Evaluation of A Foliar Applied Seed Bed Calcium Soil Conditioner in an Irrigated Cotton Production System

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Abstract

*A multi-site experiment was conducted at Paloma Ranch, west of Gila Bend in Maricopa County and at Wellton in Yuma County Arizona. NuCotn*Ô *33B was dry planted and watered-up on 28 April 1998. Various rates of application of nitrogen (N) and calcium (Ca) from CN-9 [9-0-0-11Ca ($5Ca(NO_3)_2$•NH_4NO_3•$10H_2O$)] was used to evaluate the check. The CN-9 was applied as a foliar application directly to the seed bed on 27 April 1998. Treatment 1 was the check plot that received no CN-9. Treatment 2 received a 12 gal./acre application of CN-9 while treatment 3 received a 15 gal./acre application of CN-9. Each gal of CN-9 weighs approx. 12.2 lbs. and contains 1.1 lbs. of N and 1.4 lbs. of Ca. Treatment 2 received a total of 13 N/acre while treatment 3 received a total of 17 N/acre via CN-9. Treatment 1 received only farm standard applications of UAN-32. Treatments 2 and 3 each received farm standard applications of UAN-32 after the application of CN-9 for continued crop N needs. A total of 17 lbs./acre of Ca was applied to treatment 2 and 21 lbs./acre of Ca was applied to treatment 3. No significant differences were found among the various treatments in terms of plant growth, soil water content, EC_e values, and sodium absorption ratios. Lint yields were not significantly different ($P<0.05$).*

Introduction

Soils in the desert Southwest have long been associated with saline and/or sodic conditions that can cause difficulties in water penetration as well as nutrient relationships. These soils have long been the focus of specific management techniques to control and manage sodium (Na) problems.

Sodic soils are by definition are those soils which contain an exchangeable sodium percentage (ESP) of 15% or more. 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, the problem may be exacerbated by applying additional water, particularly if it is high in Na. Leaching of a sodic soil can remove the divalent cations calcium (Ca^{2+}) and magnesium (Mg^{2+}) from the soil profile and root zone leaving the monovalent cation Na^+. Calcium and Mg are the primary elements that contribute to soil flocculation while Na causing dispersion in a soil. Sodium (Na^+) 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^+ forces the clay particles apart creating a dispersed soil condition.

Saline soils are defined as a non-sodic soil that contain sufficient soluble salts to impair plant growth and productivity (Brady, 1974). Saline soils generally are found to have an electrical conductivity (EC_e) of 4 mmhos/cm or greater from a saturated extract. Saline conditions are generally easier to correct as compared to sodic or saline-sodic soils were leaching can be an effective treatment.

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A further problem associated with irrigation is the increase in pH of the soil as a result of the introduction of anhydrous ammonia nitrogen fertilizer into the irrigation water. The increase in pH can cause the flocculating elements, Ca^{2+} and Mg^{2+}, to precipitate with bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) leaving soluble Na^+ in the irrigation water. The application of this type of water has the potential to effectively raise the ESP and the SAR of the soil. This, in turn, can cause a sodic condition that can be difficult to manage.

There are several traditional treatments used to correct sodicity problems in soils. One approach involves the use of gypsum ($CaSO_4{\bullet}2H_2O$). Gypsum ($CaSO_4{\bullet}2H_2O$) tends to increase the levels of Ca^{2+} in the soil that can then exchange with the Na^+ creating sodium sulfate (Na_2SO_4), which can be leached from the soil. This addition of Ca^{2+} lowers the SAR and contributes to the exchange and leaching of soil Na^+.

Another common treatment of sodic soils is 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^+ in the form of Na_2SO_4, which can be leached from the soil. Sulfuric Acid (H_2SO_4) can also be added to the irrigation water directly. When adding elemental S or H_2SO_4, not only can Na be converted to a leachable form but the pH of the soil is also lowed via the release of hydrogen (H^+) into the soil.

Considering the Na levels that are often accumulating in desert soils, there has been an increase in the number of soil amendments to combat the problem. Extensive studies conducted worldwide on arid soils have shown that there is a consistent relationship between the effects of SAR, pH and electrolyte concentration on relative hydraulic conductivity (K_s) and clay dispersion (Suarez et al., 1984). It has also been demonstrated that the plant available Ca^{2+} is highly independent of the amount of calcium carbonate ($CaCO_3$) naturally present in the soil (Flocker and Fuller, 1956).

Along with the conventional methods of treating sodic and saline conditions, there has been an increasing emergence of numerous synthetic water-soluble polymers (WSP's). The WSP's include polyacrylamide (PAM), polyvinyl alcohol (PVA), polymaleic anhydride (PMA), and polysaccharides. Research studies have shown that these synthetic polymers have reduced soil surface crusting (Helalia and Letey, 1989; Wood and Oster, 1985; Terry and Nelson, 1986), improved water holding capacity (Nimah et al., 1983; Shanmugananathan and Oades, 1982; Woodhouse and Johnson, 1991), improved aggregation and reduced clay dispersion (Aly and Letey, 1988), enhanced nutrient uptake by crops (Fuller et al., 1953) and enhanced ability for reclamation of saline and sodic soils (Wallace et al. 1986a). However, they do not impart an exchange for Na^+ on the soil adsorption complex.

Over the recent years there have been several commercially available Ca^{2+} bearing products have become available for treatment of sodic soil conditions. These products include CAN-17 (17-0-0-24Ca), N-Cal™ (18-0-0-6Ca), and CN-9 (9-0-0-11Ca) to name a few. These products contain a plant available form of N and Ca that are in a water-soluble form. These products can be applied through the irrigation water, sprayed directly on to the soil, or injected into the soil. These products are designed to replace Na^+ with Ca^{2+} on the soil colloids thus allowing the Na^+ to be leached from the soil profile. However, at this time these types of products have been found to be inconclusive at lowering ESP in highly a saline soil environment were high levels of Ca are already present (Griffin et al., 1998). However, there may be some advantage to water-up applications of these products in promoting early seedling vigor due to movement of Na^+ away from the seedling by Ca^{2+} (Griffin et al., 1997; Griffin et al., 1998).

Methods and Materials

The field experiment was planted with an Upland (*Gossypium hirsutum L.*) cotton variety (NuCotn 33B) on a Wellton sandy loam soil at Paloma Ranch, AZ (field 11A-7) on 24 April 1998. The experiment was dry planted then watered-up on 28 April 1998. The experimental design of the project was a three treatment, randomized complete block with four replications. Plots were eight 36-inch rows wide, extending the full length of the irrigation run approximately 1250 feet from head to tail. Pre-season and post-season soil samples were collected for each treatment on 24 April 1998 and 14 December 1998 respectively (Table 1 and 2). A surface soil sample (approx. top 5cm) was also obtained on 20 May 1998 (Figures 1 and 2). An irrigation water quality sample was taken on 24 April 1998 (Table 3).

Table 6 lists application dates and rates for all treatments in 1998. Treatments 2 and 3 used CN-9 as a foliar N source until approximately 17 lbs. Ca/acre had been applied for treatment 2 and approximately 21 lbs. Ca/acre had been applied for treatment 3. UAN-32 (urea, ammonium nitrate 32-0-0) was used thereafter to meet crop N demands for all the treatments. Treatment 1 received no Ca and was fertilized only with UAN-32. All fertilization applications for all treatments were water-run in the irrigation stream.

Treatments 2 received approximately 12 gal/acre of CN-9 and treatment 3 received approximately 15 gal/acre of CN-9. Each treatment received the CN-9 via a high cycle spray rig. A carrier rate of approximately 31 gal/acre at 50 psi was used to apply the CN-9. The spray boom of the high cycle was set at approximately 54 cm above the top of the seed bed. The CN-9 was applied only to the top of the seed bed and was not apply in the furrows. The wind was light (0-5 mph) at the time of application, 27 April 1998.

Routine plant measurements for each experimental plot were performed on a regular basis at approximately 14-day intervals throughout the 1998. 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 from the top fresh flower to the terminal (NAWF). Petioles were also obtained for nitrate nitrogen (NO_3-N) analysis. The petioles were collected at the same time as plant measurements were made.

Soil water measurements were also taken routinely directly following an irrigation event. Soil water measurements were taken from all plots with a neutron probe at 1-foot intervals from the surface to a depth of 5 feet.

Surface soil samples were taken to a depth of approximately 5 centimeters on 20 May 1998. These surface soil samples were evaluated on the water side, seed row and dry sides of the beds for exchangeable Na percentage and EC_e (Figures 1 and 2).

Yields for each treatment were determined by harvesting the entire center four rows of each plot and weighing the seedcotton with large portable electronic scales at the end of the field. Lint turnout was determined from each plot by ginning an approximately 15-lb. subsample of seedcotton.

The crop was irrigated until 26 September 1998. The entire area of study was defoliated on 15 November and again on 24 November 1998. All the plots were harvested with a mechanical picker on 14 December 1998. Lint yields were obtained for each treatment by harvesting the entire eight rows of each plot with a four row mechanical picker. Seedcotton subsamples were collected for ginning, from which lint turnout estimates were made (35%). 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 all treatments are shown in Figure 3 (A, B, C, and D) for 1998. The center line in all figures represents an optimal baseline for cotton in Arizona with the upper and lower lines representing the upper and lower 95% confidence interval thresholds (Silvertooth et al., 1996). Low height to node ratio (HNR) and nodes above white flower (NAWF), indicating low plant vigor, were observed throughout the entire season in all treatments (Figure 3 B, and D). However, fruit retention (FR) patterns remained near optimum levels throughout most of the season (Figure 3 A). Petiole NO_3^--N levels were very similar among the different treatments over then entire season (Figure 3 C).

Soil samples taken in 1998 revealed lowered Na levels from pre-season to post-season as indicated by a lowered EC_e and ESP (Table 1 and 2). Treatment showed the greatest reduction in both EC_e and ESP. All treatments had lowered EC_e values.

Figures 4 – 7 presents volumetric soil water data for four sample dates immediately following irrigation events in 1998. Analysis of variance performed on this data did not reveal any significant differences among treatments with regard to soil water content at any depth or date of sampling. This would generally indicate that there were no differences among the treatments in terms of total water penetration. Another interesting observation from these data is the apparent linear increase in soil water content from the surface to the lower portions of the profile. This indicates sufficient drainage from the surface portions of the profile but that there might be some type of impedance to drainage leading to the observed accumulation of water in the lower portions of the profile. The impedance to drainage is most likely a $CaCO_3$ layer, which is very prevalent in these arid soils. This observation appears to be independent of treatment and is apparently due to natural soil conditions.

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Table 1. Pre-season soil samples taken at Paloma Ranch (Field 11A-7) on 24 April 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**
Composite	6”-10”	8.2	7300	330	350	410	4.2	32.1	18.0	3.6	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 at Paloma Ranch (Field 11A-7) on December 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**
Trmt. 1	6” – 10”										High
Trmt. 2	6” – 10”										High
Trmt. 3	6” – 10”										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. Irrigation water quality taken at Paloma Ranch on 24 April 1998.

Quantity	**pH* (1:1 H_2O)**	**Ca**	**Mg**	**Na**	**CO_3**	**HCO_3**	**EC (dS/m)**	**SAR**	**SAR_{adj}§**
	7.20						3.0	9.26	24.64
ppm		160.0	48.0	520.0	0	248.9			
meq./L		8.00	3.93	22.61	0	4.08			
Lbs./acre-ft		435.2	130.6	1414.4	0	677.0			

§ Adjusted Sodium Adsorption Ratio [adjusted for bicarbonate (HCO_3)].

Table 4. Application dates and rates of CN-9 study, field 11A-7, Paloma Ranch 1998.

Date	**Treatment 1**	**Treatment 2**	**Treatment 3**	**Treatment 1**	**Treatment 2**	**Treatment 3**
		lbs. N/acre			**lbs. Ca/acre**	
4/27*	0	13	17	0	17	21
6/12	25	25	25	0	0	0
6/29	35	35	35	0	0	0
7/17	53	53	53	0	0	0
7/31	53	53	53	0	0	0
8/10	53	53	53	0	0	0
8/26	53	53	53	0	0	0
Total	**272**	**285**	**289**	**0**	**17**	**21**

* Foliar application of CN-9 (9-0-0-11Ca) at 12 gal. /acre and 15 gal. /acre.

Table 5. Lint yields for each treatment, CN-9 study, Paloma Ranch, 1998.

Treatment	lbs. Lint/acre
2	1006
3	963
1	957
LSD*	NS
OSL†	0.1436
C.V.(%)‡	3.33

* Least Significant difference
† Observed Significance Level
‡ Coefficient of Variation

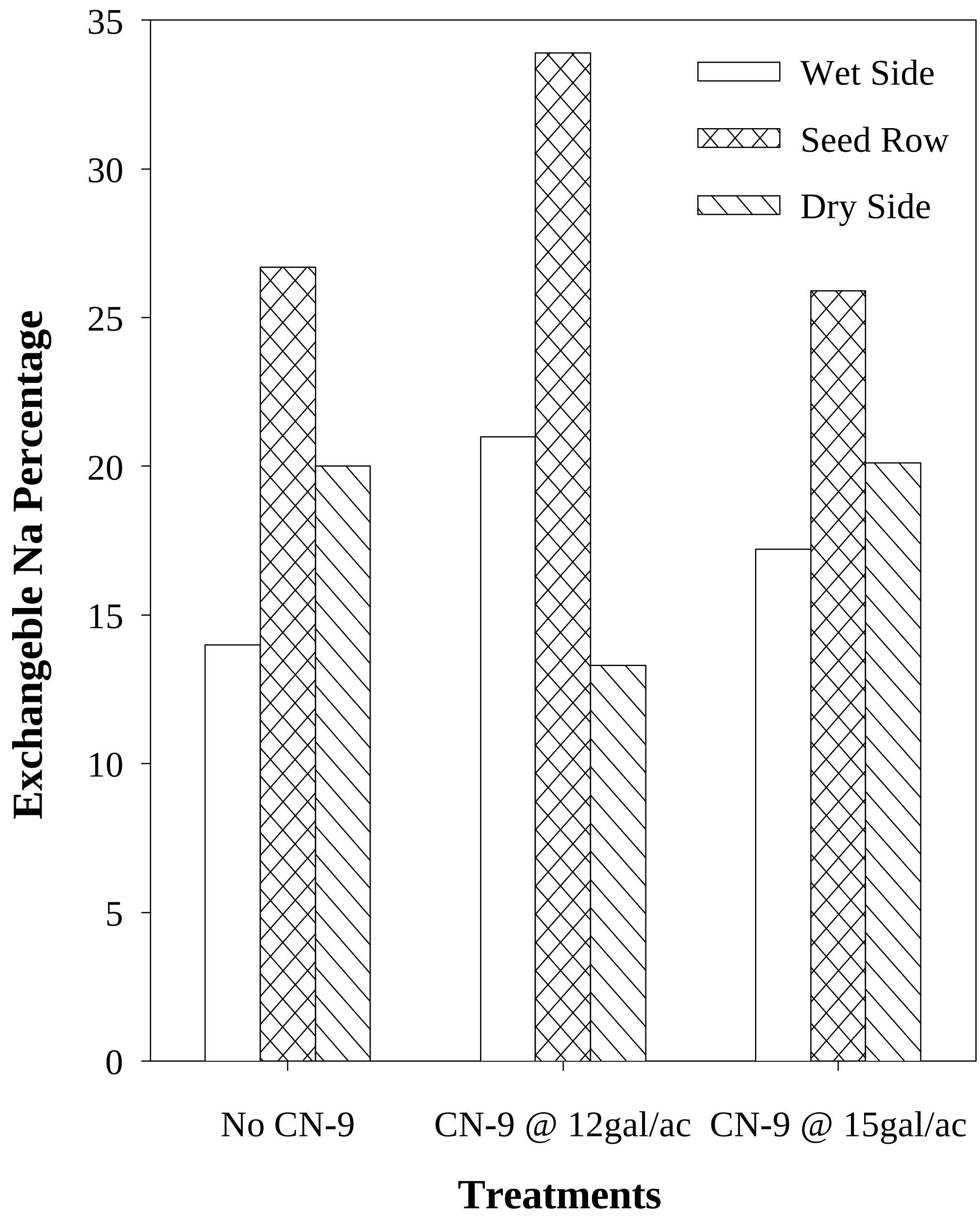

Figure 1. Exchangeble sodium percentage for each treatment across the seed bed, Paloma Ranch, 20 May 1998.

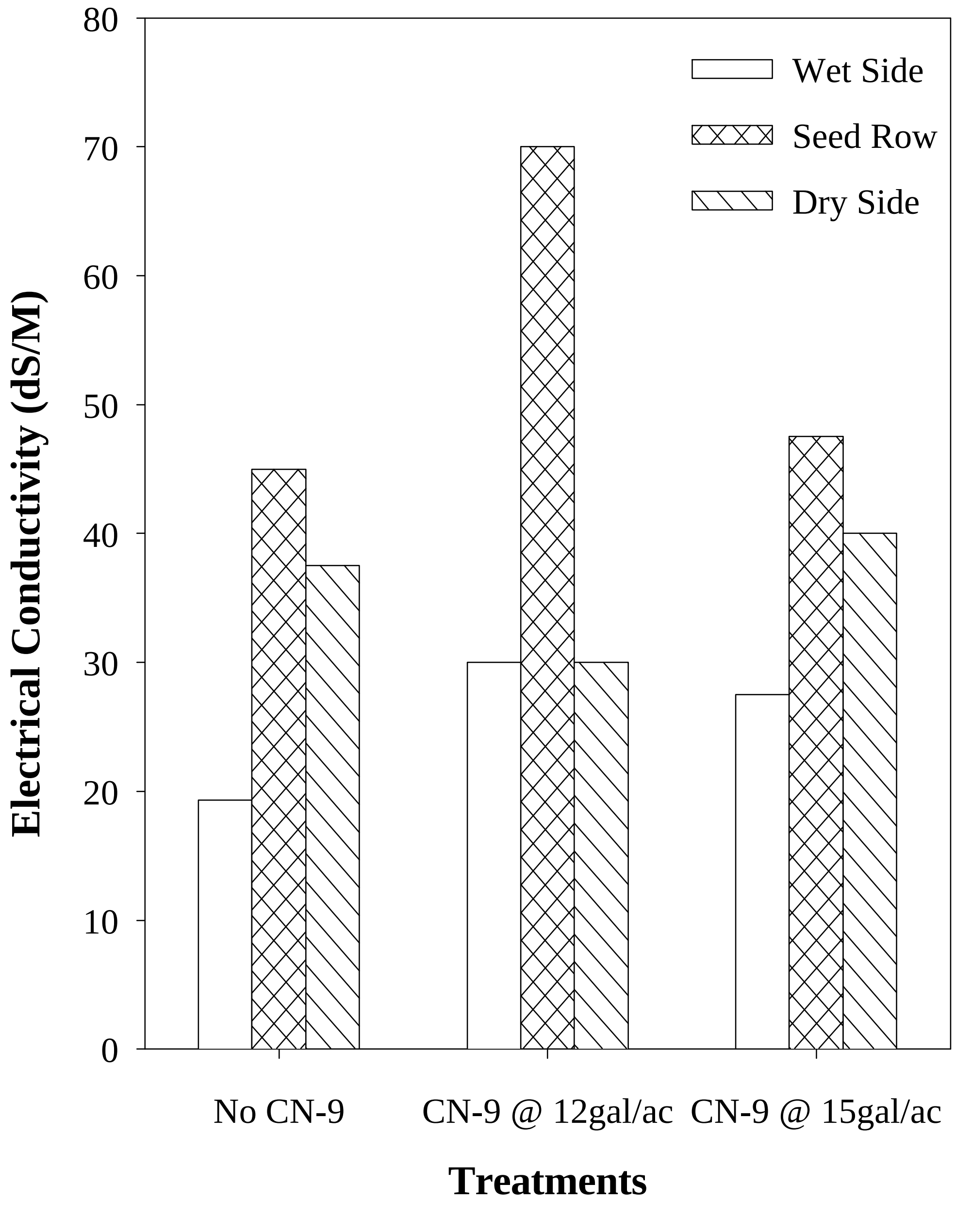

Figure 2. Electrical Conductivity results for each treatment across the seed bed, Paloma Ranch, 20 May 1998.

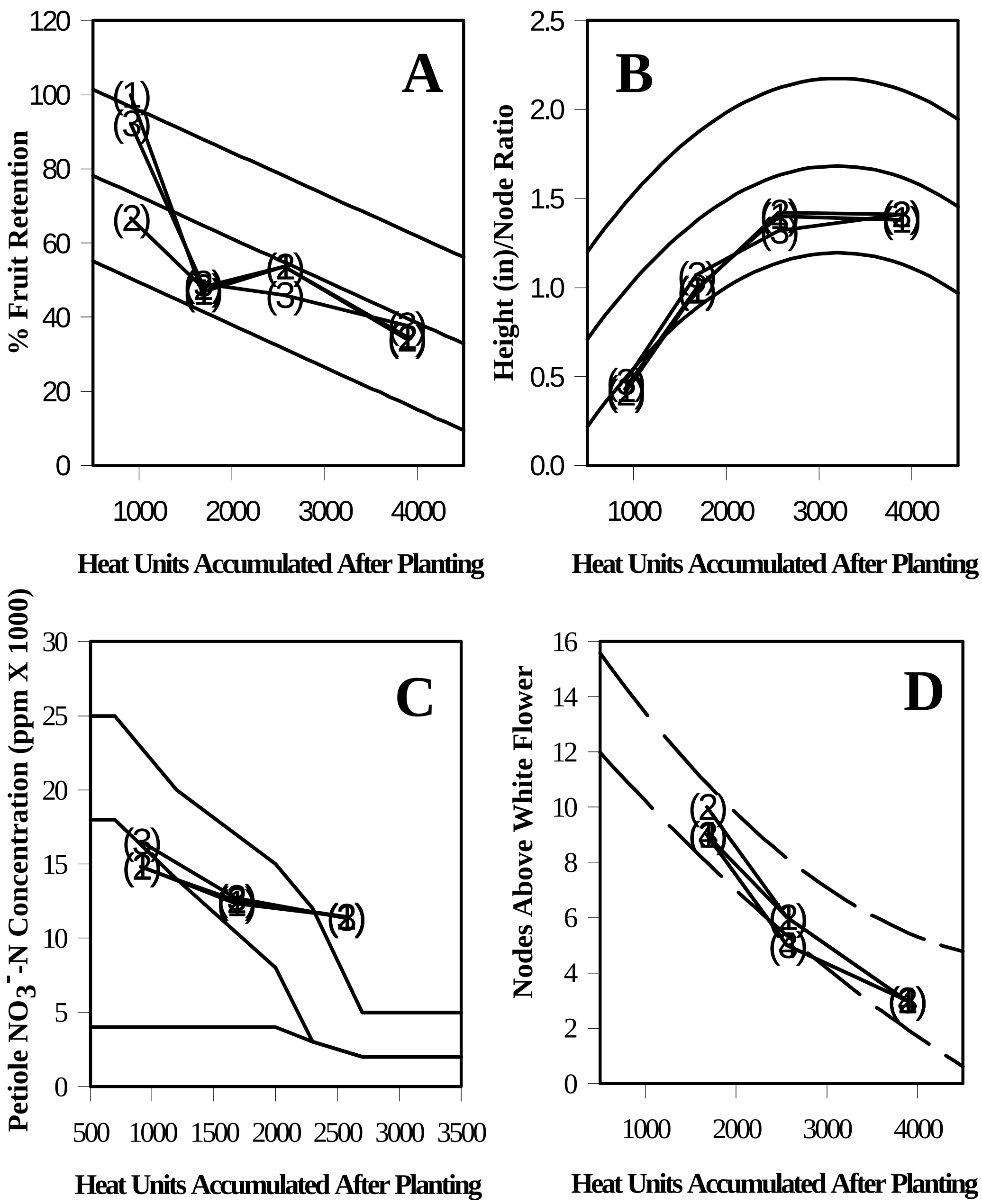

Figure 3. Data summaries for CN-9 Paloma Ranch; A) fruit retention B) height to node ratios, C) petiole nitrate-N concentrations, and D) nodes above white flower.

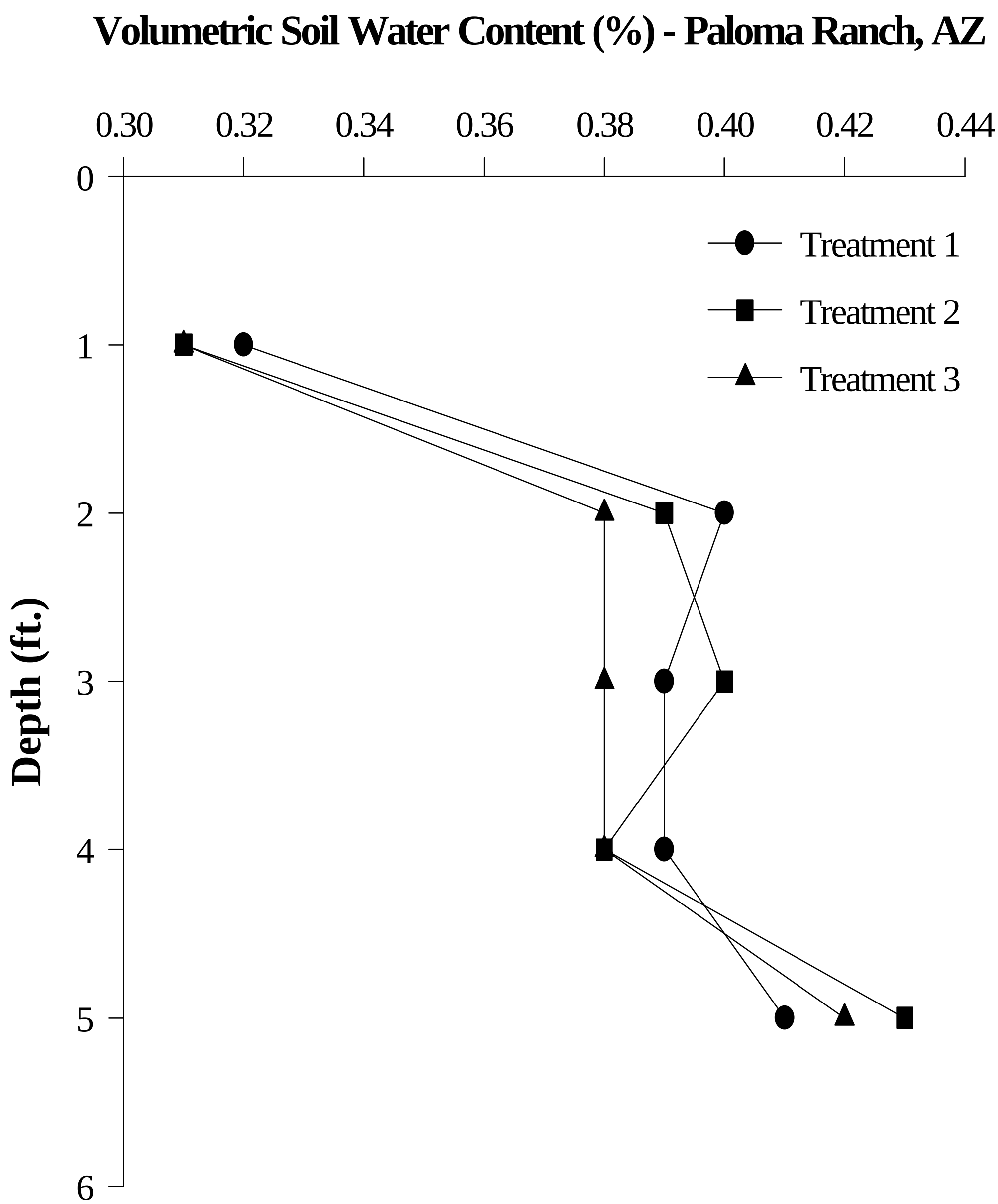

Figure 4. Volumetric soil water content (%) results for each treatment, Paloma Ranch, 16 June 1998.

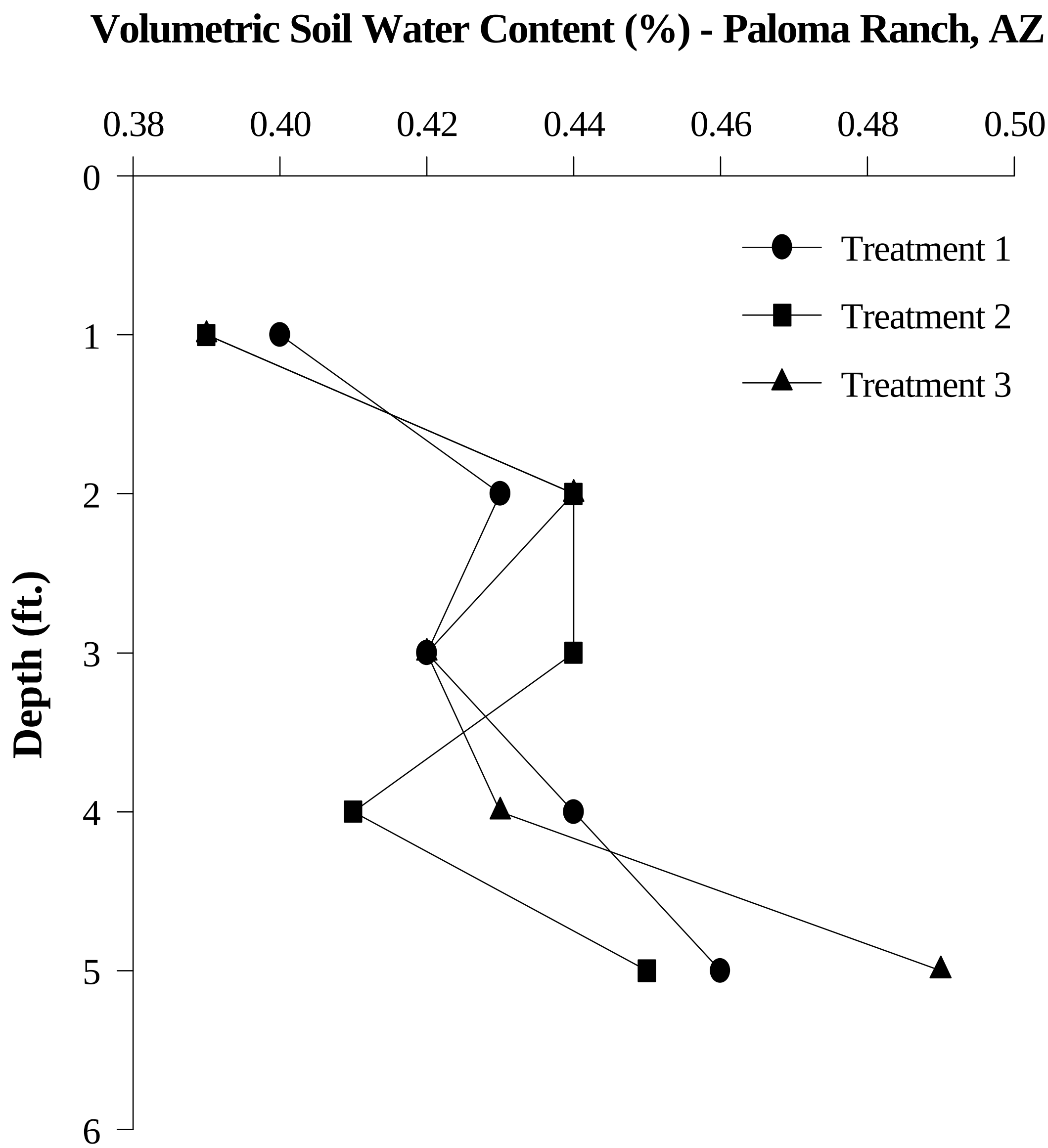

Figure 5. Volumetric soil water content (%) results for each treatment, Paloma Ranch, 30 June 1998.

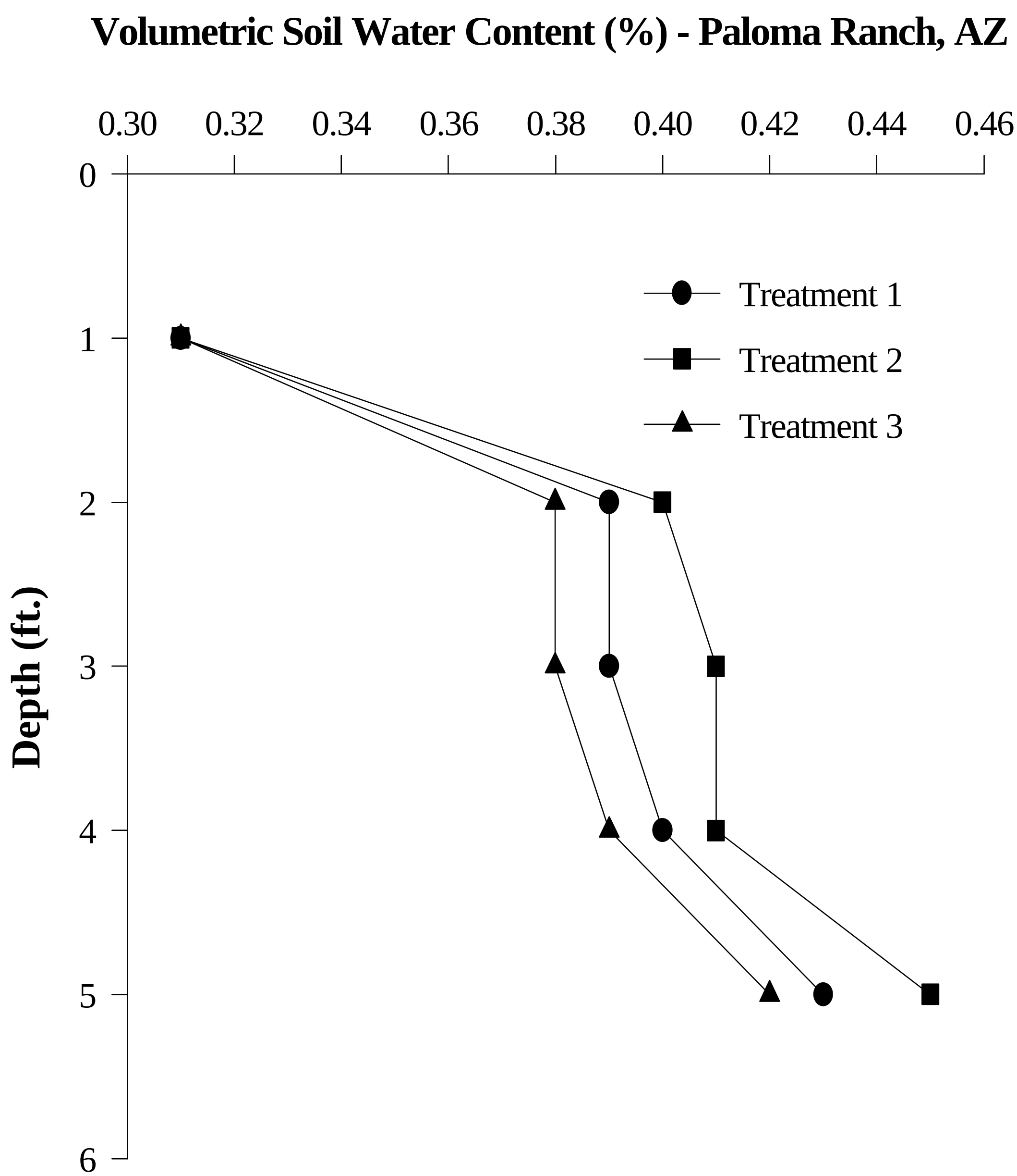

Figure 6. Volumetric soil water content (%) results for each treatment, Paloma Ranch, 20 July 1998.

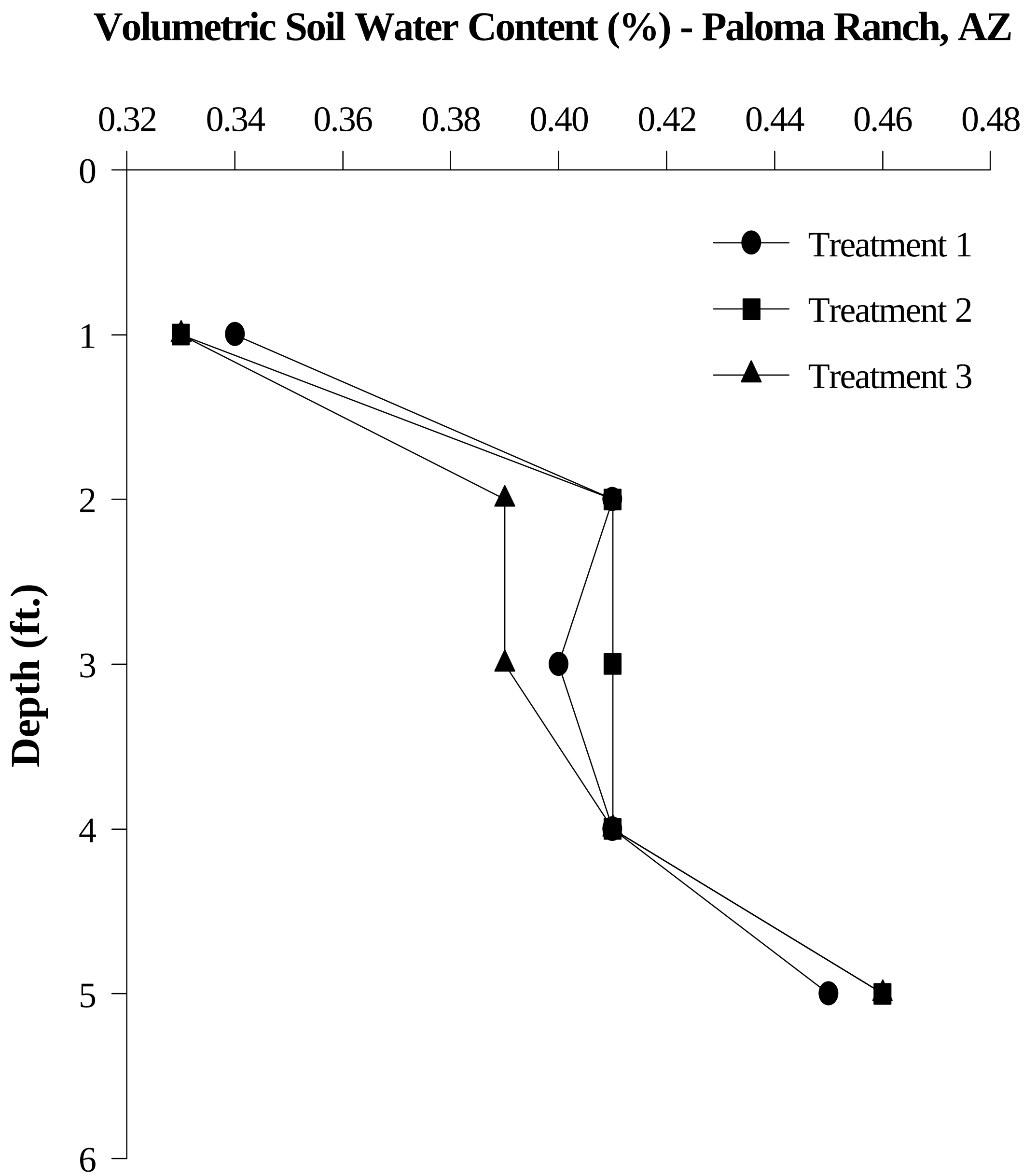

Figure 7. Volumetric soil water content (%) results for each treatment, Paloma Ranch, 25 August 1998.