Determination of Root Distribution and Physiological Parameters of Nitrogen Uptake in Almonds to Optimize Fertigation Practices

Project No.: **12-PREC5-Brown**

Project Leader: Patrick Brown
Department of Plant Sciences, M-S 2
UC Davis
One Shields Avenue
Davis, CA 95616
530.752.0929
phbrown@ucdavis.edu

Project Cooperators and Personnel:
Andres Olivos, UC Davis
Blake Sanden, UCCE-Kern County
Paramount Farming Company

Objectives:

- Determination and characterization of patterns and biological dynamics (K_m, V_{max}, $C_{min/max}$) of tree nutrient uptake and the relationship to soil nutrient concentration, tree demand and time.
- Determination of almond root phenology and characterization of root distribution and uptake activity as influenced by irrigation source, irrigation management and plant characteristics.
- Determine the explicit nitrogen uptake and demand dynamics for almond. Integrate this information into the model (in collaboration with ongoing Brown project).
- Demonstrate the efficacy of the approach in a field setting.

Interpretive Summary:

Optimal fertilization practice can only be developed if knowledge of the 4 R's (right source, right rate, right place, and right time) is explicitly developed for the almond production context. To optimize nutrient use efficiency in fertigated almond, it is essential that fertilizers injected into an irrigation system are provided at the optimal concentration and time to ensure that deposition patterns coincide with maximal root nutrient uptake. This project has been designed to provide critical information about root physiology and phenology, and the interaction with soil nutrients and fertigation practices. Results from the different treatments indicate that root physiology is dependent on current soil nutrient status as well as current plant nutrient status. In addition, different fertigation practices showed that applying the same amount of fertilizers and reducing its concentration may be a viable fertigation management strategy to increase efficiency and reduce groundwater contamination.

Materials and Methods:

In order to achieve the objectives proposed in this project, two experimental trials have been used contrasting different rates of nitrogen (N), fertigation methods and irrigation methods.

1. <u>Nitrogen rate experiment</u>

The trees used in this experiment have been selected from among those currently under investigation in related Almond Board projects (Brown/Smart/Sanden/Hopmans). The orchard is a high producing 13 year old Nonpareil/Monterey planting located south of Lost Hills in Kern County. The existing experiments provide preliminary individual tree data on yield, soil and plant water (neutron probe and plant based), plant nutrient status (5 in-season leaf samples), tree nutrient demand (sequential crop estimation and determination), leaf area index and photosynthesis and Et_0 (evapotranspiration). The ongoing project of Brown has already established very clear differences in crop yield and nitrogen demand and represents an ideal field site for this work.The treatments are described in **Table 1**.

Table 1. Treatments utilized in the current project. Selected trees within Randomized Complete Block Design (RCBD) with 6 x 15 tree replicates per treatment.

Treatment	**N source**	**N amount (lbs/ac)**	**K source**	**K amount (lbs K/ac)**
A	UAN32	125	60% SOP / 40% KTS	200
B	UAN32	200	60% SOP / 40% KTS	200
C	UAN32	275	60% SOP / 40% KTS	200
D	UAN32	350	60% SOP / 40% KTS	200

Twenty minirhizotron access tubes were installed in the ongoing experiment to follow root phenology (root flushes, root lifespan, growth, etc.) over multiple seasons under four fertilization regimes. Root images were taken during the 2012 and 2013 season on an every 2 week basis and images are being analyzed recording number of roots, color, diameter and length. Analysis of these images is being performed at the end of each season.

In addition, a total of 160 root bags filled with media were installed in the different treatments and N uptake was measured in excised roots. The relationship between the parameters of root N uptake and tree demand will be determined once yield and N content are obtained by leaf and nut sampling at harvest.

2. <u>Fertigation method experiment</u>

The effect of fertigation technique (pulsed, continuous, drip, microjet) is being examined in a subset of trees in the same orchard as above established in 2011(**Table 2**).

Table 2. Fertigation treatments in the ongoing project. Selected trees within RCBD with 4 x 7 tree replicates per treatment.

Treatment	N source	K source	Irrigation Method	Fertilization method
E	100% UAN32	100% SOP	Fanjet	4 fertigation events / year
F	100% UAN32	60% SOP / 40% KTS	Fanjet	Continuous (fertilization in each irrigation
G	100% UAN32	100% SOP	Drip	4 fertigation events / year
H	100% UAN32	100% SOP	Drip	4 fertigation events / year

In this experiment an additional 20 minirhizotron access tubes were installed in order to determine root phenology (root flushes, root lifespan, growth, etc.). Root images have been taken during the 2012 & 2013 season on an every 2 week basis, and images are being analyzed recording number of roots, color, diameter and length.

In addition, 80 soil solution access tubes (SSAT, a.k.a. “lysimeters”) have been installed in each treatment at 2 depths (150 and 250 cm) in order to measure nitrate (NO_3) leaching and transport through the soil profile throughout the season.

Individual trees have been analyzed for leaf nutrient analysis, yield, nut size and crack out percentage and contrasted among treatments (see results section).

Preliminary Results and Discussion:

1. Nitrate uptake by roots

Results from 2013 samples are still in progress as the amount of sampling was doubled and NO_3 concentration range was increased to more realistic conditions (i.e. actual NO_3 soil solution concentration). Preliminary results from below belong to 2012 data, and some of the other findings will be explained based on these parameters.

Fine roots from each treatment in experiment 1 were isolated, excised and then incubated in solutions of different NO_3 concentration for 30 minutes. The external concentration (i.e. soil solution concentration) ranged from 0.42 to 14.01 ppm of NO_3. According to the literature, nitrate uptake in fine roots will depend mostly on the concentration of the external solution as well as the demand of NO_3 by the plant (i.e. plant N status). Preliminary results from this experiment are shown in **Figure 1**. When roots where incubated in solutions from with a range of concentrations (0.42 to 3.50 ppm of NO_3), all of the treatments showed an increase in uptake followed by a saturation at the end of this range; however, roots from low N treatments exhibited a higher uptake capacity than the roots from high N treatments. This results suggests that N starved trees up-regulate N uptake and can access N from lower NO_3 concentrations than trees with sufficient N content. Trees with high N application showed a lower capacity to absorb NO_3 and at the lowest NO_3 concentration (0.42 ppm) they lost NO_3 from the roots system to the solution. At high NO_3 concentration ranges (7.01-14.01 ppm of NO_3) however, low N trees exhibited lower uptake capacity than high N status trees.

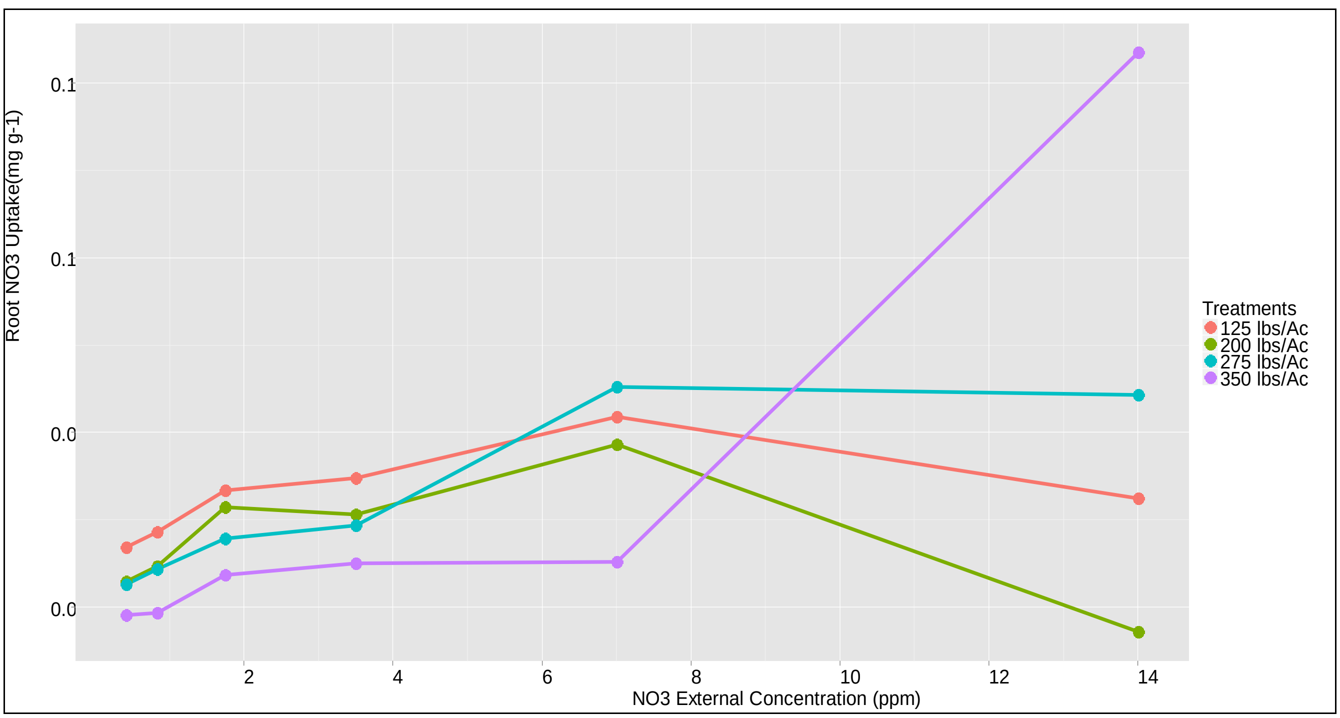

Figure 1. N-NO_3 uptake of almond roots at different N-NO_3 external concentrations.

2. Fertigation method

The objective of this experiment is to determine the best fertigation practice for almonds orchards, contrasting standard grower practice (4 fertigation events) with fertigation applied in every irrigation event. The most important goal is to reduce the potential for contamination of groundwater with pollutants (NO_3) without reducing crop performance.

Preliminary results from soil solution extraction at different soil depths are shown in **Figures 2** and **3**. In 2013, the methodology was changed in order to get more reliable data. Deeper tubes (150 and 250 cm) were installed in order to monitor the potential leaching of each treatment. Graphs represent the maximal N-NO_3 concentration measured over the season. Nitrate concentration at 250 cm, are higher than shallower depths, probably because root activity at depths greater than 150 cm is low and the main fate of the nitrate is to leach through the soil profile, producing a cumulative effect in the deeper soil profile. Regarding treatments effects on NO_3 leaching, even though no significant differences are observed (mostly due to high variability within the treatments), it seemed that standard fertilization practices yielded less NO_3 concentration than the continuous treatments (**Figure 3**) at deeper soil profile. This is presumably because the lower NO_3 concentration that continuous treatments receive in each fertigation event may have an influence on the root uptake (see **Figure 1**). In addition, NO_3 uptake may also be influenced by the demand of the tree, therefore, the constant supply of NO_3 to the roots in continuous treatments alter N dynamics in the soil. However there is a critical interaction of soil water content that must be further resolved before the results can be properly interpreted. In order to compensate for the soil water content, tensiometers have been installed at 220 and 250 cm to calculate soil water flux and to estimate the potential leaching of each treatment. In addition soil water content will be measured in order to estimate the NO_3 content (rather than concentration).

Preliminary results from the minirhizotrons installed in this experiment are shown in **Figure 4**, illustrating the root growth distribution by soil depth. Most of the roots observed were in the upper 40 cm soil profile, with almost 75% and 60% for the continuous and the standard practice respectively. More quantitative analyses have yet to be performed, including root lifespan and root seasonal dynamics (root emergence and persistence) in order to determine the right timing for nutrient application and plant response to fertigation events.

In terms of productivity (yield and nut size), results from last season (second year of the experiment) did not show significant effects of the treatments (**Table 3**). It should be noted that yields in the entire orchard were significantly lower than previous years, and contrary to previous year yields, continuous treatments yielded higher than standard practices. It is not possible to determine if this change in yield was produced because of the treatments effects or due to other factors affecting bearing.

Similarly, leaf nutrient status in mid-summer did not show any treatment effect (**Figure 5**), with the exception of leaf K concentration that was significantly lower in the standard nutrient application practices. Potassium (K) concentration in the zero K treatment was lower than the critical values recommended for almond trees **(Figures 5 and 6).**

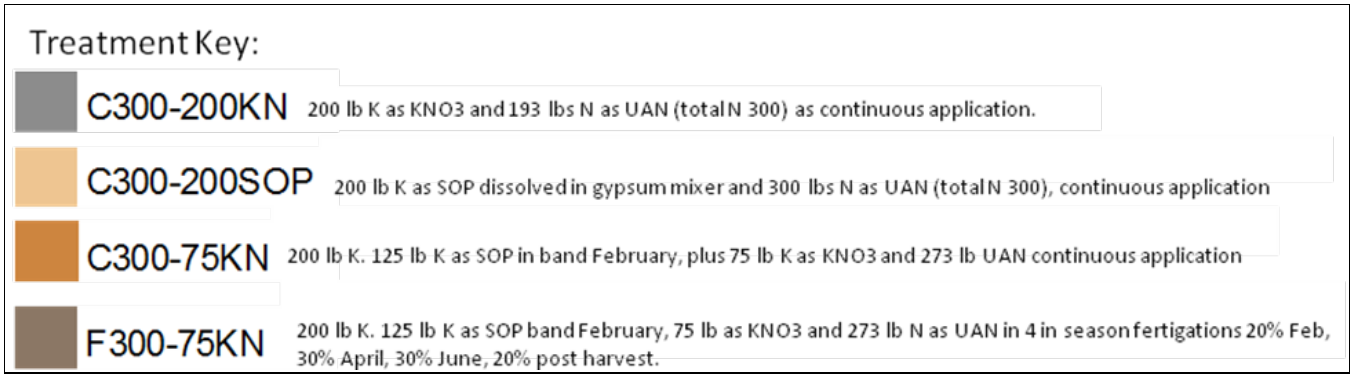

Figure 2. Treatment key for fertigation experiment

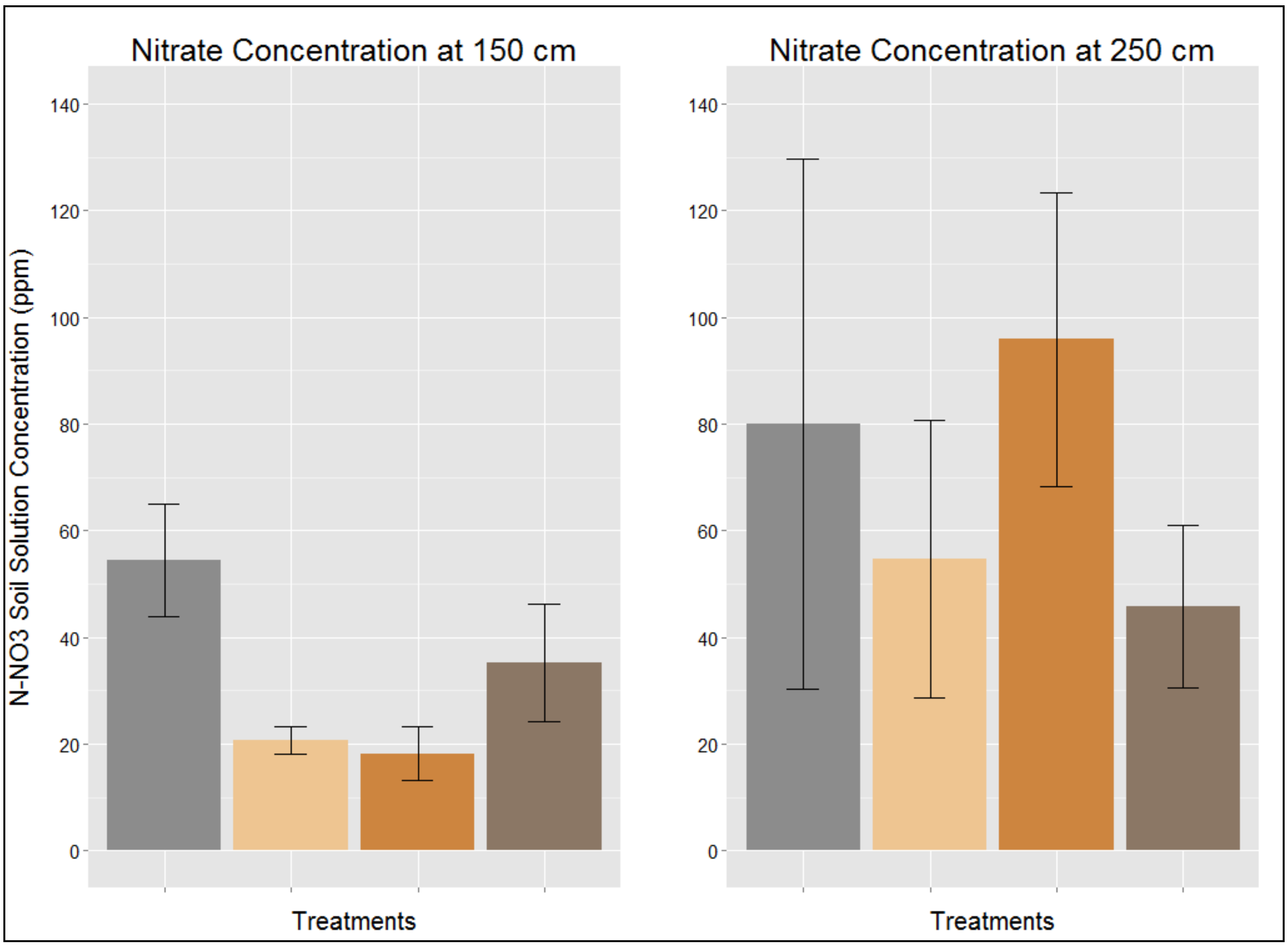

Figure 3. Soil solution N-NO_3 concentration (ppm) at 150 and 250 cm respectively from soil surface.

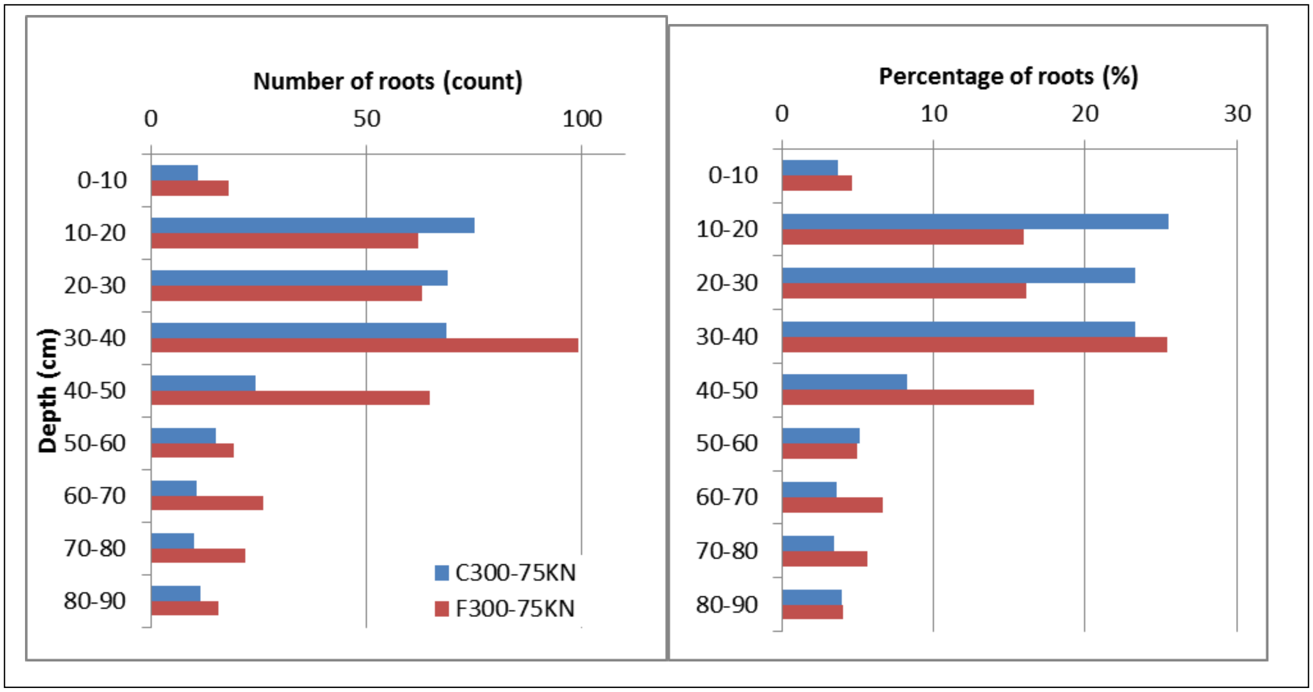

Figure 4. Vertical distributions of roots in soil depth intervals.

Table 3. Effect of fertigation practices on almond yield and nut size (2012).

Treatments	Yield (lbs/Ac)	Weight/100 Almonds (g)
F300-75KN	1072.9 a	142.2 a
F300-75KTS	1060.1 a	145.1 a
F300-0K	973.1 a	142.3 a
C300-200SOP	1192.8 a	144.1 a
C300-75KN	1275.4 a	140.0 a
C300-150KCL150KN	1194.3 a	142.0 a
C300-200KN	1224.0 a	141.2 a
C300-300KN	1317.9 a	139.3 a

Same letters between the same columns denote non-significant differences at an alpha level of 0.05.

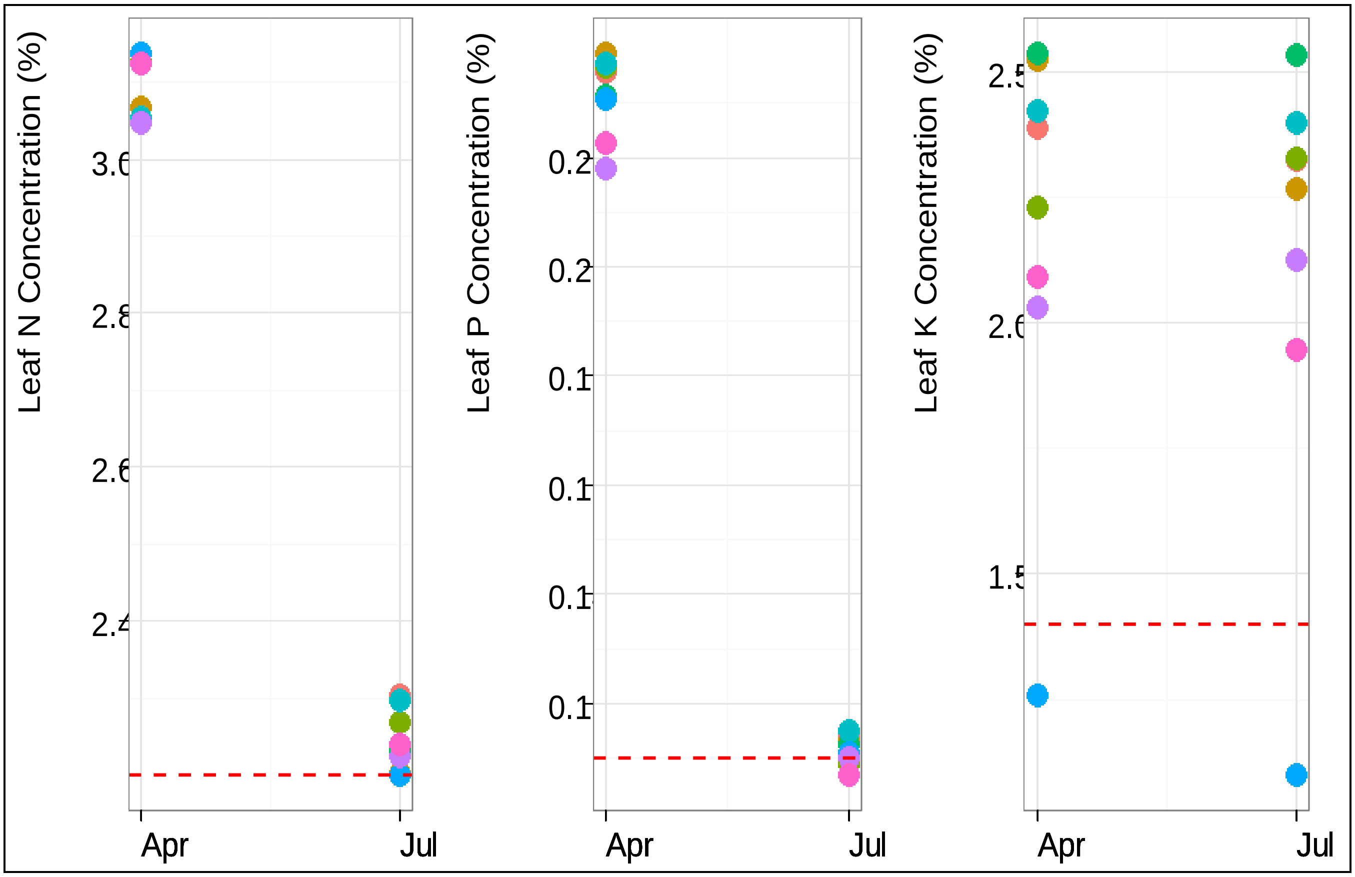

Figure 5. Effect of fertigation practices on mid-summer leaf nutrients including nitrogen (N), phosphorus (P), and potassium (K). Dashed line shows the recommended critical value for almond trees.

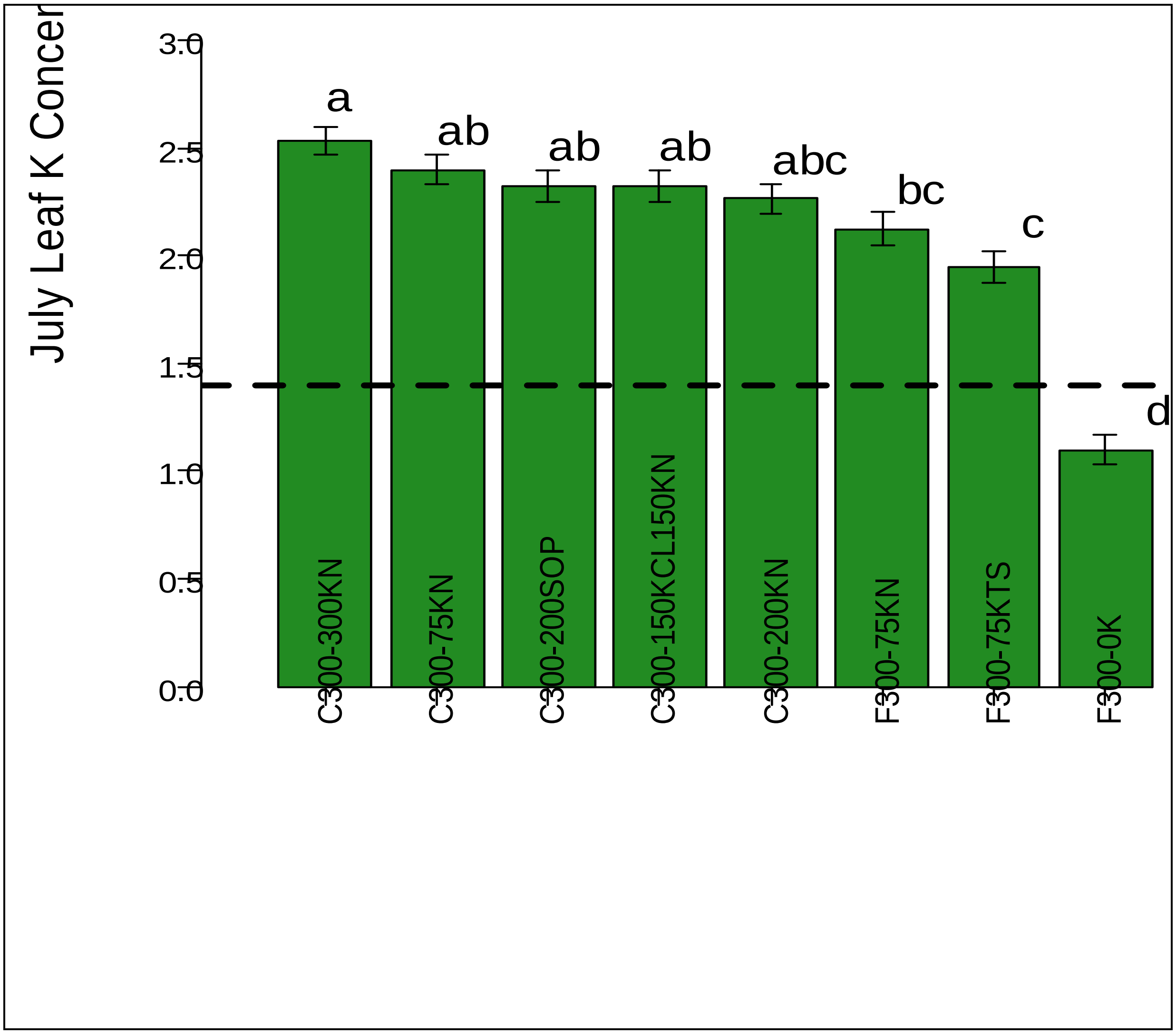

Figure 6. Effect of fertigation practices on mid-season leaf K concentration. Dashed line shows the recommended critical value for almond trees.

References Cited:

Harter, T., & Lund, J. R. (2012). Project and Technical Report Outline Technical Report 1 Addressing Nitrate in California's Drinking Water, (March). http://groundwaternitrate.ucdavis.edu/