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News and Information on natural resource management in western North Dakota

Notes from the Burleigh County Soil Conservation District Soil Health Workshop 2011 "It's About Balance"

Following is a compilation of notes taken by me from presentations made by James Hoorman. As such, they are my interpretation of what was presented. – Story and Photos by Jon Stika

Soil Ecology, Nutrient Cycling & Home Grown Nitrogen - James Hoorman, Extension Educator, Cover Crops & Water Quality, Ohio State University Extension

- North Dakota is leading the nation in cover crop diversity and the rest of country is starting to take notice. Soil Ecology is how plants, microbes and humans work together and interact in the soil. The ideal soil composition is 25% water, 25% air, 45% mineral and 5% organic matter. Soil should be 50% pore space. Organic matter is the brains and heart of the soil. It buffers the soil against big changes in moisture and temperature.

- Tillage causes soil organic matter to decline to half of its original level, infuses oxygen in the soil, increasing microbial activity and decomposing organic matter faster than it is created. Healthy soils have plants growing all the time to absorb energy and healthy microbial populations. Microbes process 90% of the energy in the soil. Sick soils are compacted, have poor infiltration, are often bare and have low organic matter with nutrient imbalances. Mimicking Mother Nature makes soils healthier.

- The Buffalo Lesson – keep soil covered year round, spread manure thin, which is how the prairie was when the buffalo roamed, for clean water and healthy soil. Soil experiences extremes in temperature if not kept covered. Green land (land with living plants) keeps water clean. Most of the nitrates leached from the soil occur during fall and spring when no actively growing crop is in place to acquire the nitrate-nitrogen. Organic matter content of the soil is directly related to nitrogen nutrient cycling efficiency.

- Seven to nine years of continuous no-till will allow the soil to recover from past misuse. Adding continuous cover crops to continuous no till will shorten the recovery time to two to four years and adding manure to the system will shorten recovery time even more. Understand natural cycles and work with those cycles to increase nutrient efficiency.

- Tilled soil is dominated by bacteria. No-till soil has bacteria and fungi in more of a balance and has macro pores throughout soil to allow for air and water exchange. Hydroponic farming (using the soil as a medium to hold water and nutrients instead of regarding the soil as a biologic system that feeds and waters plants) is a "leaky" system for managing nitrogen. Farmers need to feed microbes first, which will then feed plants, which will then feed humans. Most of the nitrogen in the soil is processed by microbes first, and then becomes plant available. Inorganic nitrogen is fast release (cycled quickly by soil bacteria), whereas organic forms of nitrogen are slow release (slowly decomposed by the soil food web) that more closely matches plant uptake.

A warm-season no-till cover crop in Burleigh County, ND.

- Nitrogen and sulfur are needed to make protein. Nitrogen is not lacking in the environment… the Earth's atmosphere is 78% nitrogen, the key is to use solar energy to power plants that host/feed the microorganisms that can fix nitrogen from the atmosphere into plant-available forms. Nitrogen must be stored in soil organic matter to increase its availability to plants. No till + cover crops allow nitrogen to be captured that might be lost with excess water in no till systems.

- Denitrification, the loss of soil nitrogen as a gas, occurs under anaerobic conditions in the soil when the soil is saturated with water.

- 50% to 75% of Phosphorous occurs in soil organic matter. Phosphorous bonds organic matter to clays (organic matter-P-clay). Loss of organic matter allows clay to bond with cations and the soil loses some of its buffering capacity.

- Flash flooding in watersheds is evidence of water not infiltrating soil. Water moving across soil must be slowed down. Water removes soil and nutrients at 2^6 for each additional mile per hour water moves.

- No till + cover crops mimic's nature with continuous plants/ cover + no soil disturbance or aeration. Soil with No till + cover crops have more enzymes produced by soil microorganisms that increase the rate of soil reactions. To add organic matter to soil you need more live roots in the soil. Active organic matter needs to be increased in the soil (microbes and polysaccharides). 1% organic matter has $650 worth of crop nutrients per acre. All of the atmospheric carbon dioxide is only 40% of the soils carbon-holding capacity. Active carbon is most rapidly lost from tillage.


A cool-season no-till cover crop on the Burleigh SCD Menoken Soil Health Demonstration Farm.

- Every farmer is a livestock farmer… soil has 50 billion bacteria in a handful of soil. Soil microbes eat soil organic matter if no living roots are feeding them. Bacteria are only 20% - 30% efficient at keeping carbon in the soil; fungi are 40% - 55% efficient at keeping carbon in the soil. Fungi connect with plants and bring water and nutrients to them in exchange for sugar. Plant roots alone explore 1% of soil. Plant roots associated with fungi explore 20% of soil.

- A C:N greater than 20:1 will result in nitrogen being tied up (immobilization), a C:N ratio less than 20:1, will release nitrogen (mineralization). 1000x to 2000x microbes live in the rhizosphere of plants as compared to the bulk soil.

- Each pound of soil organic matter can hold 18-20 pounds of water. 1% organic matter holds 1" of water.

- Compacted soil has fewer microbes. Visual way to measure compaction on the fence line of a field that has been tilled… the tilled field is often lower in elevation. Roots expand soil out and up rather than down, as tillage does.

- Glomalin forms macro aggregates about the size of a sand grain. Building soil can be compared to building a house: the roof is represented by residue on the soil surface, insulation is also surface residue, glue is Glomalin, screws are phosphorous – organic matter bonds, braces are nitrogen and sulfur, wood is plant roots and organic matter, foundation is clay particles.

- Soil compaction is a biologic problem that must be solved biologically. Cold, wet soils are the result of compaction not allowing soil to drain, not because residue on the soil surface is keeping the soil wet and shaded. As residue decomposes, it darkens and absorbs solar energy better. More biologic activity warms soil, similar to the respiration of many organisms in a compost pile.

- Earthworm populations will suffer if soil is tilled and their food (crop residues) is buried and their cocoons are moved too deep or too shallow in the soil for them to hatch and grow into worms. Earthworms reproduce based on weight, not by age. The faster they grow, the faster they reproduce.

- Legumes, with the cooperation of Rhizobia bacteria, fix nitrogen and have a relatively low C:N. Grasses accumulate nutrients with their fibrous root systems and their C:N depends on maturity at termination. Brassicas reduce compaction and suppress weeds. In a legume-grass mixture; legumes fix nitrogen which is shared with grasses via fungi and grass accumulates phosphorous with fibrous roots and shares phosphorous with legumes via fungi.

- Slower release nitrogen from biologic sources is more efficiently utilized by plants than synthetic nitrogen as the nitrogen becomes available closer to the rate the plants require it. Only 33% of nitrogen from fertilizer ends up in corn …the rest comes from organic matter.

- Protozoa eat bacteria and excrete ammonium for plants. A 10% increase in soil temperature doubles microbial activity. Approximately 2% of soil organic matter will be mineralized (liberating the crop nutrients it contains) per year.

- You cannot build organic matter in the soil and do conventional tillage. The physical disruption and aeration of the soil allows organic matter to be consumed faster than it is produced.

- Instead of tile drainage, use cover crops to transpire water and make pathways for water to move down.

- Beetles that eat slugs are more prevalent in no-till than conventional till.

- Oilseed radish is a good nitrogen scavenger but you may wish to include a grass species in a cover crop mix to immobilize nitrogen available from the rapid decomposition of radish when they die. Cover crops will have accumulated 90% of the nitrogen they need by the time they flower. After flowering, nitrogen is moved from other parts of plant into seed production. Late maturing radish develops the largest root instead of putting energy into flowering.

- Land that is in hay land for many years suffers because hay is taken off without the return of manure or other biologic food source. Hay land needs diversity of species and to leave some growth/residue to cover the soil. Properly grazing cover crops as forage, (take half and leave half) instead of haying, cycles more nutrients and biologic food back to the soil.

Carbon: the key to soil function

Story and Photo by: Jon Stika

Much of modern agronomy is focused on feeding plants the nutrients they need to grow and produce a harvestable crop. So, which element in the soil *is* the most limiting to agricultural crop production? Is it N, P, K, Ca, Mg, Mn, S, Zn, Cu, or.. ? It is actually none of the above. The most limiting element in the soil for agricultural crop production is Carbon. Yes, *Carbon*!

There is plenty of N in the air (78% of the Earth's atmosphere is N) and plenty of P, K and other elements in the soil. It is not for lack of N, P, or K that plants suffer nutrient deficiencies, but lack of *available* N, P, K, or other essential elements. The majority of available plant nutrients are contained in or made available by soil organic matter. Remember, up to 10% of what we refer to as soil organic matter is *living* microorganisms. It is this living fraction that fixes N from the air and decomposes everything from crop residues to dead animals to rocks, making nutrients available to plants. Carbon is a major and essential part of soil organic matter.

A cool-season no-till cover crop in Mercer County, ND, capturing solar energy to feed and cover the soil.

Soil organic matter often makes up less than 5% of the soil by weight, but controls *90% of soil functions essential for plant growth.* As soil organic matter increases from 1% by weight to 3% by weight, the water holding capacity of the soil doubles. Therefore, the majority of crop water and nutrient supply is at the mercy of the quantity and quality of soil organic matter, based on the element Carbon. Since most of the functions that supply plant needs are carried out by the largely microscopic life in the soil (numbering in the billions per gram of soil) our focus in agronomy should be on managing the soil as a biologic system, not managing it as a chemistry set. The fundamental thinking that must change is that we do not feed the plants with fertilizer, the soil feeds the plants, so we must learn to feed the soil so it *can* feed the plants.

The easiest source of food for soil microbes to eat is the sugar exuded through the roots of living plants. The next easiest food source for soil microbes to utilize is dead plant roots that can be decomposed by soil microbes. Following dead roots on the menu of soil microbes is above-ground crop residues: straw, chaff, husks, stalks, flowers and leaves. When root exudates, dead roots, or plant residues are not available, soil microbes will feed on other soil organic matter. When soil organic matter is the only source of food available for soil microorganisms, soil organic matter will decline in both quantity and quality.

Our role as soil managers is therefore to make the soil the best habitat possible for soil microorganisms to thrive, build soil organic matter and feed plants. This can be accomplished by disturbing the soil less, growing the greatest diversity of plants possible, keeping living roots in the soil as much as possible and keeping the soil covered at all times. This will provide the ideal habitat for soil organisms to thrive and associate with each other in order to build soil and cycle plant nutrients.

Carbon is the currency of the soil. Carbon is most efficiently added to the soil by green plants capturing carbon dioxide from the atmosphere and converting it through photosynthesis into carbohydrates. Plants feed and cover the soil and the soil feeds and waters the plants…all powered by the Sun. So, the next time you reach for that bag of fertilizer to feed your plants, remember how soil really works: biologically.

Article Review: Modeling trophic pathways, nutrient cycling, and dynamic stability in soils - Moore et. Al.

by Jon Stika

'Most plant life is not consumed by herbivores, but instead it dies or is shed and is then decomposed by microbes and a host of invertebrates.'

The underground herd of soil microorganisms cycles more plant biomass than an above ground herd of cattle and does so in many different pathways. The soil food web "digests" the majority of what is produced by plants and cycles the energy and nutrients accordingly. Grazing animals are an important part of the Carbon and Nitrogen cycles between plants and the soil, but the soil food web cycles more of these elements than above-ground herbivores.

'Second, soils that have been subjected to intensive tillage practices compared to those subject to reduced tillage practices often exhibit a higher rate of nitrogen mineralization during the shoulders of the growing season when the nitrogen is less likely to be used by the crops and more likely to be lost from the system through leaching.'

Tillage not only fosters nutrient loss by erosion, but upsets the balance of the soil food web so nitrogen becomes available too early or too late according to crop needs. Thus the nitrogen (typically in the form of nitrate) is more available for leaching below the root zone of crops. This, coupled with an often excessive application of nitrogen to the soil also disrupts the plant – soil food web association.

Cows grazing a multi-species cover crop. Photo by Ken Miller

Plants growing in an artificially rich nitrogen environment do not make associations with members of the soil food web (that the plants evolved with) because the plants will not give energy to the microbes when the plants' nitrogen needs are already met (or exceeded). In addition, soils compacted by aggregate destruction from tillage are also more likely to be anaerobic more of the time and experience denitrification, sending the nitrogen into the air as nitrous oxide, instead of remaining plant-available in the soil.

Therefore, a system based on heavy fertilization and tillage has many opportunities for the nitrogen to end up everywhere (sediment, surface water, ground water and air) except where it is desired… in the plants!

'For soils, agricultural practices and other human activities shift the community's structure and dynamics between the fungal pathway and to the

bacterial pathways. The consequences of these actions include changes in the rates of decomposition and a decoupling of nutrient dynamics from plant growth.'

A bacterial pathway is much less efficient at building soil and feeding plants than a fungal pathway of energy transfer in the soil. A soil that is dominated by bacteria (as most tilled soils are) will often decline in organic matter content as the bacteria respire more of the energy available to them than what they fix into soil organic matter. Therefore, a disturbed soil fights an uphill battle to increase in soil organic matter. An imbalance in bacterial vs. fungal activity in the soil also limits how plants can acquire the nutrients they need. Tilled soils put soil biology and the plants they feed at a significant disadvantage. A relatively undisturbed soil with good plant diversity and cover fosters biologic diversity and balance in the soil, increasing both soil organic matter and plant available nutrients.

A New Perspective on Weeds

By Jon Stika

The May 2008 issue of the No-Till Farmer included an article titled "Corn Doesn't Like the Sight of Weeds", a report by Darrell Buggink on a presentation given by Professor Clarence Swanton of the University of Guelph, Ontario, Canada. In his presentation, Prof. Swanton described a "critical period" when weeds must be controlled in corn in order to achieve the greatest yield of corn. This critical period is prior to the eight leaf stage on the corn plant. After that stage, weeds no longer had an impact on corn production.

The article reports that; "Swanton says he long believed that something other than competition for nutrients, moisture and sunlight was causing yield loss. He believes something has to be changing in the corn plant very early in the stages of its development to lose yield so quickly." Swanton stated that; "We found that our corn in the presence of the weeds grew 17% taller. Leaf area actually increased by 45% if it was grown in the presence of weeds and the dry weight of those leaves had increased by 40%... So right now you're probably thinking that maybe a little weed pressure is a darn good thing."

If weeds are not exhibiting competitive "pressure", perhaps the corn is allocating resources to collaborate with the plants around it? Our observations over the last several years that cover crop combinations out-produce single species cover crops, illustrates how plants collaborate to produce a greater total yield of biomass with a given supply of resources (soil, water, sunlight, nutrients, etc.). Perhaps instead of weeds competing for available resources (Liebig's Law of the Minimum) they are instead collaborating with corn in an attempt to produce the greatest total yield of the plant community of corn and weeds, rather than just the one species of corn?

Hairy vetch in corn at SWND Soil Health Demo in Dunn County, ND

Controlling weeds early prevents the corn from shaking hands, or roots, (aka the "brain" of the plant) and collaborating with weeds and thus transferring resources to the collaboration, reducing yield of the corn. If the corn is in a situation to go it alone early in its life, no resources will be allocated to collaborate with other plants. Instead, resources will go toward yield of the corn itself. Once corn passes the eight leaf stage, yield has been determined and any collaboration with nearby plants seems to only help, rather than hurt, corn yield.

If we control the collaborative association of corn with other plants until later in the growing season by inter-planting companion crops after the corn has grown for a time in a corn-only environment, perhaps we might be able to achieve a desired corn yield while adding diversity to feed the soil. Perhaps we should look at weeds as Nature's attempt to add diversity and provide opportunities for collaboration rather than as competitors against a crop. By controlling what and when other plants collaborate with our chosen crop (such as corn) we may be able to reduce inputs of fertilizer and pesticides while adding diversity to a cropping system. Nature has been providing the example of collaboration within native plant communities for a long time… perhaps we just need a new perspective?