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Is Your Fertility Program Stuck in the 1950's? Well, It Should Be! Nutritional Approach to Passive Plant Pest Immunity

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Summary

Many green industry production systems are not sustainable and inherently wrong. Changes are needed in our nutritional and chemical programs that enhance sustainability: environmentally, economically and culturally. It is possible to manage plant nutrition in such a way that plants become more resistant to insects and diseases. The plant health pyramid from Advancing Eco Agriculture® illustrates what we are trying to achieve in terms of plant growth and health. Mineral nutrition and microbiology are the foundation of plant immunity and pest resistance. Base Saturation or "ideal ratios of cations" in the soil/ container media are critical for balanced plant nutrition, health and pest resistance. Testing the leaf Brix index of plant sap with a refractometer is a quick way to determine plant health. The leaf Brix level/insect relation chart is an excellent tool for gauging plant health and pest resistance. A low leaf Brix level (0-6) indicates plant susceptibility, whereas plants are largely resistant to insects and disease at Brix levels 12 to 14. Optimizing the plant nutrient levels and minimizing pesticide usage - can significantly increase photosynthesis, Brix levels – and increase pest and disease resistance.

INTRODUCTION

In the 2006 movie, "Idiocracy", the lead character wakes up one day to 500 years in the future. He quickly realizes that he is the smartest person on the planet - as people have been completely dumbed down by inferior education, misinformation, propaganda and advertising. Farmers are irrigating their fields with a sports drink called Brawndo because it contains what plants crave: "Electrolytes". The lead character quickly gets them to start irrigating with water and both the crops and civilization are saved. Sounds like the most ridiculous thing you've ever heard right? No way that could ever happen in a civilized society? Well, something very similar has been happening in agriculture for decades – for over a century!

What we are going to do right now is screen a 60-sec move trailer for the sequel to this movie. Our lead character/ hero has now woken up in present day 2021 and is sitting in the audience with you. We are simply going to show him a few slides depicting how we currently grow plants. The question is how long do you think it will take – for our hero to realize that once again, he is the smartest person on the planet?

ENVIRONMENTALLY UNSUSTAINABLE PRODUCTION SYSTEMS

Cotton is considered one of the 'dirtiest' crops on the planet in terms of the amount of chemicals and pesticides used to grow it (Fig. 1). What if we tell our hero that we make clothes, bed sheets and bath towels out of this cotton? Then the rest of the plant is utilized for cooking oil and animal feed. https://www.moderndane.com/blogs/the-modern-dane-blog/why-cotton-is-called-the-worlds-dirtiest-crop

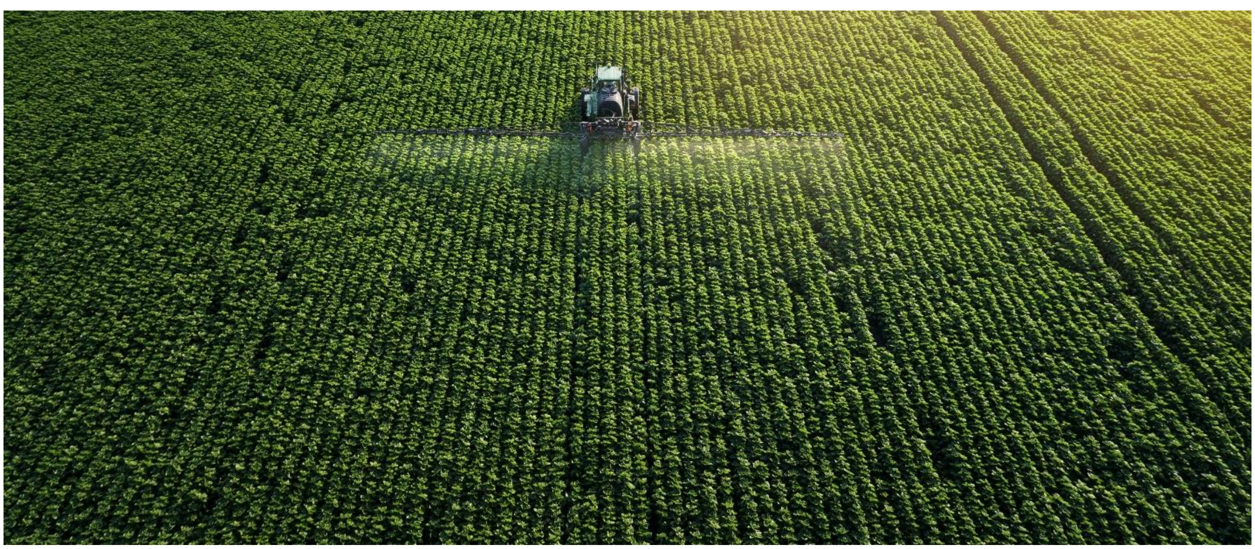

Figure 1. Cotton Farming is universally recognized as one of the most chemical-laden crops on the planet.

What if we showed him how many chemicals it takes us to produce unblemished fruit and vegetables that we consume and feed our children? What if he saw that we were destroying our pollinators by spraying all these chemicals? In some areas of China, they have killed off most of their pollinators. They literally take a sack of pollen and a stick with chicken feathers on it and climb up into the fruit trees and pollinate each of the flowers (Fig. 2). I was born and raised in central Florida so citrus is near and dear to my heart. What if he saw the methods we have resorted to keep insects off of our citrus trees (Fig. 3)? Is this really the best we can come up with as craftsmen of our trade? Is this the best we can come up with as a civilization? I think not!

Figure 2. Hand pollination of temperate fruit crops is done in parts of China because insect pollinators have been killed off. Credit: Huffington Post.

Figure 3. (right) Citrus under protective screen (CUPS). (left) Steel roll-up door with a second plastic strip door, and (right) citrus can be grown under protective screen structures for fresh-fruit production in order to exclude the Asian citrus psyllid (ACP, *Diaphorina citri*) vector of huanglongbing (HLB), or citrus greening disease, and thereby produce disease-free healthy fruit. While CUPS may be economically feasible for some fresh-market citrus crops, over 90% of Florida citrus is for juice production, so a CUPS system is not economically sustainable. https://edis.ifas.ufl.edu/publication/HS1304 Credit: Arnold W. Schumann, UF/IFAS.

Many production systems are not sustainable and inherently wrong. It defies common sense and logic. Yet we all do this every single day and think nothing of it. This is all we have known because it is all we have seen and been taught by others. It is what our educational system teaches us. It is what the fertilizer and chemical companies' market. I grew up gardening with my father and grandfather and literally thought the pesticide Sevin dust was a tomato fertilizer! It does not have to remain this way because long-term it is not sustainable: environmentally, economically or culturally.

HORTICULTURAL REALITY

What comes next is what I refer to as 'Horticultural reality' and unfortunately it is probably the first time you have ever heard some of this information. This will be the shortest, least expensive and most rewarding "PhD course" of all time. Our nursery production company is not immune to common commercial problems. We still get aphids, chili thrips, whiteflies and flea beetles. However, what were once ginormous problems have been reduced to minor inconveniences because of sustainability changes we have made in our nutritional and chemical programs.

There is a better way. It is possible to manage plant nutrition in such a way that plants become more resistant to insects and diseases. This is not a theory or hypothesis – it is something that has been executed on millions of acres. When you manage nutrition sustainably the entire system begins to behave differently. Most of the information from this point forward was gathered from books written in the 1940's through 1960…hence the title of this paper.

The plant health pyramid from Advancing Eco Agriculture https://www.advancingecoag.com illustrates what we are trying to achieve in terms of plant growth and health (Fig. 4).

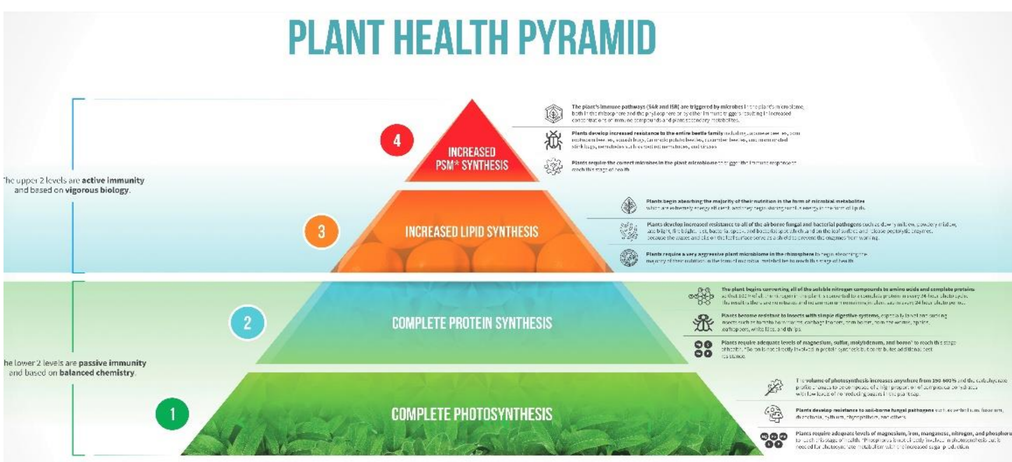

Figure 4. The Plant Health Pyramid. The lower two levels are passive immunity and based on balanced chemistry. The upper two levels are active immunity and based on the vigorous biology of a healthy plant. Mineral nutrition and microbiology are the foundation of plant immunity and pest resistance. AEA – Advancing Eco Agriculture https://www.advancingecoag.com

There are the top four levels of plant health and infinite levels below them. This paper focuses on the bottom two levels of the pyramid, which are entirely dependent upon a "balanced chemistry" and nutritional program.

SYSTEMS APPROACH

We're going to take a 'Systems Approach' to plant production. Our system includes soil, weeds, insects, diseases and nutrients – and their influence on nursery crop production. Optimum performance levels of the soil (media) are required to grow a healthy crop. It begins with base saturation which means proper cation saturation or the ideal ratios of cations. The base saturation of soil may be the most important figure in this paper (Fig. 5).

Base saturation of soil

- ❑Developed by William Albrecht at University of Missouri from 1930's – 1950's.

'Ideal Soil' Cation ranges below:

- ❑Calcium 68% (60-70%)
- ❑Magnesium 12% (10-20%)
- ❑Potassium 5% (2-7%)
- ❑Sodium 1% (anything less than 2%)
- ❑Hydrogen 10%
- ❑All other Cations combined (minor elements copper, iron, manganese, etc) 4%

Figure. 5. Dr. W. A. Albrecht saw a direct link between soil quality, food quality and human health. He drew connections between poor quality forage crops, and ill health in livestock. From this he developed a formula for ideal ratios of cations in the soil - the "Base Cation Saturation Ratio". Albrecht was also one of the early proponents of developing agroecology for more sustainable production systems.

The base saturation levels for optimum soil conditions and plant growth are 68% calcium, 12% magnesium, 5% potassium, 1% sodium, 10% hydrogen, and 4% all other cations. The most important concept to understand is that the soil is a living system with plants and rhizosphere organisms; what we are trying to accomplish with base saturation is: 1) creating a hospitable environment for beneficial microorganisms to thrive in and 2) creating an environment where all of the mineral elements are in ratios that optimize the nutritional needs of producing a crop.

If you balance the cations - you can throw your pH meter out the window! Your soil should always be around 6.4 pH when cations are properly balanced. A 6.4 pH is also the ideal pH of sap in a healthy plant and the pH of saliva and urine in a healthy human. If the mineral balance is in-line, the pH will self-correct. [Controlling the pH of irrigation water is also critical for sustainable nutritional programs].

Once the soil minerals are balanced and part of a living soil, the reliance on insecticides and other toxic "rescue" chemicals is reduced. Living organisms that are nutritionally fit have greater resistance to disease, parasites and other pests. While pH means acidity to some people, it is also an indicator of shortage of fertility elements; the same fertility elements responsible for base saturation.

CALCIUM (CA): MAGNESIUM (MG) RATIOS

Calcitic limestone has a 35:1 Ca:Mg ratio, while dolomitic limestone has a 2.5:1 Ca:Mg ratio (Fig. 6). You cannot get to a 7:1 Ca:Mg ratio by using either alone. In fact, if you were to solely use dolomite you would reach pH 6.4 long before you ever added the ideal amount of calcium, since magnesium is 40% more effective at raising pH than calcium is. With just calcitic limestone you could never get sufficient magnesium into the soil. So, a combination of both, or either with some additional amendments is required to reach the proper Ca:Mg ratio.

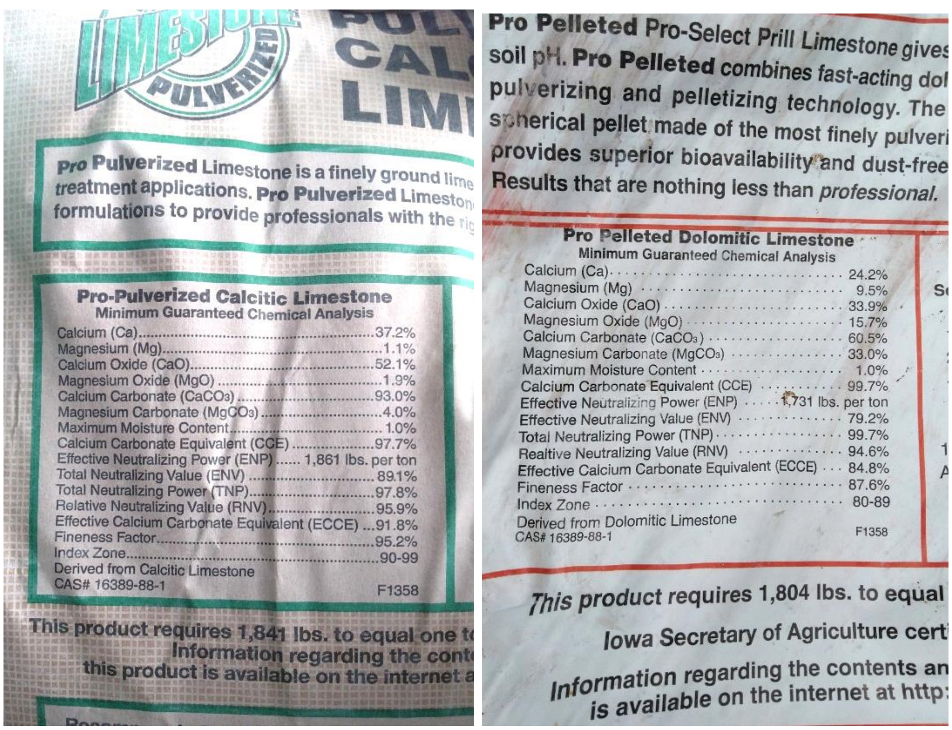

Figure 6. Nutritional components of calcitic limestone (left) and dolomitic limestone (right).

A balanced equilibrium of calcium and magnesium creates a sustainable soil environment for bacterial and fungal activity for proper decay of organic residues into CO_2, carbonic acid and a host of many weak and mild organic acids - all critical to convert and release mineral elements in the soil system. The Ca:Mg ratio sets the stage for the rest of the elements. If calcium is too high, the soil tilth will be loose, but will lose its texture and cohesiveness and water may percolate through too quickly. If magnesium is too high, the soil will be tight, restricting water and air movement.

At no time do we want the calcium to drop below 60% base saturation, or magnesium to drop below 10% - unless we are growing specialty crops such as blueberries or rhododendrons that like a high Mg and acidic soil, or certain plants that prefer a very high calcium soil.

Calcium. By weight and volume, calcium is needed more than any other element. Calcium is essential for its energy creation potential in the soil to release the other elements that cause a plant to grow. It's basically like a nuclear power plant within the soil. Calcium has the leadership role among the other essential plant nutrient ions. As protein concentration rise, calcium concentration also rises. And with an increase in protein there is also an increase in vitamins. When a small amount of calcium in 100% soluble form is introduced to the soil, its energy power is far greater than any of the other elements surrounding it. If there is calcium in the soil and some moisture, the new input has the tendency to convert insoluble calcium in the soil and into a soluble form.

Magnesium. Magnesium controls the total amount of nitrogen in the leaf so that an excess does not build up. Magnesium is the main governor of nitrogen in the soil (as such, it is an excellent antidote for nitrogen toxicity). Magnesium, pound for pound, can raise pH up to 1.4 times higher than calcium. Magnesium has a favorable effect on the movement of nitrogen and phosphorous into plants. Excessive magnesium will cause phosphorous, potassium and nitrogen deficiency.

The ratio of phosphate to potassium (potash) in the soil should be 2:1 (1:1 elemental P:K) on crops other than grasses. In grasses, this ratio should be 4 phosphate:1 potassium. If potassium is replacing calcium in the leaf, both the leaf and the stem will exhibit small black specks. When excess potassium is applied, it replaces calcium and plants are more susceptible to disease. Potassium seems to have a more pronounced effect on disease caused by soilborne fungi than on diseases caused by airborne fungi.

WEEDS CAN BE AN INDICATOR OF A SOIL'S HEALTH

Weeds can be an index of what is wrong with the soil, or at least with the fertility program. https://www.canr.msu.edu/news/weeds_are_an_indicator_of_a_soils_health Field horsetail is a good indicator of poorly drained, low pH soils. Improving the drainage and increasing the soil pH by liming will help to manage field horsetail as a weed. Weeds may be indicator plants for soils low or high in certain elements. For example, Quackgrass (*Elytrigia repens*) is a sign of improper iron-manganese ratio.

Broadleaf weed pressures can often be controlled by balancing phosphorous and potassium levels: 2 phosphate - 1 potassium are ideal. As available nutrient ratios drift from (2 Phosphate: 1Potash) broadleaf weed pressure will increase. When ratios get to 1:8 and beyond, the weed pressure becomes so intense that herbicides become ineffective.
Some examples of conditions preferred by some common weeds are as follows: prostrate spurge and yellow nutsedge both prefer low levels of calcium and phosphate, and high levels of potassium and magnesium. Crabgrass, ironweed, morning glory and dandelion are indicator plants for soil deficient in calcium. Most old timers know the best herbicide for dandelions in the yard is an application of calcitic limestone.

Grassy weeds generally indicate calcium deficiency. They are also present if the magnesium is too high in relation to calcium. It's a pretty safe assumption that if you have grassy weeds, additional calcium is needed in your soil.

Optimum fertility can mitigate weeds. See the example of a healthy young Buddleia and a weed in the same container - succumbing to a foliar pathogen (Fig. 7). The weed being attacked by a pathogen is an indicator that the container nutrition program is balanced. The intended crop is healthy and pathogen-free, while the weed is susceptible to the fungal pathogen. [A dilemma for the green industry is zero tolerance for weeds in container production systems. Weeds in container production are a costly management problem to control via integrated pest management, chemical usage, and expensive hand-weeding].

Figure 7. (left) A healthy young *Buddleia* and (right) a weed (arrow) growing in the same container as the *Buddleia* but gradually succumbing to a foliar pathogen.

NUTRITIONALLY DEFICIENT AS WELL AS UNBALANCED, "OVER-FED" CROPS ARE MUCH MORE SUSCEPTIBLE TO INSECT PESTS AND DISEASE

According to William Albrecht: "Insects are nature's garbage collectors and diseases are her cleanup crew". It may be a new way of thinking about things, but I assure you this is 'horticultural reality'. With a malnourished, unhealthy plant - insects and diseases can proliferate – ultimately 'taking out the trash' with the plant's demise. So, if you see insects and disease on your plants, they are indicators of a stressed, susceptible crop.

Phill Callahan was an Entomology professor at the University of Florida and also worked for the USDA. He published a dozen books on insects and retired from the USDA a mere decade before I went to school there. A lot of his work was on insect communication and how they see in the infrared spectrum. So, all the chemicals we spray on plants combined with unbalanced nutrition creates an environment where our plants outgas ethanol and ammonia; insects recognize this in the IR spectrum as well as sense with their antenna - and are drawn to stressed crops as if it were an "all-you-can-eat buffet".

TESTING THE LEAF BRIX OF PLANT SAP WITH A REFRACTOMETER IS A QUICK WAY TO DETERMINE PLANT HEALTH

The Brix index is measurement of carbohydrates and can be measured with a digital handheld refractometer (Fig. 8). Degrees Brix is the carbohydrate/ sugar content of an aqueous solution. Leaves can be crushed via any method (i.e. garlic press), leaf sap expressed, placed on top of the lens, and a reading taken. It is very simple. It is a very basic concept with very basic requirements. Plants require sunshine, water, air in the soil, and nutrients to photosynthesize and create high levels of carbohydrates.

Figure 8. A refractometer is used to measure the leaf Brix which is the carbohydrate/sugar concentration as a percentage. Testing the Brix leaf sap with a refractometer is a quick way to determine plant health.

What contributes to lowering Brix is not always simplistic. All the "-cides": insecticides, fungicides, herbicides can lower plant Brix. A nasty side effect is that different insecticides, fungicides and herbicides can kill very specific groups of microbes as well. So, like most of us in the green industry – there is massive rotation of insect, disease and weed sprays. In essence you are doing your best to annihilate most of the beneficial microbes inhabiting the soil as well as those colonizing the leaf, shoot and root surfaces. Sounds like the exact opposite of what we should be doing - doesn't it? High salt fertilizer will also lower Brix.

What does Brix have to do with insects? The leaf Brix level/insect relation chart was developed by Dr. Thomas Dykstra of Dykstra Laboratories, Inc. in Gainesville, FL. https://www.ecofarmingdaily.com/grow-crops/picky-eater-insects-pass-on-high-brix-plants/

His lab opened in 1997, two years after I arrived at UF. According to Dykstra: insects have a simple digestive system and cannot digest the same foods that we do. Low-Brix plants (6 and below) are easier for the insect gut to digest. Insects lack the digestive enzymes to break down healthy proteins from high-Brix plants. Essentially a high Brix (14 and above) means that insects will not attack a given plant, nor are they attracted to it.

If your plants have aphids, scale, or mealybugs they are in essence on "nutritional life support". If left alone these plants would succumb to insects and disease and be "taken down to the ground". If one raises the Brix levels above 6, insect pest species change, i.e. thrips and whiteflies, etc. dominate; at higher Brix the next level of herbivore species include caterpillars, worms, and beetles. [Once most plants reach 6 Brix, there is a significant jump in the production of secondary plant metabolites, which are phytochemicals that help contribute to a plant's odor, color, and provide natural plant defenses against pests. These 6-Brix plants are finally able to devote their energy reserves into producing new proteins and more diverse molecules]. The final pests are the grasshopper group. Chewing insects that eat the roots or leaves directly, such as caterpillars, grasshoppers, and beetles, will start to lose interest in eating a plant with a 10 or 11 Brix. At Brix level 12 to 14 - plants are largely resistant to insects and disease.

Up until a few months ago I had no idea that there were different levels of plant health that correlated with different insects. So, for years after foliar spraying nutrients to get rid of aphids and then had whiteflies or caterpillars arrive, I thought I was failing the entire time.

THE PLANT HEALTH PYRAMID, NUTRIENTS REQUIRED, AND MITIGATION OF PESTS

It is reported that most of our ornamental and agricultural crops currently photosynthesize at rate of 10-20% of their full capacity. So just by optimizing the nutrient levels required by the plant - we can significantly increase photosynthesis. The major nutrients required for photosynthesis are magnesium, iron, manganese, nitrogen and phosphorous. Once adequate photosynthesis is taking place, the plant develops greater resistance to soil-borne fungal pathogens such as Verticillium, Fusarium, Rhizoctonia, Pythium, Phytophthora, and others. In most fungal pathogen–plant systems, a high level of sugars in plant tissues enhances plant resistance. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4219568/

Sugars are also involved in metabolic and signalling pathways of plants. Sugar signals can contribute to immune responses against pathogens – leading to pathogen-associated triggered immunity in plants https://academic.oup.com/jxb/article/63/11/3989/604616

Level two of the plant health pyramid (Fig. 4) entails increasing protein synthesis, utilizing nitrogen compounds and converting amino acids into protein. The major nutrients required for protein synthesis include magnesium, sulfur, molybdenum, and boron. Plants become resistant to insects with simple digestive systems, especially larval and sucking insects such as tomato horn worms, cabbage loopers, corn borers, aphids, leafhoppers, whiteflies, and thrips.

Levels three and four of the plant health pyramid entail active immunity and are dependent on high functional levels of soil biology. Level three is increased lipid synthesis. This provides resistance to airborne fungal and bacterial pathogens such as downy mildew, fire blight, rust, bacterial speck, late blight, etc.

Level four entails increasing plant secondary metabolites. This provides resistance to beetles, nematodes, and viruses. Obviously, this means that the plant health needs to be clicking on all cylinders to achieve resistance to these pests. For those of you, who like us, suffer from red-headed flea beetles, I sympathize! I can say that supplementing molybdenum has helped us somewhat on reducing the population of the red-headed flea beetle. Evidently our plants did not have adequate amounts of molybdenum to synthesize the required amount of nitrate reductase enzyme.

So how do you get all these required minerals into the plant to satisfy levels 1 through 4? All you can do is set the stage with base saturation of the soil/ media, introduce microbes into the system and supplement with foliar feeding.

FOLIAR FERTILIZATION

How many of you have tried foliar feeding, never saw any results, and quickly gave up on it? Through most of my career, I had the same problem until I learned that there are good and bad times to foliar feed. Plants will respond 8-20 times more efficiently to foliar sprays compared to soil applications.

In layman's terms the *point of deliquescence* is simply the point at which a foliar spray (ionic salts) will dry (into crystals) on the leaf surface. It is important to keep the foliar spray in solution on the leaf for as long as possible to aid absorption. This is why evening sprays are ideal as they take advantage of higher humidity at night. Also, urea, magnesium chloride, calcium nitrate and potassium nitrate can be added to the spray to help keep the sprays in solution longer.

FERTILIZER, FUNCTION AND ENHANCED PEST RESISTANCE

Proper use of fertilizers can promote plant growth and enhance pest resistance. Fertilizers include calcium chloride, potassium nitrate, calcium nitrate - but avoid potassium chloride (muriate of potash) if possible, which can be toxic to microbes. The primary nutrients that promote reproductive growth are ammonium, phosphorous and manganese.

Boron increases calcium absorption from the soil and mobility within the plant. Calcium is the bus and boron is the bus driver. Ideal soil ratio is 1:400 Bo: Ca. All crops can benefit from a light supplemental foliar spray of boron prior to flowering. Boron increases resistance to Fusarium, Verticillium, Rhizoctonia, and some viruses.

Foliar applications of the micronutrients molybdenum and cobalt have enhanced our plants. If time-sensitive crops such as poinsettias, mums, etc. are finishing ahead of schedule - a cobalt spray will slow down their growth.

Copper is essential for fruit tree production, provides bark stretchiness and resistance to a host of bacterial and fungal diseases. Cracks in the bark of your trees or rabbit tracks on your crape myrtle leaves are indicative of copper deficiency.

Iron is a major component of multiple enzymes, protein synthesis, chlorophyll and the oxygen carrying system within the plant. It also helps mitigate some of the bacterial diseases.

Manganese also plays a major role with enzyme systems within the plant. Chlorophyll production, carbohydrate and nitrogen metabolism all depend on manganese. Manganese is best applied as a foliar application. Combine manganese with phosphoric acid to aid absorption. Manganese helps mitigate a wide range of fungal and bacterial pathogens.

Molybdenum is required for the formation of nitrate reductase enzyme which converts nitrates into amino acids. Molybdenum helps mitigate a wide range of pathogens from viruses, bacteria, fungi, and nematodes. Blueberries (*Vaccinium*), do not have the ability to make nitrate reductase enzyme, hence molybdenum is less important to them - and nitrate nitrogen can be toxic to them because of this.

Phosphate is the major catalyst in all living systems and important in photosynthesis. The more efficiently plants take up water and nutrients, the higher the photosynthetic levels and carbohydrate/ sugar production - the higher the Brix level. Phosphate is key to obtaining a high brix crop. If there is a phosphate deficiency there is typically a deficiency in all other nutrients. Phosphorous mitigates bacterial, fungal and nematode pests.

Sulfur is useful in reducing cations that are in excess. It bonds with them and makes them water soluble. Sulfur also lowers the soil pH. Magnesium sulfate, calcium sulfate, and potassium sulfate are all very water soluble. Sulfur-induced resistance is a very real phenomenon. Sulfur helps mitigate everything from fungi to spider mites.

TOOLS REQUIRED TO OBTAIN THE NECESSARY INFORMATION NEEDED FOR ACCURATE NUTRITION DECISIONS

All nutrition management decisions are based on irrigation water, soil (media), and leaf tissue analyses. For instance, a soil analysis can help determine how much calcium is needed to reach the proper base saturation levels.

In leaf tissue analysis, younger and older leaves on the plant are separated. Leaf samples are taken from two different locations of a plant, based on maturity, and bagged separately. If it is a mobile element, such as magnesium, and the younger leaves have more magnesium than the older leaves - then the plant probably does not have enough total magnesium because its robbing from the older leaves to transport it to the younger. If both the younger and the lower leaves are on the low end of the spectrum then you need a foliar spray for a faster response. I would spray a tank mix of potassium nitrate, potassium silicate, sea salt, solubor and sulfur.

Remember that we are the original Green Industry…it's time we started acting like it!