Corn Stover Removal Effects On Soil Aggregation and Squash Fruit Yield in Cover Cropping Systems

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Introduction

Recent interests in renewable energy sources has prompted the use of crop residues as potential biofuel feedstocks (Graham et al. 2007). In Southwestern Ontario, as in many corn growing regions, one of the main feedstocks for lignocellusic ethanol is corn stover, which consists of the aboveground biomass remaining after grain harvest. However, there are concerns that the removal of corn stover could negatively impact agronomic production as well as soil and environmental quality (Blanco-Canqui and Lal 2007). Soil aggregate stability has been suggested as a soil quality indicator for crop production (Ashad and Martin 2002). For squash growers using cover crops, the effect of corn stover removal on fruit yield and soil structure is not yet clear. The objective of this study was, therefore, to evaluate the effect of corn stover removal on squash fruit yield and soil aggregation in cover cropping systems.

Materials and Methods

Site description

- Cover crop trial was established on a Brookston sandy loam (Table 1) every autumn since 2007 and 2008 at the University of Guelph (Ridgetown Campus) (42˚46'N, 81˚96'W).
- Randomized complete block design with 4 replications in a split-plot arrangement.
  - Main plot factor was the cover crop (Table 2).
  - Split-plot factor was the presence or absence of corn stover.
  - Split-split-plot factor was the nitrogen rate.
- Grain corn (*Zea mays* L.) was grown in 2011 and 2012. Following corn harvest, stocks were chopped and corn stover was either removed or retained.
- Field was tilled and planted to Acorn squash *(Cucurbita pepo,* cv. Autumn Delight*)* in late May 2012 and 2013.
  - Two nitrogen rates were tested per plot: 0 kg ha^{-1} and 110 kg ha^{-1}.
- Squash harvest was in mid September 2012 and 2013. A 3m section in the middle row of each subplot.
  - Plant and fruit biomass were harvested by hand to estimate fruit yield, fruit number and plant population.

Table 1. Soil characteristics

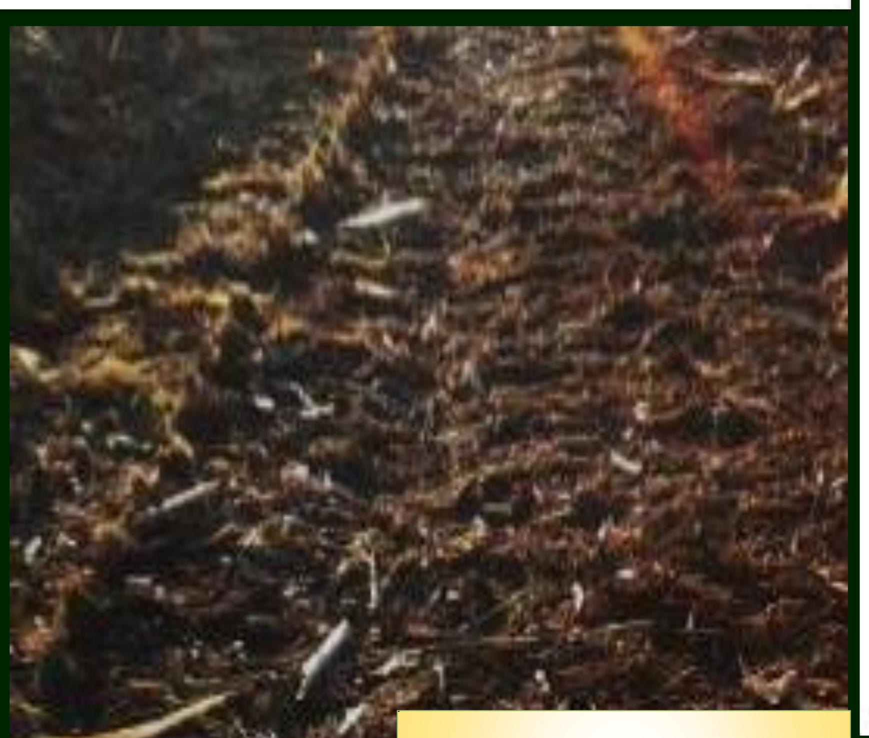
Texture	Sandy loam
% sand, silt, clay	75:18:07
pH	6.7
Organic matter (%)	3.8
CEC (MEC/100g)	9.9
Nutrients (ppm)	
P	33
K	174
Ca	1399
Mg	144

Table 2. Cover crops and drilled seeding rate

	Seeding rate (kg ha^{-1})
Control (no cover)	-
Oat (*Avena sativa.* L)	81
Cereal rye (*Secale cereale*. L)	67
Oilseed radish (*Raphanus sativus* L.)	16
Oilseed radish + Cereal rye	9+34

Table 3. Monthly weather conditions during growing season.

	Rainfall (mm)			Temperature (˚C)		
	2012	2013	30 yr mean	2012	2013	30 yr mean
May	34	64	75	15.5	15.1	14.8
June	45	102	83	22.6	18.6	20.2
July	155	78	86	22.1	21.2	22.5
August	73	53	86	19.8	19.3	21.4
September	67	89	93	15.5	15.9	17.6



Stover removed

Stover retained

Squash subplot

Soil aggregate stability

- Three core samples (7.5 cm diameter) were taken randomly within each subplot at a depth of 0-15 cm, homogenized and stored at 4˚C for up to 10 d.
- Samples were collected one day prior to tillage (late May 2012 and 2013), and one month after tillage (late June 2012 and 2013).
- Aggregate stability was measured using a wet sieving method (Pojasok and Kay 1990) to assess the stability of macroaggregates (WSA).
- Two 5g subsamples were placed on a Whatman No 42 filter paper and transferred to a wetting table for 90 minutes (-0.1 kPa), where the soil was wetted by capillarity (Photo #1 and #2).
- Samples were introduced to 50 mL test tubes, filled with 40 mL of water, and inverted over-and-end for 10 min (25 oscillations min^{-1}).
- Ensuing suspension was poured through a 250 µm sieve. Soil on the sieve was oven-dried (45˚C for 24 hr) and weighed. Filtrate was collected and turbidity was measured using HACH 2100Q turbidimeter to determine nephelometric turbidity unit.
- A correction was made for sand particles greater than 250 µm remaining on the sieve after dispersion with 5% sodium metaphosphate.

Photo #1

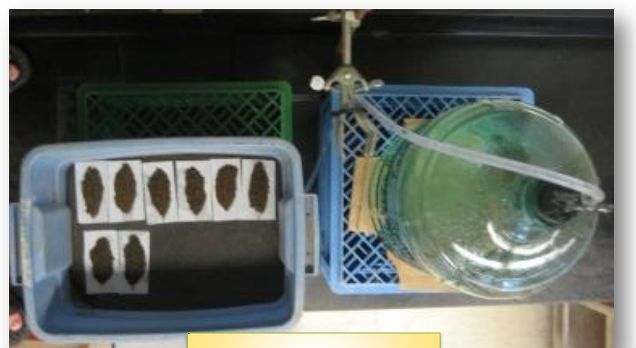


Photo #2

Results and Discussion

Soil Aggregate Stability

The removal of corn stover did not have a significant effect on soil aggregation in cover crop systems in spring 2012 and 2013 (P=0.1571). Similarly, cover crop treatments did not show significant differences (P= 0.8992) in water stable aggregates for both years. Soil aggregation was, however, significantly different between monthly sampling times (P=0.0058) for 2012 and 2013 (Table 4). Since, cover crops were not grown during the 2011-2012 winter seasons, plant biomass inputs were minimal, thus contributing less to soil organic matter. Significant reduction in water stable aggregate between monthly sampling times may be attributed to the tillage and decomposition of organic matter. Although stover-derived organic materials have been shown to increase specific surface area of soil particles and to promote soil aggregation (Kladivko 1994; Blanco-Canqui and Lal 2007), and short term effects may depend more on the amount of residue as well as the timing of incorporation. Additionally, in coarse textured soils, aggregation is weakly related to microbial biomass and products (Degens and Sparling 1996) thus may influence total aggregation in these soils.

Table 4. Impact of sampling time on soil structure in the spring of 2012 and 2013 at Ridgetown, Ontario, Canada.

	Soil aggregate stability	
	Water stable aggregates	Dispersed clay
Sampling time	— % —	- mg ml^{-1} -
May	47.5 a	0.46 b
June	41.0 b	0.56 a
se	1.11	0.021
Effect	—— P value ——	
Year	0.0891	0.4490
Sampling time	0.0058	0.0325
Cover crop (CC)	0.8992	0.3431
Corn stover (CS)	0.1571	0.5818
CC*CS	0.3031	0.4623

a-b Means within a column followed by a different letter were significantly different at P<0.05.

Yield results

Squash mean yield in 2012 was 38.0 Mg ha^{-1}; provincial yield was 19.0 Mg ha^{-1}, and accounted for all squash and pumpkin production alike. Therefore yield differences were more likely attributed to the selection of species and/or variety. The effects of cover crops and corn stover did not influence squash fruit yield per hectare or per plant (*P*≥0.0796) (Table 5). These results follow previous research by Harrelson et al. (2007), which reported no effect of winter cover crop residues on no-till pumpkin yield after one year of study. The interaction of corn stover and cover crop was also not significant for fruit yield (P≥0.3957). Previous studies have also reported no impacts of corn stover removal on grain crop productivity (Wilhelm et al. 1986; Karlen et al. 1994). However, the literature is highly variable, with some studies showing decreases in corn productivity two years out of four (Blanco-Canqui and Lal 2009). The literature is further limiting on corn stover removal and vegetable crop productivity. Corn stover impacts may depend on tillage method, cropping systems, crop management, soil-specific characteristics (e.g soil texture), topography and environmental conditions. The nitrogen rate was significant for fruit yield per hectare as well as per plant (*P*≤0.0388). Squash fruit yield was 12.0±0.89% (per hectare) and 7.0±0.01% (per plant) higher in 110 kg N ha^{-1} compared to the no fertilizer control. The lack of significant interaction between nitrogen rate and cover crop (P≥0.1959) or corn stover (P≥0.0760) suggests that crop residues had a similar effect on nitrogen availability in the soil. Cover crops were not grown during the 2011-2012 winter seasons, thus contributing less to soil organic matter. Corn stover removal did not have had a high impact on nitrogen availability for squash production. Squash yields may be more affected by weather conditions, field locations, soil type and fertility than corn stover removal systems.

Table 5. Impact of N fertilizer on squash fruit yield for 2012 and 2013 at Ridgetown, Ontario, Canada†.

	Squash fruit yield	
Nitrogen rate (NR)	- Mg ha^{-1} -	- kg plant^{-1} -
0 kg ha^{-1}	35.8 *b*	2.4 *b*
110 kg ha^{-1}	40.7 *a*	2.5 *a*
se	0.89	0.01
Effect	——— P value ———	
Year	0.6126	0.0400
Nitrogen rate (NR)	<0.0001	0.0388
Cover crop (CC)	0.1725	0.3405
Corn stover (CS)	0.6407	0.0796
CC*CS	0.3957	0.4391
Year*NR	0.4783	0.2751
CC*NR	0.1959	0.5715
CS*NR	0.2958	0.0760
Year*CC*CS*NR	0.4727	0.2661

a-b Means within a column followed by a different letter were significantly different at P<0.05 .

†Data were pooled means of two growing seasons with four replicates each.

Conclusion

- In a winter cover crop trial, corn stover removal in the fall did not affect soil aggregate stability the following spring.
- Time of sampling before and after tillage had a greater effect on soil aggregation compared to winter cover crops or corn stover removal.
- Squash fruit yield was not affected by cover crops or corn stover removal.
- The use of nitrogen fertilizer in the spring had a significant effect on squash fruit yield .
- Further research has been directed at assessing soil carbon and nitrogen dynamics in corn stover removal systems with cover crops.

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References

Arshad, M.A. and Martin, S. 2002. Identifying critical limits for SQIs in agro-ecosystems. Agric. Ecosyst. Environ. **88**:153–160.
Abiven, S., Menasseri, S. and Chenu, C. 2009. The effects of organic inputs over time on soil aggregate stability – A literature analysis. Soil Biol. Biochem. **41**:1-12.
Blanco-Canqui, H., and R. Lal. 2007. Soil and crop response harvesting corn residues for biofuel production. Geoderma. **141**:355–362.
Blanco-Canqui, H., and R. Lal. 2009. Crop residue removal impacts on soil productivity and environmental quality. CRC. Crit. Rev. Plant Sci. **28**: 139–163.
Degens, B., and Sparling, G. 1996. Changes in aggregation do not correspond with changes in labile organic C fractions in soil amended with ^{14}C-glucose. Soil Biol. Biochem. **28**: 453–462.
Graham, R.L., R. Nelson, J. Sheehan, R.D. Perlack, and L.L. Wright. 2007. Current and potential U.S. corn stover supplies. Agron. J. **99**:1–11.
Harrelson, R. E., Hoyt, G.D., Havlin, J.L. and Monks. D.W. 2007. Effect of cover crop residue on no-till pumpkin yield. Hort. Sci. **42**: 1568-1574.
Karlen, D.L., Wollenhaupt, N.C., Erbach, D.C., Berry, E.C., Swan, J.B., Eash, N.S., and Jordahl, J. L. 1994. Crop residue effects on soil quality following 10 years of no-till corn. Soil Tillage Res. **31**: 149–167.
Kladivko, E.J., 1994. Residue effects on soil physical properties. Pages 123–162 *in* P.W. Unger. ed. Managing agricultural residues. Lewis Publishers, Boca Raton, FL.
Pojasok, T. and Kay. B.D. 1990. Assessment of a combination of wet sieving and turbidimetry to characterize the structural stability of moist aggregates. Can. J. Soil Sci. **70**: 33-42.
Wilhelm, W. W., Doran, J. W., and Power, J. F. 1986. Corn and soybean yield response to crop residue management under no-tillage production systems. Agron. J. **78**: 184–189.