Tillage and Crop Rotation Effects on an Ultra-Labile Soil Carbon Pool

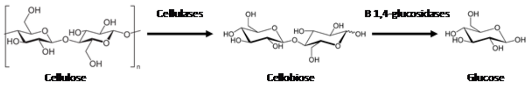
V. E. Scott, M. M. Al-Kaisi, and M. A. Tabatabai

Department of Agronomy, Iowa State University, Ames, Iowa 50011-1010

Introduction

Soil carbohydrates are among the soil organic carbon components which reach new equilibrium rapidly after changes in land use (Spohn and Giani, 2011). Although there are many sources of carbohydrates in soil, each is subject to hydrolysis by specific enzymes (glycoside hydrolases (EC 3.2.1.-).

The products of such reactions include reducing sugars, as illustrated in Fig. 1 by the breakdown of cellulose to cellobiose by cellulases (EC 3.2.1.4, EC 3.2.1.91) and further to glucose by β-glucosidases (EC 3.2.1.21). Reducing sugars are then readily metabolized by soil microorganisms, releasing CO_2 under aerobic conditions.



[Fig. 1]

Literature revealed that 60% methanol solution is effective in quenching cellular metabolic activity with minimal interference to enzymatic activity at temperatures above freezing (Faijes et al., 2007; Sellick et al., 2011). Enzyme activity in soil, especially that of glucosidases, is sensitive to soil management practices (Knight and Dick, 2004).

We developed a method involving the use of 60% methanol to inactivate the microbial populations in soils without affecting the activities of the enzymes involved. Therefore, we used this method to investigate the effects of tillage systems , crop rotations, sampling time, soil depth, and aggregate size on the total potential reducing sugar pools (RSP) in soils.

Materials and Methods

To study the effects of tillage systems and crop rotations on RSP, soils were obtained from four experimental locations in Iowa (Table 1). Soil (0-15 cm) was collected post-harvest from each location in Fall 2011, each having continuous corn (CC) and corn-soybean (CS) rotations, both with no-till (NT), chisel-plow (CP), and moldboard plow (MP) tillage treatments.

To study the effects of sampling time on RSP, soil (0-15 cm) from the Ames location was sampled again in the spring, six days before a tillage pass (Spring), and again one day after the tillage event (Spring After Disking).

To study the effects of soil depth and aggregate size on RSP, 15 cm long soil cores were collected from NT, CP, and MP tillage treatments under the CS crop rotation in Ames. Cores were then divided into surface (0-7.5 cm) and subsurface (7.5-15 cm) subsamples. Subsamples were then gently broken along planes of natural weakness into a nest of sieves sized 8, 4, 2, 1, and 0.5 mm and shaken up and down on a mechanical shaker (Sieve Tester, Model # SS15, Gilson Company, Inc.) for exactly two minutes.

Field-moist soils were stored in plastic bags at 4˚ C until analysis.

To quantify (RSP), 5.0 g (air-dry eqv.) of field-moist soil was incubated at 30˚ C for 5 days in 25 mL of 60% methanol, and the total amount of reducing sugars produced was determined colorimetrically by the Somogyi-Nelson method (Wood and Bhat, 1988), using D-glucose as a standard.

Table 1. Properties of soils used.

Location	Soil Series	Soil Classification	pH[a] H_2O[b]	pH[a] $CaCl_2$[b]	Organic C[b] ---g kg^{-1}---
Ames	Webster	Fine-silty, mixed, superactive, mesic Typic Hapludoll	5.0-5.6 (5.3)	4.6-5.2 (4.9)	18.0-32.6 (27.0)
Lewis	Marshall	Fine-silty, mixed, superactive, mesic Typic Hapludoll	5.8-6.4 (6.2)	5.3-6.2 (5.8)	15.7-24.3 (20.7)
Nashua	Kenyon	Fine-loamy, mixed, superactive, mesic Typic Hapludoll	5.2-5.9 (5.6)	4.5-5.3 (5.0)	24.9-32.1 (28.7)
Sutherland	Galva	Fine-silty, mixed, superactive, mesic Typic Hapludoll	5.3-5.9 (5.7)	4.6-5.4 (5.1)	14.9-36.2 (23.9)

[a] Soil:water or 0.01 *M* $CaCl_2$ ratio 1:2.5.
[b] Range of values reported is followed by the average for all plots at each location.

Results

Tillage and Crop Rotation Effects

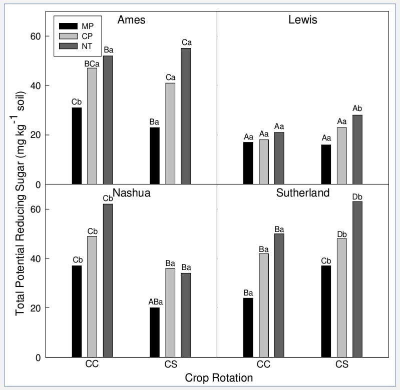


Figure 2. Effects of tillage and crop rotation on RSP in soils. Different upper case letters denote significant differences among locations within the same tillage system and crop rotation. Different lower case letters denote significant differences between crop rotations within the same location and same tillage system, based on LSD at $p < 0.05$.

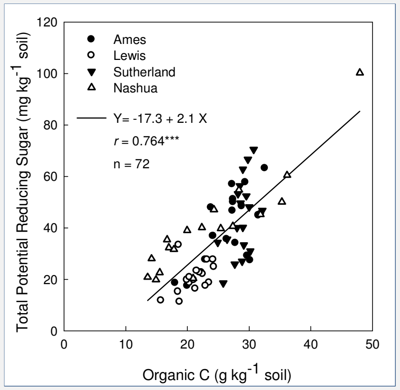


Figure 5. Relationship between RSP values and total organic carbon in soils.

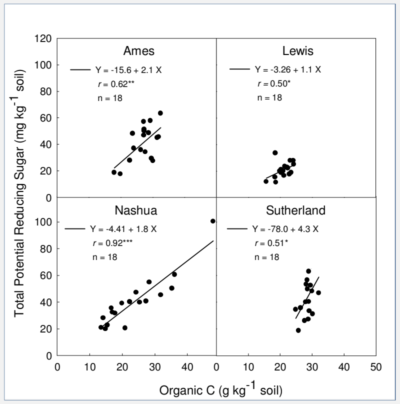


Figure 6. Relationships between RSP values and total organic carbon in soil at each of four locations.

Temporal Effects

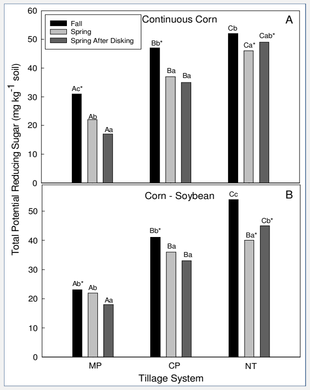


Figure 3. Effects of tillage on RSP in soils sampled in Fall, Spring, and Spring after tillage. Different upper case letters denote significant differences in RSP in soils from different tillage systems at the same sampling time within each crop rotation. Different lower case letters denote significant differences among times of sampling within the same tillage system and crop rotation. An asterisk indicates a significant difference between crop rotations within the same sampling time and tillage system. All comparisons were based on LSD at $p < 0.05$.

Aggregate Size & Depth Effects

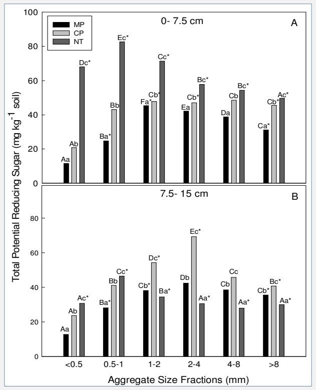


Figure 4. RSP values of field-moist soil aggregate fractions of different depths as affected by tillage. Different upper case letters denote significant differences in RSP of different aggregate size fractions for the same tillage system and depth. Different lower case letters denote significant differences in RSP among different tillage systems and the same aggregates size fraction and depth. Asterisks denote significant differences between depths within the same tillage system and aggregate size fraction. All comparisons were based on LSD at $p < 0.05$.

Interpretations & Conclusions

- Results showed that the RSP values were significantly affected by the type of tillage treatments. The values decreased in the following order: NT > CP > MP.
- Crop rotations significantly affected RSP values. Greater RSP values were found in the CS system when soils were sampled after soybean harvest than in the CC system (Lewis and Sutherland locations). Contrastingly, values were greater in CC system soils than in soils sampled after corn in the CS system (Ames and Nashua locations).
- The RSP values decreased after winter, as the values obtained for soil sampled in the Spring were lower than those of samples obtained in the Fall; a significant decrease in RSP was noted after a single secondary tillage pass in the Spring.
- On average, the greatest RSP values were found in the 0.5- 1 and 1-2 mm field-moist soil aggregates of soils sampled from both surface and subsurface depths than all other size aggregates, especially in the NT system.
- The RSP concentrations were stratified in the NT system, where greater values were observed in all aggregate size fractions from the 0-7.5 cm depth soil compared with the 7.5-15 cm depth soil. A homogeneous distribution of RSP was found among soil aggregates of surface and subsurface soils in systems subjected to tillage.
- The RSP values were significantly correlated ($p < 0.001$) with SOC of 72 surface soil samples. The linear correlation coefficients of the relationship between the RSP values and SOC varied among the four locations studied, ranging from $r = 0.50^*$ to 0.92^{***} ($p < 0.05$ to 0.001).
- We conclude that the method used is highly sensitive to changes in labile soil carbon due to management practices, and that it is useful for evaluating the potential impacts of these treatments on soil quality and C dynamics.

References

Faijes, M., A. Mars, E. Smid, 2007. Comparison of quenching and extraction methodologies for metabolomic analysis of *Lactobacillus plantarum*. Microbial Cell Factories. doi:10.1186/1475-2859-6-27.

Knight, T.R., R.P. Dick, 2004. Differentiating microbial and stabilized b-glucosidase activity relative to soil quality. Soil Biology & Biochemistry 36, 2089–2096.

Sellick, C.A., R. Hansen, G. M. Stephens, R. Goodacre, A.J. Dickson, 2011. Metabolite extraction from suspension-cultured mammalian cells for global metabolite profiling. Nature Protocols 6: 1241–1249.

Spohn, M., L. Giani, 2011. Impacts of land use change on soil aggregation and aggregate stabilizing compounds as dependent on time. Soil Biology & Biochemistry 43: 1081-1088.

Wood, T.M., and K.M. Bhat. 1988. Methods for measuring cellulase activities. In: W. Wood, and S.T. Kellogg (Eds.) Methods in enzymology. Vol 160 pp 87-112. Academic Press, New York.