DEVELOPMENT OF A NUTRIENT BUDGET APPROACH AND OPTIMIZATION OF FERTILIZER MANAGEMENT IN WALNUT

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ABSTRACT

With imminent regulations stemming from findings of high fertilizer-related nitrate contamination of groundwater, along with the launch of California’s cap-and-trade greenhouse gas regulation marketplace, and many orchard management expenses on the rise, it is critical that California walnut growers are applying their fertilizer efficiently, to reduce nitrate leaching, N₂O emissions and wasted resources. But much of the information necessary to optimize fertilizer usage is lacking. The timing and scale of nutrient needs on typical soils at today’s high yields have not been quantified, nor have the assessment tools (i.e. critical values) for today’s cultivars.

This project aims to quantify the monthly nutrient needs of walnut orchards, estimate soil nutrient losses and contributions, improve grower nutrient assessment techniques like critical values and leaf sampling, and communicate findings on opportunities for improved nutrient efficiency with a decision support mobile application, publications and presentations. With the support of the Walnut Board last year, the authors of this report launched a comprehensive multi-objective project to improve the state of knowledge of demands and potential losses of nutrients in walnuts, and to provide new and improved tools to growers to monitor the nutrient status of their trees.

As this was the first year of a three year project, there are few results to share. Complimentary funding was secured from the California Department of Food and Agriculture for approximately two-thirds of the overall financial demands of this project. Grower-cooperators were found and sampling sites were established - ‘Chandler’ and ‘Tulare’ orchards in three growing regions – the northern Sacramento Valley, the Delta and the south-eastern San Joaquin Valley. Over the course of the 2013 growing season, leaf and fruit samples were gathered monthly for building a nutrient budgeting and assessment tool. The Delta Chandler site will also be the focus of soil hydrology measurements. In fall soil samples were analyzed to assess orchard soil variability and an instrumentation and sampling plan has been developed based on those measurements. Yearly activities and planned future activities are detailed below.

OBJECTIVES

1. Develop a phenology- and yield-based nutrient demand model for walnut.
2. Determine the contribution of, and losses by, soil of nutrients for tree growth.
3. Validate current leaf critical values and determine if nutrient ratio analysis provides useful information to optimize fertility management.
4. Fine-tune sampling protocols to more accurately reflect the true nutrient status of an orchard block and to enable early season tissue sampling.
5. Integrate phenology, weather and orchard-specific details into a phenology-based nitrogen budget decision support tool (online and mobile application) and Best Management Practices publications.

**SIGNIFICANT FINDINGS**

$376,424 in complimentary funding secured from CDFA. In combination with continued support from the California Walnut Board, this funding will enable meeting the ambitious objectives of this project. This will provides California walnut growers with important findings on nutrient management at a significantly reduced cost.

Data from 2013 samples are still being processed so there are no quantitative data to report at this time.

**PROCEDURES**

Procedures to be followed for the three years of the project are outlined below. Where indicated with an asterisk, tasks planned for April or May were not accomplished in 2013 because funding had not cleared the UC system.

1. Nutrient Demand Model – regular sampling and analysis for nutrient content of catkins, leaves, fruit and perennial tree parts:
   a. Catkins, Leaf and Fruit Demand:
      i. Samples were taken from 10 trees from Chandler and Tulare orchards at 3 sites per cv. (near Los Molinos, Linden, Hanford) and analyzed for N, P, K
      ii. Catkins at senescence*
      iii. Leaves from April* (2013 started in May) through November
      iv. Fruit from May through November
   b. Perennial Parts Demand:
      i. For 3 of the 10 trees from “a” above, perennial parts were sampled for N, P, K
      ii. Sampled January (dormant)*, April (leaf-out)*, May (full leaf growth)*, July (conventional leaf-sample time), and November (post-harvest)
      iii. Roots: root sections were dug up randomly from around the trunk for roots <1cm and >1cm diameter.
      iv. Trunk: 5-cm-deep holes were drilled into the trunk with an electric drill; shavings will analyzed.
      v. Scaffold: 2.5cm holes were drilled into the scaffolds, shavings analyzed.
      vi. Canopy branches: Similar samples as in scaffold.
      vii. Branches: 2 and 3 years old branches were sampled.
      viii. Excavation: At the end of the 2015 season, three trees from one site in our last year will be excavated, divided into roots, trunk, scaffolds, canopy branches and 2-3 year old branches, and quantified for fresh and dry weights. This will allow us to estimate the biomass of each perennial part by scaling up from N/gram perennial part to whole tree demand.
c. **Yield:**
   i. The 10 sampled trees were harvested for individual yield.
   ii. PAR and LAI were measured for each tree to correct yield for tree size, vigor.
   iii. Photosynthetically Active Radiation (PAR) and Leaf Area Index (LAI) for each sampled tree will be measured in July 2014 (collected in October 2013) to provide an indicator of tree vigor.

d. **Phenology:**
   i. Nut characteristics and weight were measured at each sampling
   ii. Hourly temperature recorded by CIMIS will be transformed into Growing Degree Hours

f. **Statistical Analysis:** Initial attempts at statistical analysis will begin in 2014 with the first season’s data, though models will not be finalized until data has been collected for all three seasons. A combination of linear and non-linear statistical approaches will be utilized with individual tree analyses, replicated over several years in a mixed hierarchical model. Effects of climate, location in the field and environment on patterns of nutrient uptake, in-field variability and budget will be determined by cross site comparison. A monthly and GDH-based phenology nutrient demand schedule will be developed, normalized to give pounds of nutrients recommendations based on anticipated yield. A yield potential calculator will be developed by comparing canopy light interception with orchard yields.

2. **Soil nutrient losses**
   a. Extensive soil texture analysis was performed within the soil hydrology orchard, the Linden Chandler site, a mature high-yielding orchard on clay loam soil. Silt, sand and clay percentages were measures at 10 cm increments down to 3 meters at 14 locations in the orchard.
   b. From analysis of soil texture variability, three locations within the orchard have been chosen for intensive monitoring. Equipment will be installed in February/March 2014.
   c. Soil water and nitrate movement will be intensively monitored at 3 trees. Soil water movement and nitrate content will be measured with soil moisture and temperature sensors and solution samplers at four depths within the root zone and one depth beneath the root zone. Moisture and temperature will be measured around the clock, year round. Soil solutions will be sampled based on irrigation and rainfall events. Tensiometers below the root zone will measure movement of soil water lost from the orchard system.
   b. **Statistical Analysis:** Following the 2 seasons of data collection, results will be used to parameterize a HYDRUS model, which then could compute the spatial patterns of water content and nitrate concentration between fertigation strategies, given a specific soil type and irrigation system.

3. **Assessment Tool Refinement:** CVs and Nutrient Ratios
   a. Leaves from 10 trees from Obj 1a.iii were sampled in May and July are being analyzed for S, Ca, Mg, B, Zn, Fe, Mn, Cu in addition to N, P, K.
b. Statistical Analysis:
   i. Initial attempts at statistical analysis will begin in 2014 with the first season’s data, though models will not be finalized until data has been collected for all three seasons.
   ii. Values will be compared with true individual tree yield, as well as PAR- and LAI-adjusted individual tree yield from Obj. 1c to validate or revise critical values.
   iii. Ratios of nutrients and other mathematical relationship will be compared with yield measurements to measure how levels of multiple nutrients considered at once correlate with yield.

4. Assessment Tool Refinement: Sampling Protocol
   a. During leaf sampling for Obj 3a in May and July, leaves from 30 trees (20 additional plus 10 from Obj 3) were sampled for for N, P, K.
   b. Statistical Analysis:
      i. Initial attempts at statistical analysis will begin in 2014 with the first season’s data, though models will not be finalized until data has been collected for all three seasons.
      ii. Spatial statistics will be applied to nutrient content from the 30 trees to quantify inter-tree and intra-orchard variability. This will be used to quantify the number and spacing of trees necessary to sample for 80, 90, 95% certainty that lab results, the average of multiple trees, reflect “true average” nutrient status of an orchard.
      iii. May leaf nutrient content will be compared with July leaf content to build a predictive model. Early sampling prediction models will be distributed to the major CA leaf analysis labs.

5. Lessons and Tools Dissemination:
   a. The majority of the following will be completed in 2015-2016 when data has been analyzed, models have been developed and conclusions have been drawn. It is detailed below to demonstrate the utility of the data that has been and will continue to be gathered.
   b. Nutrient content from Obj 1a-b will be used to chart demand for N, P and K on a monthly basis.
   c. Growing season hourly temperature data from Obj 1e will be transformed into growing degree hours and nutrient demand will also be charted on the basis of GDH after budbreak. This will be compared with by-month demand for accuracy.
   d. Monthly demand measurements and GDH demand measurements will be normalized for each tree and orchard’s yield to give a __ lbs N/ __ tons yield generalization.
   e. A yield projection calculator will be parameterized based on the relationship of our measurements of canopy cover, NDVI, soil type, winter chill and previous orchard yields.
   f. Monthly and/or GDH demand generalization will be integrated with the yield projection calculator to create of phenology- and yield-based nutrient demand fertilization management decision support tool that allows growers to put in as much specific information about their site as possible, draws on existing databases to
further specify the conditions of their site (e.g. CIMIS, SoilWeb, etc) and yields fertilizer recommendations.

g. The support tool will be developed into a web-based module and a mobile application, likely by the UC Agricultural and Natural Resources Division, and posted on the UC Davis Fruit and Nut Resource Information Center website

h. The tool will be presented to farm advisors at the annual Pomology Extension Coordinating Conference, and as many grower meetings as possible

i. Generalized lessons for fertilization management – approximations and rules of thumb for when to apply, how much, and what factors to consider in adjusting these numbers, as well as revisions to sampling protocol and results analysis, will be developed into Best Management Practices publications

j. Articles on decision support tool overview and BMPs will be submitted to grower magazines such as Cal Ag

k. Manuscripts on above findings on modeling and assessing walnut nutrient needs will be submitted to peer reviewed research journals

RESULTS AND DISCUSSION

This was the first year of a three year project, thus there are few results to share. The most significant result to date is that complimentary funding was secured for two-thirds of the total three year project’s cost from the California Department of Food and Agriculture. CDFA has awarded $376,424 for this project from October 1, 2013 – June 30, 2016. This allows the Nutrient Budget project to continue with its ambitious number and scope of objectives. This also mean the walnut growers of California will gain the benefits of an approximately $700,000 nutrient management project (CDFA and UC in-kind) for around $200,000.

Regarding on-the-ground results, grower-collaborators were found and sampling sites established in May for the northern and Delta sites and June for the southern sites. Samples were collected as outlined above. Monthly samples of leaves and fruit were collected from 10 trees at each of six sites from May through harvest (began in June at two Hanford sites) (Obj 1). Leaf samples from 20 additional trees at each site were collected in May and July for predictive sampling and orchard variability modeling (Obj 3 & 4). Perennial parts were sampled in July and November at all six sites. PAR and LAI readings were collected in late September and early October for each of the ten trees being monitored at all six sites. Each of the ten trees at each site was hand-harvest for individual tree yield (Obj 1).

The cost of analyzing the collected samples is fairly high. Funding from the Walnut Board for sample collection, as well as start-up equipment costs, especially for the soil hydrology objective, already placed the amount of funding from the Walnut Board for 2013 above the level of funding for most Walnut Board projects. Thus, in the overall project budget, it was decided that the Walnut Board would fund the sample collection but CDFA would largely fund sample analysis. As such, the samples have only recently been submitted to the analysis laboratory, as funds from CDFA have only recently been made available. Full analysis and results are thus forthcoming.
In addition to the progress in funding and sample collection, progress has been made in the analysis of the Linden Chandler site for the soil hydrology part of the project (Obj 2). Soil cores down to three meters were taken from fourteen locations throughout the orchard to quantify soil textures variability for optimal placement of sampling equipment. Cores have been analyzed and sites for sampling and instrumentation within the orchard have been determined. The majority of the equipment has been ordered and assembled. Installation of equipment is anticipated in February or March, 2014.

The soil hydrology section of this project will be capitalizing on synergies with the Coalition for Urban Rural Environmental Stewardship (CURES), which has installed next-generation soil hydrology measurement equipment in the same orchard with funding from CDFA. This cooperation will provide addition measurements to add to our analysis, verify the accuracy of our results, and provide back-up data in the unlikely event of equipment failure. Our measurements will be useful to CURES to compare their newer, less-tested technologies with the tried-and-true, traditional means of measuring soil hydrology. In the long run, this could benefit the walnut industry by potentially providing less labor-intensive ways of monitoring soil hydrological activity.