RSC =

Note: Values (mean ± standard error) in each column followed by dissimilar lowercase letters are significant according to Duncan's Multiple Range Test at $p < 0.05$.

Theme 1
Status and trends of global soil nutrient budget

Long-term irrigation with alkali and partially neutralized water changes carbon fractions, microbial activities and nutrient availability in sandy loam soils

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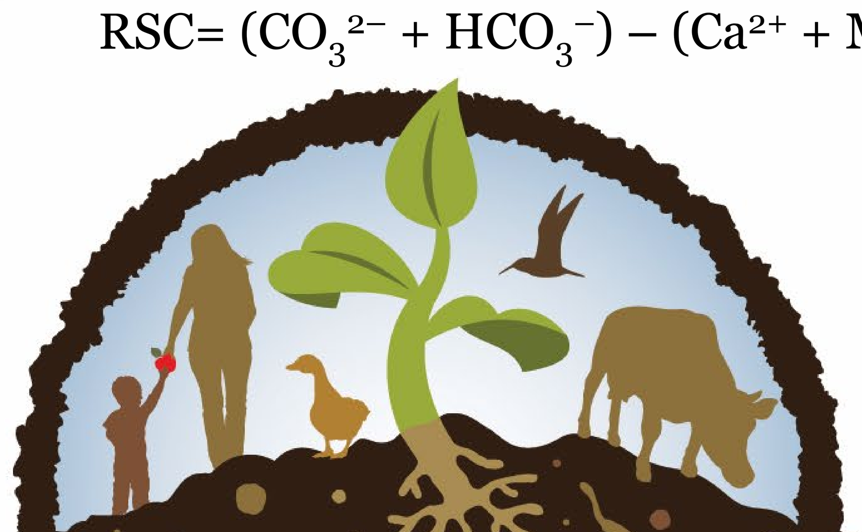
INTRODUCTION

To improve the food, nutrition and livelihood security of humankind, a conspicuous increase in groundwater exploitation for irrigation has been noticed throughout the world. However, in several arid and semi-arid regions, even though poor quality groundwater [alkali water containing high residual sodium carbonate (RSC)] is used for irrigation (Minhas et al. 2019). Therefore, effects of long-term irrigation with alkali and partially neutralized alkali water were quantified on carbon fractions, microbial activities and nutrient availability in sandy loam soils.

METHODOLOGY

The study was conducted in concrete lysimeters of size 2 x 2 x 2m with drainage outlets at the bottom. The adopted cropping systems were irrigated (since, 2004) with five types of irrigation water i.e. good quality water (GQW), synthetic alkali water (SAW) having the RSC ~5 me L^{-1} (SAW1), SAW having the RSC ~10 me L^{-1} (SAW2), SAW2 neutralized up to RSC ~5 me L^{-1} with sulphuric acid (SAW2+SA) and SAW2 neutralized up to RSC ~5 me L^{-1} with gypsum (SAW2+GYP). In October 2019, two soil samples were drawn out from 0-15 cm soil depth (after harvesting of rice) and mixed to make a composite sample. One part of the sample was used for analysis of soil pH(1:2), electrical conductivity (EC1:2), total inorganic carbon (TIC), total organic carbon (TOC), soil organic carbon (SOC), active pool (AP) (very labile carbon + labile carbon) of TOC, available nitrogen (N), available phosphorous (P) and available potassium (K). Whereas the second part of the soil sample (fresh) was used for analysis of soil microbiological parameters viz., bacterial population (BP), fungal population (FP), dehydrogenase activity (DHA), soil microbial biomass carbon (SMBC) and alkaline phosphatase activity (ALKPA). RSC of different irrigation water was calculated using following equation (Eaton 1950).

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$$



RESULTS

The key findings of the experiment are mentioned below.

- Long-term application of RSC water for irrigation, significantly declined microbial activities i.e. BP (18-51%), FP (38-59%), DHA (50-74%), SMBC (16-36%) and ALKPA (9-33%) (Table 1).
- RSC water irrigations increased TIC (217-379%) significantly, although, TOC (6-21%), SOC (18-27%) and AP (16-28%) decreased drastically (Fig. 1).
- The content of available P (75-119%) and K (24-59%) build-up in sandy loam soils significantly, while N availability remained unaffected under various alkali water treatments (Table 2).
- Perpetual use of alkali water for irrigation purposes, increased pH and EC of the soil to a detrimental level (Table 2).

Table 1: Long–term effects of synthetic alkali waters on soil microbial parameters

Treatments	BP (CFU × 10^5 g^{-1} soil)	FP (CFU × 10^2 g^{-1} soil)	DHA (µg TPF g^{-1} soil 24 h^{-1})	SMBC (µg g^{-1} soil)	ALKPA (µg p-NP g^{-1} hr^{-1})
GQW	$211±3.9^{a}$	$80.6±8.5^{a}$	$39.2±6.5^{a}$	$689±27.6^{a}$	$168±4.2^{a}$
SAW_1	$172±28.5^{ab}$	$49.9±3.0^{b}$	$19.1±5.2^{b}$	$579±54.4^{ab}$	$147±13.9^{a}$
SAW_2	$103±6.6^{c}$	$33.0±1.5^{c}$	$10.3±2.5^{b}$	$444±61.1^{b}$	$112±11.3^{b}$
SAW_2+SA	$172±20.9^{ab}$	$42.6±4.5^{bc}$	$13.3±2.6^{b}$	$485±39.8^{b}$	$137±4.2^{ab}$
SAW_2+GYP	$148±18.1^{bc}$	$45.2±2.0^{bc}$	$19.6±5.5^{b}$	$469±39.8^{b}$	$153±12.82^{a}$

Note: CFU= Colony forming unit, BP= Bacterial population, FP= Fungal population, DHA= Dehydrogenase activity, SMBC= Soil microbial biomass carbon, ALKPA= Alkaline phosphatase activity. Values (mean ± standard error) in each column followed by dissimilar lowercase letters are significant according to Duncan's Multiple Range Test at $p < 0.05$.

Table 2: Long–term effects of synthetic alkali waters on pH, EC, and nutrient availability in soils

Treatments	Soil pH (1:2)	Soil EC (dS m^{-1})	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
GQW	$8.46±0.05^{c}$	$0.36±0.03^{b}$	$75.3±0.83^{a}$	$24.9±3.13^{b}$	$57.1±1.46^{c}$
SAW_1	$9.16±0.05^{b}$	$0.75±0.08^{a}$	$73.5±2.76^{a}$	$49.6±5.70^{a}$	$72.4±4.83^{b}$
SAW_2	$9.76±0.13^{a}$	$0.90±0.15^{a}$	$71.8±1.75^{a}$	$52.5±4.77^{a}$	$90.8±8.43^{a}$
SAW_2+SA	$9.23±0.08^{b}$	$0.75±0.04^{a}$	$73.9±2.11^{a}$	$54.4±2.42^{a}$	$70.9±3.10^{b}$
SAW_2+GYP	$9.28±0.01^{b}$	$0.81±0.05^{a}$	$72.5±1.05^{a}$	$43.6±5.43^{a}$	$75.1±2.19^{b}$

Note: EC= Electrical conductivity, N= Nitrogen, P= Phosphorous, K= Potassium. Values (mean ± standard error) in each column followed by dissimilar lowercase letters are significant according to Duncan's Multiple Range Test at $p < 0.05$.

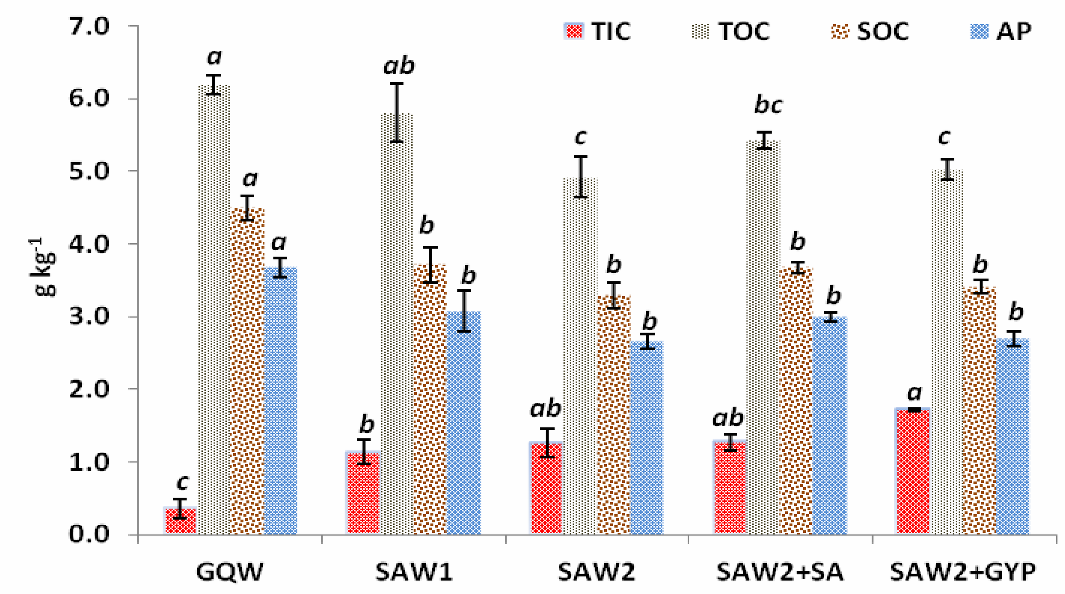


Fig. 1: Long-term effect of synthetic alkali waters on soil carbon fractions

Note: TIC= Total inorganic carbon, TOC= Total organic carbon, SOC= Soil organic carbon, AP= Active pool of soil organic carbon. Values (mean ± standard error) in each bar followed by dissimilar lowercase letters are significant according to Duncan's Multiple Range Test at $p < 0.05$.

CONCLUSIONS

Long-term irrigation with groundwater having high residual sodium carbonate degraded soil quality in terms of soil reaction, microbial activities and carbon fractions. The build-up of available phosphorus and potassium was observed in soil through perpetual application of alkali waters. Consequently, application of amendments (gypsum or sulphuric acid), for partial neutralization of residual alkalinity in irrigation water, restored the soil quality parameters to some extent. However, partial neutralization was not sustainable to maintain soil quality. Our findings propose substantial revision in the rate and method of application of the amendments as well as phosphorous and potassium fertilization on sandy loam soils where alkali water is the only source of irrigation. The acquisition of phosphorous and potassium by different crops needs to be further investigated for sustainable crop production under alkali water irrigation.

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