Time to Consider

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Over the past few years, many orchards have relied on low quality groundwater for irrigation. This water often contains high amounts of salt, which become toxic if concentrations within the soil are too high. During the dormant period and hopefully a wet year, efforts should be taken to leach accumulated salts out of the root-zone.

Almond trees are relatively sensitive to salt. Yields are impacted when average root system salinity increases above 1.5 dS/m, with research indicating a 19% decrease in potential yield with every 1.0 dS/m increase. This yield loss is due to the osmotic effects of the salts, which basically makes the tree "work harder" for water. If excess salts continue to accumulate within the root-zone, sodium, chloride, or boron uptake occurs, causing tissue toxicity.

Salts dissolved in the soil water reduce growth and yield by osmotic and toxic effects. Osmotic effects are the processes that most commonly reduce growth and yield. Within a root zone unaffected by high levels of salt, the concentration of ions are higher within the root than in the soil. Through the process of osmosis, water moves from the soil into the plant. As the salinity of the soil increases, the difference between the concentration of ions between the plant and soil decreases, slowing the rate of water movement by osmosis, making water less available to the plant. To prevent this from occurring, the plant responds by making more sugars or organic acids or accumulating salts, raising the concentration of salts in the root. These processes use energy that could have been directed to the crop, reducing growth and yield, but otherwise yielding a plant that appears healthy.

Toxic effects of salts are more noticed because of scorched leaves. This occurs when salts within the soil water are absorbed by the roots and accumulate within the plant's leaves. The concentration of the salt continues to increase and eventually becomes toxic, resulting in tissue death of leaf tips and margins. Salt burn can also occur when water high in salts is sprayed onto the leaves. In these cases, the salt is absorbed into the leaf through the surface, and accumulates to a toxic level within the plant cells.

Almonds planted on soils affected by sodium, chloride, and boron tend to have stunted growth and late season leaf burn. Trees severely affected can look golden in appearance and, in some cases, lose their leaves. Leaf sampling in Mid-July can be compared to UC critical values to determine the relative level of salt. These conditions negatively affect yields, thus making the application of salinity management practices necessary.

The impact of soil on salinity. During low rainfall years, salt burn often shows up in sandy soils, especially if the irrigation water is sourced from a well. This salt burn is a combination of accumulation of sodium within the root-zone, the use of well water, and the low exchange capacity of the soil. In contrast, finer textured soils will show minimal impact of salinity until the soil becomes completely saturated with the toxic salt. This saturation typically occurs when reliance on a low quality water source occurs and may take 2-3 years before symptoms occur. Since the severity of salt issues vary by soil type, so too does the management of these problems.

The differences described between fine and coarse textured soils are due to the differences in Cation Exchange Capacity (CEC). CEC is used to describe the amount of cations (positively-charged ions like sodium, magnesium, calcium, potassium, etc.) that can bind to the soil particle surface. The higher the

CEC, the more cations that "stick" to the soil, preventing them from entering the soil water (soil water is the amount of water that is held between soil particles – it is what the tree "drinks"), reducing salt exposure to the roots of the tree. In fine textured soils across the State, CEC values can be very high, with values ranging between 15-40 meq/100 g of soil. Sands, however, may have a very low CEC, ranging from 3-12 meq/100g of soil. Generally, sandy loams are in the teens through 20s, and silts and clays are in the 30s to 40s. This value can be determined from a soil analysis. Regardless of the CEC, once the soil is saturated with cations, the excess will stay within the soil water, exposing the tree's root to increasing levels of salinity.

Before the leaching program can be determined, plan to conduct several analyses. Soils should be sampled down to five feet to determine the concentration of salts and CEC. After sampling, the soil salinity values should be averaged to determine the root-zone's salinity. If the soil's EC is over 1.5 dS/m or the levels of sodium, chloride, or boron are greater than 5.0 ESP, 5.0 meq/l, or 0.50 ppm, respectively, than a leaching program should be considered. The determined CEC gives an idea on how much water will be needed to leach the soil; the higher the value, the more water needed for leaching. The water that is planned to be used for the leaching program should also be analyzed. Water with an EC over 1.1 dS/m should not be used, unless it is the only source of water available. It is important to realize that the soil salinity will never drop below the salt concentration of the water.

Salt problems and managing salinity in sandy/low CEC soils (<12 meq/100 g). The good news is that within sandy soils, sodium can leach almost as fast as it has accumulated. This can be done by emulating rain through winter irrigations. If possible, an application of at least 4-6 inches of water before the first week of December. This will fill the soil profile (check to be sure by probing to 5 feet). If over a half inch of rain occurs before then, it can be subtracted from the targeted total. This water should be applied in 18-24 hour shots. After an application, wait 4-5 days, and apply another irrigation until the targeted total is reached.

After the soil profile is filled, another 4-6 inches of water will be needed. This can fall as rain or irrigation. Water should be applied in 0.5" to 1" applications. After an irrigation, let the water drain for 3-5 days before making the next application. Any rain can count as leaching water.

Managing Salinity in Loam to Clay Textured Soils (>12 meq/100 g). The high buffering capacity of finer soils makes it difficult to manage salinity in comparison to coarser soils. Soil sampling is critical to determine how much leaching water is required. Sampling should occur down to five feet in one foot increments. If soil EC is greater than 1.5 dS/m as an average for the five sampling depths, a winter leaching program should be considered

Once the soil Ec is known, the amount of leaching water can be determined. Table one highlights the amount of water in inches per foot of root-zone to reach any target soil EC. An example of use is as follows: If the current soil EC is 4.0 dS/m as an average of five feet of rooting depth, and the target EC is 1.0 dS/m, an estimated 4.2 inches of water will be needed for every foot of root-zone depth to be leached. For five feet of root-zone, this is 21.0" of water. This does not include what is needed to refill the soil profile. Also, this assumes that the EC of the water is <1.00 dS/m. If the water is cleaner or saltier, less or more water may be needed, respectively. Rainfall should also be subtracted from this total.

Table 1: Irrigation water in inches per foot of root-zone required for leaching to reduce a high salinity root-zone to a tolerable level for almond.

Target root-zone salinity (dS/m)	Average root-zone salinity before leaching			
	2.0	**3.0**	**4.0**	**5.0**
1.0	1.8	3	4.2	5.4
1.5	0.6	1.8	3.0	4.2
2.0	0.0	0.6	1.8	3.0

Table sourced from table 5.10 within the chapter "Salinity Management" of "The Almond Production Manual (ed. W. Micke, 1996; UC ANR Publication 3364).

In developing a program, its best to refill the profile early with irrigation water as all subsequent rainfall will aid the leaching program. In some soils this may take between 6-8 inches of water. Leaching should begin once the soil profile is filled. Smaller quantities of water applied either through rain or irrigation more frequently is the best way to move salts below the root-zone. After an irrigation, wait 3-4 days before the next water application. Any rain that falls should be counted into the leaching water total.

The leaching program should be completed by mid-January. It will take considerably more water and time to leach a fine textured soil than a sandy soil. Try to provide enough time to allow the soil to drain in order to prevent root disease. Do not wait until mid-February. Root expansion occurs in mid-January, and irrigating later than this could create anaerobic conditions, which kill the newly developed fine feeder roots. Soil sample after completion to determine the leaching program's effectiveness.

Leaching chloride and boron. Being toxic to the tree, chloride and boron should be leached if the soil analysis indicates they are at too high of levels. Chloride toxicity often occurs rapidly, showing up within a year or two when applying poor quality water. This is due to chloride being an anion, which is unable to stick to the soil particle. Thankfully, chloride will also leach rapidly due to its negative charge, and most chloride problems can be reduced with a modest winter leaching program. Boron tends to be held in the soil as a weak anion or neutral salt. It will require more water to leach than chloride, but not as much as sodium.

Irrigation during the rain, soil amendments, and infiltration. There are other considerations when trying to apply leaching programs. Growers using single or double line drip may want to also consider to irrigate during rain events. Applications of water during this time will help “push” the salt out of the root-zone. It will also aid in filling the profile or leaching. This practice is a concern for drip irrigation systems since the volume of wetted soil and root zone are diminished. Calcium-containing amendments should be utilized to help displace sodium from the soil CEC matrix. Depending on soil pH, this could either be gypsum or lime. If the water contains high amounts of calcium, it may also be suitable, but may require acidification in order to free up the calcium. If poor infiltration, run-off, or soil saturation occurs, irrigation run-times should be reduced. It may also be of use to utilize soil amendments to help with infiltration rates within the leaching program. These include calcium containing amendments, acidifying high pH water, and, if needed, soil surfactants.

The final thought. It may not be feasible to try and reduce the soil salinity back within the target range within a single year. This is especially true if the leaching program has been neglected over the past few years. In these cases, try to reduce the salinity levels by half to help reduce the gradual build-up of salts.

Other resources available at your local extension office or http://anrcatalog.ucanr.edu/:
The Almond Production Manual. 1996. UC ANR Publication 3364.
Agricultural Salinity and Drainage. 2006. UC ANR Publication 3375.
Drought Tip: Reclaiming Saline, Sodic, and Saline-Sodic Soils. 2015. UC ANR Publication 8519.


Figure 1 caption: Symptoms of sodium and chloride uptake toxicity within almond. Note the scorched tissue of the leaves with a yellowing halo that initiates at the leaf tip or edge.


Figure 2 caption: Salts tend to accumulate in the wetting pattern of the orchard. Concentrations of salt within the pattern may be several times greater than the irrigation water.