University of California
Agriculture and Natural Resources

Nitrogen Management in Citrus and Avocado

In response to evidence of nitrate pollution of groundwater, the Central Valley Regional Water Quality Control Board has adopted a regulatory program to protect groundwater resources that requires growers to use best nitrogen (N) management practices to reduce nitrate loading. The objective of this publication is to optimize N use efficiency in citrus and avocado crops with the outcome of reducing N leaching.

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 approach 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 budgeting 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

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are applied in proportion to the demand of the crop (right rate) and timed with periods of nutrient uptake (right time). 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.

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 the largest sink for N in citrus and avocado. Nitrogen uptake is demand driven: the size of the crop determines how much and when N will be taken up by roots. 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.

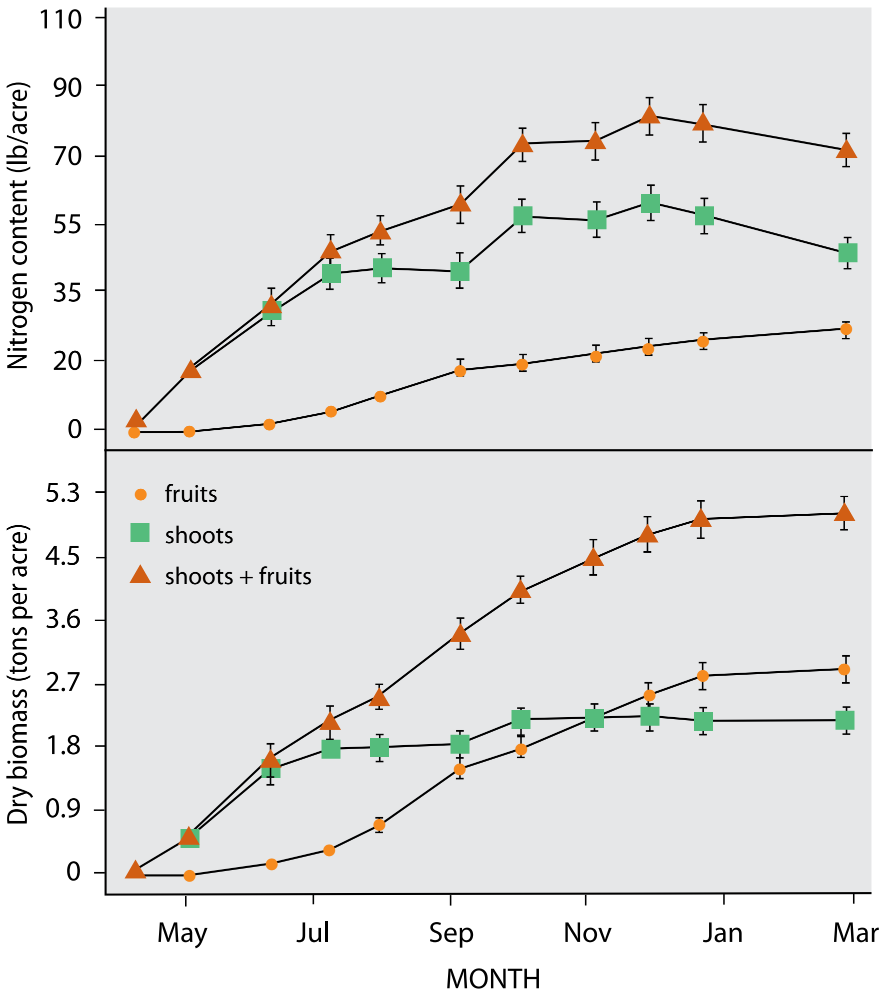
A decision on the final quantity of fertilizer applied must also consider the amount of N from secondary sources. Secondary sources of N in agricultural systems include soil organic matter, organic amendments, and N found in the environment. Soil N is derived from organic matter and includes an active 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 longer 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 ratio of the material, with cover crops being the most readily available after tillage, followed by animal manure and finally compost, where the composting process has stabilized much of the organic N. Finally, N availability is contingent on the transformation of organic N into inorganic N. Other secondary N sources include nitrate in irrigation water and N deposition from air pollution such as smog. These environmental inputs are nontrivial amounts of N in agricultural systems, but the amount depends on the air and water quality of the growing region.

The Right Rate and Time of Nitrogen Application in Citrus

Citrus has a lower demand for N than nut crops and stone fruit. The N requirement of citrus is based on yield, tree age, and canopy size. The N content of organs per unit weight is fairly similar for all citrus species. For example, 1,000 lb of fresh blood oranges and navel oranges removes 1.3 lb N from the soil (the per-acre yield of navel orange may be lower than that of red blood orange). The N demand of citrus has been studied based on whole-tree harvest, partitioning different organs, and determining the biomass and the N concentration in each organ. The N demand of citrus has also been based on tree canopy size to account for canopy coverage and age. In a yield 20,000 lb/ac, 27 lb N is exported in fruit. A mature tree accumulates 22.3 lb in the woody biomass; 21.3 lb N is removed in abscised leaves and 16 lb is removed in pruning. If the leaves and pruning are not removed from the orchard, they can be recycled as organic N. About 50% of the N in leaves may become available in the first season, and the remaining in subsequent years; the N in woody prunings would become available over a longer period.

The seasonal demand of N in orange is high early in the season (Roccuzzo et al. 2012). Nitrogen accumulation in shoots has two peaks: one from May through July and another in September. There is no net accumulation of N in the shoots after November. Fruit continue to accumulate N throughout the season until harvest, but there is no net N uptake from soil after November. After November, N from leaves is remobilized to supply N to the fruit (fig. 1).

Figure 1. Seasonal trends in nitrogen accumulation in the fruit and shoots (stem, leaves, and squares) and biomass accumulation during the season in orange trees.



Besides the high N demand from fruit, the vegetative and woody parts of the tree also require N for maintenance and growth. The amount of N needed for leaf and branch growth is high when the plants are small and decreases as the plant ages. Young trees have high shoot production and leaf growth; when the tree matures, shoot and leaf production continues at a much lower rate. Based on canopy size, a tree 1 to 5 years old with a total canopy size of 0 to 250 ft^3 accumulates 0.07 lb N/50 ft^3/yr. In most commercial orchards this represents 5 to 30 lb/ac/yr. In contrast to young trees, mature trees (greater than 8 yr old and canopy volume 1,000 to 1,500 ft^3) require 0.04 lb/50 ft^3/yr N, which accounts for 5 to 20 lb/ac/yr N in most commercial orchards.

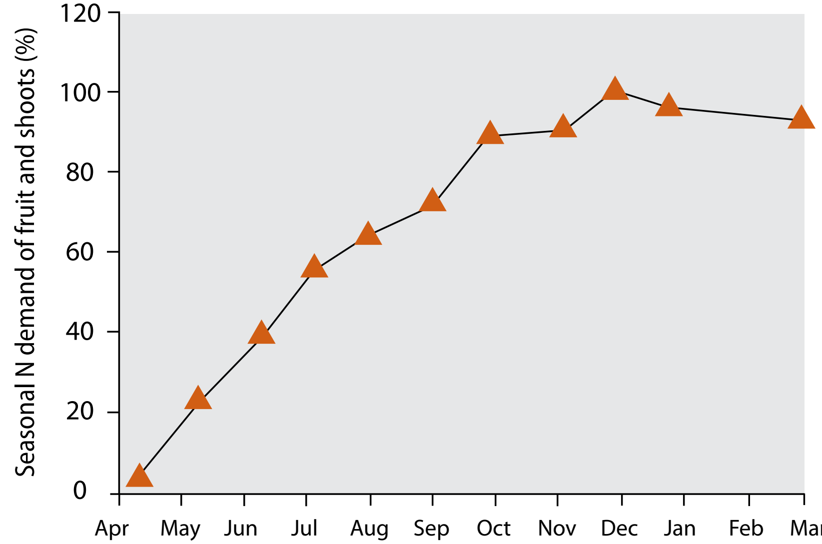


Figure 2. Percent nitrogen demand of fruit and shoots in mature orange trees during the crop season. *Source:* Adapted from Roccuzzo et al. 2012.

The accumulation pattern of N in fruit and shoots equals the tree N demand and varies during the season (fig. 2). In a mature orange orchard, N accumulation steadily increases from April to July, and 60% of the total N accumulation in fruit and shoots occurs during this time. Nitrogen continues to accumulate at a much lower rate from July to September, and about 15% of total demand accumulates in fruit and shoot during this time. Another increase in N demand from September to October is primarily driven by shoot growth. Nitrogen accumulation increases until December, followed by no net increase in N accumulation through harvest.

Below are examples of calculating the N rate for a citrus orchard of different ages and yields based on the N required for fruit and vegetative growth (see Morgan and Hanlon 2006).

Example 1

Assume a citrus orchard that is 5 to 7 yr old, has a canopy volume of 750 ft³ (12 ft tall and 9 ft diameter), contains 200 trees/ac, and produces 300 boxes of fruit (22,500 lb) per season. Assuming a canopy size increase of 100 ft³/tree/yr and a nitrogen use efficiency (NUE) of 70%, and taking into consideration the nitrogen removal factor of 1.3 lb N per 1,000 lb fruit, the quantity of N required for the orchard would be

fruit N accumulation = (22,500 lb ÷ 1,000) x 1.3 lb = 29 lb

biomass N accumulation = 0.14 x 200 trees = 28 lb

total N demand for fruit and tree growth = 57 lb

total N fertilizer required at 70% efficiency = 57 ÷ 0.7 = 81 lb N.

Example 2

Assume an average tree canopy volume of 1,500 ft³ (16 ft tall and 11 ft diameter), with 200 trees per acre that produces 700 boxes of fruit and an annual canopy increase of 125 ft³.

N required for fruit = (52,500 ÷ 1,000) x 1.3 = 68 lb

N required for biomass = 0.1 x 200 = 20 lb

Total N demand of the tree = 88 lb

N required in fertilizer at 70% NUE = 88 ÷ 0.07 = 126 lb.

After developing a budget for the orchard, a fertilization program can be monitored by taking leaf samples in summer (Lovatt 2014). Table 1 shows the critical leaf nutrient concentrations for Valencia and Navel oranges (these values have not been developed for mandarins). Lemon optimal N concentration is 2.5%, but some vigorous cultivars may not be able to achieve higher than 2.2%. Research on grapefruit is limited, although studies on desert California grapefruit give an optimum of 2.0 to 2.2% and studies on Florida give an optimum of 2.2 to 2.3%.

Table 1. Critical values for nitrogen, phosphorus, and potassium for Valencia and Navel orange

Interpretation	Nutrient values (% dry weight)		
	Nitrogen	Phosphorus	Potassium
deficient	< 2.2	< 0.09	< 0.40
low	2.2–2.3	0.09–0.11	0.40–0.69
optimal	2.4–2.6	0.12–0.16	0.70–1.09
high	2.7–2.8	0.17–0.29	1.10–2.00
excess	> 2.8	> 0.30	>2.30

The Right Rate and Time of Nitrogen Application in Avocado

The N requirement of avocado depends on annual fruit production and vegetative growth (Lovatt 2001). When the trees are young, the N requirement of the vegetative growth is high, but as trees mature the N requirement of vegetative growth decreases and N partitioning to the fruit increases. Avocado is different from many other crops in its fruiting habit: fruit remain on trees for a longer period of time (1.5 yr from flowering to fruit harvest). Studies report different N removal values, which can range from 0.55 to 4.3 lb/1,000 lb fruit. These numbers need to be refined; nitrogen removal of 2.2 lb N per 1,000 lb fruit has been suggested. Nitrogen accumulation during fruit development and maturity is represented by a double sigmoid curve. Nitrogen accumulation increases during the spring and summer of the first season, followed by no net N accumulation from October to March; N accumulation increases in the spring of the next season and continues until harvest.

Avocado trees have two types of fruit: fruit close to maturity and fruit just starting to develop. To calculate the total N demand of the crop during spring the grower must keep both crops in mind: 50% of the total N accumulates in the first season and 50% in the second season (fig. 3). If the expected yields are the same for the current and the next-season crop, 100% of the demand of both crops can be applied in one season.

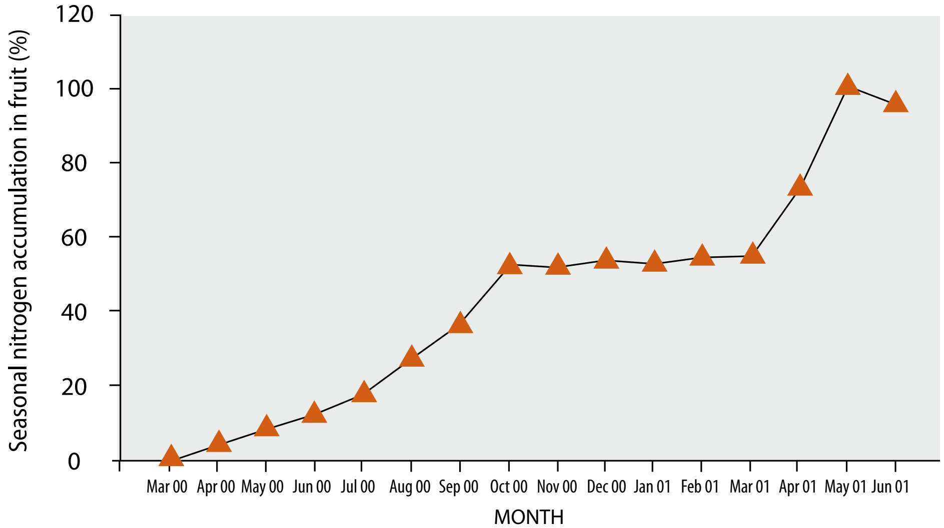


Figure 3. Seasonal N demand of fruit during the growth and development periods of fruit. Data presented is the percentage of N accumulation during the two seasons. *Source*: Recalculated from Rosecrance et al. 2012.

For an orchard with alternate bearing in one year, the total N demand will be 50% of the demand of the current crop plus 50% of the demand of the next crop, taking into consideration the nitrogen removal factor of 2.2 lb N per 1,000 lb fruit. For example, for an estimated crop yield of 10,000 lb this year and 5,000 lb next year, the N demand of the spring crop would be 2.2 times 50% of the 10,000-lb crop N demand plus 2.2 times 50% of the 5,000-lb crop N demand:

$$[2.2 \times (10{,}000 \div 1{,}000) \times 50\%\ )] + [2.2 \times (5{,}000 \div 1{,}000) \times 50\%] = 11 + 5.5$$

$$= 16.5 \text{ lb N.}$$

With good irrigation practices, 70% N use efficiency would require 23.6 lb N.

Avocado produces a significant amount of vegetative growth each year (Lovatt 1998). There is an estimated increase of 20 to 30% in vegetative growth of shoots, roots, and buildup of perennial wood. This requires an estimated 13 to 19 lb/ac/yr N. For a 10,000 lb/ac fruit yield, the total requirement of N for fruit and vegetative growth would be 41lb N/ac, and the total N required considering 70% efficiency would be 53 lb N.

The effect of N application on fruit yield and alternate bearing shows that April and November are the two critical times for N application to support fruit set of the new crop, growth of vegetative shoot flushes, and fruit growth of the maturing crop (Rosecrance et al. 2012). There is no net uptake of N in fruit from October to March (fig. 3). The total seasonal N demand of the crop should be applied in four to six split applications from April to September.

The efficiency of the N management program should be monitored by leaf analysis. Collect leaf samples from the youngest fully expanded leaves in July to August and analyze them for nutrients. The optimal N concentration in leaves of Hass avocado is over 2%, and the upper limit is probably around 2.3%. The optimal N concentration in Fuerte avocado leaves is 1.6 to 2%; yield decreases below or above this range (Embleton et al. 1960) (fig. 4).

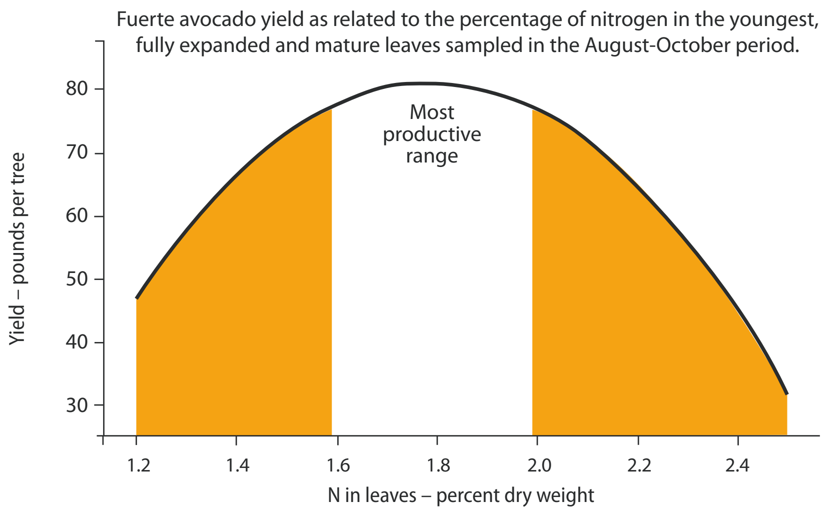


Figure 4. Fuerte avocado yield related to the percentage of nitrogen in the youngest, fully expanded and mature leaves sampled in August to October.

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