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

Project No.: **11.PREC5.Brown**

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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 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 the effects of different rates of nitrogen (N), fertigation methods and irrigation methods.

- Nitrogen rate experiment

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 experiment provides 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. 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**.

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

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

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 have been taken during the 2012 season on an every 2 week basis. Images will be analyzed: recording number of roots, color, diameter and length. Analysis of these images will be performed at the end of each season.

In addition, a total of 80 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 from leaf and nut sampling at harvest.

- Fertigation method experiment

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

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

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

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 season on an every 2 week basis. Images will be analyzed: recording number of roots, color, diameter and length. Analysis of these images will be done at the end of each season.

In addition, 72 soil solution access tubes (SSAT, “lysimeters”) have been installed in each treatment at 3 depths (30, 60, 90 cm) in order to measure nitrate (NO_3) concentration and transport through the soil profile at each fertigation event.

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

Preliminary Results and Discussion:

Nitrate Uptake by Roots

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, root uptake of 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 with a low 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 the low N treatments exhibited a higher uptake capacity than roots from the high N treatments. This results suggests that N starved trees have upregulated N uptake and can access N from lower NO_3 concentrations than trees with sufficient N content. Roots from 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 to 14.01 ppm of NO_3) however, roots from low N trees exhibited lower uptake capacity than roots from high N status trees. The concentration of NO_3 in the external solution has also been measured in the soil **(Figures 3, 4, and 5)**. This is the first year of this experiment and additional analyses and repetitions are required. Future plans include the addition of higher NO_3 concentrations to the sampling methodology, and experimentation with non-excised roots (roots will be still attached to the tree) for the incubation period.

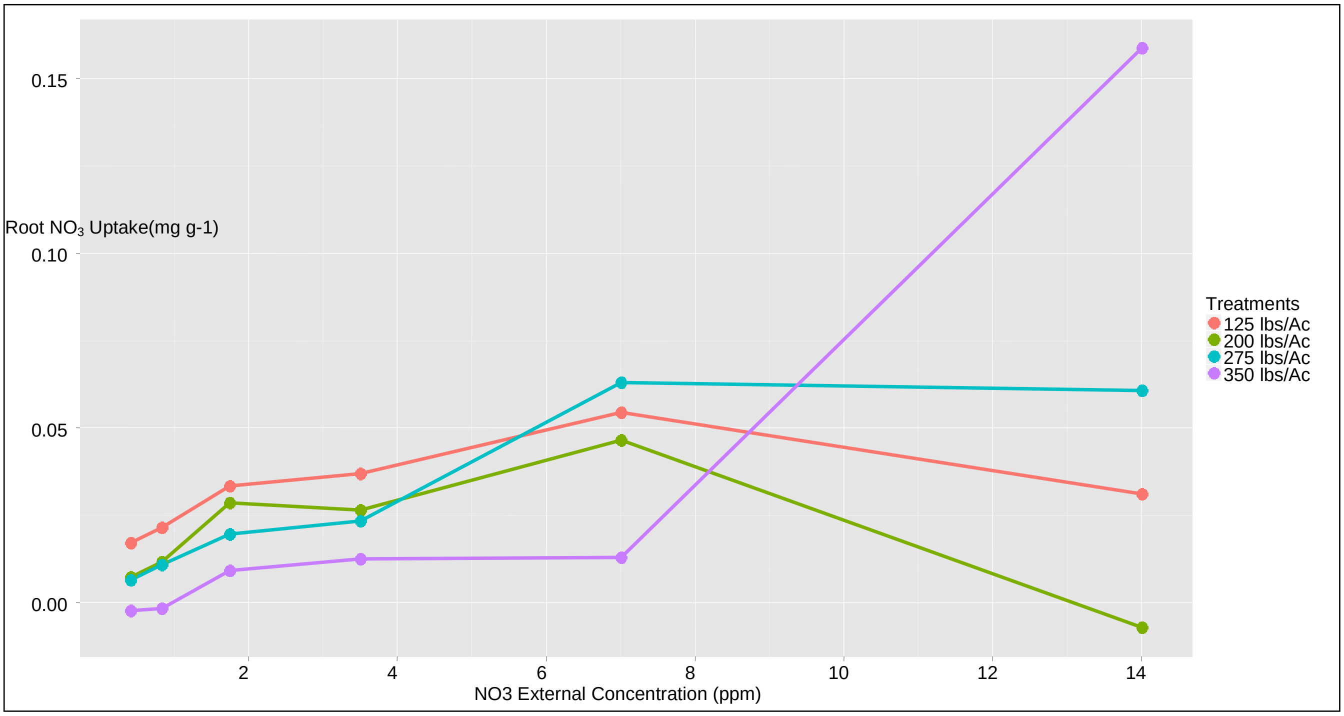

Figure 1. N-NO_3 uptake of almond roots at different N-NO_3 external concentrations

Fertigation method

The objective of this experiment is to determine the best fertigation practice for almonds orchards, and will contrast standard grower practice (4 fertigation events) with fertigation applied in every irrigation. The 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 and times are shown in **Figures 2, 3, 4** and **5**. Results from that analysis of soil solution extraction, showed that fertigation practices that include the application of the same amount of fertilizer in more events (namely continuous fertigation), are able to reduce the concentration of N-NO_3 in the soil solution at any depth at any time in comparison with the standard practice. At the deepest depth (90 cm), N-NO_3 concentration from continuous fertigation treatments, were much lower that the maximum allowed (10 ppm of N-NO_3) by California Department of Public Health under the Federal Safe Drinking Water Act of 1972 (Harter & Lund, 2012).. Future plans of this sampling will be the addition of more replication for the experimental setup as well the increment of sampling times.

In terms of production parameters (yield, nut size, and crackout percentage), results from last season (first year of the experiment) did not show significant effect of the treatments (**Table 3**). Similarly, leaf nutrient status in mid-summer did not show any treatment effect (**Figure 6** and **Table 4**), with exception of leaf K concentration that was significantly lower in the treatment with no K application.

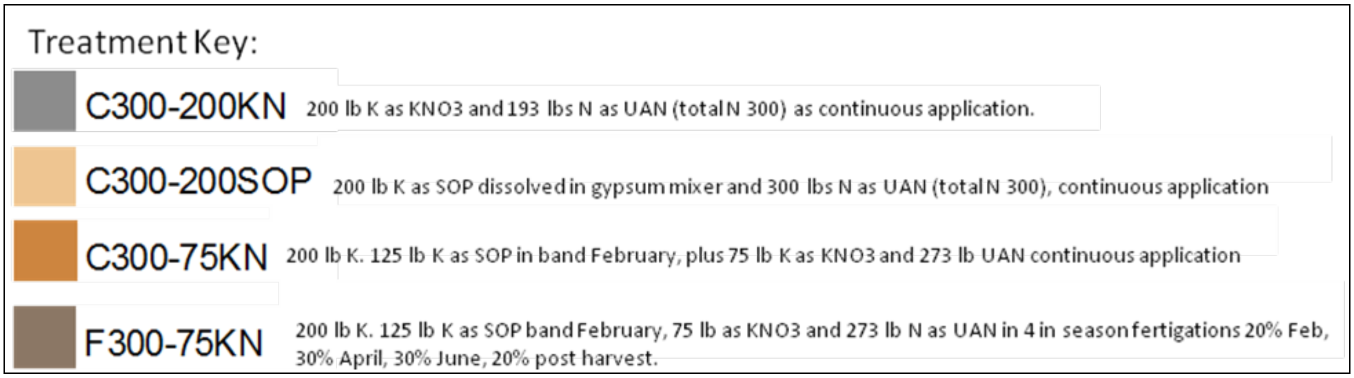

Figure 2. Treatment key for fertigation experiment

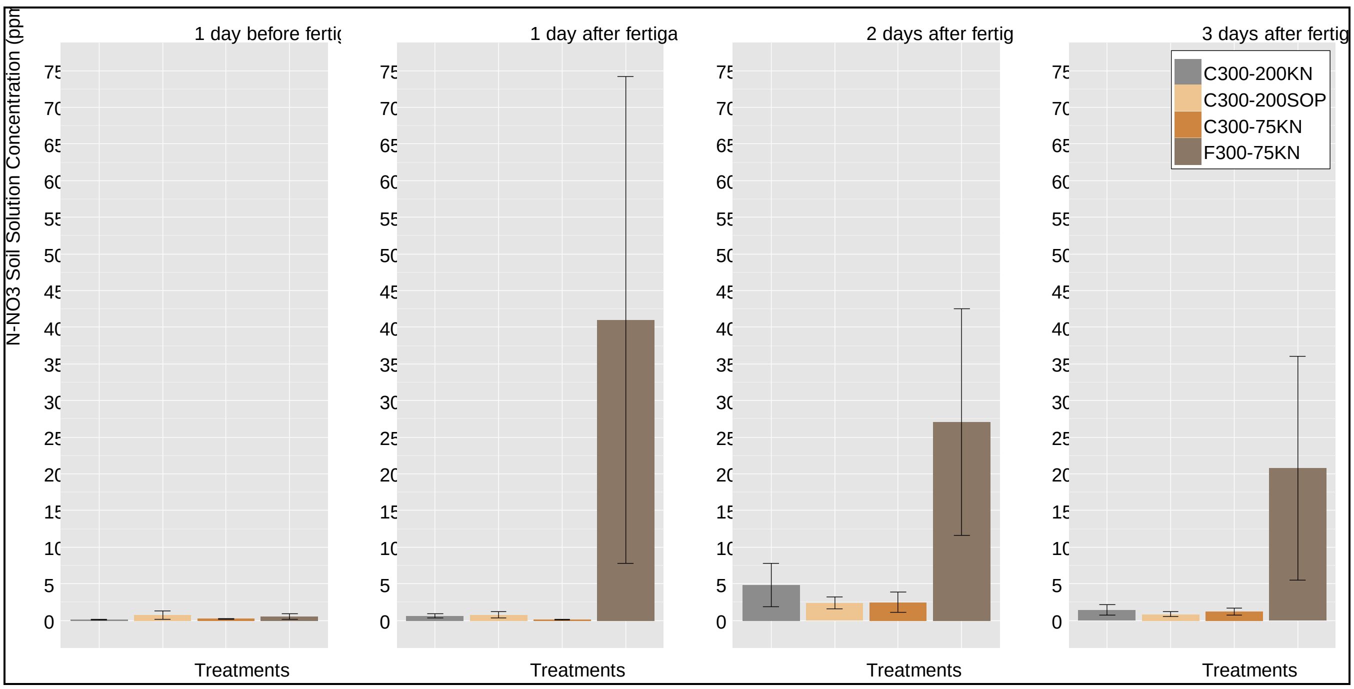

Figure 3. Soil solution N-NO_3 concentration (ppm) at 30 cm from soil surface at different times relative to the fertigation event

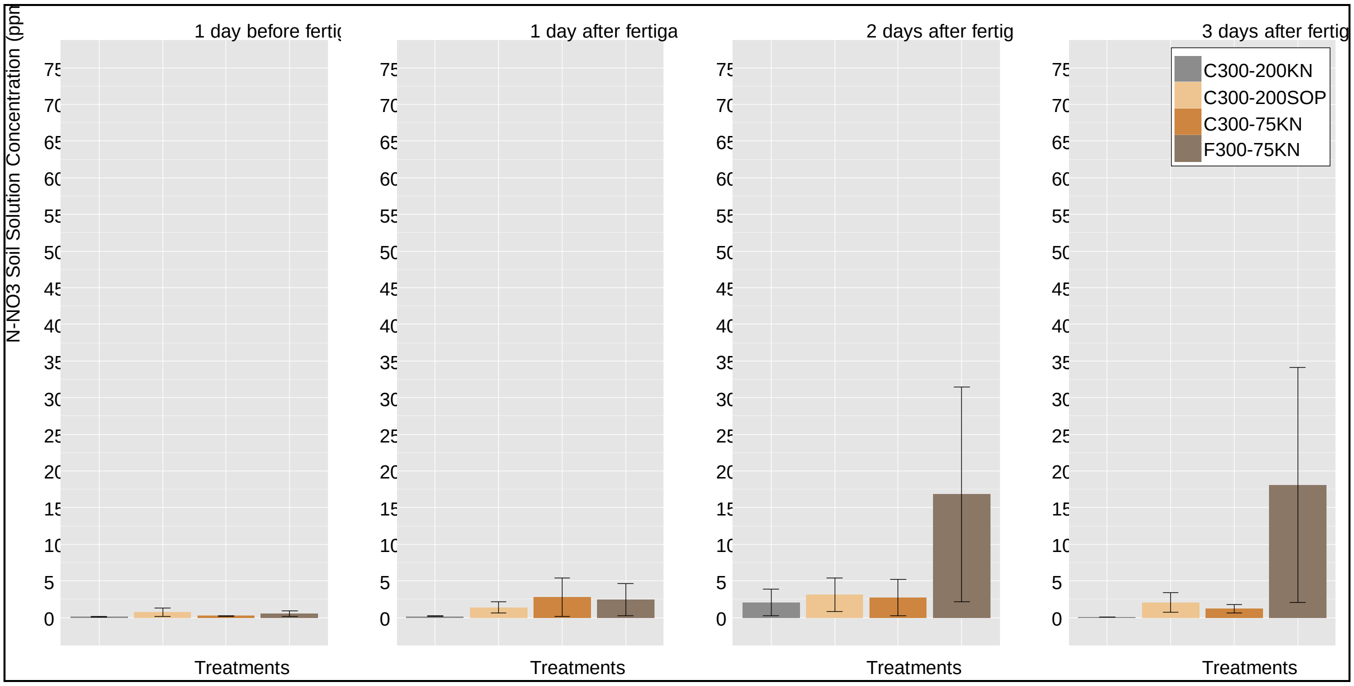

Figure 4. Soil solution NO_3 concentration (ppm) at 60 cm from soil surface at different times relative to the fertigation event

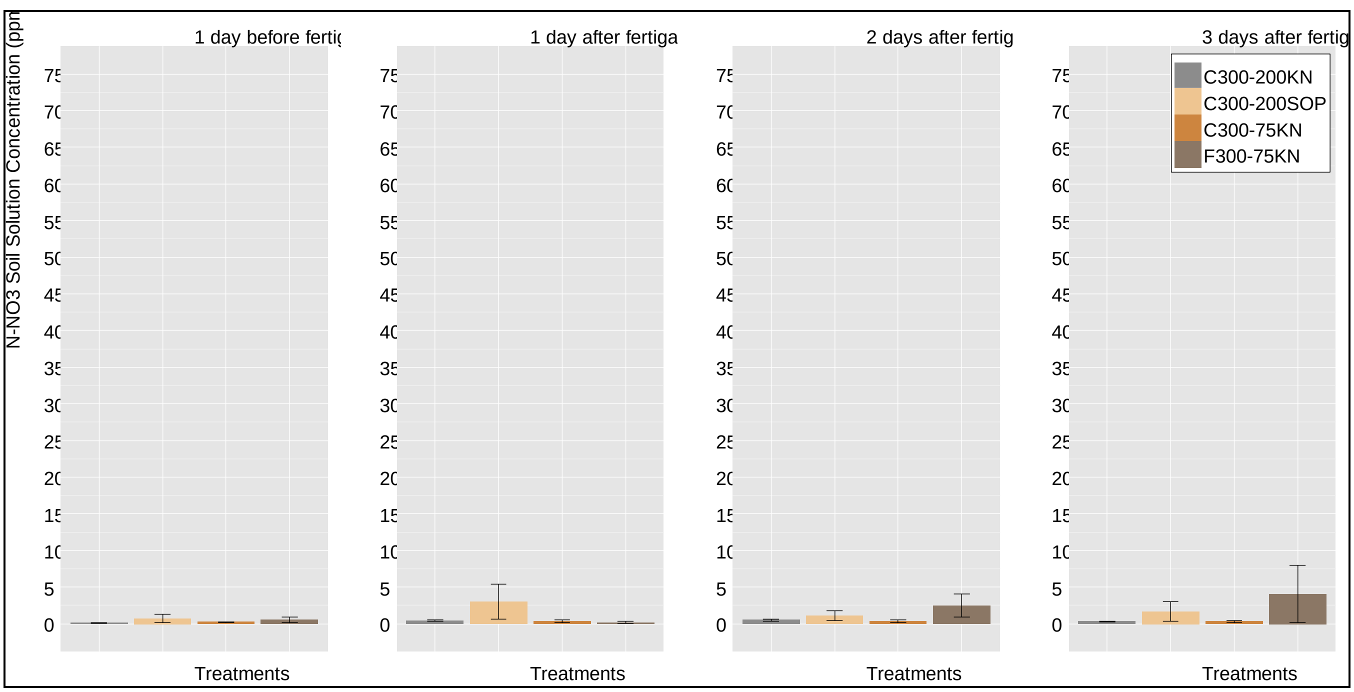

Figure 5. Soil solution NO_3 concentration (ppm) at 90 cm from soil surface at different times relative to the fertigation event

Table 3. Effect of fertigation practices on almond yield, nut size, and crackout percentage

Treatments	Yield (lbs/Ac)	Weight/100 Almonds (g)	Crackout (%)
F300-75KN	4577.4 a	116.95 a	0.26 a
F300-75KTS	4541.5 a	118.26 a	0.27 a
F300-0K	4631.4 a	114.01 a	0.27 a
C300-200SOP	4436.0 a	114.19 a	0.25 a
C300-75KN	4598.8 a	119.46 a	0.27 a
C300-150KCL150KN	4798.6 a	116.50 a	0.26 a
C300-200KN	4980.7 a	116.92 a	0.26 a
C300-300KN	4944.2 a	118.47 a	0.26 a

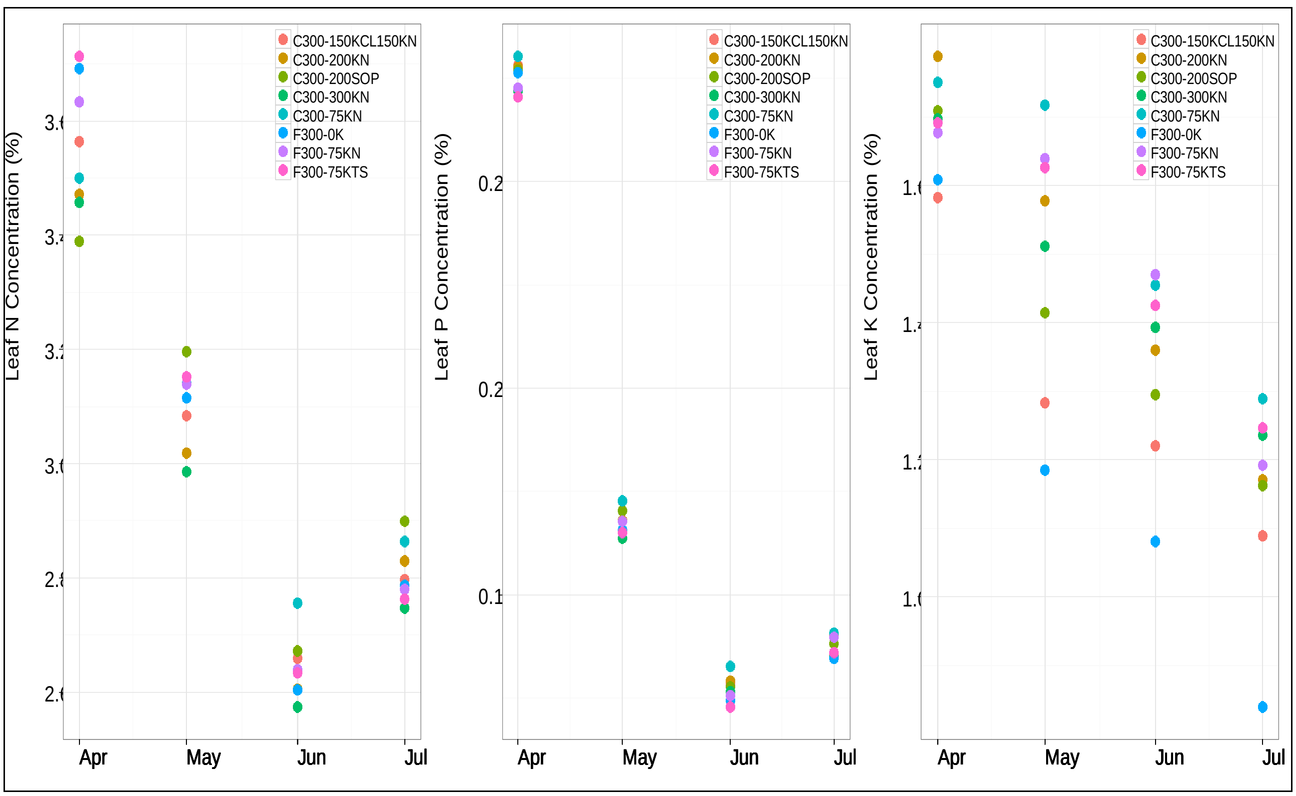

Figure 6. Effect of fertigation practices on mid-summer leaf nutrients

Table 4. Effect of fertigation practices on mid-summer leaf nutrients

Treatments	Leaf N (%)	Leaf P(%)	Leaf K(%)
C300-150KCL150KN	2.79 a	0.13 a	1.08 ab
C300-200KN	2.83 a	0.14 a	1.17 a
C300-200SOP	2.89 a	0.13 a	1.16 a
C300-300KN	2.74 a	0.13 a	1.23 a
C300-75KN	2.86 a	0.14 a	1.28 a
F300-0K	2.78 a	0.13 a	0.83 b
F300-75KN	2.78 a	0.13 a	1.19 a
F300-75KTS	2.76 a	0.13 a	1.24 a

References Cited:

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