DEVELOPMENT OF LEAF SAMPLING AND INTERPRETATION METHODS FOR ALMOND AND DEVELOPMENT OF A NUTRIENT BUDGET APPROACH TO FERTILIZER MANAGEMENT IN ALMOND

Patrick Brown, Sebastian Saa, Saiful Muhammad, Blake Sanden
Department of Plant Sciences, UC Davis, One Shields Avenue, Davis, CA 95616;
University of California Cooperative Extension, Kern County,
1031 S. Mt. Vernon Ave, Bakersfield, CA 93307

ABSTRACT

A five year research project on the use of N in orchards crops has been conducted to 1) to develop early season sampling protocols, and 2) to determine the response of Almond to various rates and sources of nitrogen (N) and potassium (K) fertilizers, 3) to develop nutrient demand curves and 4) to conduct a long term assessment of nutrient use efficiency with the goal of improving fertilizer management. Leaf and nut samples were taken at 5 stages of development throughout five seasons to determine the degree of variability in tissue nutrient concentrations over time, space, and within tree canopies. This has been used to establish sound leaf sampling protocols. Results also demonstrate that July leaf nitrogen content (and likely other nutrients) can be well predicted with an early season (April) sampling. A large fertigation rate trial was established at Belridge, Kern County, CA to develop a phenology and yield based nutrient model for Almond, to develop fertilizer response curves to relate nutrient demand with fertilizer rate and nutrient use efficiency, and to determine nutrient use efficiency of various commercially important N and K fertilizer sources. The results from the four years of data indicate a significant effect of nitrogen rates on yield and that knowledge of tree yield and nut nutrient concentration can be used to calculate orchard nitrogen removal and to plan fertilization replacement strategies. Averaged across years and locations, the N removal per 1000 lb kernel yield (calculated on basis of all fruit parts removed at harvest) removes 68 +/- 3 lb N and 85 +/- 3.2 lb K. Eighty percent of annual N uptake in almond occurs between leaf-out and mid-June.

INTRODUCTION

Almond producers are under considerable pressure to optimize the use of N in orchards so that profitability can be increased and the potential for negative environmental impacts can be minimized. To optimize the use of fertilizer N growers must have viable methods to monitor field N status and have good understanding of the amount and timing of tree demand. Historically, orchard nutrient status has been monitored by collecting leaf samples in July and contrasting those numbers with established standards, this sample date, however, is too late for current year management decisions. Collection of leaves earlier in the season would therefore be useful. A major perceived constraint with the use of early season samples in trees is attributed to rapid leaf growth early in the season, which is thought to make these sample times more variable. Furthermore, leaf sampling at any time of the year is only of value if enough samples are collected so that they adequately represent the nutrient status of the orchard as a whole. Data on in-field variability and ideal sampling strategies in orchards is not currently available. A primary goal of this research was to develop early season sampling strategies to guide current season N management.

While knowledge of orchard nutrient status derived from tissue sampling is of value it is not adequate as a means of determining fertilization strategy. Efficient and profitable nitrogen application demands that N be applied at the right rate, right timing and in the right location so that productivity is maximized and the potential for N loss to the environment is minimized. The goal of N management is to apply adequate but not excessive amounts of N, so that loss to the environment is minimized. To achieve these goals knowledge of the timing of crop nutrient demand and the relationship between yield potential and demand must be established. A primary goal of this research project is to derive the annual and long-term patterns of nutrient demand and uptake in almond and the relationship to fertilizer application and tree yield.

MATERIALS AND METHODS

Two separate experiments are reported here. In the first experiment 'Sampling Methodology and Field Variability' four field sites were used. At each site samples were collected for a period of 3 years from an 8 to 10 year old micro sprinkler irrigated (one drip irrigated) almond orchards of good to excellent productivity planted to Nonpareil (50%). For each of the 4 almond sites (Arbuckle, Belridge, Madera and Modesto), plots were 10-15 acre contiguous blocks. Leaf and nut samples from 114 trees were collected at 5 times during the season. Sample collection was spaced evenly over time from full leaf expansion to harvest. As a phenological marker, days past full bloom and stage of nut development were noted. Light interception, tree water status, and individual yields of these trees were also measured. To establish seasonal nutrient accumulation and nutrient export, composite nut samples were collected from each site at various dates through the year. Data were used to develop models to predict leaf tissue change over the season and develop early season sampling strategies. In 2012 the models developed in 2011 were validated on 6 new orchards representative of the major production areas of the California valley.

The second experiment "Development of a nutrient budget approach to fertilizer management in almond" was established in a Paramount Farms almond orchard at Belridge, Kern County, California under Fan jet and Drip irrigation systems. Each treatment was replicated in five or six blocks with 15 trees per block. Treatments consisted of four rates of nitrogen (125, 200, 275 and 350 lb/ac), supplied as two commercially important sources of nitrogen (Urea Ammonium Nitrate 32% [UAN 32] and Calcium Ammonium Nitrate 17% [CAN 17]). Nitrogen was applied in four fertigation cycles with 20%, 30%, 30% and 20% of total nitrogen supplied in February, April, June and October, respectively. Fifteen trees and their immediate 30 neighbors, in two neighboring orchard rows were treated as one experimental unit. All data were collected from six trees in the middle row. A total of 768 experimental trees were selected for this experiment. Leaf and nut samples were collected from individual trees in April, May, June, July and August. A total of 5400 leaf and nut samples were collected and analyzed for N, P, K, Ca, S, Mg, B, Zn, Cu, Mn and Fe at the Agriculture and Natural Resources (ANR) Lab at the University of California Davis. The crop was harvested in August and individual tree yields were determined for all data trees. Yield of the remaining nine non-data trees in the data trees row was also determined to get average plot yield of fifteen trees. Four-pound samples were collected from two data trees each in each replicate to determine crack out percentage and oven dry weight. Twenty nuts were collected at harvest from each experimental tree to determine the ratio of kernel to shell/hull and the partitioning of nutrients.

In the following only select results pertaining to sampling strategies, the use of early season leaf samples and the removal of N in harvested crop will be reported. For full reporting readers are referred to the 2012 Almond Research Reports.

RESULTS AND DISCUSSION

Sampling Methodology and Field Variability: Based on the trials described here we have derived a standard protocol required to effectively estimate orchard nutrient status. This protocol is based upon grower standard practice of collecting only one sample per orchard and has been validated for Nonpareil trees of greater than 8 years of age. The sampling protocol is valid when applied to a generally uniform orchard of any size, however if the orchard is known to be non uniform then independent samples should be collected in each productivity 'zone'. Sampling should always be conducted independently in all orchard blocks.

The following is a minimum sampling strategy and improved management can be attained by taking additional samples, especially in areas of lower productivity. This methodology is valid for both April or July collected samples.

- Leaf sample(s) should be collected 6 weeks after full bloom for April sampling, or at standard late July sampling time.
- Collect one sample if your orchard is uniform in terms of yield and avoid trees with obvious problems (i.e. sick trees).
- Collect multiple samples (separate bags) if zones of varied productivity are present.

Each Sample should be collected as follows:

- Collect leaves from 18 to 28 trees (90 and 95 % confidence intervals respectively.
- Sampled trees must be at least 30 yards apart from eachother
- From each tree, collect leaves from all sides of the tree from leaves on at least 6 to 8 well-exposed spurs located between 5-7 feet from the ground.
- Send the samples to the lab and ask for a UCD-ESP analysis (N, P, K, B, Ca, Zn, Cu, Fe, Mg, Mn, S)

The standard July leaf nutrient sampling was historically selected because leaf growth has been completed at this time and nutrient concentrations are less variable. Evidence from this current trial suggests that this premise is not correct and that early season leaf analysis can be used for nutrient management purposes providing a suitable phenological marker is used. Figure 1 shows the pattern of leaf nitrogen change throughout the season. Utilizing data from 20 site years and several thousand plants we have developed and validated a model that utilizes nutrient ratio analysis and crop phenology to predict expected nutrient status in July from early season leaf samples. This can be combined with improved field sampling strategies to better monitor the nutrient status of orchards.

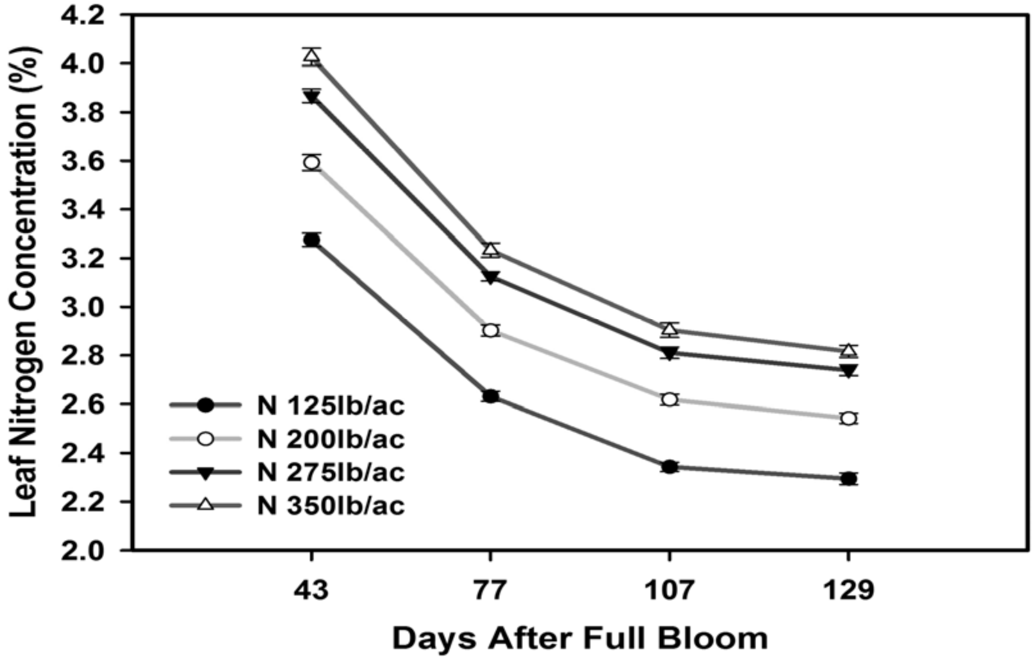

Figure 1. Changes in leaf N sampled at 4 dates from full leaf out (42 days after full bloom), to harvest (1230 days after full bloom).

Nutrient Removal in Crop and Accumulation through the Season: To determine the total N demand for a developing almond crop information on the patterns of N accumulation over the year and the amount of N removed from the orchard in harvested product is required. Nitrogen accumulation in the fruit increased from fruit formation in early March through harvest and was 80% complete at shell hardening (mid-June at this site). The amount of N removed in fruit increased as N applied increased from 125 to 275 lbs N per acre, however neither yield nor N removal increased significantly when higher rates of N were applied. Figure 2 shows changes in fruit nutrient accumulation over the year expressed on a per 1000 kg kernel weight basis (this includes all N removed from the orchard). Averaged across the 5 years of this trial N removal per 1000 kg kernel yield equaled 68 lbs in the cultivar Nonpareil and 65 lbs in Monterrey (Table 1).

SUMMARY

Results of this long term trial suggest that N management in almond can be optimized by conducting an early season sampling and leaf analysis to determine current and predicted status, by estimating current yield and applying N according to demand and timing of nutrient accumulation in fruit. The following strategy is recomended:

Base fertilization rate on realistic, orchard specific yield, account for all N inputs and adjust in response to spring nutrient and yield estimates.

- Make a preseason fertilizer plan based on expected yield LESS the N in irrigation and other inputs.
  - 1000lb kernel removes from 68lb N, 8lb P and 80lb K.
  - Apply 20% of seasonal demand after leaf out
- Conduct (properly!) a leaf analysis following full leaf out.

- In May, review your leaf analysis results and your updated yield estimate, then adjust fertilization for remainder of season.
- Time application to match demand in as many split applications as feasible
    - o 80% N uptake occurs from full leaf out to kernel fill.
    - o Apply up to 20% hull split to immediately post harvest, corrected for actual yield - but only if trees are healthy. Use foliars if N loss is possible.
- Every field, every year, is a unique decision

To assist growers implement these changes we have provided all Californian testing laboratories with UCD-ESP guidelines for collecting samples and interpreting April tissue values; this information can then be integrated with expected yield to determine annual N applications. In addition the spreadsheet utilized for these calculations can be downloaded at http://ucanr.edu/sites/scri/Crop_Nutrient_Status_and_Demand__Patrick_Brown/.

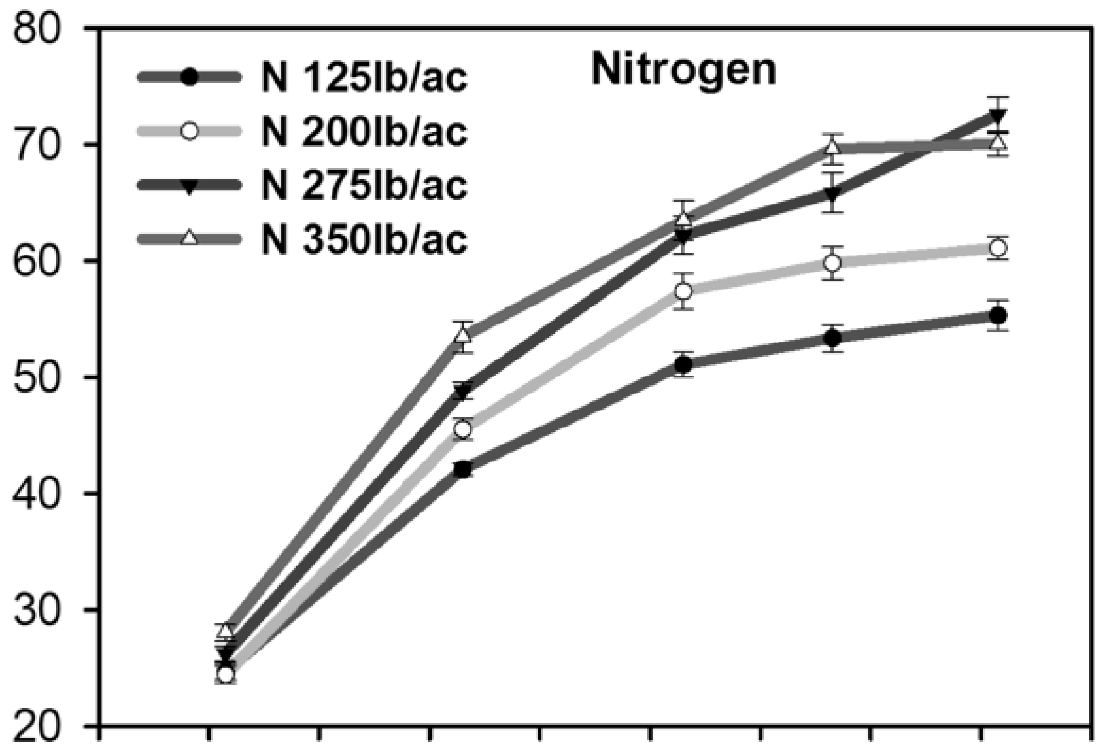

Figure 2. Nitrogen removal by almond fruit to produce 1000lb kernel yield as influenced by nitrogen rate treatment. Each point represents mean and Std error.

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Nutrient removal Per 1000 lb
(Almond =Kernel equivalent)

Nonpareil

- N removal 68 lb per 1000
- K removal 80 lb per 1000
- P removal 8 lb per 1000

Monterrey

- N removal 65 lb per 1000
- K removal 76 lb per 1000
- P removal 7 lb per 1000

Table 1. Guidelines for nutrient removal (all fruit parts) per 1000 lb kernel equivalent yield.