Long-Term Salinity Buildup on Drip/Micro Irrigated Trees in California

Charles M. Burt[1], Brett Isbell[2], and Lisa Burt[3]

Executive Summary

The Irrigation Training and Research Center (ITRC) of Cal Poly State University, San Luis Obispo, CA, hypothesized that there is salinity accumulation in the root zone of tree crops that have been irrigated with drip or micro-spray irrigation systems, located in arid and semi-arid regions. Therefore, a study was conducted by ITRC during the summer of 2002 to examine the long-term impact of drip and micro irrigation on salinity accumulation in orchards, focusing on the salinity concentration pattern across a soil profile. The project also provided information to support recommendations on the most effective and efficient leaching techniques.

During the study, two rows of soil cores were collected in ten orchards that had been irrigated with drip or micro-sprayers. Eight of the ten fields were located in the semi-arid climate of the west side of the San Joaquin Valley, CA; the other two were located in Coachella Valley, CA. Fields were selected that had a known irrigation history, without a high water table. Soil samples were collected to a depth of 2.4 m and then tested for ECe. Graphs of soil salinity concentrations for soil profiles 2.4 m deep across two tree rows were developed from these data.

Key points from the salinity accumulation study include:

- In drip-irrigated orchards, there is a significant amount of salt accumulation on the edges of the wetted areas along tree rows.
- Deep percolation with drip still leaves substantial amounts of salt in the soil.
- Orchards with micro irrigation systems accumulate salt in the middle of the tree rows, which is on the edges of the wetted patterns.
- Soil texture effects salt accumulation to a certain extent. There was more salt accumulation in heavier soils compared to sandy soils.

The results from the study suggest that salinity accumulation is a serious concern when an orchard that has been irrigated with drip/micro is removed and a new crop is planted. Many of the fields studied had salinity concentrations on the edges of wetted areas that could be detrimental to a new crop if the salts were not leached prior to planting.

The finding of this study prompted ITRC to conduct a reclamation leaching study. The reclamation leaching study was completed to quantify the leaching water required to remove salts from the effective root zone of trees. This experiment tested a new reclamation leaching technique – multiple lines of low-flow drip tape used to apply water to the area of salinity accumulation along a tree row. The reduction in salinity with a given depth of deep percolation is predictable. The new leaching procedure uses about 1/3 – ½ of the volume of water normally needed for reclamation irrigation.

[1] Professor and Chairman, Irrigation Training and Research Center (ITRC), BioResource and Agricultural Engineering Dept., California Polytechnic State University (Cal Poly), San Luis Obispo, CA 93407; 805-756-2379; cburt@calpoly.edu
[2] Formerly Irrigation Engineer, ITRC
[3] Technical Editor, ITRC

Background
Under optimum management conditions, crop yields remain at potential levels until a specific threshold electrical conductivity of the soil water solution is reached. When salinity increases beyond this threshold, crop yields are presumed to decrease linearly in proportion to the increase in salinity.

Salinity build-up becomes particularly important when trees are removed and the field is replanted. When replanted (with new trees or possibly with a less salt tolerant crop), the salt that has accumulated in the soil may inhibit crop growth and reduce tree vigor.

Procedures to Determine Soil Salinity
During the study, two rows of soil cores crossing 2 tree rows each, with samples in a core row taken 0.3 – 0.6 m apart horizontally, were collected in ten orchards that had been irrigated with drip or micro-sprayers. Soil samples were collected to a depth of 2.4 m and then tested for ECe. Graphs of soil salinity concentrations for soil profiles 2.4 m deep across two tree rows were developed from these data.

Site descriptions. Eight of the ten fields studied were located along the west side of the San Joaquin Valley, CA. The fields have the following characteristics that are pertinent to the study:

- There is little annual rainfall (about 15-17 cm), so salts are not leached out of the root zone from winter precipitation.
- Some fields are irrigated with water from the California Aqueduct and other fields are irrigated with deep well water.
- Some orchards have been irrigated with drip or micro-sprayers for over 20 years.
- There is a concern that leaching large quantities of salts from the root zone would have a negative impact on regional water quality.

Fields were selected that had a known irrigation history and known water quality. Therefore, the total amount of water applied to an orchard and the salt load distributed by the irrigation water could be considered when deriving conclusions.

In addition to the eight fields studied in the west side of the San Joaquin Valley, soil samples were also collected from two fields in Coachella Valley, CA. Therefore, the salinity patterns in soils having a different climate and a different soil type could be compared to the results from the San Joaquin Valley.

Soil Sampling. A direct-push type, hydraulically powered soil sampler was used to collect soil cores. The soil sampler was a model 9800E manufactured by Concord Environmental Equipment, located in Hawley, MN. This machine included an engine used to power a hydraulic cylinder, which is used in conjunction with a hydraulic percussion hammer to force the sampling barrel into the soil.

To develop a grid for each soil profile, 2.4 m deep soil cores were removed across two tree rows. One tube was used for retrieving soil to a depth of 1.2 m; a separate tube was used for retrieving a soil core to 2.4 m below the soil surface. A new clear plastic tube was used for each core that was removed.

Nine individual soil samples were collected from each 2.4 m core at increments of 0.3 m, starting at the surface and ending at a depth of 2.4 m. Approximately 300 grams of soil were collected for each sample to be tested.

Each soil sample was sealed in a plastic bag and labeled according to the specific location where it was taken. Just prior to bagging, the approximate soil moisture content for each soil sample was determined using the "feel method" and recorded.

Figure 1. Soil core sampler in the field.

A row of soil cores was removed perpendicular to the tree rows. The first soil core was taken close to the midpoint between two trees, in line with the tree row. The last core in the row was removed two tree rows over near the midpoint between two trees, in line with the tree row. The horizontal distance between soil cores varied between 0.3 m and 0.8 m. Core spacing was 0.3 m in areas wetted by the irrigation system. Between the wetted zones, soil cores were typically spaced 0.6 m. Two rows of soil cores, in different locations, were taken in each field. The two locations were not necessarily located along the same tree rows as illustrated in Figure 2.

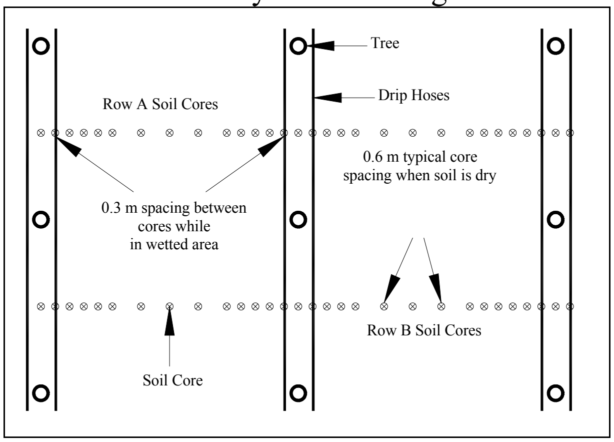

Figure 2. Plan view of typical soil core locations.

Results of Salinity Measurements

In this paper soil salinity results from a few cases are shown. They are typical of what were found. It can be seen that the salinity is more concentrated in drip systems than with micro-spray systems. This is hardly surprising because the same amount of applied salt is spread out over more soil area – resulting in the same amount of total salt, but less pockets of concentrated salt.

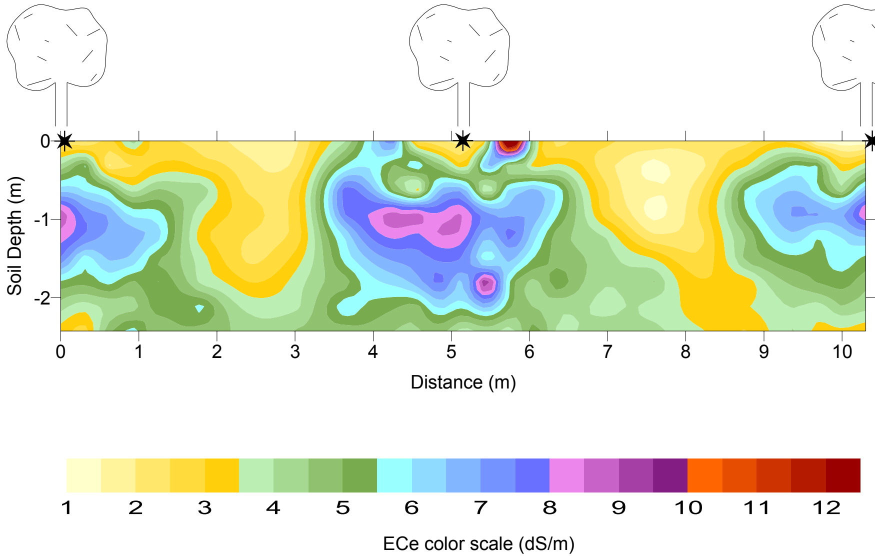

Figure 3. Field 5 (#4100) soil salinity concentration pattern (Location A). One drip hose per row, 3 emitters/tree. 5.2 m x 5.2 m tree spacing. Pistachios planted 1982. Predominant soil texture: loam. Weighted ECw = 0.46 dS/m. Average ECe = 4.5 dS/m

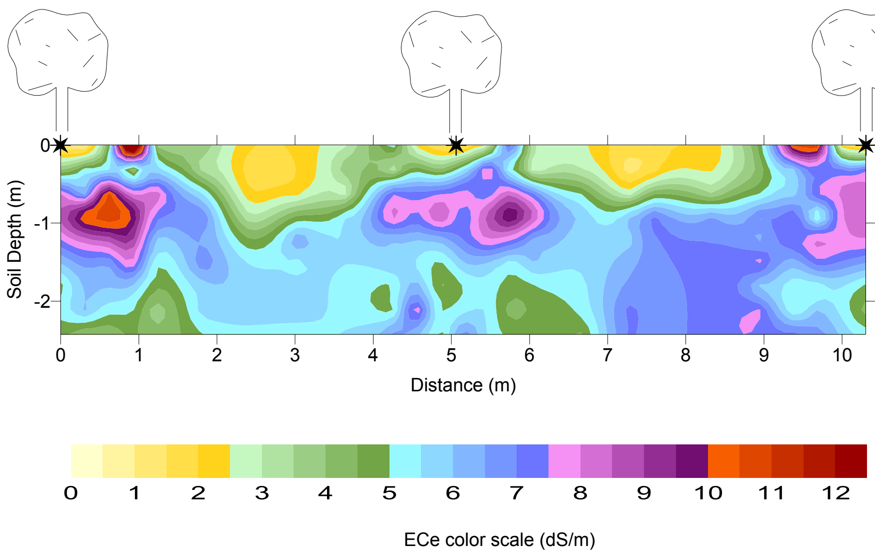

Figure 4. Field 5 (#4100) soil salinity concentration pattern (Location B) Same soil as Location A in Fig. 3. Drip. Average ECe = 5.4 dS/m

A comparison of Figures 3 and 4 show that soil salinity patterns are quite varied – even with the same irrigation management, emitter spacing, and soil type. This was typical of what was seen. This definitely shows the limitations of various 3-D soil salinity models in predicting patterns of salinity accumulation.

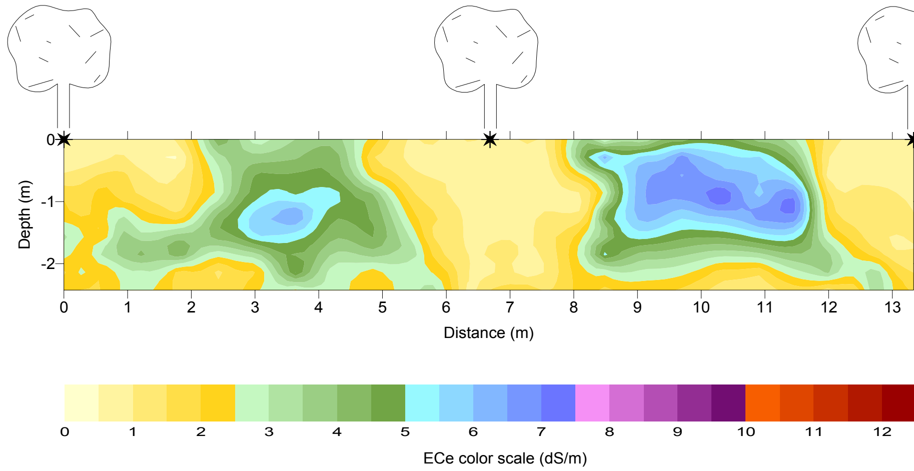

Figure 5. Field 6 (#4830) soil salinity concentration pattern (Location A). One microsprayer/tree. 6.7 m x 4.6 m tree spacing. Pistachios planted in the late 1960s. Loamy sand. Weighted average ECw = 0.44 dS/m. Average ECe = 3.0 dS/m.

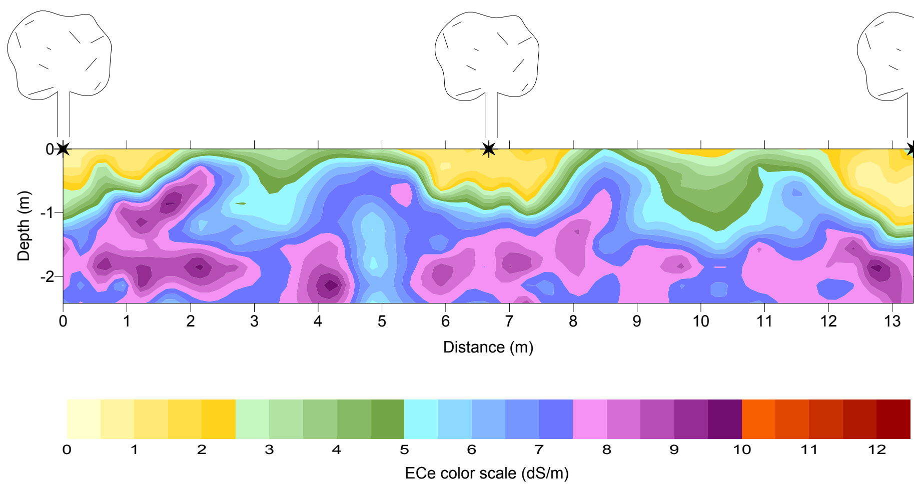

Figure 6. Field 6 (#4830) soil salinity concentration pattern (Location B) Not as sandy as Location A. Average ECe =5.9 dS/m

Conclusions from the Salinity Accumulation Study

Key points from the salinity accumulation study include:

- In drip irrigated orchards, there is usually a significant amount of salt accumulation on the edges of the wetted areas along tree rows. Additionally, we found that deep percolation with drip still leaves substantial amounts of salt in the soil.
- Orchards irrigated with micro-sprayers seem to accumulate salt between the tree rows, which is on the edges of the wetted patterns.

- Some of the salt applied through irrigation water is being leached from the root zone.
- Soil texture effects salt accumulation to a certain extent. There was more salt accumulation in heavier soils compared to sandy soils.

The results from the study suggest that salinity accumulation can be a serious concern when an orchard that has been irrigated with drip/micro is removed and a new crop is planted. Many of the fields studied had salinity concentrations on the edges of wetted areas that could be fatal to a new crop if the salts were not leached prior to planting.

Introduction – Soil Salinity Reclamation Leaching

ITRC conducted a reclamation leaching experiment, in a pistachio orchard south of Huron, CA, during the winter of 2002-2003. The study was conducted to quantify the leaching water required to remove salts from the effective root zone of trees. This experiment tested a new reclamation leaching technique – multiple lines of low-flow drip tape were used to apply water to the area of salinity accumulation along a tree row.

The pistachio orchard was planted in 1982. The trees are drip irrigated with two drip hoses per tree row. Historically, the field where the leaching study was conducted has been irrigated with both surface water and well water. The historical weighted average EC of the irrigation water (ECw) was 0.70 dS/m. The water applied during the reclamation leaching experiment had an ECw of 0.51 dS/m.

Figure 7 and Figure 8 illustrate the pre-leaching salt distribution pattern in an 2.4 m (8-foot) deep soil profile. There is salt accumulation on the edges of wetted patterns along the tree rows. The area between the tree rows is unaffected by drip irrigation and has virtually no salinity buildup from irrigation – as expected because the wetted area from the drip system did not extend to that area.

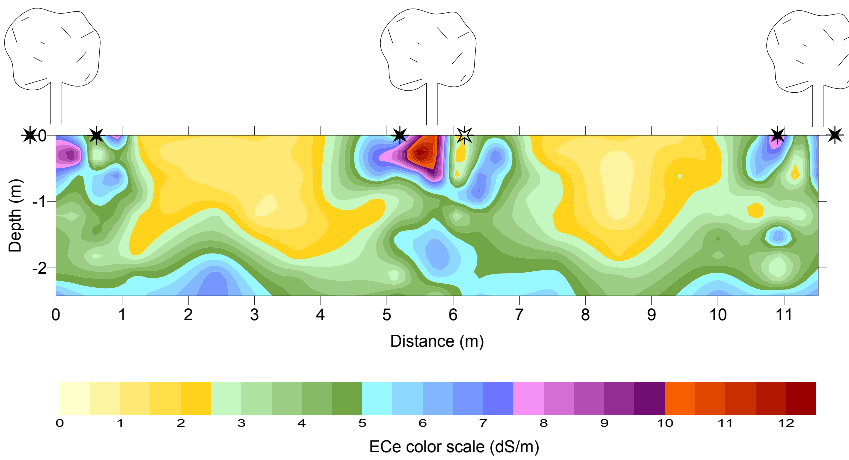

Figure 7. Typical soil salinity concentration profile in the field where the reclamation leaching study was conducted.

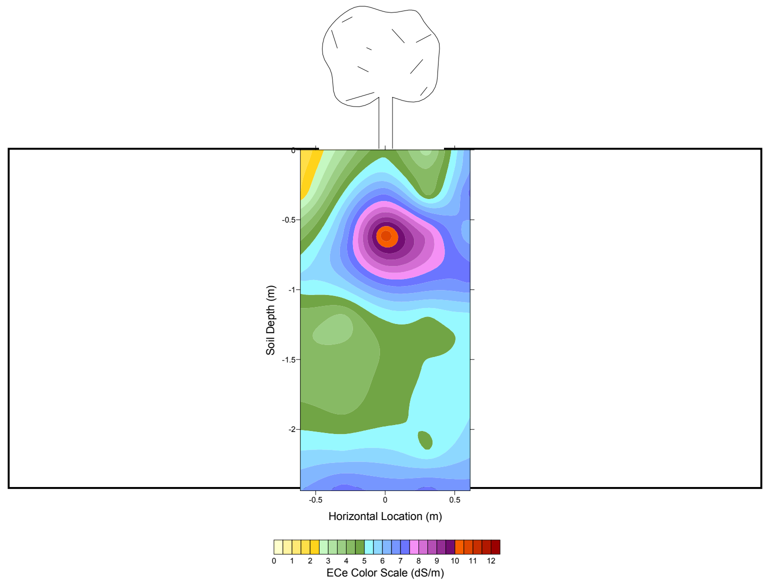

Figure 8 High salinity concentration along the tree row prior to leaching
Average ECe of 6 locations along the same tree row

Leaching Procedure

Six lines of low-flow drip tape were placed along one row of trees (30 trees total) and used to apply the leaching water. Three lines of drip tape were placed on either side of the tree. The spacing between the drip lines was .305 m (1 ft.). The emitter spacing was also .305 m along the tapes. The nominal flow of the drip tape was 1.64 LPH per meter (0.22 gpm/100 ft). The actual average application rate during leaching was approximately .5 cm/hr (0.2 inches/hour).

Figure 9. Low-flow drip tapes, spaced .3 m (1 ft.) apart, were used to apply reclamation leaching water in a pistachio orchard south of Huron, CA.

The practice of leaching using multiple lines of drip tape allows water to be applied where there is salt accumulation along the tree row, as opposed to putting water on the entire area of the field. Since reclamation leaching requires a relatively large depth of water, this technique offers the potential for significant water savings for reclamation leaching.

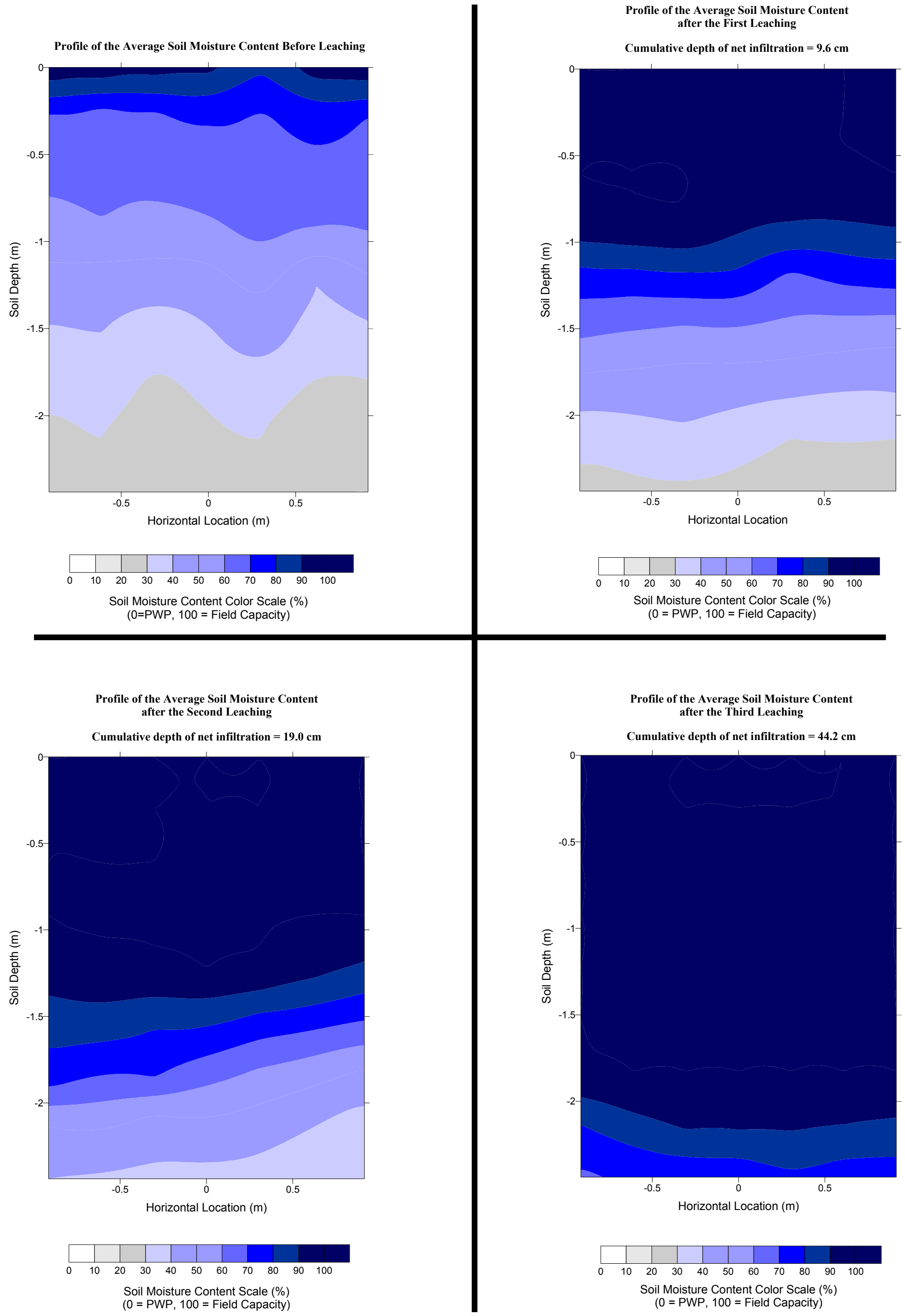

Figure 10. Profiles of the average soil moisture content after consecutive leaching applications.

Figure 10 illustrates increasing soil moisture contents down through the 2.4 m (8-foot) soil zone as increasing depths of leaching water were applied. The surface soil layer had a significantly greater depth of water that percolated through it compared to the soil layer 2.4 m deep – this is because the soil moisture contents of intermediate soil zones had to be increased to field capacity.

During the experiment, leaching water was applied four times. Soil samples were collected at six different locations along the tree row after each leaching. Evapotranspiration (specifically evaporation since the trees were dormant and there was no weeds in the area of consideration during the experiment) and precipitation were considered when determining the net depth of water infiltrated. After four leaching applications, there was approximately 56 cm (22 inches) of net infiltration over the 1.5 m (6-foot) width that the drip tapes spanned.

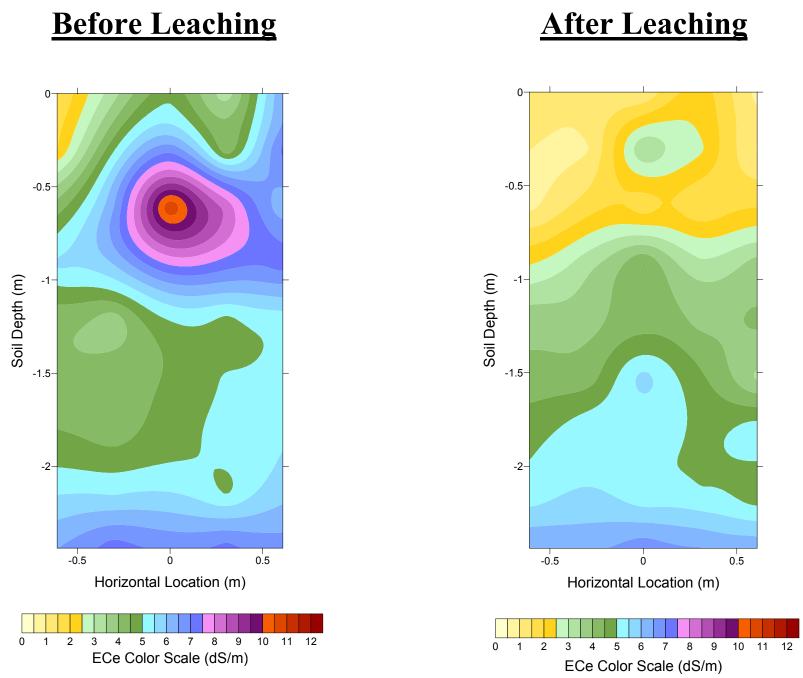

Figure 11. A comparison of the average ECe along the tree row before leaching and after 56 cm (22 inches) of net leaching water infiltration using low-flow drip tape.

Leaching Study Conclusions

A salt reduction/equivalent leaching depth relationship was developed (see Table 1 and Figure 12). An equivalent leaching depth was defined as the depth of net leaching water that percolated through a soil zone, divided by the depth of a soil zone (each having the same units). The depth of irrigation water applied for leaching must be greater than the leaching water because some of the applied water goes to soil moisture storage and evapotranspiration during reclamation.

$$\text{Equivalent leaching depth} = \frac{\text{net leaching depth that percolated past a soil zone}}{\text{soil zone depth}}$$

For example, if 3 m of water deep percolated (leached) past a soil depth of 2 m, the equivalent leaching depth would equal (3m/2m) = 1.5. To fill the root zone to field capacity and get 1 meter of net leaching water may require 1.25 meters or so of water application.

Table 1. Approximate salinity reductions for various equivalent leaching depths using multiple lines of low-flow drip tape (silt loam).

Equivalent leaching depth	Approximate fraction of original salt concentration		
0.2	0.80	to	0.60
0.4	0.57	to	0.38
0.6	0.43	to	0.28
0.8	0.36	to	0.23
1.0	0.30	to	0.20

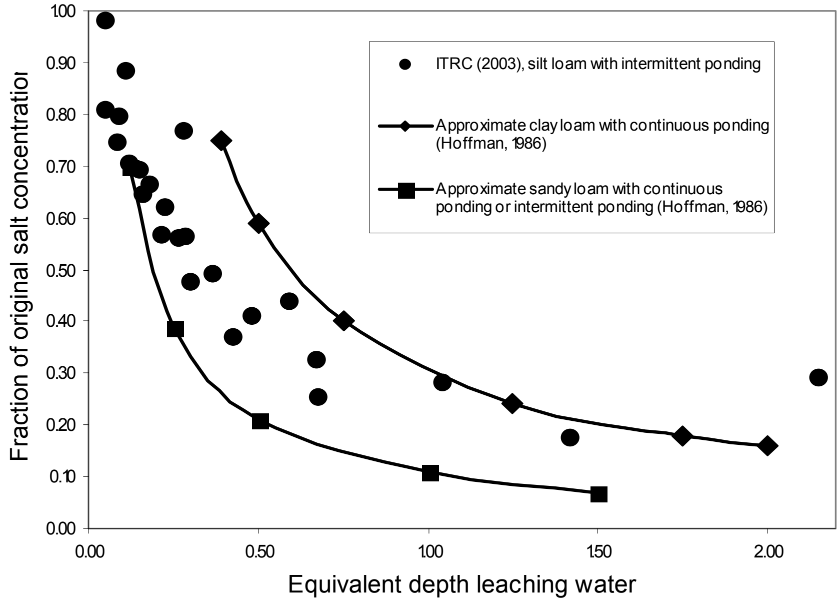

Figure 12. Salt reduction/equivalent leaching depth relationship developed by applying leaching water using multiple lines of low-flow drip tape.

The relatively high application rate of 0.5 cm/hr (0.2 in/hr) in this experiment caused surface water ponding. Therefore, it is reasonable to find the curve for silt loam between the clay loam with continuous ponding and the intermittent ponding curves developed by Hoffman (1986). If the emitters had lower discharge rates, we hypothesize that the efficiency of salt removal would have been greater.

Summary

In summary, there is salt accumulation along the tree rows of many orchards irrigated with drip/micro irrigation systems. Salinity build-up becomes particularly important when trees are removed and the field is replanted. The most effective and efficient reclamation leaching practices for tree crops irrigated with drip/micro include:

i. Apply leaching water only to the areas with salt accumulation – typically along the tree row with drip
ii. Use low application rates for maximum effectiveness of salt removal
iii. Multiple lines of low-flow drip tape can be used to achieve (i) and (ii)
iv. Consider the point of diminishing return for reclamation leaching: we found quantities of leaching water greater than 0.8 equivalent depths result in insignificant salt reduction (for a typical silt loam soil using intermittent leaching)
v. Use intermittent applications of reclamation leaching water, which minimize the effects of bypass flow

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Reference

Hoffman, G. J. 1986. Guidelines for reclamation of salt-affected soils. Appl. Agric. Res. 1:65-72