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Effect of Sulfuric Acid on Bicarbonate Concentration in Sandy Soil

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PROJECT DESCRIPTION

Water sources used to irrigate turfgrass areas in the arid southwestern states of the US can contain high levels of dissolved bicarbonates. As a result, unsightly lime deposits can stain leaves, soil pH can increase, and soil permeability can be reduced. To address the problem, turfgrass managers inject sulfuric acid into the irrigation water. However, it is unclear, whether or not such an injection is useful and necessary to improve soil conditions. Sulfuric acid injection is believed to be helpful when bicarbonates are high enough to have Ca^{+2} and Mg^{+2} precipitating in the form of carbonates from the soil solution and, at the same time, Na^{+} content is also high to present a possible concern. However, when Na^{+} concentration is low, information is lacking whether or not bicarbonates alone pose a risk and if water acidification is necessary.

Objective:

To investigate the effect of injecting sulfuric acid into irrigation water on bicarbonate levels in the soil solution and several chemical and physical properties of an alkaline soil

Treatments:

1) Chemicals: sulfuric acid and untreated control
2) 2 levels of SAR: high and low

MATERIALS AND METHODS

To investigate the effect of injecting sulfuric acid into irrigation water on changes in bicarbonate level, pH, EC, and SAR of an alkaline soil (loamy sand, a sandy skeletal mixed thermic Typic Torriorthent), a column experiment using water with a “high level” of bicarbonates (280 ppm) and a SAR of either high (15) or low (2.4) has been conducted at New Mexico State University. High bicarbonate and Sodium Adsorption Ratio levels were obtained by adding sodium bicarbonate and sodium chloride to tap water. Twelve soil columns measuring 10 cm in diameter and 35 cm in depth were filled with 5 cm deep gravel and loamy sand was placed over the gravel (Figure 1).

The columns received one of four irrigation water qualities:

- control, high bicarbonates, low SAR
- control, high bicarbonates, high SAR
- high bicarbonates, low SAR + sulfuric acid
- high bicarbonates, high SAR + sulfuric acid

The treatment containing sulfuric acid was adjusted to a pH of 6.5. Main chemical constituents of the irrigation water are given in Table 1. Irrigation water was applied by adding 275 mL of corresponding solution to each container twice a week. At the end of the 6 month research period, each container received 1820 mm or 71.6’’ of irrigation water, which reflects an amount that matches the annual ETos for the Las Cruces area. To collect leachate, Soil Solution Access Tubes (SSAT) were inserted at soil depths of 10 and 20 cm, and free draining water was collected at the base of the columns. Samples were analyzed monthly for pH, EC, Ca, Mg, and Na, and bicarbonates. Additionally, 4 columns without lysimeters, treated with the same amount of irrigation water were used for measuring infiltration rate at the beginning and at the end of the research period using a double ring infiltrometer (Turf-Tec International, Tallahassee, FL). At the end of the study, soil samples were taken from all 3 depths to be analyzed for salinity relevant parameters including bicarbonates. During the shipping process bags containing the soil were torn open and damaged. Unfortunately there was not enough remaining material in most of the bags to run a complete analysis that included bicarbonates.

Experimental Design and Statistical Analyses

The experimental design was completely randomized with two SAR levels and two water treatments. Each water treatment consisted of a high (15) and low (2.4) SAR level. All water treatments with either high or low SAR were replicated 3 times. To test the effects of sulfuric acid on level of bicarbonates, EC, pH, and SAR, data were subjected to an analysis of variance (ANOVA) using SAS Proc Mixed followed by multiple comparisons of means using Fisher's LSD test at the 0.05 probability level.

RESULTS

Statistical analysis revealed that SAR and sampling depth affected all measured parameters. Consequently, data were reanalyzed (Table 2) and are presented separately for high and low SAR content in the irrigation water at each sampling depth. We found no depositions of carbonate in the soil at any depth at the end of the study.

BICARBONATES IN LEACHATE

Soil depth 10 cm

In alkaline soils (similar to the one used in this study), a buffer reaction involving sulfuric acid, carbonates, bicarbonates, carbonic acid, and water takes place. The concentration of bicarbonates did not change for sulfuric acid treatment for the first 2 sampling dates (Figure 2). This can be explained by the dissolution of solid soil carbonates during the early stages of the study. However, after the first two sampling dates, the amount of bicarbonates in the leachate was consistently lower for both high and low SAR in the irrigation water when sulfuric acid was added.

Soil depth 20 cm

Sulfuric acid decreased the level of bicarbonates in the leachate for low SAR from September to December. Although at high SAR, sulfuric acid decreased the level of bicarbonates numerically, statistically it was lower only for one sampling date (Figure 3).

Drainage

In the drainage water, for both low and high SAR level, the amount of bicarbonates did not differ between sulfuric acid treatment and untreated control (Figure 4).

PH IN LEACHATE

- Generally, as a result of soil buffering, sulfuric acid did not affect the pH of the leachate for either SAR level at a soil depths of 10 and 20 cm and in the drainage water (Figures 5, 6, and 7).

EC IN LEACHATE

- At a soil depth of 10 cm, sulfuric acid did not affect electrical conductivity. At the end of the study, EC ranged from 1.3 to 1.2 dS m^{-1} for low SAR and from 8.2 to 8.4 dS m^{-1} for high SAR irrigation water (Figure 8).
- At a soil depth of 20 cm, in columns irrigated with low SAR water, EC was higher in the leachate from the sulfuric acid treated columns compared to the control on three sampling dates but at the end of the study the measured values ranged only from 1.1 to 1.4 dS m^{-1}. For the high SAR irrigated columns, sulfuric acid did not affect electrical conductivity. Generally, the EC values increased from the beginning to the end of the research period and reached between 5.1 and 5.6 dS m^{-1} in November and December (Figure 9).
- In drainage water, sulfuric acid did not affect electrical conductivity for low SAR. For the high SAR irrigated columns, overall there was no clear trend whether sulfuric acid affected drainage water quality (Figure 10).

SAR IN LEACHATE

- SAR values (soil depth of 10 cm) were did not affected by sulfuric acid compared to the untreated control for both high and low SAR. At the end of the study, values ranged from 3.6 to 4.0 for low SAR and from 17.2 to 18.6 for high SAR treatments (Figure 11).
- At the depth of 20 cm, SAR values did not differ between sulfuric acid and untreated control. At the end of the study, values ranged from 2.9 to 3.2 for low SAR. For high SAR the values ranged from 13.5 to 13.9 (Figure 12).

- In drainage water, values of SAR were not different between sulfuric acid and untreated control for low SAR and at the end of the study they ranged from 7.2 to 9.3. For the high SAR level, SAR values at the end of the study ranged from 27.9 to 28.4 (Figure 13).

Soil

- Statistical analysis revealed that the SAR level in the irrigation water affected measured parameters. Consequently, data were reanalyzed (Table 3) and are presented separately for high and low SAR content (Table 4).

INFILTRATION RATE

Infiltration rates were determined on one column only and treatments were not replicated. Generally, infiltration rates were lower for each treatment at the end compared to the beginning of the study (Table 5).

CONCLUSIONS

- Acidification of irrigation water by neutralizing bicarbonates with sulfuric acid until pH of 6.5 is reached appears to be an effective means to lower bicarbonates in the leachate in the top 10 cm of the rootzone for low and high SAR levels in the irrigation water. Unfortunately, there are no values for bicarbonates in the soil available.
- After 6 months of the experiment, the infiltration rate was numerically lower for all treatments compared to the rates measured at the beginning of the study.

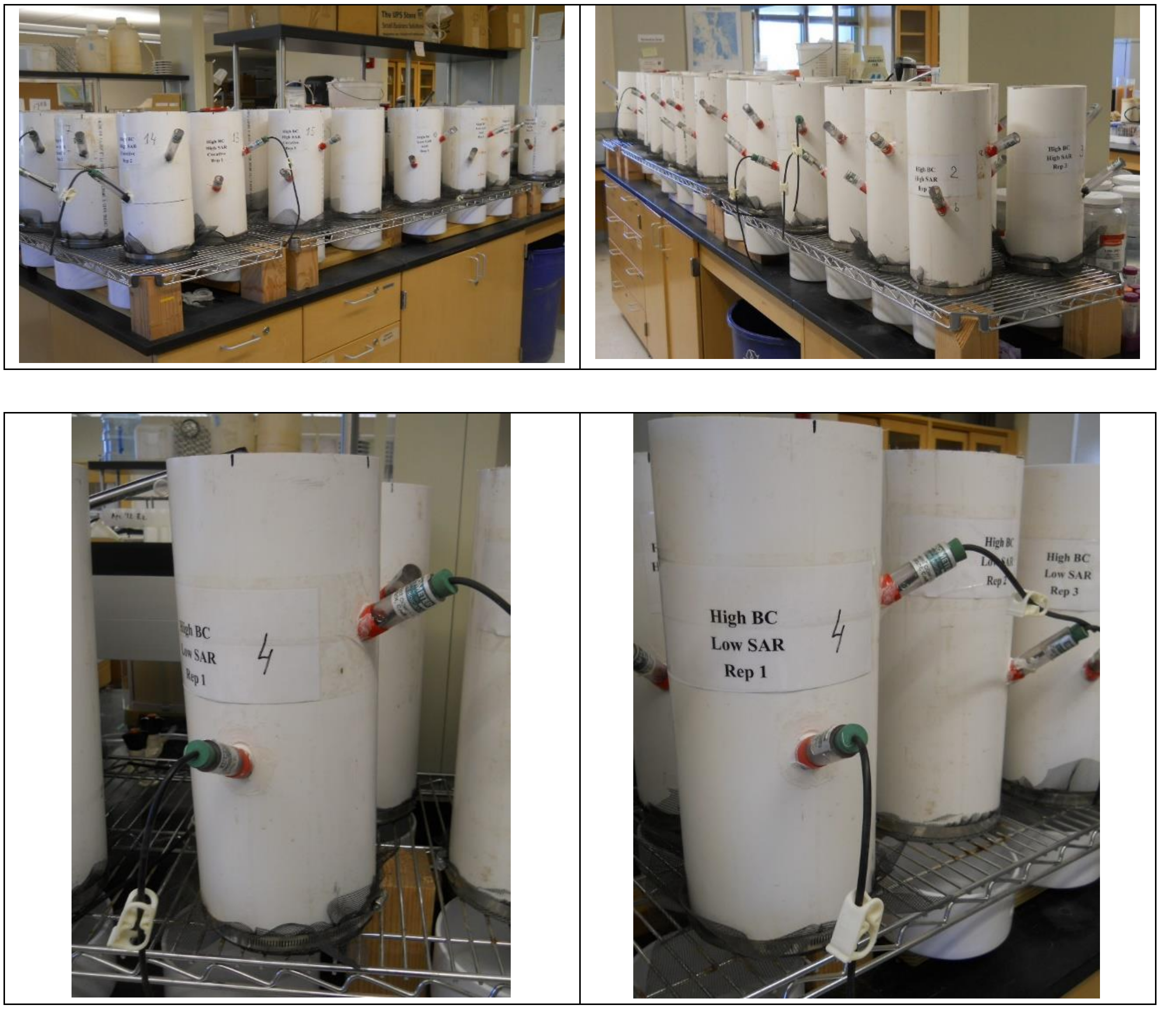

Figure 1. Set up of the soil columns in the laboratory.

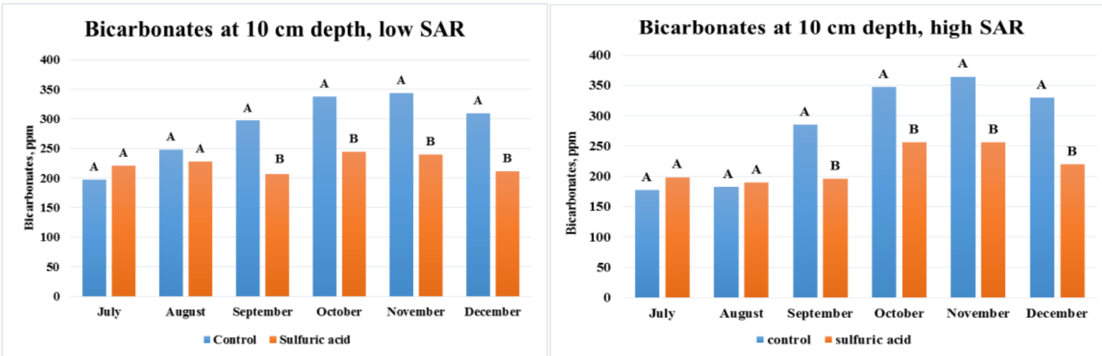

Figure 2. Bicarbonates in leachate (collected at a depth of 10 cm) of soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

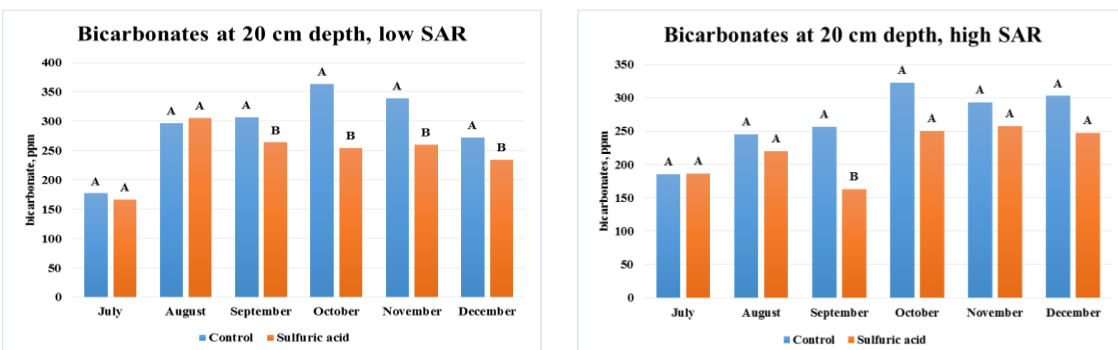

Figure 3. Bicarbonates in leachate (collected at a depth of 20 cm) collected in soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

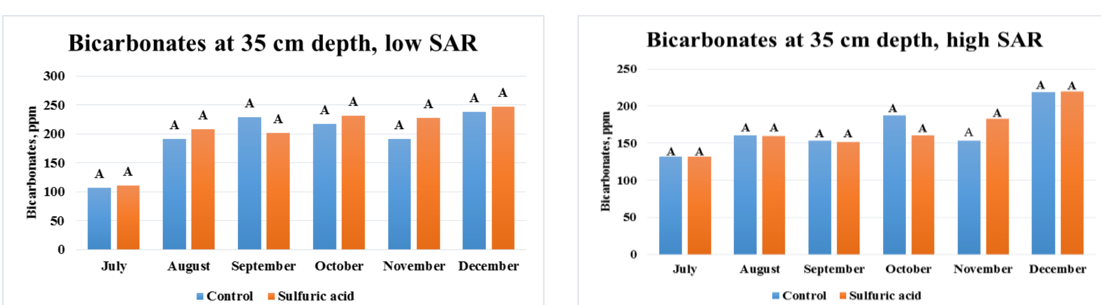

Figure 4. Bicarbonates in drainage water collected under soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

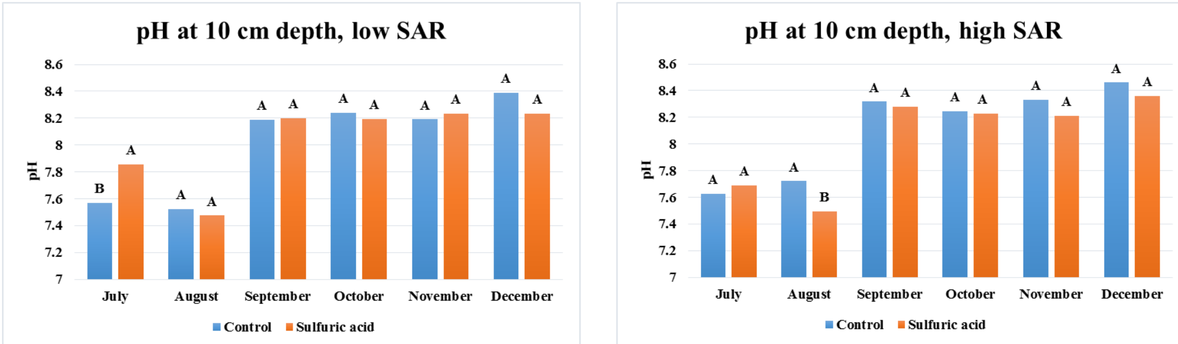

Figure 5. pH in leachate (collected at a depth of 10 cm) collected in soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

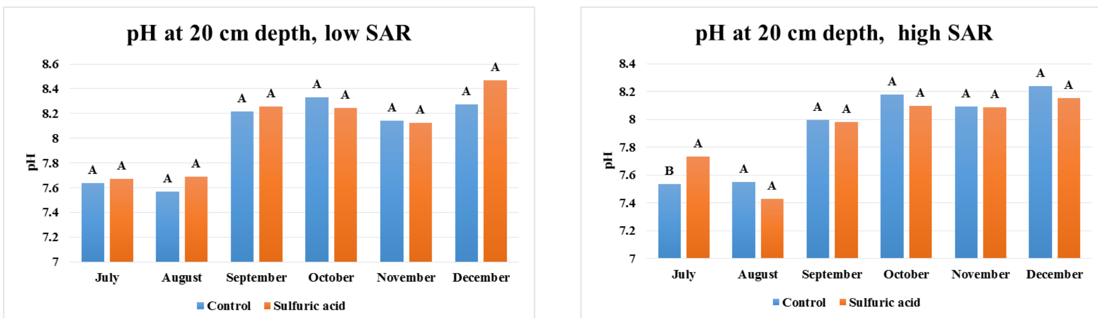

Figure 6. pH in leachate (collected at a depth of 20 cm) collected in soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

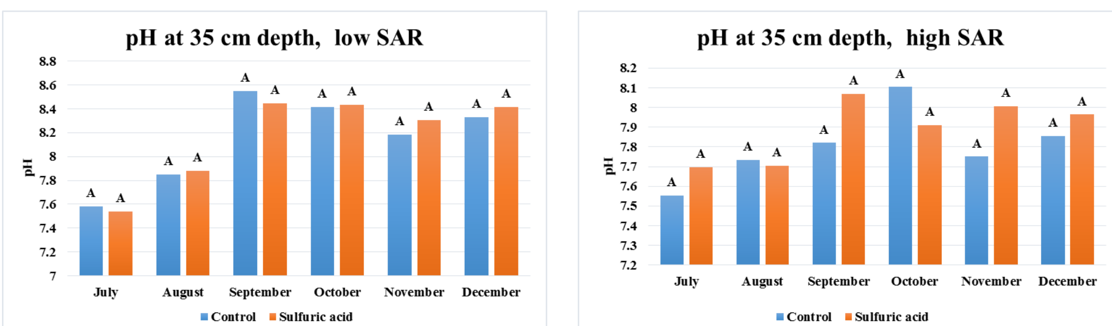

Figure 7. pH in drainage water collected under soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

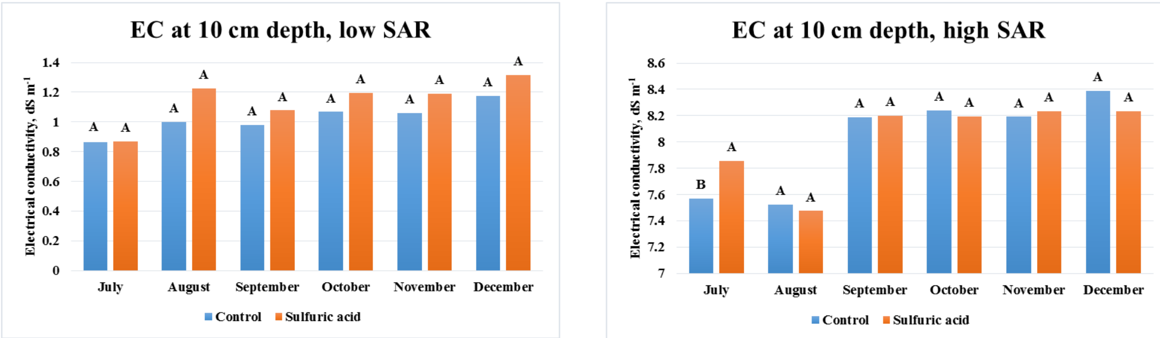

Figure 8. EC in leachate in leachate (collected at a depth of 10 cm) collected in soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

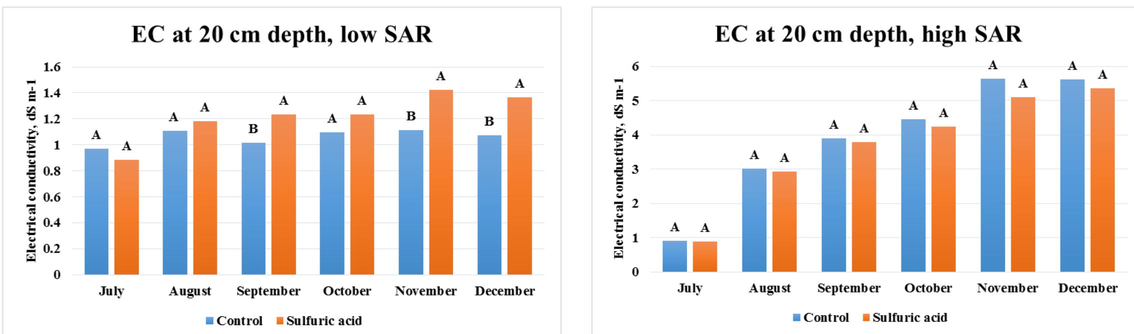

Figure 9. EC in leachate in leachate (collected at a depth of 20 cm) collected in soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

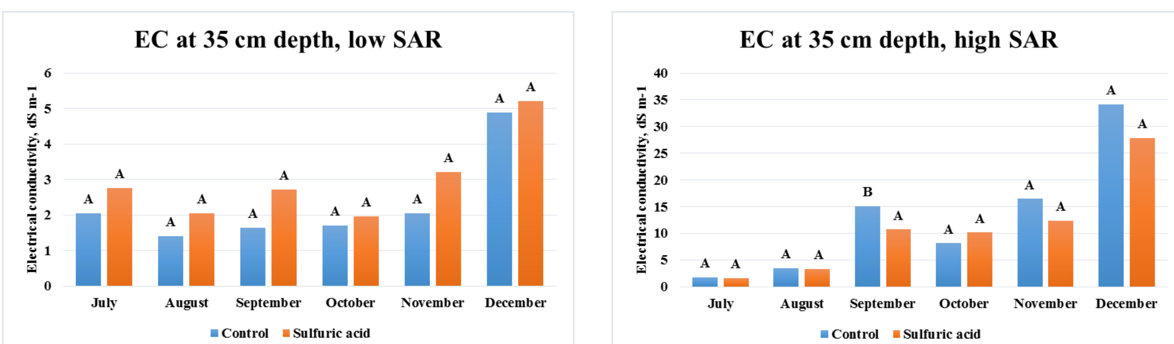

Figure 10. Electrical conductivity in drainage water collected under soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

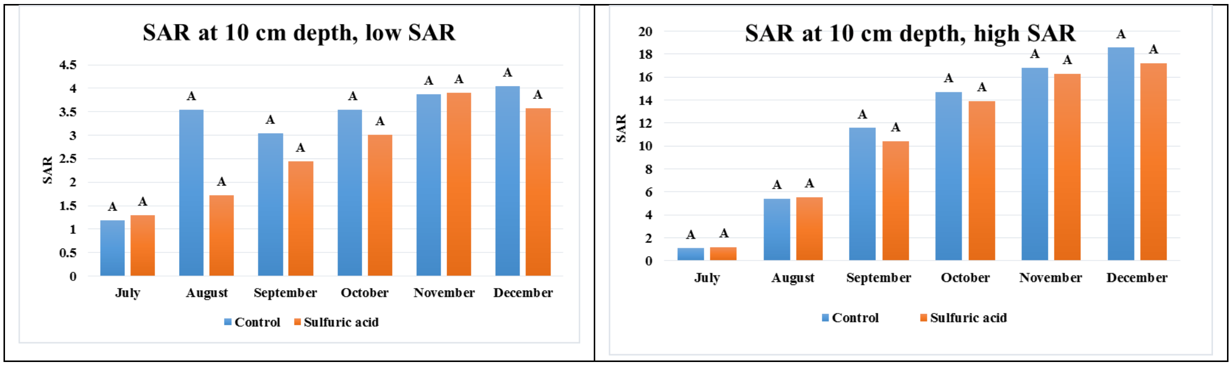

Figure 11. SAR in leachate (collected at a depth of 10 cm) collected in soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

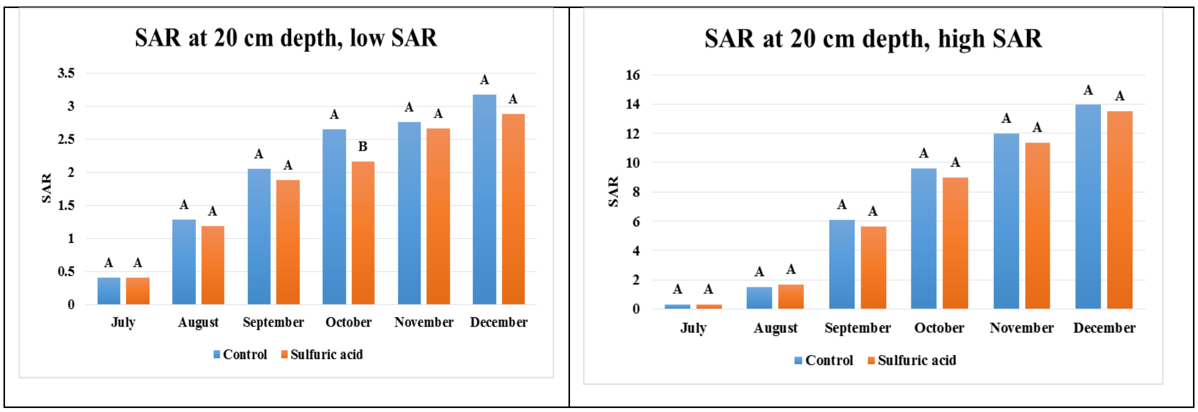

Figure 12. SAR in leachate (collected at a depth of 20 cm) collected in soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

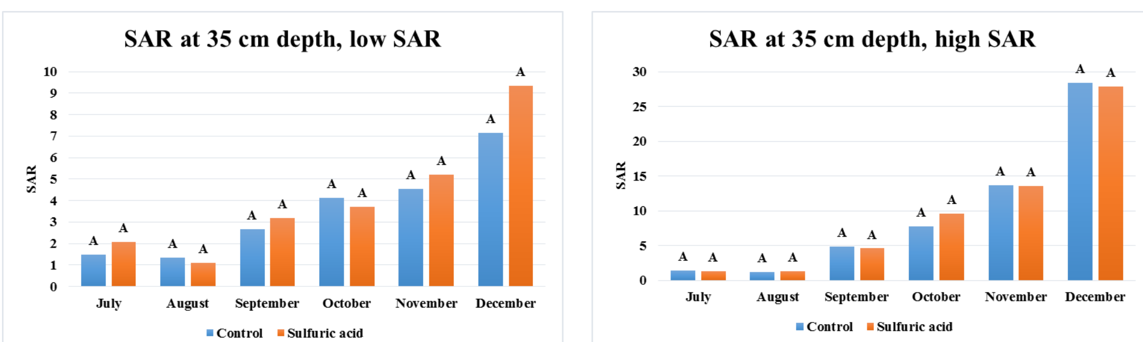

Figure 13. SAR in drainage water collected under soil columns to which irrigation water was applied with either a low (left) or a high (right) SAR.

Table 1: Main chemical constituents of the irrigation water.

Treatment	Bicarbonate, ppm	pH	EC	SAR
Control, high SAR	280-285	8.2	2.7	15
Control, low SAR	285	8.3	0.6	2.6
Acid, high SAR	205	6.5	2.65	14.7
Acid, low SAR	275	6.5	0.82	2.6

Table 2: ANOVA results for leachates.

	EC	**SAR**	**Bicarbonates**	**pH**
SAR High				
Trt	0.8217	0.327	0.088	0.8644
depth	<.0001	<.0001	<.0001	<.0001
Trt*depth	0.5603	<.0001	<.0001	0.1357
Date	<.0001	<.0001	<.0001	<.0001
Trt*Date	0.371	0.4145	0.0001	0.6086
depth*Date	<.0001	<.0001	<.0001	0.0027
Trt*depth*Date	0.4562	0.0035	0.0005	0.8862
SAR Low				
Trt	0.0816	0.0017	0.0034	0.3323
depth	<.0001	<.0001	<.0001	0.5361
Trt*depth	<.0001	0.0005	<.0001	<.0001
Date	<.0001	<.0001	<.0001	<.0001
Trt*Date	0.0303	0.0066	<.0001	0.2915
depth*Date	<.0001	<.0001	<.0001	<.0001
Trt*depth*Date	0.038	0.1385	<.0001	0.5552

Table 3: ANOVA results for salinity parameters in the soil (after the 6 months research period).

	SAR high			**SAR low**		
	EC	SAR	pH	EC	SAR	pH
Trt	0.0557	0.3556	0.0138	0.607	0.4689	0.0016
depth	0.0214	0.0002	<.0001	0.4231	0.4237	<.0001
Trt*depth	0.6252	0.4247	0.017	0.6707	0.5407	0.1706

Table 4: Electrical conductivity, SAR, and pH in soil. Values are averaged over all soil depths.

	SAR high			**SAR low**		
	EC	SAR	pH	EC	SAR	pH
Control	2.85[†]A	15.09A	9.03A	1.42A	5.75A	8.8A
Sulfuric Acid	3.28A	15.03A	8.93A	1.20A	3.33A	8.7B

[†]Values in the columns followed by the same letter are not significantly different from one another (Fisher's protected LSD, $P \leq 0.05$).

Table 5. The infiltration rate for each treatment before the first treatments application and after 6 months of treatments.

Treatment	Before treatment, mm $15min^{-1}$	After 6 months of treatment, mm $15min^{-1}$
Control, high SAR	38	22
Control, low SAR	67	53
Acid, high SAR	71	29
Acid, low SAR	64	35