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

Project No.: HORT20.Brown

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A. Summary

Heterogeneous ion distribution in soils is a characteristic of micro-irrigation systems. Improving the understanding of root responses under those conditions can help to develop more accurate management practices of fertigation and irrigation. During past years we have demonstrated that root responses under heterogeneous saline conditions are quickly reversible, proportional to salt concentration and have the potential to be driven by nutrients. However, we were not clear yet about which mineral elements can modify patterns of water uptake and root allocation. During the past year, after some pre-experiments to screen potential mineral elements to be studied, we chose continuing our research focusing on nitrogen and potassium. Our result suggests a) a well-balanced root environment is required to maximize nutrient uptake and minimize losses of fertilizer in the presence or absence of salinity. b) absence of N or K in sub-zones of the root system of a single plant leads decreases on uptake of other mineral elements, increasing chances of fertilizer losses to the environment, c) K is a key nutrient which can be used to manipulate root responses under salinity, but further study under field conditions is required to validate those results.

B. Objectives

1. Improve our understanding of roots responses when changes of salt distribution in the root zone are observed **=> Pot studies and hydroponic studies completed, field validation in process (lysimeter experiment).**
2. Study of different mineral elements which may be used to manage non-uniform saline conditions under micro-irrigation system **=> Hydroponic studies**
3. What root characteristics are responsible for differential root zone response and how does this affect salt and nitrate uptake? **=> Pot studies Completed, field validation in process (lysimeter experiment).**

C. Annual Results and Discussion

The results of this year are based on the study of nine independent hydroponic experiments. In the first stage, three experiments were used to screen mineral elements to be tested and to test different solutions which helped in later experiments. The rest of the experiments were used to test our hypotheses. Experiments were replicated to double-check the obtained results. Figure 1 shows a summary of the different patterns of water uptake measured for each tested hypothesis.

a) Treatments of reference: Uniform saline and control treatments showed no differences in water consumption in each of the treated roots. All non-uniform saline treatments showed a decrease in water consumption from saline stressed roots which induced an increase in water consumption on the other side (Control). The absence or presence of nutrients in saline-treated roots has a significant effect by increasing strongly the magnitude of the water consumption measured under lack of nutrients and a softer increase under the presence of nutrients.

b) Control versus nutrient-depleted root sub-zones (Side A: Control and Side B: X-depleted). Both root treatments (K and N depleted) presented a tendency to increase water consumption from the control side of the roots with respect to the X-depleted side. However, in the case of the K-depleted treatment, this increase was observed in earlier stages compared to N-depleted treatment.

c) Control versus saline and nutrient-depleted treatments (Side A: Control and Side B: X-depleted+NaCl). Roots treated under heterogeneous saline and nutrient-depleted conditions (N and K depleted) showed a decrease in water consumption compared to roots treated under control. Nevertheless, this decrease observed in both plant treatments is greater with respect to the treatment Nutrient/Nutrient+NaCl (from the reference treatment group), which suggests that the lack of N and K in the nutrient saline solution can induce higher decreases of water uptake than a nutrient-balanced saline solution.

d) Nutrient depleted versus saline root sub-zones (Side A: X-depleted and Side B: Control+NaCl). For the case of saline-treated roots, a two-step response is observed for water uptake. First, a saline-dominant response was measured when salinity was applied (day 0) and in a second stage (days 3, 6 and 9), water uptake increased even when salinity was present. This suggests a K-deficiency-dominance induced by roots exposed to a K-depleted solution (Side A) which overpasses the saline response. In the case of the N-depleted treatment, this response was not observed, but a tendency to expect a similar response was observed after 9 days. Possibly due to the time scale of the experiment, the secondary response was not observed in the case of N.

Take home message from these results:

- The location of nutrients in the root-soil volume determines the location where almond roots will be active. Controlling the distribution of nutrients in root sub-zones has the potential of being a useful tool to minimize root activity in saline root zones. K is a key element for this purpose. Unavailability or deficiency of K in the soil could modify the pattern of water uptake, inducing root exploration to areas of the soil where K may be available. Studying and understanding the deposition of salts and mineral elements in the root-zone under micro-irrigation is key to give correct management advice when salinity is present.

Figure 2 shows a panel with net uptake for different mineral elements over time for each tested hypothesis.

a) Treatments of reference: Uniform saline and control treatments showed no differences in nutrient uptake. Results of only one non-uniform saline treatment are presented (water samples of the other treatment are still being analyzed). The non-uniform treatment presented shows how roots from the control side can compensate completely net uptake of N and P, but this compensation is not observed with Mg, S, K and Ca.

b) Control versus nutrient-depleted root sub-zones (Side A: Control and Side B: X-depleted). Lack of K in part of the root decreases net uptake of N, Mg, P, S and Ca with respect to the control side. Lack of N has a similar effect except for S.

c) Control versus saline and nutrient-depleted treatments (Side A: Control and Side B: X-depleted+NaCl). Roots treated under heterogeneous saline and nutrient-depleted conditions (N and K depleted) showed a decrease of net nutrient uptake with respect to control for all measured elements.

d) Nutrient depleted versus saline root sub-zones (Side A: X-depleted and Side B: Control+NaCl). Increment of net uptake for all mineral elements was measured in saline-treated roots when the other treated side has a depletion of N or K (S is an exception in N-depleted roots).

Take home message from these results: Well-balanced fertilization is required to optimize nutrient acquisition. Depletion of N or K in some areas of the root system showed net uptake decreases of other mineral elements by those roots which increases the chances of nutrient losses to the environment.

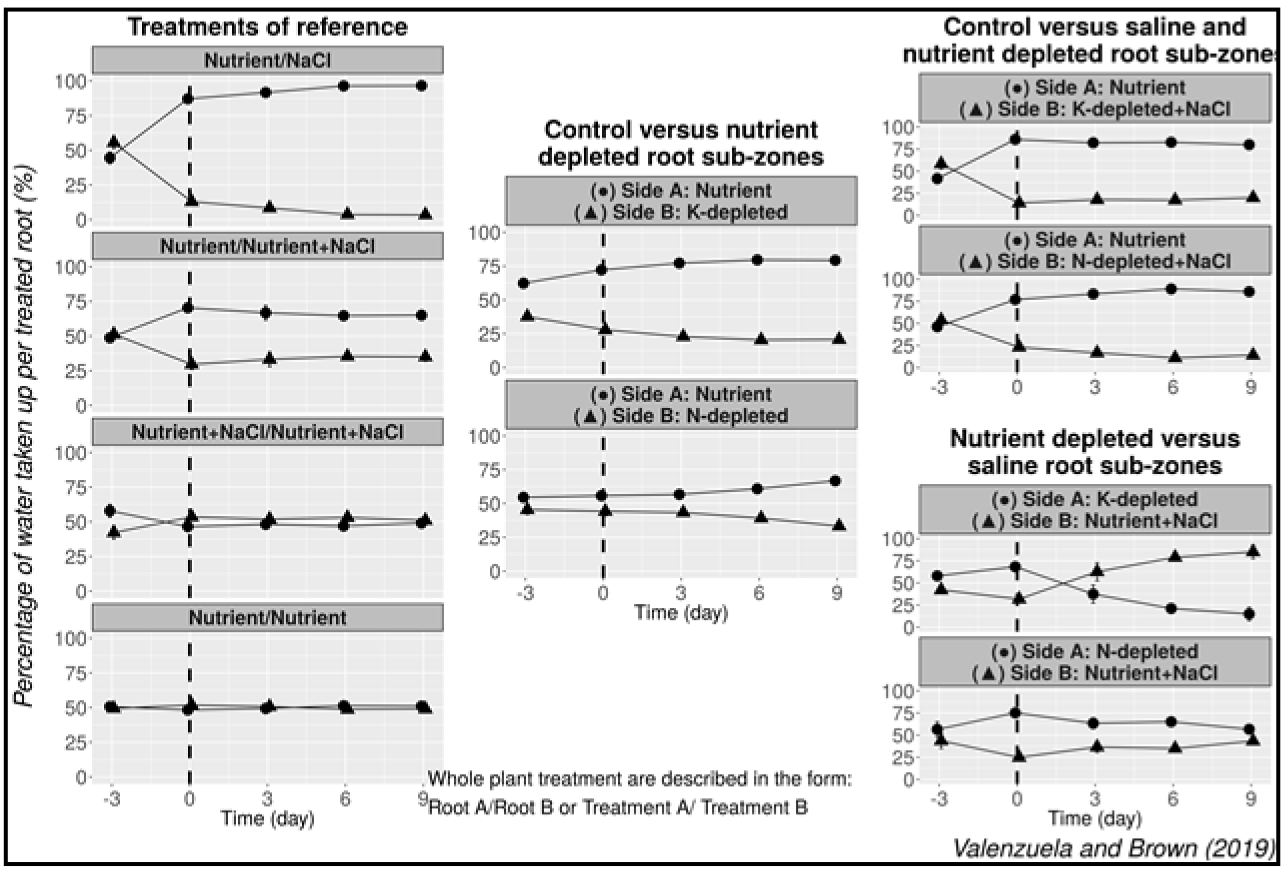

Figure 1.- Daily percent of water consumption per root side in a split root system under hydroponics. The vertical dashed line (--) shows the time when the treatment application started. Dots (●) represent treatments applied to the side A and triangles (▲) to the side B. Solution tested consisted in: Nutrient: nutrient-balanced solution; Nutrient+NaCl nutrient-balanced solution + 50 mM of NaCl; X-depleted nutrient-balanced solution without N or K; X-depleted+NaCl nutrient-balanced solution depleted of N or K + 50 mM of NaCl; and NaCl solution with only 50 mM of NaCl.

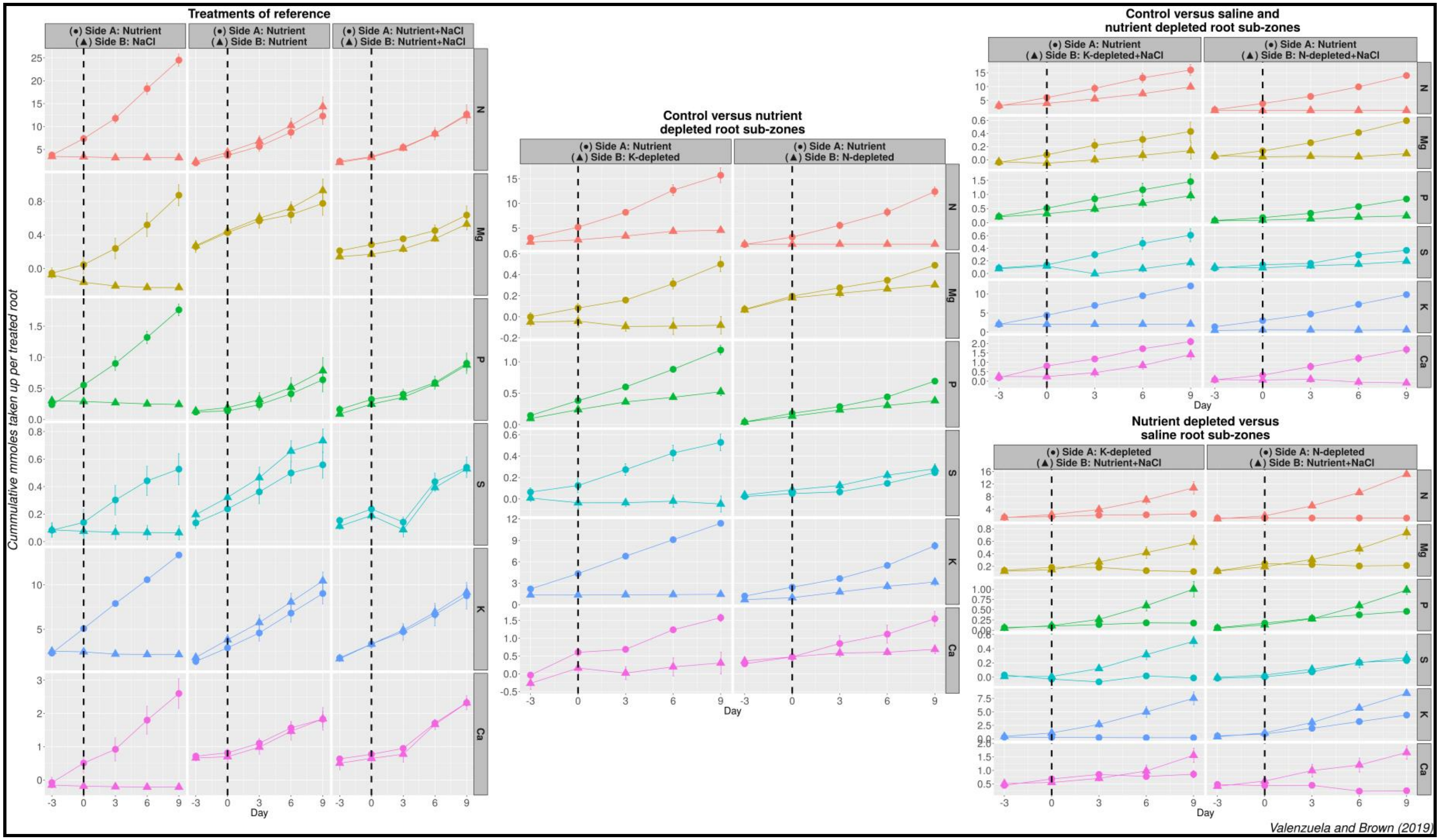

Figure 2.- Cumulative net uptake of N, Mg, P, S, K and K per root side in a split root system under hydroponics. The vertical dashed line (--) shows the time when the treatment application started. Dots (●) represent treatments applied to the side A and triangles (▲) to the side B. Solution tested consisted in: Nutrient: nutrient-balanced solution; Nutrient+NaCl nutrient-balanced solution + 50 mM of NaCl; X-depleted nutrient-balanced solution without N or K; X-depleted+NaCl nutrient-balanced solution depleted of N or K + 50 mM of NaCl; and NaCl solution with only 50 mM of NaCl.

D. Outreach Activities

Three field days were held in Fresno, Stanislaus and Chico on March 14th, 16th, and 19th, 2019 respectively. A summary of each study being performed in our lab was presented to growers.
On August 29-30th, 2019. A presentation that included the results presented in this report was given in China Agricultural University (CAU).

E. Materials and Methods

A split-root hydroponic system, where roots of each plant were divided into two equal parts (Root A/Root B), and treatments consisted of paired combinations of non-saline, non-saline depleted of N or K, nutritional-saline, nutritional-saline depleted of N or K and only saline solutions. Treatments were applied for a nine days period. Water samples of the nutrient solution of each pot were taken before treatment application (day -3), and once treatment started (days 0, 3, 6, and 9). Sampling consisted of a 20 mL solution taken early in the morning right after nutrient solutions were refreshed and another 20 mL taken by the end of the day. The volume of the pot was kept constant during the period measured using mariotte bottles, this allowed to estimate the amount of nutrients and water taken up per each pot. Once the experiment was finished, plants were harvested in order to quantify nutrient content and biomass allocation of different tissues.

F. Publications that emerged from this work

Results of the work summarized in this report will be presented in the IX International Symposium on Mineral Nutrition of Fruit Crops hold on June 2020 in Israel. From this presentation/poster (no defined yet) a peer review paper will be published.
During the last Almond Board Conference, a poster was presented with a part of the results presented in this document.