Salinity Management in Field Crops and Vegetables

Brenna Aegerter, UCCE San Joaquin County; Michelle Leinfelder-Miles, Ph.D., UCCE San Joaquin County

The Sacramento-San Joaquin River Delta region is a unique agricultural region of California characterized by organic soils, shallow groundwater (and consequently limited drainage), and access to generally good quality irrigation water. Delta farming, however, is challenged by salinity, which can stress crops and reduce yields. Results from two on-farm research projects in the Delta illustrate the unique challenges of managing salts in Delta agricultural systems. We developed a project in processing tomato to evaluate how converting to drip irrigation impacted water use and soil salinity by studying furrow and drip irrigation systems over the course of three seasons (2013-2015). In a second project which spanned the same time period, we studied seven border check irrigated alfalfa systems to understand how well soils were being leached of salts, as influenced by surface water quality and rainfall. While our projects were focused on the unique challenges in the Delta, we describe some basic principles of salinity management that broadly apply to California’s irrigated agricultural systems.

Salt problems are not unique to the Delta and occur on approximately one-third of all irrigated land in the world, particularly in arid regions like California. Some soils are salty because parent materials weather to form soluble salts. On croplands, salts may be applied with irrigation water to create or exacerbate salty conditions. In the Delta, tidal influences on surface waterways, as well as a shallow and fluctuating groundwater table, also influence soil salinity.

Salt impairment may be identified by white or black crusts on the soil surface, wet spots on the soil surface, marginal leaf burn, or the presence of salt-tolerant weeds. Salt impairs plant growth in many ways: by exerting osmotic stress that results in decreased turgor pressure in plant cells, degrading soil physical conditions that impair water penetration and the plant’s ability to access water, and specific ion toxicities that vary by plant species. Limited water supplies due to drought and deficit irrigation methods can exacerbate soil salinity, thus magnifying these stresses on plants.

The primary management strategy to combat soil salinity is leaching. Leaching is accomplished by applying water in excess of what the root zone soil can hold and the crop needs; this excess water moves below the root zone, carrying salts with it. Leaching that occurs during non-crop periods is typically done with sprinklers or flooding, which leach the entire soil profile. Leaching that occurs during the crop season is called maintenance leaching. Maintenance leaching can result in root rot or leaching of fertilizers or pesticides if not done carefully. Maintenance leaching can also be done with drip irrigation systems but with some limitations. Namely, salts move outward and downward from the tape, but the soil above the tape cannot be leached. Leaching decreases with distance from the drip tape, and no leaching occurs mid-way between adjacent lines. The greater the volume of water applied, the greater the leaching effect. UC Farm Advisors Tom Turini and Dan Munk, working at the West Side Research and Extension Center in Fresno County, showed that with the availability of high-quality surface irrigation water, they could decrease the average EC of drip-irrigated tomato soil over a 3-year period; although salinity increased in some portions of the profile.

Drip irrigation has some advantages for salinity management in row crops. Although salts can accumulate on the periphery of the wetted zone, this may not greatly impact the crop since the majority of the roots are in the wetted zone. Another advantage is that some crops are particularly sensitive to foliar accumulation of salts from sprinkler irrigation water, and drip eliminates this issue. Additionally, with more frequent irrigations, soil moisture can be maintained more evenly with drip irrigation, which minimizes the impacts of salinity.
UC Davis Specialist Blaine Hanson, working with UC Farm Advisor Don May on the west side of the San Joaquin Valley, showed that daily irrigations matched to crop water use, coupled with groundwater monitoring, allowed use of poor quality groundwater to successfully grow processing tomatoes. In the long run, however, salt build up can endanger subsequent crops unless the soil is leached.

It is important to monitor salinity (typically measured as electrical conductivity) of soil (ECe) and irrigation water (ECw) to understand baseline conditions and how management practices can change the soil salinity profile over time. Our projects involved extensive soil and water sampling to understand the soil salinity profile, how it changed over time, and whether leaching was occurring to move salts out of the profile. Ayers and Westcot (1985) provide guidelines for crop salinity tolerances. For processing tomato, yield declines are expected when the average root zone salinity ECe reaches 2.5 dS/m or ECw averages 1.7 dS/m over the season. Likewise, yield declines for alfalfa are expected at salinities of 2.0 dS/m and 1.3 dS/m for soil and water, respectively.

Our Delta research illustrates that salts are accumulating in the soil, despite relatively good quality water (particularly compared to groundwater quality in other regions of the state) being used for irrigation. In our study of tomatoes under buried drip, we observed that with high quality surface water, the average ECe increased slightly over the three years. We saw localized leaching that was less downward than what was observed in the studies conducted on the west side of Fresno County. Salts were moved out of the soil that was lateral to the drip tape (Figure 1). Some of the salt was pushed to the surface of the bed and furrow.

**Figure 2.** Soil salinity profiles, and groundwater depth and salinity, for a flood irrigated alfalfa field in the Delta. With the exception of the Spring 2015 sampling, the soil reached its highest salinity at about 3.5 feet, or around 105 cm. This was also the shallowest depth of groundwater in the spring of every year, which suggests that shallow groundwater is limiting the leaching of salts below this depth.

**Figure 3.** Soil salinity of a furrow-irrigated tomato field in the Delta. Soil depths are relative to the top of the bed, thus the blank areas near the furrow. Colors represent the salinity gradient from low (green) to high (red). The soil sampled from the top end of the field, where irrigation water enters, shows more leaching than the soil sampled from the bottom end of the field, indicating uneven distribution of irrigation water down the field.
Salt also accumulated in a layer of soil about three feet below the surface. We attribute this accumulation to fine-textured organic matter at this depth. The fine organic matter fills up soil pores and impedes water movement.

In the alfalfa project, some of the study sites accumulated salts because soil conditions and/or shallow groundwater impaired leaching. Figure 2 illustrates the soil salinity profile of one of the alfalfa sites. The soil is a silty clay loam with low saturated hydraulic conductivity. Water does not move down the profile quickly, and the groundwater can be as shallow as 3.5 feet. Likewise, the ECe was at its maximum at about 3.5 feet at every spring and fall soil sampling except Spring 2015. Thus, it would appear that soil conditions and/or groundwater are preventing leaching below this depth.

Figure 2 also illustrates the importance of soil sampling below the top foot for a better understanding of the salinity profile. While the ECe of the top foot of soil was in a tolerable range for crops like tomato and alfalfa, there was a considerable jump in salinity in the second foot below the surface. Crop roots can easily penetrate this depth, and thus, were anchoring into soil that had higher salinity than what is generally recommended (Ayers and Westcot, 1985). This, again, illustrates the need for leaching with low salinity irrigation water and/or water applied in excess of crop evapotranspiration.

Results from both the tomato and alfalfa projects illustrate that in gravity-fed irrigation systems (furrow, flood), the top end of the field, where irrigation water enters, may be more easily leached than the bottom end of the field (Figures 3 and 4). The top of the field has a longer opportunity time for water to infiltrate. Irrigating over a longer run time may provide for better leaching at the bottom of the field; however, longer run times will also increase runoff from the field and could result in standing water on clay soils.

In conclusion, salinity is an issue in the Delta and throughout California, and limited water supplies due to drought and deficit irrigation may exacerbate the issue. Leaching is the primary way to combat soil salinity, but Delta research has shown the challenges to leaching high organic matter soils with shallow groundwater. In a drip irrigated tomato field, leaching occurred laterally, but salts accumulated at the soil surface and in an organic matter layer that was still within the crop rooting zone. In gravity fed irrigation systems, uneven water distribution down the row may result in poor leaching at the bottom end of the field, and thus variable field conditions that could become difficult to manage. Additionally, shallow groundwater may be restricting leaching in the Delta. Monitoring soil and water salinity and understanding soil and groundwater characteristics will help growers optimize leaching and agricultural productivity.

Further Reading


