Effect of Diversified Crop Rotations and Nitrogen Rates on Soil Organic Matter and Nutrient Levels

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Introduction

Diversified, no-till cropping systems are beneficial for pest control and soil quality, and can produce higher net economic returns than no-till continuous wheat (Miller et al. 2008). However, long term effects of these systems and nitrogen (N) rates on soil fertility are largely unknown in Montana. Our objectives were to determine effects of diversified crop rotations and N rates on changes in soil organic matter and nutrient levels over an eight year period.

Methods

This study evaluated the nutrient status in 68 plots between the 4th and 12th year of the Crop Diversification Rotation Study (CDRS). The field study near Bozeman was initiated in 2000 with broadleaf and cereal crops grown concurrently, but converted in 2004 to a design with alternate year broadleaf-cereal rotations, to minimize insect pest problems. Rotations prior to 2004 are described in Fertilizer Fact 36 (http://landresources.montana.edu/fertilizerfacts). From 2004 to 2008, five annual no-till (NT) cropping systems were represented: diversified (NTD), winter (NTW) emphasizing winter crops, spring (NTS) with cool-season spring crops, continuous wheat (CW) alternating between winter and spring wheat, and pesticide-free production (PFP) which generally avoided soil residual and in-crop pesticides. In addition, there was an organic (ORG) system which had identical crops as the PFP rotation yet was tilled, not fertilized, and never sprayed with herbicides. A legume green manure was grown and terminated in both PFP and ORG systems one in four years. NTD, NTW and NTS had a high (H) and low (L) input strategy based largely on fertilizer N rate. Low input rotations received ½ the recommended high rate, which was similar to MSU fertilizer guidelines. PFP and CW received only the high N rate.

Urea N fertilizer was typically mid-row banded with the seed, although there were a few occasions where supplemental urea was hand-broadcast. All rotations, except ORG, were treated with 23 lb P_2O_5/ac, 22 lb K_2O/ac, and 8 lb S/ac. Each rotation, except CW, was a four-year crop rotation alternating broadleaf with cereal crops. In 2008, changes to rotations were adopted largely to address weed issues and to compare systems with legume and non-legume broadleaf crops. Specifically, the NTS system was converted to a pulse (NTP) rotation containing pulse and cereal crops and the NTW system was replaced by an oilseed (NTO) rotation to combat weeds. In addition, safflower replaced sunflower in the NTD rotation, and sweet clover green manure replaced winter pea green manure/forage in the ORG and PFP systems to compete better with Canadian thistle by extending rooting depth.

Four soil samples were collected in late March 2004 and early April 2012 (near the time of seeding) from each plot. The upper 6 in. of soil was analyzed for soil organic matter (SOM), total N, Olsen phosphorus (P), soil test potassium (K), and exchangeable zinc (Zn). Soil organic N (SON), which can supply a substantial amount of available N each year, was calculated as total N – nitrate-N.

Fertilizer Facts

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Results

Soil organic matter increased more in NTO and PFP than in NTD, NTP, or ORG between 2004 and 2012 (Figure 1). The NTO system was dominated by winter grains from 2004 to 2008 and lacked pulses from 2008 to 2012 both of which likely increased biomass returned to the soil compared to the rotations with lower SOM increases. The SOM increase in PFP likely came from the high residue provided by safflower, winter wheat, and a legume green manure rotation. The much higher SOM increase in the fertilized PFP system compared to the ORG system demonstrates the importance of fertilizer and reduced tillage in building SOM. The SOM increase in CW did not differ from NTO or PFP, likely because it was also a high residue system.

Increases in SON were higher for the CW rotation than for NTD, NTP, PFP, and ORG rotations (Figure 1), again likely related to residue returned and possibly to higher carbon:nitrogen (C:N) ratios in the CW rotation, slowing residue decomposition. Olsen P concentrations increases were not different among the NT systems and were at least 3 ppm (data not shown). Olsen P levels decreased substantially in the ORG systems and now are well below the critical level of 16 ppm. Soil test K was higher in the CW rotation than the NTP and ORG rotation (data not shown); this may in part be explained because pulses remove more K per bu than cereals. Changes in available Zn were not affected by rotation (data not shown). Somewhat surprisingly, N rate did not affect any of the soil parameters measured.

Fertilizer Facts

- Crop rotation affected SOM, SON, Olsen P, and soil test K.
- No-till continuous wheat (CW) and oilseed-wheat (NTO) rotations built SON more than diverse systems containing pulses, likely due to more high C:N residue returned in CW and NTO rotations. SON can serve as a reservoir of available N in future years but takes additional N fertilizer to build.
- All NT rotations increased Olsen P, whereas ORG rotations (w/o fertilizer inputs) decreased Olsen P.
- Fertilizer N rate (½ vs full rate) did not affect changes in any soil nutrient measured.

Acknowledgements

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References

Miller, P.R., D.E. Buschena, C.A. Jones, and J.A. Holmes. 2008. Comparison of no-till and organic diversified annual grain cropping systems: Agronomic, economic, and soil analyses. Agron. J. 100:591-599.

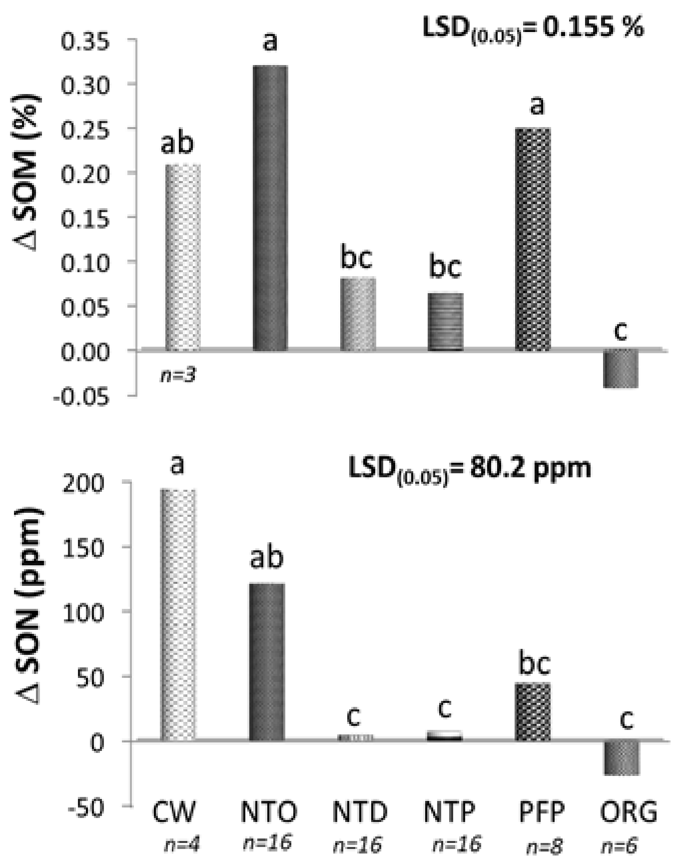

Figure 1. Mean change (Δ) in SOM and SON levels for six annual cropping systems in CDRS experiment. Bars within each graph with the same letter are equal with 95% confidence. "n" indicates the number of plots.

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