Assessment of selected soil parameters in a long-term Western Canadian organic field experiment

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Abstract

A long-term field study was used to compare soil nitrogen and phosphorous status, and soil aggregate stability in organic and conventional cropping systems. Two rotations were tested: a grain only and a grain-alfalfa hay rotation. The organic systems had a lower nitrate leaching potential than the same rotations under conventional management. After 13 years, one organic system (the grain-alfalfa; no manure return) is suffering serious soil P depletion. However, the grain only and the grain-alfalfa with manure return to land systems had soil P levels similar to the prairie grass control treatment and showed no signs of P deficiency. Despite having lower levels of organic carbon, the organic soils had higher levels of wet aggregate stability than conventionally managed soils.

Introduction

Soil fertility and erosion risk are major concerns in Canadian organic grain production. Surveys of organic fields in western Canada indicate that while soil nitrogen (N) supply appears adequate and sometime excessive, soil available phosphorous (P) is often lacking (Entz et al., 2001). Our first question regards N leaching potential in organic compared to conventional systems under the variable weather conditions experienced in western Canada. We were interested in whether the 2006 drought, which resulted in low crop N uptake that year, increased the risk of future N leaching in organic and conventional systems. Our second objective was to compare soil P in different organic farming systems and determine whether long-term organic management is depleting soil P. Western Canada is dominated by large fields and soil erosion poses a major threat to soil sustainability. Hence, our third objective was to determine the effect of long-term organic management on soil erodibility through measures of wet aggregate stability.

Materials and methods

The Glenlea study is located near Winnipeg, Canada on a Black Chernozemic soil (9% sand; 26% silt; 66% clay). Annual precipitation is 500 mm. Two, four-year rotations have been investigated at Glenlea since 1992 (grain only and grain-alfalfa). The grain only rotation consists of flax-oat-fababean-wheat, while the grain-alfalfa system consists of flax-alfalfa-alfalfa-wheat. Each rotation is conducted under conventional and organic management. The experiment also includes a restored prairie grass plot that serves as an ecological benchmark treatment. The experimental design is a randomized complete block with three replications. All grain crops are harvested for seed. Fababean is green-manured in the organic system and harvested for seed in the conventional system. Alfalfa is harvested for hay. In 2000, all alfalfa-grain system plots were divided and one-half received a one-time application of 10 t/ha composted manure, while the other half did not.

Measurements relevant to this study include crop yield and quality, soil carbon, soil nutrient status (N and P), mycorrhizal colonization of flax roots and wet mean weight diameter of soil (Angers and Mehuys 1988). A P balance was conducted using differences in P removed by crops, added through fertilizer (or manure) between 1993 and 2004.

Results

N content of soils to 120 cm was determined on samples taken in September 2006. The 2006 growing season was very dry and crop N uptake averaged <60 kg/ha (data not shown). Both conventional rotations had very high residual N levels (Table 1), and N leaching risk was considered high. Much lower N levels were observed in both organic rotations (Table 1); N leaching potential in organic was considered very low. Results suggest that organic systems, even those containing alfalfa, were at lower risk for N leaching than conventionally-managed systems.

A thorough examination of soil P was conducted from soil sampled in 2003. Results for total soil P indicate relatively high levels for all treatments, reflecting the natural fertility of these soils (Table 2). However, the grain-alfalfa system with no manure returned to land had lower ($p<0.05$) levels of P than other systems. Sodium bicarbonate extractable P was lowest ($p<0.05$) in the grain-alfalfa system (<10 kg/ha; data not shown). These observations suggest that a farming system that exports alfalfa hay but does not receive animal manure is at risk of a P deficiency. The results from our expected P balance analysis (Table 2) confirm that the alfalfa-grain system with no manure added had the highest level of P removal. It was interesting to observe that the grain-alfalfa with no manure treatment is showing physical signs of P deficiency in the alfalfa. For example, in 2006 alfalfa yields were reduced by 75% in the organic compared with the conventional plots (data not shown).

Mean wet aggregate stability was measured to assess soil erosion potential. The organic systems had significantly higher soil stability than the conventional systems in both the grain only and the grain-alfalfa systems (Table 3). This observation was surprising, especially given that soil C levels were actually lower ($p<0.05$) in the organic system (4.8 vs. 5.1% for conventional). Higher soil stability under organic compared with conventional management may be due to greater mycorrhizal colonization in the organic system (Entz et al., 2004) in 2003 (Table 3).

Tab. 1: Soil nitrate-N (kg/ha) in three soil depths for two farming systems (grain only and grain-alfalfa) under organic and conventional management at Glenlea, Manitoba in September, 2006. Numbers followed by different letters are significantly different at P<0.05.

Soil depth (cm)	Grain only conventional	Grain only organic	Alfalfa-grain conventional	Alfalfa-grain organic
0-15	91	23	100	12
15-60	62	20	67	31
60-120	31	15	43	15
0-120	***184a***	***57b***	***210a***	***57b***

Tab. 2: Total soil P (kg/ha) measured in autumn of 2003 and expected P balance (1993-2004) for different crop rotations under organic and conventional management at Glenlea.

Crop rotation	System	Total soil P	Expected P balance
Grain	Conventional	305a*	+18
Grain	Organic	301a	-56
Grain-alfalfa	Conventional	285a	+41
Grain-alfalfa	Organic	219b	-120
Grain- alfalfa	Conventional with manure	315a	+65
Grain-alfalfa	Organic with manure	275a	-100
Prairie	Organic	310a	

* numbers followed by a different letter are significant for *P*<0.05

Tab. 3: Soil mean weight diameter and percent root colonization by mycorrhiza for two rotations conducted under conventional and organic management at Glenlea in 2003.

Crop rotation	System	Aggregate Mean Weight Diameter (Wet)	Mycorrhizal colonization (% root infected)
Grain	Conventional	0.786 b	30 b
	Organic	0.946 a	50 a
Grain-alfalfa	Conventional	0.885 ab	27 b
Grain-alfalfa	Organic	0.986 a	45 a
Prairie	Organic	-	82 a

* numbers followed by a different letter are significant for *P*<0.05

Discussion

Dry seasons often cause available N to accumulate in prairie soils. This N poses a leaching risk. Both organic rotations in the present study showed less N buildup than the conventional rotations, which means the organic system was at lower risk for N leaching. This observation contradicts some previous studies where organic rotations, especially those containing perennial legumes, were found to have a high leaching potential. P depletion was discovered in the organic grain-alfalfa hay system. Therefore, despite having adequate levels of soil N, the alfalfa hay export system is not sustainable. The problem of P depletion in the grain-alfalfa rotation appears to have been overcome by returning some composted manure to the soil (Table 2). Organic farmers who produce alfalfa for off-farm export need to monitor the soil P status of their soils and be prepared to take action to reverse P depletion.

Conventional soil science wisdom suggests that a decrease in soil C will result in less aggregated soil. In the present study, higher levels of wet aggregate stability could not be attributed to soil C since soil C was lower in the organic system regardless of rotation type. Perhaps it is the improvement in soil biology, namely glomalin production by mycorrhiza, that is responsible for more stable organic soils.

Conclusions

After 13 years, soil P levels in organic grain and grain-alfalfa (with manure) systems were similar to the natural prairie and showed no signs of depletion. Soil P depletion was observed in the grain-alfalfa rotation (no manure). Crop-livestock integration appears important on organic farms.

After a drought year, organic systems were found to be less prone to nitrate leaching than conventional systems.

Organic systems were found to have greater soil wet aggregate stability than conventional systems, despite having lower soil C concentrations. Additional soil ecology research is required to better understand these results.

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References

Angers, D.A. and G.R. Mehuys. 1988. Effects of cropping on macro-aggregation of a marine clay soil. Can. J Soil Sci. 68:723-732.

Entz, M.H., R. Guilford, and R. Gulden. Crop yield and nutrient status on 14 organic farms in the eastern Northern Great Plains. Can. J. Plant Sci. 81:351-354.

Entz, M.H., K.R. Penner, J.K. Vessey, C.D. Zelmar and J.R. Thiessen Martens. 2004. Mycorrhial colonization of flax under long-term organic and conventional management. Can. J Plant Sci. 84:1097-1099.