Evaluation of An Acid Soil Conditioner in An Irrigated Cotton Production System

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Abstract

A single field study was conducted on a sodium-affected soil at the University of Arizona's Maricopa Agricultural Center (MAC) in 1999. Deltapine DP33B was dry planted and watered-up on 13 April 1999. Two treatments were evaluated; treatment 1 received no acid and treatment 2 received water-run acid applications. The acid used in this evaluation was sulfuric acid (H_2SO_4) and was applied at approximately 11 gallons acid/acre at each scheduled irrigation throughout the entire growing season. All other agronomic inputs and decisions were uniformly applied to both treatments. Lint yields were not significantly different.

Introduction

Sodic soils caused by irrigation with marginal to poor quality water are a continual and increasing problem in the agricultural regions of the desert southwest. This problem is one that is best described as a cumulative effect where the sodium (Na) levels become a problem over time via the continual addition of Na from the irrigation water and the inability to adequately leach. Soils of this type have long been the focus of specific management techniques to control and manage Na problems caused by marginal and poor quality irrigation water.

High levels of Na in a soil can have very detrimental effects to seedling emergence as well as toxicity levels that vary by crop species. By definition, a sodic soil is one that has an exchangeable sodium percentage (ESP) of 15% or more (U.S. Salinity Laboratory Staff, 1954). They can also be characterized as having a Na absorption ratio (SAR_e) from a saturated soil extract of 13 or greater.

Soils high in Na are inclined to have water penetration and infiltration problems due to the dispersion of clay particles within the soil (Yousaf et.al. 1987; Amezketa and Aragues, 1995). Dispersion of clay particles allows them to be transported into pore spaces that were previously available for water penetration and infiltration. Sealing of soil pores can produce a crusting problem that can inhibit seedling emergence and growth. Sodic conditions cannot be corrected with additional irrigation (leaching) applications alone, in fact, applying additional water may exacerbate the problem, particularly if it is high in Na. Calcium (Ca) and magnesium (Mg) are the primary elements that contribute to soil flocculation while Na causes dispersion in a soil. Sodium causes dispersion of a soil because of its large hydrated radius, as compared to Ca^{2+}, Mg^{2+} and potassium (K^+). The large hydrated radius of Na^+ essentially forces the clay particles apart leading to a dispersed soil condition.

There are several traditional treatments used to correct sodicity problems in soils. One approach involves the addition of elemental sulfur (S). Elemental S, when oxidized by soil microbes and combined with water, reacts to form sulfuric acid (H_2SO_4), which reacts with naturally occurring calcium carbonate ($CaCO_3$), releasing "free" Ca^{2+}. This Ca^{2+} in the soil solution can then exchange for Na^+ and form sodium sulfate (Na_2SO_4), which can be leached from the soil. Sulfuric acid can also be added to the irrigation water or soil directly. When adding elemental S or H_2SO_4, not only can Na^+ be converted to a leachable form, the pH of the water or soil can also be lowered.

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The objective of this study was to use H_2SO_4 in a naturally calcareous soil in an attempt to alleviate some of the problems that have been exhibited due to high Na accumulations in the soil and high Na and HCO_3 levels in the irrigation water. When the H_2SO_4 is added to the irrigation stream it is intended to reduce the pH of the water and reduce the precipitation of $CaCO_3$ and $MgCO_3$. The H_2SO_4 is also intended to release Ca^{2+} from the natural $CaCO_3$ in the soil and replace Na^+ on the soil cation exchange sites. The soil solution Na^+ can then combine with the SO_4^{2-} and be leached from the soil profile as Na_2SO_4.

Materials and Methods

The field experiment was planted with an Upland cotton (*Gossypium hirsutum L.*; variety Deltapine DP33B) on a calcareous Casa Grande sandy loam soil [fine-loamy, mixed, hyperthermic Typic Natrargid (reclaimed)] at the Maricopa Agricultural Center (MAC) on 13 April 1999. The experiment was dry planted and watered-up on the same day. The experimental structure consisted of two treatments (with and without H_2SO_4) arranged in a randomized complete block design with six replications. Plots consisted of twelve, 40-inch rows, extending the full length of the irrigation run (approximately 650 feet from head to tail). A bulk pre-season soil sample was collected from the study area on 19 November 1998 and post-season soil samples for each treatment were collected 20 January 2000 (Table 1 and 2).

Table 3 outlines irrigation and application dates, rates, and pH levels for the H_2SO_4 study. The H_2SO_4 was applied with each irrigation event in the irrigation stream (ditch) from a plastic tank at the head of the irrigation ditch, which was approximately 400 yards from the beginning of the H_2SO_4 study area. The pH of the irrigation water after addition of the H_2SO_4 was measured at the beginning of the study area. Approximately three to five pH measurements were taken and the average of these measurements was recorded (approximately pH 7.6). The target pH of the irrigation water for the H_2SO_4 treatment was approximately 5.5. The basis for the rate of application of H_2SO_4 was to lower the irrigation water pH to the target pH. Both treatments received every row irrigation throughout the growing season.

Each treatment received the same agronomic inputs with the only variation in management being the application of H_2SO_4 to treatment 2 with each scheduled irrigation. Treatment 2 received approximately 88 gallons of water-run H_2SO_4 during the course of the growing season (approx. 11 gal./acre/irrigation).

Routine plant measurements for each experimental plot were performed on a regular basis at approximately 14-day intervals throughout the season. Plant measurements taken included: plant height, number of mainstem nodes, number of flowers per 50 feet of row, percentage canopy closure, and the number of nodes above the top first position white flower (NAWF).

The crop received the final irrigation on 31 August. Lint yields were obtained for each treatment on 22 October by harvesting the entire center four rows of each plot with a two-row mechanical picker. Lint turnout estimates were made by ginning the seed cotton obtained from the study area. Results were analyzed statistically in accordance to procedures outlined by Steel and Torrie (1980) and the SAS Institute (SAS, 1988).

Results and Discussion

Plant growth and development patterns for both treatments are shown in Figures 1 and 2. There were no differences in plant growth and development as shown by plant measurements between the two treatments. Very poor fruit retention levels were experienced throughout the growing season (Figure 1). This was primarily due to extremely heavy Lygus populations. Several sources of Lygus near the experimental area provided a constant source of adult Lygus that were very difficult to control. Low height to node ratios (HNR) relative to baseline, indicating low plant vigor, were observed throughout the growing season (Figure 2).

Soil sample analyses revealed a reduction in Na from pre-season to post-season as indicated by a lowered ESP (Table 1 and 2). This decrease was seen in both the acid and no-acid treatments indicating that the decrease is not attributable to the application of acid. The EC_e levels also declined from preseason to post season.

Yields for both treatments are shown in Table 4. Yields were not significantly different for the acid and no-acid treatments. It is also very important to recognize the importance of the lygus infestation that removed the fruit load on the lower fruiting branches of the plants. The loss of fruit on the bottom portions of the plant removed the primary sink for carbohydrates in the plant. The removal of the boll load and primary carbohydrate sink allowed for an increase in plant vigor, and thus, vegetative growth.

A similar study was conducted in 1998 (Griffin and Silvertooth, 1999) that showed very similar results. No differences were observed in plant growth and development and no significant differences were observed in the final lint yield estimates between the two treatments.

References

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Table 1. Pre-season soil samples taken from field 1, borders 39-50 at MAC 19 November 1998.

Sample #	**Depth**	**pH** (1:1 H_2O)	**Ca*** (ppm)	**Mg** (ppm)	**Na** (ppm)	**K** (ppm)	**EC_e** (dS/M)	**NO_3^--N**** (ppm)	**P***** (ppm)	**ESP§**	**Free Lime**
Acid	6” – 10”	8.2	4900	300	310	310	4.0	14.0	13.0	4.6	High
No Acid	6” – 10”	8.1	5500	330	350	330	4.8	11.8	12.0	4.7	High

* Exchangeable cations using neutral molar ammonium acetate.
** NO_3^--N using ion specific electrode.
*** $NaHCO_3$ extractable P.
§ Computed - exchangeable sodium percentage.

Table 2. Post-season soil samples taken from field 1, borders 39-50 at MAC 20 January 2000.

Sample #	**Depth**	**pH** (1:1 H_2O)	**Ca*** (ppm)	**Mg** (ppm)	**Na** (ppm)	**K** (ppm)	**EC_e** (dS/M)	**NO_3^--N**** (ppm)	**P***** (ppm)	**ESP§**	**Free Lime**
Acid	6” – 10”	8.3	5800	290	240	330	1.9	5.8	10.0	3.1	High
No Acid	6” – 10”	8.3	5800	300	250	320	2.0	6.2	8.9	3.3	High

* Exchangeable cations using neutral molar ammonium acetate.
** NO_3^--N using ion specific electrode.
*** $NaHCO_3$ extractable P.
§ Computed - exchangeable sodium percentage.

Table 3. Treatment application dates and rates, acid study, MAC, 1999.

	Treatment	
Irrigation Date	**1**	**2**
	gal. H_2SO_4/acre	
28 May	0	11
10 June	0	11
24 June	0	11
6 July	0	11
20 July	0	11
2 August	0	11
17 August	0	11
31 August	0	11
Total	**0**	**88**

Table 4. Lint yields for each treatment, acid study, MAC, 1999.

Treatment	lbs. lint/acre
No Acid	935 a*
Acid	904 a
LSD**	NS
OSL†	0.2412
C.V.(%)‡	4.45

* Means followed by the same letter are not significantly different according to Fisher's LSD means separation test.
** Least Significant Difference
† Observed Significance Level
‡ Coefficient of Variation

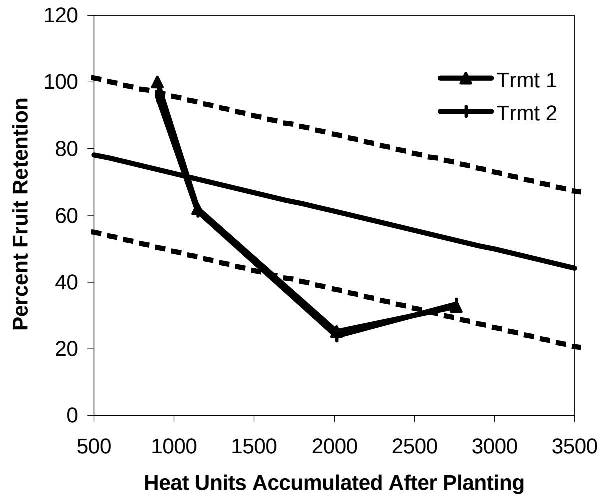

Figure 1. Fruit retention patterns for acid and non-acid treatments, Maricopa, 1999.

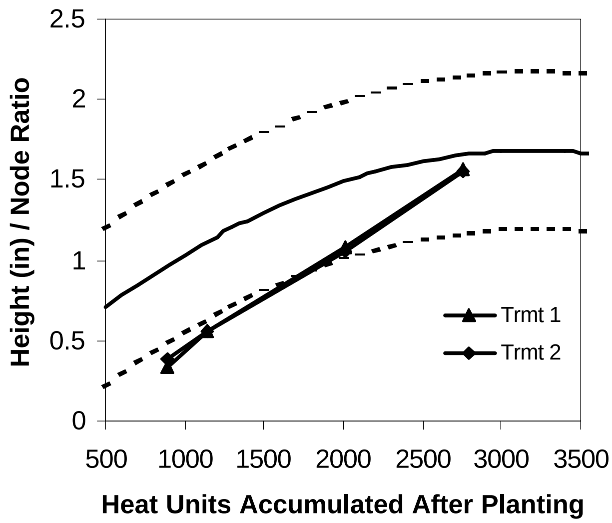

Figure 2. Height ton node ratio patterns for acid and non-acid treatments, Maricopa, 1999.