The Sugar Shuffle

by CHRISTOPHER KNIFFEN

Much like a wave gaining momentum before it breaks, the sustainable agricultural movement in the past decade has assembled a large following. Once a small niche in agricultural systems, sustainable agricultural practices have expanded and are now being taught at universities across the globe.

Farmers worldwide are noticing the benefits of sustainable agricultural practices but a clear definition of sustainability in soil/plant systems has yet to be defined. Whether the topic is agriculture or energy production, the emphasis of sustainability is on transforming energy from the surrounding environment into usable forms. In agriculture, sustainability equates to maximizing the energy output of the soil with minimal inputs. The management of biological organisms in the soil (bacteria, fungi, protozoa, roots, etc.) is imperative to this process.

Biological organisms are nature's chemists. In recent years, we have tried to understand the chemistry behind plant nutrients and use this knowledge to eliminate the middleman (biology). Many have adopted the use of synthetic fertilizers to provide plants the nutrients they need based on a law of minimums merely looking at plant nutrition mathematically. Synthetic fertilizer application rate recommendations are based on yield potential formulas. However, these recommendations rarely take into account the effect soil biology has on plant growth. When we eliminate soil biology we eliminate not only the chemical reactions that make the nutrients available, but also the spark of the soil.

Witnessed measurement of the electrical conductivity of the soil confirms that active soil biology produces a relatively consistent electrical current in the soil. When we try to manipulate the plant/soil system with synthetic fertilizers we observe spikes in soil electrical conductivity, plant sap electrical conductivity and plant growth directly after application. Typically after this spike of electrical conductivity, we will observe rapid plant growth. After the period of rapid growth, if the plant does not have the balanced minerals needed to maintain this growth, the plant often declines.

Maintaining a consistent electrical conductivity through balanced water-soluble soil minerals and active soil biology allows the plant to grow, balanced. When a plant grows balanced mineral density is achieved, photosynthesis is maximized, and the sugar content of the plant sap is increased. The sugar content of the plant sap, measured as Brix, is important because it can tell us how healthy the plant is.

Growers measure Brix by using a refractometer to measure the sugar content of a solution. One Brix equates to 1 gram of sucrose in 100 grams of solution. As the Brix number increases, it expresses the increase in the sucrose content of the solution. When taking Brix readings in a plant, the solution is the plant sap. When the plant sap has a Brix reading over 14, we have observed that the plant has a stronger immune system, increased defense compounds, better flavor and

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higher mineral density – all of which combine to make a high-quality and stronger plant.

Take for example the story of the three little pigs. A plant can build a low-Brix "house" or cellular structure with synthetic fertilizers' "sticks and straw" quickly and the house will look good, however when the wolf comes to the door (stress, disease, etc.) the house is easily destroyed. But, the plant that builds its house with high-Brix (pun intended) can withstand the wolf because the house was properly constructed. Sure, a Brix house may take a little longer to build and a bit more work, but the house is strong. The plant builds a high-Brix house with the energy derived from the biological activity of the soil, balanced water-soluble minerals and stable electrical conductivity in the soil.

How can a plant with high Brix be sustainable? Well, sustainability is based on energy feedbacks. In the plant/soil system there exists an energy feedback. The plant feeds the soil microorganisms and the soil microorganisms feed the plant; it is cyclical. The food that is being shared is sugar. Simple sugars are the energy carriers driving this soil/plant energy feedback. Sugars are shuffled between the plant and the soil microorganisms, storing and releasing energy for biological growth. If sugar production is compromised or limited, the plant will have difficulty maintaining cellular plant function (i.e. growth, maintenance and reproduction). It is this production of sugar that provides the energy which fuels cellular plant functioning. Essentially, sugar is the gasoline for the plant cell. So every day that the sun is shining, plants are at the gas station filling their tanks with sugar (energy) that can be allocated toward growth, reproduction or maintenance.

Where and when a plant allocates sugar toward growth, reproduction or maintenance depends upon the plant's life cycle and the health of the plant. A plant infected with a pathogen may allocate more sugar toward fighting the pathogen than growth or reproduction. We observe this when we observe diseased plants. Visually we see that a plant is sick or infected when growth or reproduction is compromised. However, for the plant, the reduction in growth or reproduction is simply an expression of a lack of sugar. Developed leaves act as a source of sugar, whereas new growth both above- and belowground, reproductive organs (seeds, flowers, etc.) and fighting diseases are sinks. Disease acts as a major sink for sugar. A plant with low Brix has a lower metabolism and will be unable to produce the necessary defense compounds needed to fight pathogens.

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When combined with the sinks required for growth and reproduction the sick plant cannot produce enough sugar in its sources (leaves) to handle these increased sugar demands in all of the sinks. Growth and reproduction suffers and visually this is what you observe. It is similar to your paycheck. You work all week to put money in your bank account. Your job is a source of income, and taxes, mortgages, bills, etc. are sinks. If your sinks outpace your sources, you cannot afford to live. For the plant, it's the same. If the source-to-sink ratio is not balanced, the plant will die.

Plants which maximize sugar production are able to tolerate fluctuations in the source-sink ratio with less detriment to the overall plant mass or yield. Or more simply, plants with higher sugar content are healthier, have higher nutritional quality, longer shelf life and typically produce a higher yield.

Naturally, when a plant's sources (leaves) are producing enough sugar, the plant will send those sugars to the roots as exudates into the rhizosphere, feeding the microorganisms in the soil. As mentioned previously, this process is cyclical where the plant feeds the soil and the soil feeds the plant. However, when a plant's source-to-sink ratio is imbalanced, sugars may not be allocated to the roots in quantities needed to sustain the microorganisms in the soil. When we can manage our crops in ways that increase sugar production, we are indirectly sustaining the soil's microbiological organisms. Essentially, we are using nature aboveground to feed the nature belowground. Properly functioning plant/soil energy feedback can thus be achieved, where sugars are being exchanged between the plant and the soil, providing a sustainable agricultural system with minimal inputs.

Knowing this, what can we do when the biology in the soil is not getting fed by the plant due to low Brix? First we increase the Brix of the plant through water-soluble balanced minerals (water-soluble minerals are assimilated by biological organisms more quickly than dry minerals), but also we can utilize the high energy potential of carbon sources such as simple sugars (sucrose) to build energy in our soils. Ideally these sugars need to come from the plant, however, as previously mentioned, when plant sugar production (Brix) is low we can help by supplementing the soil with a carbon source such as sucrose, water-soluble balanced minerals and amendments, all of which feed soil microorganisms.

The majority of microbiological organisms in the soil perform cellular respiration as a process to release the stored energy in simple sugars. Cellular respiration is photosynthesis in reverse. Microorganisms use the energy from sugar to produce mass. Just as in plants, the energy released from breaking down simple sugars will go toward growth, reproduction and maintenance of the microbiological cell. The addition of sucrose (a simple sugar disaccharide comprised of glucose and fructose) and balanced minerals to the soil can feed the soil microorganisms the nutrition they need when the plant cannot.

A lack of plant sugars can result from numerous factors such as soil mineral imbalances, environmental and biological stress, insects and disease. Helping the plant overcome these obstacles with the addition of water-soluble balanced minerals and sugar will allow the plant to perform translocation and allocate its naturally produced sugars (energy) for the production of nutrient-dense plant mass (yield). All the while, the plant will have enough sugar to maintain all other plant functions including the energy feedback between the plant and the soil organisms.

In the plant/soil system, building energy in the soil is essential to sustainability and producing a high-energy plant. Sugar is energy. High-energy plants (high sugar content or Brix) are nutrient-dense, have a higher test weight, a stronger immune system, a longer shelf life, and they are overall healthier than lower energy plants. These plants are physiologically functioning at their maximum potential and can sequester more carbon from the atmosphere due to the higher photosynthetic rate and sugar content. Sugar, a molecule comprised of carbon, oxygen and hydrogen can act as a global sink for carbon (the same source-sink ratio we used to describe sugars in a plant can be expanded to describe carbon on a global scale).

Carbon sequestration can be achieved from balanced minerals in the soil, active soil microbiology and energy. Achieving a properly functioning sustainable agricultural system can reduce many of our global environmental and economic problems. Sugar is central to achieving this sustainability. Building a Brix "house" is stronger than building a house with sticks and straw. A house built with Brix can sustain our agricultural industry, feed our growing population and assist in correcting many of our current environmental issues now and in the future. The wave of the future in agriculture is upon us, and that wave is Brix.

Plants use the energy from sugar to produce nutrient-dense mass.

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