Drip Irrigation in Salt Affected Soil

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Introduction

Excessive soil salinity can reduce crop yields. Thus, salinity control of irrigated land is necessary to prevent yield reductions where saline water is used for irrigation or where saline shallow water tables exist. Salinity control consists of applying sufficient water, called a leaching fraction, to flush salts out of the root zone. The leaching fraction is defined as the percent of the applied water that percolates below the root zone. A leaching fraction of 20 percent means that 20 percent of the applied water percolates below the root zone.

Soil salinity is normally characterized by the electrical conductivity of a saturated extract (ECe). The ECe is determined by collecting soil samples from a field, drying and grinding the soil, saturating the soil with distilled water, and then extracting the solution from the soil. The electrical conductivity (EC) of the extracted solution is measured and is called the EC of the saturated extract or ECe. The higher the amount of salts in a soil, the higher the ECe.

The effect of leaching on soil salinity depends on the amount of leaching water and its flow pattern and the salinity of the irrigation water. Under drip irrigation, water flows from the drip line in a somewhat radial pattern that depends on soil type and existing soil moisture content. Soil moisture content is the highest near the drip line and decreases with distance from the drip line.

Patterns of Salt Under Drip Irrigation

Under surface drip, salt patterns around a drip line reflect the water flow patterns. Low soil salinity occurs near the emitter (Figure 1). Zones of low salinity also extend downward beneath the drip lines, the result of leaching directly below the drip lines. Salinity increases with depth and distance from the emitter. Midway between the drip lines, soil salinity near the soil surface is very high because little or no leaching occurs at that location. The salinity values near the emitter reflect the salinity of the irrigation.

Salt patterns under subsurface drip irrigation differ slightly because of upward flow of water above the drip line. Figure 2 shows a salt pattern under subsurface drip irrigation where the drip line is buried about 5 inches deep. In the vicinity of the drip tape, low soil salinity occurs. Salinity increases with lateral distance from the drip tape, with high salinity under the furrow. Very high soil salinity occurs above the drip tape. Salts carried by water flowing upward from the drip tape cause this high salinity. No leaching occurs above the drip line during the drip irrigations.

The salinity of the low salt zone depends largely on the salinity of the irrigation water. However, the extent of the zone of relatively low salt soil depends on the leaching fraction. Figure 3 shows salt patterns under surface drip irrigation for leaching fractions of 5 and 25 percent (Hoffman et al., 1985). The larger the leaching fraction, the larger the zone of low soil salinity, and the smaller the zone of high soil salinity. As with surface drip irrigation, the zone of low salinity soil also increases as the leaching fraction increases for subsurface drip irrigation (Figure 4).

If no leaching around the drip line occurs, then soil salinity can increase in the vicinity of the drip line as shown in Figure 4 for April. Soil salinity was highest near the drip line and decreased with horizontal distance and with depth. The opposite in salt distribution around the drip line occurred when leaching occurred as shown in Figure 4 for July.

In many areas of California, excessive levels of soil salinity are caused by upward flow of shallow saline ground water. For furrow and sprinkler irrigation, soil salinity near the soil surface is controlled by the salinity of the irrigation water, while soil salinity at the deeper depths is controlled by the salinity of the shallow ground water. Under drip irrigation, however, the salinity in the near vicinity of the drip line is controlled by the salinity of the irrigation water, the amount of leaching, and the flow pattern around the drip line.

Figures 6 and 7 show salt patterns around the drip line for different depths to the water table and irrigation water salinity. Soil salinity in Fig. 6 (Site DI) was less than about 2 dS/m for all depths and distances from the drip line. The EC of the irrigation water was 0.34 dS/m. These ECe's were less than the threshold ECe 2.5 dS/m for tomatoes. At this location, the EC of the shallow ground water ranged from 8 to 11 dS/m. However, the depth to the water table generally was about 6 feet, and thus, little upward flow of shallow ground water into the root zone apparently did not occur. (Note: The threshold ECe value is the maximum average root zone ECe at which no yield reduction should occur (Maas, 1990). The actual root zone salinity under drip irrigation at these sites is unknown because of spatially varying patterns of soil salinity, soil moisture, and probably root density around drip lines. The threshold value is provided as a reference only to indicate a potential for yield reduction.) The salt pattern in Fig. 6 for Site BR shows much higher levels of soil salinity with the smallest values near the drip line, where the root density is likely to be the highest. The EC of the irrigation water was 0.34 dS/m. Near the drip line, ECe value were between 3 and 4 dS/m, but values as high as 7 to 10 dS/m occurred elsewhere in the soil profile, caused by upward flow of saline, shallow ground water.

Soil salinity was the highest near the drip line for Site DE in 2000 (Fig. 7). At this location, the irrigation water EC was about 1.1 dS/m. However, a severe spring rainstorm caused ponding of water at this location, which leached the salts out of the top 1 of soil. The following year the pattern, the ECe were the least near the drip line and increased with depth and horizontal distance from the drip line (Fig. 7). The higher values of 2001 near the drip line compared with the values of Site BR (Fig. 6) near the drip line appear to reflect the differences in the irrigation water electrical conductivity.

Effect of Soil Salinity on Tomato Yield under Drip Irrigation

Several studies have shown a potential for producing processing tomatoes, a moderately salt sensitive crop, under saline conditions. Hand-harvested tomato yields ranged from 129.1 Mg/ha to 140.5 Mg/ha in 1991 and from 110.7 Mg/ha to 145 Mg/ha in 1993 under saline, shallow ground water conditions (Ayars et al., 2001). Machine-harvested yields of 1993 ranged from 71.7 Mg/ha to 112.0 Mg/h. Depth to the shallow ground water was less than 2 m and its salinity was about 5 dS/m. Soil salinity ranged from about 4 dS/m to 10 dS/m for depths less than 1 m. About 10% of the water requirement of tomatoes was supplied by upward flow of the shallow ground water.

Surface drip irrigation was used to irrigate processing tomatoes under saline conditions (Pasternak et al., 1986). Treatments consisted of different levels of irrigation water salinity with electrical conductivity of 1.2 dS/m, 4.5 dS/m, and 7.5 dS/m. Results showed a yield reduction of about 10% to 12% for the 4.5 dS/m water compared to the 1.2 dS/m irrigation water, while yields of the 7.5 dS/m were reduced by about 60%.

Drip irrigation of processing tomatoes was compared with sprinkler irrigation in the salt-affected soil along the west side of the San Joaquin Valley (Hanson and May. 2003). Tomato yields under drip irrigation were 5 to 10 tons per acre more than under sprinkler irrigation. Levels of soil salinity are shown in Figures 6 and 7, where ECe near the drip line ranged from values less than the threshold ECe of tomatoes to values greater than the threshold value. However, no trend in yield was found among the three sites suggesting that soil salinity under drip irrigation had a smaller effect than would be expected under low-frequency irrigation. This study also showed that maximum yields under drip irrigation occurred for water applications of about 100 percent of the potential crop evapotranspiration.

Discussion and Conclusions

High irrigation frequency drip irrigation has a potential for affecting the relationship between crop yield and root zone soil salinity in several ways. First, relatively high levels of soil moisture content around the drip line occur throughout the irrigation season because of the high frequency irrigation and the wetting pattern for a properly managed drip system. Second, soil salinity is the least in the zone of maximum soil moisture content. Third, high frequency irrigation prevents salt accumulation near the drip line if sufficient leaching occurs. Fourth, root density is the highest near the drip line where the soil moisture content is maximum and the soil salinity is minimum.

The objective of leaching is to control the average soil salinity in the root zone such that no crop yield reductions occur. Under drip irrigation, the average root zone salinity is difficult to estimate because of spatially varying levels of soil salinity, soil moisture content, and root density. However, soil conditions near the drip line are more likely to control yield response to soil salinity than those elsewhere in the soil profile. Under drip irrigation, the higher the leaching fraction, the larger the zone of relatively low salt soil near the drip line. The levels of soil salinity near the drip line will largely reflect the salinity of the irrigation water.

References

Ayars, J.E., Schoneman, R.A., Dale, F., Meso, B., and Shouse, P. 2001. Managing subsurface drip irrigation in the presence of shallow ground water. Agricultural Water Management Vol. 47:242-264.

Hanson, B.R. and D.M. May. 2003. Response of Crop Yield and Quality of Processing Tomato, Soil Salinity, and Water Table Depth To Subsurface Drip Irrigation under Saline, Shallow Groundwater Conditions. In press. *California Agriculture.*

Hoffman, G.J., Shannon, M.C., and Jobes, J.A. 1985. Influence of rain on soil salinity and lettuce yield. In: Irrigation in Action, Proceedings of the Third International Drip/Trickle Irrigation Congress, November 18-21, Fresno, CA.

Maas, E.V. 1990. Crop Salt Tolerance. In: K.K. Tanji (ed.). *Agricultural Salinity Assessment and Management.* ASCE Manuals and Reports on Engineering Practice No. 71. American Society of Civil Engineers. 619 p.

Pasternak, D., De Malach, Y., Borovic, I. 1986. Irrigation with brackish water under desert conditions VII. Effect of time of application of brackish water on production of processing tomatoes (Lycopersion esculentum Mill.). Agric. Water Manag. 12: 149-158.

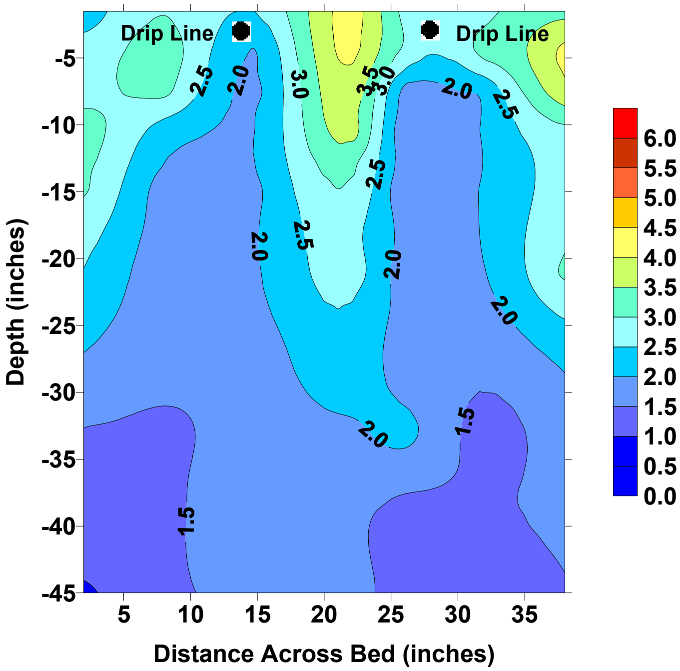

Figure 1. Pattern of ECe for surface drip irrigation of strawberries. The contour lines are lines of constant ECe.

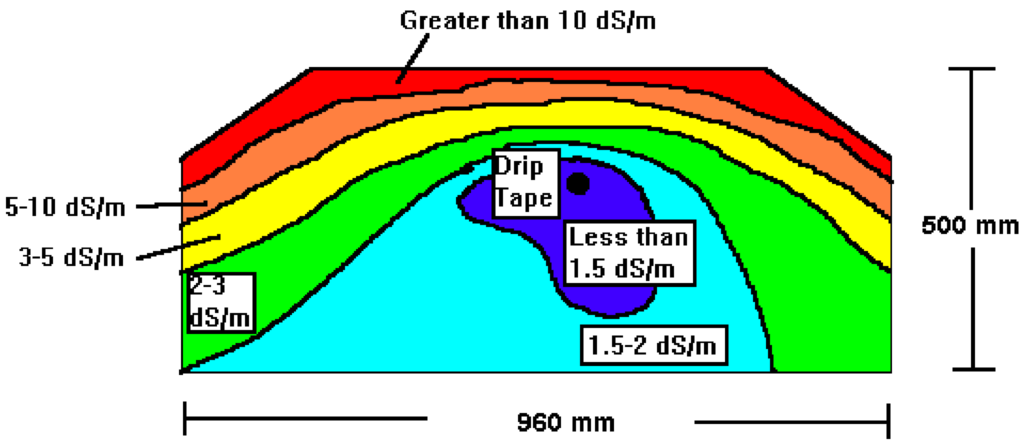

Figure 2. Pattern of ECe for subsurface drip irrigation of lettuce.

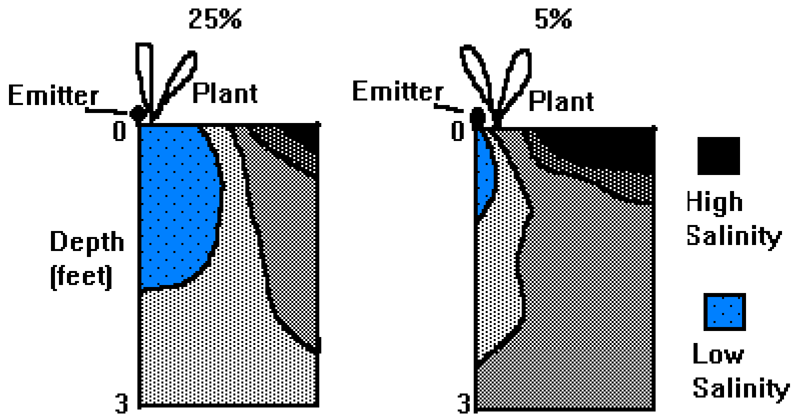

Figure 3. Patterns of salinity for different leaching fractions under surface drip irrigation.

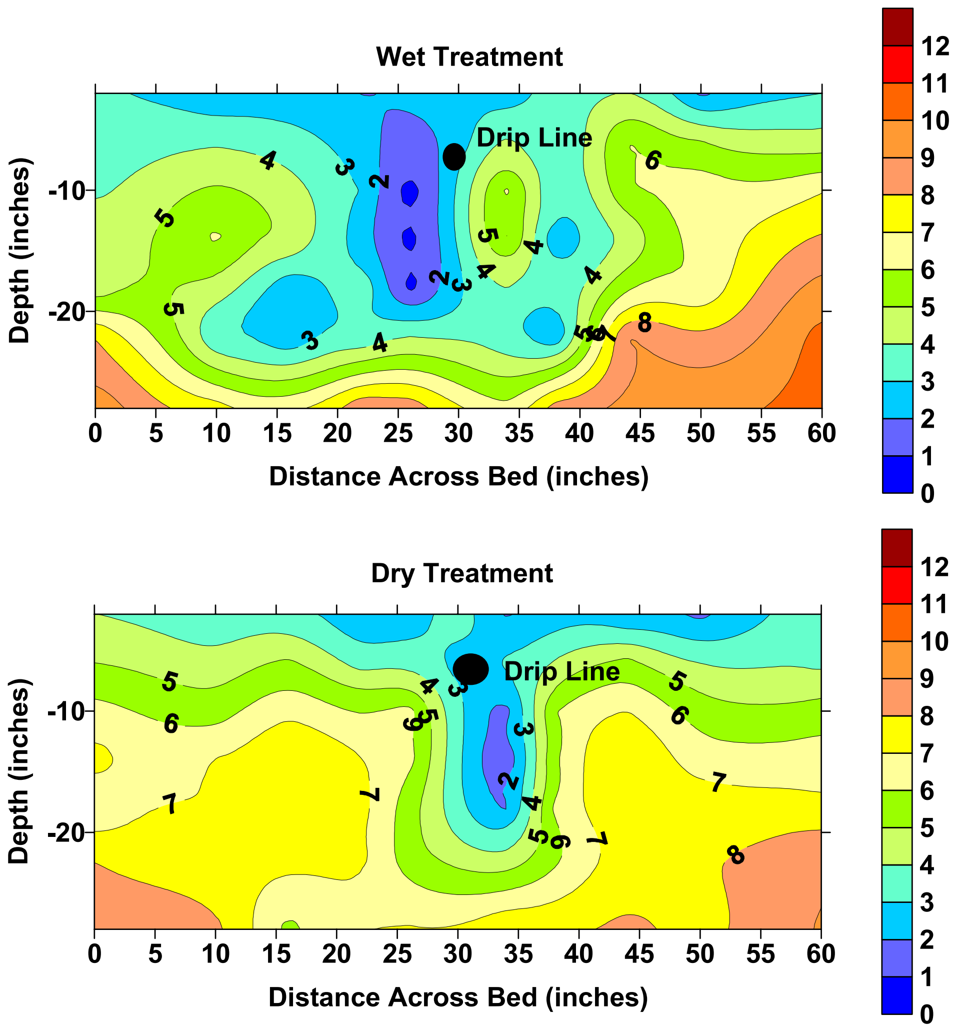

Figure 4. Patterns of ECe for different amount of applied water under subsurface drip irrigation.

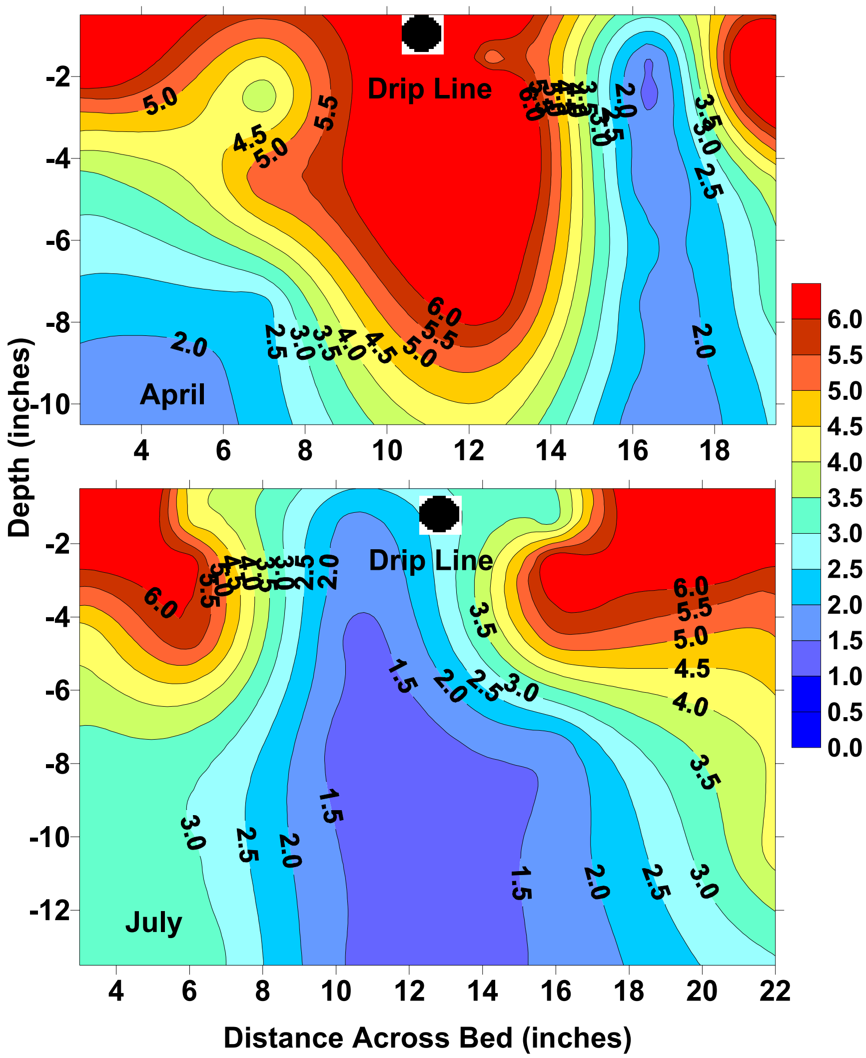

Figure 5. Patterns of ECe under surface drip irrigation for conditions of no leaching and adequate leaching.

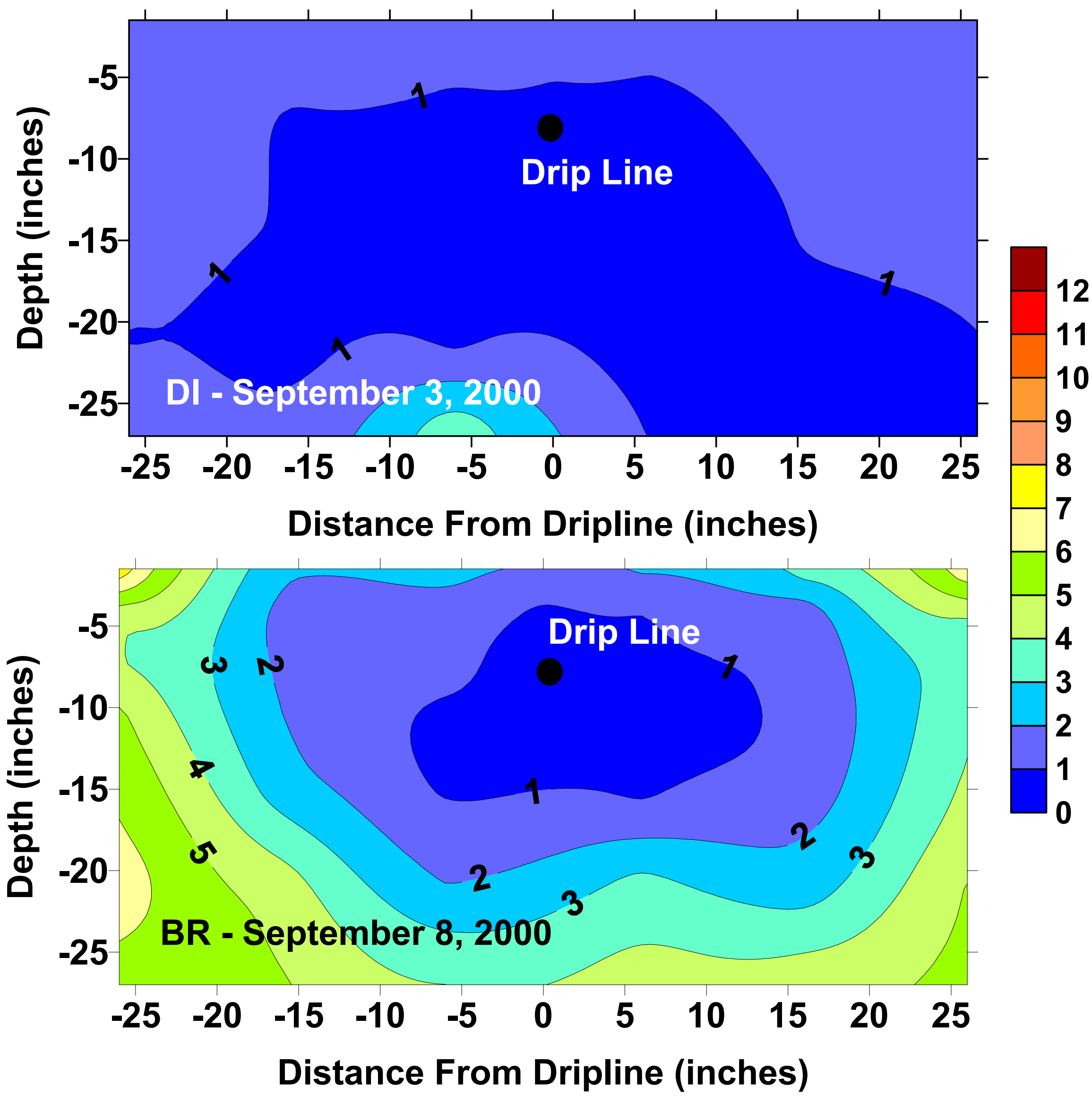

Figure 6. Patterns of ECe under subsurface drip irrigation for shallow, saline water table conditions.

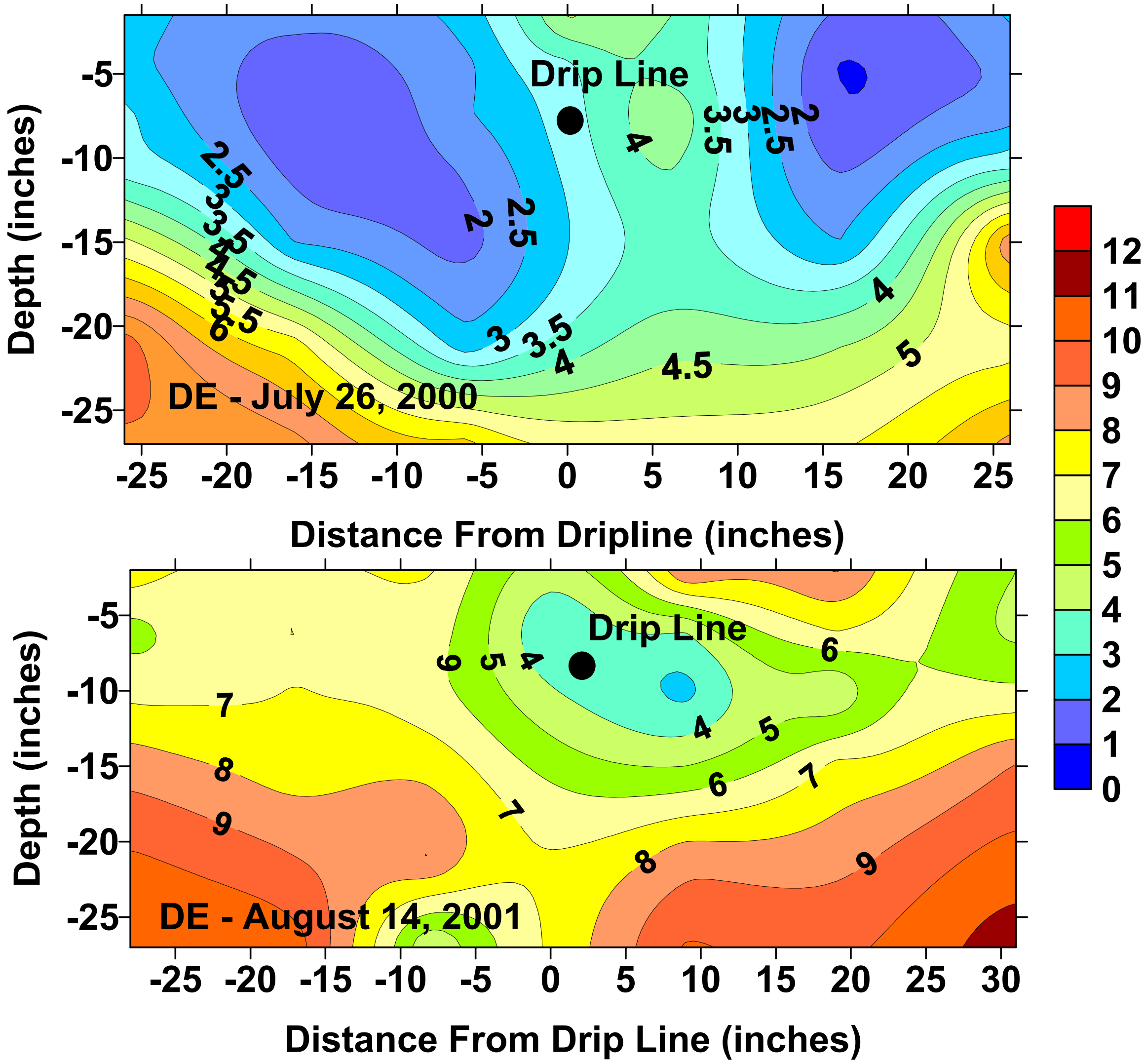

Figure 7. Patterns of ECe under subsurface drip irrigation for shallow, saline water table conditions.