USDA Northern Plains Climate Hub
U.S. DEPARTMENT OF AGRICULTURE

NORTHERN PLAINS CLIMATE HUB
EXTENSION & OUTREACH

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Changes in Soil Temperature and Nutrient Management with No-Till Farming Practices

There are many good reasons to reduce soil disturbance and tillage operations on the farm or ranch. These include reduced production costs, more efficient use of water, and increased resiliency to climate and weather variability.

The adoption of any new farming practice comes with some risk, and success with no-till will require commitment, flexibility, and an understanding of soil biology. This bulletin seeks to address two common concerns about transitioning to a no-till system: cooler soil temperatures at planting, and the need for additional nitrogen fertilizer.

Soil Biology

There are more individual microbes in a shovel full of soil than there are people on earth. These “underground livestock” include bacteria, fungi, algae, and protozoa, among others. Their job is to help plants access nutrients and water in the soil, improve seed germination, and convert raw materials like manure and crop residue into soil organic matter.[1] Insects, worms, and small animals also have an important role to play. They help break down the organic material in the soil into smaller pieces, excrete plant nutrients in their waste, and work hard to create space for air and water to move through the soil. Worms carry organic matter from the surface into the soil were the microbes can further break it down into plant food.

MP-144
July 2020

The entire soil biological system is driven by carbon. Plants convert CO_2 (carbon dioxide) into both tissue and ***root exudates***. Up to 20 percent of all photosynthetically fixed carbon is secreted by plant roots into the soil to feed microbes.[2] In return, these microbes help provide nutrients, water, and disease resistance for the plants.

Soil organic matter contains all of the 17 essential plant nutrients. It is made up of about 50 percent carbon, five percent nitrogen, 0.5 percent phosphorus, 0.5 percent potassium, and trace amounts of the other 13 essential nutrients. Many of these macro and micro-nutrients are not plant available until they have been broken down into their ionic form by the soil microbes through the process of ***mineralization***.

Think of soil organic matter as an investment that pays consistent dividends. In healthy soil with a thriving microbial population and minimal disturbance, microbes will recycle one to three percent of the soil organic matter per year and release the nutrients it contains in plant available forms. As the soil organic matter increases, so does your investment and your dividends.

Soil microbes are responsible for converting the nutrients in organic materials (e.g. manure, crop residue) into a form plants can use. They thrive in warmer soils with a "just right" balance of air and water. Cool, saturated soils will have less microbial activity and therefore less early season nutrient release from soil organic matter. This dynamic has an important effect on nitrogen management under no-till practices.

The Cost of Tillage

Tillage physically damages soil structure, causes erosion, and increases soil water loss (evaporation). Tillage also aerates the soil and stimulates bacterial activity. The majority of soil bacteria are aerobic. Tillage introduces oxygen which causes a rapid increase in bacterial activity, and consumption of soil organic matter. The result is a short-term flush of nutrients, and loss of stored soil carbon as CO_2. Think of this like cashing out your investment for a short-term benefit and losing your long-term investment.

While bacteria do thrive in heavily disturbed soils, tillage is deadly to worms and soil fungi. The long fungal filaments play a major role in soil aggregation and thus erosion resistance. Mycorrhizal fungi form beneficial associations with most plants and increase the plants ability to access water and nutrients like phosphorus and iron. Research comparing microbial biomass in cultivated and uncultivated soils of the Iowa prairie found that total microbial biomass in uncultivated soils was twice that of cultivated soils, and the uncultivated soils had three to five times more fungus than bacteria (by weight).[3]

Soils under long term no-till management have a larger, more diverse microbe population, more worms, more soil organic matter, better structure, and more water holding capacity.[4]

Bare soil is prone to wind and water erosion and loss of the farm's most valuable asset — topsoil. Soil armor (crop residue and mulch) moderates soil temperature extremes, reduces water loss through evaporation, and increases resiliency in the face of weather extremes (e.g., heavy precipitation events, or drought).

Soil Temperature

By eliminating or reducing tillage, more residue is left on the surface to protect against erosion and water loss, and moderate soil temperature. In some cases, this causes the soil to warm more slowly in the spring than it would if left bare. Producers in North Dakota[5], Idaho[6], Wyoming[7], and Montana[8] report that while some crops do get a slower start, they catch up by the end of the growing season and sometimes even do better. The benefits of cooler soil temperatures during the summer outweigh the costs of cooler temperatures in the spring.

Research in Manitoba[9] and Saskatchewan[10] found short-term differences in temperature and moisture between conventional and no-till fields at planting, but no reduction in cereal crop yield. Research in Sydney, Montana, compared no-till, strip-till, and conventional tillage practices for sugar beets and found that reducing tillage did not have a negative impact on seed germination, stand establishment, yield, or sugar content[11].

The benefits of cooler soils and less evaporation are especially significant under drought conditions or when irrigation water is restricted. Some producers report that they do not need to water up their crops after planting[12], and need to irrigate less frequently in their no-till fields.

Air is easier to heat or cool than water, so temperatures fluctuate more rapidly in drier soils (higher highs and lower lows). The temperature buffering capacity of the extra moisture in no-till soils could be advantageous in years with a late spring cold snap.

Nutrient Management

When reducing tillage and leaving more residue on the soil surface, farmers may need to adapt their nutrient management practices. Cooler soils at planting will have less microbial activity and therefore slower early season nutrient release (mineralization) from soil organic matter.

Root Exudates: Various amino acids, sugars, and organic acids that are secreted by plant roots. These exudates provide a host of benefits to the plants. They are a carbon (food) source for beneficial soil microbes, help release nutrients from soil minerals, signal neighboring plants to temporarily increase their defenses against pest or disease, inhibit or promote seed germination, and are a major source of soil carbon.

Mineralization: The microbial process by which large, complex organic compounds are broken down into smaller inorganic components that can be used by plants. For example, when a protein is broken down into nitrate, sulfate, and other ions that can be directly used by plants. This process is dependent on the ratio of carbon and nitrogen in the soil or residue being decomposed. When the ratio of carbon to nitrogen is below about 25:1, nitrogen and other nutrient will be made available for plants through the process of mineralization. The microbes that are involved in the mineralization of nitrogen require oxygen and thrive in soils between 77–95°F.

Immobilization: The microbial process by which plant-available nutrients are used by microbes and temporarily unavailable to plants. When nitrogen is immobilized in the soil it is temporarily "tied up" by soil microbes and no longer in the nitrate or ammonia form that plants can use.

In some cases, more early-season nitrogen may be required to maintain yields — depending on crop and soil conditions. While total soil nitrogen may be higher under no-till management (due to more soil organic matter), nitrate-N may be lower in wet, cool, or compacted soils.

High carbon crop residue like corn and grain stubble will immobilize nitrogen in the short-term. As soil microbial and worm activity increases over time, so will the rate of residue decomposition and organic matter ***mineralization.***[13] A review of 16 studies across the US and Europe found that on average, 32 lbs. of plant available nitrogen per acre were mineralized per one percent soil organic matter.[14] Nitrogen mineralization rates vary widely based on soil type, soil organic matter content, climate, weather, crop, and farming practices.

The soil microbes that are converting high-carbon crop residues and manures to soil organic matter need adequate amounts of nitrogen. Montana State University Extension recommends adding an additional 10 lbs. of nitrogen per 1,000 lbs. of wheat or corn stubble for the first few years of no-till.[15] This may not be necessary following low residue crops like sugar beets or beans.

References

1 Hoorman, J., and R. Islam. 2010. Understanding Soil Microbes and Nutrient Cycling. The Ohio State University. SAG-16-10. https://ohioline.osu.edu/factsheet/SAG-16

2 Walker, S., H. Bais, E. Grotewold, and J. Vivanco. 2003. Root Exudation and Rhizosphere Biology. Plant Physiology. 132: 44-51. http://www.plantphysiol.org/content/132/1/44

3 Stahl, P., T. Parkin, and M. Christensen. 1997. Fungal Presence in Paired Cultivated and Uncultivated Soils in Central Iowa. Biology and Fertility of Soils. 29: 92-97.

4 Hoorman, J., and R. Islam. 2010. Understanding Soil Microbes and Nutrient Cycling. The Ohio State University. SAG-16-10 (https://ohioline.osu.edu/factsheet/SAG-16).

5 Northern Plains Climate Hub Extension & Outreach. 2016. Learning from Your Neighbor: Climate Resiliency in Agriculture. Hosted by University of Wyoming Extension (https://www.youtube.com/playlist?list=PLBNu1peKp1UhPBPCuwle1xWsqzibGpxBk)

6 Ada Soil and Water Conservation District. 2016. Mob Grazing and No-Till in Furrow Irrigation (https://youtu.be/yjkO-PYzsoM).

7 University of Wyoming Extension. 2016. Soil Management on Wyoming Farms and Ranches (https://www.youtube.com/playlist?list=PLBNu1peKp1Uht17xauhrN-IslCgUF2XD0).

8 Montana NRCS. 2018. No-Till Sugar Beets in Montana: a Producers Perspective (https://youtu.be/PMXz_MKzRC4).

9 Gauer, E., C. Shaykewich, and E. Stobbe. 1982. Soil Temperature and Soil Water under Zero Tillage in Manitoba. Canadian Journal of Soil Science. 62: 311-325.

10 Carter, M., and D. Rennie. 1985. Soil Temperature Under Zero Tillage Systems for Wheat in Saskatchewan. Canadian Journal of Soil Science. 65: 329-338.

11 Afshar R., A. Nilahyane, C. Chen, H. He, W. Stevens, and W. Iversen. 2019. Impact of Conservation Tillage and Nitrogen on Sugarbeet Yield and Quality. Soil and Tillage Research. 191: 216-223.

12 Lilleboe, D. Dec., 2012. No-Till Sugarbeets: Working Well for N.E. Montana Growers. Sugarbeet Grower Magazine (https://www.sugarpub.com/feature/no-till-sugarbeets-working-well-for-ne-montana-growers).

13 Northern Plains Climate Hub Extension & Outreach. 2016. Learning from Your Neighbor: Climate Resiliency in Agriculture. Hosted by University of Wyoming Extension (https://youtu.be/hJauftqytrQ).

14 Vigil M., B. Eghball, M. Cabrera, B. Jakubowski, and J. Davis. 2002. Accounting for Seasonal Nitrogen Mineralization: An Overview. Journal of Soil and Water Conservation. 57: 464-469.

15 Montana State University Extension. 2014. Nutrient Management in No-Till and Minimum Till Systems. EB0182.

Issued in furtherance of extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Kelly Crane, director, University of Wyoming Extension, University of Wyoming, Laramie, Wyoming 82071.