Salinity Chloride Interactions and their Influence on Avocado Yields

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Project Overview

Avocado is one of the most salinity sensitive horticultural crops, but is commonly grown in areas having saline irrigation water (an EC greater than 0.75 dS/m and chloride >100 ppm). Resulting problems associated with high soil salinity and chloride toxicity include reductions in fruit yield and tree size, lowered leaf chlorophyll content, decreased photosynthesis, poor root growth, and leaf scorching (Mickelbart et al., 2007). During recent years, salinity problems with avocado have become increasingly common as the cost for irrigation water has gone up and the availability of low salinity water for agriculture has diminished. This has resulted in requests for information on how water quality affects avocado yields so that growers can better manage salinity problems and make decisions on use of different water sources and root stocks.

As a general rule, there are two components of salinity management. These include the effects of total dissolved salts that reduce the fraction of water that can be taken up, and the effects of specific ion toxicities that occur due to chloride and sodium uptake by the trees. There are also other indirect effects of salinity on soil structure which affect aeration, root growth, and water infiltration.

Results of prior field studies show that when the total dissolved salt concentrations in the soil solution exceed an electrical conductivity (EC) of 4 dS/m, avocado trees are no longer able to extract water even if the soil is water saturated. This is due primarily to the osmotic effects of salts that control initial transport of water by osmosis into the root tissue. The resulting effects of TDS measured as EC on avocado yields have previously been estimated using a production function model developed by Oster et al. (2007) based on results from a multiyear study at Covey Lane. These data show that avocado yields are reduced by 65% for each EC unit increase above the threshold of 0.6 dS/m (Figure 1). By comparison, most irrigation water in S. California has an EC of 1 (~640 ppm TDS), which indicates even good quality water contains enough salt to reduce potential yields by 30%.

On the other hand, researchers in Israel contend that chloride is the main limiting factor. (Lahav, 2003). In their studies, the rule of thumb is a 12% loss of production for every milliequivalent of chloride in the irrigation water (1 meq/L Cl = 35.5 ppm).

Figure 1. Avocado production function model for irrigation water salinity (Oster et al., 2007).
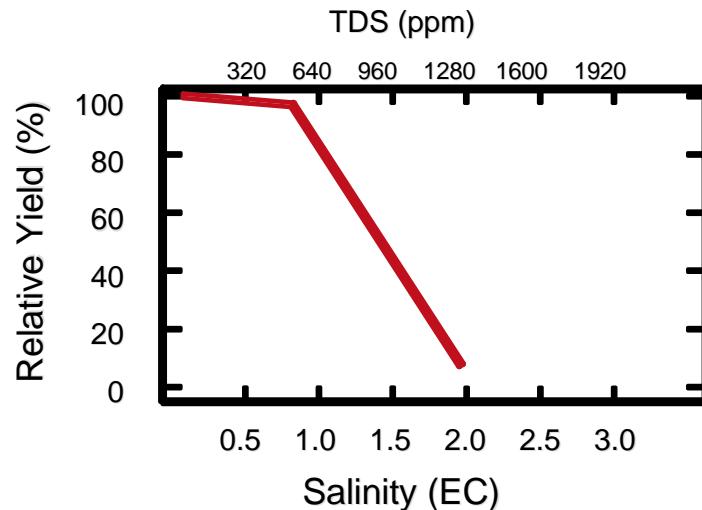
Although growers are alerted to chloride toxicity by appearance of leaf scorching, root growth is even more sensitive (Bernstein et al., 2004). This is problematic in that reduced numbers of fine roots may affect nutrient and water uptake well before chloride toxicity symptoms appear in the foliage. In a study by Bernstein and coworkers, the threshold NaCl concentration that causes root and shoot growth reduction occurred between 5 and 15 mM. A concentration of 15 mM NaCl decreased leaf biomass production by 10%, but induced a 43% reduction in the rate of root elongation and decreased the root volumetric growth rate by 33%. This 5 mM threshold is equivalent to approximately 200 ppm chloride, a level that is easily attained in saturated soils after 2 irrigation cycles without leaching, or after one irrigation cycle as the soil water dries to 50% of its available water holding capacity.

Previously most research on avocado and salinity has been conducted with Mexican rootstocks that are the standard for most of the industry. In recent years, new clonal rootstocks that were primarily selected for Phytophthora root rot resistance have been introduced, many of which also have improved salinity tolerance. However, there is no specific information available yet as to how these new rootstocks yield under conditions of different salinity (TDS) and chloride levels in the irrigation water. To answer this question, this research project is comparing avocado yields across a six county transect of the avocado growing region in California, from San Diego to San Luis Obispo. The project is in its first year and the first data are now being collected and analyzed at the time of this report.

Since there are many factors that affect avocado yields in addition to salinity, this experiment represents a statistically complex study in which we need to collect data on a wide range of variables, some of which interact with salinity through effects on soil structure, root growth, and water and air infiltration into the soil. There are also management practices that vary from orchard to orchard that include timing and frequency of the irrigation sets, and the leaching program that controls salt accumulation in the root zone. Still other factors include spatial variability in the sprinkler spray patterns and irrigation uniformity.

An exciting aspect of this research is the availability of new statistical tools that will enable us to examine the correlations between the different variables and separate out the effects of salinity and chloride on yields for the different rootstocks. At the same time, the extensive data collection obtained in this study will provide a detailed view of all of the management and soil and water factors that affect avocado yields. The primary statistical approach employs an artificial neural network model (ANN) that uses pattern recognition software to examine interrelationships between all of the variables. These interrelationships can then be examined to determine the percent of variation in yields that are attributable to different variables (Mele and Crowley, 2007). The ANN statistics are now widely used in pattern recognition problems in medicine, handwriting and speech recognition, business and military applications. A further benefit of this approach is that it may be used to construct a general model that can be placed online on the internet in the form of a questionnaire. Thus the long range goal of this research is to establish a questionnaire in which growers may enter information on their water quality, soil properties, and rootstocks to obtain a yield prediction, and cost benefit analysis of different water quality variables, as well as specific recommendations on irrigation management and leaching programs.

Table 1. Variables to be analyzed.

Soil Data	Management	Rootstock Performance
Texture (clay, silt, sand)	Irrigation water quality (TDS, Cl, Na, SAR)	Fruit yield
Salinity - TDS distribution (0-10, 10-20, 20-30 in)	Irrigation scheduling (duration, frequency)	Macronutrient uptake (N, P, K, Ca, Mg)
Bulk density	Planting density	Micronutrients
pH	Leaching cycles	Na, Cl leaf contents
Organic matter, mulching	Fertilization, gypsum	Phytophthora
Hydraulic conductivity	Canopy management	Root growth

Progress to Date

Site Selection. For the first year, a total of 12 locations have been selected for inclusion in the salinity evaluation. These orchards represent the 6 counties where avocados are grown in S. California (Figure 2). The site locations include 2 orchards in Riverside county, 3 in Santa Barbara, 2 in San Luis Obispo, 2 in San Diego, 1 in Orange County, and 3 in Ventura. These locations meet all of the criteria specified in our planning meeting with the CAC subcommittee with respect to tree age, root stock selections, and variation in irrigation water qualities. The total number of rootstocks in the trial include 60 Duke 7 trees (4 locations), 105 DUSA (5 locations), 60 nonclonal Mexican (2 locations), 45 Thomas (3 locations) and 120 Toro Canyon (8 locations).

Figure 2. Locations of orchards included in the salinity research project.
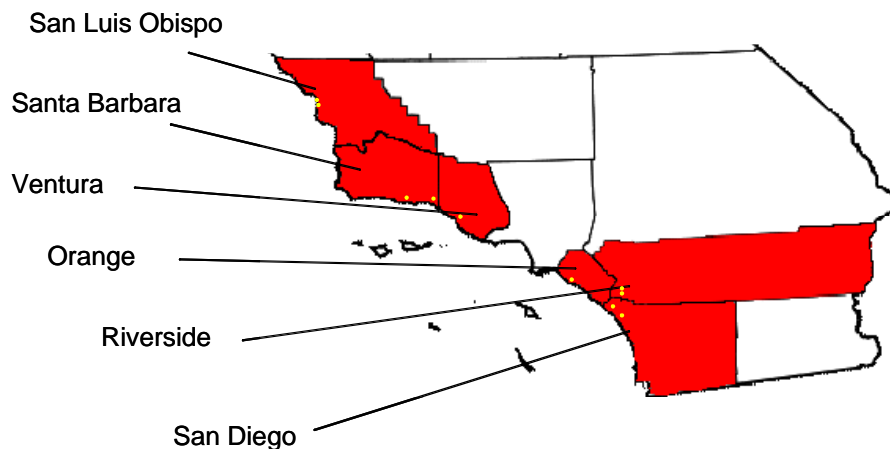

Startup Activities. During our initial site visits, we have evaluated the condition of the trees, installed Watermark data loggers at each orchard, photographed representative trees to document their condition, taken soil samples, and have discussed the management strategies with the owners and grove managers. Initial site assessment includes collection of information on irrigation scheduling, type of irrigation system used, leaching practices, water source and historical salinity problems, fertilization and canopy management practices. The project details are further reviewed with each collaborator. In addition to the data loggers, we have installed suction lysimeters at 6 and 12 inch depths for analysis of soil water salinity during the year.

In subsequent visits, we have been checking irrigation water distribution around the sprinklers to determine the effective wetting zone, and determine the precise location for soil and root sampling. We have begun measurements of hydraulic conductivity (which decreases with soil sodicity), and are collecting data from the

watermark systems to guide grower irrigation and leaching practices. Detailed records and maps for each site have been catalogued, and we are designing a web site that will provide online access to our project and data records by all interested parties.

Watermark Data. An important aspect of this research is the development and standardization of irrigation management practices across the different sites. This is being facilitated by the installation of water monitoring equipment to determine the efficacy of soil moisture control and leaching. The Watermark data loggers at each location use gypsum probes that are installed at three different depths, with individual probes at 6 and 12 inch depths for three trees, and another probe at 24 inches to monitor leaching. In some cases, growers have been able to determine that they are overwatering, and have been able to cut back while still maintaining a leaching fraction. A typical output from the data logger is shown in Figure 3.

Figure 3. Graph of Watermark probe data for three different depths between May and June 30, 2008 at Rancho Mission Viejo in San Diego.
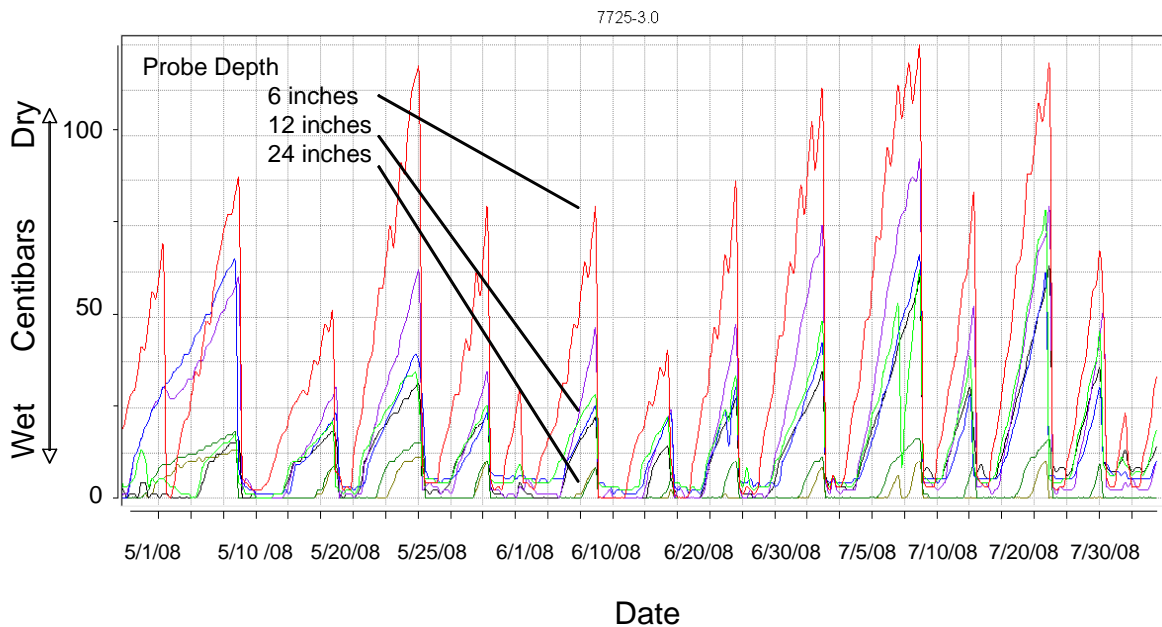
As shown in Figure 3, the top six inch depth where most of the feeder roots are typically located in the soil profile are subject to soil drying, whereas the 12 inch depth remains relatively moist. The cyclical pattern documents complete soil wetting with each irrigation at approximately 10 day intervals in May followed by more frequent watering in July. The soil rewetting at 24 inches at each interval indicates that soil leaching is occurring with each irrigation set.

Ongoing Activities. At the time of this report, we have completed the majority of leaf, soil, and root sampling for all of the locations. The leaf tissue and soil analyses are being conducted by Fruit Growers Laboratory, and the data will be available for analysis in January. Yields this year are expected to be abnormally low, but yield data will be available by June at which time we will include this data into our statistical analysis. Table 2 below provides our schedule of planned activities for the coming year and remainder of the project.

Table 2. Schedule of Planned Activities Year 2-4

Activity	Schedule Date
Irrigation uniformity check	Ongoing
Irrigation monitoring and site visits	Continuous
Tree selection and permanent tagging	July – August 2008
Leaf, soil, root density sampling	Sept – Oct 2008
Tissue, soil, water chemical analyses	Nov 08 – Jan 09
Fruit harvest data collection	Jan – April 2009
Statistical analyses completed Year 1	May – June 2009
Install Additional Sites	Jan – March 2009
Repeat Above Activities	Years 2009 - 2011

Benefits of the Research to the Industry

This research will provide several benefits to the avocado industry. These include:

- Cost benefit analysis for irrigation water quality versus fruit yields over the range of salinity levels that occur in water supplies currently used by avocado growers.

- Optimization of irrigation regimes for use of saline irrigation waters based on management of chloride versus total dissolved salts.

- Basic information on mechanisms of salinity stress and tolerance in avocado rootstocks.

- Recommendations for rootstock selections based on field performance data.

- Improved guidance to growers for salinity management strategies.

Achievements and Future Prospects

This research has initiated an urgently needed study of salinity and chloride effects on avocado yields. The data collected in this study also provide a composite analysis of the effects and interactions of soil chemical and physical variables that affect avocado yields and will provide an overall assessment of the importance of salinity in relation to avocado production.

A larger question that remains to be addressed in the future is the extent to which the new clonal rootstocks being evaluated here are able to tolerate still higher levels of chloride that may be expected with greater reliance on groundwater and the switch to reclaimed water that is ongoing for the Metropolitan and Irvine Water Districts. None of the commercial orchards in our current trial use water having greater than 100 ppm chloride, although most are affected to some extent by salinity problems, especially on heavy clay soils that are difficult to leach. In many locations, saline groundwater is available should the growers decide to pump from local wells, and growers may also elect to blend their water in storage ponds before it is applied.

In the near future, irrigation water to the UC South Coast REC in Irvine will be switched to reclaimed water. In the past, water management districts have set 100 ppm Cl as a target for maximum chloride levels for domestic water, which was based in part on the need to reduce Cl to acceptable levels for salinity sensitive crops such as avocado and strawberry. By comparison, reclaimed water to be provided by the Irvine water district (Michaelson Plant) contains an average of 153 ppm chloride with levels reaching as high as 170 ppm (irwd.com). Options to circumvent this problem are to blend the water to reduce chloride levels, reduce chloride by treatment at the water treatment plant, or convert to new salt tolerant rootstocks. Before these expensive decisions can be made, further research is needed to field validate the threshold toxicity levels for chloride and resulting yield losses that are predicted by production models as chloride levels exceed this concentration. The entire issue has now come to a head as water shortages and cutoffs have forced a switch to reclaimed water that contains much higher levels of chloride. This chloride can be removed by expensive reverse osmosis methods either at the treatment plant or at the orchard, but the degree of water treatment that is needed must first be resolved by thorough scientific study. We hope to commence research examining the impact of the IRWD reclaimed water on performance of avocado at the UC South Coast REC. We are currently seeking additional funding to take on this research activity. The results of this effort will complement the current work described in this report.

We will be continually providing all new information as the results from our study become available during the next three years of this project.

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