Carbon Building, Carbon Cycling

by John Kempf

Adequate levels of functional organic matter and a robust soil digestive system are sorely lacking in most all agricultural soils. This lack of humic substances and biology significantly reduces a soil's water-holding capacity and the ability to release nutrients, all of which leads to large losses in crop quality and yield.

Meanwhile, increasingly higher levels of atmospheric carbon or CO_2 are being produced by the burning of fossil fuels and land desertification. *Carbon sequestration* — the term has been thrown around like a rubber ball. What does it really mean for agriculture? How can carbon be stabilized in soils most effectively?

In this article we hope to provide some ideas concerning the carbon cycle and how to effectively build soil carbonic organic matter. There seem to be three primary means by which we can increase a soil's carbon content: carbon imports, carbon generation and carbon induction. Each of these possible methods can also offer other strengths to a soil-building program, compost can provide a biological inoculum, humates can provide a biological stimulant.

IMPORTING CARBON

There are three primary carbon imports. Humates or leonardite, and their derivatives such as fulvic and humic acids. The humic substances present in these materials generally provide very good nutrient exchange. Biochar is also a stable carbon import but not as active as leonardite seems to be. Compost can also be a viable carbon import with the added benefit of a strong biological component. Compost, however, tends to have a lower level of stable humic substances when compared with other materials. A fair proportion of compost can degrade over a period of a few years.

CARBON GENERATION

We have several opportunities to generate or capture carbon on the farm that would otherwise be lost. Managing crop residues, composting crop waste and animal manure, and cover cropping all provide us with a chance to capture more carbon and store it in our soils. Any of the practices will also help build a robust digestive system in the soil.

CARBON INDUCTION

Induction seems to best describe the possibility of generating higher levels of soil carbon by optimizing the carbon cycle and plant performance. Carbon induction has the greatest potential of any source to build large amounts of stable humic substances, stimulate biology, and improve soil and plant health.

Carbon cycling — how does it really work? As plants are growing in the field they absorb carbon dioxide from the air. Through the process of photosynthesis this carbon dioxide and water are used to form simple sugars which are composed of carbon, hydrogen, and oxygen. These sugar compounds are the foundational building blocks to build all the rest of the plant compounds, such as complex carbohydrates and polysaccharides, proteins and amino acids, and plant lipids. All of these compounds contain an average of roughly 40 percent carbon.

In exchange for nutrients supplied by the soil system, plants release large amounts of these substances into the soil to feed the soil biology. These root exudates contain a variety of organic and amino acids and lipids. The healthier a plant becomes, the greater the amount of root exudates and the higher the quality. According to Horst Marschner, in his book *Mineral Nutrition and Higher Plants*, healthy plants can release as much as 60 to 70 percent of their total sugar production back into the soil as root exudates. This can only occur, however, if we have truly healthy and energy-positive plants, in other words, they have an energy surplus. If we think about this for a moment we can realize the tremendous amount of carbon induction this can create. A healthy plant will have at least as much root biomass below ground as there is plant biomass above ground. So if we have 100 pounds of plant biomass above ground, and an additional 100 pounds below ground, this still represents only 30 to 40 percent of this plant's total energy production. This is the real secret to building soil carbon effectively and efficiently. We can readily see why forage-based livestock agriculture and perennial polycultures are the most efficient method of building soil organic matter and stable humic substances. Carbon induction is the answer.

THE IMPORTANCE OF FATS

As plants become healthier and have greater photosynthetic efficiency and higher levels of sugars and energy, they will begin to form high levels of lipids (fats and oils). The lipids are energy storage compounds in the plant, just the same as fats are the energy storage in animals. Once a plant has surplus energy it is stored as fat.

All plants have a minimum baseline level of lipids needed to form the phospho-lipid soul membranes. As their energy increases, however, they will form higher levels of lipids which will be stored inside the cells and utilized in building stronger cell membranes and stronger reproductive tissue. Many of these lipids will also be exuded from the roots into the rhizosphere, where they will be used as an energy source by soil microbes.

These lipids in the rhizosphere are an important piece of the puzzle in building stable humic substances, all of which have a fairly high content of both aliphatic and aromatic compounds which are based on theses plant lipids.

THE IMPORTANCE OF SOIL FUNGI

When these sugars, amino acids, and lipids are released as root exudates, they become a ready food source for the soil's microbial system. How these compounds are digested will determine whether stable humic substances are formed or not.

There are several types of digestion in the rhizosphere. If we have a bacterially dominated digestive system, the bacteria will utilize these plant exudates as a food and energy source. The bacteria are then in turn used as a primary food source by other microbes such as nematodes and actinomycetes. These microbial metabolites are then quite stable and can be utilized by plants as an energy source. This digestive cycle is termed mineralization, and is set in motion by bacterial dominance.

If a soil has a fungal dominated digestive system, the fungi will be the primary digesters of the plant root exudates. Fungi will absorb these compounds and digest them slowly over a period of time and combine them into complex long-chain compounds which are referred to as humic substances. This digestive cycle is called humification, and is a critical piece of carbon sequestration.

As can be seen, carbon induction can be the best method of building soil organic matter. However, several important pieces need to be in place. Healthy plants with high levels of energy coupled with soils which have a strong fungal dominated digestive system will get the best results. A good example of such a system would be the perennial grasslands of the Great Plains which build up 10 percent organic matter soil over a long period of time.

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