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Nitrogen Management in Nut Crops

This publication describes nitrogen (N) management in the nut crops almond, pistachio, and walnut. Demand for judicious use of N fertilizer to reduce N leaching to groundwater is increasing, which requires that fertilizer be applied according to the crop demand, optimizing yield and reducing leaching. In response to evidence of widespread nitrate pollution of groundwater, the Central Valley Regional Water Quality Control Board has adopted a regulatory program to protect groundwater resources that requires nut crop growers to use best N management practices to reduce nitrate loading. The objective of this publication is to optimize N use efficiency in nut crops in order to reduce N leaching.

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Nitrogen is the nutrient plants require in the largest quantity for better yield and quality. Nitrogen is also an integral constituent of proteins, nucleic acids, chlorophyll, co-enzymes, phytohormones, and secondary metabolites, and its deficiency can negatively affect yield. Nitrogen-deficient plants are stunted, with narrow, small, pale leaves. Excessive N application increases vegetative growth and susceptibility to diseases that infect fruit, kill spurs, and reduce yields in subsequent years.

The 4 R's of Nutrient Management

Traditionally, nutrient management has been based on leaf sampling and collection, analysis, and comparison with established critical values, combined with applying fertilizers when leaf analysis for a particular element falls below a specified critical value. While this has been a useful tool for diagnosis of nutrient deficiency or excess, it is now recognized that this approach does not provide sufficient information to define the rate and timing of fertilizer applications.

Many nutrient management tools have been used in annual and permanent crops to guide the quantity and timing of fertilizer application and to diagnose nutrient deficiency or excess. In recent years, nutrient budgets and the 4 R's approach (right rate, right time, right placement and right source) to fertilizer management have been gaining widespread acceptance (see the International Plant Nutrition Institute website, http://www.ipni.net/4R). In the nutrient budget and 4 R's approach, fertilizers are applied in proportion to the demand of the crop (right rate) and timed with periods of nutrient uptake (right time), so that crop demand is satisfied in a timely fashion, avoiding the application of fertilizers in excess of plant capacity for uptake. Placement within the active root zone is essential to maximize fertilizer use and avoid losses. This approach, integrated with the use of early-season leaf analysis, has been developed for almond and pistachio, and research is being conducted to develop the same approach for walnut.

The goal of any fertilizer management strategy is to ensure that adequate nutrients are available to supply the current demand of the plant. While N is required for all plant processes and in every organ, the development of the fruit represents by far the largest sink for N use in nut crops. Nitrogen uptake is demand driven, that is, it is the size of the crop determines how much N will be taken up by roots and when that uptake will occur. While a shortage of N can reduce yield by preventing full fruit growth, adding N in excess of plant demand does not increase yield and may result in loss of N to groundwater and a reduction in efficiency.

A decision on the final quantity of fertilizers must also consider the amount of N from secondary sources. Secondary sources of N in agricultural systems include soil organic matter, organic amendments, and N already found in the environment. Soil N is derived from organic matter and includes an active fraction consisting of microorganisms, several intermediate stages, and a stable resistant fraction also referred to as humus. These forms are characterized by their carbon to N (C:N) ratio, where matter with a higher C:N ratio takes more time to become plant available. Organic amendments such as cover crops, manure, and compost are also important N sources. Like soil organic matter, N availability from organic amendments depends on the C:N of the material, with cover crops being the most readily available after tillage, followed by animal manure, and lastly compost where the composting process has stabilized much of the organic N. Finally, N availability is contingent on transformations of organic N into inorganic N. Other secondary N sources include nitrate (NO_3^-) in irrigation water and N deposition from air pollution such as smog. These environmental inputs are nontrivial amounts of N in agricultural systems, but their amount depends on the air and water quality of the region.

Right Rate and Time of Nitrogen Application in Almond Orchards

Previously, N management in almond was based on July leaf sampling and analysis and comparing the results with established critical values. Fertilizers were applied if N was deficient. However, this approach does not provide information on the rate and timing of N fertilizer application and resulted in overuse of fertilizer. A multiyear, multisite experiment was conducted from 2008 to 2012 in which 768 trees were individually monitored for changes in nutrient concentrations and biomass accumulation in fruit and leaves during the season. Seasonal pattern of N accumulation in perennial organs was estimated by tree excavation at the beginning and end of two seasons and collecting samples from perennial tissues (digging samples from roots and coring into the trunk, scaffold, and branches) at multiple times during the season. Based on the information from this experiment, protocols were developed that guide the rate and timing of fertilizer application based on N removal in the harvested crop and N needs of the perennial organs (Muhammad et al., 2015). A leaf N prediction model was also developed that predicts N in July leaves from leaf samples collected in spring (April) to help growers with in-season fertilizer adjustment (Saa et al., 2014). The research results show that over 90% of the N accumulates in the fruit, while a small percentage is partitioned into leaves and used for perennial growth (fig. 1). Flowering, fruit set, and early fruit growth depend entirely on the N stored in the perennial organs of the tree, and N uptake from soil

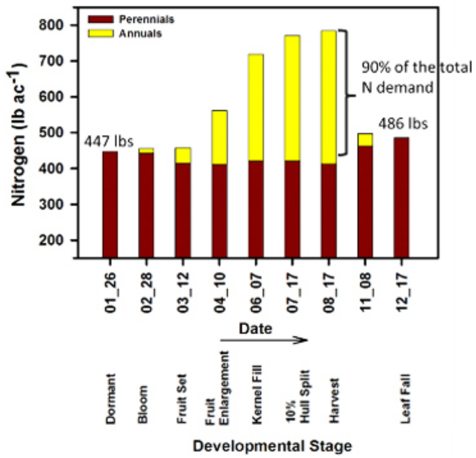

Figure 1. Nitrogen partitioning in annual and perennial organs (lb/ac) in mature almond orchard. Over 90% of the tree N is partitioned into fruit.

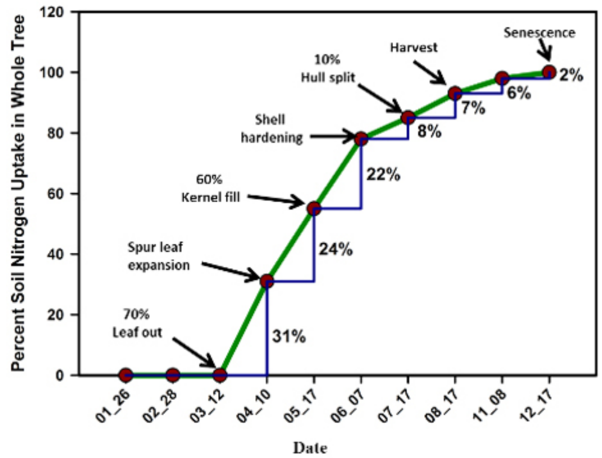

Figure 2. Nitrogen uptake as a percentage of the total tree nitrogen uptake during the season. Nitrogen demand of flowering, fruit set, and leaf out is supplied by the N stored in perennial tissues. Soil N uptake begins at 70% leaf out, which coincides with the beginning of active rot growth.

begins only with the commencement of root growth, which occurs at 70% leafout.

In an almond orchard with high yields and adequate N status, 68 lb N is removed in fruit per 1,000 lb kernel yield. Therefore, N demand of mature, productive almond orchards can be calculated by multiplying 68 lb N per 1,000 lb kernel by the estimated production. This approach works well at yields above 2,000 lb since the demand for N for tree growth is relatively low (20 to 25 lb) and sufficient N is provided to satisfy all tree demand. Trees with lower yield have greater vegetative demand either because they are younger and more vigorous or because the low yield favors more prolific vegetative growth. Younger trees are actively growing and have perennial tissues with higher N concentration (stems) than older trees that are growing perennial tissues with lower N concentrations (wood and spurs).

The general pattern of N uptake during a year is shown in figure 2. To achieve maximum efficiency of applied fertilizer N, delivery should be timed in as many split applications as possible, with applications being in proportion to the N demand during that period. In the example shown in figure 2, N is applied in 6 split applications, with 31% of the total annual N demand being provided at 70% leaf out (March 12 in this example), 24% being applied when spur leaves reach full expansion, 22% applied at 60% kernel fill, 8% applied at shell hardening, 7% at hull split, and 8% postharvest. Nitrogen uptake following the commencement of hull split is very low (maximum of 15% of annual N demand); this uptake can be compromised if trees are excessively stressed as a result of harvest. If yields are lower than previously predicted, a final planned N application can be reduced or eliminated.

While the application of N in as many splits as possible, known as “spoon feeding,” results in the greatest N use efficiency, it is sometimes not practical due to management or engineering constraints. If so, applications should still be made according to the N uptake patterns shown in figure 2, with the total N application remaining the same but being divided into fewer individual applications.

Protocols for Nitrogen Budgeting and April Leaf Sampling for In-Season Nitrogen Management in Almond

Apply the following protocols for N budgeting and April leaf sampling for in-season N management in almond.

- Estimate the expected yield at bloom based on historic yield trends for each orchard, last year’s yield, bloom intensity, climatic conditions, bee activity, and past experience.
- Estimate annual inputs of N from all sources, including irrigation water, manures, composts, etc. In many part of the

San Joaquin and Sacramento Valleys, wells have significant concentrations of nitrate, which is a source of N. The quantity of N in irrigation water can be calculated as follows.

- If water analysis is reported as nitrate-N:

total N = nitrate-N (ppm) × 2.73 × water applied (ac/ft)

- If water analysis is reported as nitrate:

total N = nitrate (ppm) × 0.61 × water applied (ac/ft)

- Calculate preliminary fertilization rates based on 68 lb N per 1,000 lb kernel yield.
- Make the first application of fertilizer in early spring (15 days post-bloom); apply 31% of the annual N demand. If rainfall is high, the fertilizer can be split in two applications to avoid N leaching.
- Collect and analyze April leaf samples.
  - Sample all the leaves of 5 to 8 nonfruiting, well-exposed spurs per tree at approximately 43 ± 3 days after full bloom (DAFB) when the majority of leaves on nonfruiting spurs have reached full size. In the majority of California almond orchards, this corresponds to mid-April. If sampling is not possible at this time, note the date of sample collection on the sample bag.
  - Collect leaves from 15 to 30 trees per orchard. Combine all leaves in a single bag for submission to a reputable laboratory. Each sampled tree must be at least 30 yd apart. A minimum of 100 leaves per sample bag is required.
  - Send the samples to the lab and ask for a full nutrient analysis (N, P, K, S, Ca, Mg, B, Zn, Cu, Fe, and Mn) and application of the UCD-ESP program.
  - Based on the N concentrations in early-season samples, the lab will predict the July leaf N concentrations and whether orchard N will be adequate, deficient, or excess.
  - If the lab did not provide estimate of the July N, estimate the July tissue N values using the worksheet at the University of California Agriculture and Natural Resources Advanced Sensing and Management Technologies website, http://ucanr.edu/sites/scri/Crop_Nutrient_Status_and_Demand__Patrick_Brown/.
- Conduct in-season yield estimation at full leaf expansion (43 ± 6 DAFB).
- Use April tissue sampling and early-season yield estimation to optimize the annual N fertilization plan by adjusting the fertilization rates at mid-April through-July, fruit maturity, and/or postharvest.

Examples and scenarios to adjust N fertilizer application according to estimated yield and early spring leaf samples are presented below. These scenarios should be adjusted based on the local environment. In the following examples, recommendations are provided as pounds (units) of N. The conversion of pounds of N required into pounds of fertilizer is determined by the concentration of N in the fertilizer. For example, UAN 32 is 32% N by weight, hence 100 lb (units) of N will be delivered in 312 lb of UAN.

- Preseason predicted crop demand in lb N (A): Predicted yield, as estimated at bloom (Y_{pred}), divided by 1,000 times 68. Example: 3,000 lb ÷ 1,000 × 68 = 204 lb N.
- Nitrogen in irrigation water in lb N (B): Nitrate concentration (ppm) times the acre-feet of irrigation water applied times 0.61; or nitrate-N concentration (ppm) times acre-feet of irrigation applied times 2.73. Example: 2.26 ppm nitrate-N × 4 ac-ft × 2.73 = 24.7 lb N.
- Nitrogen from other inputs (manures, composts, cover crops) in lb N (C): in this example, 0.
- Early-spring application rate (D): (A) minus (B+C) times 31% of annual demand. This is the number of pounds of N per acre that can be applied in the spring at 70% leafout (early-spring application). Example: D = (204 – 24) × 0.31 = 55.8 lb N.
- In-season adjustment factor (E): Conduct leaf sampling and analysis according to methods described above. The testing lab will provide a prediction of your July leaf tissue adequacy.

Using your best judgment or that of an expert consultant, visually estimate the yield of the orchard at 43 ± 6 days (Y_{est}).

In-Season Estimate Examples

The four scenarios described below illustrate the process of N management based on yield estimate and April leaf analysis.

1. If April leaf tissue analysis predicts that the July tissue concentrations will be adequate or excessive, and if estimated yields (Y_{est}) are approximately equal to predicted yields (Y_{pred}) as determined in (A) above, use the following N fertilization:
   a. Fruit growth application = 24% of total N demand (204 – 24) × 0.24 = 43.2 lb.
   b. Kernel fill applications = 22% of total N demand (204 – 24) × 0.22 = 40.5lb.
   c. Fruit maturity application = 15% of total N demand (204 – 24) × 0.15 = 28 lb.
   d. Postharvest application = 8% of total N demand (204 – 24) × 0.08 = 15 lb.
2. If April tissue analysis predicts that the July tissue concentrations will be adequate or excessive, and if estimated yields (Y_{est}) differ substantially from preliminary predicted yields (Y_{pred}) as determined in (A) above, then reduce or increase N fertilization in subsequent fertilizations accordingly:
   a. Divide field estimated yields (Y_{est}) by preliminary predicted yields (Y_{pred}) = Z. Example: 2,000 ÷ 3,000 = 0.66.
   b. Fruit growth application = 25% of total N demand: (204 – 24) × 0.66 × 0.24 = 28.5 lb.
   c. Kernel fill applications = 22% of total N demand: (204 – 24) × 0.66 × 0.22 = 26 lb.
   d. Fruit maturity application = 15% of total N demand: (204 – 24) × 0.66 × 0.15 = 18 lb.
   e. Postharvest application = Skip postharvest application.
3. If April tissue analysis predicts that the July tissue concentrations will be more than adequate, and if estimated yields (Y_{est}) differ substantially from preliminary predicted yields (Y_{pred}) as determined in (A) above, reduce or increase N fertilization in subsequent fertilizations accordingly:
   a. Adjusted fertilization = field estimated yields (Y_{est}) divided by preliminary predicted yields (Y_{pred}). Example: 2,000 ÷ 3,000 = 0.66.
   b. Fruit growth application = 24% of total N demand: (204 – 24) × 0.66 × 0.24 × 0.9 = 25.7 lb. Reduce N application by 10% due to excessive leaf N.
   c. Kernel fill application = 22% of total N demand (204 – 24) × 0.66 × 0.22 × 0.9 = 23.5 lb. Reduce N application by 10% due to excessive leaf N.
   d. Fruit maturity application = 15% of total N demand (204 – 24) × 0.66 × 0.15 × 0.9 = 16 lb. Reduce N application by 10% due to excessive leaf N.
   e. Postharvest Application = Skip postharvest application.

      Note: In regions where significant rainfall may occur during this period, growers should consider use of a foliar application of N or supply N in a manner that minimizes loss potential.
4. If April tissue analysis predicts that your July tissue concentrations will be adequate or will exceed the critical value, and if harvested yields (Y) are significantly less than preliminary predicted yields (Y_{pred}), the final fertilizer application can be eliminated.

The Right Rate and Time for Nitrogen Application in Pistachio Orchard

Like almond, most of the N in pistachio is removed in the harvested fruit. Nitrogen present in leaves during the season is either remobilized before leaf senescence or returns to the soil organic matter, which releases N over a longer period of time. Nitrogen in pruning is returned to the orchards but remains available over a longer period of time as decomposition rate is slow. Nitrogen is added to the pistachio orchard in the form of fertilizers, in irrigation water and in compost, manure, or cover crops. Pistachio has a biennial bearing habit, with heavy crop in one “on” year and a small crop in the next "off" year. During the on year, a majority of the N is partitioned to fruit; in the off year, a majority of the tree nitrogen demand is for vegetative growth.

Previously, N management in pistachio was based on July leaf sampling and analysis. A decision to apply fertilizers was made if N was deficient. Protocols on the right rate and right time of N fertilization in pistachio were developed by conducting multisite and multiyear research. The research showed that 28 lb N is removed in fruit per 1,000 lb dry CPC yield. Although this research did not involve tree excavation, a previous research (Rosecrance et al., 1998) reports annual N demand of vegetative growth as 20 to 25 lb/yr N during the on year and 25 to 30 lb during the off year.

Demand of the growing nuts is small early in the season and is filled mostly by the remobilization of stored N from the perennial organs. Mature pistachio trees entering an on year store 1.2 lb N in the woody tissues, which is sufficient to fulfill the demand of flowering, fruit set, and leaf growth. Trees entering the off year have low nitrogen storage (0.15 lb), but the early demand of the tree is small given the lower number of flowers.

A total of 18% of the total N in nuts is accumulated by 31 ± 3 DAFB; 36% by 72 ± 3 DAFB; 61% by 98 ± 3 DAFB; 86% by 131 ± 3 DAFB; and the remaining N by harvest (fig. 3). Kernel growth in pistachio begins after shell hardening, and the majority of the nut N demand is driven by kernel filling. Therefore, apply N fertilizer in multiple splits to match supply with the demand of the growing fruit.

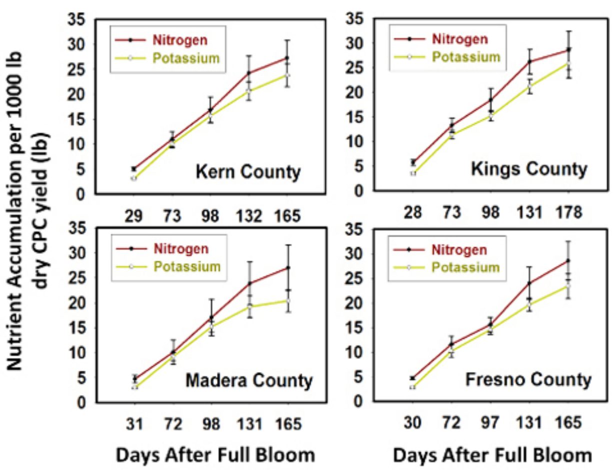

Figure 3. Nitrogen and potassium accumulation in pistachio fruit during the season based on 1,000-lb CPC yield for different sites.

Pistachio is a highly alternate bearing species, with yield varying from less than 4 lb/tree in the off year to over 40 lb/tree during the on year. The nitrogen demand of the tree also depends upon the yield. In an off year, pistachio trees store N in the woody tissues to meet the early season demand of next year's crop. If the soil organic N is low, apply 40 to 50 lb/ac N in the off year to support growth and store N in the trees. In scenario of high availability of N from organic sources or irrigation water, no additional N application may be needed.

Protocols for Nutrient Budget and Early-Season Leaf Sampling in Pistachio

The current practice of sampling leaves in July is too late to allow for current-season adjustment of fertilization. An improved method of leaf sampling and fertilization management has been developed that uses a nutrient budget based on predicted yield and adjusts N application based on May leaf sampling and yield estimations to estimate N demand and in-season fertilizer adjustments. Apply these protocols as follows.

- Preseason predicted crop demand in lb N (A): Predict the expected yield at bloom based on historic yield trends for each orchard, last year's yield, alternate bearing habit, tree age, climatic conditions, and grower experience. Calculate the quantity of N based on predicted yield and 28 lb N removal per 1,000 lb CPC yield. For example, for a predicted 4,000 lb CPC yield, the estimated N demand of the fruit and vegetative growth would be (4,000 ÷ 1,000) × 25 = 137 lb.
- Nitrogen in irrigation water, in pounds (B): Nitrate concentration (ppm) times ac-ft irrigation applied times 0.61, or nitrate-N concentration (ppm) times ac-ft irrigation applied times 2.7. Example: 4 ac-ft × 2.26 ppm nitrate-N = 24.4 lb N.
- Nitrogen from other inputs (manures, composts, cover crops) in lb N (C): Consider nitrogen from other inputs as part of

the nitrogen budget for pistachio. This will further reduce the nitrogen fertilizer application.

- Early-spring application rate (D): Early-spring N application rate equals (A) minus (B + C) times 20% of annual demand. This is the pounds of N per acre that can be applied in the spring. Make the early-spring application at 15 days post-bloom; depending on climatic conditions, the fertilizer can be split in two applications to avoid N leaching if rainfall is high,

$$\mathbf{D = (137 - 24) \times 20\% = 23\ lb\ N.}$$

  - At 40 ± 6 DAFB collect leaf samples to predict leaf N and in-season N fertilizer adjustment. For each orchard block or sub-block for which you wish to have individual information
    - Sample ten leaves from non-fruiting, well-exposed branches per tree at approximately 40 ± 6 DAFB when the majority of leaves on nonfruiting branches have reached full size. In the majority of California pistachio orchards, this corresponds to mid-May. Note the date of sample collection on the sample bag.
    - Collect leaves from 18 to 20 trees per orchard. Combine all leaves in a single bag for submission to a reputable laboratory. Each sampled tree must be at least 25 yd apart. A minimum of 180 leaves per sample bag is required.
    - Send the samples to the lab and ask for a full nutrient analysis (N, P, K, B, Ca, Zn, Cu, Fe, Mg, Mn, S) and application of the UCD-ESP program.
    - These techniques have been validated only for the Kerman pistachio variety in orchards that are at least 10 years old. If other cultivars are used, please note which cultivar was sampled on the sample bag.
    - Repeat for all orchards and orchard regions that differ in productivity, age, or soil type. Identify areas of low performance and collect samples from them independently.
    - Label all samples well with collection date, field number, cultivar, and field location if needed. Note whether foliar fertilizers have been applied.
- In-season adjustment factor (E): Conduct leaf sampling and analysis according to methods described above for leaf sampling. The testing lab will provide a prediction of your July leaf tissue adequacy. Using your best judgment or that of an expert consultant, visually estimate the yield of the orchard in late April or May (Y_{est}). Note that yield estimations need only be as good as possible, since visually estimating yield is a difficult skill and subsequent fruit drop can occur. The intent is to be flexible in management and able to respond to current-season demands by adjusting fertilization strategy.

Early-Season Sampling Examples

Four scenarios are described below to illustrate this process.

1. If May leaf tissue analysis predicts that your July tissue concentrations will be adequate or excessive, and if estimated yields (Y_{est}) are approximately equal to predicted yields (Y_{pred}) as determined in (A) above, then the following N fertilization can be used.
   a. Fruit growth application and kernel fill applications = 1.5 × early-spring application rate (23 × 1.5 = 34.5 lb N).
   b. Fruit maturity applications = early-spring application rate (23 lb). In regions where significant rainfall may occur during this period, growers should consider using a foliar application of N or suppling N in a manner that minimizes loss potential.
2. If May tissue analysis predicts that July tissue concentrations will be adequate or excessive, and if estimated yields (Y_{est}) differ substantially from preliminary predicted yields (Ypred) as determined in (A) above, reduce or increase N fertilization in subsequent fertilizations accordingly.
   a. Divide field estimated yields (Y_{est}) by preliminary predicted yields (Y_{pred}) = Z. Example: 3,000 ÷ 4,000 = 0.75.

b. Fruit growth application and kernel fill applications = (1.5 × Z) × early-spring application rate. Example: 23 × 1.5 × 0.75 = 26.

c. Fruit maturity and early postharvest applications = early-spring application rate × Z. (Example: 23 × 0.75 = 17.3). In regions were significant rainfall may occur during this period, growers should consider using a foliar application of N or supplying N in a manner that is minimizes loss potential.

3. If May tissue analysis predicts that July tissue concentrations will be less than adequate, and if estimated yields (Y_{est}) differ substantially from preliminary predicted yields (Y_{pred}) as determined in (A) above, reduce or increase N fertilization in subsequent fertilizations accordingly.

   a. Divide field estimated yields (Y_{est}) by preliminary predicted yields (Y_{pred}) = Z.

   b. Fruit growth application and kernel fill application = (1.7 × Z) × early-spring application rate.

   c. Fruit maturity applications = (1.2 × Z) × early-spring application rate. In regions where significant rainfall may occur during this period, growers should consider using a foliar application of N or supplying N in a manner that minimizes loss potential.

4. If May tissue analysis predicts that your July tissue concentrations will be adequate or will exceed the critical value and if harvested yields (Y) are significantly less than preliminary predicted yields (Y_{pred}), the final fertilizer application can be eliminated.

Nitrogen Management in Walnut

The recommendations for nitrogen management in walnut are being refined to develop a protocol for in-season N management. Like other nut crops, most of the N in walnut is removed in the harvested fruit. Some N is also removed from the orchard in pruning. Nitrogen present in leaves during the season is either remobilized before leaf senescence or added to the soil as an organic N source, which degrades and release N in the soil but over a longer period of time.

Current N management in walnut is based on July leaf sampling and analysis. A decision to apply fertilizers should be made if N is deficient. Protocols on the right rate and right timing of N fertilization in walnut are being refined by conducting multisite, multiyear research. Initial results show that N removal from a walnut orchard is lower than previously reported (Pope et al. unpublished data). Previous research reported 40 lb N removed from walnut orchard per 1,000 lb in-shell yield (Weinbaum et al., 1991). The current multisite, multiyear research shows that both Chandler and Tulare varieties remove 27.5 lb of N per 1,000 lb in-shell yield on average over six sites and 2 years. Nitrogen removal in orchards varied depending on orchard Nitrogen status and ranged from 25 to 31 lb for Chandler and 25 to 33 lb for Tulare. Nitrogen removal per 1,000 lb in-shell yield was more variable between sites than between cultivars. At the same site, varieties have no significant effect on N removal under equal yield conditions, and N removal from orchard varied based only on orchard N status.

Although fruit are the greatest sink of N removal from a walnut orchard, an estimated 15.6 to 26.6 lb/ac N is removed in the abscised leaves. While early-season leaf analysis is being developed for walnut to predict leaf N in July using leaf sampling in April and May, N can be applied according to fruit N demand calculated from estimated yield and monitored by leaf analysis in July.

Nitrogen uptake from soil begins after leaf out and is greatest from onset of shoot growth to later stages of kernel fill. Previous research shows that the early demand of leaf growth and flowers is met by N stored in the perennial organs of the tree (Deng et al., 1989). Active N uptake from soil begins after leaf emergence, active transpiration, and root growth. Walnut varieties vary slightly in their N accumulation and demand pattern (fig. 4). Chandler accumulates all N in fruit by August, while Tulare continue to accumulate N in fruit until September (table 1).

To estimate the total N demand of a walnut orchard, predict the yield based on previous yield data, flowering intensity, climatic conditions, and grower experience. After yield prediction, the quantity of N (lb) required can be calculated as

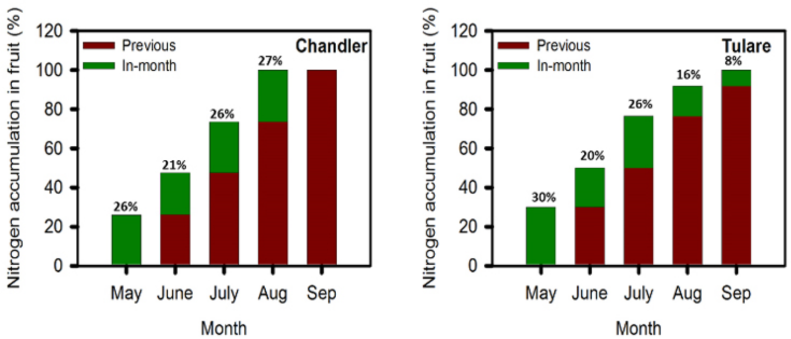

Figure 4. Percent nitrogen accumulation in Chandler and Tulare walnut fruit over the season. Data is the average of six sites and two years for each variety.

N = (expected yield lb ÷ 1,000) × 2.75 + 20.

After calculating the required quantity of N, account for other sources of N added such as manure, green manuring crops, N from irrigation water.

Apply 26% of the annual N demand at 70% leaf out. Estimate the yield at fruit set; if the estimated yield is same as predicted yield, apply 21% in late May, 26% in late June, and 26% late July. If the estimated yield is more or less than the predicted yield, increase or decrease the quantity of fertilizer according to the estimated yield.

Table 1. Nitrogen accumulation in fruit for selected walnut varieties.

Month	**Nitrogen accumulation in fruit, %**	
	Chandler	**Tulare**
May	26	30
June	21	20
July	26	26
August	27	16
September	0	8

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