Science Societies

Foliar feeding of plant nutrition

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Nutrient foliar spray in an almond orchard. Photo courtesy of Alamy/Leonard F Wilcox.

As global population growth intensifies pressure on agricultural production, foliar feeding offers a precise and efficient method to enhance crop yield, quality, and nutritional value when soil nutrient availability is limited or impaired. The article explains how foliar-applied nutrients enter plant tissues, the factors influencing their effectiveness—including formulation chemistry, molecular size, environmental conditions, and plant physiology—and the importance of proper timing and dosage to avoid phytotoxicity.

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According to studies from the United Nations, the world population will increase by one billion over the next decade, reaching an estimated 8.6 billion people by 2030. By 2050, planet Earth will have 9.8 billion inhabitants. This enormous population growth will be coupled with a corresponding increase in demand for food. Projections from the FAO have indicated that agricultural production worldwide will have to increase by an estimated 50% by 2050 to meet the needs of a growing population.

Proportionately, agricultural land is becoming scarce. Therefore, one of the biggest challenges is to improve the yield, quality, and shelf life of crops by using the best fertilizers, applied in very precise doses and with proven methods. One of the best procedures to reach those goals is foliar application of nutrients in customized doses based on critical timing for each crop.

As with any foliar spray (such as pesticides), making the decision to foliar-feed plants comes with many challenges. Wind, temperature, phytotoxicity, and even leaf structure can affect or deter from applying nutrients.

How foliar feeding works

Foliar feeding is the entry of small amounts of liquid fertilizer through the surface of plant tissue. This can allow for rapid nutrient utilization by the plant. Foliar feeding provides the consultant and applicator with the ability to blend the fertilizer with other products, such as pesticides and micronutrients. Current formulations of liquid fertilizers are believed to penetrate mostly the transcuticular pores on foliage, which are open virtually all the time compared with stomata. Nutrients also enter stomata, but these often are closed due to environmental stresses and darkness. Most stomata are located underneath leaves, away from fertilizer spray patterns.

The outer surface of the cuticle is covered by waxes that may confer a hydrophobic character to the plant's surface (Figure 1). The degree of hydrophobicity and polarity of the plant surface is determined by the species, chemistry, and topography which are also influenced by the epidermal cell. Like leaves, fruits are also protected by a cuticle. The

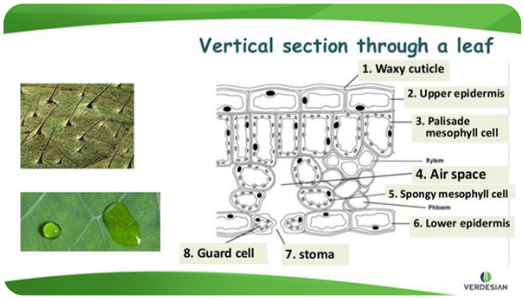

Figure 1. Vertical section through a leaf.

shape, chemistry (waxes, polysaccharides), leaf hairs, and ability of the leaf to assimilate and mobilize nutrients all play a role in efficacy.

Additional factors influencing foliar nutrient applications include properties of the spray such as molecule size, solubility, electric charge, surface tension, pH, spreaders, relative humidity, and temperature. The charge can create an attachment to the leaf or stomata pathway and prevent entry. Material can dry too fast and prevent active ingredients from entering the tissue. Some products contain a naturally plant-based hydrophilic adjuvant and surfactant. This allows applied products to have rehydrate repeatedly, which increases absorption opportunities.

We must also understand nutrient mobility in plant tissues like the leaf. Figure 2 shows the mobility of various nutrients.

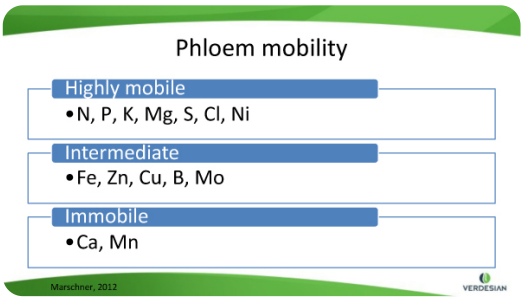

Figure 2. The mobility of various nutrients in plant tissues.

Drawbacks to foliar feeding include the inability to apply large amounts of nitrogen (N), phosphorous (P), and potassium (K) without potentially burning the foliage and possibly scarring the fruit. Referred to as spraying as phytotoxicity, an applicator must keep an ever-watchful eye on overapplication. Too much of a good thing can be very harmful. If rate is defined on the label, then follow the directions. **If still in question, spray on a small surface and visually check the leaf and fruit.** Frequent applications of the right fertilizer and fertilizer blends at a low volume are sometimes required to maintain optimum tissue levels of key nutrients resulting in consistent plant growth and functions like the production and transference of assimilates. The formulations may be complex or chelated to improve efficiency (Figure 3). Understand

the differences between each. Molecular size can greatly affect the efficacy of your spray.

Calling a product complex or chelated may not adequately describe whether the product contains the right source the plant can utilize. For example, all amino acid complexing is not equal. L-alpha amino acids, together with carbohydrates, are the group of organic molecules found in greatest quantities in living organisms. Plants can only utilize the L-alpha (left-handed) form of an amino acid. The D-alpha (right-handed) form of amino acids cannot be metabolized by the plant. So, when using an amino acid complex material, ask which amino acid is contained.

Molecular weight plays a role in the complex or chelated products as does the charge of the molecule. Measured in Daltons, see some of the differences listed below. Remember both the size and the charge can limit complex or chelated product efficiency to enter the plant.

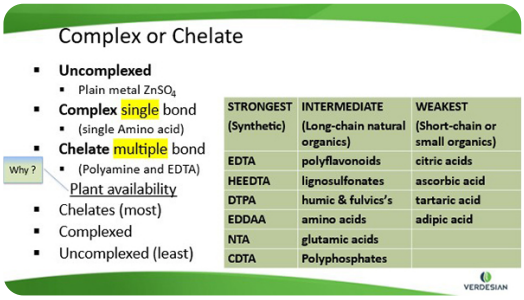

Figure 3. Understand the difference between complex or chelated formulations.

- Urea is 60 Daltons and carries a neutral charge
- Amino acids are 110 Daltons and carry a neutral charge
- EDTA is 290 Daltons and carries a positive charge
- Lignosulfonates are 140,000 Daltons and carry a negative charge

Benefits of foliar nutrition in crop production

Selecting the right fertilizers will continue to be an important part of the equation to improving yield, quality, and shelf life of crops. How we apply the nutrients is also vital.

Let us examine foliar spraying more closely. Crops treated with foliar spray tend to have a higher nutritional value. Improved total soluble solids have contributed to increased sugar, vitamins, minerals, and proteins in the harvested crops. It is not enough just to grow more crops, but those crops must have better nutritional value for us as well.

We can see very positive effects by examining just one mineral nutrient such potassium. Potassium regulates plant functions and increases nitrogen efficiency. By increasing the saline concentration of the cells, the plants are better able to resist frost. Applied at the right time and in the correct amount, potassium promotes the development of a stronger cell structure, which allows the crops to better withstand drought, disease, and pests. A better internal structure promotes a prolonged life. In many of our soils, we lack adequate available potassium to meet the crop demands. One way to meet those phenological growth stages is to supplement potassium sprays. For numerous crops, this could affect the production levels and quality, such as tuber fill and skin condition in potato, nut meat density in almond, and even oil production in mint.

When adequate potassium is not available in soils, potassium sprays could make a positive difference in, e.g., tuber fill and skin condition in potato, nut meat density in almond, and

even oil production in mint. Illustrations courtesy of Adobe Stock.

Originally it was thought that using foliar nutrient applications were only appropriate when a nutritional deficiency was present. After utilizing foliar fertilizer application in my crop nutrition programs for years, I have discovered this is not the case. Ongoing scientific research has consistently shown that periodic applications of certain nutrients in various crops can have a positive effect on both quantity and quality of fruits, nuts, vegetables, and grain crops. Although most supplemental nutrients are absorbed through the root system, it is also important to note that leaves and, to a lesser degree, stems, flowering plant tissues, and even fruit surfaces can absorb limited amounts of nutrients. It is crucial to understand which nutrients can be supplied effectively by foliar applications if the soil-supplied nutrients are inadequate or impaired in some way.

Calcium (Ca) sprays has had success in combating Ca deficiency, controlling bitter pit in apples (top) and resulting in less cracking in cherries (bottom). Photos courtesy of Adobe Stock.

In agriculture, our scientists have identified many cases where nutrient supplementation using a foliar application may be considered more effective (essential) than an in-crop topdressing application. One such situation I have had a lot of success with is during late stages of fruit development where calcium (Ca) sprays applied through the season to apples has had success in combating Ca deficiency. This deficiency can create an imbalance between potassium and calcium which is directly connected with the physiological disorder called bitter pit. The application of Ca making direct contact with the fruit has shown good results in controlling this disorder. Calcium being sprayed on cherries preharvest amounted to less cracking in fruit during late maturation stages. It prolonged the stem staying green and improved turgor pressure and shelf life.

Research trials done in almonds have also demonstrated where a foliar-applied nutrients can have a huge impact on a crop. Knowing that fruit set is crucial in almond trees, it has been proven that micronutrients, zinc (Zn) and especially boron (B), have a significant impact on fruit set as well as on fruitlet abscission. In several fruit trees, it has been reported that even foliar spraying of one or both elements has improved productivity. In one experiment, Nonpareil trees were sprayed at full blossom with boric acid at 0.2%, Zn-50 at 0.3%, and with the combination of these micronutrients as a separate treatment compared with a non-sprayed control. Fruit set was 27.7% for the B treatment and 22.2% for the Zn treatment. However, the B + Zn combination produced a significantly higher fruit set (38.1%).

As consultants, we must understand that at times only a small amount of a specific nutrient is required, and due to low soil mobility of the nutrient, it is more efficient to supply the small amount of nutrient needed as a foliar application. This can be the case for both macronutrients and micronutrients. There can also be other conditions that cause a nutrient to be less available to crop roots. One example is cool, excessively wet conditions on an alkaline soil (e.g., pH > 8.0) where iron is less available to certain crops (e.g., iron chlorosis of soybean): Even if supplemental iron fertilizer has been applied to the soil before or at planting, it may not be available through the roots. This can also be true for numerous other crops. By monitoring the trees and observing patterns, we can offset the chlorosis in our crop with a supplemental iron (Fe) foliar application.

Many studies include yield data collected after applying foliar sprays of various fertilizer solutions not only to nutritionally deficient crops, but even to crops that have adequate levels of nutrients such as potassium. Crops including wheat, almonds, tomatoes, citrus, cucurbits, pome fruits, and rice among many others react positively to certain nutrient sprays even when adequate soil nutrient levels are present.

After years of trials addressing HLB or Huanglongbing citrus greening disease in Florida, it was determined that a foliar nutrition approach to the disease was a very

viable option. USDA photo by David Bartels.

A good reference to the benefits of foliar spraying is in citrus research. After years of trials addressing HLB or Huanglongbing citrus greening disease in Florida, it was determined that a foliar nutrition approach to the disease was a very viable option. The nature of the disease restricts the ability of the plant to adequately take up nutrients though its damaged root system. Finding an alternative way to increase plant nutrition and prolong the life and productivity of the infected tree was crucial. Numerous combinations and timings were trialed. Trials show that in the case of one nutrient combination, potassium nitrate feeding increased yields in citrus. Foliar applications with potassium nitrate have proven to be highly efficient in fulfilling the potassium requirements for many crops. The combination of potassium and nitrate in this fertilizer has been found to be beneficial in improving fruit size, dry matter, color, taste and integrity, and resistance to biotic and abiotic stresses for citrus and tomato fruit. Moreover, the integration of potassium nitrate in routine management or in specific growth stages resulted in a remarkably positive benefit-to-cost ratio.

Limitations and economic considerations

In our management plan, caution should be used when foliar application might be more efficient but not practical. When a foliar application is relatively effective, but not enough of the needed nutrient can be supplied in one application, multiple applications would be needed, spaced out sufficiently in time possibly up to once a week. Multiple applications in field crops can be expensive due to fuel, equipment, and labor costs or where there may not be sufficient time to apply enough of the needed nutrient.

We must measure the economics and limitations when determining our fertilizer plan. This is demonstrated in the case of a severe phosphorus (P) deficiency where the costs of making sufficient applications of low rates of foliar P are excessive and there is not enough time to do it. In this situation, it may be better to realize there is not much that can be done for that season's P-deficient crop. The preferred course of action is to apply sufficient P fertilizer to the soil prior to the planting of subsequent crops to correct the P deficiency. As a crop consultant, I have had great success applying a combination P and K product enhanced with phosphites (PO_3) as the biostimulant carrier. This should not to be confused with adding phosphate (PO_4) into citrus and nut crops.

If we continue to use P as an example, we also need to understand foliar P efficiency and when it does have a fit in our fertilizer program. Foliar-applied nutrients have the benefit of being 4 to 30 times more efficient, and there is no risk of groundwater contamination. Studies using labeled P on apple, cherry, corn, tomato, potato, and bean crops have shown that as much as 12 to 14% of the total P can be supplied by multiple foliar sprays. Since P can be very immobile in the soil, foliar applications can be up to 20 times more effective than soil applications.

Recognizing other nutrients used as a foliar, we can see that some nitrogen (N) sprays compared with soil applications of N include lower application rates and the ease of obtaining timely, uniform applications. By paying attention to best-use guidelines, the efficiency of foliar-applied N may be optimized at nearly 95 to 100%. Based on the foregoing information, if the recovery of soil-applied N can be impaired to as low as 15 to 62%, it can be concluded by the method of estimation that foliar-applied N has an efficiency of 1.3 to 1.6 times that of soil-applied N at the low end and 7 at the upper end. This is not always the case, but understanding your N efficiency in your soils may

prompt the need for a supplemental foliar N application. This in no way warrants replacing our soil-applied nutrition program with foliar. It merely demonstrates that supplementing our nutrition program with foliar spray can be very efficient.

Integrating foliar feeding into a nutrient management plan

In summary, I want to point out that we have barely scratched the surface of all the features and benefits of foliar nutrition sprays. Get to know your crop and soils and the correlation between total nutrients and available nutrients. Understand if your crop has shown positive response to foliar treatment even when adequate nutrient levels are in the soil. Ask yourself when do soil conditions prevent adequate nutrient uptake? What conditions should I be aware of to optimize foliar applications (rain, temperature, wind, sprayer capability, pH of my solution, humidity, physiological growth stage, activity of plant parts like stomate, additives such as pesticides or adjuvants, and antagonistic as well as synergistic reactions with other nutrients)? Study absorption rates and what affects them.

Like all other things in agriculture, foliar nutrition is a tool. I have had tremendous success applying foliar nutrition in my fertilizer recommendations. I am positive it can and will benefit future crop production if applied correctly.

Self-study CEU quiz

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1. Why are stomata less reliable for nutrient uptake during foliar application?

a. They are too small.

b. They are only found on stems.

c. They are often closed due to stress or darkness.

d. They repel nutrients.

2. Foliar feeding allows nutrients to be absorbed more rapidly than soil applications because nutrients enter directly through leaf tissues.

a. True.

b. False.

3. What characteristic of the leaf surface affects nutrient absorption the most?

a. Leaf color.

b. Wax composition and surface chemistry.

c. Leaf width.

d. Plant height.

4. What is one major risk of excessive foliar fertilizer application?

a. Reduced soil pH.

b. Nutrient leaching.

c. Phytotoxicity (leaf burn).

d. Increased weed growth.

5. Which of the following has the largest molecular weight?

a. Urea.

b. Amino acids.

c. EDTA.

d. Lignosulfonates.

6. Plants can only use the D-alpha (right-handed) form of amino acids.

a. True.

b. False.

7. Why are smaller molecules generally more effective in foliar feeding?

a. They evaporate slower.

b. They are more acidic.

c. They penetrate plant tissue more easily.

d. They contain more nutrients.

8. Which nutrient is strongly associated with improving cherry turgor pressure and shelf life?

a. Nitrogen.

b. Calcium.

c. Phosphorus.

d. Magnesium.

9. Which micronutrients were shown to significantly improve almond fruit set?

a. Iron and copper.

b. Zinc and boron.

c. Calcium and magnesium.

d. Sulfur and nitrogen.

10. Why is foliar iron application effective in high-pH soils?

a. Iron moves faster in alkaline soils.

b. Roots absorb iron better at high pH.

c. Soil iron becomes unavailable under alkaline conditions.

d. Leaves convert iron into nitrogen.

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