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# Management of Sodic Waters for Sustainable Crop Productivity of Rice- Wheat Cropping System

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**A B S T R A C T**

A field experiment was conducted at Dalip Nagar crop research station, C.S. Azad University of Agriculture and Technology, Kanpur during *Rabi* and *Kharif* of 2009-10 and 2010-11 to find out the impact of sodic waters for sustainable crop productivity of rice and wheat cropping system. The experiment was laid out in randomized block design with seven treatments of sodic water and four replications. The results showed that maximum grain (4.76t ha$^{-1}$)and straw (5.07t ha$^{-1}$) yield of rice and grain (3.83t ha$^{-1}$) and straw (4.36t ha$^{-1}$) yield of wheat were recorded with the application of SA of gypsum (50% GR) + GBT) of Sodic water ($T_6$) comparison to other treatments found mean of two year. Application of these recommendation in Sodic water dominant area to gating maximum yield and maintain soil health it is also sustain crop production very profitable for marginal farmers.

## Introduction

India has been blessed with two major natural resources, relatively productive land and good reservoir of water resources. At the same time, India has one of the highest population density (382 people per km²) and population growth rate (2% per year). An increased population (India 1200 million and UP 200 million as per census 2011) pressure is expected to shrink per capita cultivable land further in the years to come. Most of the land area in our country shows evidence of degradation, affecting thereby the productive resource base. Out of the total geographical area of 329 million hectare (mha), 175 mha is considered as affected, in which sodic soils and saline soils including coastal areas account for 3.6 and 5.5 mha, respectively (Abrol and Bhumla, 1971). The sodic soils are largely predominant in the Indo-Gangetic plains encompassing the states of Punjab, Haryana, Uttar Pradesh, parts of Bihar and Rajasthan, parts of black soil areas of Gujarat, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu (Anon, 2000). Isolated patches of sodic soils also occur in some other states. In addition, with the advent of canal irrigation, salinity and sodicity is extending over large areas of fertile cultivated lands. Demand for finite water resources is increasing and with increase in population, contamination of water resources is on the rise. Also, increase in population means land reclamation of poor and salt affected soil and then intensification of agricultural production systems to feed the growing population. This means demand for irrigation water and agricultural chemicals will increase to produce more food resulting in the pollution of soil, water, air and other natural environments even further.

Intensification of agriculture in India has increased soil salinity/sodicity due to poor water management practices, water logging due to poorly managed irrigation system, and pollution of drinking water supplies. All these factors have added enormous stress on available land and water resources. Unless best irrigation and cropping management system including use of poor quality water are developed in agricultural watersheds to protect degrading land and water resources in India, social and food security is at very much risk.

In the region, poor quality of irrigation waters usually leads to an increase in soil sodicity problem and thus causes reduction in crop yields (Choudharyand Ghuman, 2008). Use of soil amendments is to counter the effect of sodium, by increasing the soluble Ca content or by increasing the salinity of the irrigation water. Gypsum is the most commonly used soil amendment. Since water infiltration problems caused by sodium affect mainly the upper few centimeters of soil, application of gypsum is preferred. Comprehensive care and planned management practices should be followed to minimize the deleterious effects of unfit ground water. The menace of unfit ground water can be reduced by using management practices along with amendments either inorganic like gypsum, H2SO4 etc or organic like manures FYM, poultry manure, press mud etc. (Qadir *et al.,* 2001; Saifullah *et al.,* 2002; Yaduvanshi and Swarup, 2006).

Present investigation falls under the preview of second aspect mentioned above and effort has been made to utilize sodic underground water for irrigation with suitable amendment techniques to boost crop production under sodic soil condition. Keeping policy decision aside, sustainable production, should emphasized on increase in production using scientific techniques without deteriorating the quality of natural resources as well as produce. Restoration and/ or make use of degraded natural resources for increasing production.

## Materials and Methods

Principles of experimentation the "Use of Sodic waters for sustainable crop productivity" was carried out during 2009-11. This is an ongoing experiment initiated in the year 2005 under All India coordinated Research Project on Management of Salt Affected soils and Use of Saline water in Agriculture (ICAR) and concluded after five years. A field experiment was carried out in Crop Research Station, Daleep Nagar, Kanpur of C.S. Azad University of Agriculture and technology. The district Kanpur is part of doab lying sandwiched between the river Ganga and Yamuna falling between the parallels of 25° 25´ to 26° 58´ N latitude and 79° 31´ to 80° 34´ E longitude. It slopes gently from North-West to South-East and it is located at an elevation of 125.9 meters above mean sea level. The experiment was laid out in randomized block design with seven treatments management of sodic water viz. $T_1$ - Control (Sodic water), $T_2$ - Gypsum bed (15 cm) treatment (GBT) of sodic water, $T_3$ - Soil application (SA) of gypsum (25% GR), $T_4$ - Soil application (SA) of gypsum (25% GR) + gypsum bed (15 cm) treatment (GBT) of sodic water, $T_5$ - Soil application

(SA) of gypsum (50% GR), $T_6$ - Soil application (SA) of gypsum (50% GR) + gypsum bed (15 cm) treatment (GBT) of sodic water, $T_7$ - Soil application (SA) of gypsum (100% GR) with four replication. Use "Gypsum bed technology" conventionally, developed by CSSRI, Karnal, and further studies the physio- chemical characteristics of soil, representative soil samples from a depth of 0-20 cm were collected. A composite sample was prepared from these primary soil samples. It was air dried and then oven dried at 105˚C for estimation of moisture content. Soil samples were air dried ground to pass through 2.0 mm sieve and analysed for its physico-chemical characteristics as presented.

Sodic water samples both gypsum treated and untreated were collected and analysed for pH, EC, ionic composition and RSC.

Soil and water samples were analysed following standard procedure as described by Chopra and Kanwar (1976). Soil texture (International pipette method), CEC (Neutral normal ammonium acetate method), gypsum requirement (EDTA or Versenate method using Erichrom black T indicator), organic carbon (Wakley and Black method), pH (digital pH meter), EC (digital conductivity meter), carbonate and bicarbonate (titrating with standard N/10 $H_2SO_4$ using phenolphthalein and methyl red indicators), Chloride (titrating with standard solution of $AgNO_3$ using potassium chromate. $K_2CrO_4$ as indicator), sulphate (turbidimetric method), Calcium and Magnesium (versenate method using Erichrome black T indicator), Calcium (versenate method using murexide indicator), Sodium and potassium (Flame photometer) were determined following standard procedures. Residual sodium carbonate (RSC) was determined by subtracting milliequivalents (meq) of (Ca + Mg) from milliequivalents of ($CO_3$ + $HCO_3$) and expressed as meq $l^{-1}$.

## Results and Discussion

The soil belongs to Typic Natrustalf having loam texture, low in organic carbon content (0.1%), high pH (9.65), EC (4.96 $dSm^{-1}$) and ESP (64.1) with gypsum requirement of 16 t $ha^{-1}$. Result of studies on gypsum dissolution by sodic irrigation water through 15 cm gypsum bed (Table 1) indicated higher average rate of gypsum dissolution during kharif (0.84 t $ha^{-1}$) in comparison to rabi (0.71 t $ha^{-1}$) season.

Gypsum bed treatment of sodic irrigation water reduced bicarbonate and sodium ions content by 0.50 and 1.33 meq $l^{-1}$ respectively with considerable increase in sulfate (3.19 meq $l^{-1}$) and Calcium (4.2 meq $l^{-1}$) ions. The RSC and pH of sodic irrigation water reduced from 8.73 to 4.0 meq $l^{-1}$ (46%) and 8.07 to 7.82, respectively whereas EC increased from 1.17 to 1.48 dS $m^{-1}$ (Table 2) for the reason that Gypsum bed treatment of sodic water reduced its pH, RSC to safer limit (<5 meq $l^{-1}$) besides increase in both available Ca and the salinity which reduce the negative effects of ESP on soil micro structure and clay dispersion to maintain soil permeability and tilth. Similar observations were also reported by Murtaza *et al.,* (2010), and Gupta (2004).

Annual average gypsum dissolution through sodic irrigation water found to be 1.55 t $ha^{-1}$ which correspond to 9.7% gypsum requirement, and studies on Ionic composition of untreated and gypsum bed treated sodic irrigation water (Table 2) revealed absence of carbonate in sodic irrigation water but rich in bicarbonate (10.6 meq $l^{-1}$) (Eaton, 1979) with relatively very less amount of chloride (0.77 meq $l^{-1}$) and sulfate (0.46 meq $l^{-1}$) anions. Sodium and potassium were the dominant cations (9.72 meq $l^{-1}$) in untreated sodic irrigation water that contains relatively less amount of Ca and Mg ion (1.87 meq $l^{-1}$), finding supported Sharma *et al.,* (2004).

Treatments effect as evident from the graded doses of soil applied gypsum alone and in combination with gypsum dissolution through gypsum bed on yield of rice and wheat (Table 3) revealed that gypsum application either through dissolution or soil enhanced yield of rice (69%) wheat (72%) significantly over control yield of rice 2.0 t $ha^{-1}$and wheat (1.5 t $ha^{-1}$). These yields are also conformity with the findings of Minhas *et al.*, (2007).

Sodic irrigation water could be use efficiently for increasing crop productivity, with the application of suitable amendments like gypsum. Critical analysis of yield data also revealed that one time soil application of gypsum @ 50% GR is beneficial and most efficient than one time soil application of gypsum @ 100% GR. Among the treatment combinations, one time soil application (50%GR) along with gypsum dissolution through sodic irrigation water recorded highest yield of both rice (4.42 t $ha^{-1}$) and wheat (3.40 t $ha^{-1}$), finding supported by (Choudhary *et al.*, 2003, Sharma *et al.*, 2008) Changes in chemical characteristic of surface soil (0-20 cm) due to implementation of treatments for five years (Table 4) revealed that sodic water irrigation (control) considerably raise the value of pH, EC and ESP of soil to 10.01, 5.46 dS $m^{-1}$ and 75.15 respectively from the corresponding initial values of 9.65,4.96 dS $m^{-1}$ and 64.10. These results corroborate the finding of Gypta, (2004).

Application of gypsum either through gypsum bed or soil significantly reduced soil pH, EC and ESP. Sodic water irrigation through gypsum dissolution for five years reduced surface soil pH, EC an ESP to 8.40,4.35 $dSm^{-1}$ and 33.50 from corresponding initial values of 9.65,4.96 $dSm^{-1}$ and 64.10, respectively.

One time soil application of gypsum @ 50% GR along with gypsum bed treatment of sodic irrigation water was found to be most effective in reducing soil pH (from 9.65 to 8.0), EC (from 4.96 to 3.35 $dSm^{-1}$) and ESP (from 64.10 to 18.50) in comparison to the sole soil application of gypsum @ 50 or 100%GR and any other treatment combinations, similar result also reported by).

The technologies for safe and efficient use of sodic water include the optimal use of both the chemical and organic amendments with their time and mode of application to maintain soil permeability and tilth. There is no single technology or approach that can ensure safe use of poor quality waters. Higher gypsum dissolution recorded during kharif season in comparison to rabi due to (1) higher solubility of gypsum because of relatively higher atmospheric temperature during kharif; and (2) Uneven rainfall distribution during kharif as evident from the meteorological data that bulk of the monsoon rain received in the month of July (97.5%) and October (92.7%) in the year 2009 and 2010, respectively, result in more frequent irrigations.

**Table.1** Gypsum dissolutions (t/ha) by sodic irrigation water through gypsum bed (15 cm)

| Year | Kharif | Rabi | Total | Cumulative |
|---|---|---|---|---|
| 2005-06 | - | 0.70 | 0.70 (4.4) | 0.70 (4.4) |
| 2006-07 | 0.53 | 0.72 | 1.25 (7.8) | 1.95 (12.1) |
| 2007-08 | 0.90 | 0.88 | 1.78 (11.1) | 3.73 (23.3) |
| 2008-09 | 0.88 | 0.89 | 1.77 (11.1) | 5.50 (34.4) |
| 2009-10 | 1.04 | 0.35 | 1.39 (8.6) | 6.89 (43.1) |
| 2010 | 0.85 | - | 0.85 (5.3) | 7.74 (48.4) |
| Total (5 years) | 4.20 | 3.54 | 7.74 (48.4) | - |

Figure in parenthesis indicate % GR

**Table.2** Change in ionic composition of sodic waters as a result of gypsum bed (15 cm) treatment (Average of kharif and Rabi seasons)

| Treatment | Physio-chemical | | | Anion ($meql^{-1}$) | | | Cation ($meql^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | pH | EC ($dS\ m^{-1}$) | RSC ($meq\ l^{-1}$) | $CO_3$ | $HCO_3$ | Cl | $SO_4$ | Ca + Mg | Na + K |
| Untreated | 8.07 | 1.17 | 8.73 | Nil | 10.60 | 0.77 | 0.46 | 1.87 | 9.72 |
| Treated | 7.82 | 1.48 | 4.00 | Nil | 10.10 | 0.96 | 3.65 | 6.10 | 8.39 |
| **Change** | | | | | | | | | |
| (+) | - | 0.31 | - | - | - | 0.19 | 3.19 | 4.20 | - |
| (-) | 0.25 | - | 4.73 | - | 0.50 | - | - | - | 1.33 |

**Table.3** Effect of sodic water treatments on grain and straw yield ($t\ ha^{-1}$) of rice- wheat cropping system

| Treatment | Rice | | | | | | Wheat | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain yield | | | Straw yield | | | Grain yield | | | Straw yield | | |
| | 2009 | 2010 | Mean (2yrs) | 2009 | 2010 | Mean (2yrs) | 2009-10 | 2010-11 | Mean (2yrs) | 2009-10 | 2010-11 | Mean (2yrs) |
| $T_1$ | 2.26 | 2.27 | 2.26 | 2.26 | 2.95 | 2.60 | 1.52 | 1.52 | 1.52 | 1.82 | 1.88 | 1.85 |
| $T_2$ | 3.00 | 3.03 | 3.01 | 3.00 | 3.60 | 3.30 | 2.33 | 2.45 | 2.39 | 2.69 | 2.80 | 2.74 |
| $T_3$ | 2.80 | 2.85 | 2.82 | 2.60 | 3.43 | 3.01 | 2.15 | 2.19 | 2.17 | 2.52 | 2.61 | 2.55 |
| $T_4$ | 3.22 | 3.44 | 3.33 | 3.22 | 3.91 | 3.56 | 3.11 | 3.09 | 3.10 | 3.51 | 4.04 | 3.77 |
| $T_5$ | 3.39 | 3.26 | 3.32 | 3.39 | 3.82 | 3.60 | 3.00 | 2.90 | 2.95 | 3.44 | 3.82 | 3.63 |
| $T_6$ | 4.69 | 4.83 | 4.76 | 4.69 | 5.46 | 5.07 | 3.82 | 3.85 | 3.83 | 4.30 | 4.42 | 4.36 |
| $T_7$ | 4.58 | 4.59 | 4.58 | 4.58 | 5.15 | 4.86 | 3.60 | 3.76 | 3.68 | 4.06 | 4.26 | 4.16 |
| **CD (5%)** | 0.27 | 0.26 | - | 0.26 | 0.19 | - | 0.21 | 0.19 | - | 0.32 | 0.28 | - |

Note- $T_1$-Control (Sodic water), $T_2$-GBT of sodic water, $T_3$-SA of gypsum (25% GR), $T_4$-SA of gypsum (25% GR) + GBT of sodic water, $T_5$-SA of gypsum (50% GR), $T_6$-SA of gypsum (50% GR)+GBT of sodic water, $T_7$-SA of gypsum (100% GR)

**Table.4** Changes in chemical characteristics of soil (0-20 cm) as Affected by the treatment after 2 years

| **Treatments** | | **pH** | **EC (dSm$^{-1}$)** | **ESP** |
|---|---|---|---|---|
| $T_1$ | Control (Sodic water) | 10.01 | 5.46 | 75.15 |
| $T_2$ | GBT of sodic water | 8.40 | 4.35 | 33.50 |
| $T_3$ | SA of gypsum (25% GR) | 8.65 | 4.48 | 49.30 |
| $T_4$ | SA of gypsum (25% GR) + GBT of sodic water | 8.55 | 4.15 | 34.00 |
| $T_5$ | SA of gypsum (50% GR) | 8.25 | 3.80 | 23.20 |
| $T_6$ | SA of gypsum (50% GR) + GBT of sodic water | 8.00 | 1.96 | 18.50 |
| $T_7$ | SA of gypsum (100% GR) | 8.15 | 3.65 | 24.30 |
| Initial values | | 9.65 | 4.96 | 64.10 |

Response of rice-wheat system to sodic water irrigation (Choudhary *et al.*, 2008, Minhas *et al.,* 2003) revealed that the rainfall dilution coupled with greater dissolution of calcium from $CaCO_3$ owing to high leaching fraction and high $PCO_2$ attained during rice growth appear to be the dominant processes leading to the development of low pH and sodicity level in the irrigated soil, and minimum yield of 60% both in rice and wheat of their respective maximum (6, 5 tha$^{-1}$) could be sustained with the use of sodic water when 1.25 tha$^{-1}$ gypsum was applied each year in a relatively high rainfall (500-900 mm) semi-arid region. Result of present investigation also corroborates the above findings by Murtaza *et al.*, 2009.

Sodic soils of the Indo-Gangetic plains (Minhas and Sharma, 2003) invariability contain free $CaCO_3$ concretions throughout the soil profile which plays an important role in sodic soil reclamation. The quantity of an amendment required for a sodic soil depends on the amount of exchangeable Na to be replaced, exchange efficiency and depth of soil to be reclaimed. Experimental results showed that gypsum applied @ 50% GR is sufficient to initiate reclamation process in rice based cropping systems.

Results were concluded that the present investigation clearly revealed that the sodic waters can be used safely for irrigation with suitable amendment techniques to boost crop production under sodic soil condition. (i) Gypsum bed treatment of sodic irrigation water. (ii) Soil application of gypsum @ 50% GR at an interval of 5 years (iii) Use of recommended dose of NPK and Zn fertilizers. (iv) Use of organic manure like FYM, compost, rice straw and green manuring. (v) Adoption of rice-wheat-green manure rotations during initial years.

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