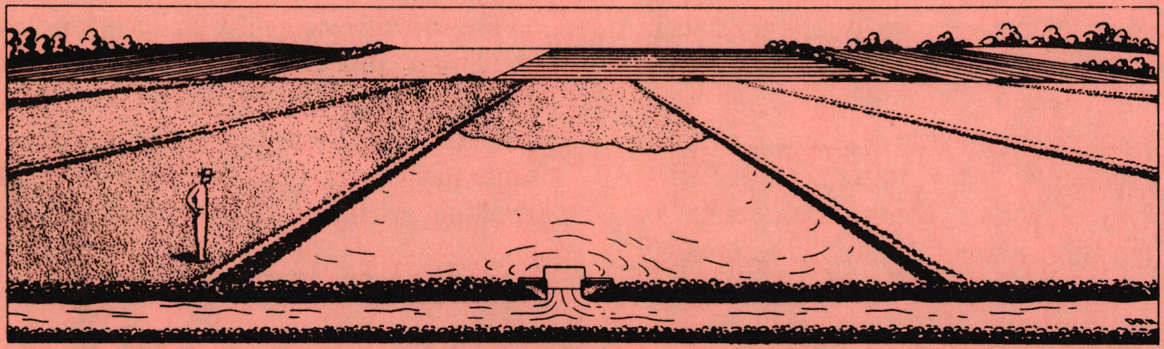
IRRIGATION NEWS

UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION KINGS COUNTY



July 1, 1993

IMPROVING WATER INFILTRATION WITH WATER AMENDMENTS

Today's Perspective

Most growers can cite field experiences where they believe either crop yield, quality, or both are being lost due to soils with poor water infiltration rates. Typically, July and August are the months where the crop water requirements are the highest and at the same time the infiltration rates of many soils are the lowest. This results in the inability for farm managers to adequately irrigate their crops and achieve maximum yield and quality.

A 1984 survey of growers in Kings, Tulare, and Fresno counties suggested 380,000 acres of land were severely affected by poor water infiltration. Income losses were estimated from $200 to $500 per acre in trees and vines and $200 to $300 per acre for cotton, alfalfa, and other crops.

Historic Perspective

Slow water infiltration into soils has been a problem since at least the 1940's. Several factors contribute to poor water infiltration. Some such as soil texture and mineralogy are not very manageable. Meanwhile, others such as traffic, soil organic matter content, irrigation practices, subsoil layers and salinity composition in irrigation water and soils are more manageable.

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Development of Gypsum Applicators

For decades farmers have experimented with additions of gypsum and other amendments in irrigation water. Some very early attempts were made to develop functional gypsum dispensers. However, the concept of treating water with gypsum had not been consistently practiced until 1986. A private company introduced the first reliable method of adding controlled amounts of gypsum to irrigation water. Today the technology is growing in acceptance. There are at least four commercial manufacturers and suppliers in the local area.

1. Ag Solution Master
   Available by Soil Solution Corporation
   Visalia, CA
   (209) 651-4100

2. S & R Specialty Equipment Co.
   Corcoran, CA
   (209) 992-4191

3. H.M. Holloway
   Wasco, CA
   (800) 441-1887

4. Farmers System Solution Applicators
   United Welding Machine Works
   Goshen, CA (209) 651-3600

Effects of Salinity in Irrigation Water and Soil

Research in Kern County (Huberty and Pilsbury, 1941 and Doneen, 1948) was among the first to report that irrigation water quality could be a factor causing slow water infiltration. They identified that high sodium composition in irrigation waters could contribute to poor water infiltration rates. Researchers with the US Soil Salinity Laboratory (Henderson, 1958) found that irrigation waters very low in salinity regardless of the sodium composition could also contribute to slow water intake rates. Recent research (Peacock, 1988) and others have also confirmed the early science that water quality can contribute to poor infiltration rates.

Soils irrigated with sodic or very pure water supplies will become unstable. Large aggregates will break down when irrigated and the finer soil particles will actually become suspended in the irrigation water.

The suspended clay particles will eventually settle on the soil surface as the water infiltrates and plugs the larger soil pores. When all the water has infiltrated and drying is completed, a crust is formed which is a barrier for infiltration during subsequent irrigations. Figure 1 illustrates soil swelling, particle dispersion, and crust formation.

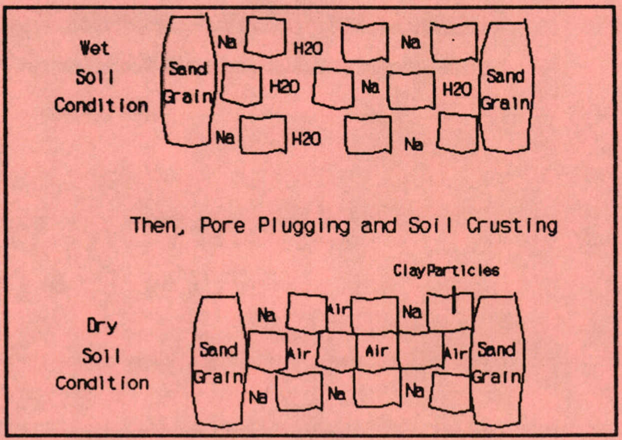

Figure 1
Low Salinity and Sodic Irrigation Waters Cause Soil Swelling and Dispersion.

Research has indicated that the addition of calcium amendments into the irrigation water will stabilize soil aggregates, prevent swelling and dispersion, and achieve higher, more sustained infiltration rates. Figure 2 portrays the stabilizing effect of calcium amendments.

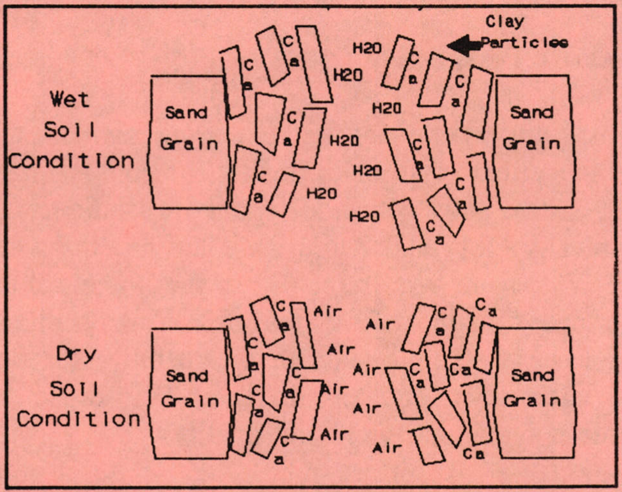

Figure 2
Calcium amendments stabilize soil structure and soil porosity.

Knowing When to Treat Water

Skill in using irrigation water and soil salinity analyses is essential to diagnose whether irrigation water amendment is needed. Making the proper diagnosis requires information about the total salinity content and the sodium, calcium, magnesium, and bicarbonate composition of the water and surface soil. Two indices in a lab report, the EC and SAR are especially useful to evaluate irrigation water supplies and surface soil salinity for infiltration problems.

EC is an abbreviation for electrical conductivity of the irrigation water or the soil extract. An increasing EC value indicates a higher total salinity content in the irrigation water or soil. However, the EC does not give any information concerning the composition of salts in the water or surface soil.

The SAR is an abbreviation for Sodium Adsorption Ratio. This index provides information about the sodium, calcium, and magnesium composition of an irrigation water or soil extract. As the SAR value of an irrigation water increases, it indicates that sodium is becoming a more dominant element in the irrigation water or surface soil salinity. An adjusted SAR is used to predict the effect of bicarbonates in the irrigation water. Significant levels of bicarbonates in the irrigation water will cause the adjusted SAR to be higher than the unadjusted SAR.

RESULTS

	pH	ECw (dS/m)	Na	Ca	Mg	CO3	HCO3	SO4	SAR
			-----------	-----------	(meq/l)	-----------	-----------	-----------	
River #1	8.0	0.2	1.1	0.6	0.02	0.1	1.3	0.2	1.9
Well #2	8.1	0.8	7.6	0.5	0.04	0.1	5.9	0.5	14.6

Could these waters cause poor water intake? → Use the circled information and refer to guidelines to to evaluate water for infiltration hazards.

Figure 3
Example of critical lab results needed to evaluate possible infiltration problems.

Figure 3 emphasizes that both EC and SAR are required to evaluate an irrigation water or surface soil for infiltration problems. Figure 4 provides quidelines to assess a lab report and gives two example assessments. These guidelines can be used for both irrigation water and soil extracts.

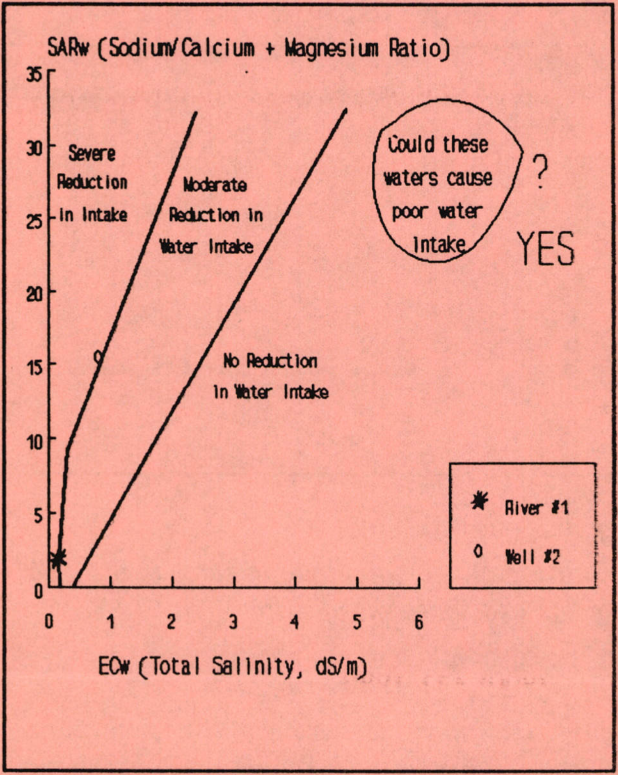

Figure 4
Guidelines to evaluate lab results and two example assessments.

Determining a Gypsum Rate

The new gypsum applicators accommodate a wide range of treatment rates from about 235 to over 2000 lbs. of gypsum per acre-foot of water. Common rates are 500 to 1000 lbs. of gypsum per acre-foot of water. These rates are generally appropriate for the common irrigation water in the area and are affordable. These rates will cost $20 to $45 per acre-foot of treated water not including the cost of the applicator machine.

It is important to understand how the irrigation water quality changes when gypsum is added to water. Table 1 gives conversions describing the effects of adding increments of gypsum on EC and calcium composition of the water. Approximately every 235 lbs. of pure gypsum will increase the EC of the water 0.1 dS/m (mmhos/cm) and add 1.0 meq Ca/1 to the calcium composition of the water.

Rate meq Ca/l	Rate lbs gyp/ac-ft	Increase in ECw
1.0	234	0.1
2.0	468	0.2
3.0	702	0.3
4.0	936	0.4
5.0	1170	0.5
6.0	1404	0.6
7.0	1638	0.7

Assumes pure gypsum, EC units dS/m or mmhos/cm

Table 1
Conversions for application rates in meq Ca/1 to lbs gypsum/ac-ft of water.

There are two approaches to determine an appropriate gypsum treatment rate for irrigation water. The first is to apply a general rule: "Add enough gypsum so the calcium and sodium levels are of equal proportions in the water." Refer to the example below:

Example: Lab Analysis of Untreated Water

Na = 1.1 meq/1
Ca = 0.6 meq/1

Add 0.5 meq Ca/1 or 117 lbs. pure gypsum per acre-foot to increase calcium to 1.1 meq/1.

A more accurate approach is to select an arbitrary treatment rate. Recalculate the EC and SAR that would be achieved if the water were treated at that rate. Then re-evaluate the water quality using the guidelines shown in Figure 4. An example recalculation and evaluation of a treatment rate is given in figures 5 and 6.

Step 1: Recalculate EC of treated water (refer to Table 1)

Original EC = 0.8 dS/m
From Table 1, a rate of 4.0 meq Ca/l will increase the EC of the water by 0.4 dS/m.
New EC after water treatment 1.2 dS/m.

Step 2: Recalculate SAR if 4.0 meq Ca/l is added to water

Na=7.6 meq/l
Ca=0.5 (original) + 4.0 (added)=4.5 meq Ca/l
Mg=0.04 meq/l
ECw=1.2
SAR=9.7

$$SAR= \frac{7.6 \text{ meq Na/l}}{\sqrt{\frac{0.5+4.0+0.04}{2}}} = 9.7$$

Step 3: Refer to water quality guidelines to determine whether the water has been treated sufficiently.

Figure 5
Example of recalculating EC and SAR to evaluate a proposed solution gypsum rate.

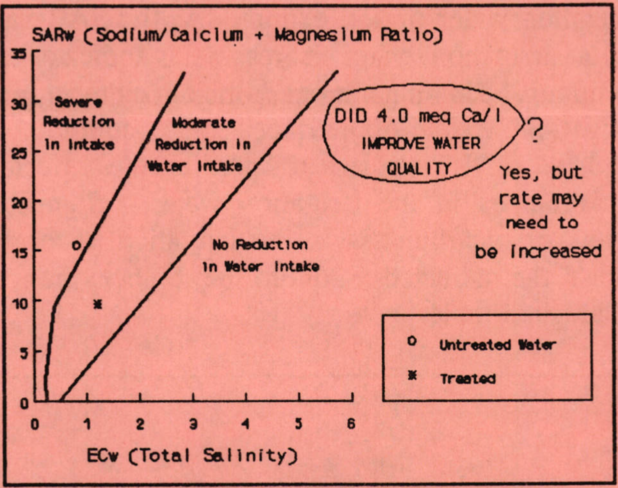

Figure 6
Guidelines to evaluate water quality and an example evaluation of a gypsum rate.

FIELD EVALUATIONS

From 1988 through 1992, UC Cooperative Extension in Kings County studied the solution gypsum technique in both orchard and row crops. Improvements in water infiltration, accumulation of salts in the root zone, and production responses were monitored.

Affects on Water Penetration

In 1990, improved infiltration was very evident in a cotton field with a sandy loam surface soil and a sodic well water. The specific water analysis for this well is given in Figure 3. An application of about 6.0 inches of untreated water applied after layby would stand 5 to 6 days while a similar application of water treated with 1000 lbs gypsum per acre-foot after layby would infiltrate in 24 hours. The result was significantly improved water penetration into the second and third foot of soil. A comparison of soil water content throughout July and August 1990 is shown in Figures 7 and 8 for the untreated and treated irrigation water supplies in the cotton.

Water infiltration in a Vina walnut orchard where a very pure well water supply was treated at rates of 580 and 1160 lbs. gypsum per acre-foot improved significantly but not as dramatically as in the cotton field. We could detect significant differences in total infiltrated water by using a special infiltrometer. Visually, standing water declined for a 3.0 inch flood irrigation from about 6 days to 2 or 3 days. The smaller response to the gypsum treatment was attributed to a more complex soil problem. The soil texture consisted of over 60 percent silt, mica was very evident in the soil mineralogy, and short term benefits from ripping indicated that subsoil compaction at 6 to 9 inches was a significant factor.

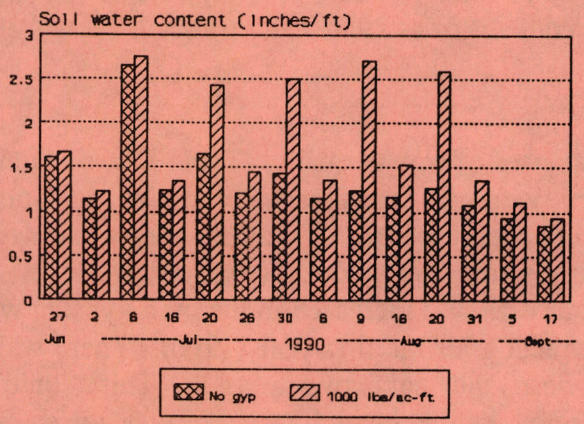

Figure 7
Comparison of soil water content in the top foot of soil of 1990 cotton field.

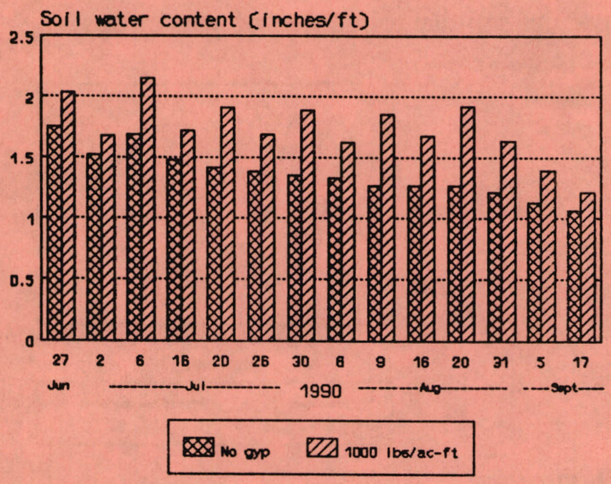

Figure 8
Comparison of soil water content in the second foot of soil in 1990 cotton field.

Salinity

Since gypsum is a salt, calcium sulfate, one needs to recognize the root zone salinity (ECe) will increase with applications unless there is sufficient leaching. Much of the leaching may have to be accomplished during the dormant winter season each year.

Figure 9 shows the salinity profile in the Vina walnut orchard after 3 years of solution gypsum treatment. Approximately 10 inches of fresh water was applied to these plots each winter either by irrigation or rainfall. The ECe in the root zone increased with additions of gypsum. The control averaged 0.75 dS/m, the low rate 1.23 dS/m and high rate 1.72 dS/m. As expected, a higher rate of gypsum will cause a more rapid accumulation than a moderate treatment level.

In general, excess salinity affects soil water availability. When average root zone salinity exceeds a threshold for a crop, reduced crop growth and production can be expected. It is important that you recognize that gypsum water treatment will increase root zone salinity without enough leaching.

If you use solution gypsum regularly you should make provisions to monitor root zone salinity and know the salinity tolerances of your crops.

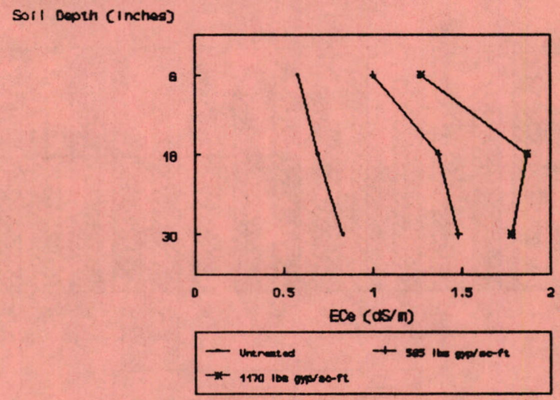

Figure 8
Soil Salinity profiles after 3 years of water treatment in walnuts.

Production Responses

The most apparent yield response to the gypsum water treatment and improved water penetration was observed in a 1990 cotton trial. Lint yields are provided below. On average, yields were about 200 lbs/acre higher where the water was treated. (Figure 9). It was statistically significant at a 10 percent probability level even with just two replications. In this case, the value of the added production was about $160 per acre and the treatment cost was about $90 per acre. Perhaps, the same effect could have been achieved with a lower rate of gypsum amendment and improve the margin of profit.

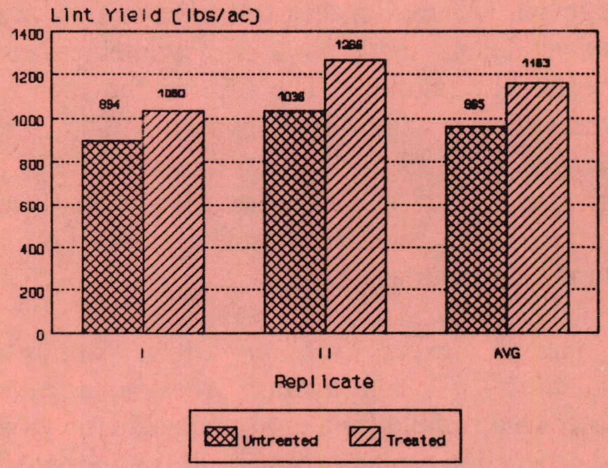

Figure 9
Effect of water treatment on cotton lint yields in 1990.

Responses in the Vina walnut orchard are more difficult to interpret. Three years of dry in-shell walnut yields are presented in Table 2. Yield responses were inconsistent. After a year of water treatment, paired t-statistical tests showed no significant effect of either a moderate or high rate of water treatment. After the second year of treatment, the statistical tests showed a significant yield advantage of 900 to 1450 lbs/ac for both gypsum treatments. It looked encouraging. In 1992 there was no apparent yield advantage. It is possible the yield advantage was lost to an unrelated factor. For example, mite damage was extremely high in 1992. The yield data is inconclusive, statistically there are no data trends that give confidence that water treatment improved yield. However, from a practical perspective, the 3 year total yield was 1200 and about 1700 lbs/acre higher in the moderate and high gypsum treatments than in the control.

Treatment	1990	1991	1992	3 yr Total
Control	5371	5842	5746	16,959
600 # per ac-ft	5612 (p=0.15)	6756 (p=0.02)	5833 (N.S.)	18,201
1200 # per ac-ft	5553 (N.S.)	7318 (p<0.002)	5825 (N.S.)	18,696

Table 2
Dry in-shell walnut yield response to gypsum treatment from 1990-1992 (lbs/ac).

Responses of walnut quality (Table 3) were similar; there were no consistent trends or statistically significant responses. Paired t-tests showed a highly significant probability (3 percent level) that walnut size was increased in the high gypsum water treatment after the first year (1990). There was no response the next two years. This could be expected in the second year because yields were higher in the gypsum treatments. However, in 1992, when the yields were lower in the plots receiving water treatment there was no advantage in nut size.

Treatment	1990	1991	1992
Control	57.9	46.5	67.1
600 #/ ac-ft	53.7 (N.S.)	47.3 (N.S.)	69.2 (N.S.)
1200 #/ ac-ft	64.2 (p=0.03)	47.3 (N.S.)	64.2 (N.S.)

Table 3
Effect of gypsum treatment on large sound walnut orchard, 1990-1992 (percent)

Edible yield response is shown in Table 4. Paired t-tests did not indicate a response in edible yield that could be confidently attributed to the water treatment and improved water infiltration. However, after 3 years, edible yield averaged 1.1 and 1.5 percent higher in the gypsum treatments.

Treatment	1990	1991	1992
Control	38.3	44.2	38.0
600 #/ ac-ft	39.3 (N.S.)	44.3 (N.S.)	39.7 (N.S.)
1200 #/ ac-ft	39.3 (N.S.)	45.2 (N.S.)	39.6 (N.S.)

Table 4
Effect of gypsum treatment on edible yield, 1990-1992 (percent).

Alternatives to Gypsum

There are a number of sulfur and other calcium products that can be applied without any special applicator. Consequently, growers are often interested in these alternatives. If you choose a sulfur amendment there must be lime in the surface soil for the product to react and provide free calcium in the soil. Selecting an alternative amendment largely depends on economics. You must recognize that different products have different formulations. A pound of one product will not provide the same amount of free calcium and potential to improve water infiltration as a pound of another product because they have different formulations. Table 5 gives conversion factors for some alternative amendments so that you can adjust for formulations and make comparisons.

Alternative amendment	Pounds to add 1.0 meq/l calcium per ac-ft water
Calcium Chloride (13 % Ca)	199
Sulfuric Acid (96 %)	133
Sulfur (100 % S)	44
Lime-Sulfur (23.3% S)	192
* Nitro-Sul (40 % S)	52
* Urea-sulfuric acid (10/55)	105
Gypsum (100 % purity)	234

* The nitrogen containing amendments are assumed to exchange 1.0 mole NH4 with 2.0 moles Na.

** Water running elemental sulfur will require a sulfur burner or micron size sulfur products

Table 5
Quantities of common amendments to supply equal amounts of calcium.

Additional Reading

"Water Penetration Problems in California Soils", Kearney Foundation of Soil Science, 1993. Contact:

Jim Oster
Gwen Dixon
UC Riverside
(909) 787-5522

"Agricultural Salinity and Drainage." A Handbook for Water Managers, University of California Irrigation Program, UC Davis, 1993.
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