Evaluation of Calcium Soil Conditioners in an Irrigated Cotton Production System

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Abstract

In 1996 a single field experiment was conducted at Paloma Ranch, west of Gila Bend in Maricopa County Arizona. Nucoton 33B was dry planted and watered-up on 15 April. Treatments consisted of various rates and times of application of nitrogen (N) and calcium (Ca) from two sources (N-Cal™ and CAN-17), as well as a standard N source, UAN-32, along with a Calcium (Ca) check which received no Ca. Treatments1, 2,and 3 each received a total of 280 lbs. N/acre. Treatment 4 received a total of 210 lbs. N/acre while treatment 5 received a total of 301 lbs. N/acre. Treatment 1 was a check plot and received only standard applications of UAN-32. Treatments 2 and 4 each received a total of 72 lbs. of Ca/acre. Treatment 5 received a total of 79 lbs. Ca/acre while treatment 4 received a total of 300 lbs. Ca/acre. 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 significantly different ($P<0.07$).

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 generally defined as those soils which contain an exchangeable sodium percentage (ESP) of 15% or greater. They can also be characterized as having a Na absorption ratio (SAR_e) from a saturated extract of 13 or greater. Soils high in sodium 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 forces them to be transposed into pore spaces that were previously available for water penetration and infiltration. Sealing of soil pores produces 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, primarily if it is high in Na. Leaching of a sodic soil can removes the divalent cations calcium (Ca^{2+}) and magnesium (Mg^{2+}) from the soil profile and root zone leaving the monovalent cation sodium (Na^+). Calcium and Mg are the primary elements that contribute to soil flocculation with Na causing dispersion in a soil. Sodium causes dispersion of a soil because of its large hydrated radius, as compared to Ca^{2+}, Mg^{2+} and 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 contains 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 easier to correct as compared to sodic or saline-sodic soils. Leaching can be an effective treatment of a saline condition.

A further problem associated with irrigation is the increase in pH as a result of the introduction of anhydrous ammonia based nitrogen fertilizers into the irrigation water. The increase in pH can cause the flocculating elements, Ca^{2+} and Mg^{2+}, to precipitate with bicarbonate (HCO_3^-) leaving Na^+ in the irrigation water. The application of this water has the potential to effectively raise the ESP and the SAR of the soil. If the soil is at a marginal limit with respect to Na^+ concentrations, continued use of this practice can create a situation in which the soil is pushed beyond its capabilities to contend with the increasing Na. 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 addition of elemental sulfur (S). Elemental S, when oxidized by soil microbes and combined with water, reacts to become sulfuric acid (H_2SO_4), which reacts with naturally occurring calcium carbonate ($CaCO_3$), releasing free Ca^{2+} which can exchange for Na^+ creating sodium sulfate (Na_2SO_4), which can be leached from the soil. Sulfuric acid can also be added to the irrigation water directly. When adding elemental sulfur or sulfuric acid, not only is Na converted to a leachable form but the pH is also lowed via the release of hydrogen (H^+) into the soil.

Another common treatment is the use of gypsum ($CaSO_4$). Gypsum tends to increase the levels of Ca^{2+} in the soil which can then exchange with the Na^+. This addition of Ca^{2+} lowers the SAR and contributes to the exchange and leaching of soil Na^+.

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 consistency 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 ($CaCO_3$). The amount of exchangeable Ca^{2+} in soils is significantly correlated with the amount of available Ca^{2+} in soils. However, $CaCO_3$ is found to be poorly available to plants regardless of its source (Flocker and Fuller, 1956).

Along with the conventional methods of treating sodic and saline conditions, there has been an increasing emergence of synthetic polymers. The synthetic polymers include polyacrylamide (PAM), polyvinyl alcohol (PVA), polymaleic anhydride (PMA) and polysaccharides. Research studies have shown that these synthetic polymers have produced reduced soil surface crusting (Helalia and Letey, 1989; Wood and Oster, 1985; Terry and Nelson, 1986), improved water holding capacity (Nimah et al., 1983; Shanmuganathan 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).

N-Cal™ (18-0-0-6) was introduced as an alternative to synthetic polymers, gypsum and elemental sulfur for use as a soil conditioner. N-Cal™ supplies a plant available form of nitrogen (N, a macro nutrient for plant growth), as well as Ca, to the plant. N-Cal™ uses an plant available form of Ca ($CaCl_2$) in an attempt to decrease the SAR and ESP of the soil system. The amendment also causes improved flocculation and reduces clay dispersion of the soil system by replacing Na^+ on the soil clay colloid exchange sites with Ca^{2+}. By creating a more flocculated soil system, a more hydraulically conductive system is created.

Materials and Methods

The field experiment was planted with an Upland cotton variety (Nucoton 33B) on a sandy loam soil at Paloma Ranch, AZ (field 24D2) on 14 April 1996. The cotton in this experiment was dry planted then watered up on 15 April 1996. The experimental design of the project was a five treatment, randomized complete block with four replications. The plots were eight, 36 inch rows wide extending approximately 1200 feet from South (head) to North (tail). A pre-season and post-season soil sample was collected for each treatment on 12 April and 20 December respectively (Table 3 and 4). A surface soil sample (approx. top 5cm) was also obtained on 16 June 1996 (Figures 2 and 3).

Table 1 lists application dates and rates for all treatments. For treatments 2, 4, and 5, N-Cal™ was used as the primary N source until approximately 70 lbs Ca/acre had been applied. UAN-32 (urea, ammonium, nitrate 32-0-0) was used thereafter (9 and 17 August) to meet crop N demands. Treatment 5 received an application of N-Cal™ with the water-up irrigation that resulted in an additional 21 and 7 lbs of N and Ca per acre respectively. For treatment 3, CAN-17 (17-0-0-24) was used as the primary N source. In order to meet crop N demands approximately 300 lbs. Ca/acre was applied.. Treatment 1 received no Ca and was fertilized only with UAN-32. All applications were water-run in the irrigation stream.

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 from the top fresh bloom to the terminal (NAWB). 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 preceding and directly following an irrigation event. Soil water measurements were taken from all plots with a neutron probe at 1 foot intervals from the surface down to a depth of 5 feet.

Surface soil samples were taken to a depth of approximately 5 centimeters on 19 June 1996. 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 2 and 3).

The crop was irrigated until 1 October 1996. The entire area of study was defoliated on 1 November 1996 and the plots were harvested with a mechanical picker on 11 December 1996.

Results and Discussion

Plant growth and development patterns for all treatments are shown in Figure 1 (A,B, and C). 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 threshold conditions (Silvertooth et al., 1996). Low plant vigor (HNR) was observed throughout the entire season in all treatments (Figure 1B). However, fruit retention patterns remained near optimum levels throughout most of the season (Figure 1A). Petiole NO_3^--N levels were very similar among the different treatments over then entire season (Figure 1C).

Figures 4 - 7 present soil water data for four dates immediately following an irrigation event. Analysis of variance performed on this data did not reveal any significant trends in differences among treatments with regard to soil water content at any depth. This would indicate that there were no differences among the treatments in terms of water penetration. Another interesting observation from these data is the apparent linear increase in soil water content as you move from the surface to the lower portions of the profile. This would indicate that there is sufficient and rapid 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. This observation appears to be independent of treatment and is most likely due to general soil conditions.

A gradient of increasing yields were observed across the study area from East to West. This observation is most likely attributable to a high degree of inherent soil variability. Yields were significantly higher for treatments 4 and 5 relative to 1 and 3 (P=0.07) (Table 2). However the cause is not directly apparent based upon plant and soil data obtained. In general, EC_e and ESP values were slightly lower at the end of the season relative to the pre-season (Tables 3 and 4) samples, but these differences are not particularly attributable to any specific treatment. In light of only one site-year of data, the effectiveness of N-Cal™ can not be determined because the results are somewhat inconclusive at this time

Acknowledgment

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Table 1. Treatment application dates and rates, Paloma Ranch, 1996.

	Treatment					Treatment				
Date	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
	lbs. N/acre					lbs. Ca/acre				
12 April	--	--	--	--	21	--	--	--	--	7
9 June	70	70	70	70	70	0	24	100	24	24
26 June	70	70	70	70	70	0	24	100	24	24
15 July	35	35	35	35	35	0	12	50	12	12
29 July	35	35	35	35	35	0	12	50	12	12
9 August	35	35	35	0	35	0	0	0	0	0
17 August	35	35	35	0	35	0	0	0	0	0
Total	**280**	**280**	**280**	**210**	**301**	**0**	**72**	**300**	**72**	**79**

Table 2. Lint yields for each treatment Paloma Ranch, 1996.

Treatment	lbs. Lint/acre
5	1627 a*
4	1578 a
2	1567 ab
3	1547 b
1	1530 b
LSD**	NS
OSL†	0.0661
C.V.(%)‡	2.76

* Means followed by the same letter are not significantly different according to a Fisher's LSD

** Least Significant difference

† Observed Significance Level

‡ Coefficient of Variation

Table 3. Pre-season soil samples taken at Paloma Ranch (Field 24D-2) on 12 April 1996.

Sample #	Depth	pH (1:1 $_2$O)	Ca* (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	EC$_e$ (mmhos/cm)	NO_3^--N** (ppm)	P*** (ppm)	ESP§	Free Lime
Trmt. 1	Surface	8.3	7300	600	610	410	4.7	15.7	15	5.90	High
Trmt. 2	Surface	8.0	7300	580	600	390	5	15	12	5.80	High
Trmt. 3	Surface	8.2	7500	580	580	390	4.6	16.4	12	5.50	High
Trmt. 4	Surface	8.2	7600	600	590	410	4.7	17.1	15	5.50	High
Trmt. 5	Surface	8.1	7400	610	650	410	6	24.3	11	6.10	High

* Exchangeable cations using neutral molar ammonium acetate.

** NO_3^--N using specific ion electrode.

*** $NaHCO_3$ extractable P.

§ Computed - exchangeable sodium percentage.

Table 4. Post-season soil samples taken at Paloma Ranch (Field 24D-2) on 20 December 1996.

Sample #	Depth	pH (1:1 $_2$O)	Ca* (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	EC$_e$ (mmhos/cm)	NO_3^--N** (ppm)	P*** (ppm)	ESP§	Free Lime
Trmt. 1	Surface	8.8	7000	560	510	310	3.8	18.6	13	5.2	High
Trmt. 2	Surface	8.7	6900	590	520	300	3.4	6.4	12	5.3	High
Trmt. 3	Surface	8.2	7200	560	610	310	4.0	6.4	13	6	High
Trmt. 4	Surface	8.2	7200	580	540	310	3.8	4.9	22	5.3	High
Trmt. 5	Surface	8.3	7200	570	520	290	3.6	5.3	15	5.2	High

* Exchangeable cations using neutral molar ammonium acetate.

** NO_3^--N using specific ion electrode.

*** $NaHCO_3$ extractable P.

§ Computed - exchangeable sodium percentage.

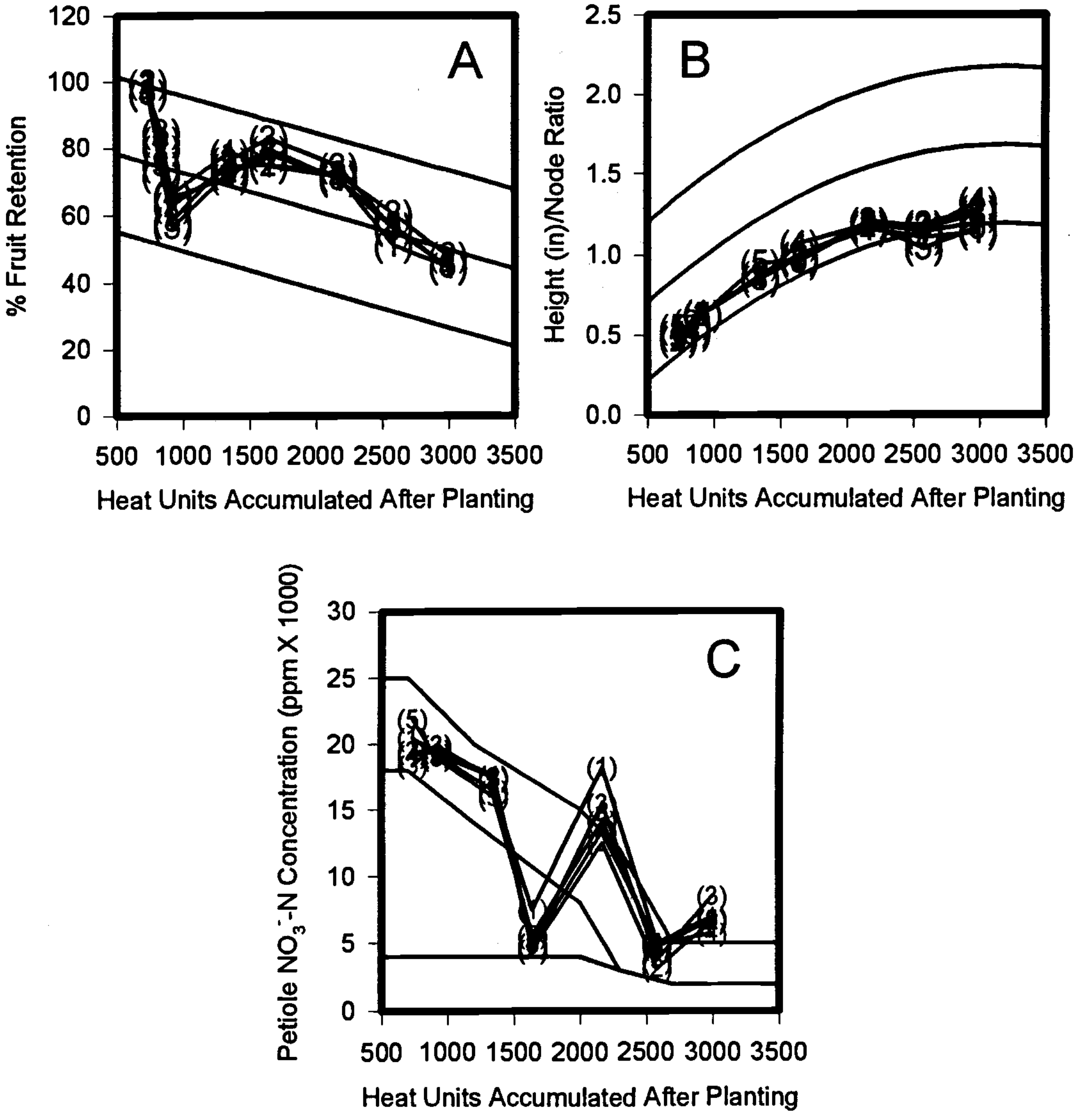

Figure 1. Data summaries for Paloma Ranch N-Cal study; A) fruit retention B) height to node ratios, and C) petiole nitrate-N concentrations.

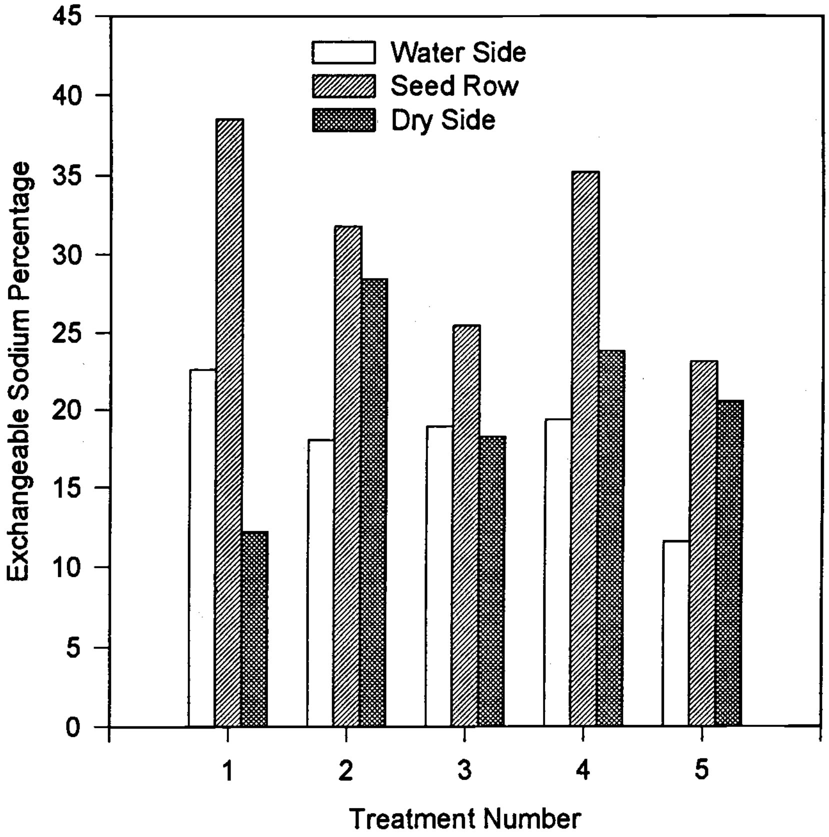

Figure 2. Exchangeable sodium percentage for each treatment across seed bed, Paloma Ranch, 19 June, 1996.

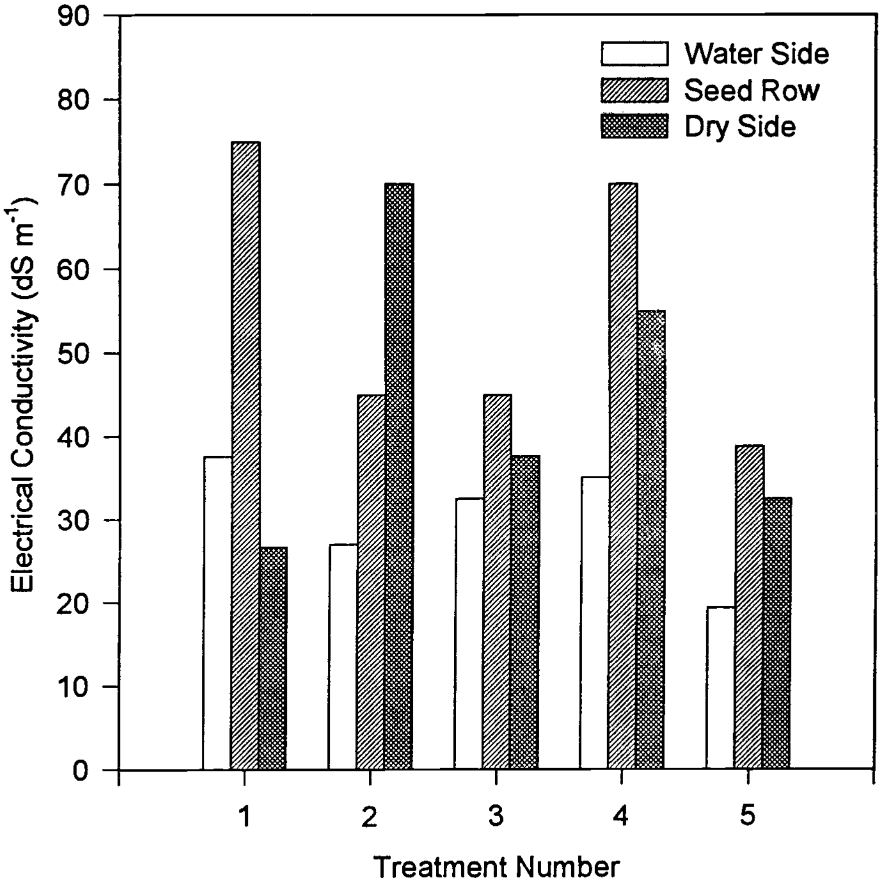

Figure 3. Electrical conductivity results for each treatment across seed bed, Paloma Ranch, 19 June, 1996.

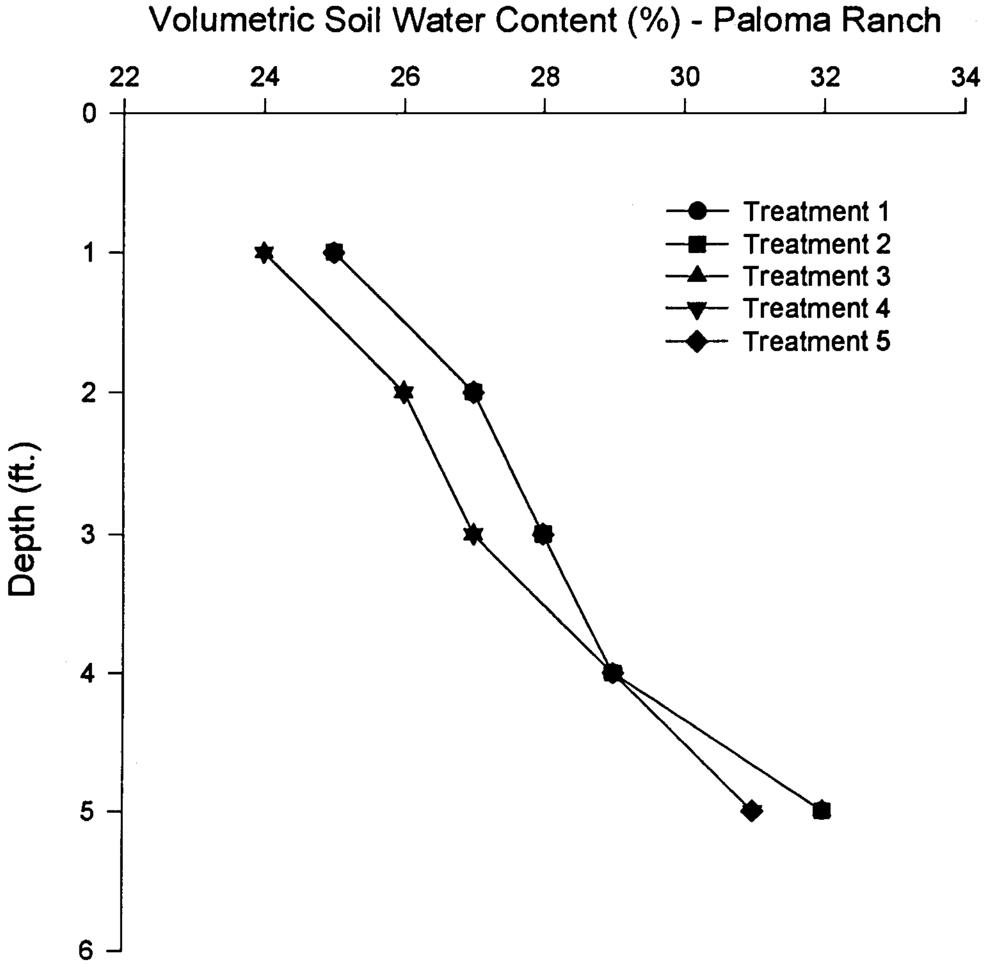

Figure 4. Soil Moisture Content (%) results for each treatment, Paloma Ranch, 28 May 1996.

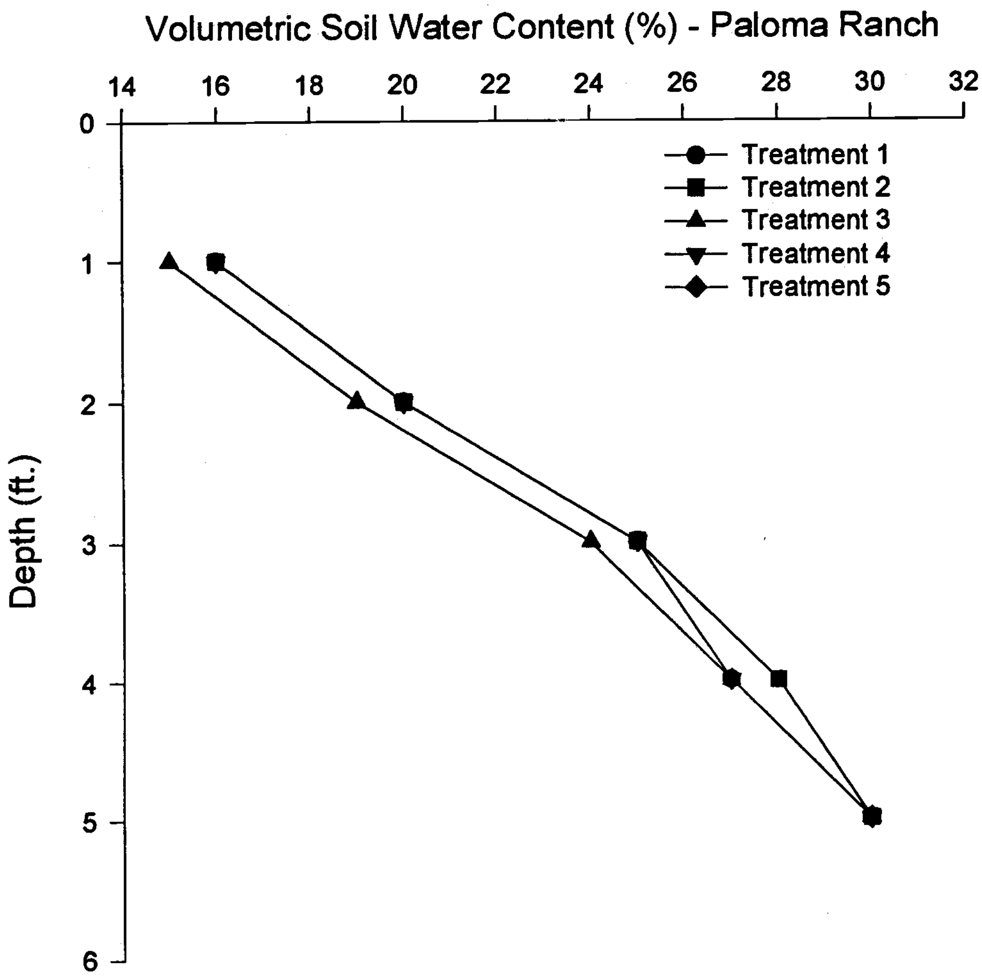

Figure 5. Soil Moisture Content (%) results for each treatment, Paloma Ranch, 28 June 1996.

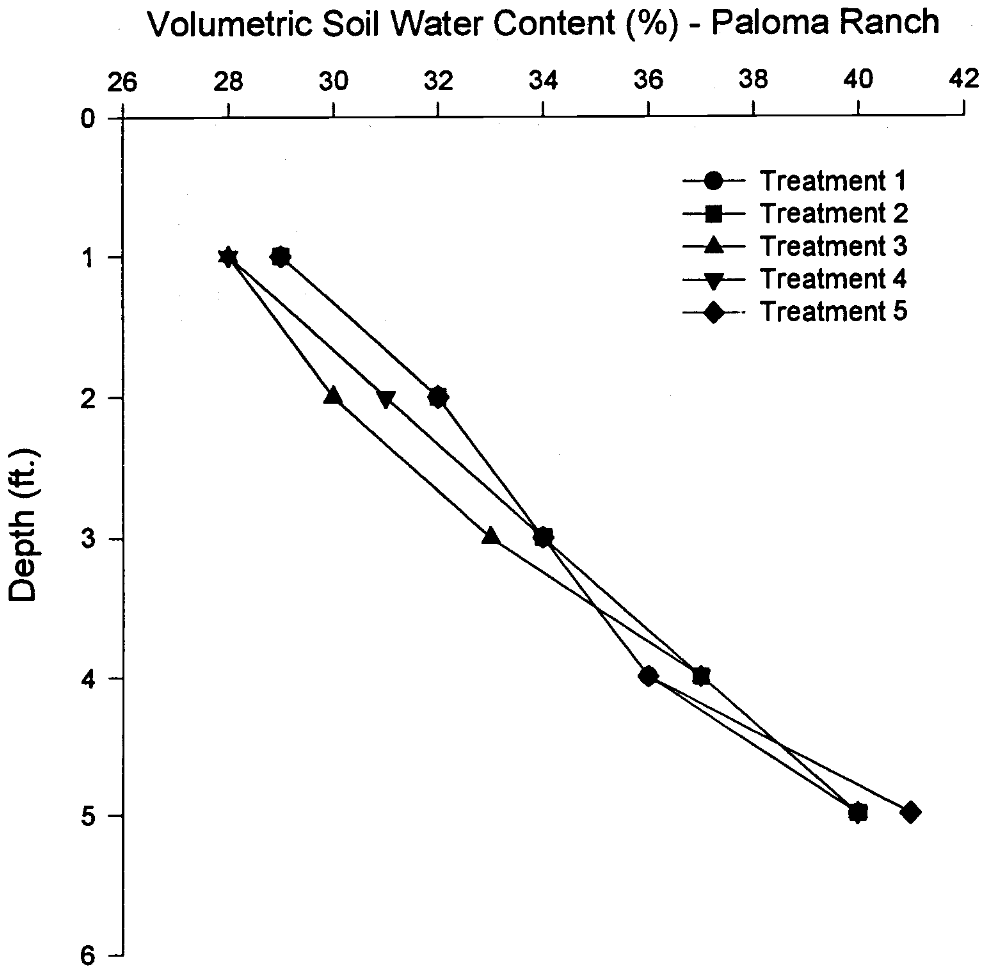

Figure 6. Soil Moisture Content (%) results for each treatment, Paloma Ranch, 31 July 1996.

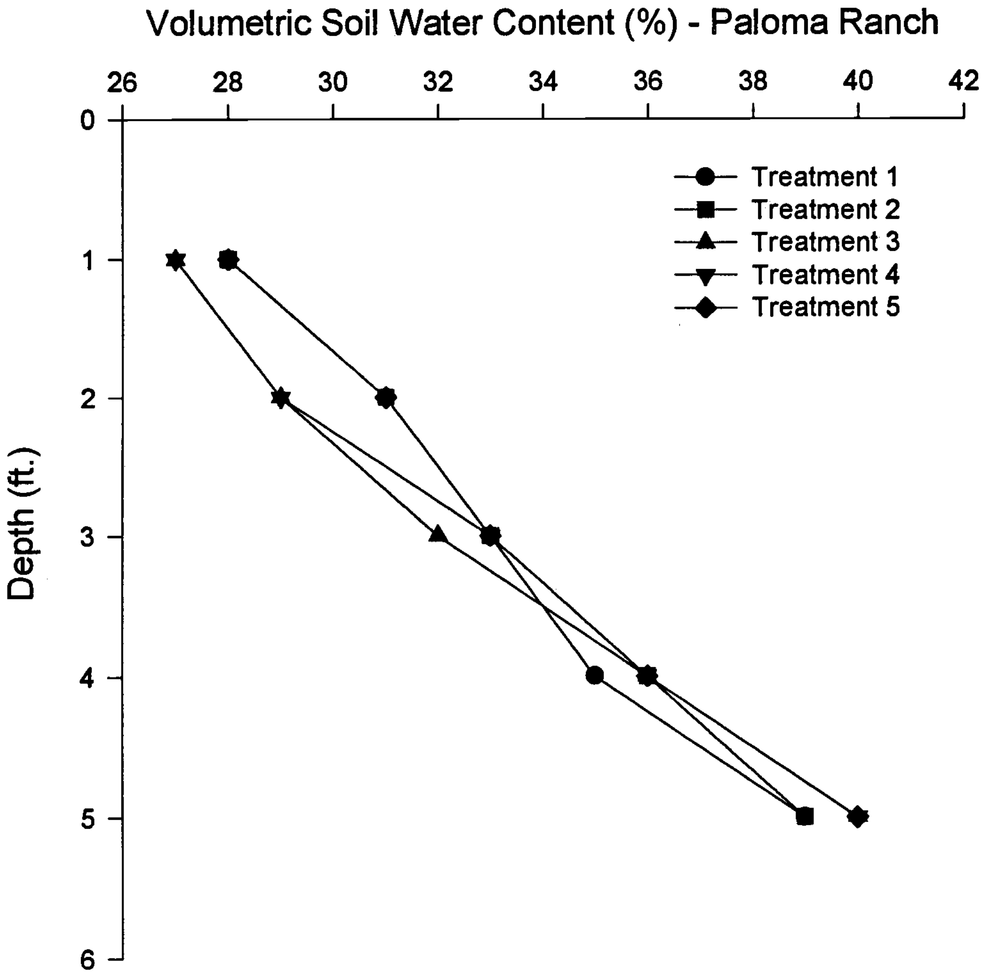

Figure 7. Soil Moisture Content (%) results for each treatment, Paloma Ranch, 06 August 1996.