

Soil Fertility Status after a 4-Year Transition Period to Diversified No-Till and Organic Systems

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Introduction

Continuous wheat and wheat-fallow systems in Montana are facing challenges from pest, environmental, and economic perspectives, especially with higher than normal fertilizer nitrogen (N) costs and relatively low wheat prices. Therefore, diversified cropping systems are being studied that are profitable, and improve, or maintain soil fertility. No-till systems have become very common in Montana due both to fuel savings and decreased soil erosion. Organic systems are also becoming more popular; though available nutrient levels could become depleted over time on organic farms because it is often not practical or economical to add organic fertilizers. Therefore, a multi-year study was initiated in 2000 to compare yields among four no-till systems and one organic system (Table 1), during the transition from conventional tillage. Winter wheat grain yields from 2001-2003 varied by up to 30% between rotations, yet the cause of these differences was not known, and possibly was due to differences in soil nutrient levels between rotations.

Methods

Soil test phosphorus (P), potassium (K), and sulfate ($\text{SO}_4\text{-S}$) were all above critical levels at this site; therefore, only 'starter' amounts (15, 22, and 7.5 lb/ac of P, K, and S, respectively) of each were added with the seed in each of the four years of the study. Application amounts of N were based on Fertilizer Guidelines for Montana Crops (EB 161). No manure was added to the organic plots because manure is generally not added to organic small grains grown in Montana due to expense and the potential for weed seeds. All 68 plots were soil sampled in March 2004, prior to spring seeding. Sampling was conducted between rows of fall-seeded crops. Four subsamples from each plot were sampled with a 1.5 in. diameter auger at 0-6, 6-12, and 12-24 in., and each depth increment was composited in a stainless steel mixing bowl. Samples were submitted for nutrient analyses, and potentially mineralizable N (PMN) was determined using a 7-day incubation at 104°F. PMN gives a relative estimate of the amount of organic N that is readily made plant-available by soil microbes.

Results

No-Till – Organic Comparison

Nitrate-N and sulfate-S were significantly lower in the organic rotations than in the fertilized no-till plots (Table 2). The higher nitrate-N in the no-till plots led to vigorous early season growth and increased water stress; this stress was the likely cause of observed lower winter wheat yields in the no-till fertilized plots. The organic winter wheat had lower proteins than the other rotations, likely as a result of the lower N levels. Olsen P and soil test K levels were also significantly lower in the organic plots than in the no-till treatments. The Olsen P concentrations in the organic plots were not much higher than the critical level in Montana (16 mg/kg). Due to the lack of P inputs to the organic plots, lack of P will likely limit yields in the organic rotations in the future. Potentially mineralizable N (PMN) was significantly higher in the organic plots than in the no-till plots. This difference is likely due to both the incorporation of green manure in the organic soils and increased surface area of soil organic matter and residue caused by tillage (used for weed control in 3 of 4 years). Organic N (TKN), organic matter (O.M.), and soil test Zn, were not significantly different in the organic plots than in the no-till plots.

Rotation Comparison

Nitrate-N concentrations in specific rotations were largely a function of previous fertilization, and were elevated due to very low summer moisture which depressed yields and N uptake (Figure 1). Olsen P concentrations were significantly higher in the winter wheat based and diverse rotations than in the organic and spring wheat based rotations (Figure 2). The spring wheat based rotation may have had more P uptake from the upper 6 in. or taken up more P later in the growing season (closer to sampling time) than the other no-till rotations. It is expected that the differences in nutrient levels between rotations will become larger with time. Because nutrient concentrations were adequate for growth in all rotations, the yield differences mentioned previously were likely not caused by nutrients, but by differences in water use of previous crops. This was confirmed by comparing 2004 winter wheat grain yield to April 2004 soil moisture as estimated by a Paul Brown probe (data not shown).

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Summary

In conclusion, there were some small, but measurable differences in soil nutrient levels after four years of a cropping systems study. The most consistent differences were between no-till and organic systems, not unexpected given the lack of fertilization in the organic systems. There were also some differences in nutrient levels between no-till systems, strongly suggesting that previous crop and cropping system can affect nutrient levels, and possibly yield and quality. In this study, yield differences were more likely a result of differences in water use of previous crop(s) than due to differences in soil nutrient levels.

Edited by Clain Jones, Extension Soil Fertility Specialist, and Evette Allison, Research Associate

Fertilizer Facts:

- Average soil concentrations of nitrate-N, P, K, and sulfate-S were all significantly lower in organic rotations than fertilized no-till rotations.
- There were some significant differences in soil nutrient levels between crop rotations, and therefore, rotations may affect long-term soil fertility.
- Spring wheat based no-till rotations had lower N and concentrations than the other no-till rotations.
- Producers should consider not just yield and economics when selecting cropping systems, but also the effects of previous crops on available soil nutrient levels, mineralizable N, and soil moisture levels.

Table 1. Crops in each rotation of crop diversity rotation study from 2000-03 (all phases present each year).

Rotation	Phase 1	Phase 2	Phase 3	Phase 4
Organic (Org)	winter pea grn mnr*	winter wheat	lentil	barley
No-till Spring (NTS)	spring pea	spring wheat	spring canola	spring wheat
No-till Winter (NTW)	winter pea	winter wheat	dormant spr canola	winter wheat
No-till Diverse (NTD)	spring pea	winter wheat	millet/corn	sunflower
No-till Cont. Wheat (CW)	winter wheat	spring wheat	winter wheat	spring wheat

* Organic winter pea green manure was seeded directly (i.e. no-till) into phase-4 barley stubble.

Table 2. Mean nutrient concentrations for fertilized no-till and organic rotations after 4 years of cropping.

Rotation	Number of plots	Nitrate-N 0-24 in. (lb/ac)	Olsen P 0-6 in. (ppm)	K 0-6 in. (ppm)	Sulfate-S 0-24 in. (ppm)	PMN* 0-24 in. (lb/ac)	TKN 0-6 in. (%)	O.M. 0-6 in. (%)	Zn 0-6 in. (ppm)
No-Till	52	125	21	413	11.7	71	0.123	2.11	0.54
Organic	16	74	18	387	9.6	87	0.121	2.05	0.51
NT vs Org (P-value)**		<0.0001	0.08	0.07	<0.0001	0.06	0.14	0.12	0.20

* Potentially Mineralizable Nitrogen from a 7 day, 104°F incubation.

** Means with a P value less than 0.1 are significantly different (with at least a 90% probability).

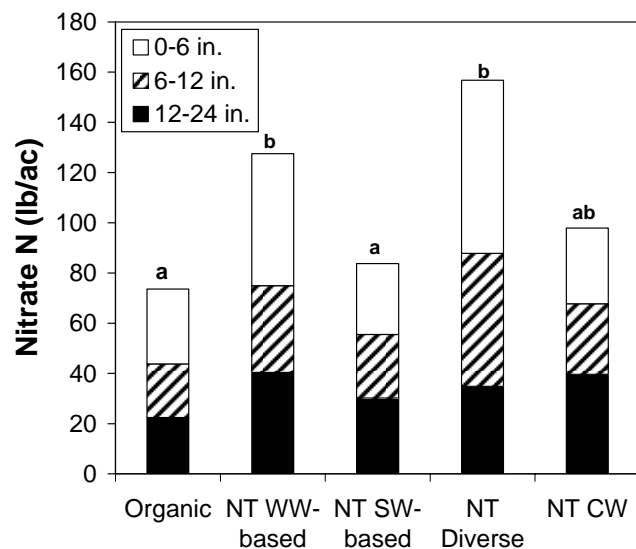


Figure 1. Nitrate-N concentrations in three depth increments for each rotation. Different letters above each bar indicate significant ($P < 0.1$) differences.

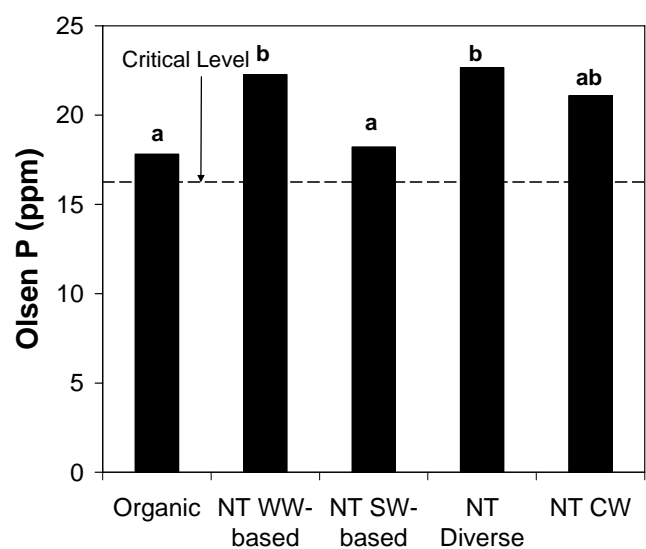


Figure 2. Olsen P concentrations (0-6 in.) for each rotation. Different letters above each bar indicate significant ($P < 0.1$) differences.