Physiology and Management of Salinity Stress and Nitrate Leaching in Almond: Influence of Rootstock, Scion and Supplemental Nutrition

Project No.: HORT20.Brown

Project Leader: Patrick H. Brown
530-752-0929
3045 Wickson, UC Davis, One Shields Ave, Davis CA 95616
phbrown@ucdavis.edu

Project Cooperators and Personnel:
Francisco Valenzuela, UC Davis
Daniela Reineke, UC Davis

A. Summary

The goal of field research in 2020 was to investigate the implications of the conclusions drawn from research conducted in previous years using a simplified system (split-root system in the greenhouse) for irrigation and fertigation management in a drip-irrigated almond orchard under saline conditions. Experiments were conducted using four year old almond trees grown outdoors in large (8 m long, 2.2 m wide, 1.2 m high) fiberglass bins that were exposed to three different irrigation/fertigation treatments (low frequency saline (LFS), high frequency saline (HFS), high frequency non-saline (HFNS)). It was shown that application of saline water (LFS) significantly increased leaf Cl concentration but increasing the irrigation/fertigation frequency in presence of salinity (HFS) did not significantly decrease leaf Cl concentrations. HFS and LFS did however alter leaf Cu, Zn, Fe, and Mg concentrations, indicating that irrigation/fertigation frequency may still have an impact on plant growth. The absence of an effect of irrigation/fertigation frequency on Cl may be explained by insufficient nutrient concentrations within the non-saline zone created by the drip emitters or due to a smaller than expected difference in salinity and nutrient distributions between the HFS and LFS treatments. The difference with respect to other elements between the two treatments could either be an effect of the salinity dynamics caused by the different systems or by the different irrigation frequency and therefore moisture dynamics itself. As expected, a lower salinity zone under the area wetted by the drip-emitters (only LFS; soil samples for HFS are still being processed) *was observed and root abundance was higher in these areas, confirming the concept of salinity-heterogeneity under drip irrigation and illustrating the preferential exploration of non-saline zones by roots. Future data analysis will show to what degree the root distribution pattern is affected by irrigation/fertigation frequency and how nutrient availability is distributed in relation to these patterns.*

B. Objectives *(300 words max.)*

1. Improve our understanding of plant response to spatial/temporal variation in ion distribution in the rootzone
2. Determine which specific mineral element is responsible for heterogeneous root response
3. Determine how water and ion uptake responds in different root ages and types (in progress)
4. Determine how root architecture parameters respond to heterogeneous nutrient/salinity stress
5. Determine the influence of nitrification inhibitors on dynamics of N in the wetted root zone, the impact on root activity and growth and N leaching (in progress)

C. Annual Results and Discussion

Objective 1: Improve our understanding of plant response to spatial/temporal variation in ion distribution in the rootzone

A field experiment is being conducted with the goal to investigate the implications of the findings from the greenhouse experiments conducted in previous years for irrigation and fertigation management in the orchard. Results from split-root experiments in the greenhouse have shown that trees are able to preferentially use non-saline zone within an overall saline rootzone as long as sufficient nutrient concentrations are sustained within this zone. Based on this, it was hypothesized that in a drip-irrigated almond orchard, trees will be relatively little affected by soil salinity as long as a high irrigation frequency is used that continuously leaches salt out of a small zone under the drip emitter and a high fertigation frequency sustains a sufficient nutrient concentration in this zone at all times.

The data collected in the field experiment so far show that as expected, a low-salinity zone appears under the area wetted by the drip emitter (only LFS; soil samples for HFS are still being processed). The soil salinity of samples 5 to 8 and 11 to 12 (Fig. 1a) which were taken directly under the infiltrating surface have soil salinities between 1.5 dS/m and 2 dS/m, which is close to the irrigation water salinity of 1.7 dS/m. Higher salinities were observed in the middle between the driplines and at the edges of the wetted area, where soil salinity can reach values exceeding 10 dS/m. This means that a low salinity zone, from which roots could preferentially take up water to avoid the salt, does indeed exist and the conditions may therefore be similar to the ones simulated in the split-root experiment.

The root concentrations show that, as expected, roots preferentially explore the zone under the wetted area and root concentrations drop off towards the margins of the wetted area. Root abundance is particularly high right under the drip emitter (samples 6 and 12). Surprisingly, root concentration in the middle between the two wetted areas (samples 9 and 10) were about as high as in most of the samples that were taken from directly under the wetted areas, even though the salinity in these samples was quite high (11.9 dS/m and 5.0 dS/m, respectively). This suggests that factors other than salinity (e.g. soil moisture or nutrient availability) may be important in controlling root distribution.

Analysis of soil samples is still incomplete for two trees in the HFS treatment and three trees in the LFS treatment. A comparison of the trees in the LFS treatment with the trees in the HFS treatment will be used to determine whether the irrigation/fertigation frequency has an impact on EC and/or root distribution pattern. Additional soil sampling at the end of 2021 will also show whether there are differences between the soil types and the rootstocks. Another interesting question that will be answered with the additional data is whether the observed patterns can be predicted by a model.

The irrigation/fertigation treatment had a significant effects on leaf Mg, Zn, Fe, Cu and Cl concentrations (Fig. 2) but not on leaf N, P, K, S, B, Ca or Mn concentrations (data not shown). Chloride concentrations differed significantly by rootstock, soil, and irrigation treatment. Chloride concentrations were lower for the Viking rootstock than for the Nemaguard rootstock and lower for the sand than for the loam soil. The application of saline water markedly increased leaf Cl concentrations in the saline treatments. The difference between the HFS and LFS treatments with respect to Cl is, however, not significant. Compared to the LFS treatment, the HFS treatment is characterized by overall higher concentrations of Zn and Cu, and lower concentrations of Mg (for Nemaguard).

These results indicate that increased irrigation water salinity resulted in increased uptake of Cl and accumulation in leaves which may result in decreased tree growth and yield in the long term. The high frequency irrigation/fertigation frequency approach (HFS) did not reduce Cl concentrations relative to the low frequency approach (LFS) in this case, which is in contrast to our hypothesis that a high frequency system will reduce Cl uptake by helping to sustain a zone of low chloride levels, and sufficient nutrient concentrations and moisture that allows the tree to reduce root activity in high-chloride zones. However, as has been shown in the greenhouse experiments, nutrient distribution in the soil is another important factor determining the spatial distribution of root activity and the management approach chosen may not have been sufficient to retain enough nutrients in the non-saline zone. Additional measurements of soil nutrient concentrations in 2021 will provide more insight on how nutrients are distributed in the rootzone. Another possible explanation of the lack of an effect of irrigation/fertigation frequency on leaf Cl concentrations may be that the spatial distributions of salinity within the rootzone may not have been as different between LFS and HFS as was originally expected.

Uptake of nitrogen was apparently unaffected by salinity as no significant difference in leaf nitrogen was found between the saline and nonsaline treatments. This may change in the next year as soil salinity increases further. Also, leaf nitrogen oncentrations showed that nitrogen levels were overall low. Bigger differences in N uptake may be expected when nitrate supply is increased in 2021.

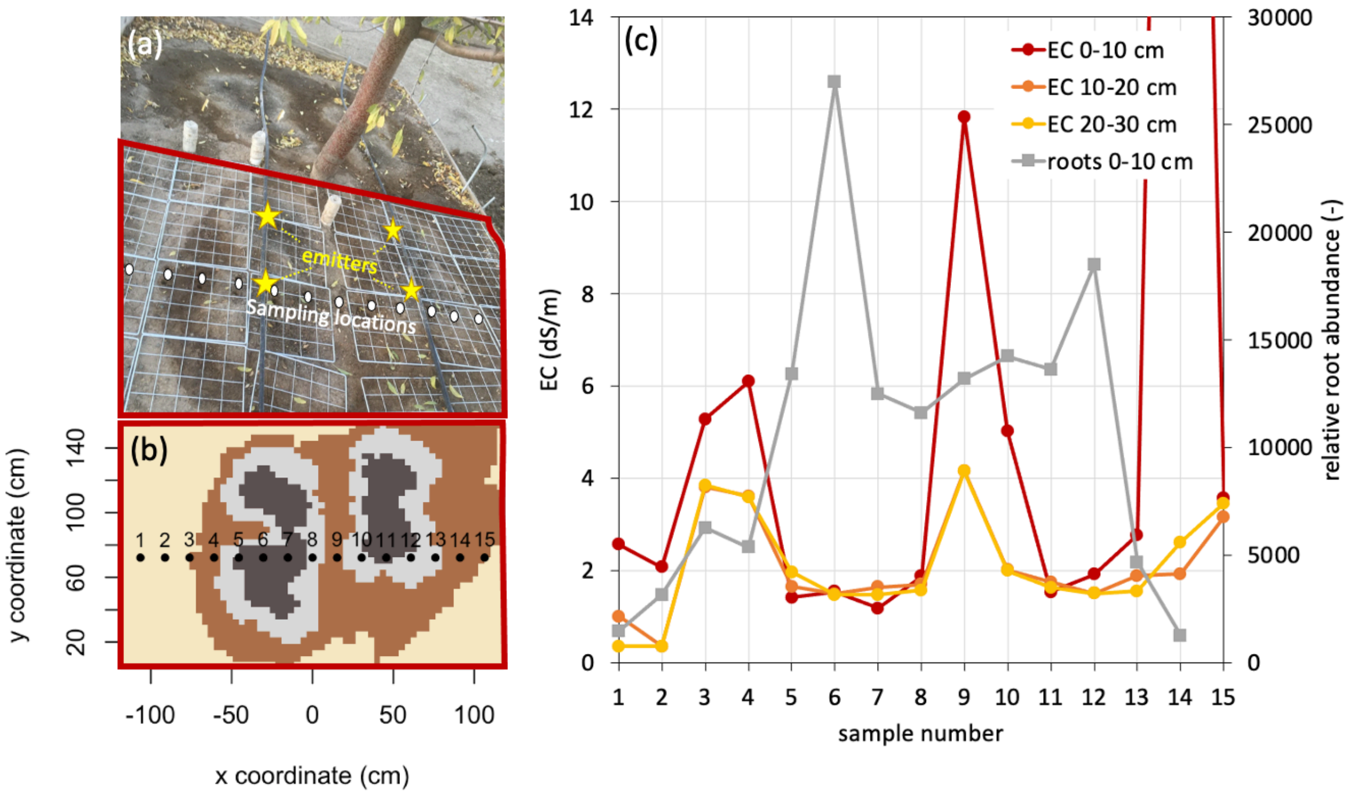

Fig. 1: Soil sampling results. (a) picture of the sampled surface area in tub 22 (LFS, Viking, sandy loam). (b) Sampled area as a soil color map illustrating the areas wetted by the drip emitters (areas that are flooded during irrigation in dark grey) and the location of the 15 soil samples. (c) Electrical conductivity (EC) of the saturated paste extract of the samples at three different depths and relative root abundance at 0-10 cm depth.

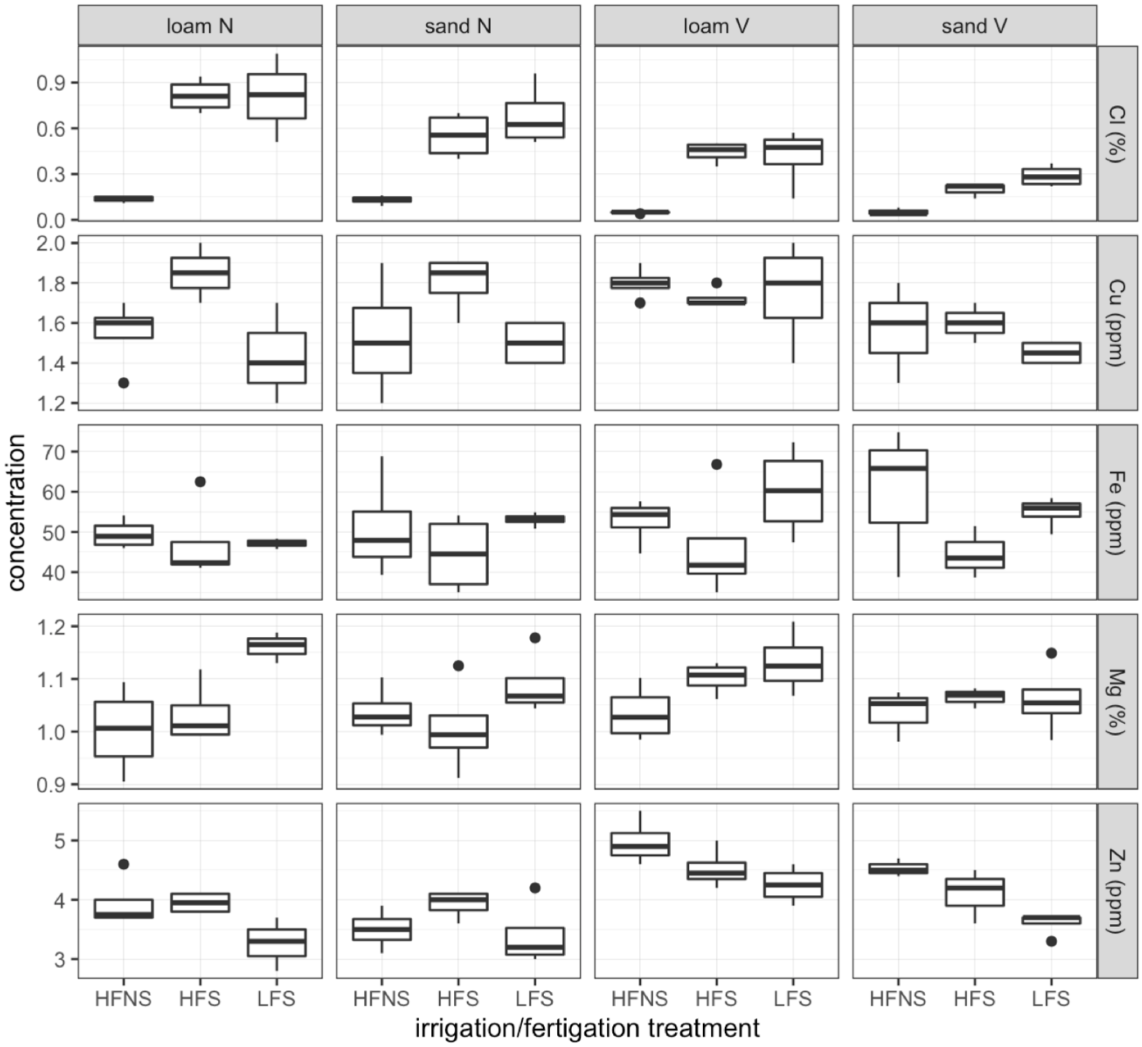

Fig. 2: Leaf element concentrations in August 2020 for the different irrigation/fertigation treatments (HFS: high frequency, HFNS: high frequency, low salinity, LFS: low frequency), rootstocks (N: Nemaguard, V: Viking) and soil types (sandy loam and loamy sand). Only the elements that showed significant differences between irrigation/fertigation treatments are shown.

Objective 2: Determine how root architecture parameters respond to heterogeneous nutrient/salinity stress

Figure 3 shows the horizontal root distribution (perpendicular to the driplines) in the rootzone of 6 trees (3 in the HFS treatment and 3 in the LFS treatment) at two different depths measured using a mini-rhizotron camera. The patterns of root distribution are different between trees even within the same treatment. One reason for this is probably that even though the drip emitters are approximately at the same locations with respect to the tree, the actual locations where the water infiltrates into the soil are different between the trees due to the microtopography of the soil surface. Due to the large variability between trees, a clear difference between the HFS and LFS treatments hasn't been observed yet. However, it seems that root density is overall higher at 80 cm depth than at 30 cm depth, which may be due to the rootzone being restricted by the bottom of the fiberglass tub. Comparisons with the locations of the wetted areas and measured distributions of soil salinity and nitrate concentrations with the patterns observed will allow for a more detailed analysis of how root distribution is determined by these parameters and to what degree root distribution can be predicted for a given management system.

The root data from the minirhizotron is subject to a high degree of measurement variability and we are currently reconciling apparent differences between the direct soil sampling determination or root activity and rhizotron measurements.

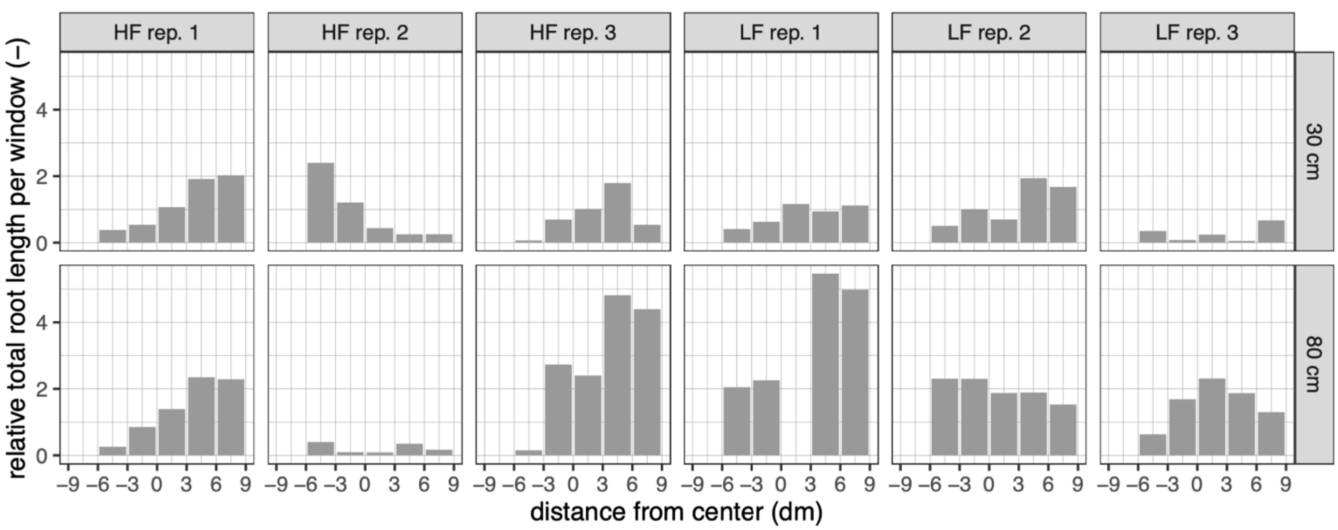

Fig. 3 Horizontal root distribution of the Nemaguard trees across the width of the tub at two different depths (top = 30 cm, bottom = 80 cm) for the high frequency irrigation/fertigation treatment (HFS) and the low irrigation/fertigation frequency treatment (LFS). Each treatment was replicated three times and data shown was collected in August 2020. Due to difficulties in the measurement procedure, there may be an offset between the center in the graphs and the center of the tub that has not yet been corrected for.

D. Outreach Activities

Presentation at the WPHA/FREP conference, October 28, 2020
Title: Improving nitrate and salinity management strategies for almond grown under micro-irrigation
Number of participants: over 200
Type of audience: Participants from academia, agricultural consulting, farming, and state and federal agencies

E. Materials and Methods *(500 word max.)*:

The experiments corresponding to objectives 1 and 5 (field validation part) were conducted using 48 almond trees (Nonpareil) grown in 8 m long, 2.2 m wide and 1.2 m deep fiberglass bins (2 trees per bin). The salinity of the irrigation water was increased from 0.3 dS/m to 1.7 dS/m by adding salt in the saline treatments. The experimental design is a 3x2x2 factorial design with three different irrigation/fertigation treatments, two different rootstocks (Nemaguard and Viking), and two different soils. There are four trees within each treatment. The irrigation/fertigation treatments are a low frequency treatment (LFS; irrigation every 4 days and fertigation every 8 days), high frequency treatment (HFS; daily irrigation and fertigation) and high frequency treatment with non-saline water (HFNS, daily irrigation and fertigation without added salt). All treatments were fertigated with calcium nitrate and no other nutrients were applied via the irrigation water.

Soil sampling
Soil samples were taken from treatments HFS and LFS (Viking and sandy loam treatments only) in October 2020. Fifteen samples from 0-30 cm depth were taken from the rootzone of three trees in each of the two treatments (HFS, LFS) along a cross-section across the width of the tub (Fig. 1b) using a 30 cm long auger drill bit. After removing the auger drill bit from the hole, the soil on the auger bit was divided into sections from 0-10 cm, 10-20 cm and 20-30 cm depth. The electrical conductivity (EC) of the 1:2 soil-water extract of each sample was measured in the laboratory. The EC of the 1:2 soil-water extract was converted to the EC of the saturated paste extract using a relationship previously measured in the laboratory using the same soil. Roots were separated from the soil by passing the soil-water suspension through a No. 35 sieve and manually sorting the material remaining in the sieve using tweezers and pipettes. Root fragments were then distributed on a sheet of paper while still wet and scanned using a document scanner. A relative root abundance was derived from the size of the area that was classified as “root” using a K-means classification approach.

Leaf sampling
Leaf samples wer taken in all treatments in June and August 2020. One sample per tree was taken and leaves were sampled from about 15 non-fruiting spurs distributed around the tree at about 1.5 meters height. After transferring to the laboratory in ice-filled coolers, the leaves were washed, dried at 60°C and ground. The samples were then sent to the UC Davis Analytical lab and analyzed for N, P, K, S, B, Ca, Mg, Zn, Mn, Fe, Cu and Cl. Differences between treatment were tested by means of ANOVA for each element separately.

Mini-rhizotron
Mini-rhizotron access tubes were installed horizontally across the whole width of the tub in the rootzones of the HFS and LFS treatments (Nemaguard and sandy loam treatments, only) at two different depths. Pictures of the roots were taken bi-weekly in 2019 and 2020 with a CID602 Root Imager (CID Biosciences, Inc.) and analyzed using the Rootfly software (Clemson University).

F. Publications that emerged from this work

No publications yet.