A Description of Amino Acid Chelate Fertilisers and Their Mode of Action

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Amino acid chelate fertilisers were first developed by American chemists seeking to improve nutrient delivery to plants.

Minor elements are just as important to plants as the major elements (N-P-K) and rigorous field trials have demonstrated the outstanding performance of amino acid chelates on crop yield and quality.

This document gives a brief overview of the science and technology behind amino acid chelate fertilisers and illustrates why they are able to deliver minor elements to plants so effectively.

Structure of Amino Acid Chelates

Amino acid chelate fertilisers are formed by chelating (i.e. binding) a nutritional element required by a plant (e.g. calcium) with one or more amino acids to form a new molecule that is readily accepted by plants and delivers the nutrient with high efficiency.

There are twenty two naturally occurring amino acids, and they are defined by a certain structure containing nitrogen, oxygen, carbon and hydrogen. They are the basic "building blocks" of proteins and are present in all living things. Figure 1 below shows the simplest amino acid, glycine.

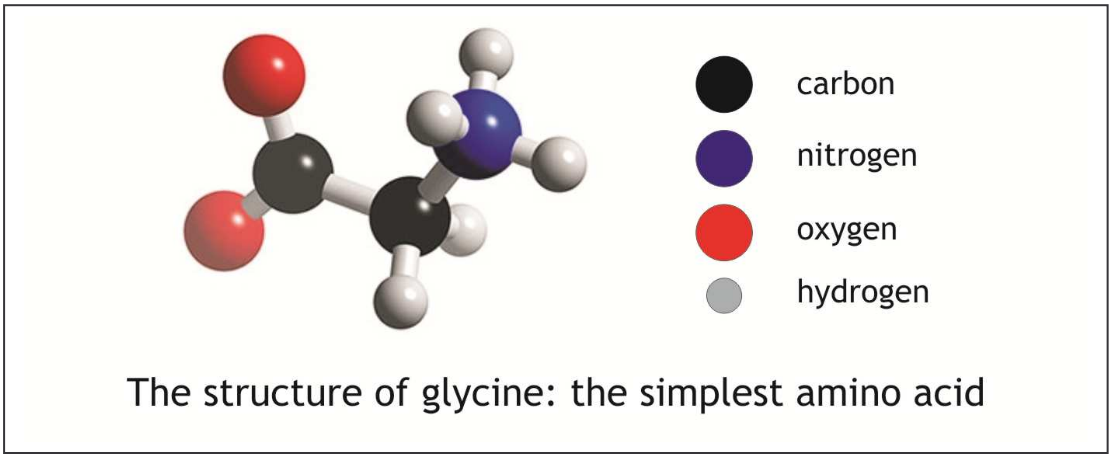


Figure 1

Figure 2 shows an atom of magnesium that has been chelated with two molecules of glycine.

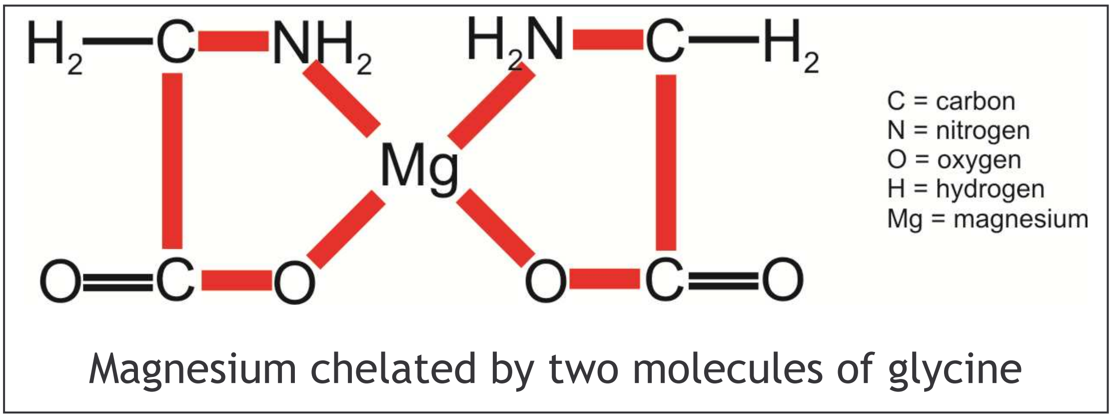


Figure 2

The red lines indicate chemical bonds and it can be seen that two "ring" structures are formed, with magnesium at the center. Note that the magnesium atom is held by four chemical bonds: this is one of the keys to the success of amino acid chelates.
The magnesium ion has two positive charges, and each glycine molecule has a negative charge, and so two ionic (electrically charged) bonds form between them.

However, the nitrogen atom of each amino acid also shares a pair of electrons with the magnesium to form two new *co-ordinate covalent bonds*.

These four bonds together chelate the magnesium and bind it more tightly than two ionic bonds alone: tightly enough that it can overcome many physical and chemical barriers within a plant before arriving at the cell interior where it is needed. If only two ionic bonds are present, they are called salts *or* complexes*, not chelates.*

Figure 2 shows magnesium chelated with two molecules of amino acids, however anywhere between 1 and 4 amino acid molecules may be used (at least 1 is required to be called an amino acid chelate).

A convenient way to represent amino acid chelates graphically is shown in figure 3.

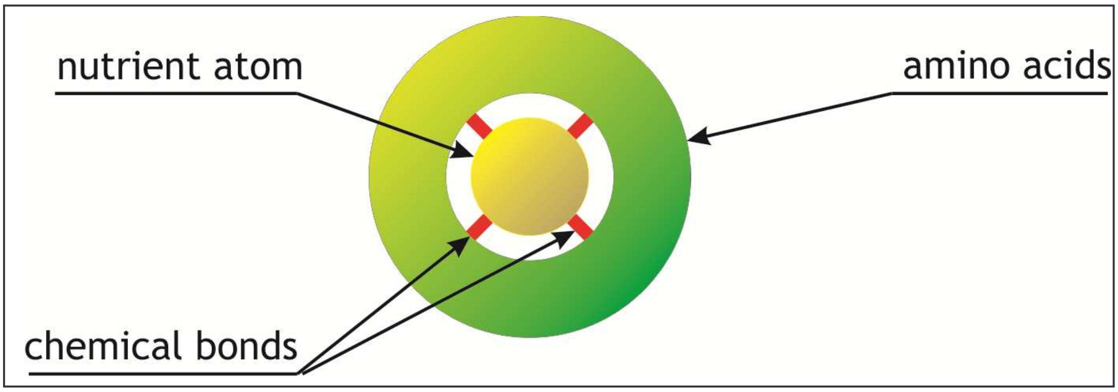


Figure 3.

Minor Element Fertilisation

Before a nutritional element can be used by a plant, it must pass many physical and chemical barriers and be transported to the inside of a plant cell.

Mineral Fertilisers Applied to Soil

Attempts to correct or prevent minor element deficiencies by applying minerals directly to the soil are often unsuccessful. When mineral fertilisers are applied to the soil, large fractions of the minor elements (sometimes almost the entirety) are unavailable for use by the target plant. Often this is due to: poor solubility caused by soil pH, leaching by water, mineral-mineral interactions, consumption by soil micro organisms etc. Even when the mineral is available, it is often released to the plant slowly and unable to correct acute shortages. Mineral that is unavailable to the plant represents a waste of money and potential pollution of the soil and groundwater.

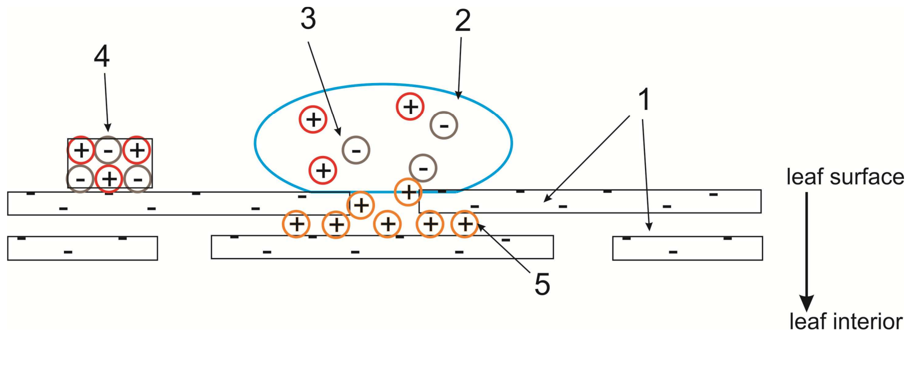
Applying Amino Acid Chelate Fertilisers to Foliage

Applying minor elements to foliage rather than the soil is a possible alternative since plants can absorb very efficiently through leaves. To be useful however, foliar fertilisers must be of a type that can deliver the nutrients with a high degree of efficiency and a low risk of phytotoxicity.
Foliar fertilisers must also pass physical and chemical barriers before becoming usable by a plant and amino acid chelates pass these barriers with a very high degree of efficiency.

The first barrier to be passed by a foliar fertiliser is solubility. Any foliar fertiliser must be water soluble: any solids that form simply coat the leaf and are unusable by plants. Modern Plant Nutrition chelates are water based and completely soluble*.

The next barrier to be passed is the cuticle of the leaf: a waxy layer made of fatty acids. The cuticle exists on both the upper and lower surfaces of the leaves, and even inside the stomatal crypts (cavities): this barrier must be passed by all foliar fertilisers. The most important quality required of a nutrient molecule here is electrical neutrality. Fatty acids possess negative electrical charges that will attract positively charged species.
Take for example a foliar application of an iron sulphate solution. When added to water, solid iron sulphate immediately dissolves and breaks up into positively charged iron and negatively charged sulphate components (an ionic solution). When applied to the surface of a leaf, the positively charged iron is immediately susceptible to binding by the negatively charged fatty acid components: the element is no longer available for use by the plant. Furthermore, the accumulation of high levels of charged species in the leaf can be phytotoxic, causing burn.

* Agribuff ™ water conditioner must be used to prevent dissolved materials that are present in many water sources from precipitating the chelates.

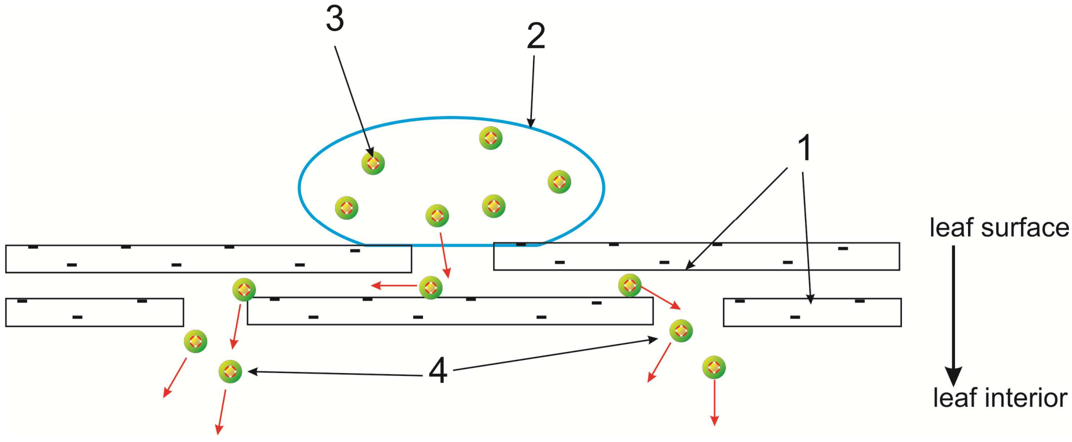


Traditional Mineral Fertiliser Applied to Leaves

1. Cuticle layer of leaf with negatively charged fatty acids
2. Water droplet containing ionic solution of mineral
3. Free, electrically charged ions (+ = nutrient, - = counterion e.g. sulphate)
4. Undissolved mineral not available to plant
5. Postitively charged mineral bound to fatty acids: unavailable for plant use

Figure 4.

Amino acid chelates, however, do not break up: the molecule remains intact and electrically neutral, allowing it to pass this barrier with minimal interference. This is illustrated in figure 4 and figure 5. Because the chelate molecule does not break up and become charged, the risk of phytotoxicity is low.



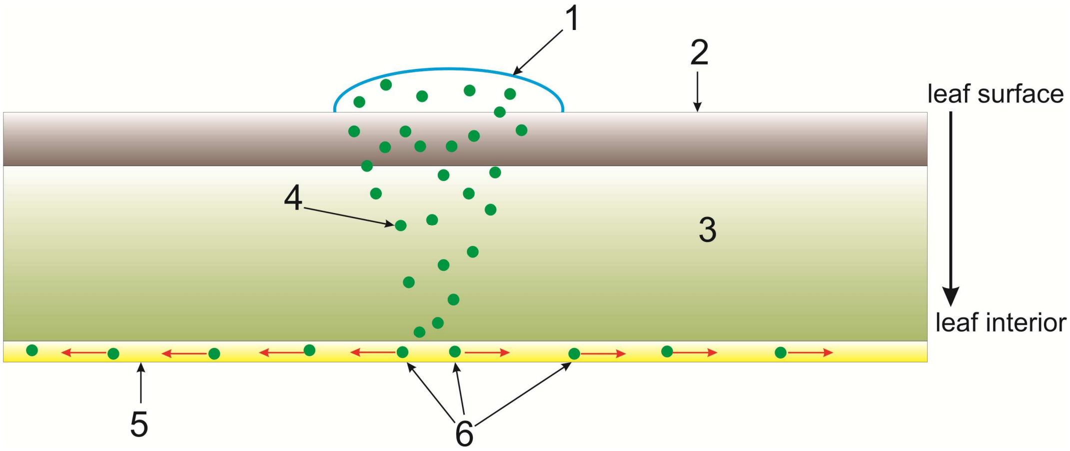
Amino Acid Chelates Applied to Leaves

1. Cuticle layer of leaf with negatively charged fatty acids
2. Water droplet containing dissolved chelate
3. Electrically neutral amino acid chelate
4. Electrically neutral amino acid chelate, relatively unaffected by the charged environment, rapidly penetrates into the leaf

Figure 5

After passing through the cuticle, the amino acid chelate must penetrate a complex environment of cells and intercellular spaces. Of importance here is molecular size. Generally speaking, the smaller the molecule, the more easily it diffuses through this environment and penetrates the leaf. Modern Plant Nutrition uses glycine as a chelating agent: it is the lightest amino acid and rapidly penetrates the leaf. Studies have shown that within 2-3 hours after application, essentially all the amino acid chelate has penetrated the leaf.

While diffusing through the leaf, the amino acid chelate may be absorbed and used by cells in the leaf, or it may reach the phloem: a vascular system used by plants to transport photosynthesates and other high value materials to parts of the plant most in need: typically fast growing regions such as new leaves, flowers, fruit etc. Once the amino acid chelate has reached the phloem, the nitrogen component of the amino acid is recognised and the molecule is then considered by the plant to be high-value: it is then transported through the phloem to those rapidly growing parts of the plant where it is most needed. (This was determined by tests where the carbon in the amino acid was replaced with a radioactive isotope and a geiger counter used to monitor the transport of the chelate through the plant). This means that amino acid chelates are very mobile in plants and transported to where they are most needed (figure 6).



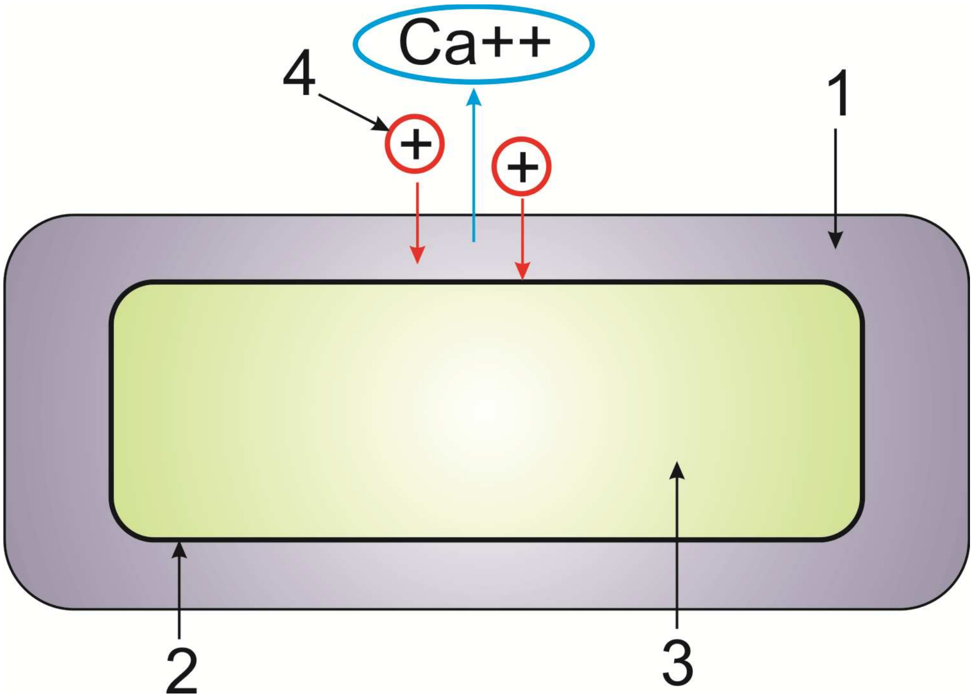
Penetration of Amino Acid Chelates Through Leaf and Phloem

1. Water droplet containing dissolved chelate
2. Cuticle
3. Interior of leaf
4. Small molecular size and electrical neutrality allow amino acid chelates to rapidly penetrate the leaf interior
5. Phloem
6. Amino acid chelates that reach the phloem are recognised as a source of organic nitrogen and translocated to growing plant tissues

Figure 6

The mobility of amino acid chelates in plants is an extremely important advantage when applying certain elements. Take calcium for example: soils usually have an abundance of calcium, but calcium is stored in leaves in a form that has very low mobility, so that deficiency is common in rapidly growing tissues (even in spite of leaf analysis indicating sufficient calcium). This is due in part because the calcium ion (Ca^{++}) is not transported via the phloem. Calcium chelated with amino acids, however, is transported by the phloem and reaches those tissues that need it.

Once the mineral has reached a cell, it must be able to overcome further barriers before it can be used. First, the cell wall must be passed. Plant cell walls are made of complex fibrous structures and binding materials. Charged (ionic) forms of nutritional elements displace calcium present in the cell wall and become bound and unavailable (figure 7). Because they are small and electrically neutral, amino acid chelates diffuse through the cell wall with little resistance.



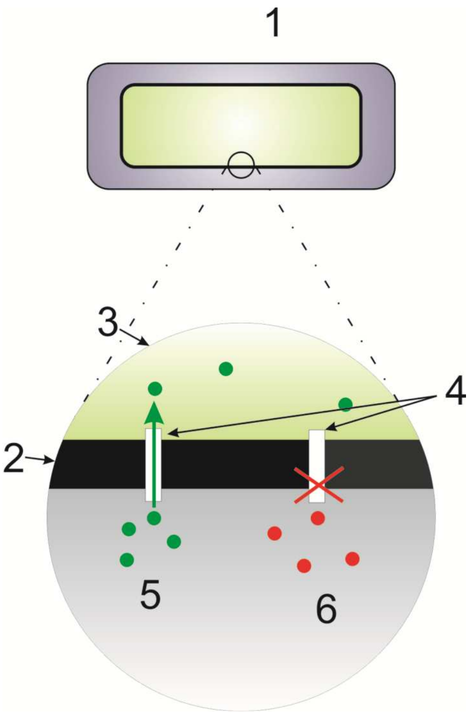
Non-Chelated Minerals Can Damage the Cell Walls of Plants

1. Cell wall
2. Cell membrane
3. Cell interior
4. Non-chelated minerals can displace calcium from the cell walls, with potential phytotoxic results

Figure 7

After penetrating the cell wall, the mineral must pass the cell membrane before finally entering the interior of the cell. Cell membranes are lipid (fatty) bi-layers containing complex protein structures, some of which are used to transport nutrients into the cells. Amino acid chelates are recognised by some of these transport structures as a source of valuable organic nitrogen and are rapidly transported into the interior of the cell. These transport structures do not recognise synthetic chelating agents such as EDTA and will not transport them to the interior of the cell (Figure 8). Instead, EDTA must first give up its nutrient by “swapping” it for a calcium ion: this depletes calcium and can lead to phytotoxicity (figure 7).

Once inside the plant cell, enzymes finally break down the chelate where the mineral is now freed for use.



Synthetic Chelating Agents are Not Transported Across the Cell Membrane

1. Plant cell
2. Cell membrane
3. Interior of cell
4. Cell membrane transporters
5. Amino acid chelates are recognised and transported to the interior of the cell
6. Synthetic chelates are not transported into the cell interior

Figure 8