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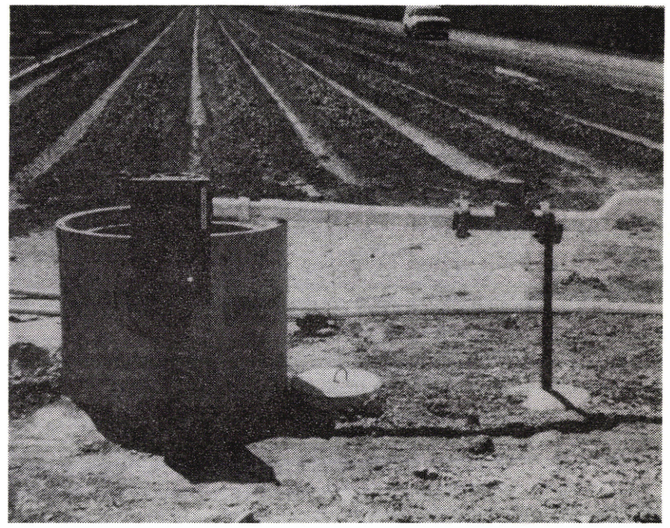
SOIL and WATER

SPRING 1987 NO. 70

SELENIUM IN MELONS AND TOMATOES IRRIGATED WITH SALINE DRAINAGE WATER

S.R. Grattan, C. Shennan, D.M. May
J.P. Mitchell, and R.G. Burau

The future of irrigated agriculture on much of the westside of the San Joaquin Valley depends, in part, upon the development and implementation of an economically and environmentally sound strategy for drainage water disposal. A reduction in the volume of agricultural drainage-water would help reduce the cost of its treatment or ultimate disposal. This would improve the prospects for sustained crop production on the westside of the San Joaquin Valley. Reuse of saline drainage water for irrigation is one immediate management practice that growers are currently considering to reduce its volume. It should be clear that this management practice alone will not solve the long-term drainage problem in the Valley but must be coupled with a means of salt removal from the Valley.



Sump used for source of saline drainage water (Se = 250-350 ppb) at Mendota study.

Drainage water reuse experiments have been conducted in California by both USDA and University scientists. For the most part, agronomic crops have been studied since they are relatively tolerant to salinity. Tomatoes and melons, on the other hand, are popular in this region and are economically more attractive than most agronomic crops. Consequently, we conducted several experiments to examine the influence of saline drainage waters, used as a source of irrigation water, on the yield and quality of melons and processing tomatoes. The feasibility of this reuse practice will depend, in part, upon the uptake and accumulation of selenium in edible plant parts.

Experimental locations and design

Four drainage water-use studies were conducted. Two experiments, one with melons and the other with tomatoes, were carried out at the University of California West Side Field Station (WSFS) at Five Points where the selenium concentration of the drainage water was found to be 30 to 40 µg/L* (Table 1). Two similar experiments were located at Murrieta Farms in Mendota where the selenium concentration in the drainage water was an order of magnitude higher (250 to 350 µg/L). The locations were comparable with respect to soil

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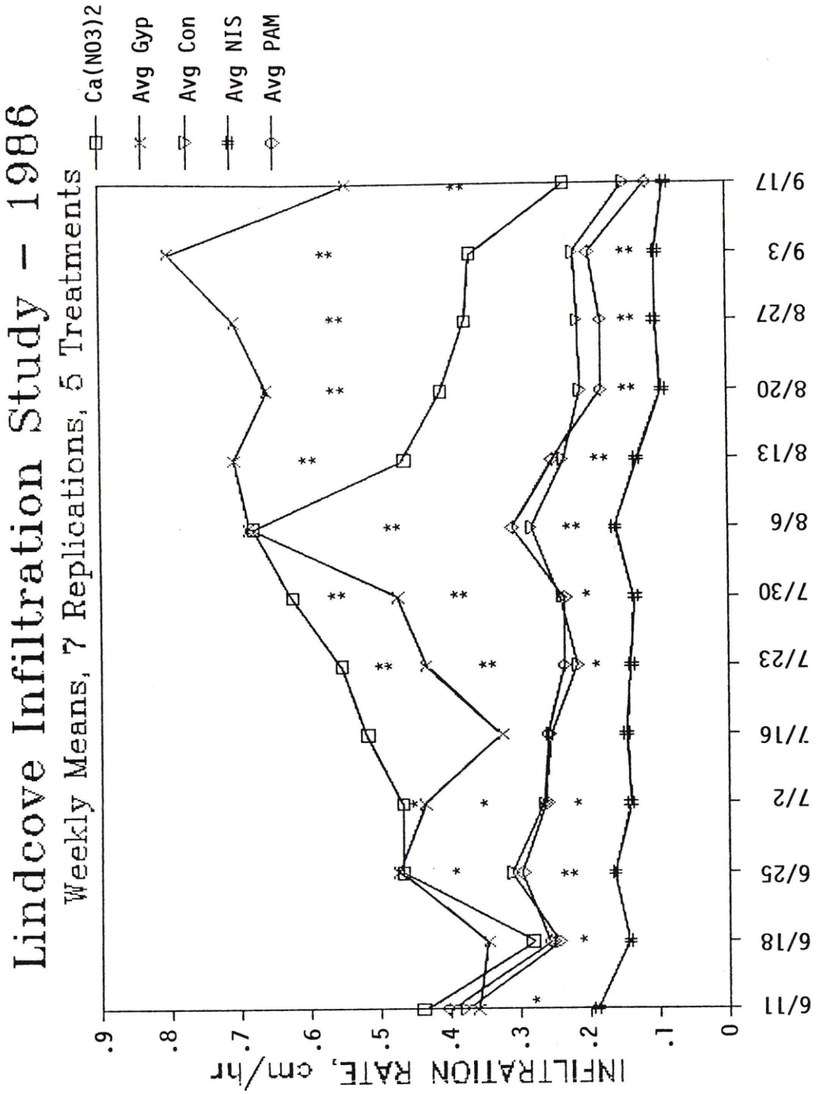

Figure 4. Infiltration rates of all nine treatments with disturbed and undisturbed treatments averaged. Asterisks indicate significant differences at 5% (*) and 1% (**) between curves.

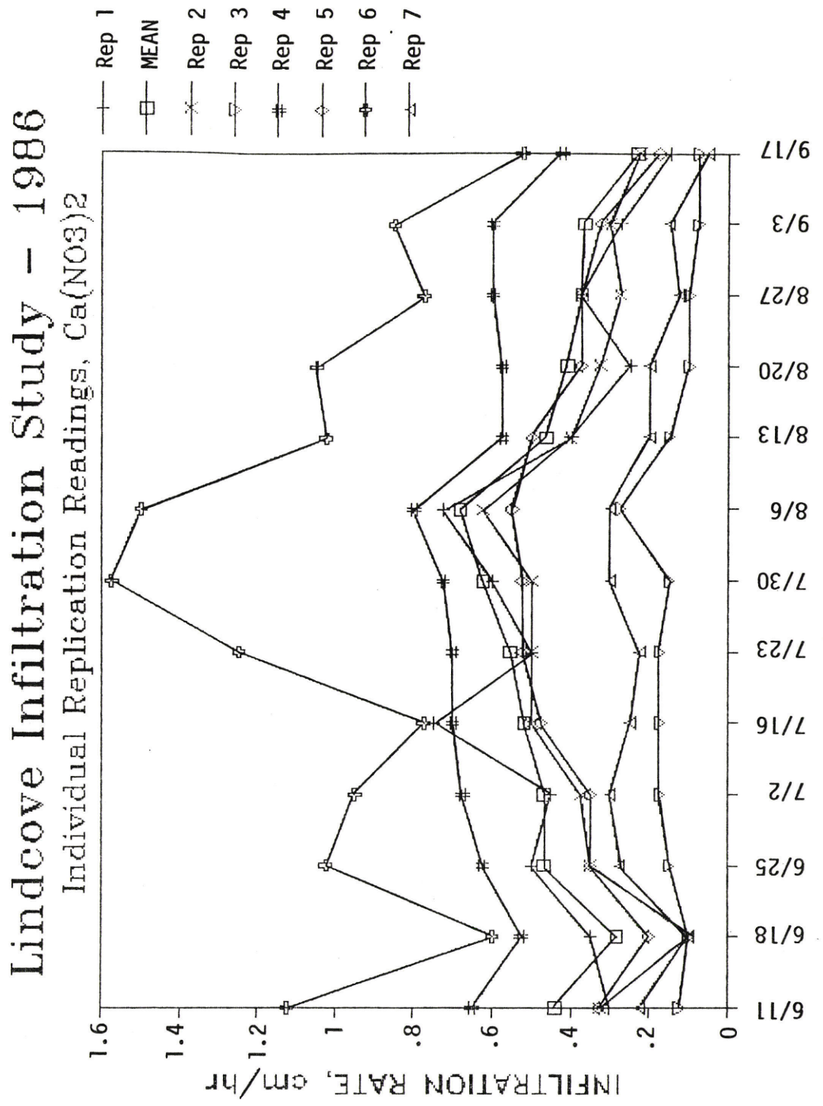

Figure 3. Infiltration rates of seven individual calcium nitrate replications. Despite wide variations, all curves increased through 8/6, then steadily decreased after calcium nitrate was cut off.

type (Panoche clay loam) and salinity both in terms of electrical conductivity and ionic composition. The California Aqueduct water used for the controls was low in salts (EC 0.2 dS/m) and selenium (< 5 µg/L) (see Table 1).

Plots in all studies were irrigated with California Aqueduct water until first flower since most annual crops are more sensitive to salinity during early vegetative growth than at maturity. From first flower onwards, crops were irrigated with saline drainage water. Water was applied weekly to each plot by furrow irrigation in quantities sufficient to replace estimated losses by evapotranspiration. The quality and quantity of irrigation water applied to both treatments (saline and control) in each study are described in Table 1. The saline and control treatments were replicated 4 to 12 times depending upon the study. Yield and soluble solids were determined at harvest and plant samples were taken for selenium analysis.

Results

Saline drainage water did not reduce the yields of tomatoes or melons at either location. Fruit yields from our studies were similar to those obtained by the average grower in the San Joaquin Valley. On the other hand, irrigation with saline drainage water significantly increased the soluble solids (^{o}Brix) in tomatoes at both locations and cantaloupes at Mendota. Increased soluble solids is an indication of improved fruit quality.

Selenium content

Irrigation with saline drainage water significantly increased the selenium concentration in melons and tomatoes in most cases (Figure 1).

---

* µg/L = ppb

This effect, however, was not significant for honeydew fruit at Mendota or tomato fruit at Five Points. The data on plant selenium content indicate the following:

1. Melon and tomato fruits from plots irrigated with California Aqueduct water contained more selenium when grown at Mendota than at Five Points. This is likely related to the higher soil-Se concentrations reported for Mendota relative to Five Points.

2. Melon and tomato fruits from plots irrigated with saline drainage water contained more selenium when grown at Mendota relative to Five Points. This increased accumulation is not unexpected since the concentration of Se in the drainage water at the Mendota site was an order of magnitude higher than at the West Side Field Station.

3. Selenium concentration in tomato plants at Mendota were greater than those found in melons grown under the same conditions in adjacent plots. This could be due to differences in the plants ability to absorb and translocate selenium or differences in root distribution among species.

4. The distribution of selenium within the shoot was similar for both melons and tomatoes. The concentration of selenium was found to be highest in the leaves, intermediate in the stems, and lowest in the fruit.

Selenium levels were also determined in casaba and 'topmark' cantaloupe grown at Five Points but were not reported in Figure 1. Respective concentrations were 25 to 33 µg/Kg dry wt. in plants irrigated with a high quality aqueduct water and 52 and 87 µg/Kg dry wt. in plants treated with drainage water.

Words of caution

Clearly, melons and tomatoes accumulate selenium when irrigated with selenium containing drainage water and when grown in soils high in Se. Although these values are higher than those previously reported in the literature, the estimated daily intake of Se would still be relatively low (6-8 µg Se) and was not considered to constitute a health hazard by Dr. Anna Fan, Staff Toxicologist, California State Department of Health Services.

At first sight, the findings presented here look promising, suggesting that saline drainage water could be reused for irrigation of melons and tomatoes without incurring any loss of yield or constituting a health hazard in terms of Se levels within the fruit. However this interpretation is subject to the following questions:

1. What are the long-term effects of this reuse practice on the physical structure of the soil which in turn could affect water infiltration?

2. What are the long-term effects of this reuse practice on the build-up of soil salinity and accumulation of boron which could influence plant performance?

3. What are the long-term effects on Se and other toxic element accumulations in the soil and will these constituents induce a future health hazard?

4. How can reuse management be practiced to maximize plant performance and minimize adverse environmental effects over many years?

In light of potential long-term adverse consequences of drainage water reuse on vegetable crop growth and quality, a long-term rotation study was initiated in 1986 at the West Side Field Station to address many of these concerns.

Table 1. Irrigation water quality and quantity used in the field studies

Saline Drainage Water	WATER QUALITY EC (dS/m)	Selenium (µg/L)
Five Points	7.7-8.1	30-40
Mendota	7.7-8.1	250-350
Control*		
Five Points	0.2	<5
Mendota	0.2	<5

	WATER APPLIED (in.) Before 1st Flower		After 1st Flower	
	Aqueduct Water	Saline	Control*	Saline
Melons				
Five Points	3.0	--	9.2	9.6
Mendota	5.0	--	12.8	12.0
Tomatoes				
Five Points	5.0	--	18.9	18.9
Mendota	8.0	--	12.8	14.7

*California Aqueduct Water
µg/L = ppb

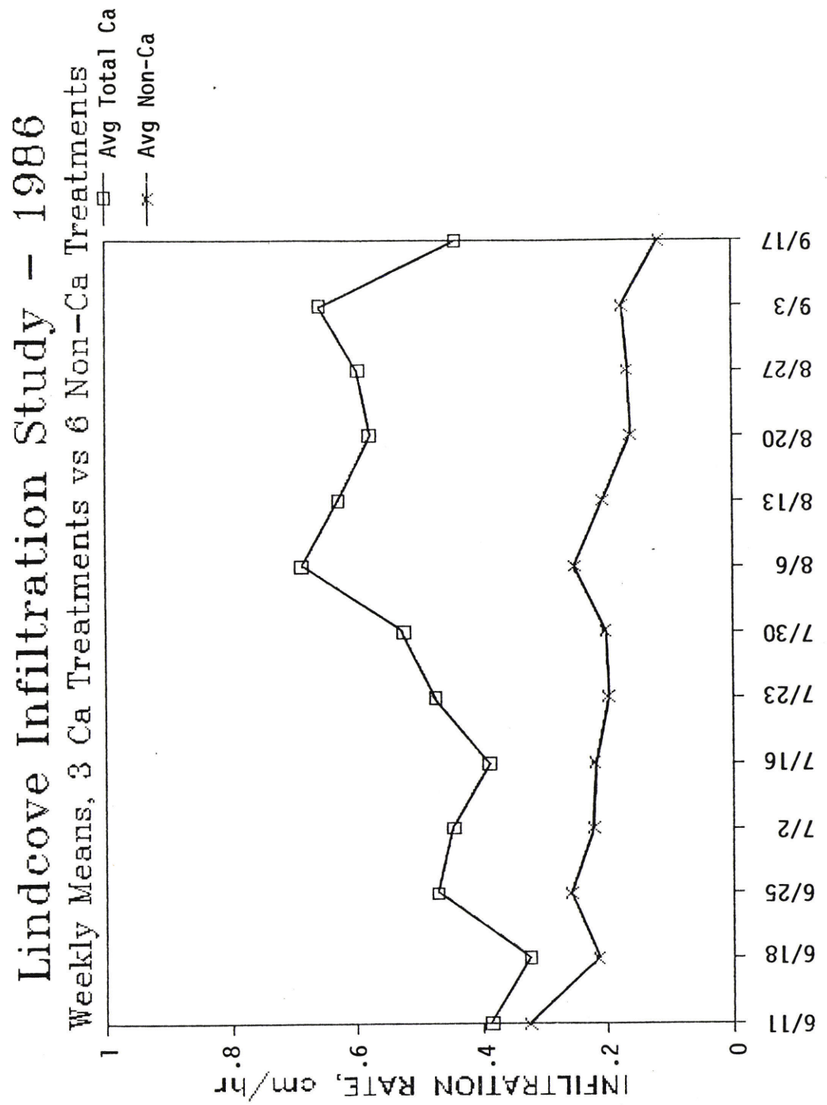

Figure 2. Infiltration rates of average of three calcium treatments versus average of six non-calcium treatments.

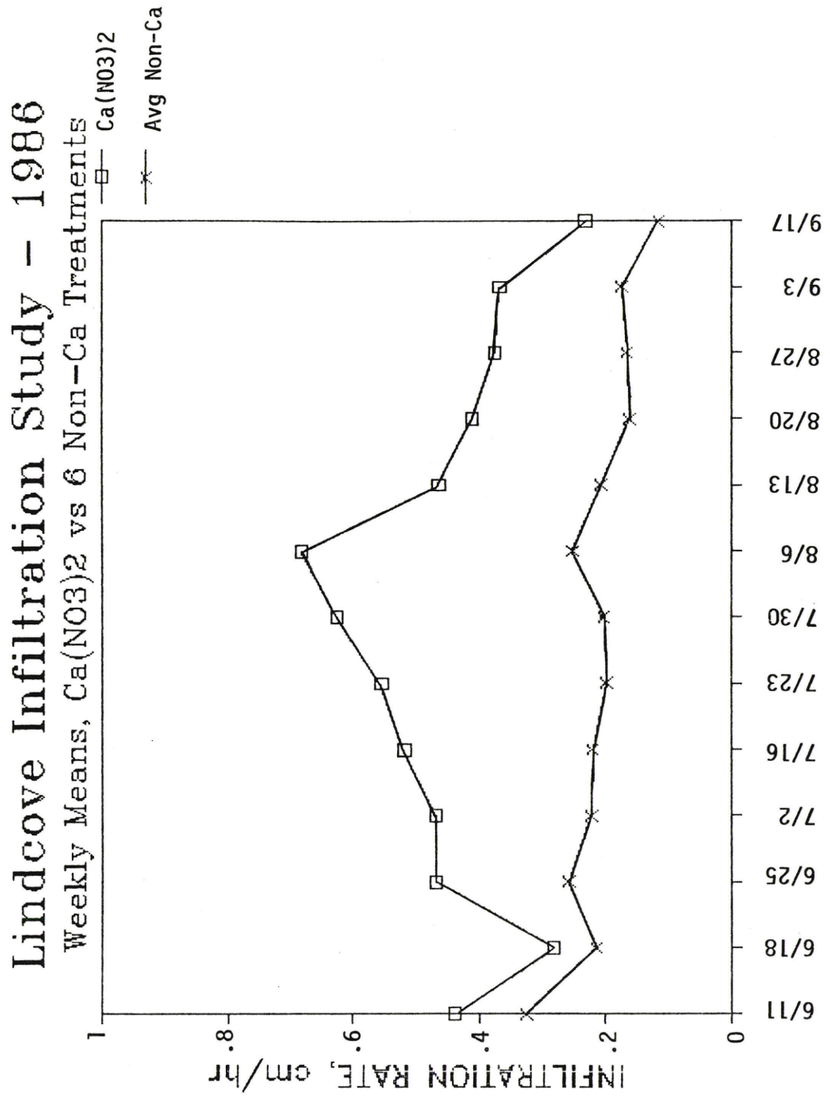

Figure 1. Infiltration rate of calcium nitrate treatment versus average six non-calcium treatments.

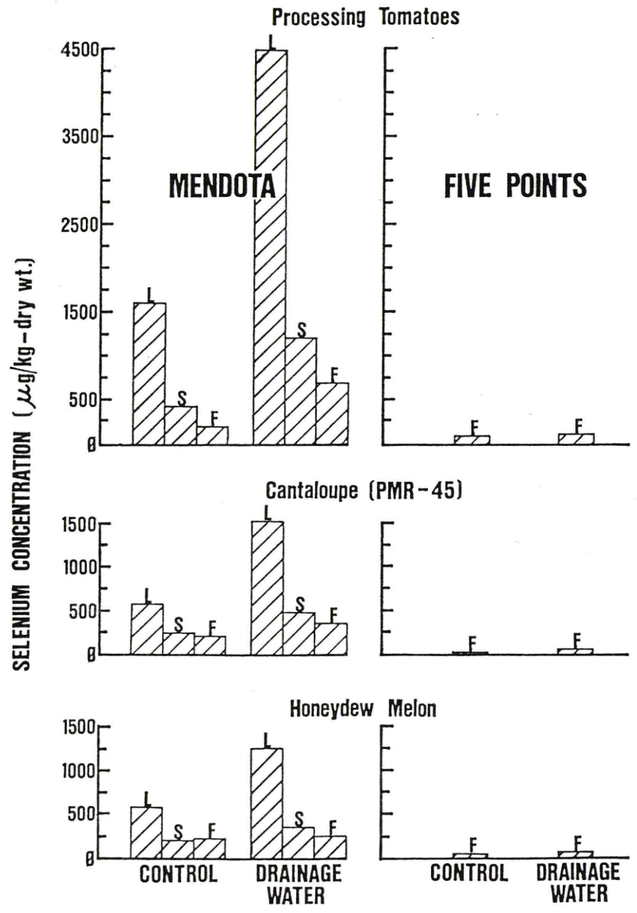

Figure 1. Selenium concentration (µg/Kg dry wt.) in processing tomatoes, honeydew, and PMR-45 cantaloupe grown at Five Points (drainage water Se = 30-40 µg/L) and Mendota (drainage water Se = 250-350 µg/L. L, S, and F refer to leaves, stems, and fruit. Both µg/L and µg/Kg are equivalent to ppb.

Table 2. F values obtained using orthogonal comparisons among various treatments.

Orthogonal Comparison	6/11	6/18	6/25	7/2	7/23	7/30	8/6	8/13	8/20	8/27	9/3	9/17
1. Ca $(NO_3)_2$ vs. 8 other	1.1	.23	2.8	4.4*	11.7**	12.6**	7.3**	1.4	1.4	0.58	.09	.01
2. NIS vs. 6 other	5.9*	6.1*	7.3**	6.5*	5.4*	5.6*	8.3**	9.8**	10.3**	11.6**	10.4**	8.4**
3. Gyp vs. 4 other	.15	2.6	4.9*	5.4*	8.6**	8.5**	16.3**	26.2**	29.7**	38.5**	34.9**	39.3**
4. PAM vs. Con	.05	.04	.03	.01	.06	.01	.06	.02	.09	.13	.03	.16
5. Disturbed vs. Undisturbed	0.7	0.3	.01	.01	.01	.02	.01	.20	.74	.70	1.1	3.3
6. 2 vs. 5	1.3	1.8	0.7	0.3	0.3	0.4	.04	.01	.01	.02	.01	0.6
7. 3 vs. 5	.01	.04	.01	.02	0.1	.02	.04	.03	1.4	1.7	2.8	4.8*
8. 4 vs. 5	.02	.09	.08	.04	0.1	.01	.01	.07	.03	.01	.01	.01

*Significant at 5%. Required F = 4.02
**Significant at 1%. Required F = 7.12

FIELD ANALYSIS OF SEEPAGE FROM DRAINWATER EVAPORATION PONDS

M. E. Grismer

Introduction

A problem of general concern for irrigated agriculture and of particular concern to farmers on the west side of California's San Joaquin Valley is disposal of saline, potentially toxic, waters collected from subsurface drainage. Environmental and economic problems have resulted in closure of the San Luis Drain and Kesterson Reservoir which served to transport and contain this region's drainage flows. As a result, attention has been diverted towards development of alternative methods for drainwater disposal and reducing drainwater production. Currently, of the alternatives available, a local drainwater evaporation pond is the most commonly used disposal method.

Drainwater evaporation ponds are designed to receive and contain subsurface drainage water for disposal by evaporation. Ponds vary in size from roughly 10 to 100 ha containing drain water at depths of 0.1 to 2.0 m.

Of critical importance in evaluating the efficacy of drainwater evaporation ponds as a disposal method, is occurrence of seepage from the pond. Evaporation results in concentration of dissolved salts, including toxic constituents, which may be transported via seepage to contaminate adjacent groundwater. As with many wastewater lagoons, if significant contamination occurs, the evaporation pond can be regarded as a point source of pollution and deemed unusable as a disposal facility. Despite the importance of seepage from such a facility, little field information quantifying its magnitude and variability existed.

It was the purpose of this study to compare and evaluate different field methods for estimating seepage from evaporation ponds and to assess factors affecting seepage variability in the field. Field methods considered included mass balance and point-wise seepage measurements. Although mass balance techniques have been used to estimate seepage from lakes, reservoirs, liquid-waste impoundments and canals, no work was found correlating multiple "point" measurements of seepage with mass balance estimates. Such information is of importance to correlating preconstruction measurements of infiltration with post-construction overall seepage rates and incorporating effects of this correlation in impoundment design. Research conducted thus far has attempted to address some of these considerations using field data collected from a 36.6 ha drainwater evaporation pond.

Mass balance estimates of seepage

Conceptually and practically, the mass balance method was the simplest and most adequate technique for estimating seepage in the field. Average seepage estimates from this method for the winter and summer months were 5.8 and 4.0 ft/yr, respectively. Decreasing seepage rates with time are typical in the field, and in the case, the nearly one-third reduction in seepage during the summer months may have also been due in part to increased microbial activity during this period.

Infiltrometers and spatial variability of seepage

Average pond seepage rates were also estimated using grids of 24 and 90

infiltrometers. Based on infiltrometer measurements, it was determined that seepage rates followed lognormal distribution in space. Measured values ranged from 0.3 to 92 ft/yr with a geometric mean of 4.9 ft/yr. Most of the variability in seepage rates was due to the spacial variability of soil properties. Information presented in Table 1 indicated how average seepage rates decreased with time in a manner similar to that estimated by mass balance method.

Laboratory measurements

When the grid of 90 infiltrometers was removed from the field, undisturbed soil cores were collected from each infiltrometer. These cores were subjected to laboratory measurements of hydraulic conductivity (K), bulk density, particle-size distribution, porosity, and percent saturation. Each of the laboratory measured parameters was correlated with each seepage rate on an individual infiltrometer and its associated core basis. Such point-by-point correlations yielded small correlation coefficients averaging 0.4 or less. Thus, laboratory measurements are capable of predicting less than 20% of the actual seepage rate. Although point-by-point correlation of laboratory data and seepage rate was quite low, a better estimate of infield seepage rate was obtained from the arithmetic mean of the hydraulic conductivity data of 4.5 ft/yr. Theoretically, it is more correct to use the geometric mean, however, significant compaction of the cores during extraction from the infiltrometers resulted in an artificially small value.

For comparative purposes, Figure 1 summarizes estimates of seepage from the various methods examined, and provides some indication of the accuracy of each method in comparison to the field mass balance method.

Closure

From the present study, it appears that seepage from evaporation ponds decreases with time after filling and may vary considerably within the pond. Secondly, estimates of seepage based on laboratory data may be low, and, finally, mass balance estimates of seepage in the field are reliable and relatively simple to obtain.

Table 1. Average seepage rates from all infiltratometers during winter and summer seasons.

Period	Average Seepage (ft/yr)
11/85-3/86	14.9
5/23-6/1/86	12.3
6/1-6/6/86	11.6
6/6-6/15/86	9.6
6/15-6/21/86	9.0
6/21-6/29/86	9.2
6/29-7/16/86	8.1
7/16-8/13/86	7.0

Table 1. Analyses of soil at end of experiment

Treatment	Depth, cm	pH *	EC dS/m **	Ca me/l **	Mg me/l **	X Ca me/100 g ***
$Ca(NO_3)_2$	0 - 2.5	7.0	0.4	2.7	0.6	6.7
	2.5-30	6.6	0.2	1.3	0.6	6.7
Gyp - U	0 - 2.5	7.0	0.9	7.4	0.6	8.7
	2.5-30	6.3	1.0	7.2	2.3	7.7
NIS - U	0 - 2.5	6.9	0.5	3.0	1.0	6.4
	2.5-30	6.4	0.2	1.4	0.7	6.7
Con - W	0 - 2.5	6.9	0.3	2.1	0.7	6.4
	2.5-30	6.4	0.5	2.9	1.3	6.5

* Saturated soil paste
** Analysis conducted on saturated soil extract
***Analysis conducted on ammonium acetate soil extract

only one replicate clearly shows a large increase in infiltration rate prior to the August 6 cutoff. Thus, there is some indication that continuous injection of calcium nitrate is beneficial, but more study is needed.

In contrast, the mean gypsum treatment infiltration rates did not decline immediately after the August 6 cutoff date (Fig. 4). Apparently enough excess gypsum had built up from the weekly additions that residual gypsum maintained the high infiltration rate until the final measurement on 17 September. This supposition is supported by the soil analyses (Table 1) which show no differences in EC, soluble Ca, or exchangeable Ca among the calcium nitrate, nonionic surfactant or control treatments, but a higher EC and soluble Ca value, and slightly higher exchangeable Ca value in the gypsum treatment. The lower Ca in the calcium nitrate treatment is particularly interesting. The lower Ca in the calcium nitrate treatment is particularly interesting. If the infiltration rate prior to cutoff was increased because of higher exchangeable Ca, calcium nitrate must be continuously injected to maintain the concentration.

An analysis of variance was made for each weekly set of infiltration data. The means were separated using orthogonal comparison coefficients. Since the calcium nitrate treatment did not have a disturbed counterpart, it had to be partitioned first from the other eight treatments. This comparison represented a single degree of freedom of the total of 8. Next, the two nonionic surfactant treatments were partitioned from the remaining six for another degree of freedom. The two gypsum treatments were then compared with the remaining four, and finally the PAM treatments were compared to the controls. Another degree of freedom was used to compare disturbed versus undistrubed treatments. The final three degrees of freedom provided for the interactions. The significant differences are summarized in figure 4, in which disturbed and undisturbed treatment pairs have been averaged. The calcium nitrate treatment gave significantly higher infiltration rates than the average of the other eight treatments from July 2 through August 6, just before it was cut off. The nonionic surfactant produced significantly lower rates than the remaining six treatments during the entire period. The gypsum treatments gave significantly higher rates than the remaining four treatments from June 25 through September 17. There were no significant differences between PAM versus control, disturbed versus undisturbed, or in any of the interactions except No. 7 (undisturbed versus disturbed gypsum interaction) on the last date.

The depression in infiltration rate by the nonionic surfactant was unexpected and we have no explanation for it. It has been suggested that an insufficient concentration was added to obtain the optimum effect (W. G. Howells, personal communication). Although we used the recommended rate (1 gallon per acre per month), we converted that to one quart per acre per week, with the idea that more frequent applications were more realistic when using drip irrigation systems.

Conclusions

Although there was considerable variability in infiltration rates among all the treatments, it appears that dissolved calcium compounds produce greater infiltration rates than non-calcium treatments.

There is some evidence that calcium nitrate may be used as a calcium amendment where the nitrate can be substituted for that normally applied to the crop. Calcium nitrate is very soluble and the solution is easy to make and to meter accurately into irrigation water in a drip or sprinkler system, or even into a flooding system.

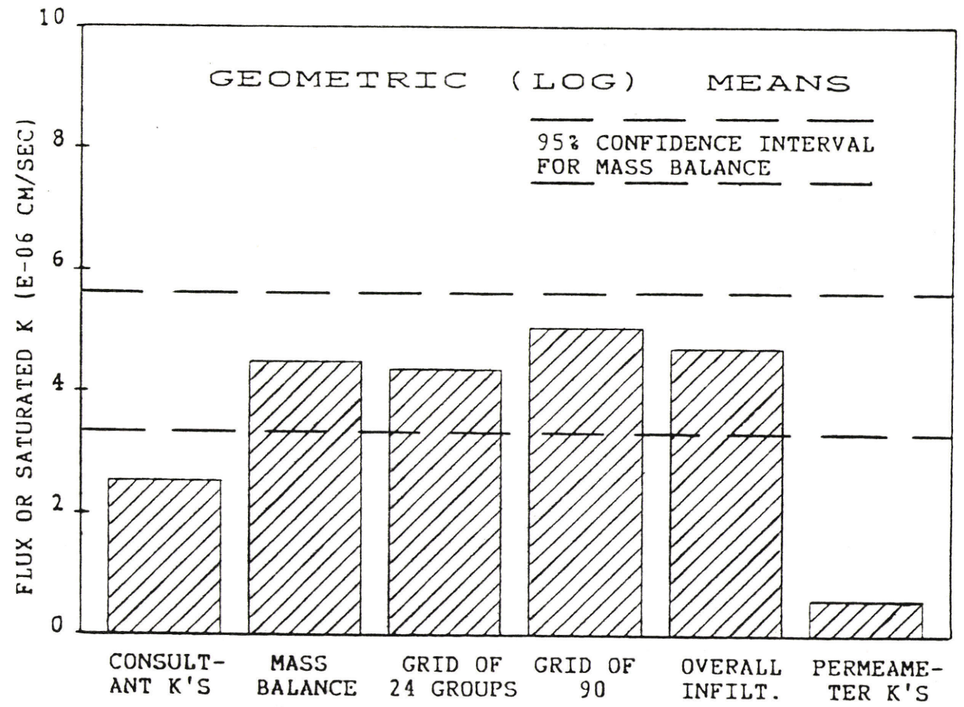

Figure 1. Comparison of seepage estimates for the overall geometric means of various data. Mass balance estimate is the arithmetic temporal mean for all periods and the standard.

EFFECT OF SOIL AND WATER AMENDMENTS ON WATER PENETRATION FROM DRIP IRRIGATION

W. E. Wildman, W. Peacock,
and A. Wildman

Introduction

Gypsum is applied on soils or in irrigation water for amelioration of at least three conditions (1) soil sodicity, (2) low nutrient sulfur content, and (3) and poor water infiltration and penetration. Gypsum can improve water infiltration by (1) lowering the sodium adsorption ratio (SAR) of the applied water and (2) by increasing the electrolyte concentration of low salt irrigation water. Calcium nitrate can also provide this effect, and if its nitrogen contribution to crop needs is considered, it may be cost effective.

Gypsum applied on the soil surface dissolves in the applied water before the water infiltrates. Depending on purity, particle size, quantity, and uniformity of spreading, gypsum may dissolve too slowly or too rapidly, resulting in inefficient use. If it dissolves too slowly or not uniformly over the area, water infiltration may not be improved to its maximum potential. If it dissolves more rapidly than necessary to achieve a desired level of water infiltration, then it will require more gypsum to last the entire season.

The optimum amount of gypsum needed to increase water infiltration to an acceptable level is on the order of 3 to 5 milliequivalents of calcium salt per liter of low salinity irrigation water (EC ~ 0.1 dS/m). This is equivalent to 720 to 1200 pounds of gypsum per acre foot of water. Unfortunately, devices needed to meter the dissolution of solid gypsum into irrigation water are not easy to regulate. Also, the solubility of gypsum is about 28 me/l, which is six to nine times the desired final concentration. As an alternative, calcium nitrate can be dissolved in water to a concentration of approximately 8000 me/l, (i.e. 1600 to 2700 times the desired final concentration). This means that an acre foot of water could be amended with only 120 to 200 gallons of a concentrated calcium nitrate solution. However, the use of calcium nitrate to improve water infiltration is contingent on the ability of the crop to effectively utilize the nitrate portion of the salt. At 3 me/l of commercial calcium nitrate, 124 pounds of N are added with each acre-foot of water. (Commercially available calcium nitrate contains around 2.6% N as ammonium nitrate and 13% N as calcium nitrate).

An experiment was designed to compare the effects of calcium nitrate applied through drip irrigation and gypsum applied to the soil surface on water infiltration rate. Two commercially available soil amendments, a nonionic surfactant (NIS) and a polyacrylamide compound (PAM) were also compared.

Materials and Methods

The experiment was conducted on the University of California's Lindcove Field Station in Tulare County. The soil is a San Joaquin loam to sandy loam and is classified a fine, mixed, thermic, Abruptic Durixeralf. The irrigation water was from the Kaweah River and had an electrical conductivity of about 0.1 dS/m. Seventy two PVC rings, cut from 12 inch diameter irrigation pipe, were driven approximately 3 inches deep into the soil with about 5 inches extending above the soil surface. Six rings were placed adjacent to each of 12 navel orange trees. The rings served as single ring infiltrometers for weekly infiltration measurements. The orange trees were irrigated with six emitters per tree for six hours on each Monday, Tuesday, Wednesday, and Thursday, and on some Fridays during the summer of 1986. On days when infiltration measurements were not taken, a hole near the base of each ring was left open, so that water did not build up from the emitter placed inside the ring. When infiltration measurements were made, the hole was stoppered and water was allowed to pond in the ring, exhausting through an outlet tube about 3 inches above the ground surface. After an irrigation, when the water level in the ring stabilized, an initial depth measurement was made to the water surface. Depth readings were repeated at either one hour or two hour intervals.

Eight replicates of nine treatments were assigned randomly to the 72 rings. It has been a suggestion that gypsum spread on a cultivated surface may have a protective effect on soil aggregates (Wildman, unpublished data). Also, PAM is thought to be most effective when applied to an aggregated surface (Garn Wallace, personal communication). Consequently, all but the calcium nitrate solution were applied to both disturbed and undisturbed soil. Calicium nitrate was applied only to undisturbed soil. Disturbance was performed within the rings by tilling the soil with a forked hand tool to a depth of two inches. The soil was then allowed to dry for several hours before the gypsum, PAM and surfactant treatments were applied. Abnormally high infiltration rates were observed within several rings. Consequently, the highest reading ring for each treatment was removed from the data analyses, leaving seven replications. The treatments were as follows:

1. Calcium nitrate, undisturbed
2. Gypsum, disturbed
3. Gypsum, undistrubed
4. Polyacrylamide, disturbed
5. Polyacrylamide, undisturbed
6. Nonionic surfactant, disturbed
7. Nonionic surfactant, undisturbed
8. Control, disturbed
9. Control, undisturbed

A stock solution containing 920 g/l of reagent grade $Ca(NO_3)_2 \cdot 4H_2O$ was diluted by a factor of 84 and placed in an intravenous (IV) bag suspended above the ring. Tubing led from the bag to an individual drip tube and the solution was introduced into the drip tube at 30 drops (2 ml) per minute to give a further dilution factor of 30 and a final concentration of about 3 me/l continuously during each irrigation. The gypsum used was a mined product of 40% purity. Laboratory tests indicated that it would dissolve to a concentration of about 20 me/l when water was passed through a gypsum layer on top of a pad of soil. Initially, and each week following, gypsum was added inside the PVC rings to provide a slight excess over the amount anticipated to be dissolved. This amounted to an addition of 372 grams of gypsum per ring per week. After 5 weeks, the 60% of inert material had accumulated to a level that interfered with infiltration measurements in the gypsum rings. Therefore, the inert material was removed almost down to the soil surface.

Polyacrylamide (Complete Green, 4.5 g) and 18 g of ammonium sulfate were dissolved in 3-liters of water to make a stock solution for treatments 4 and 5. The stock solution was diluted to make a 250 ppm solution. Six-hundred mls of this solution was applied to the soil inside rings on both disturbed and undisturbed treatment rings and allowed to dry for 3 days before the first irrigation started. The quantity of liquid wet to about a two inch depth of soil.

Nonionic surfactant (Shaklee Basic H Concentrated Organic Cleaner) was diluted by a factor of 35,000. Six-hundred mls of this diluted solution applied on the soil surface each week in treatments 6 and 7. This resulted in an application rate equivalent to one quart of surfactant per acre per week.

On August 6, after 9 weeks of experimentation, applications of calcium nitrate, gypsum, and surfactant were discontinued. Water infiltration measurements were continued for an additional 5 weeks.

One week after the final infiltration measurement was made, soil samples were taken just outside the PVC rings in a location near the outlet hole. This soil should have received the full benefit of any of the soluble amendments. The $Ca(NO_3)_2$ treatment and the undisturbed gypsum, NIS, and control plots were sampled at 0-2.5 cm and 2.5-30 cm depths. The purpose was to identify any soluble or exchangeable calcium differences that might have resulted.

Results

All calcium treatments produced a significant increase in infiltration over all non-calcium treatments (Fig. 1). Figure 2 shows that the mean infiltration rate of 7 replicates of the calcium nitrate treatment rose through the month of July and early August, while the non-calcium treatment rates slowly declined throughout the summer. When the calcium nitrate was cutoff after August 6, however, the infiltration rate plummetted for the next 5 weeks, approaching rates produced from the non-calcium treatments at the end. Figure 3 shows that there was considerable variability among the seven calcium nitrate replications and