SUSTAINABLE USE OF BRACKISH WATER FOR BETTER CROP PRODUCTION IN DIFFERENT TEXTURED SOILS

UTILISATION DURABLE DE L'EAU SAUMÂTRE POUR MEILLEURE PRODUCTION AGRICOLE SUR DIFFERENTES TEXTURES DU SOL

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ABSTRACT

Irrigation by brackish water for reduces crop yield and deteriorates soil physical and chemical properties. Attempts have been made in the past to minimize the adverse effects of saline-sodic irrigation water through different irrigation, soil, and crop management practices. The use of such marginal-quality water would permit the horizontal expansion of irrigated agriculture. The present study evaluates the performance of different wheat and maize genotypes irrigated with brackish water in different texture soils and salt accumulation in soils. The soils of three textures (sandy loam, clay loam and clay) were used in 100 cm long lysimeters. Four brackish water treatments along with one good quality water treatment (canal water) were applied with two amendments; gypsum and FYM @ 25 Mg ha^{-1} for two year wheat-maize crop rotation. Plant growth and yield components of both crops were adversely affected with the application of brackish water with the maximum reduction in high EC-SAR-RSC water treatment. However, use of gypsum significantly improved the wheat grain yield as well as fresh biomass of maize fodder as compared to application of high EC-SAR-RSC water. The salt tolerant wheat genotype SARC-1 performed best in all treatments and similarly, the salt tolerant maize genotypes (Sahiwal-02) had better plant growth and fresh biomass in all brackish water treatments. Brackish water affected the soil textures and the maximum reduction in yield was observed in clay as compared to sandy loam and clay loam textures.

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Net salt added in 0-30 cm soil layer was highest in high EC-SAR-RSC water application treatment in clay (15.6 t ha^{-1}) while this was significantly less in sandy loam (56%) texture after two years. Application of gypsum reduced salt accumulation and total salt in upper layer (8.28 t ha^{-1}) which was 38% less compared to EC-SAR-RSC water application in clay texture. The gypsum application was more effective in improving soil properties (EC$_e$, SAR & infiltration rate) in clay texture. Thus, in clay texture use of gypsum along with brackish water is very important for sustainable crop production and to reduce the adverse effects of brackish water.

Key words: *Brackish water, Soil texture, Supplementing canal water, Lysimeter.*

RESUME ET CONCLUSIONS

L'utilisation d'eau saumâtre pour l'irrigation a entraîné une réduction du rendement des cultures et la détérioration des propriétés physiques du sol et chimiques. Des tentatives ont été faites dans le passé pour réduire au minimum les effets néfastes de l'eau d'irrigation salins-sodiques grâce à l'irrigation différentes, le sol et les pratiques de gestion des cultures. L'utilisation d'eau de qualité marginale de tels permis l'expansion horizontale de l'agriculture irriguée. L'étude pour évaluer le rendement de blé et de maïs différents génotypes irriguées avec des eaux saumâtres dans les sols de textures différentes, ainsi, la charge en sel dans les différentes textures de sol dans la rotation blé-maïs et les moyens de réduire l'accumulation de sels dans la zone racinaire a été étudié.

Les sols de trois textures (loam sableux, loam argileux et d'argile) ont été utilisés dans 100 cm de long lysimètres. Quatre traitements de l'eau saumâtre avec un traitement de l'eau ajustement T1 (eau du canal), T2 = [(EC (10 dS m^{-1})-SAR (20 (mmol L^{-1})$^{1/2}$ d'eau], T3 = [EC (10 dS m^{-1})-SAR (20 (mmol L^{-1})$^{1/2}$-RSC (5.4 meq L^{-1})] de l'eau, T4 = [EC (10 dS m^{-1})-SAR (20 (mmol L^{-1})$^{1/2}$-RSC (5,4 meq L^{-1}) + eau de plâtre sur l'eau exigence de base] et T5 = [EC (10 dS m^{-1})-SAR (20 (mmol L^{-1})$^{1/2}$-RSC (5.4 meq L^{-1}) + eau FYM @ 25 Mg ha^{-1}] ont été utilisés pendant deux années la rotation des cultures de blé-maïs. croissance des plantes et les composantes du rendement des deux cultures effectuées négativement à la demande de l'eau saumâtre avec l'abattement maximal haute EC-SAR+ RSC-traitement de l'eau. eau Cependant, l'utilisation de gypse (plâtre selon l'exigence de l'eau avec l'eau EC-SAR-RSC, a sensiblement amélioré le rendement en grain de blé ainsi que la biomasse fraîche de fourrage de maïs par rapport à la demande du EC-SAR-RSC seule. De même, l'application de FYM amélioré le rendement de croissance des végétaux et de céréales, mais son effet a été relativement moins de EC-SAR-RSC eau + traitement de gypse. Le génotype de blé tolérant le sel SARC-1 qui a été identifié après examen du matériel génétique disponible dans le pays, les meilleurs résultats dans tous les traitements, y compris l'eau EC-SAR-RSC application seule et même façon, les génotypes maïs tolérant le sel (Sahiwal-02) avaient une meilleure croissance des plantes et la biomasse fraîche par rapport à tous les traitements de l'eau saumâtre. eau saumâtre affecté la production agricole différemment lorsque par rapport aux textures de sol et la réduction maximale de rendement a été observée dans l'argile par rapport à loam sableux et loam argileux textures. A la fin de l'expérience, la EC a été 12.8, 15.1 et 21.3 dans le traitement de EC-SAR-RSC application de l'eau dans un loam sableux, loam argileux et la texture du sol d'argile, respectivement. sel ajoutée nette en 0-30 cm du sol était plus élevée dans le traitement de CE-SAR-SRC demande d'eau *dans l'argile (15.62 t ha^{-1}) par rapport à loam sableux (6.8 t ha^{-1}) et loam argileux (10.04 t ha^{-1}) après deux ans. L'accumulation de sels a été beaucoup moins dans un loam sableux (56%) par rapport à l'argile de texture. Application de l'accumulation de sel de gypse et de sel réduit total dans la couche supérieure (8.28 t ha^{-1}) qui était de 38% de moins par rapport à la demande d'eau CE-SAR-RSC de texture argileuse. Il a également observé que l'effet de gypse a été plus dans la texture d'argile par rapport aux autres. L'application de gypse a été plus efficace pour améliorer les propriétés du sol (EC, SAR et le taux d'infiltration) dans la texture d'argile. Ainsi, dans l'utilisation texture argileuse de gypse avec l'eau saumâtre est très important pour la production agricole durable et de réduire les effets néfastes des eaux saumâtres.*

Mots clés: *Eau saumâtre, texture du sol, augmenter l'eau du canal, Lysimètre.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Water is a basic necessity for sustaining life. In plants, water helps in maintaining turgidity, leaf stomata functions, uptake and translocation of nutrients and metabolites, sequestration of excessive salts and toxic material into vacuoles or out of tissue and serving as medium for all biochemical and bio-energy reactions (Salisbury and Ross, 2004).

The area of irrigated land has expanded substantially in the world, particularly in the second half of the last century and has accounted for more than 50% increase in global food production (El-Ashry and Duda, 1999) and it produces more than a third of the food and fiber harvested throughout the world (Hillel, 2000).

Competition for freshwater already exists among the municipal, industrial and agricultural sectors in several regions due to an increase in population. The consequence has been a decreased allocation of freshwater to agriculture (Tilman *et al*., 2002). This phenomenon is expected to continue and intensify in less developed, arid region countries such as Pakistan, that already have high population growth rates and suffer from serious environmental problems (Qadir and Oster, 2004).

The shortfall in irrigation water requirement is likely to reach 107 MAF[5] by 2013 in Pakistan (Ghafoor *et al*., 2002b). A supplemental source of water has to be made to meet this deficit from groundwater. In order to supplement the canal water availability at farm-gate (43 MAF), more than 531,000 tube wells are pumping 55 MAF in Pakistan (Anonymous, 2004). Estimates show that about 70–80% of pumped water in Pakistan (67,842 million m^3) contains soluble salts and/or sodium ions (Na^+) levels above the permissible limits for irrigation water (Latif and Beg, 2004). The long term use of poor quality water results in deterioration of physical and chemical properties of soil due to accumulation of salts (Oster, 2004; Chaudhary, 2004). Rafiq (1990) estimated the development of surface salinity and/or sodicity on an area of about 3×10^6 ha in the country as a result of marginal-quality drainage and groundwater use without appropriate management practices. Unscientific and continuous use of poor quality water could result in deterioration of soil health and adverse effect on plant growth. Growth of most

5 MAF = Million Acre Feet: 1 acre-foot = 1233.5 m^3.

agricultural crops irrigated with poor quality water suffers adversely (Chaudhry *et al*., 2001; Murtaza *et al*., 2006).

There are two major approaches for improving and sustaining productivity in a saline soil and water environment: modifying the environment to suit the plant and modifying the plant to suit the environment. Both these approaches have been used, either singly or in combination (Minhas, 1996), but the former has been used more extensively because it facilitates the use of alternative production inputs. The development of management options requires the analysis of sensitivity parameters that affect interactions between salinity and crop yield (Zeng *et al*., 2001).

However, for sustainable agricultural production, just like the irrigation water balance, the salinity balance also has to be maintained at the irrigation system and basin levels (Tyagi, 2003). Conjunctive use, water table management, rain water conservation in precisely leveled basins and chemical amelioration of alkali water are some of the important practices to achieve these objectives.

The available management options are mediated through the management of crop, irrigation water, chemical amendments and cultural practices, but there seems to be no single management measure to control salinity and sodicity of irrigated soils, but several practices interact with each other and should be considered in an integrated manner. The reduction in wheat yield from 12 to 43% was reported (Sharma *et al*. 2001; Hamdy *et al*. 2005), when irrigated with high EC water as compared to fresh water treatment.

However, recent studies and other evaluations indicated that waters previously thought unsuitable for irrigation can often be used successfully for longer periods without hazardous consequences on crops or soils. Use of such water would not only permit the horizontal expansion of irrigated agriculture but would also reduce drainage disposal and associated environment problems (Oster and Grattan, 2002).

This work will be help in successful planning of brackish water use for wheat yield and maize fodder production and helpful in selection of best genotypes which can be economically grown by irrigating with brackish tube well water. Keeping in view these considerations, the present studies were planned with the objectives to evaluate the performance of different wheat and maize genotypes irrigated with brackish water and to assess the change in chemical and physical properties of soil irrigated with brackish water on different soil textures.

2. MATERIALS AND METHODS

2.1. Experimental conditions

A lysimeter study was carried out during 2003-05 at the Saline Agriculture Research Centre (SARC), University of Agriculture, Faisalabad, Pakistan. Seeds of wheat genotypes (8670 and SARC-1) and maize genotypes (Sahiwal-2002 and Akbar) were collected from SARC and Fodder Research Institute, Sahiwal.

Salts (Na_2SO_4, $CaCl_2.2H_2O$, $MgSO_4.7H_2O$ and $NaHCO_3$) were used to develop brackish water in laboratory. Salts were calculated for developing different levels of EC, SAR and RSC in distilled water according to the treatments of synthetic brackish water using guidelines given by Abid (2002).

The experimental design was completely randomized, with four replications.

T1 = Control

T2 = 10-20-1.5 (EC-SAR-RSC)

T3 = 10-20-5.4 (EC-SAR-RSC)

T4 = 10-20-5.4 (EC-SAR-RSC) + FYM @ 25 Mg ha^{-1}

T5 = 10-20-5.4 (EC-SAR-RSC) + Gypsum @ GR*

*Gypsum requirement on water RSC basis

Different soil physical and chemical determinations (Table 3.1) before and during experiments were done. Soil physical parameters (particle size analysis and saturated hydraulic conductivity) were determined after harvesting of each crop in wheat – maize (fodder) cropping pattern. Chemical parameters (pH, EC, SAR) of irrigation water and soil samples were determined chemically by using following methods described by U.S. Salinity Lab. Staff (1954). GR of irrigation water was determined on RSC basis using the following formula (Eaton, 1950).

$$\text{GR (kg ha}^{-1}\text{)} = \frac{98 \times 220 \times 30 \times \text{irrigation depth} \times \text{decrease in RSC} \times \text{eq. wt. of gypsum}}{1000 \times 1000 \times 1000}$$

Salt concentrations in soils inferred from measured electrical conductivity values were converted to salt loads using the functional relations suggested by Ma. et al. (2007):

$$Cm = 0.670 \times EC_e$$

$$Sm = 0.1 \times Cm \times \theta v \times L$$

Where Cm = salt load of the soil solution (kg m^{-3}); EC_e = electrical conductivity of a saturation extract (dS m^{-1}); Sm = total salt load of the soil layer (t ha^{-1}); θv = volumetric water content (%); L = thickness of the sampled soil layer (m).

Salt budgets as follows:

$$\Delta S = Rs + Is + Fs + Cs + Ls + Ts + Es$$

Where ΔS = net salt increment in the soil (t ha^{-1}); Rs = salt added with rainwater (t ha^{-1}); Is = salt added with irrigation water (t ha^{-1}); Fs = salt added with fertilizer (t ha^{-1}); Cs = salt imported with upward capillary rise (t ha^{-1}); Ls = salt exported with leaching water (t ha^{-1}); Ts = salt exported with harvested produce (t ha^{-1}); Es = salt exported with evapotranspiration (t ha^{-1});

The salt loads of rainwater and evapotranspiration are negligible. It was assumed that salt input by fertilizers and losses at crop harvest would even out. It is difficult to quantify net capillary rise and leaching losses with precision and consequently salt inputs and losses with capillary rise and leaching. One can however calculate the overall net change in salt load of the soil if the salt loads at the beginning and the end of an observation period are known. Hence:

$$\Delta S = b - a$$

Where ΔS = net salt load; a = initial salt load (t ha^{-1}); b = final salt load (t ha^{-1});

Table 1 Initial soil analysis (Analyse initiale du sol)

Characteristics	Sandy loam	Loam	Clay loam
Sand %age	78	48	26
Silt %age	12	28	36
Clay %age	10	24	38
ECe (dS m^{-1})	1.00	1.10	1.21
pHs	7.60	7.70	7.65
SAR (mmol $L^{-1})^{1/2}$	2.10	2.13	2.20

2.2. Preparation of plastic lysimeters and soil filling

Three soil textures sandy loam, clay loam and clay were used in lysimeter experiments. Twenty plastic pipes (75 cm height and 23 cm dia.) were used for each texture with four brackish water treatments with and control having four replications. At lower end of lysimeters stainless steel wire gauze was fixed with help of rubber inner tube band and a thin layer of glass wool was spread over wire gauze before attaching it with plastic pipe and two inch layer of black river sand placed in bottom of plastic pipe. These plastic pipe were filled with air dried, ground, passed through 2mm sieve thoroughly mixed soil of sandy loam, clay loam and clay texture. The soil filling was accomplished in two steps. In the first step 16 kg soil was put in lysimeters with gently tapping sides of column and applying heavy irrigation for compaction and in the 2nd step remaining 16 kg soil was filled in each plastic pipe and irrigation was applied. In this way, all 60 lysimeters were filled and arranged in CRD on the basis of textural class and treatments. Eight seeds of each genotype were sown in each lysimeter and recommended dose of NPK was applied (120-90-60 kg ha^{-1}) for wheat and (200-150-200 kg ha^{-1}) for maize. Farm Yard Manure (FYM @ 25 Mg ha^{-1}) was applied in soil in the respective treatment and mixed well before lysimeters filling while gypsum was applied with each irrigation according to gypsum requirement of water (Eaton, 1954). Irrigation was applied after 15-20 days interval. Soil sampling (0-15 & 15-30 cm) was done during the experimental period i.e. soil sampling prior to experiment and then after each crop (1st wheat, 1st Maize, 2nd wheat and 2nd Maize).

2.3. Leachate collection and soil sampling

Water was allowed to infiltrate through each lysimeter in the receivers. A representative sample was collected from the leachate of each lysimeter. At termination of the experiment soil columns were allowed to dry up to workable water contents. Then each lysimeter was sampled with the help of core sampler. These samples were ground, mixed thoroughly and produced for chemical analyses.

3. RESULTS

3.1. Soil Salinity

Soil salinity exerts osmotic effects on plants (Grattan and Grieve, 1999) and most often causes physiological drought if the salinity levels are greater than the critical limits. Our results indicated that application of EC-SAR water increased soil salinity (EC_e) in all the 3 textures. However, use of gypsum along with EC-SAR-RSC water minimized the adverse effect of brackish water and lowered the increasing trend of EC_e. Similarly use of FYM along with EC-SAR-RSC water also lowered the adverse effects of brackish water (Table 4). The data regarding the changes in EC_e (Fig. 1) with brackish water application in different textured soils (after wheat 04-05, maize 05, wheat 05-06 and maize 06) indicated that EC_e increased with EC-SAR-RSC water application in all the textures but the extent of increase was more in clay loam soil as compared to other textures. Soil EC_e increased with continuous use of brackish water and it was 8.4 folds higher than control after the 1st crop (wheat 04-05) which increased after each crop and reached 10.7 times in clay loam texture at the end of experiment. Cucci *et al*., 2002 observed salt build up in soil when irrigating with saline water was 13.9 dS m^{-1} in 1st year and up to 19.5 dS m^{-1} in 2nd year.

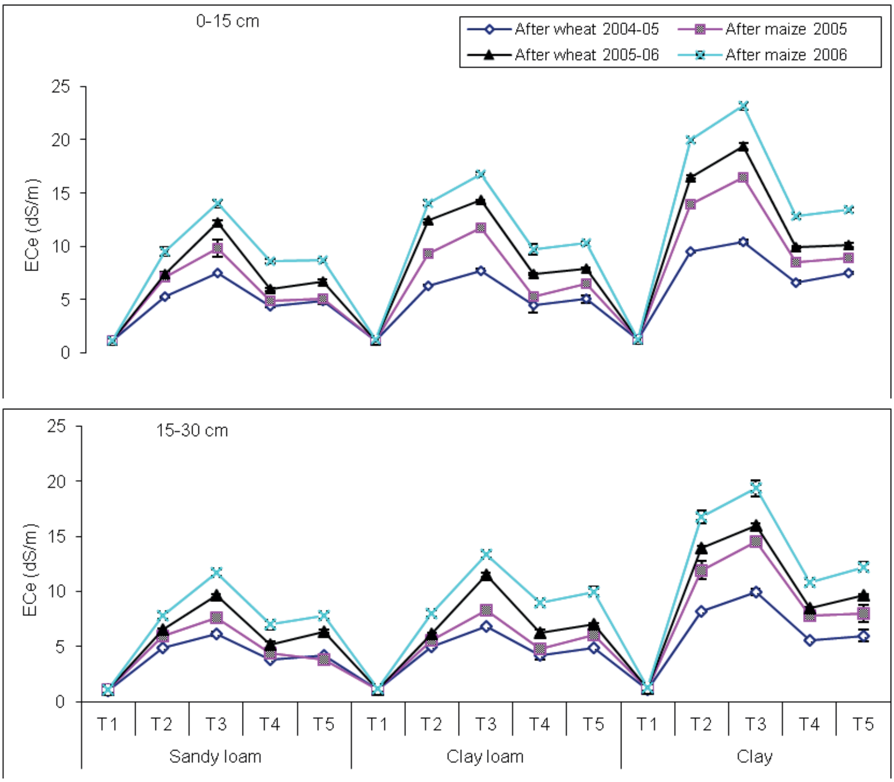

Fig. 1: Effect of brackish water on ECe (dSm^{-1}) in different textured soil (0-30 cm depth) (Effet de l'eau saumâtre de la EC (dS m^{-1}) dans un sol à texture différentes (0-30 cm de profondeur)

Soil texture also determine the salinity build up by controlling how much water will be able to pass through the soil, how much salts accumulated in soil. In present study, it was observed that increase in ECe was more drastic in clay loam texture (up to 21.3 dS m^{-1}) followed by loam (14.4 dS m^{-1}) and sandy loam (13.4 dS m^{-1}) textures by EC-SAR-RSC water application as more clay percentage and poor infiltration occurred due to an increase in clay swelling (Emdad *et al*., 2004).

Applications of gypsum or FYM along EC-SAR-RSC water reduced the adverse effects of brackish water and lowered the salt accumulation by improving soil aggregation and downward movement of water as in this study, gypusm application lowered the ECe of soil especially in upper layer (0-15 cm). Use of higher EC and SAR water increased soil EC ranged from 12-100% within three years along with increase in SAR of soil, but when this water was used with 100% gypsum applied to soil on RSC based of water, it decreased soil SAR (Chaudhry *et al*., 2003).

T1 = [Fit Water]

T2 = [EC (10.0 dS m^{-1}) SAR (20 m mol L^{-1})$^{1/2}$ Water]

T3 = [EC (10 dS m^{-1}) SAR (20 (m mol L^{-1})$^{1/2}$ RSC (5.4 me L^{-1}) Water

T4 = [EC (10 dS m^{-1}) SAR (20 (m mol L^{-1})$^{1/2}$ RSC (5.4 me L^{-1}) Water + Gypsum requirement on water RSC basis

T5 = [EC (10 dS m^{-1}) SAR (20 (m mol L^{-1})$^{1/2}$ RSC (5.4 me L^{-1}) Water + FYM @ 25 Mg ha^{-1}

3.2. Soil Sodicity

Application of EC-SAR water increased Soil SAR but damage was more when with high RSC (EC-SAR-RSC water) and it went upto 2 to 15 in SLS, 2 to 18 in LS and 2 to 19 (mmol L^{-1})$^{1/2}$ in CLS texture respectively (Figure 2). However, use of gypsum with EC-SAR-RSC water decreased the adverse effect of brackish water and lowered the SAR and similarly was when FYM was use.

The data regarding SAR of soil (Fig. 2) including four cropping seasons indicated that application of EC-SAR and EC-SAR-RSC water increased soil SAR as compared to fit water treatment. In EC-SAR water application SAR in 0-15 cm layer was 10.21, 11.91, 13.7 and 15.8 (mmol L^{-1})$^{1/2}$ and it was 9.3, 10.8, 12.0 and 14.0 (mmol L^{-1})$^{1/2}$ in 15-30 cm layer of soil after 1st, 2nd, 3rd and 4th crop respectively in clay loam textured soil. It was further increased with EC-SAR-RSC water application and was 10.80 in 12.30 in 0-15 cm and 10.8 in 15-30 cm of soil layers in clay loam texture at the end of experiment (after 4th crop). Increase in soil SAR with brackish water was due to deterioration of soil structure, low infiltration rate and deficiency of nutrients. An increase in soil SAR is directly proportional to SAR_{iw} under average management conditions (Ahmad *et al*., 2002). Application of EC-SAR-RSC water had more adverse effect as compared to EC-SAR water. The water having EC_{iw} 0.8 dS m^{-1}, SAR 13.5 and RSC 10.3 me L^{-1} would create more sodium saturated soil than that having EC_{iw} 0.8 dS m^{-1}, SAR 8.4 and RSC 8.8 me L^{-1} Maximum sodium saturation with both waters occurred in surface (0-30 cm) and declined rather sharply with increase in depth. Clay loam texture was affected more followed by loam and sandy loam due to more clay percentage and poor downward movement of water to leach down salts form root zone.

Highest SAR values were observed in clay loam texture which were 5.44, 6.23, 7.26 and 8.43 times or respective control in upper layer (0-15 cm) and lowest increase in SAR was found in sandy loam texture which was 4.27, 5.32, 6.14 and 6.93 times of respective control, in upper layer (0-15 cm) after 1st, 2nd,3rd and 4th crop respectively, with EC-SAR-RSC water application treatment and same trend was observed in EC-SAR water. The adverse effects of brackish water was more on fine textured soils as compared to light textured soils (Abid *et al*., 2003). The results indicated that SAR values lowered in T4 (EC-SAR-RSC water + Gypsum) and T5 (EC-SAR-RSC water + FYM) as compared to EC-SAR-RSC water alone.

Murtaza *et al*. (2006) observed significant increase in ECe and SAR with the application of saline sodic water in sandy clay loam soil. Use of amendments like gypsum is recommended especially when RSC>5 me L^{-1}, soils are medium textured and annual rainfall of the area is less than 500 mm (Minhas *et al*., 2004).

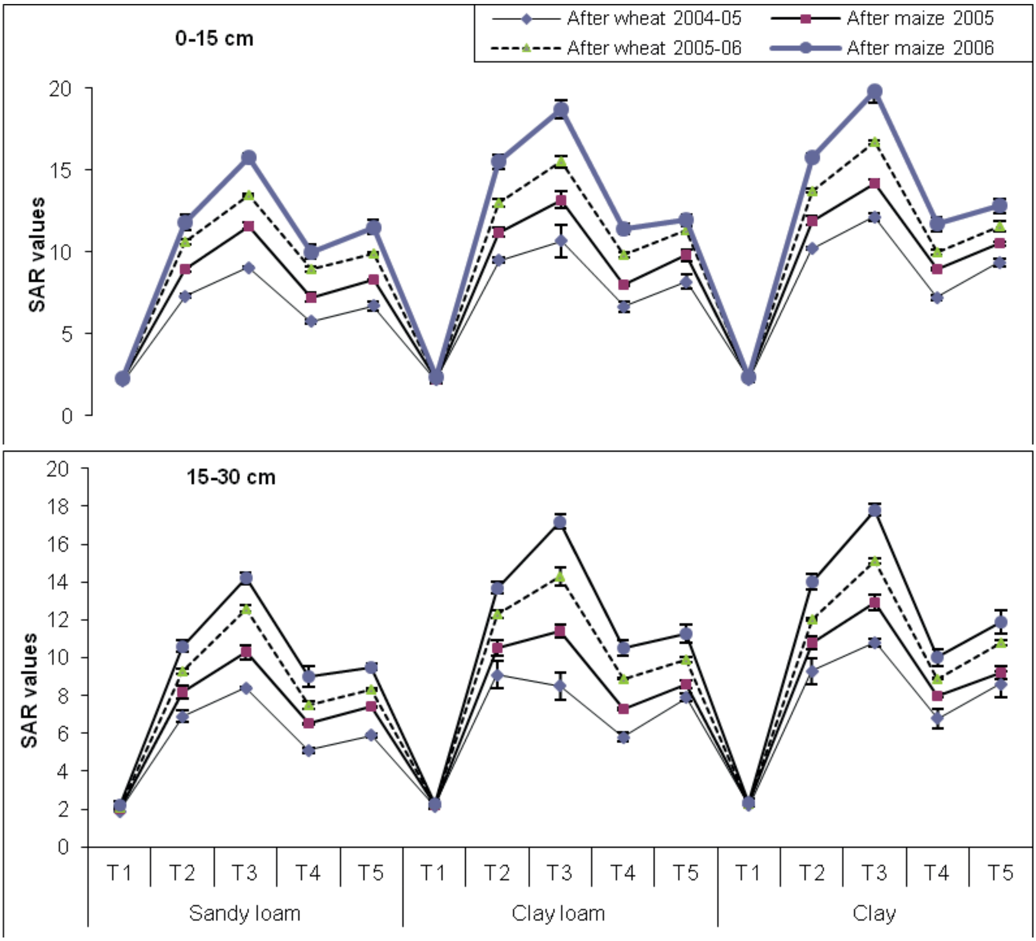

Fig. 2: Effect of brackish water on SAR in different textured soil (Effet de l'eau saumâtre sur la SAR au sol de texture différentes)

T1 = [Fit Water]

T2 = [EC (10.0 dS m^{-1}) SAR (20 m mol $L^{-1})^{1/2}$ Water]

T3 = [EC (10 dS m^{-1}) SAR (20 (m mol $L^{-1})^{1/2}$ RSC (5.4 me L^{-1}) Water

T4 = [EC (10 dS m^{-1}) SAR (20 (m mol $L^{-1})^{1/2}$ RSC (5.4 me L^{-1}) Water + Gypsum requirement on water RSC basis

T5 = [EC (10 dS m^{-1}) SAR (20 (m mol $L^{-1})^{1/2}$ RSC (5.4 me L^{-1}) Water + FYM @ 25 Mg ha^{-1}

3.3. Saturated hydraulic conductivity

Saturated hydraulic conductivity was 0.89 to 0.97 (cm h^{-1}) in sandy loam soil while it was 0.74 to 0.80 (cm h^{-1}) in loam and was 0.68 to 0.77 (cm h^{-1}) in clay loam soil during the experiment. Application of EC-SAR water caused decrease in saturated hydraulic conductivity that was 0.89 to 0.55 (cm h^{-1}) in sandy loam, 0.74 to 0.44 (cm h^{-1}) in loam and 0.68 to 0.40 (cm h^{-1}) in clay loam soil respectively during the experiment. Similarly application of EC-SAR-RSC water (Fig. 3) further decreased saturated hydraulic conductivity and it was 0.89 to 0.50, 0.74 to 0.39 and 0.68 to 0.33 (cm h^{-1}) in sandy loam, loam and clay loam soil respectively during the experiment. Use of gypsum along with EC-SAR-RSC water increased saturated hydraulic conductivity as compared to brackish water application and it increased from 0.89 to 1.12, 0.74 to 1.09 and 0.68 to 0.92 (cm h^{-1}) in sandy loam, loam and clay loam soil respectively. Use of FYM along with EC-SAR-RSC water also lowered adverse effect of brackish water. The data (Fig. 3) regarding hydraulic conductivity as affected by brackish water application with and without amendments, for four cropping seasons on three soil textures (sandy loam, loam and clay loam) showed that application of EC-SAR water for four cropping seasons significantly lowered saturated hydraulic conductivity (0.88, 0.68 and 0.61 cm h^{-1} in sandy loam, loam and clay texture respectively) as compared to fit water irrigation treatment in which hydraulic conductivity was 1.08, 0.90 and 0.88 cm h^{-1} in sandy loam, loam and clay loam texture respectively. Application of brackish water caused clay dispersion which decreased infiltration rate and hydraulic conductivity.

Swelling and dispersion increase with increasing SAR_{iw} and decreasing EC_{iw} that effect the physical properties of soil (Oster, 1994). Quirk (2001) confirmed hydraulic conductivity in low Na;Ca ratio and lower hydraulic conductivity in higher Na:Ca ratio in irrigation water. Application of brackish water had more adverse effect on soil that had more clay particles compared to sandy soils, due to dispersion of clay particles. There was more decrease in HC with EC-SAR-RSC water application in clay loam texture (0.36 cm h^{-1}) at the end of 4th crop. The degree of dispersion with higher EC, SAR water was more in sandy clay loam soil due to higher clay contents and comparatively high amount of Na^+ adsorbed (Hussain *et al*., 1991b). Changes in soil sodicity may also results in decreased soil permeability, which in long term could restrict leaching, leading to increase in soil salinity. The adverse effect of long term use of alkali/sodic water on the physical and chemical properties of soil can be mitigated by the use of amendments. Use of gypsum with EC-SAR-RSC water improved hydraulic conductivity (1.32, 1.36 and 1.33 cm h^{-1} in sandy loam, loam and clay loam texture respectively) in all the textures as compared to EC-SAR-RSC water alone treatment in which HC was 0.56, 0.45 and 0.36 cm h^{-1} in sandy loam, loam and clay loam texture respectively. Maximum improvement (88.9%) in infiltration rate was recorded with green manure and FYM application with saline irrigation water (Kahlown and Azam, 2003).

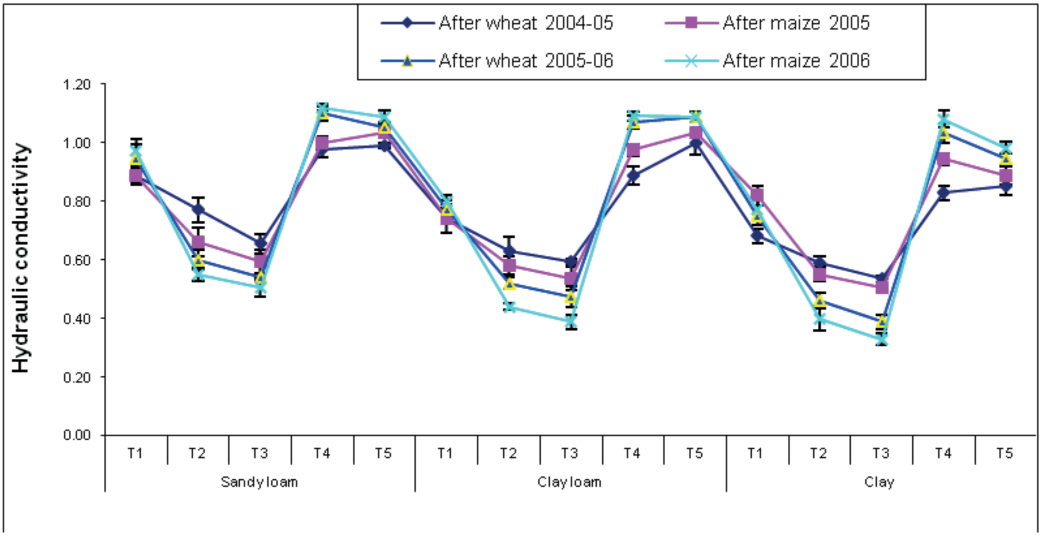

Fig. 3. Effect of brackish water on saturated hydraulic conductivity (K_{sat}) of different textured soil (Effet de l'eau saumâtre sur la conductivité hydraulique à saturation (Ksat) du sol de texture différentes)

T1 = [Fit Water]

T2 = [EC (10.0 dS m^{-1}) SAR (20 m mol $L^{-1})^{1/2}$ Water]

T3 = [EC (10 dS m^{-1}) SAR (20 (m mol $L^{-1})^{1/2}$ RSC (5.4 me L^{-1}) Water

T4 = [EC (10 dS m^{-1}) SAR (20 (m mol $L^{-1})^{1/2}$ RSC (5.4 me L^{-1}) Water + Gypsum requirement on water RSC basis

T5 = [EC (10 dS m^{-1}) SAR (20 (m mol $L^{-1})^{1/2}$ RSC (5.4 me L-1) Water + FYM @ 25 Mg ha^{-1}

4. CONCLUSIONS

Soil salinity increased with application of brackish water and highest increase was observed in EC-SAR-RSC water application that was 11, 13 and 17 folds increase with respective control of sandy loam, loam and clay loam soil respectively after two years. Application of brackish water without amendments also increased soil sodicity that was 7, 8 and 9 folds of respective control in sandy loam, loam and clay loam respectively at the end of experiment. But use of amendments; gypsum and FYM along with EC-SAR-RSC water lowered the adverse effects of brackish water application and reduced down the increase in soil salinity and sodicity.

Saturated hydraulic conductivity decreased with brackish water application, however, use of gypsum and FYM with brackish water improved these soil physical conditions. More adverse effects of brackish water were observed in clay loan texture as compared to others.

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