

Maximizing Foliar Efficiency and Results

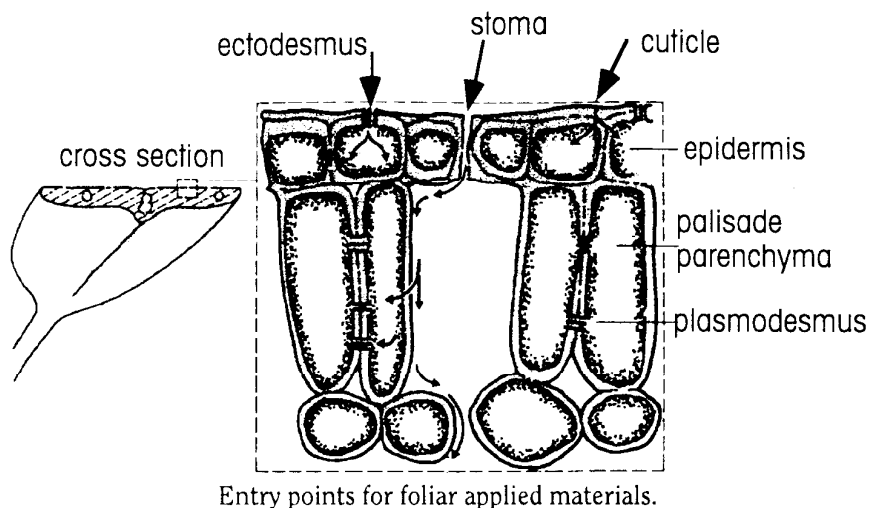
Foliar applied fertilizer is a valuable tool in agriculture, however, there are many important factors to consider and know before the customer will realize full value of his input dollar. Furthermore, knowing more about foliar application of nutrients leads to consistent results. The main topics covered are:

1. Complications in Foliar Uptake
2. Importance of Soil Fertility
3. Foliar Timing
4. Avoiding Phytotoxicity
5. Additional Chelation
6. Advancing Foliar Technology

1. Complications in Foliar Uptake

The development of a complete system of foliar nutrition also includes addressing and dealing with some of the complications.

First a diagram of a leaf surface:



The first point to consider is that most plants have only a low percentage of total stomata's on the upper surface. A general rule in determining which plants have the least is how well the plant tolerates drought. For example, some desert living plants have nearly no stomata's on the upper leaf surface. Depending on the crop and foliar conditions, there are

several methods of increasing stomata uptake of foliars, they are; (1) decreasing spray droplet size to a “mist”, (2) creating enough wind velocity with spray to physically expose lower leaf surface and (3) a developing technology of charging spray droplets to become electrostatically attracted to plant surfaces.

The second point to consider is the cuticle wax that plants produce as a natural protection system. It is important to address and understand the effect of this natural coating on foliar applications, because in most cases this surface is what greatest percentage of the foliar application must pass through. The following can reduce the negative effects of cuticle wax:

- Neutralizing the charges of minerals (mostly positive) by the addition of chelating agents (negative).
- Using compounds, which have a low molecular weight (size).
- A surfactant that lowers the surface tension of water droplet so that it spreads out on the leaf surface.
- Cuticle wax naturally repels water, so a sticker compound must be used to increase adhesion capacity to leaf surface.
- Evaporation and rain can wash off applied nutrients, and cuticle waxes repel water, therefore a surfactant is needed that will penetrate the wax and pull in the spray solution.
- Lower surface tension of the spray droplet is important, but this also increases the surface area of spray for quicker evaporation. In this case, humectants should be present to help guard against total evaporation.

2. Importance of Soil Fertility

Foliar applications serve two main purposes: (1) an effective method of supplying deficient micronutrients to a plant, and (2) an effective method of reducing plant stress by supplying nutrients (NPK included) when soil uptake is limited. Foliar feeding does not replace soil fertilization or soil fertility. Actually foliar feeding nutrients and other plant compounds can increase the growth and vigor of a plant, therefore requiring more soil nutrient support, especially nitrogen and potassium.

There is also the availability of foliar additives such as NUE Stimulate that help a plant support natural root microorganisms such as mycorrhizal fungi. These important organisms will be able to further improve the plants ability to take up nutrients from the soil.

Conclusion: The better the base fertility of soils, the better the foliar programs will respond. Poor soil fertility will always yield poor crops, no matter how good the foliars.

3. Foliar Timing

Although a common practice is to apply foliar elements “piggyback” with disease and pest control sprays, foliar nutrient sprays require proper timing for maximum effect. The timing will vary depending on the crop and nutrient required, but one general rule is to target foliar applications at stress points in a crop cycle such as: flowering, seed development, early regrowth and environmentally induced stresses.

A promising foliar technique being developed is utilizing timing, various minerals and other natural plant compounds to trigger the crop into desired growth cycles. For example, along with soil management techniques it is possible to control the amount of tuber set that various varieties of potatoes produce. This system is of course dependent somewhat on uncontrollable factors such as temperature and weather patterns, but 5 years of on farm demonstrations have proven this foliar system as a valuable management tool.

The following table contains the BEST timing for a complete foliar for various different crops. This should be the timing for a NUE – NPK + Limited Soil Micronutrients + a plant stimulant such as NUE Stimulate.

CROPS	Best Possible Timing
Alfalfa	One treatment 6-8 weeks after planting, one treatment 7 days after each cutting.
Almonds	One treatment in the spring as soon as sufficient foliage has emerged.
Apples	One treatment in the spring as soon as sufficient foliage has emerged.
Asparagus	One treatment approximately 4-6 weeks after planting, or fern re-growth.
Avocados	One treatment before blossoming. May be repeated after fruit setting if needed.
Bananas	One treatment during early growth. May be repeated 4 weeks later if needed.
Barley	One treatment 14-20 days after plant emergence.
Beans	One treatment approximately 10 days before flowering.
Berries	First treatment after leaves has matured. Second treatment 6 weeks later.
Broccoli	One treatment at 4-5 leaf stage.
Brussel sprouts	One treatment approximately 4-6 weeks after planting.
Cabbage	One treatment approximately 4-6 weeks after planting.
Cantaloupe	One treatment when first flowering commences. May be repeated 3-4 weeks later.
Carrots	One treatment approximately 4-6 weeks after planting.
Cauliflower	One treatment approximately 4-6 weeks after planting.
Celery	One treatment approximately 4-6 weeks after planting.
Cherries	One treatment in the spring as soon as sufficient foliage has emerged.
Citrus	One treatment before blossoming. May be repeated after fruit setting if needed.

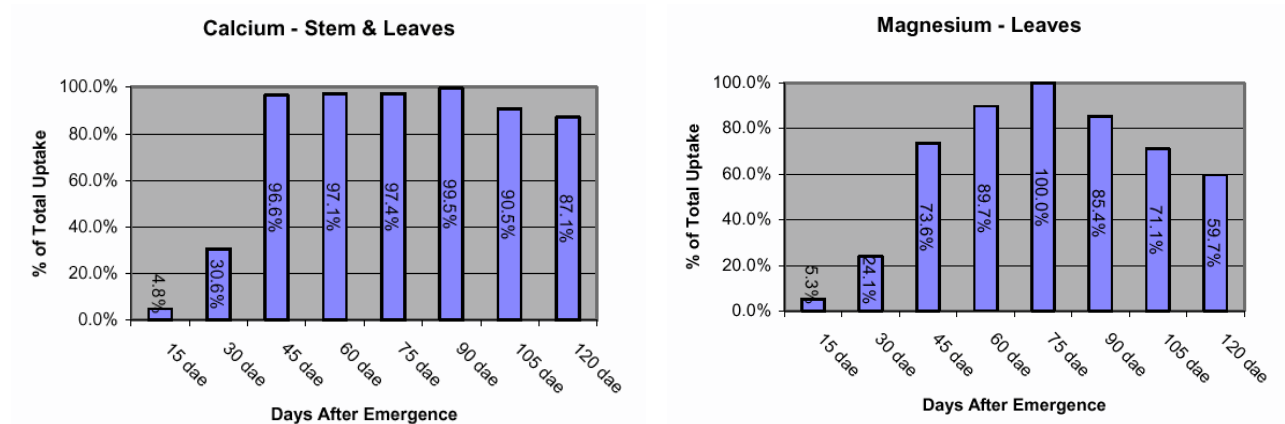
Bio-Gro's Complete Fertility System - Maximizing Foliar Efficiency and Results

Corn	One treatment 21-42 days after emergence.
Cotton	One treatment before squaring.
Cucumber	One treatment approximately 6 weeks after planting. May be repeated 3-4 weeks later.
Eggplants	One treatment approximately at 4-5 leaf stage. May be repeated 3-4 weeks if needed.
Endive	One treatment approximately 4-6 weeks after planting.
Escarole	One treatment approximately 4-6 weeks after planting.
Figs	One treatment after foliage has matured.
Garlic	One treatment approximately 6 weeks after planting (or shortly after thinning).
Grapes	One treatment before blossoming. May be repeated after fruit setting if needed.
Lettuce	One treatment approximately 4-6 weeks after planting.
Maize	One treatment approximately 10 days before tasseling commences.
Milo	One treatment 14-20 days after plant emergence.
Oats	One treatment 14-20 days after plant emergence.
Olives	One treatment before blossoming. May be repeated after fruit setting if needed.
Onion	One treatment approximately 6 weeks after planting (or shortly after thinning).
Palms	One treatment before blossoming. May be repeated after fruit setting if needed.
Peaches	One treatment in the spring as soon as sufficient foliage has emerged.
Pears	One treatment in the spring as soon as sufficient foliage has emerged.
Peas	One treatment approximately 10 days before flowering.
Pecans	One treatment in the spring as soon as sufficient foliage has emerged.
Peppers	One treatment approximately at 4-5 leaf stage. May be repeated 3-4 weeks if needed.
Prunes	One treatment in the spring as soon as sufficient foliage has emerged.
Rice	One treatment approximately 10 days before booting.
Rye	One treatment 14-20 days after plant emergence.
Sorghum	One treatment approximately 10 days before tasseling commences.
Spinach	One treatment approximately 4-6 weeks after planting.
Squash	One treatment approximately 6 weeks after planting. May be repeated 3-4 weeks later.
Strawberries	First treatment after leaves have matured. Second treatment 6 weeks later.
Sugar beets	One treatment immediately after thinning. Second treatment 6-8 weeks before harvest to increase sugar content.
Tomatoes	One treatment approximately at 4-5 leaf stage. May be repeated 3-4 weeks if needed.
Walnuts	One treatment after foliage has matured.
Watermelon	One treatment when first flowering commences. May be repeated 3-4 weeks later.
Wheat	One treatment 14-20 days after plant emergence.
Zucchini	One treatment approximately 4-6 weeks after planting.

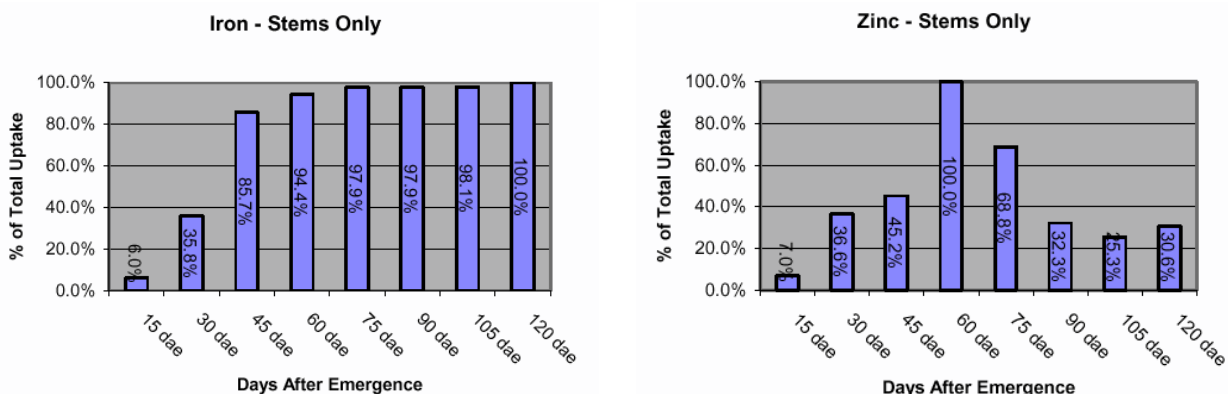
A true CFS program will go much further. Using a combination of soil test data (pH especially), the most limiting micronutrients are first identified. Then the optimum timing of the micronutrient should be identified by tissue testing and weighing the dry matter of the crop at the time of tissue. This results in the ability to know **HOW** much to put on and **WHEN**. It is also important to know **WHICH** form of nutrient to use.

This work as been already done on potatoes. A spreadsheet, which calculates each nutrient as a percentage of uptake in dae (days after emergence), is used to input local nutrient removal guidelines. Then charts are made to show the nutrient peak and optimum window of uptake. **Currently, very few agronomists use this approach; it is a tremendous CFS opportunity.**

For example, compare the different uptake “PEAKS” of calcium and magnesium. From this you can see that the majority of calcium is taken up in the 30-45 dae period (majority of canopy growth), whereas with magnesium, an addition 27% is taken up in the following 30 days. Therefore, it is important to run a high Ca to Mg ratio early and then use magnesium later.



This is not the only surprising example that was discovered from plotting out these nutrient uptake curves. Micronutrients also showed a surprising difference. Fe, Cu and Mn are all relatively taken up in the same time frame, however zinc is significantly different. This uptake pattern will also illustrate the most important functions of each micronutrient in the crop. In this example, it was discovered that potatoes require a large amount of zinc AFTER full canopy and unlike much of the other nutrients a great percentage is translocated to the tuber.



4. Avoiding Phytotoxicity

Nutrient phytotoxicity is a viable concern in developing any type of foliar program. However, understanding the mechanism of what causes phytotoxicity is most important in avoiding the problem.

Two major factors that contribute to phytotoxicity are:

- a) **Excessive rate of application.**
- b) **A foliar mix that is too acidic or alkaline (pH).**

In order to help understand the effect of these factors, the function of nutrient uptake and translocation in a plant should be discussed. However, to present the exact functions as to how a plant takes in and utilizes a foliar applied nutrient would probably require writing volumes. Even then the only obvious fact is that there is still much to be discovered and learned. Yet, there are some basic observations that can be made.

Often the question is raised, how can you make foliar applied calcium available in a plant? This question has been debated for a long time. We may not have the answer, but nature does, think about it. Every crop we produce is perfectly capable of translating and moving large quantities of calcium and other nutrients to new growth points. Some potato vines can reach lengths of 3 feet and up, can one really assume that there is no calcium in the growing points of these vines? There is, but how did it get there? A simple answer is that plants produce the right compounds (discovered and undiscovered) in the right balance to

make calcium perfectly translocatable, even under huge demands and poor soil conditions. Agreed, sometimes the level of nutrient may not be adequate, but it is still there.

This observation is related to understanding foliar applied nutrient phytotoxicity, because in a foliar application you are basically “short circuiting” the plants natural mineral uptake and translocation system. For example, take a 10% solution of zinc sulfate, and say that the right conditions prevail to get this entire amount mineral into the plant. Plants are capable of many things, but anticipating this foliar application is not likely to be one of them! What happens at this point? As far as we can understand, the nutrients are bound with organic compounds that the plant has produced or is capable of producing. **This does take energy on the part of the plant and this could also partially explain why foliar applying nutrients to “suffering” or “sick” plants often has a more detrimental effect, than positive.**

At this point the level of free ions of zinc in the plants tissue becomes important. If the plant has the compounds or energy available to complex all of the zinc, it is understandable that it will be able to utilize these compounds to increase its natural functions. However, an overdose can result in two negative functions:

- a) The plant attempts to excrete the excess zinc ions from its leaves resulting in burn around the outer edge of the leaf or at the tip.
- b) The plant “deposits” the zinc ions in “pockets” causing these areas to burn.

Complexing and chelating minerals with naturally produced plant compounds is a very effective method of reducing the possibility of mineral phytotoxicity of foliar applications. In the following section, the percentage of chelation of each mineral is further discussed.

Surface or sectional leaf burn can also occur when the pH of the foliar spray is too acidic. Acidic foliar sprays can penetrate leaf surfaces more effectively, but it is possible for a negative effect to occur when too much acidity is present. This has to do with the chelation of the minerals with organic acids. Each type of organic acid has its own pH disassociation range with the mineral as the pH drops (increased acidity). In order for the mineral to be chelated, it must be associated (bond) to the chelating agent. If the mineral is not bonded, the positive effect of adding organic acids for chelation is lost; the mineral becomes a free ion.

Conclusion:

Foliar application of minerals can result in phytotoxicity. However, Bio-Gro's NUE Amino minerals contain natural plant compounds that will help reduce the risk of phytotoxicity over the use of straight mineral solutions. On the other hand, because the minerals are chelated, more effective plant utilization does occur. Therefore, it is not advised to use higher rates than normally used.

5. Additional Chelation:

The concentration of fulvic, organic and amino acids utilized in the formulation of NUE Amino minerals are sufficient for adequate plant uptake and utilization based on a cost to performance ratio. However, this mixture is not 100% chelated. Following is a table which illustrates the approximate percentage of chelation in the base NUE Amino formulation and the amount of Bio-Gro NUE Chelate - 42% that should be added to each gallon used to reach the desired percentage of chelation. Note that the percentage is an approximate figure reached by mathematical calculation.

Mineral	% in Base NUE Minerals	NUE Chelate - 42%/gal to reach 30%	NUE Chelate - 42%/gal to reach 50%	NUE Chelate - 42%/gal to reach 75%
NUE Amino Cu	14.1%	7 oz	16.25 oz	27.6 oz
NUE Amino Fe	13.3%	8 oz	17.6 oz	29.6 oz
NUE Amino Mg	9.2%	14.4 oz	28.25 oz	45.6 oz
NUE Amino Mn	14.1%	7 oz	16.25 oz	27.6 oz
NUE Amino Zn	15%	6.4 oz	15 oz	29.6 oz

This information is supplied to help increase the leaf uptake and performance of NUE Amino minerals. Additional NUE Chelate - 42% (to get more chelation) is recommended in the following circumstances:

1. When tank mixing with ortho phosphate N-P-K solutions that have a higher final pH reading. The extra NUE Chelate - 42% provides both additional acidity (H⁺) and more chelate stability at higher pHs.
2. Organic and amino acids chelation is the best method of preventing nutrient phytotoxicity in foliar feeding. The higher the rates of mineral used, the greater the end percentage of total chelation should be. Also, the higher the level of stress in the plant, the greater the end percentage of chelation should be.

NOTE:

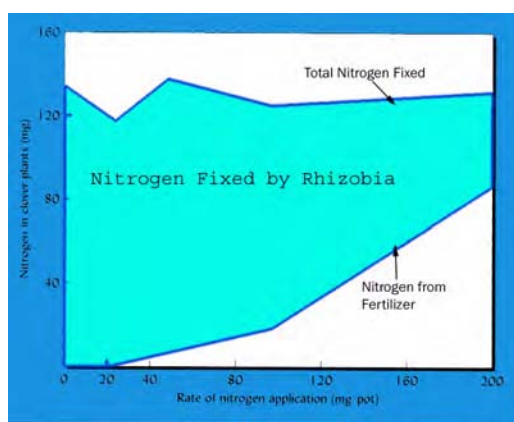
NUE minerals are very effective as formulated, the addition of extra NUE Chelate - 42% is only recommended for the field personnel who need to fully maximize foliar effectiveness. Low input crops such as wheat, barley and alfalfa will not likely benefit in the additional input cost to return in productivity. However, higher input crops such as vegetables and fruits can benefit. Rates should be tested by both tissue testing and crop quality or yield increases.

6. Advancing Foliar Technology

The technology utilized in the production of NUE minerals is important to understand. The formulation of this unique mix of fulvic acids, organic acids and amino acids results in a product designed specifically for plant translocation and uptake as a foliar. These discoveries have also opened up an entire new field of foliar application technology. Its development is based on some very basic observations of both farm and laboratory research. To help understand this new technology, we will give a brief description of how it has been developed.

When plants are deficient of a particular nutrient, they have the “ability” to change their normal growth pattern and produce various compounds in an attempt to make the mineral available. Two important known plant functions illustrate this wonderful ability;

It is known that when legume plants are feed nitrogen fertilizer they do not establish the beneficial rhizobium bacteria. As a matter of fact, soils need to be also deficient of N to get the most N-Fixation by the plant. Nitrogen fixed is directly related to level of available soil nitrogen.



In iron deficient plants (apple trees) in high pH soils (“lime induced iron deficiency”), the levels of organic acids (chelating agents) are much higher in the leaves and roots! **As a matter of fact, the total organic acids level in the leaves increases by 1089% (ten-fold)! Even in the roots there is a 310% increase in exuded chelating agents!**

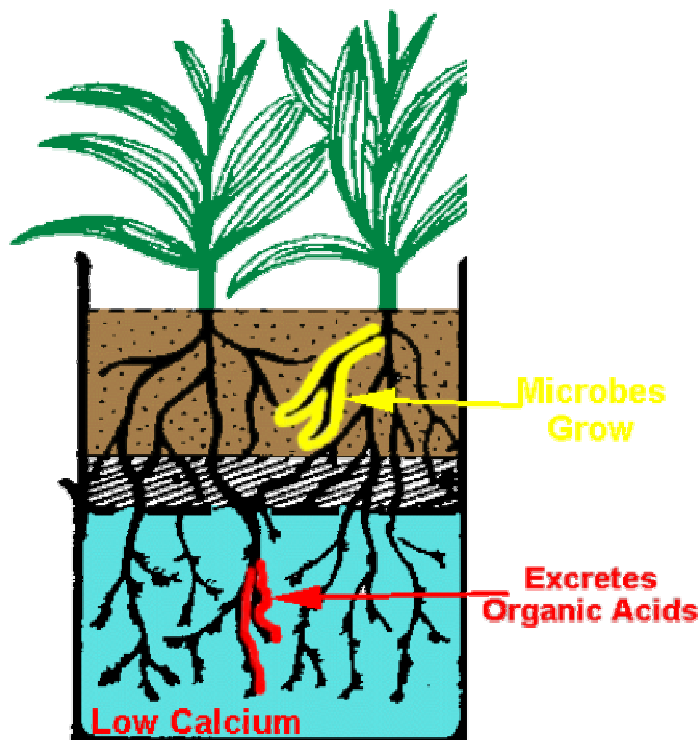
	Succinic Acid	Malic Acid	Quinic Acid	Citric Acid	Total
Young Leaves					
With Fe	23	249	6421	164	6858
Without Fe	84	2670	465	4286	7506
Old Leaves					
With Fe	0	285	3982	275	4543
Without Fe	2	1792	3320	2035	7150
Fibrous Roots					
With Fe	0	760	213	1020	1984
Without Fe	83	1822	113	3593	5613
Total = 13385 verses 20224 (34% more) Organic Acids = 2,769 verses 16,371 (+591%)					

Actually, these two examples illustrate two very important points dealing with foliar product selection and development:

1. Soil & Plant nutritional status regulates root microbiology
2. When a plant is nutrient deficient, it makes CHELATING Agents to get minerals from the soil!

THEREFORE, studying the types of microbes and the types of chelating agents that plants support under NUTRIENT DEFICIENCY, gives important clues to developing chelating agents and plant stimulants! This work as been done in part.

Plants are grown in hydroponics with and without the desired nutrient left out. At the point the plants began showing visual nutrient deficiency, the root hairs were washed and the resulting solution was analyzed for its balance of organic compounds. This information was used in choosing the raw ingredients and essential microbiology needed for the production of NUE Chelate - 42%.



The research has led to further understanding of the symbiotic biological functions of soils and plants. The majority of these positive biological functions occur in the immediate vicinity of the root hair, commonly referred to as the “rhizosphere”. From the study of rhizosphere microbiology, the basic understanding of nutrient solubilization and translocation into plants has become clearer.

From this work has come the development of NUE Stimulate and other upcoming amino acid based plant stimulants that trigger root exudes, root growth and help feed and support root microbiology.

NUE – Nutrient Uptake Enhancement – More than a simple foliar!