumping groundwater for sale

Type of the well	Investment (Rs. lakhs)	Cost of pumping for selling water (Rs./hr)
Deep submersible	2.0 – 2.5	150 – 175
Shallow centrifugal	0.5 – 0.6	50 – 60

STUDY OF SKIMMING WELL AND OTHER ALTERNATIVE TECHNOLOGIES FOR DEVELOPMENT OF WATER RESOURCES IN COASTAL SANDY SOILS

While the inland aquifers are suffering from the maladies of over exploitation, coastal aquifers are prone to seawater intrusion and saline water upcoming due to overexploitation or inappropriate pumping. Nearly 1.74 lakh ha coastal sandy soils exist along the Andhra coast with fresh water lens at shallow depth with a thickness ranging from 0.5 m to 3.0 m. In these areas, fresh water lens is exploited for irrigation using conventional *doruvu's*. A survey carried-out in the coastal belt of Guntur district, Andhra Pradesh revealed that the ground water is being developed through various structures such as traditional *doruvu* (a conical pit) with manual pot irrigation, traditional *doruvu with* 1 HP pumping unit, radial subsurface collector well with horizontal collectors using 1-5 HP pumping units, shallow tube wells with 1 HP pumping unit and two strainer tube wells with 1-5 HP pumping unit.

Traditional Doruvu

A dug out conical pits locally called *Doruvu*, is used to skim fresh water floating on the saline water. It is used to draw water manually and is splashed on crops such as vegetables, flowers, groundnut and nurseries of paddy, vegetables, tobacco and chillies using pitchers. Each *Doruvu* occupy an area of about 200 m^2. The water collected from each *Doruvu* is just sufficient to irrigate 800 m^2. As such 10-12 *Doruvu* are needed for an area of 1 ha area thus, occupying about 20% of the cultivable area.

Subsurface collector well

As an alternate to traditional *Doruvu,* AICRP Saline Water Scheme, Bapatla developed a popularly known Improved *Doruvu* Technology. In this set up, flow of water 1.8-2.4 m below the ground surface in collectors embedded below the ground at appropriate depths is collected in a sump. This water is pumped and used to irrigate crops using sprinklers/drip and specially designed hand held jerry (Fig. 51).

Fig. 51 (a) Traditional Doruvu (b) Improved Doruvu

Adoptability and monitoring of subsurface collector wells

The centre has installed 83 subsurface collector wells in coastal sandy soils of 24 villages in Guntur, Praksam and West Godavari districts covering a cultivable area of 192 ha and 6 drinking water wells under the rural drinking water scheme of Government of Andhra Pradesh/CONSIDER (NGO) (Table 185). During 2006-07, two skimming wells were installed at Yajali in Guntur district and carried out feasibility studies for installing two more wells at Pandurangapuram and Bapatla area. During 2007-08, two skimming wells were installed in Pandurangapuram area. The salinity of skimmed water ranged from 0.45 to 0.79 dS/m. On the whole, experiences revealed that system is able to supply good quality water that is sufficient to meet crop demands of 2 ha area during rabi through use of sprinklers or 4 ha of plantation crops except oil palm through mini sprinkler/drip irrigation system. Monitoring of the water table fluctuation and water quality at monthly interval in selected 24 skimming structures indicated that water table fluctuations for Bapatla and Timmareddy Palem areas during most of the year remained above the normal drain depth (Fig. 52).

Table 185 Collector wells installed under the AICRP Saline Water Scheme, Baptala

Name of the village	Collector wells (No.)	Area covered (ha)	Purpose/crops grown
Bapatla	22	47	Paddy nursery, pulses, rabi groundnut/ plantation crops
Vedullapalli	3	4	Rose nursery
Reddypalem	13	33	Mango and coconut nursery, paddy nursery, rabi groundnut and aromatic plants.
Muthaipalem	2	5	Forest crop nurseries
Keerthivaripalem	1	2	Rabi groundnut, vegetables and poultry
Kavuru	1	2	Different crop nurseries and vegetables.
Bavanamvaripalem	1	2	Vegetables and ground nut.
Rambotlavaripalem	1	4	Paddy nursery and Rabi groundnut
Padison peta	4	8	Paddy nursery, leafy vegetables, vegetables, watermelon and for fish tank.
Khajipalem	1	1	Coconut and mango
G.N.Palem/ P.V.Palem	4	5	Paddy nursery, paddy, pulses and vegetables.
Chandolu	1	2	Paddy nursery, paddy pulses and vegetables
Dammanavari palem	3	6	Rabi groundnut, vegetables and paddy
Manubroluvari palem	6	20	Paddy nursery, pulses, plantation crops, cattle and sheep farms.
Kothapalem	3	6	Paddy nursery, pulses and plantation crops.
Chinamatlapudi	1	1	Paddy nursery, pulses and groundnut.
Akkayapalem	1	2	Vegetables and paddy nursery.
Nagendrapuram	4	6	Groundnut, *Casurina* and paddy
Pandillapalli	3	6	Paddy and vegetable crops
Yetigaddavaripalem	1	2	Groundnut, paddy nursery and paddy pulses
Perupalem	1	4	Mango garden and vegetables
Vetapalem	2	6	Paddy nursery and rabi groundnut
Yajali	2	2	Groundnut /Groundnut-paddy nursery
Pandurangapuram	2	16	Groundnut/Groundnut
Alakapuram, Alluru, G N Palem, Shantinagar Jonnavaripalem and Lakshmipuram	6	-	Drinking water wells under rural drinking water scheme of Govt. of Andhra Pradesh
Total	**89**	**192**	

The salinity of skimming well waters varied from 0.5–8.9 dS/m during 2006-07. The salinity of skimming well water at Bapatla and Timmareddy Palem is less than 1 dS/m. The water table in skimming wells varied from 0.0 to 1.88 m and the salinity of water harvested through different skimming structures varied from 0.13 to 8.8 dS/m during 2007-08. The salinity of skimming well water at Bapatla and Timmareddy Palem was in the range of 0.13-0.97 dS/m.

Hydraulic performance of skimming wells

The major factors that influence the design of a collector well are: a) Installation depth to avoid entry of underground saline water; b) Collector line spacing as a function of their length and soil hydraulic conductivity. Measurements on the area of influence of wells installed at Reddypalem showed that the collector line with 15 cm diameter receive water from a surrounding of 50 m radius on either side of the sump well and a spacing of 100 m between two collector wells would be optimum. The bi-directional water discharge rate into sump depends upon the hydraulic head over the collector line and soil hydraulic conductivity. The hydraulic conductivity values estimated for sandy soils of Reddypalem dominated with coarse sand is 20 m/day and for sandy soil dominated with fine sand is 7 m/day.

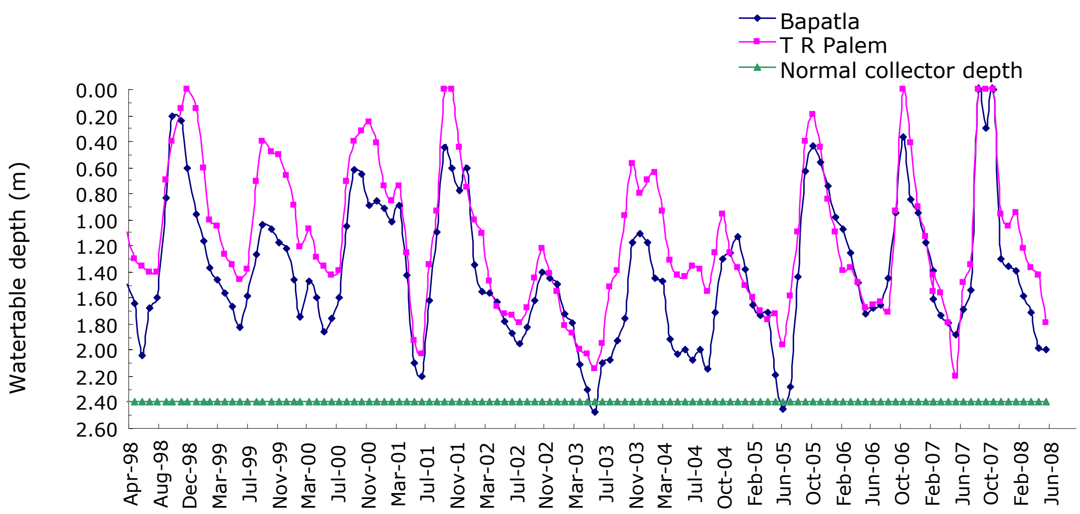


Fig. 52 Periodical water table fluctuations in coastal sandy soils of Bapatla and TR Palem

Shallow and multi-strainer tube wells

During the recent past, innovative and progressive farmers installed shallow depth (4.5-6.0 m) low discharge tube wells and multi-strainer bore wells with varying designs in Andhra Pradesh to tap the top layered shallow fresh water. The systems performance was assessed by the centre in terms of yield, quality, quality changes using state of art multi-electrode imaging techniques and also worked out their economic viability and social acceptability.

Performance of different skimming structures

- Harvested water quality analysis indicated little change in the salinity of water harvested through the traditional *doruvus* with pot irrigation (0-1.5%), traditional doruvu with 1 HP pumping unit (1.5–5.9%) and skimming well with horizontal collectors (1.5–5.6%). In case of shallow tube well, a gradual increase (8.1-46.0 %) in salinity of pumped water with increasing pumping time was observed. In case of multi-strainer well a moderate rise of salinity (3.5 to 13.7%) was observed.

- Multi-electrode imaging studies carried-out under shallow vertical tube well with pumping (Fig. 53) and horizontal skimming well (Fig. 54) revealed an abnormal resistivity reduction in vertical tube well area. The reduction in resistivity indicates the degrading of water quality due to possible upconing of saline water. Contrarily, in case of horizontal skimming well, negligible change in resistivity proved that horizontal skimming is safe method of harvesting ground water. From the image studies, it was clear that during pumping of the well, there was little quality change in the bottom layer as well as the same has not come up much to reach the skimming well bottom depth of 4.5 m or to the collectors depth of 3.3 m below the ground level. If the depth of 9.6 m is considered as interface of fresh-poor waters, than a distance of 6 m exist between interface and skimming well collectors lines compared to the difference of 3.6 m for the tube well bottom (tube well depth of 6 m). As such, a larger cushion is available in a collector than a vertical pumping well.

- The upconing trends studied at 8 different locations indicated that with vertical pumping (tube well), safe pumping hours ranged from 0.3 to 13 hours (Table 186).

- The economic appraisal of the improved technologies assessed using discounting techniques revealed that skimming well with horizontal collectors had a higher benefit cost ratio (2.15) followed by multi-strainer tube well (1.96) and shallow tube well (1.35) (Table 187).

Table 186 Upcone values for different locations with safe pumping time under existing field conditions

Location	Upconing parameters				Safe pumping time (hours)
	Z critical (m)	Z max (m)	Fcr	Fs*	
Muthaipalem	2.00	1.00	0.790	0.5	1.0
Baptala	2.00	1.00	0.815	0.5	1.0
Padisonpet	3.60	1.80	0.619	0.5	6.0
Karlapalem	3.20	1.60	0.419	0.5	11.0
T R Palem	1.90	0.95	0.732	0.5	1.0
RBV Palem	3.20	1.60	0.363	0.5	5.0
Kothapalem	4.50	2.25	0.191	0.5	13.0
P V Palem	0.50	0.25	-	0.5	Not feasible

Z critical: A critical level at which the apex of the upcone rises and reaches the bottom of partially penetrated well within the fresh water zone
Z max : A maximum permissible saline upcone with ordinates well below a buffer zone of fresh water aquifer underlying the entry point of well
Fcr : The reduction factor at critical level and equal to drawdown/ Z critical
Fs* : The reduction factor for permissible upconing ordinates - 0.4- 0.6

Table 187 Economic appraisal of technologies at constant input-output prices

Technique	Skimming well with collectors	Shallow Tube well	Multi-strainer (Point) tube well
Net Present Worth, NPV (Rs.)	53716	29392	46051
Benefit-cost ratio	2.15	1.32	1.88
Interanl rate of Return, IRR (%)	37	27	34

EFFECT OF GYPSUM APPLICATION ON CROP PRODUCTION AND SOIL CHEMICAL ENVIRONMENT ON FARMER’S FIELDS

All India Coordinated Research Project on Management of Salt Affected Soils and Use of Saline Water in Agriculture (ICAR), Indore has generated various technologies for reclamation of black sodic soils in irrigated as well as in rain fed conditions. Various location specific technologies are based on physical (leaching, drainage and mechanical), chemical (gypsum/pyrites/distillery spent wash) and biological (tolerant crops/varieties, grass cultivation, forestry, agro-horticulture, agro-forestry and silvi-pastoral systems) processes. The technologies generated by the center are still to gain momentum in this area. To achieve this, technological demonstrations were conducted in five farmer’s field in two villages of two districts (Indore and Khargone) of Malwa and Nimar agro-climatic zones. Gypsum was used as reclaiming agent to reclaim alkali soils as detailed below:

A. Gypsum doses (4): 0, 25, 50 and 75% GR

B. Crop rotations (2): Suitable crop rotation (Soybean-wheat for Indore and Cotton for Khargone)

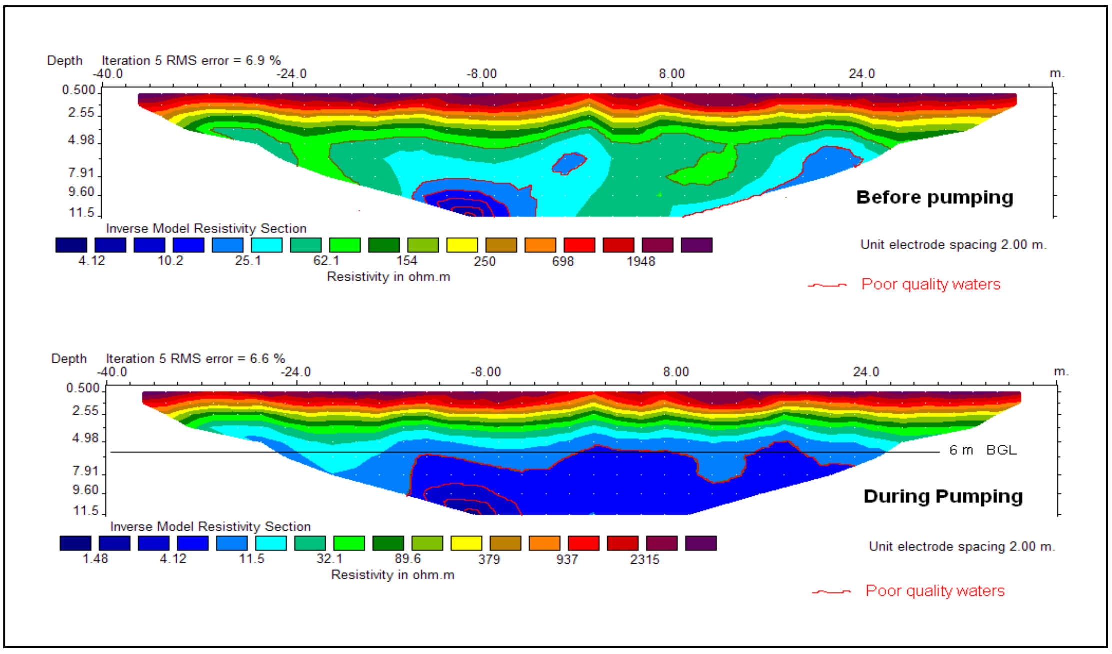


Fig. 53 Resistivity image profile near a shallow tube well at Bapatla

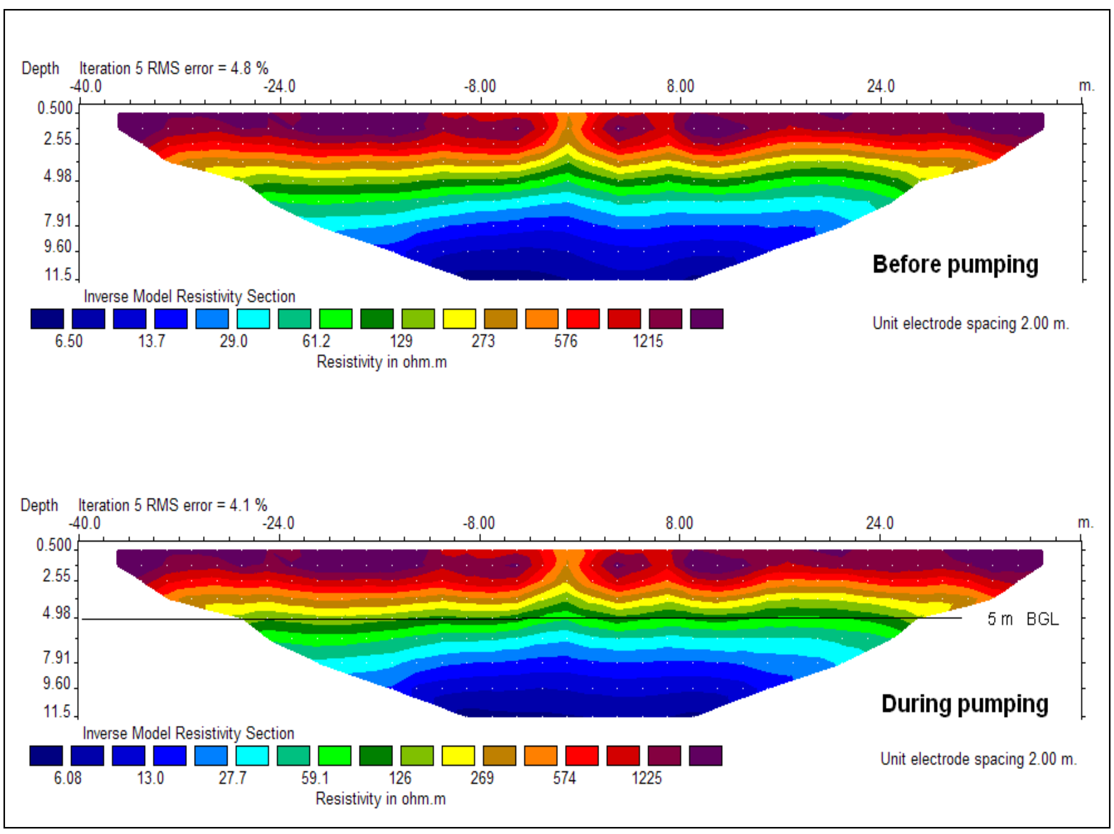


Fig. 54 Resistivity image profile above collector lines of a skimming well at Bapatla

Soybean-wheat

The demonstrations on five farmers' fields were conducted with soybean (variety JS 9560) and wheat (variety Lok-1). Gypsum was applied on the basis of gypsum requirement (GR) estimated in the laboratory for each farmer field separately. The perusal of the data in Table 188 revealed that ESP values decreased with gypsum application. Lowest values of ESP were observed under 75% GR, which are statistically at par with 50% GR. The data (Table 189) revealed that application of gypsum significantly increased seed yield of soybean as well as grain yield of wheat over control. Application of gypsum @ 75% GR registered significant increase in yield over 25% GR. The differences between 50% GR and 75% GR were statistically non-significant.

Table 188 Effect of different doses of gypsum application on ESP

Treatments	Name of the farmers					Mean
	Babu Lal	Mangi Lal	Dinesh	Moti Ram	Badri Lal	
Control	22.24	20.70	22.91	17.65	19.27	20.55
25% GR	21.22	19.61	19.22	17.40	19.12	19.31
50% GR	19.79	18.22	18.35	15.20	18.06	17.92
75% GR	18.98	17.00	17.90	15.99	18.40	17.65
CD (5%)						1.11

Table 189 Effect of gypsum application on grain yield of soybean and wheat

Treatments	Name of the farmers					Mean
	Babu Lal	Mangi Lal	Dinesh	Moti Ram	Badri Lal	
			Soybean			
Control	1.77	1.88	2.45	1.58	1.47	1.83
25% GR	1.98	2.30	2.70	1.79	1.75	2.10
50% GR	2.23	2.17	2.90	1.66	1.98	2.19
75% GR	2.16	2.23	3.15	1.74	2.17	2.29
CD (5%)						0.18
			Wheat			
Control	4.67	4.22	3.78	4.67	5.22	4.51
25% GR	5.11	4.78	4.44	5.44	5.56	5.07
50% GR	5.51	5.51	4.62	5.56	4.67	5.17
75% GR	5.78	5.33	4.78	5.78	6.11	5.56
CD (5%)						0.45

Cotton

The demonstrations on farmer's fields were conducted with cotton as test crop. Gypsum was applied on the basis of laboratory estimated gypsum requirement for each farmer field separately. The perusal of the data indicated that ESP values decreased with gypsum application as compared to untreated soil. Lowest values of ESP were observed under 75% GR, which are statistically at par with 50% GR (Table 190). The data (Table 191) revealed that application of gypsum significantly increased seed cotton yield over control. Application of gypsum @ 75% GR registered significant increase in yield over 25% GR. The differences between 50% GR and 75% GR were statistically non-significant.

Table 190 Effect of different doses of gypsum application on ESP

Treatments	Name of the farmers					Mean
	Pappu	Balya	Bhagwan/Hira	Bhagwan/Laxman	SAS Farm	
Control	26.20	28.56	26.42	23.86	30.50	27.12
25% GR	23.56	25.62	23.82	20.43	26.67	24.02
50% GR	20.41	21.61	20.60	19.16	22.53	20.86
75% GR	19.86	20.26	20.10	18.47	20.85	19.91
CD (5%)						1.18

Table 191 Effect of different doses of gypsum on seed cotton yield (t/ha)

Treatments	Name of the farmers					Mean
	Pappu	Balya	Bhagwan/Hira	Bhagwan/ Laxman	SAS Farm	
Control	1.23	1.09	1.14	1.21	1.17	1.17
25% GR	1.26	1.14	1.08	1.28	1.23	1.20
50% GR	1.31	1.16	1.17	1.35	1.28	1.25
75% GR	1.28	1.18	1.15	1.38	1.38	1.27
CD (5%)						0.05

STUDY ON MONITORING SALINITY HAZARDS IN VEGETABLE CROPS GROWN UNDER DRIP FERTIGATION WITH MARGINALLY SALINE WATER IN VERTISOLS

A study was carried out during 2006-07 and 2007-08 to monitor effect of drip fertigation with marginally saline well water on salinity and economics of horticultural crops grown in Vertisols at farmer's field of village - Bagda khurd, of district Khargone (MP). The EC of irrigation water was 1.15 dS/m. The average values of EC for 0-30 cm depth indicated that the EC values increased with the number of irrigation applied (Table 192 and 193). For example average values of EC were 0.40, 0.38 and 0.50 dS/m at sampling point "on drippers" in case of capsicum crop for 1st 2nd and 3rd sampling respectively. Similar trend was observed in all other crops and sampling points. The study further revealed that higher salt accumulation was observed on sampling points on the side of ridge, side of drippers and between drippers as compared to sampling point "on drippers" in case of all the crops and discharge rates. It implies that salt accumulation was more as we move away from drippers and was highest on side of the ridge. Similar results were obtained during 2007 although the salinity increased or decreased depending upon the rainfall in between (Table 193).

The crop wise cost of production as per actual was worked out (Table 194). The results revealed that growing horticultural crops with drip fertigation in black soils is an economically viable venture as indicated by B:C ratio. B:C ratio is more than 1 in case of all crops with water melon showing the highest B:C ratio of 3.2:1. Next was bitter gourd with 3.11:1 followed by 2.25:1 by potato. The lowest B:C ratio was obtained in the case of Capsicum. It could be due to the reason that chilli was adversely affected in later stages by increased salinity. The highest WUE was obtained as 8.5 q/ha/cm in case of potato crop followed by water melon with 6.03 q/ha/cm and lowest with chilli as 0.58 q/ha/cm.

FIELD TRAILS ON FARMER'S FIELD ON ALKALI WATER IRRIGATION

Two technology transfer demonstrations were conducted at the fields of Tejpal Singh S/0 Sh. Sahajad Singh, Village Bhurjat, district Mahendragarh and Kirori Mal, Village Khudana, district Mahendragarh. Five strips of variable gypsum application (0, 25, 50, 75 and 100% neutralization of RSC) were made. The requisite amount of gypsum in various treatments on the soil and water basis was applied in a single dose before sowing of crop and mixed well in the soil. Recommended cultural practices and fertilizer doses were applied for raising the crop. Uniform fertilizer applications were made in all the treatments. Irrigation schedule was based on the recommendations for the non-saline irrigated soils. The crops were irrigated with sodic water having average RSC of 9.6 and 11.1 meq/l respectively (Table 195).

Table 192 Average values of EC for 0-30 cm soil profile during 2006-07

Crop	Sampling points	EC (dS/m)		
		1st	2nd	3rd
Capsicum	On dripper	0.40	0.38	0.50
	Between drippers	0.62	0.65	0.66
	Side of ridge	0.30	0.52	0.83
	Side of drippers	0.4	0.83	0.89
Chilli	On dripper	0.53	0.59	0.61
	Between drippers	0.62	0.65	0.66
	Side of ridge	0.52	1.12	0.73
	Side of drippers	0.82	0.89	0.96
Tomato	On dripper	0.42	0.72	0.33
	Between drippers	0.80	1.33	0.68
	Side of ridge	0.67	0.99	0.68
	Side of drippers	0.37	0.42	0.55
Okra	On dripper	0.46	0.58	0.35
	Between drippers	0.64	0.83	0.62
	Side of ridge	0.56	0.32	0.61
	Side of drippers	0.38	0.53	0.59
Water melon	On dripper	0.48	0.31	0.37
	Between drippers	0.51	0.34	0.78
	Side of ridge	0.39	0.51	0.69
	Side of drippers	0.50	0.62	0.74

Table 193 Average values of EC for 0-30 cm soil profile during 2007- 08

Crop	Sampling pts.	EC (dS/m)					
		1st	2nd	3rd	4th	5th	6th
Bitter Gourd	On dripper	0.49	0.48	0.50	1.07	0.62	0.51
	Between drippers	0.69	0.50	0.69	0.96	0.75	0.74
	Side of ridge	0.68	0.74	0.56	3.35	1.11	0.65
	Side of drippers	0.86	0.45	0.64	0.98	0.81	0.36
Potato	On dripper	0.48	0.56	0.70	0.81	0.82	0.55
	Between drippers	0.65	0.55	0.58	0.93	0.86	0.68
	Side of ridge	0.74	0.61	0.93	0.97	1.25	0.73
	Side of drippers	0.82	0.77	0.45	0.93	0.96	0.65
Chilli	On dripper	0.53	0.39	0.73	0.91	0.91	0.74
	Between drippers	0.37	0.33	0.77	1.29	0.83	1.29
	Side of ridge	0.38	0.22	1.00	0.86	0.77	0.75
	Side of drippers	0.75	0.86	0.66	1.73	0.73	0.75
Onion	On dripper	0.55	0.42	0.91	0.96	0.83	0.72
	Between drippers	0.87	0.99	0.83	1.22	0.75	0.87
	Side of ridge	0.45	0.54	0.63	1.61	0.84	0.86
	Side of drippers	0.71	0.83	0.77	1.45	0.86	0.79

Table 194 Economic analysis of vegetable crops grown under drip fertigation

Name of crop	Cost of production (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio	WUE (q/ha/cm)
Potato	80000	180000	100000	2.25	8.5
Water melon	80000	256000	176000	3.20	6.03
Chilli	90000	175000	85000	1.94	0.58
Capsicum	75000	120000	45000	1.60	0.67
Okra	80000	168000	88000	2.10	3.96
Bitter gourd	90000	280000	190000	3.11	2.92
Onion	80000	100000	20000	1.25	4.72
Tomato	95000	205000	110000	2.16	5.47
Total	670000	1484000	814000	2.21	3.31

Table 195 Initial parameters of the demonstrations sites

Initial parameters	Demonstration site	
	Tejpal Singh S/o Sh. Sahajad Singh, Village Bhurjat (Mahendragarh)	Kirori Mal, Village Khudana (Mahendragarh)
EC_{iw} (dS/m)	1.45	2.0
RSC (meq/l)	9.6	11.1
Soil pH (0-15 cm)	9.6	9.4
(15-30 cm)	9.6	9.2
(30-45 cm)	9.4	9.3
(45-60 cm)	8.9	9.6
Crop	Mustard	Wheat
Variety	RH-30	WH-283
Date of sowing	27.10.2007	20.11.2007
Date of harvesting	18.03.2008	02.04.2008
No. of irrigations	2	2

The yield of both crops increased significantly with the addition of increasing levels of gypsum application (Table 196). Mustard crop yield in G_{100} treatment increased by more than 5.5 times of the yield obtained in G_0 treatment. Similarly, wheat crop yield also increased in G_{100} treatment by 3.7 times of the yield obtained in control. Appreciable increases in yields were obtained in other treatments also.

The pH of soil at the time of mustard harvest decreased with the addition of increasing levels of gypsum (Table 197). The minimum pH (8.82) was obtained in G_{100} treatment where 100% RSC of water was neutralized with gypsum. Similarly, the pH of soil at the time of wheat harvest also decreased with the addition of increasing levels of gypsum (Table 197). The minimum pH (8.72) was obtained in G_{100} treatment where 100% RSC of water was neutralized with gypsum.

Table 196 Yields (t/ha) of crops in relation to gypsum application at two sites

Treatments	Sites	
	Bhurjat (Mustard)	Khudana (Wheat)
G_0	0.30	0.39
G_{25}	0.89	0.99
G_{50}	1.20	1.32
G_{75}	1.53	1.45
G_{100}	1.69	1.53
CD (at 5%)	0.09	0.10

Table 197 Effect of gypsum level on pH of soil after the harvest of crops

Gypsum level	Mustard		Wheat	
	Soil depth (cm)		Soil depth (cm)	
	0-15	15-30	0-15	15-30
G_0	9.60	9.53	9.65	9.85
G_{25}	9.58	9.80	9.25	9.35
G_{50}	9.50	9.33	9.00	9.10
G_{75}	8.91	9.20	8.90	8.91
G_{100}	8.82	8.93	8.72	8.83

From the experimental studies and the field demonstrations, it clearly emerged that gypsum application is essential in alkali water irrigated lands in Mahendragarh district. In the first year gypsum on the basis of soil and water analysis and later on the basis of alkali water must be applied to get higher yields of wheat and mustard.

F. AD-HOC STUDIES/NOTES

- **Evaluation of Crops with Alkali Water Irrigation through Sprinkler System**
- **Exploiting Nutrients Pool of Distillery Effluents at Cuddalore and Villupuram Districts through Private Agency Schemes**
- ***Prosopis Juliflora* for Charcoal Making in Tamil Nadu**

EVALUATION OF CROPS WITH ALKALI WATER IRRIGATION THROUGH SPRINKLER SYSTEM

In alkali soils of Tiruchirapalli district, mono-cropping of rice is practiced during September to February using good quality canal water from Cauvery irrigation command and monsoon rains. For the rest of period between March to September, the lands are kept fallow because ground water is alkali in nature but it could be exploited. The RSC of alkali water ranges from 8 to 12 meq/l. This water can be better utilized under pressurized irrigation systems like sprinkler and drip, where quantity of water applied is less compared to surface irrigation. Hence this project was undertaken to evaluate the suitability of alternate crops viz., pulses, vegetables, flowers and fodder under sprinkler irrigation system.

Treatment details:

T_1 : Farmer's practice + gypsum @ 50% GR

T_2 : Farmer's practice

T_3 : Sprinkler irrigation with alkali water + gypsum @ 50% GR

T_4 : Sprinkler irrigation with alkali water

Design : Randomized Block Design (RBD)

Replications : 4

Crop/Variety : Green gram-Vamban 2

The effect of sprinkler irrigation with alkali water with soil application of gypsum on green gram yield is given in Table 198. Alkali water through sprinkler irrigation and gypsum application @ 50% GR, recorded the highest green gram yield of 684 kg/ha followed by sprinkler irrigation without gypsum (602 kg/ha). The yield of green gram in the farmers practice with gypsum application was next best to sprinkler irrigation with alkali water. The lowest yield was recorded in the farmers practice (456 kg/ha). Water used in sprinkler and furrow irrigation revealed that 18% water could be saved in sprinkler irrigation compared to the farmers practice.

Table 198 Effect of alkali water on yield of green gram

Treatments	Yield (kg/ha)
Farmer's practice + gypsum @ 50% GR	576
Farmer's practice	456
Sprinkler irrigation with alkali water + gypsum @ 50% GR	684
Sprinkler irrigation with alkali water	602

EXPLOITING NUTRIENTS POOL OF DISTILLERY EFFLUENTS AT CUDDALORE AND VILLUPURAM DISTRICTS THROUGH PRIVATE AGENCY SCHEMES

Studies on short and long-term effects of bio-earth, post methanated distillery effluent (PME) and effluent turned liquid fertilizer have been conducted to assess its effect on changes in soil physical, chemical and biological properties and yield of crops

The distillery effluent generated from distillery industry is of plant origin and contains large quantities of organic matter and plant nutrients. The post bio-methanated distillery effluent (PME) is found to contain all major and micronutrients in considerable amount to sustain growth and yield of crops. However, PME cannot be directly applied to the growing crops because of its high biological oxygen demand (BOD) and chemical oxygen demand (COD). It should be diluted with irrigation water to reduce its BOD and COD, so that it can be used as a nutrient source for crops. Technology has been developed to use this effluent as nutrient source through fertigation to crops like sugarcane and sunflower after diluting it with irrigation water to reduce the BOD level in the ratios of 1:10 to 1:50. Land disposal of PME is also an alternative for reducing pollution, as its application in agricultural fields improves soil fertility and yield of crops.

Though numerous researches are being conducted all over the world on the utilization of PME for agriculture, site specific and long-term studies are needed for its environmentally safe utilization. Hence, to develop suitable environmentally safe technologies for eco-friendly utilization of this post methanated distillery effluent in agriculture, this scheme has been sponsored by EID Parry (I) Ltd., Nellikuppam as a collaborative programme with Tamil Nadu Agricultural University.

The use of PME in varying quantities and proportions as pre-plant application was conducted at Edayanvelli and Poongunam villages of Cuddalore district (Table 199 and 200). The experiments are being continued without disturbing the layout to evaluate the long-term effect of PME on the changes in soil physico-chemical properties, fertility status, microbial population and sugarcane yield. PME was applied @ 1.25, 2.5, 3.75 and 5.00 lakh l/ha for M_2, M_3, M_4, M_5 treatments respectively and allowed to oxidize naturally while M_1 was maintained as control. The soil was thoroughly mixed and sugarcane planting was taken up 45 days after PME application at all the locations.

Table 199 Initial soil properties of the experimental field at Edayanvelli

Soil properties	Value	Soil properties	Value
Soil texture	Sandy loam	Exchangeable Ca (cmol (p^+)/kg)	7.40
Bulk density (g/cc)	1.41	Exchangeable Mg (cmol (p^+)/kg)	3.75
Water holding holding capacity (%)	36.3	Exchangeable K (cmol (p^+)/kg)	0.30
pH	8.40	Exchangeable Na (cmol (p^+)/kg)	1.45
EC (dS/m)	0.10	ESP (%)	11.2
Organic carbon (%)	0.50	DTPA Zn (mg/kg)	2.20
Available N (kg/ha)	139.0	DTPA Fe (mg/kg)	9.80
Available P (kg/ha)	18.0	DTPA Cu (mg/kg)	2.10
Available K (kg/ha)	240.0	DTPA Mn (mg/kg)	9.80

Table 200 Initial soil properties of the experimental field at Poongunam

Soil properties	Value	Soil properties	Value
Soil texture	Sandy clay loam	Exchangeable Ca (cmol (p^+)/kg)	7.41
Bulk density (g/cc)	1.35	Exchangeable Mg (cmol (p^+)/kg)	3.70
Water holding holding capacity (%)	41.0	Exchangeable K (cmol (p^+)/kg)	0.28
pH	8.18	Exchangeable Na (cmol (p^+)/kg)	1.45
EC (dS/m)	0.25	ESP (%)	11.20
Organic carbon (%)	0.48	DTPA Zn (mg/kg)	2.19
Available N (kg/ha)	171.0	DTPA Fe (mg/kg)	9.80
Available P (kg/ha)	12.5	DTPA Cu (mg/kg)	2.08
Available K (kg/ha)	192.0	DTPA Mn (mg/kg)	9.80

The recommended doses of fertilizers (RDF) viz., 275:60:112 kgN:P_2O_5:K_2O/ha was reduced and applied at 75% viz., 206, 45 and 84 kgN, P_2O_5 and K_2O/ha. The results revealed that yield of sugarcane increased progressively with the application of increasing doses of PME. The yield increase was significant for 1.25 lakh l/ha of post methanated distillery effluent application both in sandy loam and sandy clay loam soils. An increased cane yield of 23.88, 34.38, 41.71, 48.38 per cent in sandy loam soil and 47.12, 42.52, 35.63, and 21.83 per cent in sandy clay loam soil were recorded in 1.25, 2.5, 3.75 and 5.0 lakh l/ha of PME application, respectively over control (Table 201). The results also showed that both in sandy loam and sandy clay loam soil, PME application @ 1.25 lakh l/ha along with N and P fertilizers were found to be the best dose for getting higher yield of sugarcane. The application of PME brought the soil pH from alkaline to near neutral. Even when PME was applied @ 5 lakh l/ha, the increase in EC of soil was not significant. There was no significant change in exchangeable Na in sandy loam and sandy clay loam soils due to the application of PME. The availability of N, P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, B and Mo were higher in PME applied plots than control (Table 202 and Table 203).

Table 201 Effect of PME and fertilizers on yield of sugarcane (t/ha) (a) Sandy loam soil and (b) Sandy clay loam soil

(a)

Treatments	No fertilizer	N	NP	NK	PK	NPK	Mean
Control	43	67	79	71	56	86	67.0
1.25 lakh l/ha	54	74	94	83	67	95	77.8
2.50 lakh l/ha	60	76	94	85	70	97	80.3
3.75 lakh l/ha	65	79	98	86	72	99	83.2
5.00 lakh l/ha	71	80	100	90	75	102	86.3
Mean	58.6	75.2	93	83	68	95.8	-
	M	S	S x M		M x S		
CD (5%)	7	10	19		21		

(b)

Treatments	No fertilizer	N	NP	NK	PK	NPK	Mean
Control	60	78	91	86	75	103	82.2
1.25 lakh l/ha	75	92	110	99	90	112	96.3
2.50 lakh l/ha	81	96	113	106	96	114	101.0
3.75 lakh l/ha	86	97	111	109	100	112	102.5
5.00 lakh l/ha	89	99	113	111	102	113	104.5
Mean	78.2	92.4	107.6	102.2	92.6	110.8	-
	M	S	S x M		M x S		
CD (5%)	8	11	20		22		

Table 202 Effect of diluted distillery effluent on (a) physico-chemical properties (b) fertility of sandy loam soil

(a)

Treatments	pH	EC (dS/m)	OC (%)	Exchangeable cations (cmol (p+)/kg)				ESP (%)
				Ca	Mg	Na	K	
Control	8.38	0.094	0.40	7.27	3.51	1.507	0.249	12.02
1.25 lakh l/ha	8.31	0.113	0.75	7.93	4.14	1.488	0.350	10.70
2.50 Lakh l/ha	8.28	0.121	0.82	8.11	4.31	1.500	0.387	10.52
3.75 lakh l/ha	8.18	0.130	0.86	8.31	4.55	1.513	0.427	10.27
5.00 lakh l/ha	8.15	0.152	0.89	8.56	4.96	1.542	0.456	10.02
CD (5%)	0.11	-	-	0.35	0.20	NS	0.021	1.4

(b)

Treatments	Available nutrients (kg/ha)						
	N	P	K	Zn	Fe	Cu	Mn
Control	130	16.27	216	2.05	8.94	1.94	13.38
1.25 lakh l/ha	170	18.72	322	2.50	11.36	2.42	16.23
2.50 Lakh l/ha	180	19.74	350	2.67	12.79	2.69	16.75
3.75 lakh l/ha	191	20.12	382	2.75	13.23	2.79	17.33
5.00 lakh l/ha	194	21.52	394	2.89	14.46	2.94	17.68
CD (5%)	9	1.1	14	-	-	-	-

In fertigation experiments at Edayenveli (sandy loam soil) PME was applied in different dilutions along with irrigation water in the ratio of 1:10, 1:20, 1:30, 1:40 and 1:50. The PME was applied 4 times at 40 days interval starting from 45th day after planting. The recommended doses of N and P @ 275 kg N and 60 kg P_2O_5/ha were applied. The results revealed that sugarcane responded positively to application of PME at different ratios along with irrigation water (Table 204). The highest cane yield was recorded at 1:10 dilution. When compared to control, there was an increase of 37.9, 31.0, 21.8, 18.4 and 12.6% cane yield in 1:10, 1:20, 1:30, 1:40 and 1:50 ratios of PME: irrigation water respectively. Application of PME changed the soil pH from alkaline to near neutral. Though there was a significant increase in the soil EC at 1:10 and 1:20 dilutions, the EC levels were within the safer limits. There was no significant change in the soil ESP due to PME application. Significant build-up in available plant nutrients due to application of PME at different dilutions was observed.

Table 203 Effect of diluted distillery effluent on (a) physico-chemical properties (b) fertility of sandy clay loam soil

(a)

Treatments	pH	EC dS/m	OC (%)	Exchangeable cations (cmol (p+)/kg)				ESP (%)
				Ca	Mg	Na	K	
Control	8.38	0.211	0.60	13.60	7.92	2.087	0.249	8.90
1.25 lakh l/ha	8.31	0.223	0.86	15.53	9.00	2.195	0.352	8.03
2.50 Lakh l/ha	8.28	0.226	0.87	15.81	9.48	2.252	0.388	7.93
3.75 lakh l/ha	8.18	0.236	0.89	15.98	9.78	2.295	0.424	7.90
5.00 lakh l/ha	8.15	0.254	0.92	16.07	10.86	2.345	0.453	7.60
CD (5%)	0.16	0.024	0.54	0.08	0.30	NS	0.025	0.31

(b)

Treatments	Available nutrients (kg/ha)						
	N	P	K	Zn	Fe	Cu	Mn
Control	157	11.5	184	2.48	25.95	1.97	13.38
1.25 lakh l/ha	176	11.78	254	2.86	29.35	2.37	16.13
2.50 Lakh l/ha	183	12.48	285	2.96	30.77	2.49	16.66
3.75 lakh l/ha	190	13.18	322	3.12	31.15	2.67	17.25
5.00 lakh l/ha	194	13.62	350	3.17	31.59	2.89	17.61
CD (5%)	1.3	0.6	17	-	-	-	-

In field experiment with coconut, application of PME @ 40, 80 and 100 l/tree increased the nut yield of coconut over control to the tune of 20, 32 and 41% nut yield/tree/year, respectively. The results revealed that application of distillery effluent @ 100 l/tree once in six months is optimum for getting higher nut yield of coconut.

Table 204 Effect of diluted distillery effluent at different dilutions on (a) sugarcane yield and physico-chemical properties and (b) fertility of soil

(a)

Treatments	Cane yield (t/ha)	pH	EC dS/m	OC (%)	Exchangeable cations (cmol (p+)/kg)				ESP (%)
					Ca	Mg	Na	K	
Control	87	8.33	0.07	0.46	7.7	3.87	1.59	0.41	11.72
1:10 dilution	120	8.13	0.31	0.83	11.86	6.09	1.63	0.85	7.98
1:20 dilution	114	8.16	0.27	0.79	10.58	5.87	1.6	0.81	8.48
1:30 dilution	106	8.19	0.24	0.70	10.35	5.59	1.58	0.76	8.64
1:40 dilution	103	8.25	0.21	0.59	9.82	5.39	1.59	0.71	9.08
1:50 dilution	98	8.24	0.20	0.61	9.59	5.03	1.57	0.66	9.32
CD (5%)	-	0.23	0.05	0.060	0.41	0.33	NS	0.08	1.9

(b)

Treatments	Available nutrients (kg/ha)						
	N	P	K	Zn	Fe	Cu	Mn
Control	231	18.2	278	4.96	13.79	2.09	10.01
1:10 dilution	272	26.8	479	6.25	17.02	4.51	13.19
1:20 dilution	267	25.7	460	5.95	16.48	3.94	12.79
1:30 dilution	261	24.5	428	5.79	16.34	3.67	12.32
1:40 dilution	259	23.9	411	5.75	15.73	3.27	11.96
1:50 dilution	248	22.8	395	5.61	15.31	3.01	11.52
CD (5%)	15	1.8	19	0.28	0.68	0.24	0.61

PROSOPIS JULIFLORA FOR CHARCOAL MAKING IN TAMIL NADU

To meet out the shortage of fodder, arresting increase in atmospheric CO_2 levels, making the waste lands productive and to improve rural economy, planting of fuel wood and fodder trees is an important intervention. *Prosopis juliflora* is considered as an excellent candidate for short rotation energy plantations considering the fast growing nature and higher biomass production with good coppicing potential. In Tamil Nadu, *Prosopis juliflora* was first introduced during 1960 in Ramnad and Thirunelveli district as live fence. Currently, area under *Prosopis* in the state is estimated at 2.5 lakh ha. Even a shift from food crops to commercial crops and *Prosopis* has been noticed in the Thuthukudi, Ramanathapuram and Sivagangai districts. Frequent drought condition at critical crop growth stages, assured income, scarcity of labour at critical junctures and inability to cultivate other crops since employed elsewhere are some of the reasons for the shift. Cultivation of *Prosopis juliflora* has transformed the economy of coastal district of Tamil Nadu and sustained the farm income. The majority of the farmers in Ramanathapuram and Sivagangai districts did not make any effort to plant *prosopis*. They only allowed their fields to be occupied by this crop naturally. *Prosopis* being an aggressive plant, it grows without any attention. In Thuthukudi district however, nearly 56% of the farmers resorted to sowing of this crop in rows with a spacing of about 1.2 m. With a spacing of 2 m x 3 m i.e. 1666 plants/ha, 33.3 t/ha of biomass (26.5 t/ha utilizable and 6.8 t/ha non-utilizable) could be obtained. The tree also provides pods as fodder from the 2^{nd} and 3^{rd} year after planting and is assessed at 20-40 ton/ha/year. Besides, it helps to reduce soil pH, increase the status of organic matter and nitrogen in the upper 15 cm soil layer helping in reclamation of problem soil. It can also be raised with saline water with an EC of 12-29 dS/m. It is estimated that 1,36,000 tons of charcoal is produced per annum in Tamil Nadu alone. A survey conducted in the three districts revealed that area under *Prosopis* in the sampled farm was more than 60% of the land holding (Table 205).

Table 205 Average farm size and area under *Prosopis*

Details	Districts			
	Thuthukudi	Ramanatha-puram	Sivagangai	Mean
Average farm size (ha)	6.75	4.45	3.15	4.78
Average area under *Prosopis* (ha)	4.83	3.46	1.94	3.41
Percentage of area under *Prosopis* to the total area	71.56	77.75	61.59	71.34

Source: Sample Survey by FC & RI, Mettupalayam

Charcoal making

Charcoal made from partial combustion of wood is used in large quantities by steel, ceramic, rayon and carbide industries and hence it forms an important value added product of forest plants including *Prosopis*. Apart from the traditional use as cooking fuel, some of the major industrial uses of charcoal are: clarification of sugar, as a reducing agent in blast furnaces of metallurgical industry, calcium carbide/calcium carbonate industry and also in textile dyeing. Activated charcoal is also used for removing bad odour, taste and colour from foods, medicine and to some extent in water purification.

For charcoal making *prosopis* is usually felled at the age of 3-4 years, 80% for charcoal making while the rest for fuel wood. The industry operates at various scales as follows:

- Small families specialized in the job
- Wholesalers and commission agents who buy wood from the farmers on an area basis and organize production
- Large-scale operators engage labourers/award piecemeal contract to labour groups involved in this activity.

Cost of production

Normally the estimated recovery of charcoal is about 25 % i.e. one ton of charcoal is produced with every four tons of wood, depending on the size and quality of the wood used. Charcoal from *Prosopis juliflora* has a calorific value of 6,930 KCal/kg which is less than that of the charcoal from *Eucalyptus tereticornis, which* has a calorific value of 7,500 KCal kg and more than that of *Casurina*, with a calorific value of 4,950 KCal/kg. The cost analysis works out as follows:

Items	Cost (Rs.)	Percentage
Cost of 4 mt of wood @ Rs. 1200/mt (Farmer and cutting charges)	4800.00	81.60
Labour charges for stacking the wood and burning	300.00	5.10
Labour charges for collecting the charcoal and removing the material	150.00	2.55
Cost of 18 gunny bags @ Rs. 24/bag	432.00	7.35
Labour charges for bagging	150.00	2.55
Other expenses	50.00	0.85
Total	5882.00	100.00

Benefits

Selling price at site : Rs. 7200/ton
Profit due to value addition : Rs. 7200 –5882 = Rs.1318/ton

While the cost of wood alone accounts for more than 80% of the total cost of production, labour accounts for more than 11% indicating that charcoal production is a farm labour intensive process, which helps to generate employment in the rural areas. The labour requirement is assessed as below:

Labour requirement to convert 10 ton of wood into Charcoal

Activities	Labour /10 tons of wood	
	Women	Men
Harvesting	10	20
Stacking	2	3
Watch and Ward	5	5
Dismantling	4	4
Packing and loading	2	1
Total	23	33

Quality control

The major characteristics of quality charcoal are:

- Should be dry black porous but fairly hard
- Should have a black glistering appearance with bluish tinge
- Should have a clear metallic note when struck on a hard object
- Free from taste and smell
- Low ash content with a moisture content of 5-6 per cent
- Should not spoil the fingers when transverse if it is rubbed
- Should be easy to light and burn without production of smoke and sparks

Policy issues

- Though *Prosopis* cultivation has expanded to cover a large area yet its monitoring is limited. The area coverage should be monitored and reported.
- The production process is highly traditional and needs modernization.
- Monitoring the supply to other states should be upgraded by the designated agency.
- It is necessary to find out genotypes that would give high yield and good quality charcoal.
- There is an urgent need to evolve an optimum rotation period with reference to the quality of the charcoal as well as to standardize the other cultivation practices for better growth.

G. GENERAL

G -1: ORGANIZATION

The All India Coordinated Project on 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. 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 Tiruchirrapalli were added. These Centers started functioning from Ist 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.   Lakhs including the state share of Rs.   . The center wise mandate of the project is as follows:

G -2: MANDATES FOR COOPERATING CENTERS

AGRA

1. Develop strategies for conjunctive use of saline and canal water
2. Improve nutrient use efficiency in saline environment
3. Water quality guidelines in relation to cropping systems
4. Rain water management for dry land salinity control
5. Micro irrigation system for saline water use for high value crops
6. To undertake operational research for saline water use

BAPATLA

1. Dorovu technology for skimming fresh water in coastal sandy soils
2. Crop–water production functions with saline water for coastal sands
3. Water quality limits with sprinkler irrigation
4. Rehabilitation of saline soils formed as a result of aquaculture
5. Upconing problems of seawater in coastal sandy soils
6. Fertility management of coastal sandy saline soils
7. Operational research project on dorovu technology/ saline water use/subsurface drainage

BIKANER

1. Establish tolerance limits of crops for the use of saline/alkali waters through sprinklers
2. Develop efficient schedules to establish horticultural species using drip irrigation system
3. Amelioration of micro–nutrient deficiencies in calcium rich soils irrigated with saline waters
4. Studies on salinization/desalinization under shallow water table conditions in IGNP area
5. Irrigation management for saline water use and control of salinity and water logging
6. Evaluation of salinity and water table gradients following plantations with some native tree species for their effectiveness as bio-drainage

GANGAWATI

1. Performance evaluation of vertical/subsurface drainage system in TBP command
2. Reuse of drainage effluents/conjunctive use strategies for saline waters
3. Drainage requirement of crops for saline black soils
4. Evaluation of tree species for their role in halting canal seepage and salinity control
5. Role of organic materials for sustaining yields in rice–rice rotation

6. Evaluation of efficient schedules for saline soils/irrigation with drip to upland field/ vegetable crops
7. Amendment requirement for horticultural species irrigated with high RSC waters

HISAR

1. Development of appropriate conjunctive use modes for sustaining yields with saline/drainage waters
2. Water production functions of crops under stress conditions
3. Develop guidelines for the use of saline waters through sprinklers/drip irrigation systems
4. Evaluation of micronutrient requirement of major crops irrigated with saline/alkali waters
5. Develop and verify models for soil quality deterioration viz.–a–viz. crop performance with saline/alkali irrigation waters and their applications
6. Saline water use for stabilization of sand dunes through agro forestry systems

INDORE

1. Reclamation of alkali lands under rain fed conditions
2. Water production functions for crops in black alkali soils
3. Develop parameters incorporating the effect of Cl/SO_4, Mg/Ca and SAR on sodication and soil permeability
4. Use of industrial effluent in agriculture
5. Alternate land use of black alkali soils (agro-forestry).
6. Resource inventories of soil and ground water resources in new irrigation Commands
7. Operational Research Project on reclamation technologies for black alkali soils

KANPUR

1. Practices to halt resodication of reclaimed alkali soils
2. Seeding techniques for semi-reclaimed alkali soils
3. Water treatment techniques for use of alkali water
4. Conjunctive use of alkali and canal water
5. Soil/land/water resource inventories in Ramganga/Sarda Sahayak command
6. Performance of tree/fruit species in alkali soils
7. Fertility management under conditions of alkali water use

TIRUCHIRAPALLI

1. Conjunctive use of alkali waters in rice based cropping systems
2. Planting methods to establish tree plantations on rain fed alkali soils
3. Identification of efficient schedules for alkali water using drip irrigation to sugarcane and other upland crops
4. Establish sodicity tolerance limits of major crops in Inceptisols
5. Nitrogen management in sodic soils using SPAD system
6. Appropriate land use systems with high SAR waters in Kangayam area

NET WORK TRIALS FOR ALL CENTERS

1. Identification of appropriate cultivars for saline/alkali environments in different agro–ecological regions
2. Water quality/salt affected soil resource inventories/mapping

COORDINATING UNIT

1. Use of saline water in high value low water requiring crops
2. Subsurface drainage for land reclamation including modelling crop response in saline environment
3. Generating chemical/physical parameters for computers models

G -3: STAFF POSITION

STAFF POSITION AT THE COOPERATING CENTERS

X plan	Agra	Bapatla	Bikaner	Gang–awati	Hisar	Indore	Kanpur	Tiruch–irapalli	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	8
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. 2009

Name of the post	Coordinating Unit, Karnal	Centers							
		Indore	Kanpur	Bikaner	Agra	Bapatla	Ganga–wati	Tiruch–irapalli	Hisar
Project Coordinator	1(1)	–	–	–	–	–	–	–	–
Chief Soil Scientist	–	–	–	1	–	1(1)	–	–	–
Soil Chemist	-	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
Jr. Soil Physicist	–	1	–	–	1	–	–	–	–
Jr. Drainage Eng.	–	–	–	1	–	1	1	–	–
Soil Water Eng.	–	–	–	–	–	1	1	1	1
Jr. Plant Physio.	–	–	1	–	–	–	–	–	–
Jr. Agronomist	–	–	–	1(1)	1	1	1	1	1
Jr. Soil Survey Officer	–	1	1	–	–	–	–	–	–
Tech. Officer	1	–	–	–	–	–	–	–	–
Sr. Tech. Asstt.	–	2	3(3)	–	–	–	–	–	–
Overseer	–	–	1	–	–	–	–	–	–
Lab. Tech.	1	–	–	–	–	–	–	–	–
Tracer	--	–	–	–	–	–	–	–	–
Field Asstt.	–	1	–	1	2	1	1	1	1
Fieldman	–	1	–	–	–	–	–	–	–
Lab. Asstt.	1	1	1(1)	1	1	2	1	1	1
UDC	1	1	1	1(1)	1	1	1	1	1
Jr. Steno.	1	–	–	–	–	–	–	–	–
Jeep Driver	–	1	1	1	1	1	1(1)	1	1
Lab. Attendant	3(2)	1	1	1	1	1	1	1	1
Messenger	--	1	1	1	1	1	1	1	1

( ) Vacant position

STAFF POSITION AS ON 31. 03. 2009

Name of the post	No.	Name of incumbent	Date of joining	Date of leaving
		COORDINATING UNIT, CSSRI, KARNAL		
Project Coordinator	1	Dr. P. S. Minhas	13.06.1997	21.05.2006
Sr. Agronomist & PC (A)	1	Dr. O. S. Tomar	04.10.1988	06.06.2007
Project Coordinator	1	Dr. S. K. Gupta	07.06.2007	Contd.
Sr. Agronomist	1	Dr. R. L. Meena	18.07.2007	Contd.
Sr. Scientist	1	Vacant	–	–
Sr. Tech. Officer	1	Sh. S.P. Gupta	03.07.2007	Contd.
Technical officer	1	Sh. Brij Mohan	04.10.1988	Contd.
Personal Assistant	1	Mrs. Rita Ahuja	25.04.1992	Contd.
Messenger	1	Sh. Raj Kumar Sukhbir Singh	01.05.2003	 Contd.
		COOPERATING CENTRES		
AGRA				
Soil Chemist	1	Dr. C.P.S. Chauhan	28.11.1979	Contd.
Jr. Soil Chemist	1	Dr. Bhu Dayal	30.11.1987	Contd.
Jr. Soil Physicist	1	Dr. R.B. Singh	30.11.1987	Contd.
Jr. Agronomist	1	Dr. S.K. Chauhan	15.03.1996	Contd.
Sr. Tech. Assistant (Soils)	2	Sh. R.S. Chauhan Dr. P.K. Shishodia	01.08.1991 11.07.1994	Contd. Contd.
UDC	1	Sh. Rajeev Chauhan	04.09.1991	Contd.
Field Assistant	2	Sh. N.P. Pachauri Sh. Vijendra Singh	04.10.1972 23.07.1973	Contd. Contd.
Lab Assistant	1	Sh. Sarnam Singh	18.12.1989	Contd.
Driver	1	Sh. Doodh Nath	26.06.1989	Contd.
Lab. Attendant	1	Sh. Devi Singh	28.08.1972	Contd.
Messenger	1	Sh. Kishan Singh	23.07.1980	Contd.
BAPATLA				
Principal Scientist	1	Dr. V.Shankra Rao	24.02.2005	25.08.2008
Soil Scientist/ Senior Scientist	1	Dr. G.V. Lakshmi Dr. V.Shankra Rao Dr. P.R.K. Prasad	10.01.2006 26.08.2008 08.11.2008	25.08.2008 02.11.2008 Contd.
Sr. Chemist (SS)	1	Dr. P. Ravinder Babu	04.02.2004	Contd.
Scientist (Agronomist)	1	Sh. Y. Radha Krishna Vacant	27.04.1999 -	14.07.2008 -
Scientist (SWE) –I	1	Sh. M. Raghubabu	16.10.1993	Contd.
Scientist (SWE) –II	1	Sh. G.V.Srinivasa Reddy; Vacant	10.09.2007 -	24.04.2008 -
Sr. Assistant	1	Sh. M. Raju	28.10.2005	Contd.
Lab Assistant	3	Sh. S. Baba Vali Sh. S.K. Mastan Vali Sh. S.K. Moulali	04.09.1990 07.07.2005 03.05.2006	Contd. Contd. Contd.
Field Assistant	2	Sh. Syed Khasim Sh. K. Siva Kumar	19.05.2005 12.07.2006	Contd. Contd.
Lab Attendent	1	Sh. D.V. Siva Rao	16.07.1992	Contd.
Driver	1	Sh. D.V. Brahmam	13.09.2007	Contd.

Messenger	1	Sh. A. Mark	29.12.1995	Contd.
BIKANER				
Chief Scientist &O/I	1	Vacant	-	-
		Dr. B.L.Verma*	31.12.2005	-
Soil Chemist	1	Dr. B.L.Verma	07.05.1996	31.12.2005
Jr. Soil Chemist	1	Dr. Yogesh Sharma	07.05.1996	Contd.
Jr. Agronomist	1	Vacant	–	–
Jr. Drainage Engineer	1	Er. A.K. Singh	10.09.2001	Contd.
Technical Assistant	2	Sh. Deepak Gupta	16.09.2002	31.10.2007
		Vacant	-	-
		Sh. N.K. Pareek	01.06.2007	31.10.2007
		Sh. B. L. Naik**	05.11.2007	Contd.
Field Assistant	1	Sh. B.C.Kumawat	18.07.2001	Contd.
UDC	1	Vacant	–	–
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.

*Working as OIC against the post, ** AAO working as TA

GANGAWATI				
Principal Scientist	1	Vacant	-	-
Scientist (SWE) & OIC	1	Er. Subhas Balagnavi	15. 07. 1999	Contd.
Scientist (Soil Science)	1	Dr. Viswanath J	18. 10. 2008	Contd.
Jr. Drainage Engineer	1	Vacant	-	-
Jr. Agronomist	1	Vacant	-	-
Junior Asstt.	1	Vacant	-	-
Field Assistant	2	Sh. K.Veeranna	02.04.1998	Contd.
		Sh. P.Balasaab	19.11.2001	Contd.
Lab Assistant	2	Sh. B. Nagaraj	26.09.2003	Contd.
		Vacant	–	–
L.V. Driver	1	Sh. Huligeppa Naik	27.07.2006	Contd.
Lab. Attendant	1	Vacant	-	-
Messenger	1	Sh. M. Srinath	27.07.1998	Contd.
HISAR				
Soil Scientist & OIC	1	Dr. S.K. Sharma	08.08.2002	Contd.
Soil Chemist	1	Dr. Vinod K. Phogat	19.06.1997	Contd.
Soil Water Engineer	1	Dr. Sanjay Kumar	10.06.1997	Contd.
Agronomist	1	Dr. Satyavan	11.03.1997	Contd.
Sr. Technical Assistant	2	Sh. D.S. Dahiya	27.07.2002	Contd.
		Vacant	–	–
Field Assistant	1	Sh. Jagdish Chander	03.02.2001	Contd.
Lab. Assistant	1	Sh. Ram Jivan	11.07.2007	30.06.2008
		Vacant	-	-
LDC	1	Smt. Poonam Pahuja	22.09.1999	Contd.
Lab Attendant	1	Sh. Dhan Singh	01.04.1997	Contd.
Messenger	1	Sh. Karan Singh	01.08.2001	Contd.
INDORE				
Soil Chemist &OIC	1	Dr. S.K. Verma	19.09.2003	02.09.2008
		Dr. U. R. Khandkar	02.09.2008	Contd.

Drainage Engineer	1	Er. R.K. Sharma	09.05.2000	Contd.
Jr. Soil Chemist	1	Dr. U.R. Khandkar	01.07.2002	02.09.2008
Jr. Soil Chemist	1	Dr. K.S. Bangar	22.02.1996	Contd.
Jr. Soil Physicist	1	Dr. 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	Smt. Monika Sarga	16.09.2002	Contd.
Field Assistant	1	Sh. T.L. Dhamne	01.07.2000	Contd.
Field man cum– T. D.[1]	1	Sh. S.R. Hirve	25.08.2003	Contd.
Lab. Assistant	1	Ms. R. Ansari	16.11.1995	Contd.
Jeep Driver	1	Sh. Madan Lal	15.07.1999	28.02.2007
		Sh. Kailash Mandloi	19.04.2007	29.10.2008
Lab. Attendant	1	Sh.Uttam Ingle	01.04.1984	Contd.
Messenger	1	Mrs. Rama Gupta	28.08.2003	Contd.

* Agricultural Extension Officer posted against the post of Technical Assistant; [1] Tractor Driver

KANPUR

Soil Chemist & OIC	1	Dr. Samir Pal	01.12.2006	Contd.
Soil Physicist	1	Dr. B.N. Tripathi	22.01.2007	Contd.
Jr. Agronomist	1		01.10.2004	Contd.
Jr.Soil Survey Officer	1	Dr. Navneet Awasthi	28.07.2003	Contd.
Sr.Technical Assistant	1	Sh. G.S. Tripathi	01.09.2004	Contd.
Field Assistant	2	Sh. Ved Prakash Yadav	31.01.2006	Contd.
		Sh. Kumar Prafful	31.08.2006	Contd.
UDC	1	Sh.P.K.Shukla	01.03.1991	09.07.2007
		Sh. Komal		Contd.
Lab. Assistant	1	Sh. P.S.Katiyar	01.09.2004	Contd.
Driver	1	Sh. Ram Babu	19.08.1997	Contd.
Lab. Attendant	1		01.05.1991	Contd.
Messenger	1	Sh. Ganga Ram	01.04.1988	Contd.

TIRUCHIRAPALLI

Soil Chemist & O/I	1	Dr. M.Sheik Dawood	24.05.2006	17.05.2007
		Dr. D. Jayakumar	18.05.2007	Contd.
Jr. Agronomist	1	Dr. S. Pazhanivelan	24.08.1998	09.05.2006
		Dr. S. Panneerselvam	10.05.2006	29.05.2008
		Dr. R. Kavimani	30.05.2008	Contd.
Jr. Soil Water Engineer	1	Dr. K. Nagarajan	08.05.2000	13.05.2007
		Dr. N. Anandraj	14.05.2007	26.05.2008
		Dr. K. Sara Parwin Banu	27.05.2008	Contd.
Jr. Soil Chemist	1	Dr. A.Bhaskaran	01.12.2004	07.05.2008
		Dr. L. Chitra	08.05.2008	Contd.
Lab. Technician	1	Sh. A. Palanivelu	11.11.2003	Contd.
Field Assistant	2	Sh. K. Karikalan	14.12.2000	Contd.
		Sh. S.Pandarinathan	01.11.2005	01.08.2007
		Sh. A. Susai	01.08.2007	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.Arockiasamy	05.10.1998	Contd.
Messenger	1	Sh. V. Palaniyandi	01.04.1995	Contd.

G -4 WEATHER DATA (2006-2008)

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				
			2006-2007			
April, 2006	38.6	21.9	81.0	000.2	08.4	11.2
May	40.6	26.9	84.0	043.3	08.1	11.3
June	39.9	28.2	83.0	011.7	07.8	11.3
July	34.2	27.5	81.0	306.2	04.0	11.2
August	33.8	26.4	81.1	043.8	05.2	11.5
September	36.1	24.9	82.7	014.3	05.8	11.3
October	34.9	21.1	83.1	001.5	06.0	11.9
November	30.6	15.5	83.0	000.0	03.0	12.0
December	24.2	08.0	83.5	003.8	02.0	12.3
January,2007	23.5	06.9	83.1	000.0	02.0	12.4
February	24.6	12.9	93.0	069.0	02.0	11.9
March	30.2	15.6	88.0	062.1	04.0	11.9
			2007-2008			
April, 2007	39.5	22.9	85.2	002.2	08.0	12.2
May	41.7	27.3	85.0	000.0	09.0	12.3
June	39.3	28.8	81.5	086.2	07.0	12.6
July	35.0	27.0	86.1	070.4	00.4	12.2
August	34.0	26.0	90.0	129.7	00.4	12.3
September	34.4	24.8	88.4	017.5	00.4	12.3
October	34.5	17.5	74.4	000.0	00.4	12.6
November	30.5	12.6	87.7	000.0	00.2	13.0
December	23.4	07.4	91.3	001.3	00.1	13.0
January,2008	21.1	06.2	90.5	000.0	00.1	13.1
February	23.5	07.1	83.3	000.0	00.1	13.1
March	33.8	15.6	75.4	000.0	00.3	13.5

BAPATLA

Latitude - 15^o 54’ N **Longitude - 80^o 29’ E**

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Decennial mean rainfall (mm)	Water table (m)
	Maximum	Minimum				
			2006-2007			
April, 2006	33.9	25.4	77.0	062.0	036.6	1.26
May	36.3	26.4	69.5	096.8	040.6	1.48
June	36.7	26.2	64.5	096.3	087.4	1.72
July	36.5	26.5	61.5	072.9	103.9	1.68
August	35.0	25.1	68.0	084.5	172.0	1.65
September	33.1	24.3	81.0	147.2	198.9	1.45
October	32.4	23.5	79.5	474.3	255.8	0.95
November	29.8	21.2	85.0	091.2	047.1	0.37
December	30.3	18.0	83.0	000.0	031.0	0.84
January,2007	30.2	16.3	80.0	000.0	008.2	0.95
February	30.5	18.1	80.5	042.0	009.7	1.17
March	31.9	21.7	81.5	000.0	003.5	1.39
			2007-2008			
April, 2007	33.8	24.7	76.5	000.4	033.3	1.98
May	40.2	27.1	61.5	031.0	039.7	2.51
June	35.4	25.9	75.5	382.2	114.2	2.75
July	35.0	25.1	73.0	264.1	118.5	0.91
August	33.5	25.2	78.5	152.8	170.3	0.68
September	32.3	25.3	82.0	326.2	210.4	0.24
October	31.3	23.7	84.0	166.1	247.6	0.29
November	30.9	20.4	78.0	025.7	045.2	0.2
December	30.6	19.1	79.0	000.2	028.2	0.57
January,2008	30.0	17.4	80.0	000.0	007.5	0.75
February	30.4	20.9	83.0	086.4	016.7	0.84
March	32.2	21.6	77.0	095.7	011.9	1.35

BIKANER

Latitude - 28.1° N **Longitude - 73.35° E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Wind velocity (km/hr)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum			
			2006-2007				
April, 2006	39.2	22.8	38	11	000.0	09.4	10.9
May	43.4	29.2	45	15	015.0	12.8	13.2
June	41.2	26.6	59	24	028.0	11.3	12.1
July	39.3	27.2	65	38	045.7	12.2	11.0
August	36.6	24.6	73	45	002.6	09.1	08.5
September	36.9	22.2	68	34	017.7	08.3	08.7
October	35.4	18.1	62	26	028.5	07.1	07.5
November	30.4	13.0	60	22	000.0	04.7	04.0
December	23.1	07.8	77	33	003.1	04.7	02.9
January,2007	22.8	05.7	71	24	000.0	04.4	03.4
February	26.3	12.0	81	33	089.0	06.5	03.9
March	29.7	14.4	65	28	028.0	06.2	05.1
			2007-2008				
April, 2007	40.4	22.5	38	10	002.5	08.0	10.0
May	42.4	26.7	41	13	000.0	10.4	14.6
June	40.9	27.6	58	27	046.5	13.8	15.6
July	38.6	27.5	67	39	030.7	12.2	11.7
August	37.1	26.2	70	43	087.5	11.8	10.3
September	37.0	25.2	69	37	017.2	07.9	08.7
October	35.7	16.6	46	14	000.0	05.2	06.6
November	32.5	11.0	44	15	000.0	04.2	04.5
December	24.0	05.4	72	26	000.0	04.2	02.7
January,2008	20.3	05.3	64	20	000.0	05.1	03.0
February	24.7	07.4	53	15	000.0	06.0	04.3
March	35.4	16.7	44	12	000.0	07.6	08.0

GANGAWATI

Latitude - 15^0 0’N **Longitude - 76^0 0’ E**

Months	Temperature (^oC)		Relative humidity (%)	Total rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum			
		2006-07			
April, 2006	40.0	25.3	79.1	000.0	*
May	40.2	26.1	73.8	008.0	*
June	35.0	24.6	79.0	009.0	*
July	30.0	22.0	82.9	056.5	*
August	31.5	23.2	84.4	015.0	4.96
September	32.7	22.9	83.8	054.4	4.73
October	32.3	22.0	83.2	015.5	4.78
November	30.4	19.5	87.2	024.0	4.69
December	31.1	17.8	79.2	000.0	5.18
January,2007	31.3	16.1	81.4	000.0	5.30
February	32.2	17.0	73.6	000.0	5.40
March	36.0	20.4	80.7	000.0	5.61
		2007-08			
April, 2007	39.0	22.3	77.9	003.5	*
May	39.2	24.3	85.0	094.2	*
June	33.3	23.7	87.5	164.0	*
July	31.9	23.7	86.8	019.5	*
August	30.5	22.7	88.3	074.75	*
September	30.1	22.3	89.4	405.75	*
October	31.8	24.3	86.3	056.25	4.01
November	31.4	16.8	78.2	000.0	4.51
December	30.7	18.0	81.5	000.0	4.44
January,2008	32.7	17.9	77.7	000.0	4.06
February	31.1	18.4	80.9	005.0	4.63
March	32.3	18.8	78.8	190.2	4.30

* Evaporation 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		
			2006-2007			
April, 2006	37.0	18.0	66.0	29.0	000.0	08.3
May	40.6	23.9	68.0	36.0	069.2	09.9
June	38.1	24.2	72.0	45.0	074.7	08.8
July	35.4	26.8	85.0	62.0	091.3	06.4
August	35.0	25.5	82.0	58.0	007.9	07.0
September	34.2	22.7	86.0	53.0	069.8	05.3
October	33.7	17.3	81.0	38.0	000.0	05.0
November	28.5	10.9	91.0	51.0	000.0	02.7
December	21.9	05.5	95.0	46.0	006.0	01.8
January,2007	20.1	03.3	94.0	43.0	000.0	01.7
February	22.8	08.8	96.0	72.0	086.0	02.2
March	27.0	11.2	90.0	45.0	044.3	03.7
			2007-2008			
April, 2007	38.0	17.7	66.0	22.0	002.0	07.6
May	39.8	23.8	59.0	27.0	044.2	10.1
June	38.5	26.5	72.0	46.0	167.3	09.3
July	36.9	26.4	81.0	52.0	021.0	07.4
August	35.4	26.2	86.0	59.2	068.8	06.3
September	34.0	23.7	90.5	55.8	066.3	05.1
October	33.7	13.9	83.0	25.0	000.0	04.6
November	29.4	10.6	88.0	35.0	000.0	02.6
December	21.2	04.5	91.5	38.8	003.8	01.6
January,2008	18.6	03.2	90.0	38.0	003.3	01.8
February	21.5	04.3	86.0	37.0	000.9	02.7
March	32.4	12.3	85.0	31.0	000.0	04.7

INDORE (Barwaha Experimental Station)

Latitude - 22° 14 ′ N **Longitude - 76° 01 ′ E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/month)
	Maximum	Minimum	Maximum	Minimum		
			2006-2007			
April, 2006	-*	-	-	-	005.0	391.5
May	-	-	-	-	019.6	516.0
June	-	-	-	-	100.7	360.5
July	-	-	-	-	389.2	107.0
August	-	-	-	-	388.8	067.0
September	-	-	-	-	195.2	100.5
October	-	-	-	-	014.6	170.0
November	-	-	-	-	000.0	133.0
December	-	-	-	-	000.0	131.5
January,2007	-	-	-	-	000.0	119.0
February	-	-	-	-	000.0	143.5
March	-	-	-	-	000.0	281.5
			2007-2008			
April, 2007	-	-	-	-	000.0	410.0
May	-	-	-	-	002.8	478.0
June	-	-	-	-	196.6	279.0
July	-	-	-	-	374.6	126.0
August	-	-	-	-	267.4	66.5
September	-	-	-	-	077.5	113.5
October	-	-	-	-	000.0	138.5
November	-	-	-	-	000.0	135.0
December	-	-	-	-	000.0	83.0
January,2008	-	-	-	-	000.0	88.0
February	-	-	-	-	000.0	116.5
March	-	-	-	-	016.5	231.0

*: Data not available

KANPUR

Latitude - 29^{0}27'N **Longitude - 80^{0}20'E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2006-2007			
April, 2006	38.1	20.4	58.0	21.1	025.0	08.2
May	38.5	26.1	68.0	38.0	034.4	09.6
June	37.8	27.4	66.7	44.0	042.3	08.0
July	33.1	26.6	86.6	70.8	317.6	04.9
August	33.0	26.3	83.3	66.2	034.7	05.6
September	34.8	24.8	81.4	54.0	044.4	03.6
October	33.4	19.9	77.7	44.3	036.0	03.9
November	28.7	14.5	87.8	46.6	001.5	01.7
December	24.6	09.9	89.4	53.3	000.4	01.1
January,2007	22.8	07.8	87.7	42.9	000.0	01.1
February	24.3	12.0	92.9	58.0	042.5	01.0
March	29.4	14.8	78.5	46.6	017.4	02.0
			2007-2008			
April, 2007	38.8	23.0	62.8	39.3	000.0	04.4
May	39.0	25.4	56.8	33.5	006.0	08.7
June	39.0	27.3	67.2	42.4	038.8	09.5
July	34.2	26.8	82.9	63.0	186.4	07.5
August	32.8	26.3	87.5	72.9	272.2	04.7
September	33.3	25.2	83.6	63.2	023.6	05.2
October	33.3	18.0	78.1	39.0	000.0	04.3
November	29.0	13.1	88.8	48.5	000.0	02.0
December	23.6	08.6	86.6	47.0	000.0	00.0
January,2008	22.0	07.3	82.5	36.6	000.0	00.7
February	23.5	09.0	77.4	38.1	001.6	00.8
March	32.7	16.0	70.9	33.5	000.0	01.7

KARNAL

Latitude - 29^0 43' N **Longitude - 76^0 58' E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2006-2007			
April, 2006	36.4	18.1	60	18	000.0	06.3
May	37.8	24.9	62	35	018.7	08.6
June	37.3	25.3	67	41	049.8	07.6
July	37.3	25.3	67	41	128.0	04.5
August	33.8	25.8	86	63	008.2	05.0
September	33.2	23.1	88	58	065.2	03.6
October	32.3	18.1	91	43	007.9	07.0
November	27.1	13.0	91	41	004.2	02.1
December	21.2	08.2	94	51	005.4	01.5
January,2007	19.6	05.6	94	47	014.4	01.6
February	21.2	10.0	95	63	216.0	01.9
March	26.0	12.5	89	47	060.3	03.6
			2007-2008			
April, 2007	37.5	19.5	65	21	000.0	06.9
May	38.0	23.8	61	27	007.2	09.2
June	36.9	26.2	72	47	108.9	08.6
July	34.3	26.8	86	66	100.3	05.4
August	33.3	25.8	88	69	133.1	04.8
September	32.4	23.3	92	63	119.0	03.8
October	32.1	14.8	90	40	000.0	04.0
November	27.6	10.8	93	39	001.2	02.0
December	20.7	06.7	90	47	001.4	01.7
January,2008	18.1	05.1	84	47	001.4	02.0
February	20.1	06.5	86	47	001.2	02.5
March	30.1	13.5	89	40	000.0	04.0

TIRUCHIRAPPALLI

Latitude - 10^0 45′ N **Longitude - 78^0 36′ E**

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Evaporation (mm/day)
	Maximum	Minimum	Maximum	Minimum		
			2006-2007			
April, 2006	38.3	26.9	91.8	54.9	007.2	06.5
May	36.9	27.7	88.9	59.1	075.6	08.9
June	36.6	27.5	88.7	62.3	032.0	08.2
July	35.9	27.9	88.4	65.4	000.0	08.6
August	35.9	26.8	87.6	65.1	220.4	10.2
September	33.8	25.5	91.7	77.1	064.8	04.9
October	31.9	25.1	92.9	79.5	177.6	04.4
November	29.9	24.5	94.8	85.7	238.6	03.4
December	29.5	21.4	91.9	81.2	035.0	03.4
January,2007	30.5	21.4	90.9	76.5	000.0	03.5
February	32.9	21.5	89.8	57.6	001.6	05.1
March	35.2	23.9	86.7	65.4	000.0	06.2
			2007-2008			
April, 2007	37.4	27.3	86.6	59.1	063.0	05.9
May	39.3	28.8	83.6	49.7	055.4	08.7
June	36.4	27.9	85.2	62.6	030.4	08.6
July	35.5	26.6	85.5	63.8	064.4	08.8
August	34.6	25.9	88.5	68.4	121.4	10.8
September	34.85	26.4	86.8	67.3	061.2	08.4
October	33.0	25.3	90.1	73.2	197.8	06.2
November	31.4	23.5	89.9	76.7	062.4	05.9
December	29.0	21.7	92.2	79.2	310.6	03.5
January,2008	30.4	20.1	92.4	77.4	010.0	04.5
February	32.7	21.3	94.0	73.3	041.8	06.6
March	32.4	23.2	95.2	74.0	143.6	05.7

G -5: LIST OF PUBLICATIONS (2006-2008)

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G - 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. 2132.15 lakhs (ICAR Share Rs. 1695.63 lakhs). The budget head and center wise statement of expenditure for 2006–2007 and 2007–08 is given below:

AGRA

Budget head	2006-07		2007-08	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	2850000	3304662	3820000	3554402
T.A. & P.O.L.	120000	70134	120000	70060
Contingencies				
Recurring	300000	296039	340000	337035
Non-recurring	0	0	0	0
Total	3270000	3670835	4080000	3961497

BAPTALA

Budget head	Expenditure (ICAR share Rs in lakhs)	
	2006-07	2007-08
Pay & Allowances	3454454	3744891
T.A. & P.O.L.	71177	61404
Contingencies		
Recurring	343491	343682
Non-recurring	0	0
Total	3869122	4149977
ORP		
TA	32953	46933
RC	245768	246546
Total	278721	293479
Grand Total	4147843	4443456

BIKANER

Budget head	2006-07		2007-08	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	1600000	1933007	3000000	2246279
T.A. & P.O.L.	100000	38337	80000	78457
Contingencies				
Recurring	300000	298269	387000	385473
Non-recurring	0	0	0	0
Total	2000000	2269613	3467000	2710209
ICAR Share (75%)	1500000	1702210	2600000	2032657

GANGAWATI

Budget head	2006-07			2007-08		
	Allotment ICAR share	Released ICAR share	ICAR share of expenditure	Allotment ICAR share	Released ICAR share	ICAR share of expenditure
Pay & Allowances	1400000	1255000	1698189	1400000	2440000	1698189
T.A. & P.O.L.	60000	60000	49502	90000	80000	49502
Contingencies						
Recurring	225000	225000	224947	310000	290000	224947
Non-recurring	0	0	0	0	0	0
Total	1685000	1540000	1972638	1800000	2810000	1972638

HISAR

Budget head	2006-07		2007-08	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	2384100	2146261	2532600	2486100
T.A. & P.O.L.	93330	66075	120000	91670
Contingencies				
Recurring	266660	232388	413300	245330
Non-recurring	0	0	0	0
Total	2744090	2444724	3065900	2823100
ICAR share	2058068	1833543	2299425	2117525

INDORE

Budget head	2006-07		2007-08	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	3120000	3047552	3430813	3322704
T.A. & P.O.L.	120000	116810	146667	108793
Contingencies				
Recurring	360000	359329	413333	412391
Non-Contingencies	0	0	0	0
Total	3600000	3523691	3990813	3843888

KANPUR

Budget head	2006-07		2007-08	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	1293000	2181000	2413000	2296000
T.A. & P.O.L.	106000	92000	147000	123000
Contingencies				
Recurring	320000	311000	413000	383000
Non-recurring	453000	338000	0	0
Total	2172000	2924000	2973000	2802000

KARNAL

Budget head (in lakhs)	2006-07		2007-08	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	0.00	0.00	0.00	0.00
T.A. & P.O.L.	0.50	0.50	0.50	0.45
Contingencies				
Recurring	3.50	1.55	4.00	1.00
Non-recurring	0.50	0.45	0.00	0.00
Total	4.50	2.50	4.50	1.45

TIRUCHIRAPALLI

Budget head	2006-07		2007-08	
	Sanctioned	Expenditure	Sanctioned	Expenditure
Pay & Allowances	2240000	2214910	2133300	2402386
T.A. & P.O.L.	93333	92282	146600	144696
Contingencies				
Recurring	266666	266531	413300	413140
Non-recurring	0	0	0	0
Total	2599999	2574723	2693200	2960222