THE IMPORTANCE OF SILICON

Interview with Prof. Dirk Van Den Berghe

Silicon: The Missing Element

While the importance of (Si) in agriculture is poorly accepted, it will be when the consequences of adding (Si) to the soil are properly understood! In the past everyone thought that Si was not needed except as an ordinary constituent of the soil. Now it is slowly being accepted as an important beneficial element inside plants for their proper functioning.

Silicon (Si) is the second most abundant element on the surface of the earth and surrounds us in the form of sand, building bricks, glass etc. It is present everywhere in the soil and water. Through acidification by carbonic acid and organic acids produced by soil micro-organisms and plant roots, Silicates present in the soil are slowly attacked to liberate **OSA** (Ortho**-**Silicic Acid) - $Si(OH)_4$. OSA is soluble in water and is usually present in the soil in very low concentrations. Silicic acid consists of a very small molecule and is biologically active only in the form of OSA. This is taken up by plants in very low concentrations but at concentrations that have a very important effect on plant growth (and animal health). Living organisms need OSA, not silicates.

Silicon Cycle versus Carbon Cycle

The Silicon Cycle is directly related to the much better understood Carbon Cycle. Without (Si) there can be no life. Silicon dependent organisms such as Diatoms and Silicon flagellates that populate the upper surface of the Oceans account for more than 50% of the earth's organic carbon fixing.

The Silicon Cycle is directly related to the Carbon Cycle and the mean element is OSA. Diatoms use it to make their hard protective exoskeltons. When they die they sink to the bottom and slowly decompose, ultimately forming a type of diatomaceous sediment. This sediment is slowly dissolved by acid to release low concentrations of OSA which rise back to the surface of the oceans. Alternatively Diatoms are eaten by other organisms and Si enters the food chain. Diatoms represent one of the first organisms to exist on the Earth and many scientists are now studying the Silicon Cycle. If you compare seas teeming with life (e.g Baring) you will find high levels of OSA as opposed to very low OSA levels in the more impoverished seas (e.g. Baltic).

Silicon is in the front line in the evolution of life; Silicic acid polymers are compatibile with all types of molecules from sugars to proteins to DNA and RNA, fats, membrane structures and macro-molecules. The first proteins were created with the help of Silicic acid polymers. In animals and human beings Si is fundamental in the synthesis of connective tissues where it has an essentially protective function.

Today, Silicon can be described as 'an element essential for survival'. It protects DNA and privileges reproductive tissues. In the case of humans, the Si content of the pregnant mother is very low because it is all passing to the growing foetus. The highest OSA concentration in plants is

observed in seeds and OSA contributes significantly to seed production and to the viability of the seed and thus to improved germination.

All Plants Need Silicon

Plants have been classified according to their ability to accumulate OSA. Monocotyledenous plants such as sugarcane accumulate Si strongly. It is interesting to note that plants that obtain greatest benefit from accumulated Si are agricultural crops that have survived through the ages to feed the entire world (grain crops, maize). This phenomenon is also witnesed in a variety of Dicotyledenous plants such as *Equisetum* and *Urtica* which are little affected by insect pests because of the tougher leaf surfaces. OSA is also very important to *Citrus* plants. Other plants such as tomatoes (classified as non Si accumulators) still grow much better with OSA. Plants are strengthened and demonstrate more uniform better growth and yield, and the skin of the fruit is stronger. Almost all plants are able to accumulate OSA – but in different ways.

OSA appears to have an important regulating function in the uptake by the plant of other important minerals. In the cultivation of Rice, researchers in Japan demonstrated that in the presence of OSA, the uptake of phosphates by plants growing in a high phosphate soil was reduced, while the uptake of phosphates was proportionally greater in soils with low phosphate levels. This leads us to believe that there is some form of regulatory mechanism at work, orchestrated by OSA.

Macro Effects of Silicon on Plants

The most evident effects of OSA can be seen in the reinforcing of plant tissue. OSA polymers accumulate in the cuticle and epidermis of the leaf. This strengthening of the leaf restricts penetration of fungal hyphae and makes it more difficult for insect pests that feed on the lymph. Fungal spores are everywhere in the air and on dust particles, they always have been. But today's agricultural crops are more susceptible to fungal infection (and death as a result) because the balance between pathogen and host has been weakened through the regular use of fungicides and other chemicals. This was one of the first major observations of Prof. Van Den Berghe ten years ago. When OSA was applied to roses, a more positive effect was seen in growth and development in comparison to a number of fertilizers.

OSA polymers strengthen the cell walls of plants and are deposited in the extracellular matrix. The 'siliconization' of the cells that make up the xylem (vascular tissue) is particularly important. It ensures that the vascular tissue that conducts water and minerals throughout the plant, is strengthened and less subject to collapse. A stronger vascular system results in a better more even distribution of water and minerals throughout the plant. Plants try to keep their mineral content complete and stable; if there is adequate Calcium in the soil, relatively more Calcium will be taken up by the plant. OSA helps regulate this. Together with Si accumulation in leaf tissue, the overall effect of OSA is to give the plant more control over transpiration and water capacity and thus greater resistance to conditions of stress.

A similar reinforcing action of OSA in humans and animals concerns *connective tissues*. After a very short time taking pharmaceutical quality OSA + Boron, patients with arthritis have less pain are are more mobile.

Growth Regulation

Plants with adequate OSA grow more naturally and more compact. Flower and fruit production tends to be slightly delayed but with the benefits of fuller flowering and higher levels of sugar in the fruit. There are many specific benefits of using OSA is agricultural and horticultural production.

To some extent OSA alters the water cycle and the plant cannot grow soft and lanky. An overdose of OSA on *Ribes* and *Lilac* has been found to stop growth completely. In some cases an overdose will burn the leaves but in all cases the plant is not killed and the later regenerated growth is exceptionally strong and healthy. It seems that the OSA accumulates somewhere in the roots for use in the subsequent juvenile growth.

Metabolic Effects

Recent work in Japan demonstrated the existance of a protein molecule in Rice that actively transports OSA across the cell wall, so the entry of OSA into cells is not just by diffusion. This again proves the importance of Silicon to plants. There are enzyme systems influenced by OSA but the process is not yet fully understood.

There is a very big attraction between Si and Boron (OSAB = OSA + Boron). Boron also effects other elements such as Potassium and some enzymic reactions in plants and animals.

OSA appears to have an inhibitory effect on the production of ethylene in plant tissues. Researchers in Poland observed that *Chrysanthemum* plants grew normally at low OSA concentrations. At higher concentrations plants produced more flowerbuds. Flowering was delayed but the flowers were stronger. Fundamentally, growth is slower and more natural with OSA. Plants are stronger, more compact and are living more economically.

OSA has an effect on the production of anthocyanin pigments that indicates some involvement in the ripening/colouring of fruit. In Morocco Citrus fruit stays yellow due to poor saline soils. In a trial application, after OSA was applied the fruit turned orange.

The production of polyphenolic substances when plant tissue is cut or damaged is always associated with the presence of OSA. Polyphenolic substances have antisceptic properties.

The Great Food Issue

In the USSR the mineral and vitamin content of vegetables has been measured at regular intervals over the last century. Over the whole period of measurement up to the year 2000, the mineral and vitamin content of the varieties in question had dropped by a up to 90%. Results in the USA between 1963 and 2002 showed a drop of 40% in the varieties being monitored. It is impossible for us to compensate by eating the extra quantity of vegetables and fruit necessary to obtain the same quantity of minerals and vitamins as before!

The mineral and vitamin content of vegetables has significantly fallen over the last century by putting plants in a stressful situation by applying fertilizers, fungicides and pesticides and telling them 'grow-grow-grow'; always faster, to look greener and more beautiful, more uniform and of good size. Little or no atttention has been applied to looking at what is happening inside the plants, at their nutritional content and chemical residues. We are now producing totally artificial plants through artificial methods of cultivation.

The effect of lower vitamen and mineral content in vegetables has a negative effect on health. It is known that a serious under-estimate has been made on the quantities of vitamins that humans require for good health. This lack is not being adequately compensated for through vitamin supplements.

Toxic Residues

Agriculture and horticulture are producing vegetables contaminated by residues and pesticides which have a tremendous effect on our health by accumulation and combination. We have laws that limit the maximum concentration of individual chemicals in agricultural products but no understanding of or legislation concerning the maximum permitted concentrations of the compounds created by their chemical interaction. So to respect existing legislation in France, grapevines are being sprayed with many different chemicals with the result that there are many times more fungicides and pesticides in the table grapes we eat without even considering the products created through chemical interactions. We are creating amphi-boxes of chemical substances that have a tremendous effect on the health of humans and animals.

Contaminated Soils

Agriculture and horticulture are creating a completely unnatural soil-water environment contaminated by chemicals. Most natural Calcium sources used in agriculture are contaminated by Lead which then enters the whole food chain. It is possible to have the Lead removed (for food supplements etc.) but the purification process is costly. In general Calcium availability from vegetables has been progressively declining.

The natural presence of Bacteria in soils aids soil fertility and acts in symbiosis with plant roots. The presence bacteria in the soil has greatly declined because most bacteriocides and fungicides applied to the soil are not selective and also kill the good micro-organisms.

A low concentration of OSA in the soil is essential. In this form it can be taken up by the plant with the water and other minerals. But in the agricultural soils of today we have fertilizers, fungicides, pesticides and other compounds that block the bio-availability of OSA to the plant roots. More than 50,000 artificial, man-made silicon compounds are used in the world today. Many Si compounds and products that are 'siliconized' are also finding their way into the soil. The products of degredation come into solution, compete with OSA and interfere with the absorption of OSA by plant roots.

Phosphate (P) fertilizers in the soil also compete with OSA and inhibit the uptake of OSA by plant roots. In the past this problem hardly existed because, like silicates, almost all phosphates existed as polyphosphates which degraded only very slowly in the soil to monophosphates and diphosphates. It has been proven by scientists at the University of Florida that the application of phosphate fertilizers on sugarcane production can be reduced 5 times by adding silicates to the soil. As a result phosphates have been freely draining into the rivers and waterways, encouraging algal blooms. These algae produce potent neurotoxins that enter the fish. Symptoms are seen in the humans that eat this fish.

Soils containing heavy metals such as Aluminium can be decontaminated by OSA accumulating plants. Mercury and Lead also bind to Silicon to some extent.

Today's Consumers Want Clean Food

Consumers want safer food and they are prepared to pay for it. Consumer pressure in the USA is so high that through the insistance of the USDA (United States Department of Agriculture) most relevant Universities have long initiated research and development programs on organic, bio-food. It requires a very different approach to traditional agricultural practices. Other Universities are working on food related health issues and are blaming agricultural scientists for doing such a bad job regarding the cultivation of unhealthy poor quality vegetables (and farm animals). Agricultural scientists are under pressure to research new products and production techniques and the forgotten element Silicon is at the centre of these programs. The problem can only be solved through improved agricultural practices.

Silicon in Agriculture

Agriculture and horticulture that uses OSA is an insurance policy for good quality production and more efficient utilization of all chemicals such as fungicides and fertilizers. In the opinion of Prof. Dirk Van Den Berghe, OSA is essential to **Organic** cultivation. OSA treated crops need less Phosphate and will grow better, more naturally, in a more balanced environment. Using OSA it is possible to cultivate crops such as potatoes and apples with a 50% reduction in the application of chemicals. Production is better and toxic residues are much lower.

We do not yet know when it is best to apply OSA, how best to apply it and in what ways. This will also differ from soil to soil and crop to crop. Yet Calcium fertilizers have been applied to soils for centuries despite the fact that little is still understood about Calcium availability in the soil and how it is taken up by plants.

OSA helps regulate the relative concentrations of various mineral salts taken up by the plant, including Magnesium, Sodium and Potassium. Copper and Zinc are also important to plants even though only about 2% is taken up – the rest remains polluting the soil. In the presence of OSA the amount of Copper and Zinc needed for the plant are reduced. When Calcium is applied to the soil there is a greater uptake of Calcium by the plant in the presence of OSA. We also see a higher uptake of Potassium. It is interesting to note that OSA always increases the uptake of

Potassium. Potassium is often applied to to harden fruit and assist in ripening. In the case of OSA treated Apple trees, the fruit ripens fully without such a spray. Prof. Van Den Berghe considers that the quantities of all available minerals in the soil required by the plant can be reduced by applying more OSA.

OSAB is normally applied applied as a foliar spray. However it is also taken up by the roots via drip irrigation or soil drench. Further trials are required to determine more precise protocols for specific soils and crops.

It can be mixed together with most chemicals and fertilizers for application. Humic and Fulvic acids are degredation products always associated to large quantities of Silicon. If Humic and Fulvia acids are added to soils that contain OSA, the Humic/Fulvia acids will bind with OSA and as a consequence these nutrients are made more available to the plant.

The application of Si fertilizers in the form of Silicate salts or better OSA/OSAB, are particularly effective in agriculture where cultivation conditions are less that ideal. It plays a major role in Plant Stress Dynamics in helping plants to tolerate or resist environmental (abiotic) and bilogical (biotic) stress. In the first instance, substantial research is currently aimed at cultivating agricultural crops where the water is of poor quality, salty and contaminated.

Prof. Dirk Van Den Berghe first produced stabilized Silicic acid (OSA) some 10 years ago while Professor at the Faculty of Pharmacy, University of Antwerp, Belgium.