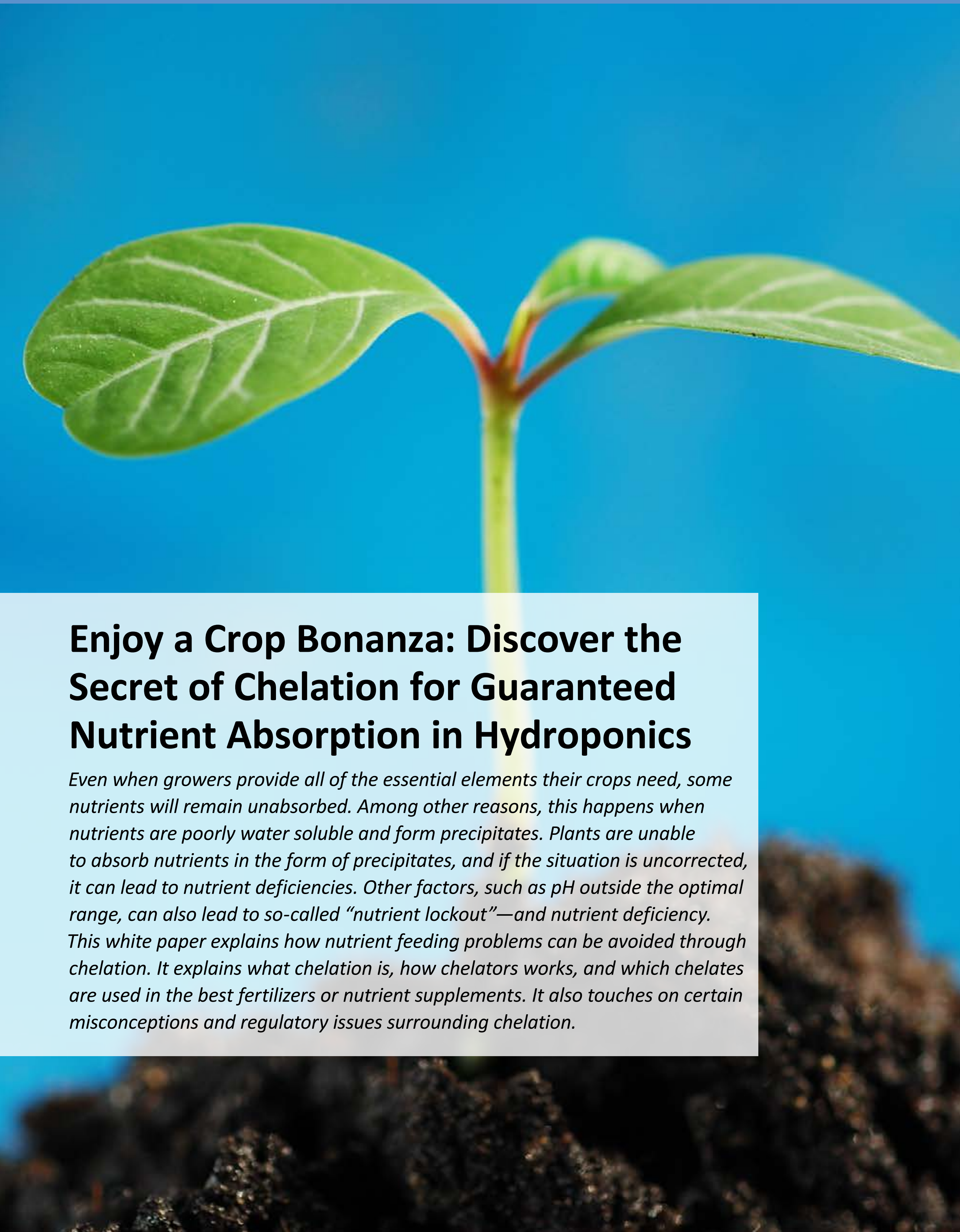
Enjoy a Crop Bonanza: Discover the Secret of Chelation for Guaranteed Nutrient Absorption in Hydroponics

Julian Karadjov, PhD
Bulgarian Academy of Sciences
December 10, 2012

CONTINUING A SERIES OF WHITE PAPERS BASED ON RESEARCH AND FACT



Enjoy a Crop Bonanza: Discover the Secret of Chelation for Guaranteed Nutrient Absorption in Hydroponics

Even when growers provide all of the essential elements their crops need, some nutrients will remain unabsorbed. Among other reasons, this happens when nutrients are poorly water soluble and form precipitates. Plants are unable to absorb nutrients in the form of precipitates, and if the situation is uncorrected, it can lead to nutrient deficiencies. Other factors, such as pH outside the optimal range, can also lead to so-called "nutrient lockout"—and nutrient deficiency. This white paper explains how nutrient feeding problems can be avoided through chelation. It explains what chelation is, how chelators works, and which chelates are used in the best fertilizers or nutrient supplements. It also touches on certain misconceptions and regulatory issues surrounding chelation.

Discover the benefits of chelation

You did everything by the book.
You followed the instructions on the fertilizer bottle and on the feeding chart to the letter. You watered consistently.
You provided ample light.

A problem may have escaped the eye. Maybe your pH deviated from the optimal range too often? Maybe your nutrients slipped out of balance, locking out essential elements and compromising plant nutrition? Maybe the water you used was too hard or too soft?

Wouldn't it be nice to have a safety net that provided your valuable crops with a secondary layer of protection—one that guarded against extreme pH, poor water quality, and other wild cards?

Well, there is such a safety net. It is woven of ions. This white paper unveils the mystery of ions and explains how chelation could make your next hydroponic harvest an amazing success.

Understanding ions

Ions are atoms or molecules that have an electrical charge. There are negative and positive ions. Positive ions have lost at least one electron. Negative ions have gained at least one electron. Both types of ions are important to all types of gardening, but especially to hydroponics (Table 1).

Positive ions (cations)		**Negative ions (anions)**	
Common name	**Formula**	**Common name**	**Formula**
Potassium	K (+)	Phophates	H2PO4 (-), HPO4 (2-)
Ammonium nitrogen	NH4 (+)	Nitrate nitrogen	NO3 (-)
Calcium	Ca (2+)	Sulfate	SO4 (2-)
Magnesium	Mg (2+)	Molybdate	MoO4 (2-)
Iron	Fe (2+), Fe (3+)	Borate	B(OH)4 (-)
Copper	Cu (2+)		
Zinc	Zn (2+)		
Cobalt	Co (2+)		
Manganese	Mn (2+)		

Table 1. Nutrients are either positive or negative ions.

Most ions are water soluble. For example, almost every chemical compound containing potassium, ammonium, or nitrate ions is readily soluble in water. This means that highly concentrated fertilizers containing only these ions will remain stable almost indefinitely. But these ions alone do not provide sufficient plant nutrition for proper growth and flowering.

Ions can cause precipitation, clogging, and nutrient lockout

Ions that are less water soluble have to be added in order to provide complete plant nutrition. These ions tend to form precipitates—solid participles undissolved in the nutrient solution—which can clog feed lines and lock out other nutrients from being absorbed by the plant roots.

Quality nutrient manufacturers who use only the best chelation avoid this problem by keeping challenging ions in separate bottles. Examples include two- or three-part base nutrients that are mixed together just before use. It is also why some manufacturers recommend using several separate products together. Such a nutrient program provides a more complete, balanced diet to your crops while avoiding precipitation and other problems that can occur from bottling incompatible elements together.

All this is based on pure chemistry. It also explains why all-in-one products that employ cheap chelation do not work very effectively. To avoid problems, troublesome ions have to be left out of these inexpensive fertilizers. However, your crops may need these ions too.

Take phosphate. The concentration of this mineral in solution is much higher than that of micronutrient ions. Thus micronutrients are locked out by phosphate

An ion is an atom or molecule with an unequal number of protons and electrons, giving it an electrical charge. A cation is an ion with more protons than electrons, resulting in a positive charge; an anion is an ion with more electrons than protons, resulting in a negative charge.

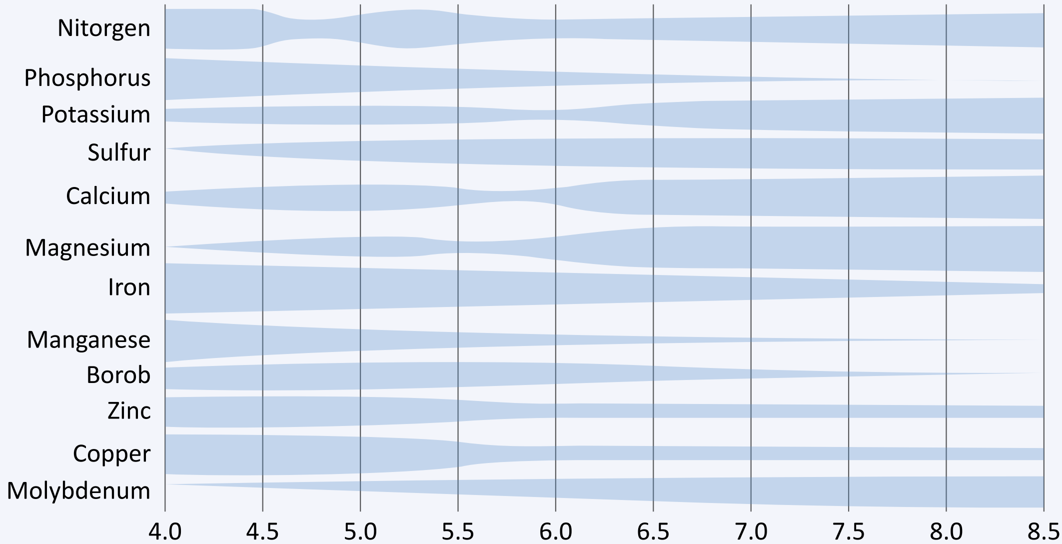


Figure 1 shows how pH affects the absorption of different nutrients. For example, magnesium prefers a slightly alkaline pH, while iron is better absorbed when the pH is more acidic.
The optimal pH range for your plants is therefore a compromise between the preferred pH absorption ranges of different nutrients.

and tend to fall out of solution as precipitate. When this happens, crops receive ample phosphate, but they lack micronutrients.

The risk of nutrient lockout increases if the pH drifts outside the optimal range. Every nutrient has a “favorite” or optimal range. For most plants the optimal range is pH 5.5–6.3, where all nutrients are sufficiently absorbed (Figure 1) and nutrient deficiencies will not be an issue.

If the pH falls too far above or below this “sweet spot,” certain nutrients may be preferred by plants over others. For instance, at pH 5, iron and manganese are readily absorbed while calcium and magnesium are not. Absorption of calcium and magnesium are significantly reduced at pH 5 and below; the plant roots cannot absorb them easily and the plant is highly likely to suffer calcium and magnesium deficiencies.

(Read our white paper on pH, the role pH plays in nutrient absorption, and how you can eliminate the need for tiresome pH monitoring and adjusting.)

What is chelation?

Chelation is a chemical process involving a special class of compounds called chelators. Chelators bind to positive ions, forming a protective shell around the host ion. The result is a new chemical compound with improved absorptive properties called a chelate (Figure 2).

The chemical bond between a chelator and a host ion is often so strong that it will extract the ion from a precipitate. This renders the ion soluble and readily available to plants as food.

Most soils contain natural chelators (Sussman, 1999). However, hydroponic growing media do not. Therefore, in hydroponics, chelators have to be provided to the growing medium.

What are natural chelators?

Chlorophyll is an example of a natural chelator (Figure 3). This miraculous enzyme used in photosynthesis is a magnesium chelate.

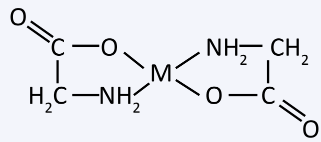
Many living organisms even export chelators into their environments. For example, plants and beneficial microbes produce chelators that free up valuable nutrients, making them available for absorption by the roots (Sussman, 1999). That is why adding microbial fertilizer supplements to mineral fertilizers is helpful: the microbes produce amino chelators, which speed up nutrient uptake.

So, when you want bigger yields, look for products rich in diverse chelators, such as those discussed in the next sections.

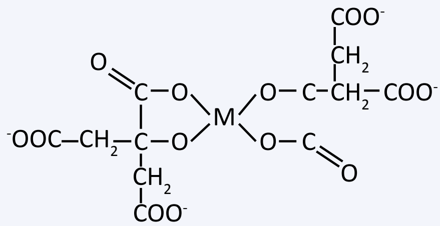
Amino acids

Amino acids are the proverbial building blocks of life, and every protein is composed of them.

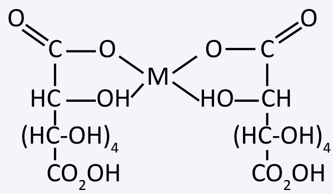
They are also chelators. Amino acids are not as strong as EDTA and other synthetic chelators (see “Synthetic



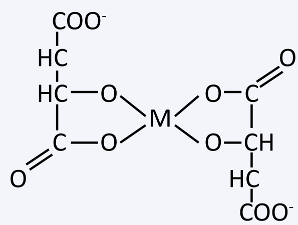
Glycine



Citrate



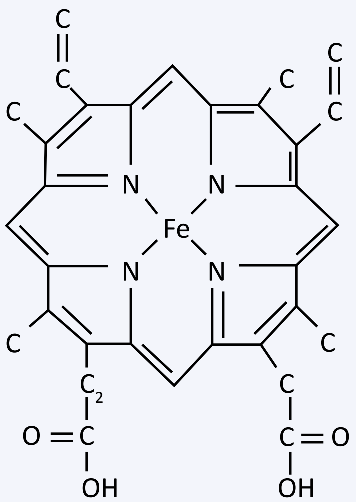
Gluconate



Tartrate

Figure 2: These are typical agrochemical chelates. The M in the center is a metal ion wrapped within one or more chelator molecules. The result is a chelate.

Heme
(Oxygen carrying portion of Hemoglobin)



Chlorophyll

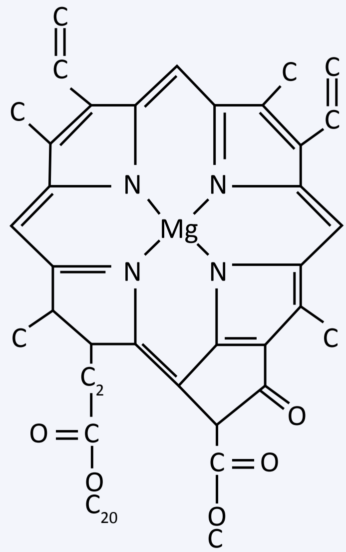


Figure 3. Nature sometimes uses sophisticated chelators. The chelating structures of hemoglobin in animals (left) and chlorophyll in plants (right) are similar. The former is an iron chelate; the latter is a magnesium chelate.

chelators" below), but they do have certain significant advantages.

For one, they are absorbed very readily by plant roots. So, when their job as chelators of nutrient ions in the growing medium is done, some of the amino acids are absorbed by plants and used as ready-made construction materials for building proteins.

Amino acids exist in two forms: D- and L-amino acids, which are mirror images of each other. Both are good chelators, but only L-aminos can be easily absorbed by the roots to build proteins and stimulate flowering. That's why only L-amino acids are recommended for use in fertilizers.

Amino acids can be purchased as ready-made mixtures, but the proportion of different aminos in the mixture is imprecise. Moreover, pure individual amino acids are indispensable, yet costly, when a very pure form of nutrient needs to be prepared.

For example, to provide pure iron amino chelate, individual aminos have to be used to achieve the desired purity of iron. This requires using pharmaceutical-grade amino acid chelates, which add to the cost of the product. Nevertheless, quality manufacturers do not hesitate to take this extra step to ensure their micronutrients are pure and free of toxic contaminants.

Quality amino fertilizers are therefore based on complex mixtures of amino acids extracted from natural sources by either chemical (acid) or microbiological (enzyme) treatment of proteins. Enzyme treatment is preferred, because in this way all the aminos are kept in their original L-forms, which deliver the full range of their beneficial effects to crops.

For example, amino acids such as L-Tryptophan and L-Arginine have been proven, in the right concentrations and quantities, to increase the size, weight, and girth of flowers and fruits (Mohamed and Khalil, 1992). However, obtaining aminos by acid treatment will break down L-Tryptophan, destroying its beneficial effects.

So, to recap, not only is the source of the amino acid important, but also the method by which it was derived and processed. For this reason, quality fertilizer manufacturers should always use amino acids that have been obtained by a gentle enzyme treatment of the source proteins.

Proteinates

Proteinates, mixtures of free amino acids with short pieces of proteins (peptides), also have chelating properties. In fact, plants synthesize their own special proteinates, which they use to transport valuable nutrients inside the plant (Van Der Zaal et al., 1999; Figueira et al., 2001). However, while proteinates are good chelators and plants can take them up, if a manufacturer wants its nutrients to be even more bioavailable, low Dalton weight amino acids, which are more easily and quickly absorbed by plant roots than proteinates, are preferred.

A combination of free amino acids and peptides applied to the roots is particularly useful since it can chelate and stabilize a wide range of nutrient ions. This type of chelator supplement is often used in foliar sprays (Ashmead et al., 1986). Micronutrients may also be added by foliar application, but not secondary nutrients, such as calcium and magnesium.

When looking for a good source of amino acids and proteinates, a quality fertilizer producer should avoid using proteins from genetically modified organisms. For example, proteins from genetically modified soybeans are too rich in a kind of sulfur-containing amino acid that differs from other aminos since it can form insoluble chelates with most micronutrient ions, making them unavailable to plants. Therefore, responsible fertilizer manufacturers use proteinates from non-genetically modified sources only.

Other organic acids

Other organic acids also provide the benefits of chelation. For example, succinic, citric, tartaric, and other non-amino organic acids can be used as chelators. Indeed, citric acid is particularly effective for chelating iron.

Plants synthesize these acids and export them into the growing medium or nutrient solution to catch nutrients (He and Loh, 2000). After being absorbed, these non-amino acids can be used by plants as ready-made food. So they have a double benefit.

Non-amino acids are cheap, plentiful, and widely applied in large-scale agriculture. However, in hydroponics, amino acids, which offer both chelators and protein building blocks, are preferred.

Humic acids, including fulvic acid

Humic acids, including fulvic acid, are somewhat different than simple organic acids. They are not produced by microbes, but rather by the natural decay of organic matter in soils.

In simplest terms, humic acids are associated with the physical characteristics of soil, and fulvic acid, a more refined subset of humic acids, is associated more closely with the plant's own biochemical reactions, which influence its metabolism.

—Konstantin Chakalov, PhD

However, fulvic acid and other humic acids are not extracted from soils, which need them to remain fertile. Instead, they are obtained from a particular coal called leonardite deposited millions of years ago.

This product is a complex mixture that behaves as a weak organic acid. Fulvic acid is more soluble and oxidized; other humic acids are only soluble when the pH is alkaline. They also have a larger molecular weight than fulvic acid and a darker color. However, all humic acids, whether soluble or not, possess excellent chelating properties.

The good news is that humic acids, particularly fulvic acid, are more than just chelators. Some of their molecules can penetrate the plant, where they exhibit hormone-like properties. Thus, humic and fulvic acids not only keep nutrients in solution (i.e., prevent precipitation), but they also increase plant growth and flowering potential. In other words, they produce bigger yields.

The bad news is that many coal deposits rich in humates are contaminated by toxic heavy metals. In soil, however, humic substances and high-molecular-weight organic matter can reduce the concentration of metal ions to non-toxic levels. Consequently, humic and fulvic acids in soil actually serve as an antidote to toxicity in plants (Jones and Darrah, 1994).

In hydroponics, by contrast, adding humics or fulvic acid contaminated by toxic heavy metals can make both plants and the people who consume them sick. This is why quality nutrient manufacturers always test their raw materials before they use them.

Azomite®

Azomite is a complex silica ore mined in Utah, USA (Azomite Mineral Products, Inc. website, 2012). It is widely used in both agriculture and health food additives. Azomite contains natural, ready-made chelates with pre-chelated micronutrients. It also contains 70 trace elements—including rare earth elements such as lanthanum, praseodymium, and cerium—which act as efficient natural promoters of floral initiation (He and Loh, 2000).

Metal ion	Formation constants log_{10}
Kr	
Fe^{3+}	25.10
Hg^{2+}	21.70
Cu^{2+}	18.80
Pb^{2+}	18.04
Zn^{2+}	16.50
Cd^{2+}	16.40
Al^{3+}	16.30
Fe^{2+}	14.32
Ca^{2+}	10.69
Mg^{2+}	8.79
Na^{+}	1.66
K^{+}	0.80

Table 2. The formation (stability) constant of different metal ions demonstrates that, e.g., zinc (Zn), a beneficial micronutrient, and cadmium (Cd), a toxic metal, are absorbed equally readily.

Boron and carbohydrates

Boron is crucially needed by plants for successful flowering. However, most chelators are helpless when confronting this nutrient.

When the pH is within the sweet spot of 5.5–6.3, less than 1/1000 of the boron in the growing medium exists as soluble borate ions. It is present mainly as boric acid, which has a strong affinity for carbohydrates and certain minerals. Consequently, the boron is absorbed by the growing media and withdrawn from the fertilizer, resulting in boron deficiency and weak or no flowering.

Fortunately, since boron binds strongly with soluble carbohydrates, adding carbs to the nutrient solution will chelate the boron and keep it in a highly available form (Thorp, 2011). Simple carbs also provide a ready-made food source for plants and beneficial microbes.

(Read our white paper on carbohydrates, the role carbohydrates play in flowering, and how best to apply carbs to your hydroponic garden.)

Synthetic chelators

Synthetic chelators are widely used in agriculture due to their availability. They are produced under tightly controlled conditions and tested for toxic metal ion contamination. Because so much is known about them, it is easy to calculate how much synthetic chelation is required to stabilize a nutrient solution.

EDTA (ethylene diamine tetraacetic acid) is the best known synthetic chelator. It binds strongly to numerous metal ions. An even more potent and versatile chelator is DTPA (diethylene triamine pentaacetic acid). All are widely used in fertilizers. And there are others.

Some growers consider synthetic chelators unsafe. However, EDTA and similar chelators have been safely used for decades in both fertilizers and human therapeutic treatments (NCCAM, NIH, 2012). Synthetic chelators are also commonly used to fight toxic contamination in soils (Grčman et al., 2001).

The myth about chelators and heavy metal toxicity

You may come across unreliable information about synthetic chelators. Uninformed authors may state that synthetic chelators stimulate root absorption of toxic metals, while natural chelators help plants absorb beneficial metals. The implication is that the use of synthetic chelators by nutrient manufacturers is poisoning plants and people.

Chemistry proves this wrong.

Every chelator binds different metal ions with different strengths. Table 2 lists the formation (stability) constant of various metal ions. Note that zinc, a micronutrient, and cadmium, a very toxic metal for both plants and humans, are almost equally chelated by EDTA.

Natural chelators work the same way. They boost the absorption of every metal ion they bind to. In other words, chelators, whether synthetic or natural, do not differentiate between good and bad heavy metal ions. Fortunately, beneficial micronutrients are far more abundant in fertilizers than toxic heavy metal ions, so plants absorb more micronutrients than poisons.

The important thing to remember is that chelators should be non-toxic in and of themselves as well as free from toxic metal contamination. By purchasing products only from quality nutrient manufacturers, you can rest assured that the chelators you are feeding your crops have been checked and tested.

Chelation and pH

Reliable chelation is also influenced by stable pH—which, in turn, helps to keep nutrients available to your plants.

Indeed, chelators themselves act as pH stabilizers. This is because they release hydrogen ions into the nutrient solution as a result of binding with ions. This action, in turn, helps keep the pH stable within the optimal range.

That said, numerous factors can affect the pH—and if, despite your best efforts, the pH of the growing medium veers outside the sweet spot, chelators will serve as a safety net, making nutrients more available than they would be otherwise, even at high or low levels of pH.

How chelators work for you

The main purpose of chelators in fertilizers is to build a strong buffer. They do this by stabilizing nutrient ion concentrations the same way that pH stabilizers keep the pH within the optimal range. The presence of different chelating agents, and their various affinities for different metal ions, improves the pH buffering capacity of your nutrient solution.

Remember the crucial word: diversity. Many, various chelators work together better than one chelator alone. Synthetic chelators, such as EDTA, DTPA, and EDDHA, and natural chelators, such as fulvic and humic acids, amino acids, and Azomite, when combined make for an excellent, flexible pH buffer ensuring uptake of a wide range of metal ions.

And they offer that safety net on top of it all.

Regulations can be misleading

Many countries forbid the use of more than one synthetic chelator in liquid fertilizers. Why? Apparently the rule was established to make it easier for some regulators to control fertilizers.

Look for nutrients that offer a range of chelating compounds, so that nutrients will be available through a wide range of conditions, including those above or below the optimal.

— Erik Biksa

It is easier and cheaper to determine the presence of one chelator in a batch of fertilizer than to measure the concentration of several similar chelators. The regulation has nothing to do with the health of your plants. In fact, as stated earlier, a combination of different chelators works best.

In order to avoid coming into conflict with the one-chelator rule of certain countries, nutrient manufacturers put different chelators in different products. That is yet another reason why manufacturers of high-quality nutrients recommend using several products together in order to get the best results.

In some countries, you will not find certain chelators listed on a label, even though they are in the product. Fulvic acid chelate is one example. The reason it cannot be listed is cost. There is no inexpensive way of discriminating between humic acids. To avoid the problem of analyzing long-chain humic acids and fulvic acid separately, only "humic acids" are listed on the label.

Regulators are supposed to protect you against false claims, and they often do a good job of it. But sometimes the regulations meant to protect you create needless complications and expense for both nutrient manufacturers and growers.

Advanced Nutrients uses the science of chelation to create better products

To provide you with a hassle-free way of controlling pH and give your plants the smorgasbord of natural and synthetic chelators they need, Advanced Nutrients has developed pH Perfect® base nutrients. This nutrient breakthrough supplies a broad spectrum of chelators that work together with other pH stabilizers and buffers to create a pH-stable, nutrient-rich growing environment.

The chelators used in pH Perfect Grow, Micro, Bloom; pH Perfect Sensi Grow and Bloom; and pH Perfect Connoisseur include the highest-quality synthetic chelators available complemented by natural chelators, such as long-chain humic acids and fulvic acid, and a wide spectrum of amino acids derived and processed from proteins by enzyme treatment. What's more, Advanced Nutrients base nutrients and supplements contain raw materials from non-genetically modified sources only.

When pH Perfect base nutrients are used in tandem with Advanced Nutrients Bigger Yields Flowering System®, the result is a comprehensive feeding program with a well-designed and formulated chelation safety net. The program enhances root size and nutrient absorption, protects plants from pests and diseases, speeds growth rates, and increases harvest size and quality.

* * *

To learn more about the superior chelation in pH Perfect base nutrients, call Advanced Nutrients Tech Support at 1-800-640-9605 or visit the pH Perfect landing page.

Read more white papers and special reports on the Hydroponics Research website at www.hydroponicsresearch.eu.

Share this white paper now with friends, coworkers, and family.

References

Ashmead, H.D. et al., 1986. *Foliar Feeding of Plants with Amino Acid Chelates*. Park Ridge: Noyes Publications.

Azomite Mineral Products, Inc. website, 2012. FAQ, (online) Available at: <http://www.azomite.com/index.php?option=com_content&view=article&id=60&Itemid=53> [Accessed 26 June 2012].

Figueira A. et al., 2001. Identifying sugarcane expressed sequences associated with nutrient transporters and peptide metal chelators. *Genetic Molecular Biology*, 24 (1–4), pp. 200–20.

Grčman, H. et al., 2001. EDTA enhanced heavy metal phytoextraction: metal accumulation, leaching and toxicity. *Plant and Soil*, 235 (1), pp. 105–14.

He, Y. and Loh, C., 2000. Cerium and lanthanum promote floral initiation and reproductive growth of *Arabidopsis thaliana*. *Plant Science*, 159 (1), pp. 117–24.

Jones, D.L. and Darrah, P.R., 1994. Role of root derived organic acids in the mobilization of nutrients from the rhizosphere. *Plant and Soil*, 166 (2), pp. 247–57.

National Center for Complementary and Alternative Medicine (NCCAM), National Institutes of Health (NIH), 2012. Questions and answers: the NIH trial of EDTA chelation therapy for coronary artery disease. National Institutes of Health, (online) Available at: <http://nccam.nih.gov/health/chelation> [Accessed 30 March 2012].

Mohamed, S. M., and Khalil, M. M., 1992. Effect of tryptophan and arginine on growth and flowering of some winter annuals. *Egyptian Journal of Applied Sciences*, 7 (10), pp. 82-93.

Sussman, M.R., 1999. Pumping iron. *Nature Biotechnology*, 17 (3), pp. 230–231.

Thorp, T.G. et al., 2011. Is boron transport to avocado flowers regulated by carbohydrate supply? *VII World Avocado Congress*, (online) Available at: <http://www.worldavocadocongress2011.com/userfiles/file/Grant%20Thorp%200920-0940.pdf> [Accessed 30 March 2012].

Van der Zaal, B.J. et al., 1999. Overexpression of a novel *Arabidopsis* gene related to putative zinc-transporter genes from animals can lead to enhanced zinc resistance and accumulation, *Plant Physiology*, 119 (3), pp. 1047–55.