

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 1994 three field studies were initiated, two identical studies were located in the Yuma Valley and one at Paloma Ranch. At Yuma Valley the experiments included 0, 1, and 2 tons gypsum/acre, over which, various soil-applied treatments were made; including, a check, soluble PMA (Sper Sal_{sm}), and PAM (Hydro-Growth_{sm}). Upland cotton 'DPL 5461' was grown in both Yuma Valley studies. At Paloma Ranch, Upland 'DPL 5415' planted. Prior to planting, two gypsum applications were made at 0 and 2 tons/acre. Also included as treatments were various methods and rates of Sper Sal_{sm}. No differences among treatments were detected in either of these locations relative to crop yield. At Paloma Ranch there were some early-season differences in soil crusting among the various soil amendment treatments, however, these differences dissipated as the season progressed and did not result in lint yield differences.

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 (EC_e), 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_e) ≥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. 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_2SO_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_2SO_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; Shanmuganathan 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 Abouzanam, 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.

Materials and Methods

Three field experiments were carried out as a part of this project in 1994, two were located in the Yuma Valley and one at Paloma Ranch.

Yuma Valley

Two field experiments were conducted at the University of Arizona Yuma Valley Agricultural Center (YVAC) on two different soil types. The first experiment was planted to Upland cotton (DPL 5461) on 18 March at 479 heat units accumulated since 1 January (HU/1 Jan., 86/55 °F thresholds) on a Gadsden clay loam soil (North Farm). The second experiment was located on the South Farm on a Holtville clay loam soil, with the same Upland variety being planted on 31 March (607 HU/1 Jan.).

Soils were sampled in each experimental area before the start of the project for complete characterization. The experimental design employed was a split-plot within a randomized complete block (RCB) with four replications for both studies. Treatment configurations were the same in each experiment. Mainplots consisted of gypsum treatments at 0, 1, and 2 tons gypsum/acre, and were divided into seven subplots that were four, 40-inch rows and 50-feet long. Subplots consisted of various soil-applied treatments including: a check, a soluble polymaleic anhydride called Sper Sal_{tm}, from FMC and a polyacrylamide called Hydro-Growth_{tm} (Table 1).

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. All plots were harvested with a mechanical picker on 4 and 5 October 1994.

Paloma Ranch

A field experiment was planted to Upland cotton (DPL 5415) on a Wellton loam soil (Table 2) on 23 March (438 HU/1 Jan.). All plots in this experiment were dry planted and watered-up on 24 March. The experimental design used in this study was also a split-plot within a randomized complete block with four replications. Mainplots were 40, 36-inch rows wide that extend the full length of the irrigation run (1200 feet). Prior to planting, gypsum applications were made to mainplot areas at 0 and 2 tons gypsum per acre. Subplots were eight 36-inch rows and extend the full length of the irrigation run. Subplot treatments consist of various rates and methods of application of Sper Sal_m (Table 3). An in-season water-run Sper Sal_m treatment (treatment no. 5) was made 27 July, all other Sper Sal_m treatments were made at planting or with the water-up irrigation. The crop was irrigated until 19 September, when the final irrigation was made. The entire study area was defoliated on 18 October. Harvesting was completed on 28 November.

Results and Discussion

Yuma Valley

No differences among treatments were detected in either of these experiments relative to soil crusting, or crop development. There were no differences among gypsum treatments or among the various soil amendment treatments. Lint yield results are shown in Table 1.

Paloma Ranch

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_m with the water-up irrigation and all other treatments, irrespective of gypsum treatment. Those plots receiving the water-run Sper Sal_m 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_m plots and all others at very early stages in the season, however, differences among treatments dissipated as the season progressed.

Yield results are shown in Table 3, based upon soil amendment treatments. No differences were detected among the various treatments consisting of the polymaleic anhydride (Sper Sal_m) in terms of final yields, despite the early season effects.

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