Development of Leaf Sampling and Interpretation Methods for Almond and Development of a Nutrient Budget Approach to Fertilizer Management in Almond

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Objectives:

- Determine the degree to which leaf nutrient status varies across a range of representative orchards and environments.
- Determine the degree to which nutrient status varies within the canopy and throughout the year.
- Validate current Crticial Values and determine if nutrient ratio analysis provides useful information to optimize fertility management.

- Develop a phenology and yield based nutrient model for almond.
- Develop fertilizer response curves to relate nutrient demand with fertilizer rate and nutrient use efficiency.
- Determine nutrient use efficiency of various commercially important N and K fertilizer sources.
- Develop and extend an integrated nutrient BMP for almond.

Interpretive Summary:

Development of leaf sampling and interpretation methods for almond

This study aims at determining the variability of nutrient concentrations between orchards, within orchards, between trees and within trees. To this end, leaf samples are being taken from three mature almond orchards in the San Joaquin Valley (Belridge, Modesto and Madera) and one in the Sacramento Valley (Arbuckle). A subset of results is shown. Leaf samples were taken from four positions in the trees (nuts, leaves from non-fruiting spurs – NF, leaves from spurs with one fruit – F1 and leaves from spurs with two fruits – F2) in April, May, June, July and October of 2008 and 2009 in a grid pattern designed for assessing spatial variability.

Results from the first growing season revealed significant differences in leaf nutrient concentrations between sites for most nutrients (**Figure 1**). These data will be used to derive relationships between nutrient concentrations, nutrient ratios and yield. A total of 780 trees have been individually sampled for nutrients and yield. Based on these relationships, sampling strategies for zone specific nutrient management will be developed.

(For additional research related to this project please see:
HORT 11 Shackel/Sanden – Fertigation: Interaction of Water and Nutrient Management
HORT 11(b) Sanden/Shackel – Fertigation: Interaction of Water & Nutrient Management – Kern Co.
HORT 13 Lampinen - Development and Testing of a Mobile Platform for Measuring Canopy Light Interception and Water Stress in Almond
Air 2 Smart – Nitrous Oxide Emissions from an Irrigated Almond Orchard)

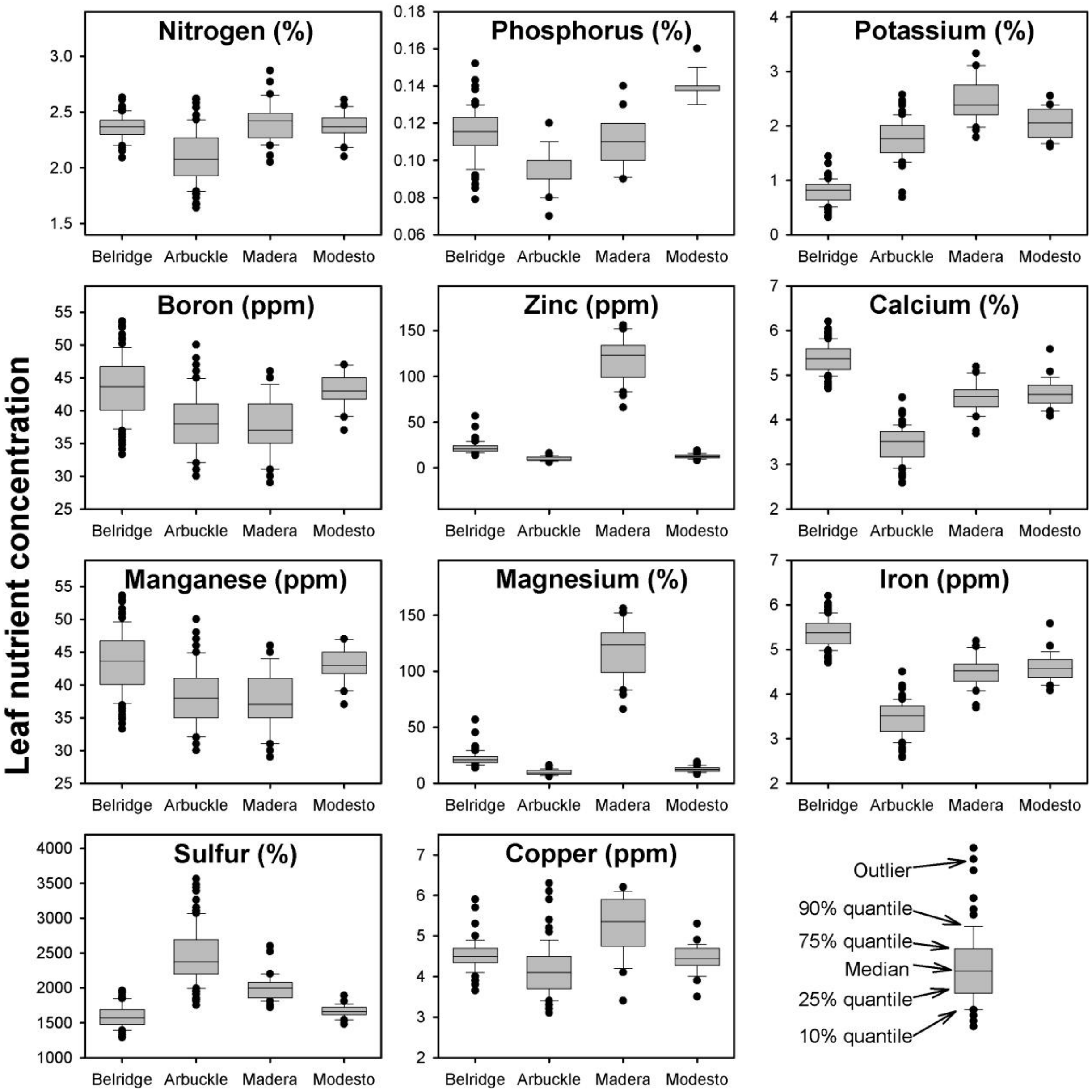

Figure 1. Leaf nutrient concentrations of all tested nutrients across the four study sites in July of 2008.

Changes in tissue nutrient concentrations over time were examined in an attempt to derive early season sampling strategies and interpretation. Clear trends were visible over time in all major nutrients (**Figure 2**). Nitrogen and phosphorus concentrations declined steadily, while concentrations of calcium, magnesium and iron increased over the seaon in all leaf types. Zinc and potassium levels remained constant during the first two samplings, before declining in the second half of the season. The consistency of trends for key elements (N, P, Zn) suggests that early season sampling may be effectively used to predict late season nutrient status.   The effect of yield on this trend is being examined.

Leaf samling and tissue analysis is used to determine the nutritional adequacy of the orchard. Typically, leaves from non-fruiting exposed spurs are collected the validity of this sampling strategy has not been adequately examined. In this experiment leaves from non-fruiting spurs (NF), spurs with one fruit (F1) and spurs with two fruits (F2) were collected independently to estimate the effect of local fruit load on nutrient dynamics. Local fruit load significantly influences concentrations of N, P, K, B, Zn, S, and Cu. For N and P, clear deficiencies (symptoms of deficiency and tissue concentrations below the CV) were observed in F1 and F2 leaves at several sites. Tissue concentrations in F1 and F2 leaves were always significantly lower than in NF leaves. The importance of this is not yet clear, however results may suggest that the current sampling protocol of non fruiting spur leaves may not reflect critical tree nutrient status.

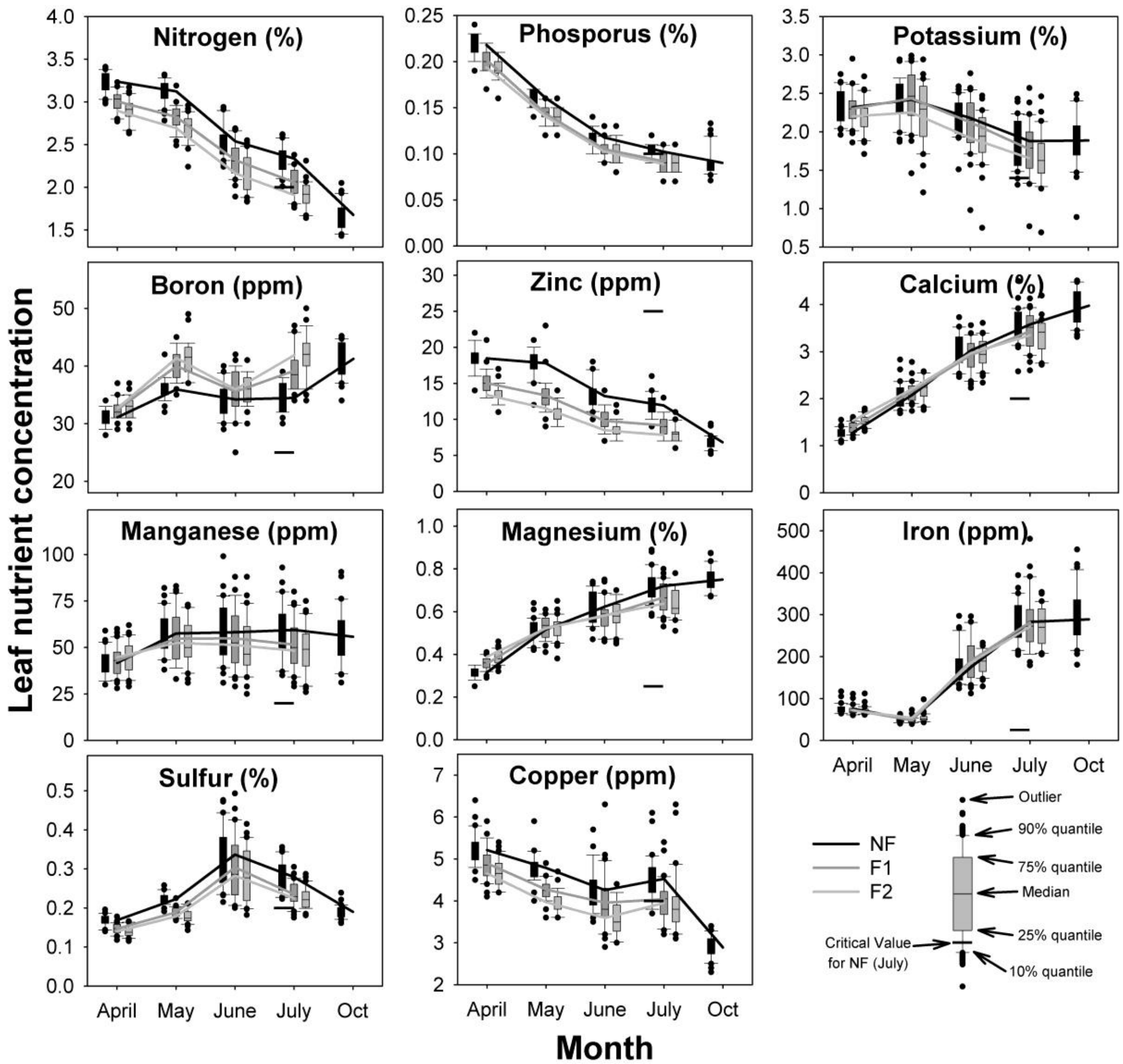

Figure 2. Leaf nutrient dynamics over time for all tested nutrients at Arbuckle, CA, during the 2008 field season. Separate curves and box plots are shown for leaves from non-fruiting spurs (NF), spurs with one fruit (F1) and spurs with two fruits (F2).

Development of a nutrient budget approach to fertilizer management in almond

A large-scale multi-year experiment was set up to develop a phenology and yield based nutrient model for almond to provide guidance on fertilization rates and timings and patterns of crop response. Seven-year-old almond trees in an orchard near Belridge, Kern County, CA, are being supplied with variable rates and sources of nitrogen and potassium. Nitrogen from two sources (CAN17 and UAN32) is applied at four rates (125, 200, 275 and 350 lbs/ac; all at 200 lbs/ac K as SOP+KTS). Various K treatments were set up at 275 lbs/ac nitrogen (as UAN32). Three K sources (SOP, SOP+KTS and KCl) are being compared at 200 lbs/ac, and three rates of SOP+KTS (100, 200 and 300 lbs/ac) are also tested. All treatments are set up under two irrigation systems (fan jet and drip), and replicated 5-6 times per treatment. Each experimental unit consists of 15 trees, 6 of which are sampled 5 times during the season. Samples were taken in 2008 and 2009, and sampling is set to continue for another two years.

Only data for the first sampling season has been fully evaluated. Nutrient removal by the 2008 almond crop in the N rate trial with UAN32 as the N source is shown in **Table 1**. Only nitrogen removal varied systematically with N application rate. Apparent nitrogen use efficiencies per treatment, calculated as the ratio of removed/applied N ranged from 61% in the highest N treatment to 136% in the lowest N treatment. Nutrient use efficiencies of > 100% suggest that trees are mobilized stored nutrients rather than depending exclusively on fertilizer applied in that season. Over the long term this must result in tree and soil N depletion and contribute to yield decline. Full evaluation of this trial will only be possible after 2-3 years.

Table 1. Nutrient removal in crop from the nitrogen rate trial. Nitrogen was applied as UAN32.

N treatment (UAN32)	N	P	K	B	Ca	Mg	Zn
	Nutrient removal in crop (lbs/ac yield=3560 kernel lbs)						
125 lbs/ac	170	19.8	162	0.814	26.3	14.6	0.174
200 lbs/ac	201	23.6	186	0.909	28.1	16.1	0.201
275 lbs/ac	203	21.9	176	0.844	27.0	15.6	0.190
350 lbs/ac	216	22.5	181	0.863	28.3	16.5	0.186
	Nutrient removal per 1000 lbs of kernel weight (lbs)						
125 lbs/ac	47.9	5.6	45.4	0.23	7.4	4.1	0.05
200 lbs/ac	51.0	6.0	47.3	0.23	7.1	4.1	0.05
275 lbs/ac	52.2	5.6	45.2	0.22	6.9	4.0	0.05
350 lbs/ac	55.0	5.7	46.0	0.22	7.2	4.2	0.05

The effect of N treatments on nutrient uptake rates differed substantially among nutrients (**Figure 3**). Not surprisingly, nitrogen uptake was most affected by N rates, though interactions with potassium, phosphorus and zinc were also observed.

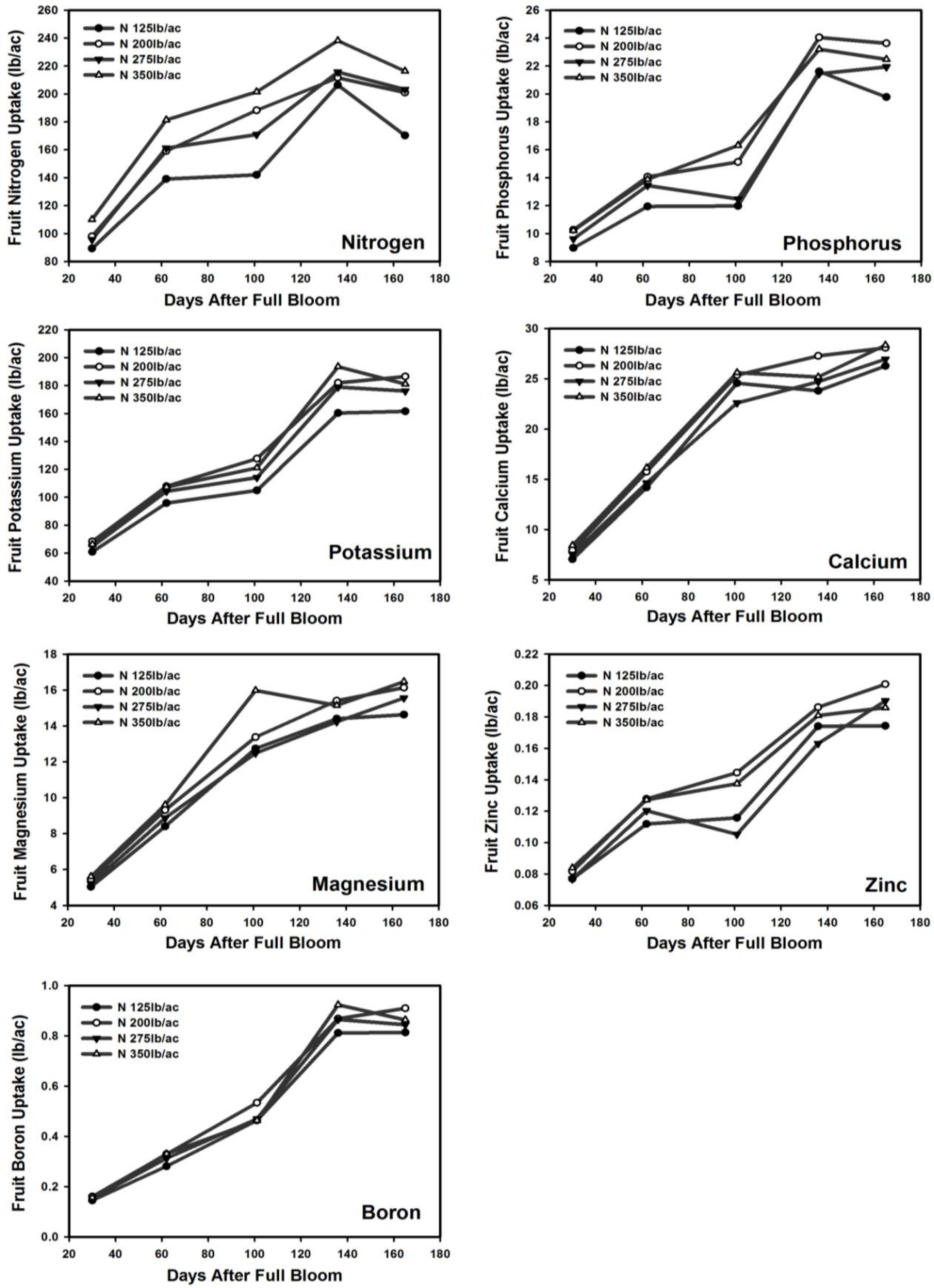

Figure 3. Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Zinc and Boron uptake by almond fruit from nitrogen rate treatments

The K rate experiment showed low potassium uptake at the lowest fertilization rate, whereas uptake under the two higher treatments was similar (**Figure 4**). These results imply that K uptake in this orchard was optimized when K was applied in amounts greater tha 200 lb/ac. Effects of fertilizer treatments on almond yields and nutrient use efficiency where not seen in the first year.

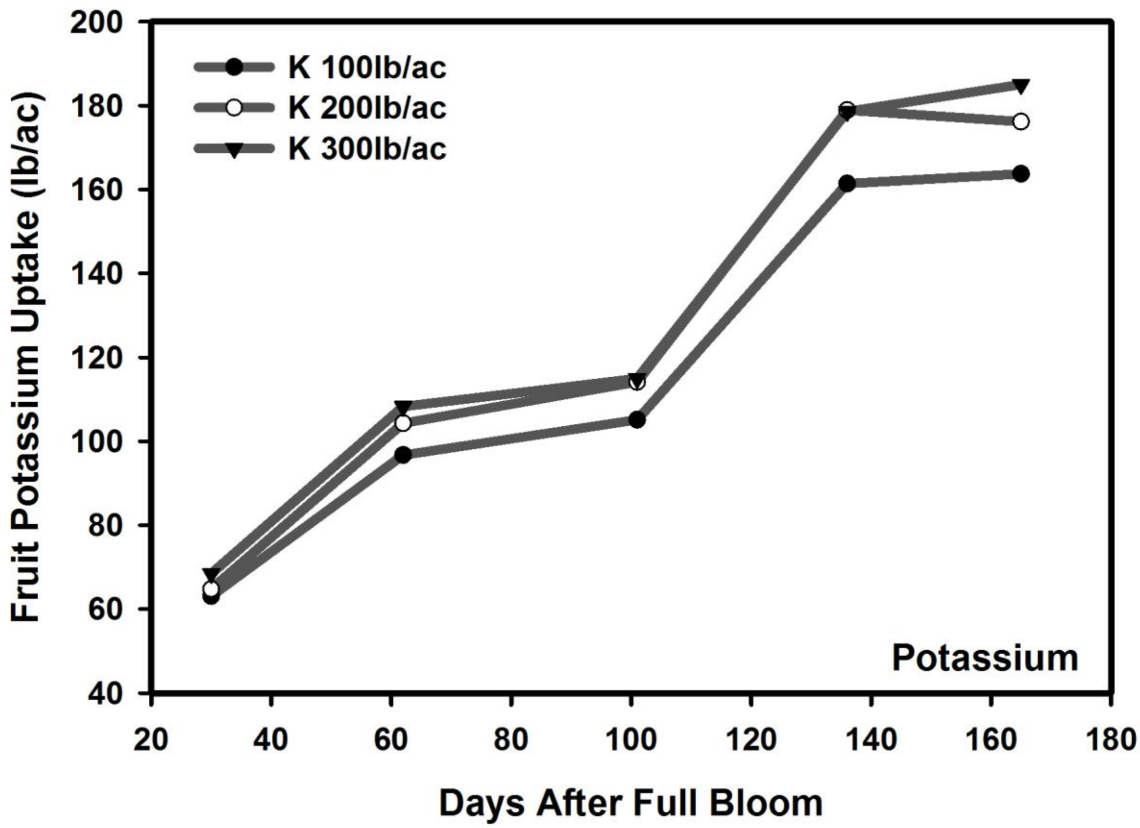

Figure 4. Potassium uptake by almond fruit from potassium rate treatments

Preliminary Conclusions:

Results presented here represent only 18 months of a long-term experiment and must be interpreted with caution.

- There is substantial within field, between field and within tree variability in nutrient concentrations and the relationship of concentrations to yield. Understanding the cause and extent of this variability will help in optimizing orchard leaf sampling, interpretation and orchard zone management.

- The presence of clearly deficient leaves on fruiting spurs but not on leaves on non-fruiting spurs of the same tree, suggests that current protocols may not adequately reflect tree nutrient status. A re-examination of sampling strategy is underway.

- For N and P (and potentially other elements), very consistent patterns of change in nutrient concentrations over the season were observed. These patterns were independent of location or yield suggesting that early season tissue analysis can be used to effectively predict late season nutrient status for these elements.

- Nutrient export in harvested crop suggests a potential for high nutrient use efficiency in almond. Efficiency declines rapidly as N application increases beyond that required to optimize yield.