Boron - The Bouncer

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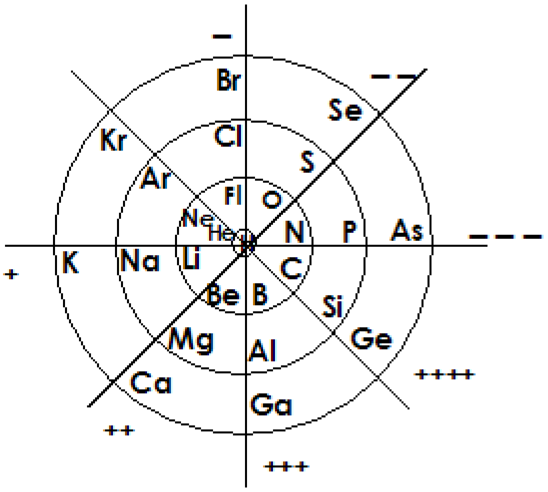

If we look at the periodic table, the first row (or circle) of eight, reveals the key flavours of chemical reality. This first row is extremely reactive because the protons in the nucleus are enshrouded in the very thinnest layer of electrons. Looking from lithium to neon, carbon clearly falls in the middle, while the completed, inert gas, neon, fills out the Pythagorean octave rule. This rule of eight is seen also in music and the colour spectrum, and according to some (including Pythagoras) it relates to our solar family comprised by the moon, mercury, venus, sun, mars jupiter, saturn and the earth.

The chemical reactions of Li^{+}, Be^{++}, B^{+++}, $C^{\text{four (balanced + or –)}}$, $N^{\equiv}$, $O^{=}$ and F^{-} are extremely intense. In subsequent rounds of the table, these reactions are muted by additional layers of electrons, and a far lower percentage of total charge. For example, aluminium is a plus three like boron and combines with silica to make clay, which has a negative charge, but is reasonably inert. Aluminium's outer three electrons make up three thirteenths of its total charge, whereas boron's outer three electrons make up three *fifths* of its total. This means boron guards its outermost electrons much more jealously than aluminium. In clay, aluminium is very doughy and pliable. But it doesn't have any bounce, whereas boron reacts with silica to kindle the ebb and flow of sap in plants, and in doing so it bounces like a super ball.

Note that versatile, ambidextrous carbon is perfectly balanced between positive and negative charge. It is either positive or negative, whichever is needed. Carbon is the perfect buffer.

Only the plus one alkali elements such as lithium and the minus one halide elements such as fluorine actually give up or take on electrons to reach an inert configuration in their outer electron shells. Lithium gives up an electron to go back to the first paired electron shell of helium, while fluorine takes on an electron to mimic neon's perfect eight. This makes lithium fluoride a salt, which ionizes in aqueous solution. When salts dissolve in water, the individual atoms float around changing partners more freely than people at a square dance. Such electron transfer is called ionic bonding.

The other atoms in the first row—beryllium, boron, carbon, nitrogen and oxygen—share pairs of electrons in bonds that hold the participating atoms together more tightly, as though two partners were doing a slow waltz or were intimately coupled. These bonds are called covalent bonds. A plus two atom such as beryllium can form two covalent bonds with minus two oxygen, resulting in beryllium oxide or BeO. This keeps nuclear charges balanced while achieving similar electron shell configurations with helium and neon.

Covalent bonding makes carbon the jack of all trades as it forms four covalent bonds, mixing these up with other carbon atoms as well as other positively or negatively charged partners.

Like carbon but far milder in its chemical reactions, silicon also behaves as either a plus or minus four, though it tends to act more like a plus because with fourteen electrons it doesn't miss a few quite as much as carbon, which has only six. Silicon double bonds with two oxygens to form silicon dioxide, otherwise known as silica, the same way carbon double bonds with two oxygens to form carbon dioxide gas. But unlike the free-wheeling carbon dioxide, silica is stodgy and locks up into a crystal lattice structure commonly known as quartz. In its purest form silica becomes clear, hexagonal crystals that transmit light—though computers use delicate arrays of silica chips to transmit information as well.

Glass, however, is made by melting silica along with a small admixture of boron. This causes the silica molecules to spin about, stirred up by the hyperactive boron. The result is that when glass cools its molecules are amorphous like a fluid rather than lined up in a crystalline pattern.

As carbon is far more reactive than silicon it catches and holds boron, where silicon merely chases it. This means that burning up rich, organic soils with soluble nitrogen fertilizers causes them to lose their boron as carbon is depleted. Then when soluble nitrogen compounds oxidize to the negatively charged nitrate (NO_3^-) they take positively charged boron with them as they leach away.

In fact triple positive boron has a special relationship with triple negative nitrogen. When these two react as pure substances they form triple bonded boron nitride, the strongest, even if not the hardest, substance known. Boron nitride nanofibres have the highest tensile strength of any material. Cubic boron nitride, while not quite as hard as diamond where carbon closely bonds with itself, can take far higher temperatures and is used in the place of diamond for high speed grinding and cutting. Together boron and nitrogen form so strong a union that ceramic tiles made from boron nitride are used on the space shuttle to withstand the extreme stress and heat of re-entry from space.

Nitrogen, a minus three atom, is so sensitive to its surroundings that it is attuned even to the distant starry background. It seeks electrons to fill out its shell so strongly it is the vehicle for consciousness and awareness and carries the master plan in the chemistry of living organisms.

By way of contrast, boron would give up all its three outer electrons if it only could. However, this would create serious charge imbalance with its nucleus, so it bounces around stirring things up and sharing its three outer electrons in a most frenetic way. It bonds with oxygen and hydrogen to form boric acid (H_3BO_3). But this hardly quells its restlessness as it then seeks to bond with sodium, calcium and water to form various borates such as borax. Even then it will do the dance with carbon in a Sidney second.

Of particular interest to agriculture, however is its effect on silica. As far as soil biology is concerned silica is rather an aloof aristocrat that bathes regularly and wears white gloves. Whether it is in the form of sand (silica), or clay (aluminium silicate), silicon is not especially soluble. It doesn't mix with the ordinary down and dirty carbon biology with much enthusiasm—unless there is a bit of the ebullient, pixyish boron around to stir it up and get it going. Yet it is silica, with its upstanding generousity, that provides the lift, the capillary action, that lofts calcium and all the other minerals upward into the growth of plants. The erect grasses such as sugar cane, rice, corn and cereals all need adequate levels of boron to uptake the silica they require in such great abundance. Boron engages silica, and grasses take this up and unite it with carbon. But calcium rich legumes are even more dependent upon adequate boron to stimulate the silicon, since silica is what drives the pump that feeds calcium to these fat pigs so they can unite it with carbon also.

It is notable that silica follows the sun. Available silica builds up in the soil during fall and winter when the nights are longer than the days. Then with the emergence of spring when the days become longer than the nights, this silica drives the sap flow, and growth shoots upward into bud burst, flower, fruit and seed. During this period silica works most strongly to carry calcium upward into cell division, growth and reproduction. For example, lettuce, spinach, Chinese vegetables, etc. bolt very quickly to seed in spring. After midsummer when day length begins its decline the silica forces taper off in intensity, and calcium is not driven forth with quite so much strength. As summer fades and fall leads into winter these same vegetables fill out fat leaves but are in no danger whatsoever of bolting.

Many crops grow and form fruit best in spring when silica is strongest, taking their time and filling out their fruits as summer matures. In their rapid growth phase, as the cell division is occurring in the formation of leaf and fruit, calcium is required in the replication of DNA as cells divide. Thus there is a critical window for boron's activity to take effect. If it has been active in the soil all winter, the spring silica stream will be strong enough to fulfill calcium requirements. But if the silica stream is not strong enough as cell division is taking place, the cells will be calcium deficient and weak, and may become diseased or fail to fill out well later on.

This means that if boron is supplied after spring is already well underway its effects will not be nearly so profound. For example boron deficiency shows up in maize when the ears do not fill out to the tips and the ends are shriveled. When such an ear of corn is analyzed for calcium, its deficiency can be traced back to when the ear was first formed. Though it rarely is done, if it were analyzed for silicon it would prove silica deficient. Thus boron is understood to govern calcium uptake while the role of silica is overlooked. Then agronomists puzzle why late spring and summer applications of boron often disappoint.

Silica works on the vertical axis and calcium works on the horizontal. Thus boron deficiency, and of course silica deficiency, shows up first as hollow stems (vertical) in broccoli, cauliflower and lucerne, and in limp, droopy growth of rice, corn, and other grasses even when these crops seem to fill out in their horizontal parts. But if silica is deficient, chances are calcium deficiency will follow even though the soil may contain ample calcium.

Crops like apples, oranges, pecans, strawberries, tomatoes, lettuce, cabbages, radishes, etc. all must get their entire calcium requirement during early cell development when the DNA patterns are set. Once this is over deficient cells cannot turn into succulent, tasty fruits and vegetables. This means that if boron does not engage silica well enough over the winter then silica will not provide sufficient lift to supply calcium abundantly during early development.

It does nowhere near as much good to supply it later on. Foliar applications of boron can be next to useless once fruit is set and cell division is underway. Apples will end up mottled and corky. Oranges will lack juice and sugar at the stem end. Pecans will be shriveled in the butt. Strawberries won't fill out to the tips. Tomatoes will get blossom end rot. Lettuces and cabbages will burn at their leaf tips. Radishes and turnips will be spongy and lack juice. Soybeans will shed pods and corn will fail to fill its cobs, etc.

Commonly boron is applied as soluble boron or solubor, also known as disodium octaborate tetrahydrate. It is mixed up in water and sprayed to make even application of small amounts easy, as boron over about three parts per million may be toxic. There are several problems with this, however.

For one thing boron is easily lost. While soluble nitrogen is the most readily leached nutrient in the soil, soluble boron is lock-step behind it, and because there is so little boron, depletion seems lightning fast. Almost the only thing that holds on to boron is carbon, particularly carbon in the form of living organisms. If there is insufficient biology and organic matter to hold it, soluble boron sprayed in the fall will leach at the first chance. Thus it is tempting to spray it during the growing season as a foliar. But think again. If boron is used as a foliar, not only does this miss its optimum window of effectiveness, it has to be quite dilute as it is strongly reactive and easily burns foliage. Thus one or two foliar feedings are unlikely to be sufficient to build soil boron to the 1 to 3 parts per million required for adequate stimulation of silica. And we have to build *soil* boron levels in order to stimulate silica.

Nevertheless, waste and insufficiency of applying soluble boron sprays are not so bad. It is unfortunate that so many are uninformed about the role of silica, but we've lived through worse things. We can simply chalk this up to myopic research while we spread the word. However, the bad news is that spraying soluble boron is deadly to ants. Killing all ants is ecological suicide, and if it were done deliberately it would be akin to murder. When we ignore the roll of biology in agriculture, massive damage becomes routine. Ants are the fungal cultivating virtuosos of soil ecology, and fungi are of enormous importance in holding boron and distributing it where it is needed. When blanketing everything with soluble boron eliminates ants it is a clear sign this an inappropriate way to apply it.

It is our top priority to conserve and enhance our soil biology at all times, as this is what holds on to nutrients and makes them available as needed. Using compost and mixing in the appropriate amount of boron would lock it in and buffer it so it neither leached nor killed ants. As a quick and easy method, blending boron into humic acid granules would sequester and hold on to it as well as making it easy to spread. And because humic acid is a rich, fungal food, this way of applying boron ensures that it will be held and distributed by fungal networks in the soil. This is ecologically friendly and spares ants. Most importantly, incorporating boron with carbon allows fall application without fear of leaching, so it can work on silica in winter as nature requires.

For more than a hundred years the role of biology has been ignored in agriculture. One of the results has been across the board loss of soil life and organic matter—and along with this, loss of boron. Currently there is a public perception of calcium insufficiency in much of the food presently available. But what few have noticed is the widespread deficiency of silica in modern diets. Silica probably is the most pervasive mineral deficiency today. To cure it will require restocking with boron, which in turn will necessitate rebuilding soil biology and organic matter levels.

By itself soluble boron is not the answer.

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