Effect of Crop Residue Removal Rate on Micronutrient Availability and Soil Quality

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Background and Approach

Corn stover is a potential alternative feedstock for bioenergy and bio-based products, but there are questions about how much residue can be removed while maintaining the sustainability of the cropping system. Although secondary and micronutrients do not typically need to be applied in most Minnesota soils, the accelerated rate of soil removal if residues are harvested warrants this investigation.

Objectives

For continuous corn with 3 different residue removal rates:

1) evaluate the plant removal rate and soil availability of secondary nutrients, Ca, Mg, and S, and micronutrients (B, Zn, Cu, and Mn)

2) determine effect of residue removal on the soil quality indicators potentially mineralizable nitrogen and carbon (PMN and PMC) and particulate organic matter carbon and nitrogen (POM-C and POM-N).

Methods

Samples were collected in 2010 and 2011 at three Minnesota locations under continuous corn. The experiments were located at Rosemount (Waukegan silt-loam) and Southwest (Lamberton; Normania Ves silt loam) Research and Outreach Centers; and in a farm field in Northfield (Waukegan silt-loam).

Treatments

➢**Tillage systems (T): Conventional-till (CT), Strip-till (ST)**
Lamberton & Rosemount CT = chisel; Northfield CT = moldboard plow.

➢**Residue removal rate (R): 0%, 50%, and 100%**

▪Soil was sampled before planting at depths (D) of 0-5, 5-15, 15-30, 30-60 and 60-90 cm.
▪Ca and Mg extracted with NH_4OAc in a 1:10 ratio
▪Zn, B, Cu, Mn extracted with DTPA in a 10:20 ratio.
▪Elemental analyses with ICP atomic emission spectroscopy.
▪S extracted with KCl (5:12.5 ratio); analyzed by flow injection turbidometric method.
▪Plant and grain biomass collected at harvest in 2010 and 2011. Nutrient concentrations determined by dry ashing (485ºC) and elemental analysis by ICP. Total S determined using a LECO SC-132 S Determinator.
▪Potentially mineralizable N and C (PMN and PMC) determined in 28 day incubations modified from the aerobic method described by Drinkwater et al. (1996). Particulate organic matter (POM-C and POM-N) was fractionated as SOM >53 µm using the Turbo POM methodology (Marriot and Wander, 2006).

Results

Plant nutrient removal

• At Northfield and Lamberton, there were no differences between tillage systems in amounts of plant nutrients removed in either growing season.
• At Rosemount, the CT treatment removed greater amounts of Ca and Mg in both years, and more S and B than ST in 2010 (Table 1), probably due to greater yields in the CT system.

Table 1. Effect of tillage systems on plant nutrient removal during 2010 and 2011 corn growing season. Significant effects only at Rosemount.

		Biomass	Ca	Mg	S	B	Zn	Mn	Cu
			Rosemount-Plant nutrient removal						
		$Mg\ ha^{-1}$	…….kg nutrient ha^{-1}……..			……….g nutrient ha^{-1}……..			
2010									
	CT	**5.7 a**	**11.8 a**	**9.2 a**	**4.2 a**	**22.1 a**	149.2	149.9	31.0
	ST	**4.4 b**	**8.4 b**	**5.5 b**	**2.7 b**	**15.2 b**	135.1	108.4	21.7
2011									
	CT	**3.9 a**	**12.7 a**	**9.3 a**	2.1	12.9	74.4	66.8	11.9
	ST	**3.3 b**	**9.2 b**	**5.4 b**	2.0	12.7	81.3	57.7	13.6

• Amounts of nutrients removed were greater for the 100% than the 50% removal rate treatments for all locations in both years (Table 2).
• Where 50% of all combined plant parts was removed rather than just the top half and cobs (Lamberton), nutrient removal was about half that of the 100% removal rate.
• Where only the top half of the plants and the cobs were removed, more than twice the nutrients were lost in the 100% removal treatments, because more of the corn biomass, and hence more of the nutrients are in the bottom half.

Table 2. Effect of residue removal rates on plant nutrient removal

	Residue removal rate	Biomass removed	Ca	Mg	S	B	Zn	Mn	Cu
			Plant nutrient removal						
	%	Mg ha	……..kg ha^{-1}………			……..g ha^{-1}………..			
Lamberton									
2010	50	3.1	10.8	5.5	1.9	14.0	44.1	116.9	9.4
	100	6.1	22.9	9.9	3.8	28.1	66.3	199.3	19.0
2011	50	2.8	10.4	6.2	1.7	18.9	50.0	116.2	11.1
	100	6.0	21.5	11.5	4.4	41.3	99.9	231.3	20.6
Northfield									
2010	50	4.0	11.7	3.1	2.7	15.4	69.8	85.8	18.6
	100	7.9	25.5	8.3	5.2	30.3	102.7	192.4	30.0
2011	50	4.0	10.7	2.9	2.8	18.3	94.2	94.3	18.1
	100	7.7	24.7	10.3	5.5	37.1	125.1	191.7	32.0
Rosemount									
2010	50	2.6	5.0	3.5	2.1	8.4	98.5	57.0	16.0
	100	7.5	15.2	11.3	4.8	28.9	185.8	201.3	36.7
2011	50	2.0	5.5	3.3	1.1	7.2	49.5	32.3	8.1
	100	5.2	16.4	11.5	3.0	18.5	106.2	92.2	17.4

Soil nutrient removal

• Soil nutrient availability from 0-15 cm did not differ between tillage systems in Spring 2011. In 2010, only B and Cu levels were higher in CT at Rosemount, and Mg levels were higher in ST at Northfield.
• For most nutrients, there were no detectable differences in soil nutrient availability for any of the residue removal rates either in the 0-15 cm depth or in the top 90 cm.
• Levels of S and micronutrients tended to be higher at Northfield than at Lamberton and Rosemount, where organic matter levels were lower.
• For the 0-15 cm depth, soil nutrients (Cu in 2010 and Cu and Zn in 2011) were lower for 100% than 0% removal only at Lamberton; in all other cases, nutrients were equal or greater at the 100% removal rate.
• For 0-90 cm, only Cu at Lamberton (2011) and Mg at Rosemount (2011) were lower for the 100% removal rate.

Table 3. Soil nutrient availability at 0-15 cm.

	Year	Ca	Mg	S	B	Zn	Mn	Cu	pH	TOC
		………………mg kg^{-1} (ppm)………………								
Northfield										
	2010	3361	318	21 **a**	0.93 **a**	6.85 **a**	38 **a**	2.13 **a**	6.08	3.6
	2011	3290	307	7.3 **b**	0.69 **b**	5.47 **b**	28 **b**	1.88 **b**	6.11	3.4
Lamberton										
	2010	3755 **a**	457 **a**	11 **a**	0.83 **a**	0.79 **a**	33 **a**	1.23 **a**	6.04 **a**	2.1
	2011	3094 **b**	402 **b**	6.9 **b**	0.69 **b**	0.51 **b**	27 **b**	1.12 **b**	5.81 **b**	2.1
Rosemount										
	2010	2280 **a**	523 **a**	9.3 **a**	0.32 **a**	1.37 **a**	25	0.68	6.39	2.2
	2011	2022 **b**	433 **b**	4.4 **b**	0.27 **b**	1.13 **b**	24	0.66	6.41	2.2

• Averaged across all treatments (Table 3), there were lower concentrations of available soil nutrients in 2011 than 2010 at Northfield (S, B, Zn, Mn and Cu), Lamberton (all) and Rosemount (Ca, Mg, S, B, Zn), but these differences could not be explained by tillage or residue removal treatment.
• Nutrients in most cases were well above critical levels, except for Zn at Lamberton and B at Rosemount.

Labile C and N fractions

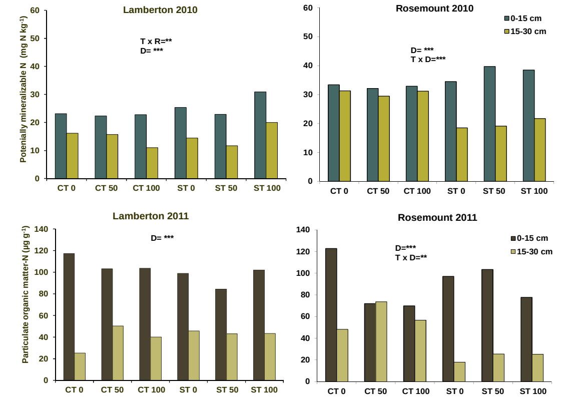

*Figure 1. Effect of tillage (T), removal rate (R) and depth (D) on potentially mineralizable N (PMN) and particulate organic N (POM-N). Statistical results indicated significant differences at :*P<0.10, ** P<0.05, *** P<0.01.*

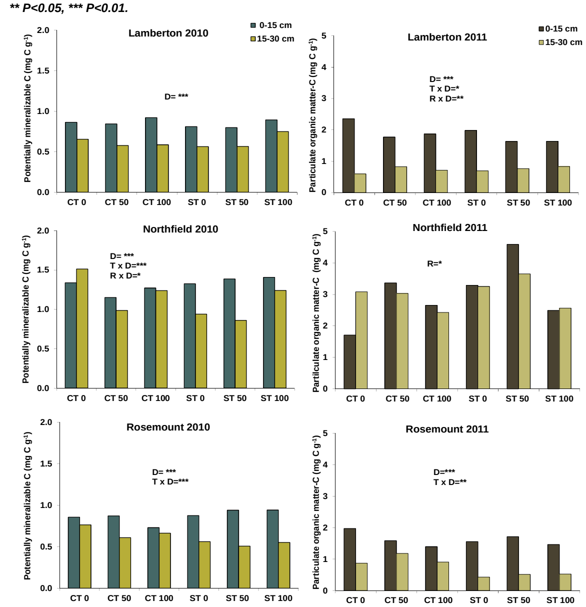

*Figure 2. Effects of tillage (T), removal rate (R) and depth (D) on potentially mineralizable C (PMC) and particulate organic C (POM-C). Statistical results indicated significant differences at:*P<0.10, ** P<0.05, *** P<0.01.*

• At Rosemount and Lamberton, PMN and PMC were greater at 0-15 cm compared to 15-30 cm (Figs. 1 and 2), but for Northfield, only PMC showed differences with depth (Fig. 2).
• At both Rosemount (PMN and PMC) and Northfield (PMC) there was a significant T x D interaction, where concentrations of PMN and/or PMC were similar at 0-15 and 15-30 cm for CT, but were significantly greater for the 0-15 cm depth than for the 15-30 cm depth in the ST system (Figs. 1 and 2).
• At Northfield, there was also a R x D interaction, where PMC was similar at 0-15 and 15-30 cm for the 0 and 100% removal rate, but at the 50% removal rate PMC was significantly greater at 0-15 cm than 15-30 cm (Fig. 2).
• Concentrations of POM-N and POM-C at 0-15 cm were higher than 15-30 cm for both Lamberton and Rosemount (Figs. 1 and 2).
• At Rosemount, a significant T x D interaction was detected, where the concentrations of POM-N and POM-C were similar at both depths for CT, but were significantly greater for the shallower depth in the ST system (Fig 1 and 2).
• At Lamberton, significant interactions for T x D and R x D were observed for POM-C (Fig. 2). Both tillage treatments had greater concentrations of POM-C in the surface, but POM-C in the CT treatment tended to be greater than ST for the shallow depth and less than ST at 15-30 cm. Differences between the depths were greater for the 0% removal rate than for the 50 or 100 % (Fig. 2) .
• At Northfield, rate of residue removal treatment affected POM-C. The concentration of POM-C in the top 30 cm was similar for the 50% removal rate (3.66 mg g^{-1}) and 0% removal rate (2.84 mg g^{-1}), and both had significantly more POM-C than the 100% removal rate (2.53 mg g^{-1}) (Fig. 2).

Summary

➢ **Amounts of plant nutrient removal were similar for both tillage systems, except at Rosemount where greater Ca, Mg, S and B were removed under CT than ST systems, due to higher yields of the CT systems.**

➢ **Amounts of nutrient removal were significantly greater in the 100% than 50% residue removal rate.**

➢ **Despite the higher rate of nutrient removal under 100% treatments, there were almost NO changes observed in soil availability of nutrients within 2-3 years after treatments were imposed.**

➢ **During this same time period, soil quality indicators did reflect differences between tillage treatments due to stratification under ST systems compared with CT systems, but NO differences were detected due to residue removal rates, except in Northfield where POM-C tended to be greater in the 0 and 50% than in the 100% residue removal rate.**

➢ **It appears that longer time periods are required to detect effects of residue removal on the measured soil properties, including availability of secondary and micronutrients and amounts of active C and N in these soils.**

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