Drip irrigation as a sustainable practice under saline shallow ground water condtions

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Abstract

Many areas along the west side of the San Joaquin Valley of California are affected by saline soil due to shallow, saline ground water conditions. Artificial subsurface drainage is not an option for addressing the salinity problem because of the lack of drainage water disposal facilities. Thus, the salinity/drainage problem of the valley must be addressed through improved irrigation practices such as converting to drip irrigation. The effect of drip irrigation on soil salinity, soil water content, and water table depth was evaluated from both experimental and model results. While a water balance showed little or no field-wide leaching, soil salinity data clearly showed localized leaching around the drip lines.

Key Words

Irrigation water management, leaching fraction, water use.

Introduction

About 1 million ha of irrigated land are affected by saline, shallow ground water conditions along the west side of the San Joaquin Valley, California. Upward flow of the shallow groundwater has resulted in excessive levels of root-zone soil salinity. The traditional approach to coping with shallow ground water problems is to install subsurface drainage systems for water table control and improved leaching, but the proper operation of these drainage systems requires disposal of the subsurface drainage water. No economically, technically, and environmentally feasible drain water disposal method exists for the San Joaquin Valley, and thus, the drainage problem must be addressed through options such as better management of irrigation water to reduce drainage below the root zone. Schoups *et al.* (2005) concluded the following:

- for irrigated agriculture to remain sustainable, a soil salt balance must be maintained that allows for productive cropping systems,
- continued irrigation without changing management practices is not sustainable.

One option for improving irrigation water management is to convert from furrow or sprinkler irrigation to drip irrigation. Drip irrigation can apply water both precisely and uniformly compared with furrow and sprinkler irrigation resulting in the potential to reduce subsurface drainage, control soil salinity, and increase yield.

Subsurface drip irrigation of processing tomatoes was evaluated to determine its effect on crop yield and quality, soil salinity, water table depth, and profitability in salt-affected, fine-textured soil underlain by saline, shallow groundwater. Because tomatoes are a high cash value crop, a better potential for increased profitability with drip irrigation exists compared to cotton. However, tomatoes are much more sensitive to soil salinity, which could result in reduced crop yields in salt-affected soil. This study presents a sensitivity analysis of drip irrigation for different quality irrigation water with a shallow groundwater, using both experimental and modeling results.

Materials and Methods

Field Experiments

Experiments in three commercial fields involved comparing subsurface drip irrigation of processing tomatoes with sprinkle irrigation under saline, shallow ground water conditions. Drip irrigations occurred every two to three days. At one field, water table depths were about 2 m, while at the other two fields, water table depths generally ranged between 0.5 m and 1 m. The electrical conductivity (EC) of the irrigation water ranged between 0.30 to 0.35 dS/m and between 1.06 to 1.2 dS/m , whereas the EC of the shallow ground water ranged from 4.7 dS/m to 16.4 dS /m, depending on the particular field and time of year. Soil type was clay loam at the three sites.

Computer Simulations

Soil water and soil water salinity distributions around the drip line were modeled using an adapted version of the computer simulation model HYDRUS-2D (Šimůnek *et al.* 1999). This software package can simulate the transient two-dimensional or axi-symmetrical three-dimensional movement of water and nutrients in soils. This model has been previously used in studies of water and chemical movement under drip irrigation (Gardenas *et al.* 2005; Hanson *et al.* 2006). Subsurface drip irrigation was simulated using system design characteristics typical of the drip systems used for processing tomatoes.

Simulations were conducted for water table depths of 0.5 and 1.0 m, irrigation water salinities of 0.3, 1.0, and 2.0 dS/m, and applied water amounts of 80, 100, 115% of the potential evapotranspiration. For the 0.3 dS/m irrigation water, additional simulations for a water application of 60% were also conducted. Two irrigations per week were applied for the 1.0 m water table depth and daily irrigations were used for the 0.5 m depth. The EC of the shallow ground water was assumed to equal 10.0 dS/m and 8.0 dS/m for the 0.5 and 1.0 m water table depths, respectively, based on measured levels at the field sites.

Results and Discussion

Field Experiments

Soil salinity around drip lines was found to depend on the depth to the ground water, salinity of the shallow ground water, salinity of the irrigation water, and amount of applied water. For water table depths of 2 m, soil salinity (expressed as the EC of a saturated extract) was smaller than the threshold salinity and was distributed relatively uniformly around the drip line (Figure 1A). For water table depths of less than 1 m, soil salinity varied considerably around drip lines with the smallest levels near the drip line and high values near the periphery of the wetted volume (Figure 1B). Higher values of soil salinity occurred near the drip line for the field using the higher EC irrigation water (Figure 1C).

The key to the profitability and sustainability of drip irrigation of tomatoes in the valley's salt affected soils is salinity control. Salinity control requires leaching or flushing of salts from the root zone by applying irrigation water in excess of the soil moisture depletion. The leaching fraction, defined as the percent of applied water that percolates below the root zone, is used to quantify the amount of leaching. It was concluded that because of salinization issues, sustainable agriculture may not be possible in these salt affected soils of the valley, based on a regional salt balance assessment which showed salt imports into the valley to exceed salt exports (Schoups *et al.* 2005).

The field-wide leaching fraction historically has been calculated as the difference between the seasonal amount of applied water and the seasonal crop evapotranspiration. Data from our experiments showed that based on the historical approach, little or no field-wide leaching occurred, which appears to raise questions about the sustainability of drip irrigation. The field-wide leaching fraction is the ratio of the seasonal crop evapotranspiration (determined with a computer evapotranspiration model and measurements of canopy growth and reference crop evapotranspiration) to the seasonal applied water.

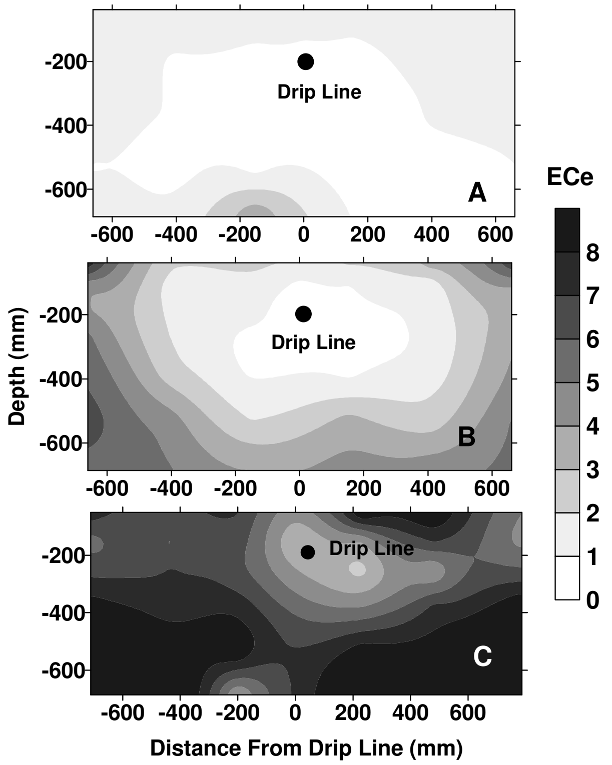

Figure 1. Patterns of soil salinity around drip lines for (A) an average water table depth = 2 m, EC of the irrigation water = 0.3 dS/m, and ground water EC = 8 to 11 dS/m; (B) water table depth between 0.61 and 1 m, EC of the irrigation water =0.3 dS/m, and ground water EC = 5 to 7 dS/m; and (C) water table depth between 0.61 and 1 m, EC of the irrigation water = 1.1 dS/m, and ground water EC = 9 to 16 dS/m. The black dots are the drip line locations. Values are EC of saturated extracts (dS/m).

Yet, considerable leaching occurred around the drip lines (defined as localized leaching), as seen in Figure 1. Localized leaching increased with increasing amounts of applied water. Thus, the historical approach to estimating leaching fractions may be inappropriate for drip irrigation. However, it is difficult to estimate the localized leaching fraction under drip irrigation because leaching fraction, soil salinity, soil moisture content, and root density all vary with distance and depth around drip lines. Thus, HYDRUS-2D was used to estimate leaching fractions under drip irrigation.

Computer Simulations

The simulations showed that reclamation of the soil near the drip line was rapid with salt patterns around the drip line similar to those shown in Figures 1B and 1C. As time progressed, the volume of reclaimed soil increased with most of the reclamation occurring below the drip line and salt accumulating above the drip line (data not shown). However, the simulation data show that considerable leaching occurred around the drip line for water applications of 60 and 80 percent, considered to be deficit irrigation conditions with no field-wide leaching (Hanson *et al.* 2008).

Based on the water balance approach, no field-wide leaching occurred for water applications equal to or less than 100% of the potential crop evapotranspiration. However, the actual leaching fraction, called the localized leaching fraction, ranged from 7.7% (60% water application) to 30.9% (115% water application), and was 24.5% for the 100% water application. The localized leaching fraction is defined as the ratio of the cumulative amount of flow out of the bottom of the modeling domain to the amount of irrigation water applied. As the salinity of the irrigation water increased, the localized leaching fractions increased for a given amount of applied water because of reduced root water uptake. Thus, even for applications considered to be deficit irrigation conditions, considerable localized leaching occurred around the drip lines. This behavior reflects the wetting patterns that occur under drip irrigation. This localized leaching is highly concentrated near the drip line, an area where root densities are likely to be the highest. These data, coupled with the measured soil salinity data, indicate that the historical approaches to measuring leaching fractions are inappropriate for drip irrigation.

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