Season-long Changes in Infiltration Rates Associated with Irrigation Water Sodicity and pH

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Abstract

There is increasing need to substitute low quality waters, including saline sodic waters and treated municipal waste water for fresh water when irrigating land in arid and semi-arid regions of the world. In almost all instances low quality waters are more sodic than the fresh waters currently utilized. A major hazard associated with these waters is the reduction in water infiltration rates due to the increase in the soil exchangeable sodium percentage. Deterioration of soil; physical properties may threaten the present and future productivity of these lands. We examine the effect of even small increases in sodium on the infiltration rate over the span of a complete cropping season in a series of experiments from sodium adsorption ratio (SAR) of 0-13. Based on these controlled studies with wetting and drying cycles over 180 d conducted in container studies, we conclude that for the non-calcareous soil examined, even small increases in SAR resulted in significant decreases in infiltration rates. The deterioration in infiltration capability increased with time, suggesting that short term experiments may not characterize the long term consequences of using degraded waters for irrigation. Increased pH resulted in decreased infiltration at comparable SAR values.

Key Words

Infiltration soil, sodicity, pH, irrigation.

Introduction

Decreasing availability of fresh water in arid and semi arid lands means that in order to sustain irrigation in these regions we will need to utilize lower quality waters. Use of more saline and more sodic (higher SAR) waters will result in increased soil salinity and exchangeable sodium. Many low quality waters available for irrigation, such as treated municipal waste water, also have elevated alkalinity and pH. Use of these waters for irrigation will result in increased soil pH as well as increased exchangeable sodium. In well drained soils, if there is sufficient fresh water available, salts can be periodically leached and amendments can be applied to reduce exchangeable sodium and lower pH. The major hazard in terms of soil properties is not the change in chemical properties per see but rather the impact of those changes on the soil physical properties, such as hydraulic conductivity, soil strength etc.

Water quality criteria have been primarily based on guidelines such as Ayers and Westcot (1985). In turn these guidelines were developed from field observations and short term laboratory experiments that measured hydraulic conductivity under saturated water flow and changing solution composition, such as McNeal *et al.*(1966, 1969), Frenkel *et al.* (1978). Also, current water suitability guidelines do not consider the effect of pH. Suarez *et al.* (1984) determined that elevated pH adversely impacted saturated hydraulic conductivity in laboratory column experiments with applied waters at SAR 20 and SAR 40. Classification of a soil as sodic, generally regarded as exchangeable sodium percentage of 15% or greater, was developed to describe soils that were clearly adversely impacted. One difficulty with visual observations is that important deterioration of soil physical properties is not always evident. The column experiments have provided a very useful database but prediction has been difficult due to the very large differences among soils relative to their stability under sodic conditions (Pratt and Suarez (1990). In addition, column studies may not be representative of field conditions in that they do not consider wetting and drying, surface impacts, and long term effects. In order to better evaluate the SAR effects, we have conducted experiments over a season interval with wetting and drying and in the presence and absence of rain.

Methods

Pachappa (fine sandy loam soil), was collected, air dried, and crushed to pass a 5-mm screen. We utilized plastics containers of 35.50 cm height and 28 cm diameter. We added 1 cm of fine quartz sand (No. 90) to the bottom of the containers, then horizontally placed two ceramic extractors (1 bar air entry value) into the sand, then added an additional 7 cm of sand. The soil was packed into the container (20 cm of soil) at a bulk density of 1.30 Mg/m^3. Containers were placed in an outdoor area under a rainfall simulator using a randomized design. There were 12 water treatments and three repetitions. The rain machine is a traveling sprinkler system with an overlapping spray pattern with rain drop diameter of 1.8 mm. The details of the rainfall simulator are available in Suarez *et al.* (2006). An additional set of containers with soil were placed at an adjacent location outside the rain machine. These containers receive only irrigation water, again with 12 treatments and three replications.

The simulated rain consisted of water with an EC of 0.016 dS/m. The 12 different water compositions were prepared with variation of the value of SAR (0, 1, 2, 3, 5, 7, 5, 10 and 13) and two values of pH (7.0 and 8.2). The pH differences were achieved by substituting some of the Cl^- ions with HCO_3^-. Waters were prepared and stored in 240 L containers. Tap water (EC = 0.6 dS/m and SAR < 0.4 $mmol^{1/2}/ L^{1/2}$) was initially applied to enable soil settling before the start of the treatments. Containers with more than 5% deviation from the mean infiltration rate were removed and the containers were repacked. The soil under the rain simulator was subject to an initial rain event in order to establish the starting infiltration rates before application of the treatment irrigation waters. After this rain event and subsequent drying, the first irrigation water treatments were initiated. The experiment under the rain simulator consisted of alternate rain and irrigation events with drying between water applications, for a period of six months (2005-2006).

For the irrigation water experiment only irrigation water was applied with drying between irrigations. A pressure of -50 kPa (0.5 bars), was applied to the extractors, before, during and after the application of the water but it was suspended once drainage flow ceased. An irrigation event consisted of an application of 5 cm depth of water. Infiltration times were recorded for the applied depth of water to infiltrate into the soil surface. After irrigation the soil was allowed to dry and another event was initiated after tensiometers in two adjacent control soil containers registered values of -33 kPa or lower.

Results

The initial infiltration rates with irrigation water at pH 7.0 were at 68 ± cm/d, as shown in Figure 1. These initial variations were not significantly different. The infiltration rate of the SAR 0 treatments decreased only slightly, over the 180 d of irrigation and drying cycles. The very first incremental increase in SAR (to SAR 1) resulted in a slight but significant decrease in the infiltration rate relative to the control, SAR 0 treatment, as can be seen in Figure 1.

Increasing SAR of the irrigation water resulted in a decreasing infiltration rate at all times. The greater the increase in SAR, the greater was the decrease in the infiltration rate. Based on these data shown in Figure 1 we conclude that for a noncalcareous soil, any increase in SAR results in a corresponding decrease in infiltration rate. Comparable experiments with 2 calcareous soils from the Northern Great Plains (Suarez *et al.* 2006) showed statistically different rates at SAR above either 4 or 6, however those experiments had much greater experimental variation within the treatments and thus less ability to distinguish difference among treatments. Also, those experiments did not have SAR 1 and SAR 3 treatments, thus the present experiment was better able to define infiltration changes at low SAR.

Further examining the data in Figure 1 it is observed that the SAR impacted the time dependence of the infiltration rate. The greater the SAR, the more pronounced was the rate decrease with time. For example at SAR 13 the rate after 170 d was approximately 50% of the rate after 20 d, while for SAR 2 the final rate was only reduced by 8% when compared to the rate after 20 d. This suggests that short term experiments will underestimate the extent to which SAR impacts infiltration, especially with increasing SAR.

Additional experiments conducted were conducted with this container system using waters of pH 8.2 and comparable SAR and irrigation water compositions and experimental methodology. In this instance the infiltration rates were lower than those reported above at the same SAR values at pH 7.0, suggesting that even a small increase in the pH also contributed to a loss in the soil infiltration rate.

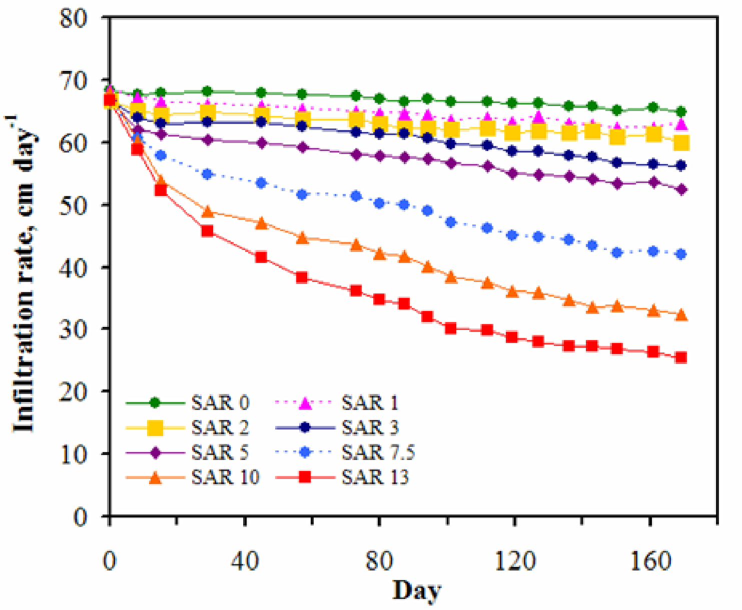

Figure 1. infiltration rate as a function of time and SAR of the irrigation water for treatments at pH 7.0 and irrigation with wetting and drying cycles.

Conclusion

The consequences of reduced soil productivity associated with irrigation with low quality water are very severe. At present there is uncertainty about the utility of existing guidelines. There are large differences in the response of different soils in hydraulic conductivity of laboratory saturated columns of soils reacted with sodic waters. The current results indicate that soils are affected by even small increases in SAR and that season-long studies of infiltration show much larger reductions in infiltration than that observed over limited times and in column studies of saturated hydraulic conductivity. Until the guidelines can be applied with confidence, the impact of sodic waters on soil properties and productivity can best be evaluated with season-long studies with wetting and drying cycles.

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