Evaluation of Soil Conditioners and Water Treatments for Cotton Production Systems

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Abstract

Advanced technologies to produce synthetic polymers such as polyacrylamide (PAM), and polymaleic anhydride (PMA) have produced products which may be economically feasible alternatives to traditional treatments such as gypsum in the desert Southwest. In 1995 a single field study was conducted at Paloma Ranch, west of Gila Bend in Maricopa County Arizona. Upland 'Nucoton 35, DPL' was dry planted and watered-up on 10 and 11 April. Treatments consisted of various rates and times of applications of Sper Sal, which included a check (no Sper Sal), 1 and 2 qts./acre with the water-up irrigation; 1 and 2 qts./acre with a mid-season irrigation; and 1 qt./acre mid-season following 1 or 2 qts./acre with the water-up irrigation. No differences among treatments were detected among any treatments in terms of plant growth and development or final lint yields.

Introduction

Many soils in the Southwest are naturally saline and/or sodic and are often the cause of difficulties in getting and keeping a good stand of cotton in many fields, even though cotton is considered moderately salt-tolerant. These soils are usually the object of reclamation and management techniques to control and minimize salt and sodium problems.

Saline soils are defined as nonsodic soils containing sufficient soluble salts to impair productivity (Brady, 1974). Salt contents which result in electrical conductivity measurements of 4 mmhos/cm or greater from a saturated extract (ECe), are generally referred to as saline soils. Saline conditions are relatively easy to treat, compared to sodic or saline-sodic conditions. Any rotation to a crop that includes border flooding or alternate row irrigation with good quality water can be helpful since non-sodium salts can be leached from the rooting zone.

Sodic soils are defined as soils that contain sufficient sodium (Na+) to interfere with the growth of most crop plants, and in which the exchangeable sodium percentage (ESP) is 15% or greater. They can also be characterized as having a sodium absorption ratio from a saturated extract (SAR) >13. Soils high in sodium are found to have water penetration problems due to the dispersion of soil particles. Soil sealing that results from particle dispersion is often seen as a crusting problem with the associated difficulties in seedling emergence and vigor. This condition can be exacerbated by rainfall or irrigation practices that cause water to cover the soil surface. Sodic soil conditions cannot be corrected with additional irrigation (leaching), in fact, the sodicity problem may be made worse by this practice since cations such as calcium (Ca2+) and magnesium (Mg2+) may be leached out of the root zone leaving the Na+.

In some cases the sodic conditions of a soil that are within tolerable levels can be pushed to dangerous levels by applying anhydrous ammonia with the irrigation water. When anhydrous ammonia is added to the water, the pH is increased by
the formation of ammonium hydroxide. This increase in pH can cause soluble Ca\(^{2+}\) and Mg\(^{2+}\) in the water to precipitate from solution by combining with bicarbonate (HCO\(_3\)^{-}), while any Na\(^+\) in the water remains in solution. This may result in irrigation water that is high in Na\(^+\), in proportion to Ca\(^{2+}\) and Mg\(^{2+}\). Continuous use of this practice can create sodic soil conditions that are increasingly difficult to manage.

There are several approaches to correcting a sodic soil problem after it has been properly identified. Incorporation of gypsum (CaSO\(_4\)) results in the exchange of Ca\(^{2+}\) for Na\(^+\) and the formation of sodium sulfate (Na\(_2\)SO\(_4\)) which is soluble and can be leached from the soil. Elemental sulfur or sulfuric acid may also be used if the correct soil conditions exist. Ultimately, the incorporation of these soil amendments results in the production of Na\(_2\)SO\(_4\) that must then be leached from the soil, provided that good quality water is available.

There are also other less traditional soil amendments that have been utilized over the years. Synthetic polymers were first extensively investigated in the 1950's and 1960's. An extensive series of studies conducted in Arizona with polymers available at that time showed reduced soil compaction, improved stands, increased N and P uptake, and increased yields compared to untreated controls (Fuller et al., 1953). Although effective, most of these products were not economically feasible under field conditions. However, recent advances in technology have made the economic utilization of polymers a realistic possibility. Synthetic polymers such as polyacrylamide (PAM), polyvinyl alcohol (PVA), polymaleic anhydride (PMA), and polysaccharides have shown promising results in research studies. Reduced soil surface crusting (Helalia and Letey, 1989; Wood and Oster, 1985; Terry and Nelson, 1986), improved aggregation and reduced clay dispersion (Aly and Letey, 1988), enhanced stand establishment (Cook and Nelson, 1986; Wallace and Wallace, 1986a; 1986b), improved water holding capacity (Nimah et al., 1983; Shanmugananathan and Oades, 1982; Woodhouse and Johnson, 1991), reduced soil erosion with furrow and sprinkler irrigation (Ben-Hur et al., 1990; Lentz et al., 1992; Levy et al., 1992), enhanced nutrient uptake by crops (Fuller et al., 1953; Wallace and Abouzanzam, 1986; Wallace et al., 1986b), and an enhanced ability for reclamation of saline and sodic soils (Wallace et al., 1986a) have been reported with the use of synthetic polymers.

These research results suggest that several soil amendments may offer a practical and economical means for managing problem soils in arid regions. Based on findings in other areas these materials could substantially lower costs associated with the management of problem soils and increase the yield potential for crops produced on them. The objective of this research was to evaluate several soil conditioners as tools for managing soils used for cotton production in the low-desert. This project was initiated in 1994 on soils that are known to be prone to crusting problems, which can be a serious problem in many Sonoran Desert soils. In 1994, results from this project were promising in terms of crust reduction after planting from Sper Sal applications with the water-up irrigation, which facilitated a much better stand establishment as compared to other treatments (Unruh et al., 1995).

**Materials and Methods**

Soils were sampled in the experimental area before the start of the project for complete characterization (Table 1). The field experiment was planted to Upland cotton (DPL Nucoton 33) on a Wellton loam soil on 9 April 1995. All plots in this experiment were dry planted and watered-up on 10 April. The experimental design used in this study was a randomized complete block with four replications. Plots were eight, 36-inch rows wide, and extended the full length of the irrigation run (1200 feet). Plots consisted of : a check, and various treatments consisting of a soluble polymaleic anhydride called Sper Sal\(_{an}\) from FMC. Treatments consisted of various rates and times of application of Sper Sal\(_{an}\) (Table 2), with all treatments being applied via the irrigation water either with the initial water-up irrigation or with a mid-season irrigation (28 July).

The mid-season application of Sper Sal with the irrigation water was included due to the fact that water infiltration rates appear to reduce in many cases during the mid to later stages of the season. This is often recognized with shorter amounts of time needed for water to reach the tail of the field in a given irrigation set later in the season. Usually, this is attributed to sedimentation of finer soil particles in the bottom of the irrigation furrows, which can serve to clog soil pores and presumably reduce water infiltration. Sometimes this is most pronounced mid-season immediately following a monsoon rainfall event. One proposed mechanism associated with this phenomena is the possible dispersion of surface soil
particles due to relatively high amounts of Na, which levels may have been accentuated due to the addition of high quality (low solute level or low Ca and Mg levels) water from rain.

Routine plant measurements for each experimental area were carried out on a regular basis at approximately 14 day intervals throughout the season. Measurements taken included: plant height, number of mainstem nodes, number of flowers per 50 feet of row, percent canopy closure, and the number of nodes from the top fresh bloom to the terminal (NAWB). Sequential plant maps were also collected on regular intervals.

The crop was irrigated until 28 September, when the final irrigation was made. The entire study area was defoliated on 25 October. All plots were harvested with a mechanical picker on 1 December 1995.

**Results and Discussion**

In 1994, a similar experiment was conducted at Paloma Ranch (Umuh et al., 1995). One day after the initial water-up (25 March) approximately 1 inch of precipitation was recorded at this location, which resulted in the development of a substantial crusting problem. Another irrigation was made on 30 March in an attempt to move soluble salts away from the seed-line, soften the surface crust, and to encourage the germination and emergence of seeds not sufficiently moistened by the first irrigation. The heavy crusting conditions persisted and by 6 April significant differences could be detected between the treatments receiving the Sper Sal,,,, with the water-up irrigation and all other treatments, irrespective of gypsum treatment. Those plots receiving the water-run Sper Sal,,,, had an average of 15 emerged plants per meter, while all other treatments had an average of 2 emerged plants per meter. A third irrigation was made on 6 and 7 April, which was successful in reducing crusting problems and encouraged seedling emergence to the extent that by 14 April all treatments averaged from 14 to 16 plants per meter of row. There was a slight difference in plant maturity between those in the water-run Sper Sal,,,, plots and all others at very early stages in the season, however, differences among treatments dissipated as the season progressed.

In 1995, cool weather conditions persisted for several weeks following planting, but a rainfall event did not occur, and soil crusting was not a problem with regard to stand establishment. Stand counts were taken on 27 April and no differences among treatments were detected, with an average stand count of 14 plants/meter of row (56,000 plants per acre).

Plant growth and development patterns for all treatments are shown in Figures 1 and 2. Figure 1 outlines the height (in.) to node ratios (HNR) and Figure 2 describes the fruit retention (FR) for all treatments over the season as a function of heat units accumulated after planting (HUAP, 86/55 °F thresholds). The center line in both figures represents an optimal baseline for Arizona cotton and the upper and lower lines represent general thresholds conditions. All treatments experienced low vigor conditions (low HNR) throughout the season, which was a problem throughout this part of Arizona in 1995. However, FR levels were relatively high. Although the check treatment (treatment no. 1) did experience a drop in FR early in the season in relation to the other treatments it was not a significant or consistent trend.

Yield results are shown in Table 2, based upon soil amendment treatments. No differences were detected among the various treatments consisting of the polymaleic anhydride (Sper Sal,,,,) in terms of final yields.

Based upon two years of work with this project, there is evidence that Sper Sal can be effective in reducing soil crusting and providing for conditions more conducive to stand establishment, providing crusting conditions are going to exist. If one is able to predict a heavy rain or is confident that the probability is high for a rainfall event or conditions favorable to crusting at any time in the season, a Sper Sal application may be justified.

**Acknowledgement**

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References


Table 1. Soil test results from the Paloma Ranch site, Gila Bend, AZ, 25 February 1995.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Ca†</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>NO3-N‡</th>
<th>P§</th>
<th>pH</th>
<th>EC₀</th>
<th>ESP¶</th>
</tr>
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<tbody>
<tr>
<td>ft</td>
<td>ppm</td>
<td></td>
<td></td>
<td></td>
<td>(1:1 H₂O)</td>
<td>ds/m</td>
<td>%</td>
<td></td>
<td></td>
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<tr>
<td>0-1</td>
<td>6300</td>
<td>410</td>
<td>370</td>
<td>300</td>
<td>22.0</td>
<td>9.4</td>
<td>8.3</td>
<td>2.8</td>
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<td>5900</td>
<td>640</td>
<td>1420</td>
<td>205</td>
<td>18.5</td>
<td>10.0</td>
<td>8.1</td>
<td>4.0</td>
<td>4.9</td>
</tr>
</tbody>
</table>

† Exchangeable cations using neutral molar ammonium acetate.
‡ NO₃-N using specific ion electrode.
§ NaHCO₃ extractable P.
¶ Computed, exchangeable sodium percentage.

Table 2. Lint yield means for the soil amendment study at Paloma Ranch, 1995.

<table>
<thead>
<tr>
<th>Treatment Number</th>
<th>Rate and Time of Application (qts. Sper Sal/acre)</th>
<th>Lint Yield (lbs./acre)</th>
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<tbody>
<tr>
<td>1</td>
<td>check</td>
<td>1371 a†</td>
</tr>
<tr>
<td>2</td>
<td>1 qt. @ water-up</td>
<td>1378 a</td>
</tr>
<tr>
<td>3</td>
<td>2 qt. @ water-up</td>
<td>1329 a</td>
</tr>
<tr>
<td>4</td>
<td>1 qt. @ water-up, 1 qt. mid-season (28 July)</td>
<td>1390 a</td>
</tr>
<tr>
<td>5</td>
<td>2 qt. @ water-up, 2 qt. mid-season (28 July)</td>
<td>1368 a</td>
</tr>
<tr>
<td>6</td>
<td>2 qt. mid-season (28 July)</td>
<td>1381 a</td>
</tr>
<tr>
<td>OSL‡</td>
<td></td>
<td>0.7045</td>
</tr>
</tbody>
</table>

CV (%)* 3.0
Figure 1. Height to node ratios for each treatment, soil amendment study, Paloma, 1995.
Figure 2. Fruit retention levels for each treatment, soil amendment study, Paloma, 1995.