AvoTech

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# Avocado Fertilization:

## The Macronutrients

In the Summer 2019 issue of *From the Grove* I reviewed the basics of plant mineral nutrition, covering the concepts of essential nutrients, macro and micronutrients, and nutrient uptake. In this article, I'll dive deeper into understanding the macronutrient fertilization of avocados.

| A comparison of recommended avocado leaf macronutrient optimum ranges for California and Mexico.[1] | | |
|---|---|---|
| **Nutrient** | California | Mexico |
| **Nitrogen %** | 2.2-2.4 | 2.2-2.6 |
| **Phosphorus %** | 0.08-0.44 | 0.08-0.25 |
| **Potassium %** | 1.0-3.0 | 0.71-2.0 |
| **Calcium %** | 1.0-4.5 | 1.0-3.0 |
| **Magnesium %** | 0.25-1.0 | 0.25-0.8 |
| **Sulfur %** | 0.2-0.6 | 0.2-0.6 |

[1] Data from www.avocadosource.com.

### Macronutrients

As a reminder, the macronutrients are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). These six nutrients can be further divided into primary (N, P and K) and secondary (Ca, Mg and S) macronutrients. Because of their relatively large abundance in plants, macronutrients are always reported as percent of dry matter or dry weight in a plant tissue analysis.

While various "optimum range" guidelines for macronutrients in avocado leaves are available, these ranges vary based on the source of the information and from region to region. Ideally, you should have tissue nutrient analyses performed on your leaf samples sometime between mid-August and mid-October every year. Over time you will develop a data set for your trees, and will be able to track their nutrient status and judge those levels relative to yield and the overall performance of your trees.

### Nitrogen

Nitrogen is required in greater quantities by avocados than any other nutrient except K. Avocados take up N primarily as nitrate ($NO_3^-$) but also can take up some ammonium ($NH_4^+$).

Nitrate is highly soluble, which means it easily can be leached below the root zone, where it can potentially contaminate ground water supplies. Ammonium is held by soil particles and is therefore retained in the soil for a longer period until it is converted to nitrate by soil bacteria through nitrification. Nitrification is temperature dependent and can occur in as little as 1 to 2 weeks in warm soils (75°F) or up to 2 to 3 months in cold soils (50°F). The use of ammonium fertilizer will acidify soil over time as a result of the hydrogen released during the nitrification process. Urea [$CO(NH_2)_2$] is a commonly used form of N because it is relatively cheap. Urea moves into the soil with the irrigation water and is rapidly converted to ammonium, which then undergoes nitrification.

The decomposition or mineralization of organic matter also can serve as a source of N. Most avocado soils in California are naturally low in organic matter so mineralization is not a major source of N, unless organic amendments are routinely used.

Nitrogen is mobile within the plant — the plant can take N from an existing tissue and reuse that N elsewhere. As a result, N deficiency symptoms will first appear on old leaves since the plant can take the N from the old leaves to support new growth when there is insufficient N available in the soil. Nitrogen deficiency appears as a general yellowing or chlorosis of old leaves and reduced tree vigor.

### Phosphorus

Phosphorus is taken up by plants in the form of phosphate ($HPO_4^{2-}$ in alkaline soils; $H_2PO_4^-$ in acid soils). Most soils contain ample amounts of P, but it is often tied up in only slightly soluble compounds. Phosphorus is maximally available at a soil pH of 6.5 to 7.5, but

| Macronutrients essential for 'Hass' avocado production and their primary functions in the tree's physiological processes. | | | |
|---|---|---|---|
| **Nutrient** | Symbol | Uptake Form | Primary Functions |
| **Nitrogen** | N | $NH_4^+$, $NH_3^-$ | Synthesis of amino acids (proteins), DNA and RNA, hormones |
| **Phosphorus** | P | $HPO_4^{2-}$, $H_2PO_4^-$ | Synthesis of ATP, DNA and RNA; cell membrane integrity |
| **Potassium** | K | $K^+$ | Ionic balance of cells, opening and closing of stomates |
| **Calcium** | Ca | $Ca^{2+}$ | Cell wall and membrane structure |
| **Magnesium** | Mg | $Mg^{2+}$ | Chlorophyll formation |
| **Sulfur** | S | $SO_4^{2-}$ | Amino acid synthesis |
| **Adapted from: Datnoff, Elmer and Huber (2007) and Taiz and Zeiger (2010).** | | | |

the available P may be only one percent of the total P present in a soil.

There are many different P fertilizers available, including superphosphate and various forms of ammonium phosphate. In the U.S., the P content in fertilizers is given as percent phosphorus pentoxide ($P_2O_5$). To convert phosphorus pentoxide content of a fertilizer to elemental P content, the phosphorus pentoxide content is multiplied by 0.44. For example, a fertilizer with an analysis of 0-46-0 contains 0 percent N, 46 percent $P_2O_5$, and 0 percent $K_2O$, which equates to 46 x 0.44 = 20 percent P.

It should be noted that phosphite ($PO_3^{3-}$) and phosphorous acid ($H_3PO_3$) products used in the control of pathogens such as phytophthora root rot are not converted to phosphate in the plant and cannot serve as replacements for phosphate fertilization. There are soil bacteria capable of converting these products into phosphate, but the rate of this conversion is too slow to be of any practical benefit. There are no known plant enzymes that can carry out this conversion.

Symptoms of P deficiency are somewhat non-descript and include slowed growth and poor fruit development. Random, necrotic spots may appear on leaves of severely deficient avocado trees.

## Potassium

Potassium is unique among the essential plant nutrients in that it does not become part of complex organic molecules. Rather, K remains in ionic form within the plant and acts as a regulator in many essential processes, including the opening and closing of stomates, regulating enzymes and controlling cellular pH.

Potassium is taken up by plants as potassium ions ($K^+$) dissolved in the soil solution. Avocados have higher K levels than almost any other fruit, and require K in amounts equal to or greater than N.

Common fertilizer sources include potassium nitrate ($KNO_3$), potassium sulfate ($K_2SO_4$) and potassium thiosulfate (KTS; $K_2S_2O_3$). In the U.S., the K in K fertilizers is reported as percent potash ($K_2O$), even though the fertilizers don't contain $K_2O$. This can cause confusion since K fertilizer recommendations may be based on actual pounds of elemental K needed. To convert fertilizer $K_2O$ to elemental K, multiply a fertilizer's $K_2O$ content by 0.83. For example, potassium nitrate has an analysis of 13-0-44 — 13 percent N, 0 percent $P_2O_5$ and 44 percent $K_2O$. In elemental terms it contains 44 x 0.83 = 36.5 percent K.

Potassium is highly mobile within plants; thus, deficiency symptoms appear first on older leaves. However, K deficiency can be difficult to diagnose in avocados since it is manifested as tip and marginal chlorosis and necrosis on older leaves, which is often masked by tip burn caused by chloride toxicity. Other symptoms of K deficiency are slow growth, weak stems and small fruit.

## Calcium

Calcium exists in the soil and is taken up by plants as the calcium ion ($Ca^{2+}$). Calcium is a critical structural element in plants, being a component of cell walls and membranes. Once Ca is taken up and integrated into the plant it is immobile and cannot move to other parts of the plant. Thus, there must be a continuous supply of Ca available in the soil for plants to support new growth.

Deficiency of Ca appears first in new tissues and symptoms include death of growing points, including shoot and root tips.

Despite most soils having relatively high levels of Ca, it may be necessary to provide supplemental Ca fertilizer, especially on alkaline soils where Ca availability is reduced. Common fertilizer sources include calcium nitrate, calcium ammonium nitrate (CAN17) and calcium thiosulfate (CaTS).

## Magnesium

Magnesium is taken up as the magnesium ion ($Mg^{2+}$). Magnesium is a critical component of the chlorophyll molecule, which is essential for photosynthesis, and acts as an activator of numerous plant enzymes important for normal plant growth.

Magnesium is mobile within plants; thus, deficiency symptoms appear first on older leaves. Magnesium deficiency appears as interveinal chlorosis (yellowing between the leaf veins) on older leaves. As symptoms progress, the edges of leaves may become completely yellow leaving green veins down the middle of the leaf appearing as a "Christmas tree."

Magnesium is generally abundant in California soils, and may be too high in certain locations. This can lead to competition with Ca. There is no good way to manage high Mg levels other than to ensure sufficient availability of Ca in the soil.

## Sulfur

Sulfur is taken up from the soil in the form of sulfate ($SO_4^{2-}$). Sulfur is a component of amino acids and is therefore necessary for protein synthesis.

Like $NO_3^-$, $SO_4^{2-}$ is leachable from soils and deficiencies can occur on most soil types. However, in low rainfall areas like California, $SO_4^{2-}$ can form precipitates in soil as gypsum (calcium sulfate; $CaSO_4$).

Sulfur is immobile in the plant and deficiency symptoms appear on new leaves first. Symptoms of S deficiency include slow growth and pale green to yellow new leaves.

## When to Fertilize

We are fortunate that Dr. Carol Lovatt, retired professor of plant physiology at UC Riverside, spent many years looking at optimum timing of fertilizer application. To fully appreciate her research, it is important to remember a few key points:

1. Fertilizer should be applied to correspond with plant uptake.
2. Fertilizer should be applied in a quantity sufficient to replace what is lost due to crop removal.
3. You are fertilizing for three crops at any given time.

Let's look at each of these in more detail.

## Timing of Plant Uptake

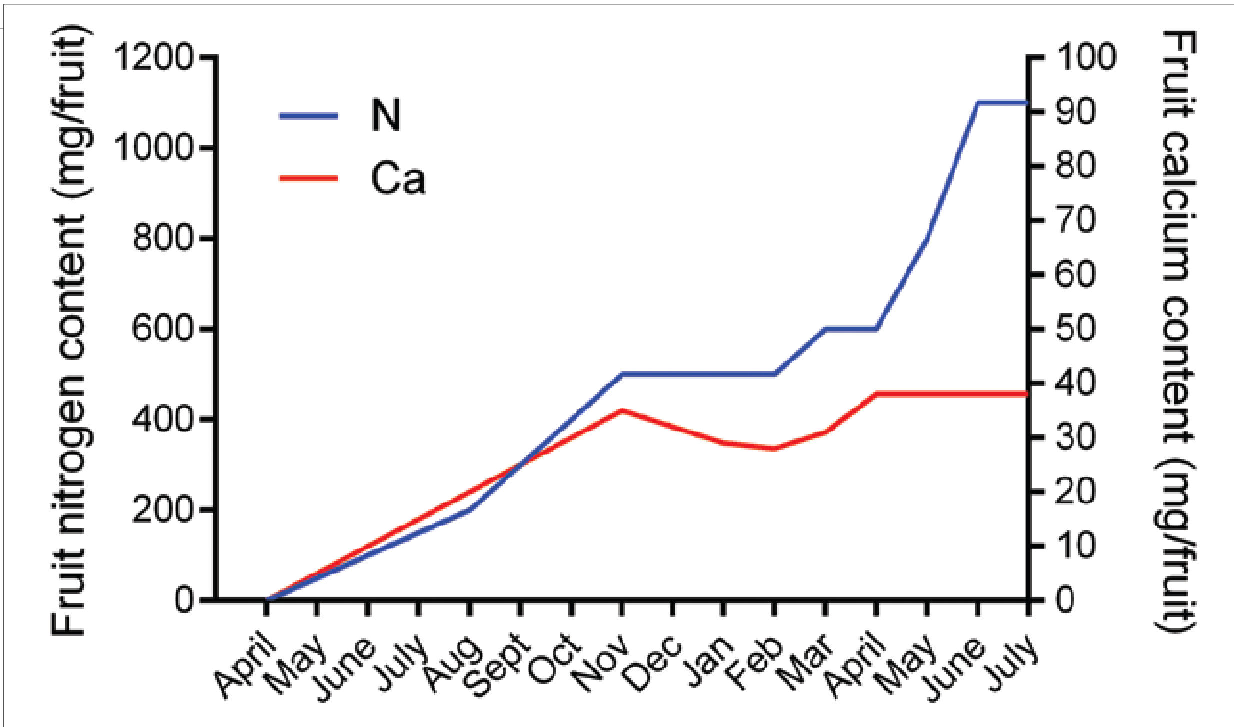
The primary goal in fertilizing avocado trees is to support fruit growth and development. Avocados grow in what is called a double sigmoid or "S" curve. That is, the fruit grow relatively slowly for an initial period, followed by a period of rapid growth, followed by another period of slow growth, and finally another period of rapid growth. In California, these periods of growth generally correspond to periods of bloom through July, August through October, November through February, and March through harvest.

To maximize yield, it is important to have nutrients available to support

**Nutrients removed by an avocado crop based on a yield of 7,500 pounds per acre.**

| Macronutrient | lb/ac | Micronutrient | oz/ac |
|---|---|---|---|
| Nitrogen | 16.5 | Boron | 2.3 |
| Phosphorus | 3.0 | Iron | 0.5 |
| Potassium | 22.5 | Zinc | 0.8 |
| Calcium | 0.8 | Manganese | 0.15 |
| Magnesium | 2.3 | Copper | 0.3 |
| Sulfur | 3.8 | | |

**Calculations based on data from Rosecrance, Faber and Lovatt. 2012. Better Crops Vol. 96, No.1.**




*Accumulation of nitrogen (N) and calcium (Ca) in 'Hass' avocado fruit. Redrawn from Rosecrance, Faber and Lovatt. 2012. Better Crops Vol. 96, No. 1.*

the periods of rapid fruit growth. However, not all nutrients are taken up in the same pattern. Approximately half the required N, P, Mg and S are accumulated during both periods of rapid fruit growth. Thus, these nutrients need to be applied in spring and following bloom, so they are in the plant and available to support rapid fruit growth as well as the development of recently set fruit.

Potassium is more rapidly taken up during the second season of fruit development. Thus, depending on the crop load of the tree more K may be required to support fruit development in one year compared with another.

Calcium is the opposite of K, with most uptake occurring during the first season of fruit development. Therefore, Ca must be readily available during early fruit development each spring.

## Replace What is Lost to Crop Removal

Nutrients that are in leaves or stems of the tree will eventually be returned to the grove as leaf litter decomposes and wood from pruning is chipped or shredded on the grove floor. However, the nutrients in fruit are exported from the grove when the crop is harvested. These are the nutrients that must be replaced on an ongoing basis.

Estimates of how much of each nutrient are removed from the grove based on fruit nutrient analysis are surprisingly low. A 7,500 pound-per-acre crop of 'Hass' avocados, which is the California industry average production, removes just 16.5 pounds of N.

## Fertilizing for Three Crops

This last point can be a bit tricky to understand. Let's look at January of a given year as an example. At that point the crop hanging on the tree is getting ready to enter a period of rapid growth that will continue until harvest and those nutrient demands must be met. The tree also is getting ready to bloom. Flowering is a period of high nutrient demand — it is common to see trees turn yellow during bloom as they mobilize nutrients from around the tree to support the flowers — and adequate nutrition needs to be supplied to support bloom and early fruit set. As the bloom progresses, a spring flush of vegetative growth will appear from the terminal of indeterminate inflorescences. This growth will help to support the new setting crop, protect it from sunburn and contribute some inflorescences to next year's bloom. Thus, inadequate nutrition at any given time can potentially impact three different crop years.

How much fertilizer your grove needs depends on the specifics of your situation and should be based, in part, on annual leaf and soil analyses. If you are unsure how to develop a fertilizer program for your grove you should consult with your testing lab, a Cooperative Extension Farm Advisor, grove manager or other crop consultant to develop a program tailored to meet your grove's needs and your production goals. Just remember, your trees are eating for three and must be fed accordingly.