Development of a Nitrogen Fertilizer Recommendation Model to Improve N-Use Efficiency and Alleviate Nitrate Pollution to Groundwater from Almond Orchards

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Objectives
1) Conduct field validation of leaf nitrate analysis in almond.
2) Develop an “on-site” test of tissue nitrate concentration throughout the growth season.
3) Determine almond tree seasonal and total N demand for optimum yield.
4) Develop a grower-used computer-based site specific N management program.

Summary
Studies involving 9 commercially managed orchards with 12 trees each and two locations with predetermined N application rates suggested that both leaf total N and leaf nitrate-N are poor predictors of almond meat production. The lack of response of leaf nitrate-N to different N application rates resulted in no improved criteria to diagnose plant N status. Results of tree excavation at different growth stages suggested that total removal of N from almond harvest and leaf drop from a mature tree with a per acre nut meat yield of 4200 lb was 3.8 lb per tree. Storage N from woody plant components contributed 1.7 lb per tree to supply the N demand of early season growth. This storage pool was subsequently replenished in late summer. During spring flush plant growth N needs are satisfied by storage transfer from stem, roots and uptake from soil (33 % each). To balance the full year N demands of the almond tree, total N uptake from soil was 4.3 lb per tree. Of this amount, 13 % was taken up during spring flush (Jan-mid-March), 42 % between spring flush and nut fill (Mid May), and 45 % during summer. This information on N uptake throughout the growth season, will provide guidance for determining the timing of split N

applications, to optimize the nitrogen use efficiency. This information is now being used to develop a fertilization recommendation model.

WORK DESCRIPTION

Task 1: Validating leaf nitrate concentration as an indicator of N status by field survey in 8 to 10 orchards

The purpose of this task was to correlate almond nut yields and leaf nitrate-N concentration in July over a range of fertilization management levels. The task has been completed.

Task 2: Validating leaf nitrate concentration as an indicator of N status on existing pre-determined N application blocks.

The purpose of this task was to correlate almond nut yields and leaf nitrate-N concentration in July over prescribed N levels (0 to 500 lb N/acre) in two orchards located in Yolo and Colusa Counties. The task has been completed.

Task 3: "On-site" measurement of nitrate level in leaves and immature fruits.

The purpose of this task is to develop an "on-site" measurement technique that can detect nitrate level in leaves and immature fruits at early growth stages by using a portable nitrate meter (HORIBA Inc.) and Merck color indicator strips. The task has been completed.

Task 4: Orchard identification, tree selection, pretreatment and sampling.

The purpose of this task is to select highly uniform trees for tree excavation. This task has been completed. 25 highly uniform trees in tree size and leaf total N and nitrate level were selected and labeled for sequential harvest.

Sequential harvest of Almond trees

The purpose of this task is to estimate total and seasonal N demand and N distribution among different components of the tree on well nourished Almond trees. The product of this task will provide the fundamental basis for a N recommendation model based on plant N demand.

Final selection of 25 uniform trees in two sites for the sequential harvest. This will involve exhaustive tree comparison to ensure tree uniformity. Completed.

Leaf, current shoots, old woods, fruit and root sampling at biweekly interval and analysis of N content. Measuring diameter and circumference of old woods of the selected trees biweekly**.** Completed.

Excavation of four trees at each of four growth stages (late dormancy, post-bloom, nut maturity and post harvest). Completed.

Division of whole trees into four components (roots and trunks, shoots, leaves and fruits) and measurement of total biomass of each components. Completed.

Subsampling and estimation of total N among the different components of the tree. Relationship of almond nut yield and total biomass and current growth will be established. Completed by 1/99.

Analyze results, prepare report.

Development of a N management program

The purpose of this task is to assemble all available information into a computer based N management program in which growers can input local variables and receive a best management recommendation for N fertilization. Evaluation of the model effectiveness in providing recommendation will be tested in almond orchards throughout the state in subsequent years. A simple spreadsheet model will be developed that requires input of site-specific data to calculate the total amount of nitrogen required and the best time to apply it.

Development of preliminary PC based N management model as a balance worksheet used by PCAs, farm advisors and growers on farm. Completed.

RESULTS AND DISCUSSION

Relationship between almond meat yield and leaf total N and nitrate-N

This study involved 9 commercially managed orchards with 12 trees each and their corresponding almond meat yield. Results of this study throughout the state suggested that almond meat yield production was not significantly correlated with leaf total N level at the end of July. Thus leaf total N is a poor predictor of almond yield. Leaf Nitrate-N level in July was a better (but not adequate) predictor for almond meat yield. However, this conclusion contradicted to our studies at two locations (Yolo and Colusa County) with predetermined N application rates (ranging from 0 to 500 lb/A), in which almond meat yield of three varieties (Nonpareil, Carmel and Mission) was highly correlated (r=0.50 to 0.75) with total N at the May sampling date for all three varieties (Table 1). In these trials almond meat yield was only poorly correlated with leaf nitrate-N level. The poor correlation between meat yield and leaf Nitrate-N level is attributed to the fact that leaf Nitrate-N levels changed dramatically during the growth season in response to fertilization and irrigation patterns. Thus it is concluded that leaf nitrate-N level is not a good predictor for almond meat production.

It is concluded that both leaf sampling techniques are strongly affected by location and cultivar and each provide only a very poor indication of tree N status and response.

Comparison of nitrate-N analytical methods

Nitrate levels in fresh leaves and immature fruits were tested by using different portable methods and the results were compared with those determined using standard laboratory procedure (Carlson's gas diffusion conductimetric method). Compared with the standard laboratory method (Table 2), the portable nitrate meter (HORIBA Inc.) is over-sensitive for measuring tissue extracts of almond, while the semiquantitative method (Merck color indicator strips) provides only limited sensitivity in measuring nitrate level in the tissue extracts. Agri-Lab (Spectrum Technologies, Inc. Plainfield, Illinois) provided a result similar to the standard laboratory method. However, nitrate-N levels in both leaves and immature fruits at early growth stages could not be detected reliably due to their low concentrations at this stage of growth. Reliable nitrate-N can only be obtained when leaf nitrate-N level is above 100 ppm.

Nitrate-N variation over the growth season

Leaf Nitrate-N level varies significantly among different orchards and over the growth season. Leaf nitrate-N level varies from 10 to 78 ppm in young almond orchards (Yolo County) and is not significantly affected by N application rate. In a mature orchard (San Joaquin County), leaf nitrate-N level was below 100 ppm before June, and increased to about 300 ppm after that, and it did not decrease till one month after harvest (Figure 4).

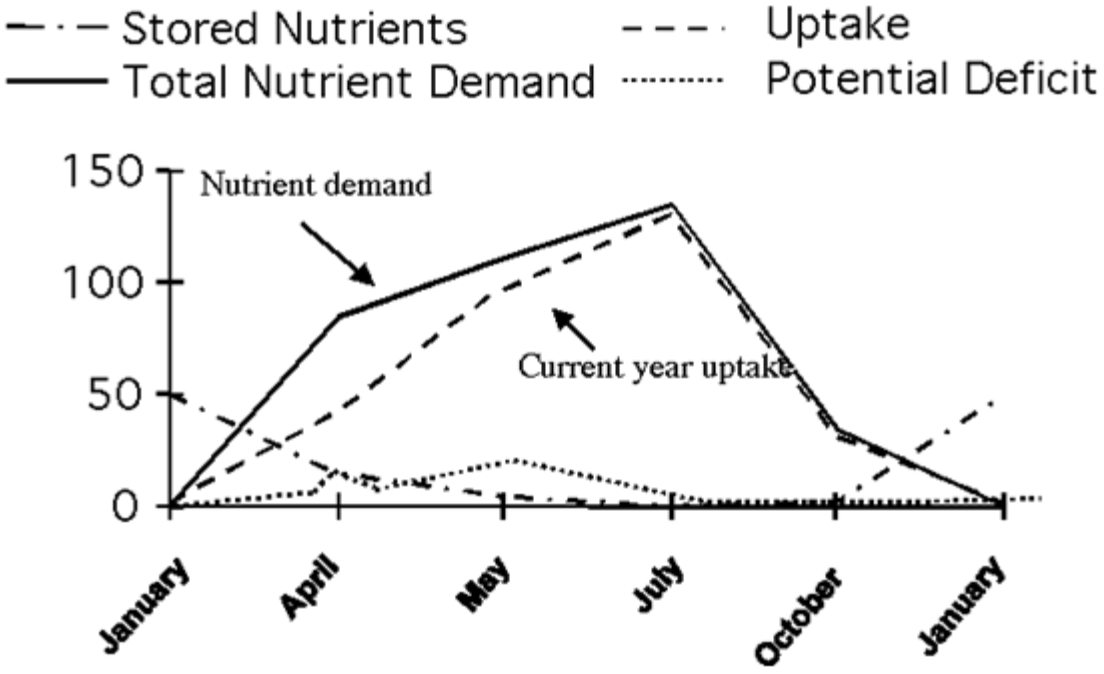
Uptake and distribution of N

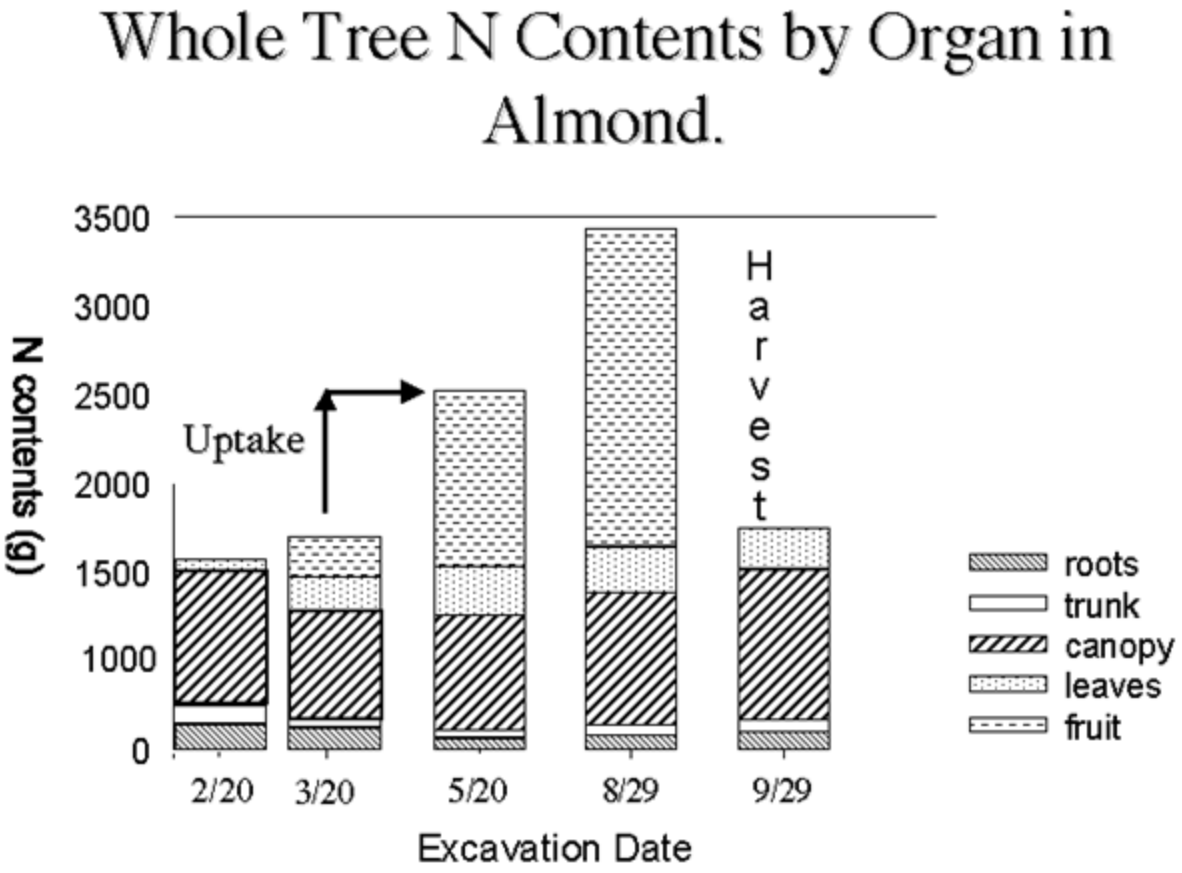
The total N requirement for tree growth which included 57 lb almond meat and 42 lb leaves, was 4.3 lb N/tree. Since there was about 0.5 lb N recycled back to perennial tissues from leaves prior to leaf drop (which represents 42 % of the maximum leaf N content), total removal of N from almond harvest and leaf drop from a mature tree was 3.8 lb per tree.

To fulfill this N requirement, storage N from woody plant components contributed 1.7 lb per tree. During spring flush plant growth N needs are satisfied by storage transfer from stem, and roots and uptake from the soil (33% each). Storage N contribution from roots reached a maximum (1.7 lb/tree) at mid May, which is about 46% of N content in fruit and leaves at this stage. Above ground perennial tissue contributed 28% of the storage N with the remaining (78%) from roots. Replenishment of N storage in roots started after mid-May, and about 50% of N uptake during mid May through harvest was used to replenish storage in the roots.

To provide for the N demand of these almond trees, total N uptake from soil was 4.3 lb per tree. Of this amount, 13% was taken up during spring flush (Jan-mid-March), 42% between spring flush and nut fill (Mid May), and 45% during summer. This proportion of N uptake throughout the growth season provides guidance for determining the timing and rate of split N applications in our fertilization recommendation model which is under development. The pattern of N uptake and distribution in the almond tree is presented in Figures 1 and 2

Nutrient Fluxes (N) in Almond

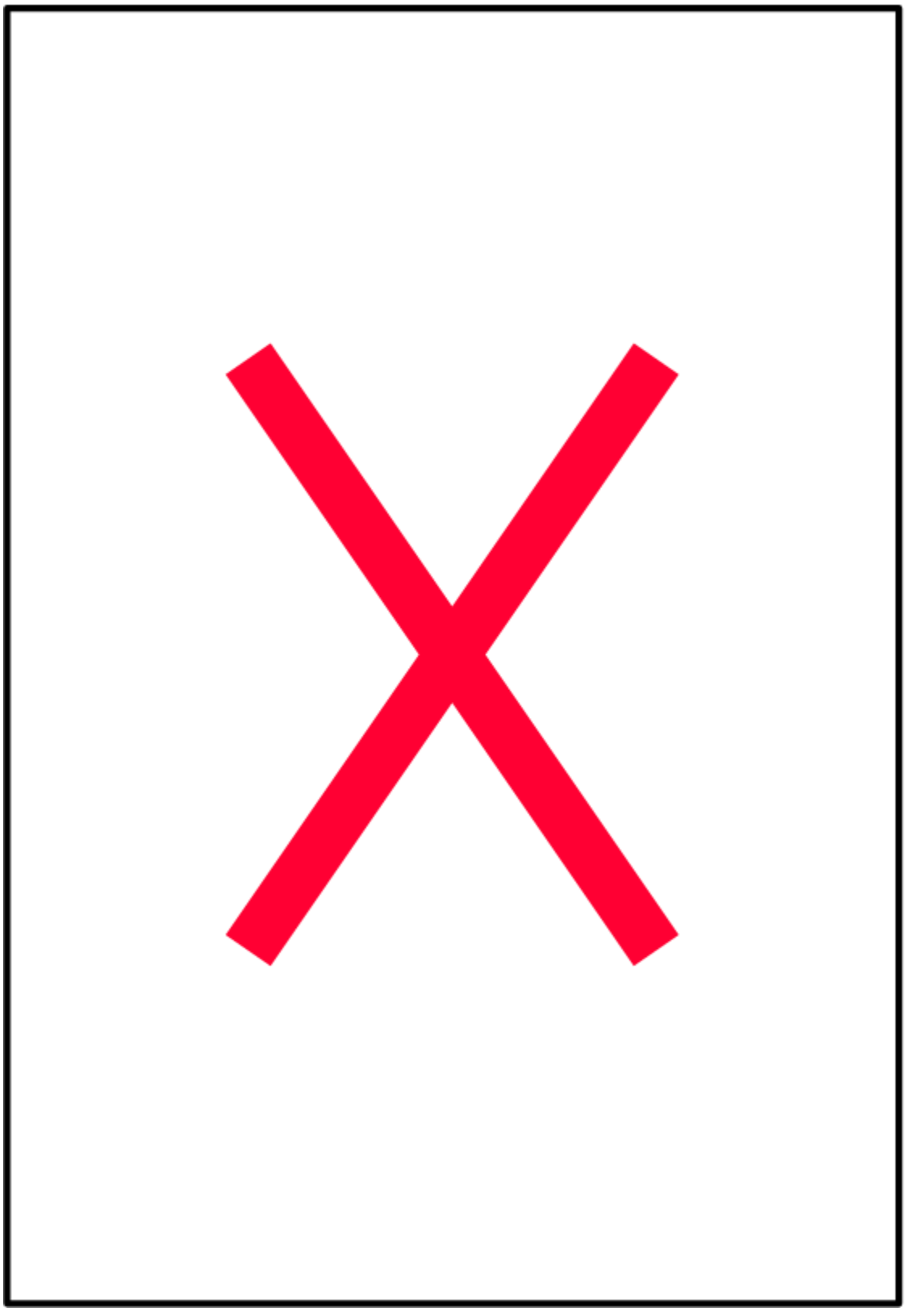




Development of Nitrogen Management Program: The final task of this project was the development of an interactive nitrogen management program. The first working version of this program is now available and has been released to growers through a variety of conferences and mailings. Ongoing refinement of the program is underway. The following brief description is provided, a fully functional version of this program is available by contacting the author.

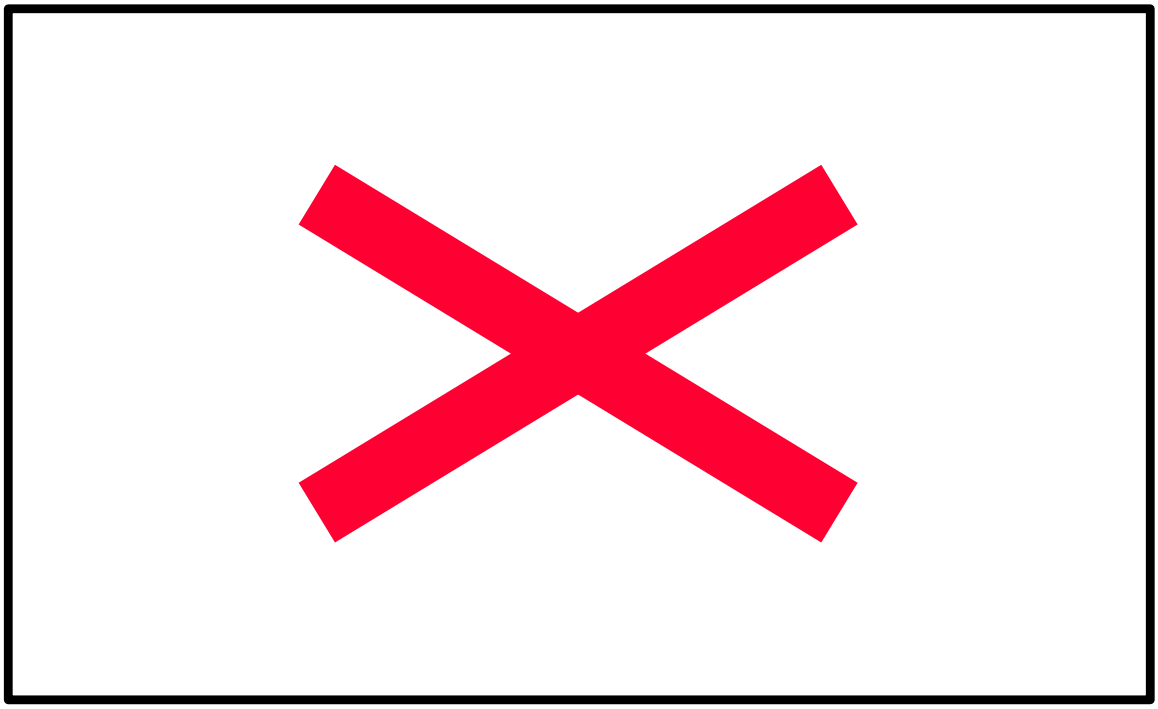
Page 1: General introduction and instructions. (Not shown)
This page includes background information and instructions on how to use the program. Description of pop-up menus, program authors and funding is included.

Page 2: Input screen for individual field data. This screen provides an interactive format for growers to enter historic yield data, current flowering conditions, fertilization strategy, irrigation water source, amount and N content, inputs from manures, cover crops etc., as well as previous years leaf nitrogen status. This data is then used to calculate an estimated N use pattern and quantity to guide fertilization.



Page 3: Estimated N Demand and Recommended Fertilization Strategy.

This final page provides the specific fertilization recommendations for the given field, using historic and current conditions. Data can be saved and printed and new information entered as required. Information throughout provides guidance for growers to help reduce excess N usage and increase efficiency of application.



Summary: This project has now provided the means to estimate seasonal N demand in a mature, high yielding 'Non Pareil' almond orchard and has been used to develop a computer based N fertilization and recommendation program. This program should be a useful tool to guide grower N usage and to aid in the complex calculations required to optimize fertilization programs. This approach also helps encourage growers to consider the impact of various management strategies and practices with the ultimate goal of minimizing excessive N fertilization. If successful this approach can help improve economic efficiency and reduce environmental damage associated with almond production.