Effect of saline and alkali water irrigation on physical and chemical properties of sodic clay loam soil

Muneer Naji Ahmed Al-Falahi[*1,2], Nirmalendu Basak[2], S.K. Chaudhari[2] and D.K. Sharma[2]

[1]*Ministry of Sciences and Technology, Anbar Province, Iraq*
[2]*Central Soil Salinity Research Institute, Karnal-132 001, Haryana, India*
E-mail: muneer84@yahoo.com

ABSTRACT

Presence of appreciable amount of soluble salts has a deleterious impact for raising salinity/ alkalinity in semiarid and arid regions. We evaluated the effect of varying saline and alkali waters on physical and chemical properties of alkali soil which has characteristics of soil pH of saturation paste, electrical conductivity of saturation extract and exchangeable sodium percentage (ESP) of 8.75, 4.98 dSm^{-1}, 31.2%. Soil were sequentially leached in a constant head method using 1 litre volumetric flask and cores with normal (T_1), saline water at 5.0 (T_2) and 50.0 (T_3) me L^{-1} of total electrolyte concentration (TEC) at a fixed SAR of 2.5 mmol$^{1/2}$L$^{-1/2}$ with Ca:Mg ratio of 2:1, alkali water having residual sodium carbonate (RSC) of 1.0 (T_4) and 5.0 (T_5) me L^{-1} with Ca:Mg ratio of 2:1, respectively. Incoming solution of concentrated saline water (T_3) has a favourable influence for upkeeping soil hydraulic properties among the simulated saline and alkali water. Increase and decrease in pH$_2$ of soil water suspension revealed that both Ca^{2+} and Mg^{2+} build up and displace from exchange sites due to continuous application of normal and saline water, respectively. Residual carbonate and bicarbonate loading in incoming water aggravated alkalinity build up in soil when it was percolated with RSC water with varied quality. Abundance of HCO$_3^-$ and CO$_3^{2-}$ in alkali water caused the complete precipitation of the divalent Ca^{2+} and Mg^{2+} and increased the ESP to very high values.

Key words: *Alkalinity, residual sodium carbonate and bicarbonate, total electrolyte concentration*

Introduction

It is noteworthy that soil salinity is the most widespread problem in irrigated arid and semi-arid regions of the world where irrigation is essential to increase agricultural production to satisfy food requirements (Abrol *et al.,* 1988). Coupled with this, presence of soluble sodium carbonates and bicarbonates, abundant exchangeable sodium in water has a deleterious impact for raising salinity/ alkalinity in semiarid and arid regions (Pal *et al.*, 2003; Dasberg *et al.*, 1991). Salt stress imposes limits on plant growth and development by causing physiological abnormalities. Food production is severely affected due to increase in area under salinization and decrease in overall productivity of good and fertile soils as a result of improper irrigation and water management practices (IAEA, 1995). Even at low salt concentrations, there are widespread direct and indirect harmful effects (Shannon *et al.*, 1994). The degree of adverse effects depends upon the type and quantity of salts, soil texture, type of crop, variety, stage of growth, cultural practices, and environmental factors (temperature, relative humidity, and rainfall) (Chhabra, 2005). The burgeoning world population has put tremendous pressure on food supplies

from the scarce land and water resources. This situation demands effective management of degraded salt-affected lands and poor quality waters. Soils of the Indo-Gangetic plains are of alluvial origin but at some places Aeolian processes are still running. Cultivation of these fertile landscape was compelled to irrigate with alkali/ saline underground water containing a high amount (>2.5 mol m^{-3}) of residual sodium carbonate (RSC) which leads to precipitation of soluble Ca^{2+} as CaCO$_3$ and thus increases SAR (Chhabra, 2005). Historically, based on pH of the saturated paste, electrolytic conductivity of the saturated paste extract (EC$_e$), and exchangeable sodium percentage (ESP), the U.S. Salinity Laboratory (Richards, 1954) classified these soils into three categories, *viz.*, saline, alkali and saline-alkali. Excess of soluble salts and high exchangeable sodium are main feature of saline-alkali soil. High in pH$_s$ (>8.5) and ESP (>15%) and EC$_e$ being ~4 dS m^{-1} are the characteristics of alkali soil. Some advanced attempts had been made by a number of researchers for distinguishing alkali soil from others salt affected soils. These are: dominance of Na$^+$ as cation and CO$_3^{2-}$ +HCO$_3^-$ in saturation extract (Chhabra, 2005); or the ration of [Na$^+$]/ ([Cl$^-$] + [SO$_4^{2-}$]) in soil solution more than 1.0 (Bajwa and Swarup, 2009). Formation of alkali soils may

involve microbiological reduction of sulfate and ferric iron to form sulphide (FeS), which with CO_2 released by biological oxidation of abundant organic matter forms bicarbonate (Whittig and Janitzky, 1963). Small amounts of soluble carbonate compared with bicarbonate suggest that, because of high evaporation rates, and maintenance of a proper Ca/Mg ratio in the soil solution becomes difficult because Ca^{2+} ions are precipitated as $CaCO_3$. The soil solution consequently becomes impoverished in Ca^{2+} ions and this causes an increase in SAR and ESP. Thus, concomitant formation of $CaCO_3$ and development of alkaliity (Pal *et al.*, 2000, 2001) account for the abundance of soluble Na^+ ions and the calcareousness of the soils. The sodium adsorption ratio (SAR) has frequently been used to characterize the clogging hazard of irrigation water based on the composition of sodium relative to calcium and magnesium (Ayers and Westcot, 1989). The SAR value reflects the preference of soils to adsorb calcium and magnesium ions over sodium ions and is correlated with the degree of sodium saturation on the exchange sites. Reduced soil permeability with higher SAR solutions has been well documented in the literature (Suarez *et al.,* 2006). Because of high pH, soil organic matter gets dissolved and forms black organic-clay coatings on soil aggregates and on the surface giving the term black-alkali for such soils. Growing plant faces adverse effects not only due to high ESP but also due to high pH and associated poor physical properties like of such low hydraulic conductivities and degraded in soil structure (Mandal *et al.*, 2008). Irrigation with water of moderate SAR (~ 6 mmol$^{1/2}$1$^{1/2}$) leads to an exchangeable sodium percentage (ESP) of a comparable value in the soil and adversely affects on soil hydraulic conductivity (HC), due to Na^+-induced clay dispersion (Halliwell *et al.*, 2001). Usually, it is observed that the hydraulic conductivity of soils decreases with an increase in SAR and effects are more pronounced at low electrolyte concentrations (Girdhar, 1996). However, Gharaibeh *et al*, 2009, claimed that high electrolyte concentration in leaching water increases the hydraulic conductivity; this effect is amplified as the ESP of the soil being reduced in sandy clay loam, mixed, hyperthermic, Typic Xerochrept soil. Quirk, 2001 concluded that the use of concentrated solutions for reclamation of alkali soils of high ESP saves time and water. Keeping all this in mind the main approaches of this paper is to evaluate the performances of different poor quality water on the chemical and hydraulic properties of the soil.

Material and Methods

Bulk soil sample was collected from upper 30 cm depth of A or Ap horizon of clay loam soil of Krishi Vigyan Kendra (29°45.775'N, 76°24.550'E) of Chaudhary Charan Singh Harayana Agricultural University, Kaithal, Haryana India. Soil pH_s and EC_2 was measured in a 1:2 soil-water suspension using a glass electrode and conductivity meter, respectively (Page *et al.*, 1982). Soil EC_e was determined by measuring the electrical conductance of soil saturation paste extract with a conductivity meter (USSL, 1954). Exchangeable-Na percentage (ESP) of soils was determined by alcoholic NH_4 chloride method described by Tucker (1971). Soil organic C was determined by wet oxidation method (Walkley and Black, 1934). Soil texture was determined by International pipette method. Calcium carbonate equivalent was measured by neutralization with HCl and cation exchange capacity (CEC) by extracting the sample with sodium acetate solution of pH 8.5. Ca^{2+} and Mg^{2+} were estimated by complexometric titration involving ethylene diamine tetra-acetic acid (EDTA) developed by Schwartzenbach *et al*, 1946. Chloride (Cl^-) was measured by argentometric (Mhor's) titration as described by Jackson, 1973. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) were determined by methyl red and phenolphthalein end point titration.

Dry soil sample (<2 mm) was packed to a bulk density of 1.25 g cm^{-3} upto 7-cm in cores. The soil cores were slowly wetted from the bottom by capillary rise with deionized water (EC < 1.0 dS m^{-1}) for 24-h or until the water reached the soil surface. Saturated hydraulic conductivity (Ks) of soils was determined by constant head method using 1 litre volumetric flask and cores. Soil-filled rings, after tightening inside the ring-holders, were transferred to the hydraulic conductivity stand. The different quality waters, *viz.*, normal (tap water EC < 1.0 dS m^{-1}) (T_1), dilute saline water (TEC 5.0 me L^{-1} and SAR 2.5 mmol$^{1/2}$ L$^{-1/2}$) (T_2), concentrated saline water (TEC 50.0 me L^{-1} and SAR 2.5 mmol$^{1/2}$ L$^{-1/2}$) (T_3), dilute alkali water (RSC 1.0 me L^{-1}) (T_4) and concentrated alkali water (RSC 5.0 me L^{-1}) (T_5) were used for hydraulic conductivity experiment by passing through the soil. Pure chloride salts of calcium, magnesium and sodium at Mg:Ca = 1:2 were used to prepare different saline water quality combinations whereas, chloride salts of calcium and magnesium and bicarbonate salt of sodium at Mg : Ca = 1:2 were used to prepare different alkali water quality combinations. Soil samples were then saturated for 12-hours inside the container. By fixing the volumetric flask, maintained constant head in inner water level in the core. Hydraulic head was precisely measured and the flow rate periodically recorded until the steady state reached. Procedure followed for Ks determination was similar to that described by Klute and Dirkson (1986). All the determinations were repeated three times to reduce the experimental error. Ks was calculated by rearranging Darcy's equation for constant head determination as:

$$Ks = \frac{V.L}{A.t.H}$$

Where,

V = Volume of water at steady state in mL
L = Length of the soil samples in cm

A = Cross sectional area of the soil sample in cm^2

T = Time in hour and

H = Hydraulic head difference in cm

Ionic consumption of each saline quality waters was computed as follows-

$$SAR = \frac{Na^+}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}} \qquad \ldots(1)$$

Now, if SAR = A and TEC = $Na^+ + Ca^{2+} + Mg^{2+}$ = B

or, $Ca^{2+} + Mg^{2+}$ = B - Na^+

SAR can be re-written as:

$$A = \frac{Na^+}{\sqrt{\dfrac{B - Na^+}{2}}} \qquad \ldots(2)$$

$$\text{or, } \frac{(B - Na^+)}{2} = \frac{(Na^+)^2}{A^2}$$

rearranging in a quadratic equation

$$2(Na^+)^2 + A^2 Na^+ - A^2 B = 0 \qquad \ldots(2)$$

and hence, $Na^+ = \dfrac{-A^2 \pm \sqrt{A^2 + 8A^2 B}}{4}$

$$\text{or, } Na^+ = \frac{\left[\sqrt{8B + A^2} - A\right]}{4}, \text{ me L}^{-1}$$

if Na^+ (me L^{-1}) = x, then

$Ca^{2+} + Mg^{2+}$ (me L^{-1}) = B – x

but Ca:Mg = 2:1, and therefore

Ca^{2+} (me L^{-1}) = [(B-x)×2]/3

and Mg^{2+} (me L^{-1}) = B – ($Na^+ + Ca^{2+}$)

First effluents, corresponding to the pore volume, were discarded. After appearing steady state water flow volume of effluent solution was measured at 2-h interval for getting the saturated hydraylic conductivity. At the end of saturated hydraulic conductivity experiment, soil cores were left to drain free, then cut it to dry. Soil samples of different cores were analysed for EC, pH and exchangeable Na^+, Ca^{2+} and Mg^{2+} and anion CO_3^{2-}, HCO_3^- and Cl^- and ESP.

Results and Discussion

Selected soil properties

Basic physico-chemical properties of experimental soil paste extract are presented in Table 3. Soil pH is considered the single most important chemical property of soil because it governs most of the soil processes including the concentration of Ca^{2+}, Mg^{2+}, Na^+ as well as Al^{3+} availability in soil (Panda *et al.*, 2009; Bajwa and Swarup, 2009). The pH_s was 8.75 in saturation paste extract. Electrical conductivity (EC_2) of experimental soil was 0.98 and 4.98 dSm^{-1} in soil water suspension and soil water saturation paste extract, respectively. Exchangeable sodium which one of important properties for differentiating boundary between saline and alkali soil can also exerts an adverse effect on the soil physical properties. Our finding showed that the experimental soils were alkali in nature as pH_2 is 8.7, EC_e 4.98 dSm^{-1} and ESP 31.2%. Soil organic carbon was found high (i.e. 0.86 %). Cation exchange capacity (CEC) can be used as an indicator of the potential fertility and nutrient supply capacity and a guide to methods of fertilizer application for efficient utilization by crops for better crop responses. CEC of a soil depends largely on amount and type of clay besides the organic matter content. The CEC of the soil was 13.54 $cmol_{(P+)}$ kg^{-1}. The relative proportion of sand, silt and clay content of the experimental soil was 44.3, 24.0 and 31.8, respectively. These indicated that the soil was clay loam in texture with good amount of clay.

Cations and anions in saturation paste extract

The Na^+ concentration in saturation extract of saline was almost 4.3- and 7.8-times higher than Ca^{2+} and Mg^{2+}, respectively (Table 3). Dominant Na^+ concentration in soil saturation paste was preveously reported by Chhabra,

Table 1. Chemical composition of saline waters

Total electrolyte concentration (me L^{-1})	Ca/Mg ratio	Ionic composition at SAR (2.5 mmol$^{1/2}$ L$^{-1/2}$)		
		Na$^+$	Ca^{2+}	Mg^{2+}
T$_2$: Dilute saline waters 5.0	2:1	0.157	0.114	0.078
T$_3$: Concentrate saline waters 50.0	2:1	0.645	2.884	2.641

Whereas, Ionic consumption of each alkali quality waters was computed as follows-
RSC = $(CO_3 + HCO_3)$ - $(Ca + Mg)$

Table 2. Chemical composition of alkali waters

Residual sodium carbonate(me L^{-1})	Ca/Mg ratio	Na$^+$	Ca^{2+}	Mg^{2+}
T$_4$: Dilute alkali waters 1.0	2:1	0.157	0.114	0.078
T$_5$: Concentrate alkali water 5.0	2:1	0.645	2.884	2.641

Table 3. Physico-chemical properties of the experimental soils

pH$_s$		8.75
EC$_2$	dS m^{-1}	0.98
ECe		4.98
Cation exchange capacity	cmol$_{(P+)}$ kg^{-1}	13.54
Exchangeable sodium percentage	%	31.2
CaCO$_3$		1.3
Organic C		0.86
Sand		44.3
Silt		24.0
Clay		31.8
Texture		Clay loam

Table 4. Ionic composition (me L^{-1}) of saturation extract of the experimental soils

Ca^{2+}	18.1
Mg^{2+}	10.0
Na$^+$	78.17
K$^+$	0.25
Cl$^-$	21.6
CO$_3^{2-}$	nil
HCO$_3^-$	14.0

1996 under a wide range of alkali soils. Increasing soil alkalinity always manifests the limited uptake of Ca by plant as the antagonistic effect between Na and Ca are persist in soil water solution. The saturation extract of experiment soil contained measurable amounts of HCO$_3^-$ and Cl$^-$ but CO$_3^{2-}$ was non detectable (Table 4).

Effect of normal and synthetic water on soil hydraulic conductivity (Ks):

Hydraulic-conductivity plays an important role in computing the soil-water balance and salt, nutrient, and pesticide dynamics in the soil (Chaudhari et al., 2010). Saturated hydraulic conductivity of soil was greatly influenced by the quality of water viz., normal (tap water EC < 1.0 dS m^{-1}) (T$_1$), dilute saline water (TEC 5.0 me L^{-1} and SAR 2.5 mmol$^{1/2}$ L$^{-1/2}$) (T$_2$), concentrated saline water (TEC 50.0 me L^{-1} and SAR 2.5 mmol$^{1/2}$ L$^{-1/2}$) (T$_3$), dilute alkali water (RSC 1.0 me L^{-1}) (T$_4$) and concentrated alkali water (5.0 me L^{-1}) (T$_5$) flowing through the soils (Fig. 1). Low Ks value (0.002 cmh^{-1}) was recorded when soil core was percolated with normal tap water. Incoming solution of concentrated saline water sharply enhanced Ks value i.e. 0.016 cm h^{-1}. However, percolating dilute saline water failed to enhance Ks value. Soil Ks value

increased 4 and 2.4- times when fed with dilute alkali water (RSC 1.0 me L^{-1}) (T$_4$) and concentrated alkali water (5.0 me L^{-1}). This indicates that concentrate alkali water is not very effective in reclaiming highly alkali soils. Irrigated with concentrated saline water has a favourable influence for upkeeping soil hydraulic properties among the simulated water quality levels.

Effect of normal and synthetic water on pH$_2$ and EC$_2$

Results showed that the experimental soils become more alkaline by percolating normal tap water (Fig. 2). Due to continuous feeding with normal tap water, the
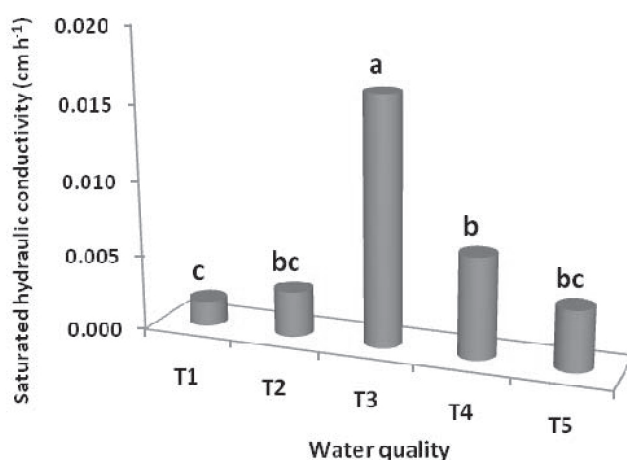
Fig. 1. Effect of different water quality on saturated hydraulic conductivity (Ks). (Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)
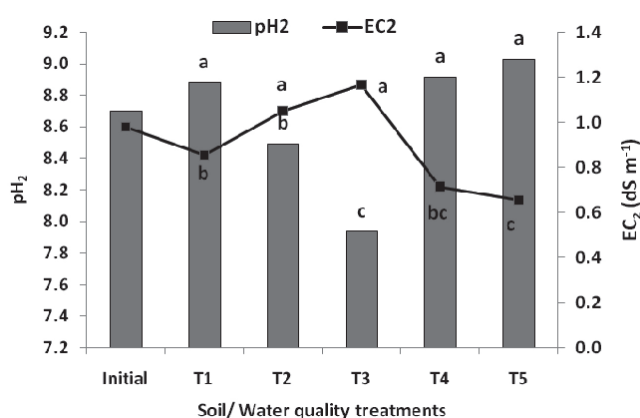

Fig. 2. Effect of different water quality on pH$_2$ and EC$_2$. (Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)

soils might undergo in physic-chemical transformations, which are reflected in terms of variation in pH. However, pH_2 increase with the rapid displacement of Ca^{2+} and Mg^{2+} compared to Na^+ from exchange sites. A similar increased in pH of soil effluent was recorded both by Basak (2012) in response to the feeding the soils with deionized water in both saline-alkali and alkali soil. The pH_2 of the soil drastically declined from 8.70 to 7.94 when soil was fed with concentrate saline water. However, this decrease in soil pH_2 might be due to enrichment of exchange phase of soils by Ca^{2+} and Mg^{2+} which was abundant in incoming solution of concentrated saline water with low SAR. This was explained by Rai, 2012 who speculated that loaded salt moderate the dispersing action of Na^+ and no further deterioration of soil structure is quite restricted. Minimum decrease in soil pH_2 was reported when soil was leached with dilute saline water. The possible reason behind this may be due to incoming solution had a low Ca^{2+} and Mg^{2+} loading with fixed SAR of 2.5. Soils pH_2 become more alkali from 8.70 to 8.92 and 9.03 when it was fed with carbonate rich water of RSC 1.0 and 5.0 meL^{-1}, respectively. Residual carbonate and bicarbonate loading in incoming water aggravated alkalinity build up in soil when it was percolated with RSC water. Choudhary et al., 2011 reported that long-term irrigation with alkali water with RSC of 10.0 $mmol_c$ L^{-1} from 1991-1999 and of 12.5 $mmol_c$ L^{-1} from 2000 onwards raises soil pH to 10.04 from 7.9 in a calcareous sandy loam soil in rice-wheat system at Ludhiana.

The graphical representation of EC_2 did not find similar signature as that of pH_2 (Fig 2). EC_2 of soil water suspension decreased when tap water was used as incoming solution. Dissolution followed by leaching of soluble salt from exchange site may help to reduce soil EC_2. A similar decrease in EC_2 of soil was recorded both by Basak (2012) and Rai (2012) in response to the percolation of soil with deionized water in alkali and saline-alkali soil. A significant increase in EC_2 was noticed in soil water suspension when soil was feeding with concentrated saline water compared to dilute saline water. The existence of cations (Ca^{2+}, Mg^{2+} and Na^+) and anion (Cl^-) in incoming solution may increase EC_2 (Minhas and Bajwa, 2001; Choudhary et al., 2004; Jalali and Ranjbar, 2009). Decline in the EC_2 under different treatments of studied soil with increment of pH_2 are described in Fig. 3. However, long-term application of alkali irrigation in rice-wheat system raised 1.67 dS m^{-1} unit in EC_2 along with pH_2 (Choudhary et al., 2011).

Effect of normal and synthetic water on cations and anions

The soil solution of a saline alkali soil mainly contains cations *viz.*, Na^+, Ca^+, Mg^{2+} and K^+ and anions like Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-} & NO_3^-. All the cations and anions studied in soil water extract. Soil water extract of initial soil sample had 10.6 times higher values of the Na^+
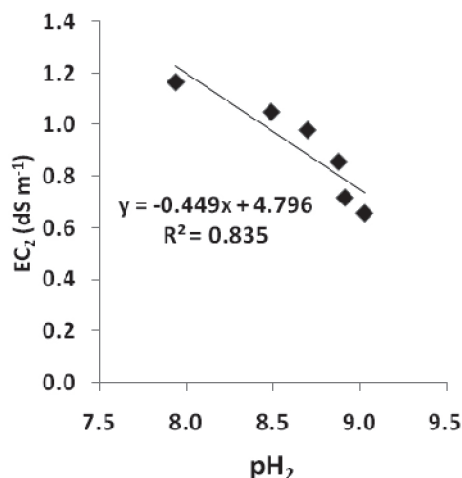

Fig. 3. Relationship between pH_2 and EC_2 under different treatments of studied soils

compared to Ca^{2+}, Mg^{2+} and 5- times higher values of Cl^- compared to HCO_3^-, CO_3^{2-}. As soils were saline alkali in nature, Na^+ was dominant amongst all the cations and Cl^- amongst anions (Table 5). Alkalinity of experimental soil had been inclining towards more alkaline by leaching appreciable amount of soluble and exchangeable amount of Na^+ (~68%) from soil when it was fed with normal water. Incidentally, $CO_3^{2-}+HCO_3^-$ build up was noticed when soil was percolated with concentrated alkali water (5.61 meL^{-1}) compared to normal water (0.64 meL^{-1}). This value was previously corroborated in pH_2, EC_2 and ESP values of untreated and normal water percolated soil. This shows that ~10.0 fold change in alkalinity ($CO_3^{2-}+HCO_3^-$) has a dominative effect than ~68% reduction of Na^+ concentration for unit changing in pH (Bajwa and Swarup, 2009). However, our study not match with Eaton and Sokoloff (1935) who reported that alkali soils are formed due to leaching of soluble salts, particularly Ca^{2+} and Mg^{2+} and subsequent replacement by sodium. Concentrated saline water leached out good amount of Na^+ and $CO_3^{2-}+HCO_3^-$ *vis-a-vis* increased the concentration of $Ca^{2+}+Mg^{2+}$ in exchange sites. However, dilute saline water was able to leach an appreciable amount of Na^+ but totally in vain to leach $CO_3^{2-}+HCO_3^-$. Moreover, it sustained alkalinity of 5.71 meL^{-1} ($CO_3^{2-}+HCO_3^-$). Alkalinity was built-up was noticed by application of both dilute and concentrate alkali water. However, content Na^+ and alkalinity was higher in soil water solution when it was percolated with concentrated alkali water compared to dilute alkali water. Irrespective of water quality, leaching loss of Cl^- was higher from exchange sites to solution at dilute TEC level than the lower TEC level. However, Cl^- built-up was noticed when it was fed with concentrate saline was except in normal Vertisols. An appreciable and minimum quantity of Cl^- was detected in soil water extract when it was fed with concentrate saline and dilutes alkali water, respectively.

Table 5. Ionic composition and CaCO$_3$ of soil water solution extract of the experimental soils under varied treatment

Soil/ Treatment	Na$^+$	K$^+$	Ca^{2+}+Mg^{2+}	CO$_3^{2-}$	HCO$_3^-$	Cl$^-$	CaCO$_3$
				mel^{-1}			%
Normal tap water	13.18^a	1.41^a	2.00^{bc}	0.71^b	4.90^a	1.63^b	0.83^{ab}
Dilute saline water	11.82^{ab}	0.68^b	2.13^{bc}	0.78^b	4.93^a	2.17^b	0.83^{ab}
Concentrated saline water	10.42^{bc}	0.07^c	2.70^a	0.01^c	0.23^b	10.67^a	0.83^{ab}
Dilute alkali water	8.79^c	0.85^b	1.63^c	0.71^b	5.30^a	1.38^b	0.90^a
Concentrated alkali water	9.63^c	1.01^{ab}	2.40^{ab}	0.96^a	5.60^a	1.52^b	0.70^b
Mean	10.77	0.80	2.17	0.64	4.19	3.47	0.823
SE($\pm$)	0.48	0.13	0.13	0.09	0.55	0.98	0.0446
Initial	20.15	0.92	1.90	1.2	0.2	7.0	1.30

(Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)
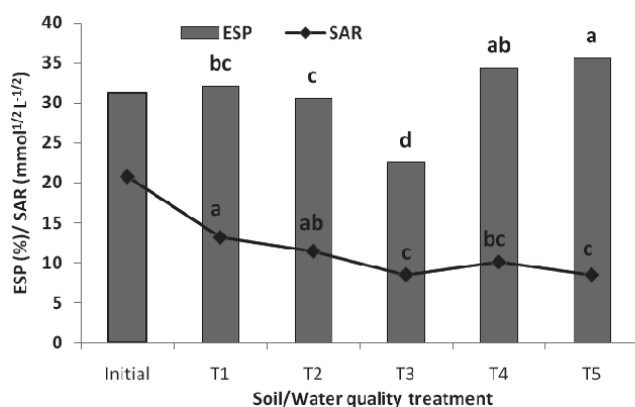
Fig. 4. Effect of different water quality on ESP and SAR. (Different small letters within the same column show the significant difference at P = 0.05 according to Duncan Multiple Range Test (DMRT) for separation of mean)

Effect of normal and synthetic water on ESP and SAR

High ESP value of salt affected soils is unfavourable to water availability by plant, soil hydraulic property, soil conservation, plant nutrient balance, and subsequently specific ionic effect (Qadir and Schubert, 2002), which hinders the development of sustainable irrigated agriculture (Li and Keren, 2008). The poor physical soil conditions accompanied with high soil pH make soil poor in stability. Salt concentrations of the soil solution affect clay and silt dispersion (Dontsova and Norton, 2002). The ESP and SAR value of initial soil was 31.2% and 20.8 mmol$^{1/2}$ L$^{-1/2}$. Leaching with normal tap water had the marginal disparity in ESP built-up but reduced SAR. Predicting the marginal ESP built-up in clay loam soil with CEC of 13.54 cmol$_{(P+)}$ kg^{-1} was not clear and we need further extensive work (Fig. 3). However, an appreciable amount of Na$^+$ was leached by percolation with normal tap water. The low SAR value of 20.8 mmol$^{1/2}$ L$^{-1/2}$ vividly depicted the remarkable higher losses of Na$^+$ than Ca^{2+} and Mg^{2+}. When SAR increases, the rate of the soil sodification process also increases (Herrero and Perez Covetta, 2005). Alkalinity enhances deterioration of the hydraulic properties of soils, which could increase the possibility of surface runoff and erosion, and impair soil drainage (Keren and Ben-Hur, 2003). The experimental ESP built-up was lowest when soil fed with dilute saline water compared to concentrated saline water with fixed SAR of 2.5 mmol$^{1/2}$ L$^{-1/2}$. As the lower volume of solution was percolated associated with low Ks (0.002 cmh^{-1}), higher the development of ESP (Chaudhari, 2004). During leaching, presence of higher amount of Ca^{2+} and Mg^{2+} in concentrate saline water may maintained Ca^{2+} and Mg^{2+} in solution phase and displaced and followed by leached the Na$^+$ and decreased SAR. Percolation with both dilute and concentrated alkali water caused an ESP built-up. Contrarily, decline the SAR form initial soil value. Excess of HCO$_3^-$ and CO$_3^{2-}$ caused the complete precipitation of the divalent Ca^{2+} and Mg^{2+} and increased the ESP to very high values (Eaton et al., 1950). The magnitude of Na$^+$ in soil is quantified by the exchangeable sodium percentage or by its estimator, the sodium adsorption ratio SAR.

Conclusions

Incoming solution of concentrated saline water has a favourable influence for upkeeping soil hydraulic properties among the simulated saline and alkali water. Increase and decrease in pH$_2$ of soil water suspension revealed that both Ca^{2+} and Mg^{2+} build up and displacement from exchange sites may possible due to continuous application of tap water and saline water. Residual carbonate and bicarbonate loading in incoming water aggravated alkalinity build up in soil when it was percolated with RSC water with varied quality. Abundance of HCO$_3^-$ and CO$_3^{2-}$ in alkali water caused the complete precipitation of the divalent Ca^{2+} and Mg^{2+} and increased the ESP to very high values.

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