The Biochemical Sequence of Plant Nutrition

by Hugh Lovel

Back in 1994 at an Eco-Fair event I had lunch with one of America's top soil consultants, who was lecturing about the key importance of calcium in the early stages of fruit development, when cell division occurs. His metaphor was that an apple not much bigger than a prune had virtually all the calcium content it would ever have. He tested soils for calcium and applied it as needed, but unfortunately this did not guarantee that sufficient calcium got into the apple.

When I asked him what he did in regard to boron, which was responsible for sap pressure, he responded, "Of course, boron is necessary for calcium uptake, and we test for it. If it is needed we put it there, but we still can't guarantee that calcium gets in the apple."

Then I asked what he did about silicon, the basis of transport in both plants and animals. His response was, "We don't test for silicon. It's in all soils, whether sand or clay."

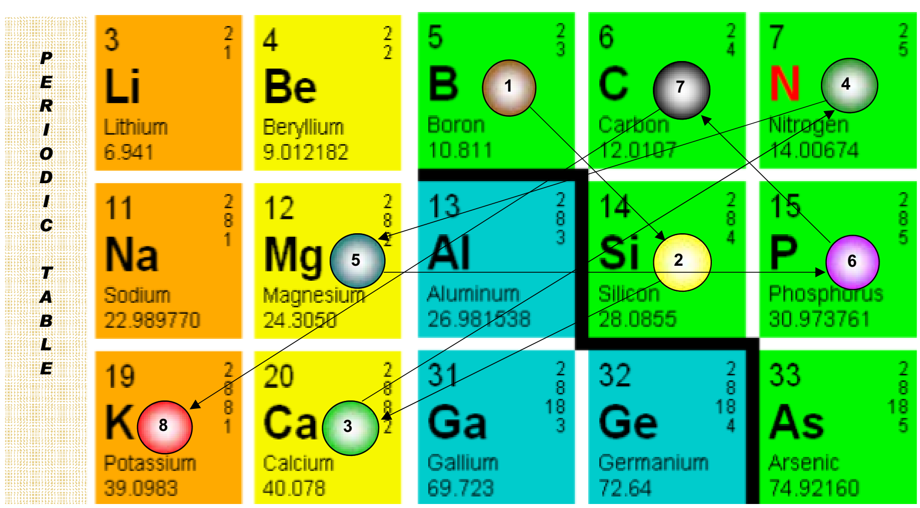
Until then it hadn't sunk home that although I was used to looking for visual signs of silicon in plants, I hadn't actually seen any soil or leaf tests that included it. This got me wondering, and as I investigated I found, almost uniformly, soil and leaf testing labs did not test for silicon unless it was specifically requested.

As a biodynamic grower, I knew that Rudolf Steiner, with a doctorate in math, chemistry and biology, identified the oxides of calcium and silicon, lime and silica, as the opposite poles of life chemistry. I'd used this concept for years and years, along with Jochen Bockemühl's leaf studies from his book *In Partnership with Nature* and Johann Wolfgang von Goethe's treatise *The Metamorphosis of Plants* as guides. Looking further, I found that in the early days of agricultural chemistry Justus von Liebig tested both soils and plants for silicon, found it in all cases, was unable to prove it was an essential nutrient by excluding it from plant media, and thereafter dropped it from his tests. This became the norm for agricultural testing.

The soil consultant, with his riddle of getting calcium into early fruit development, started me thinking about possible connections. I began to realize there was an obvious hierarchy of how elements worked in living organisms. One thing had to occur before the next thing could happen, and so on down the line in a sequence. Eventually I developed my theory of this hierarchy of elements, calling it the Biochemical Sequence.

Boron kicks off the biochemical sequence by activating silicon, making it an amorphous fluid and providing sap pressure. I knew that boron is used in making glass, which is amorphous fluid silica, and I'd found this relationship also held true for plant chemistry.

Biochemical Sequence of Nutrition in Plants



Plant Biochemical Sequences begin with:

1. **Boron,** which activates →
2. **Silicon,** which carries all other nutrients starting with →
3. **Calcium,** which binds →
4. **Nitrogen** to form amino acids, DNA and cell division. Amino acids form proteins such as chlorophyll and tag trace elements, especially →
5. **Magnesium,** which transfers energy via →
6. **Phosphorus** to →
7. **Carbon** to form sugars, which go where →
8. **Potassium** carries them.

This is the basis of plant growth.

Of course, sap pressure would be of no use without a transport system to contain it, and silicon provides the actual transport of nutrients. Interestingly, applying too much boron too early in a crop cycle is notable for burning seedlings and young transplants — such as sprouting squash or beans — because too much sap pressure in such a tiny plant drives sodium out the leaf margins. Nevertheless, in plants where leaf veins are highly branched, such as flowering beans, squash and tomatoes, boron is important in later growth to maintain strong enough sap pressure to make such a complex system work.

On the other hand, highly siliceous plants, such as grasses, need less boron to give them sap pressure since their transport vessels all run parallel without branching. That's like a system of irrigation lines that only feed one sprinkler head — it doesn't take much pressure. An exception is bananas, which have a huge transport system with lots of fluid flow. They need plenty of boron to send calcium and amino acids all the way to the top of the bell stalk for cell division to occur in the bunch.

Without robust transport, nowhere near as much nutrient reaches the leaves or is stored in the fruit. Chemical agriculture gets around this problem to some extent, since even with a weak transport system, anything that is highly soluble, such as potassium nitrate, is simply taken up along with water. Although nutrients are diluted, the sap flows quite easily despite low density. This is why chemically grown foods commonly have coarse, watery cell structure, as well as lower nutrition and poorer keeping quality. However, without a robust transport system, heavier nutrients such as calcium, magnesium, complex carbohydrates and amino acids can easily be left behind.

Third in the biochemical sequence is calcium. This is the last thing you want to leave behind because of its role in nitrogen fixation and amino acid chemistry. Calcium balances the electrical charges in protein chemistry and is particularly important in cell division, which is the first thing that happens in fruit or seed formation after pollination. Without it there would be no fruit or seed.

An ear of sweet corn with optimum boron, silicon, calcium and amino acid nitrogen.

For example, in corn, calcium leaf test targets are between 0.3 and 1 percent, increasing as the corn approaches tasseling with the higher target range more desirable near kernel formation. If calcium does not reach the ear in sufficient quantities, the kernels near the end of the ear simply do not fill out. With a crop such as soybeans, double or even triple the calcium values of maize are needed for full pod set without shedding pods — a common problem in soybeans. Wouldn't you like to see every kernel on your corn fill out to the end of the ear, or every soybean blossom produce a pod of beans? This only happens when boron, silicon and calcium work together optimally.

As just mentioned, wherever calcium goes, there also goes nitrogen, which is the basis of amino acid formation, protein chemistry and DNA replication. Once nitrogen enters the picture all sorts of proteins, enzymes and hormones are produced, and very complex things are set in motion involving trace elements such as iron, zinc, copper, manganese, cobalt, molybdenum and so on.

Above all there must be energy harvest or plants would never grow. Although all parts of a plant's protein chemistry require amino acid nitrogen, large amounts of amino acids go into the formation of chlorophyll where energy is gathered. Since photosynthesis requires magnesium, it is fifth in the biochemical sequence, ahead of all the minor trace elements. Of course, photosynthesis is not simply a matter of chlorophyll catching energy. The energy has to be transferred into the production of sugars out of carbon dioxide and water, which requires phosphorus for energy transfer. Otherwise the chlorophyll burns up, and the leaves turn a wine-red color.

As long as there is enough phosphorous, however, carbon is pried loose from carbon dioxide so it can combine with water to make sugar and release oxygen. Then the sugars pass into the plant's sap, where potassium, the electrolyte, conducts them to wherever they most need to go.

Understandably, this sequence is oversimplified. For example, sulfur is

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the classic catalyst in carbon (organic) chemistry. Without it, nothing — not even the boron — would work. Also, potassium has a very close relationship with silicon, so when silicon carries calcium and amino acids to cell division sites in the plant, potassium plays the role of an electronic doorway that lets the calcium and amino acids enter the cells that are preparing to divide. If cold weather slows potassium down, or if it is in short supply, then calcium and amino acids cannot reach the cell nuclei, the DNA cannot divide, cell division fails, and the fruit falls off the plant. Sometimes entire fruit crops are lost to a couple degrees of frost when a light spray of kelp with potassium silicate would save the day.

Nevertheless, the most important thing to understand is the role of boron, silicon and calcium in the hierarchy of plant chemistry. Growers who simply feed plants nitrogen, phosphorus and potassium (NPK) tend to short-circuit the biological processes where strong sap pressure (boron) leads to good nutrient transport (silicon). Then optimal cell division and photosynthesis can occur (calcium, nitrogen, magnesium and phosphorus).

With high plant energy (carbon and potassium), plants are able to shed enough of their sap as root exudates to feed abundant microbial mineral release, nitrogen fixation and protozoal digestion around crop roots. Then crops enjoy rich nutrition and are truly healthy. This only works where boron, silicon, calcium and amino acid nitrogen from steady microbial fixation and digestion are all high. If calcium and amino acids are watered down with nitrate and potassium salts, then sap pressure is impaired, cell division is hampered, photosynthesis is weaker, magnesium and phosphorus are diluted, and we're where NPK growers are today.

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