How Much Phosphorus Do Crop Residues Release Under Conventional and Zero Tillage Systems?

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Abstract

In a field experiment conducted at Fort Vermilion in north-western Alberta, we used the litter-bag method to quantify phosphorus (P) release from red clover green manure, field pea, canola and wheat residues under conventional tillage and zero tillage. Wheat residues added significantly less P (1.7 kg ha^{-1}) to the soil than the other residues (5.6-8.5 kg P ha^{-1}). Tillage had no significant effect on residue P applied, but the trend was for slightly greater amounts under ZT than under CT. Clover released the most P (3.8 kg ha^{-1} under CT and 2.8 kg ha^{-1} under ZT, compared with 1.4 kg ha^{-1} or less from the other residues). There were no significant tillage effects on the amounts released by clover, pea and canola residues, but wheat immobilized 0.2 kg P ha^{-1} under ZT compared with 0.4 kg P ha^{-1} released under CT. Soil phosphate contents were not significantly different between tillage systems. Phosphate contents decreased with soil depth, especially under ZT. However, there was no tillage by soil depth interaction with canola residues, where soil phosphate was greater (although not significantly) under ZT than under CT at all depths. Uptake of P by wheat was significantly greater where pea and, to a lesser extent, canola residues had been applied than where clover and wheat residues had been applied, and tillage had no significant effects on P uptake.

Introduction

It is usually assumed that, because crop residues usually decompose more slowly under zero tillage than under conventional tillage, less nutrients are also released in a given time period. This assumption may not be always correct because the amount of a nutrient released depends not only on decomposition rate, but also on the amount added with crop residues. Another issue with respect to relatively immobile soil nutrients like P under reduced tillage is soil stratification, i.e., P accumulating only on or near the soil surface (Franzluebbers and Hons 1996; Essington and Howard 2000). It is unclear whether stratification is similar under different crop residues.

The objective of this work was to quantify how much P is released from red clover, field pea, canola and wheat residues under conventional and zero tillage systems, and to determine soil P stratification under these crop residues.

Materials and Methods

The trial was conducted on the gray Luvisolic soil at Fort Vermilion in north-western Alberta in 1998-1999 and 1999-2000. There were two tillage systems: conventional tillage (CT) and zero tillage (ZT), each with four different crop rotations that included red clover green manure (GM), field peas, canola, fallow and continuous wheat (Lupwayi et al. 1999). Crop residues of clover green manure, field peas, wheat and canola were collected at harvest, weighed, and analysed for P to determine the amounts applied. The residues were then placed in decomposition-resistant litter bags with 1 mm mesh (Lupwayi and Haque 1999) and either buried in the soil (CT), or placed on the soil surface (ZT). The bags were sampled periodically over a 12-month period and the residues analysed for P to determine how much P still remained in the decomposing residues and, by difference from the amounts applied, how much P had been released. The C and lignin contents of the residues applied were also determined and related to P release. Wheat was grown in all plots as decomposition proceeded. Soil available phosphate (extracted with sodium bicarbonate) was determined at four depths (0-5, 5-10, 10-15 and 15-20 cm) to assess P stratification and, at wheat harvest, P uptake by wheat was determined.

Results and Discussion

The 1999-2000 results are presented here. The amounts of residues produced and added to the soil did not differ significantly between tillage treatments, but the trend was for slightly greater amounts under ZT than under CT (Table 1). Wheat produced significantly less residue DM than the other crops. The same trends as residue DM were observed for amounts of P added. Canola residues were the most carbonaceous and lignified, and clover residues the least, and tillage had no significant effects on these residue characteristics. Clover contained significantly more P, and lower C/P and lignin/P rations, than the other residues. There were no significant interactions between tillage and crop residues in residue DM produced, residue quality, or P applied.

Table 1. Amounts of Crop Residues and P Applied.

Treatment	Residue quality					Amount applied	
	%C	%Lignin	%P	C/P	Lignin/P	DM (t ha^{-1})	P (kg ha^{-1})
Tillage							
CT	43.6a	8.5a	0.11a	482a	99a	4.27a	4.7a
ZT	44.0a	8.6a	0.11a	450a	85a	5.05a	6.2a
Crop residue							
Clover	43.6bc	6.3c	0.16a	274b	39b	5.32a	8.5a
Pea	42.6c	8.5b	0.09b	571a	120a	6.05a	6.1ab
Canola	44.6a	13.0a	0.11b	420ab	122a	5.09a	5.6b
Wheat	44.4ab	6.4c	0.08b	599a	88ab	2.18b	1.7c
Interaction	ns	Ns	Ns	ns	Ns	Ns	Ns

The mean *percentage* of P remaining in clover residues during decomposition was significantly greater under ZT (69%) than under CT (52%), i.e., decomposition was significantly slower under ZT than under CT (Table 2). However, tillage had no significant effects on P decomposition in the other residues although the difference was almost significant for wheat residues, in which P was immobilized (tied up) under ZT. These P decomposition patterns were positively correlated with %P in the residues and negatively correlated with C/P ratios. There were no significant interactions between tillage and sampling time in P decomposition.

Table 2. Percent P Remaining in Crop Residues During Decomposition.

Treatment	%P remaining in residue			
	Clover	Pea	Canola	Wheat
Tillage				
CT	52.0b	95.9a	74.2a	78.9a
ZT	69.4a	86.6a	77.4a	124.9a
Time (weeks)				
0	100.0a	100.0a	100.0a	100.0a
1	91.6a	73.7a	67.4d	99.6a
2	76.3b	89.2a	83.0bc	87.6a
3	61.9c	92.9a	71.7cd	103.1a
5	35.0e	90.7a	71.8bcd	121.4a
10	51.8cd			
32				100.1a
35		92.0a	62.8d	
44	40.3de	102.0a	86.2ab	98.6a
52	28.8e	89.3a	63.8d	104.6a
Interaction	ns	ns	Ns	Ns

There were no significant tillage effects on the *amounts* of P released by clover, pea and canola residues, but wheat immobilized 0.2 kg P ha^{-1} under ZT compared with 0.4 kg P ha^{-1} released under CT (Table 3). Although this difference due to tillage was significant, the amount of P released under CT was too small (< 1 kg ha^{-1}) to have practical significance. Clover released the most P (3.8 kg ha^{-1} under CT and 2.8 kg ha^{-1} under ZT, compared with 1.4 kg ha^{-1} or less from the other residues). There were no significant tillage by sampling time interactions in amounts of P released.

Table 3. Amounts of P Released From Crop Residues During Decomposition.

Treatment	P released (kg ha^{-1}) from residue			
	Clover	Pea	Canola	Wheat
Tillage				
CT	3.8a	0.8a	1.4a	0.4a
ZT	2.7a	1.0a	1.3a	-0.2b
Time (weeks)				
0	0.0e	0.0a	0.0d	0.0a
1	0.7e	2.0a	1.7ab	0.1a
2	2.0d	1.3a	1.0bc	0.3a
3	3.1cd	0.6a	1.7ab	-0.0a
5	5.4a	1.1a	1.6abc	-0.4a
10	3.9bc			
32				0.2a
35		0.6a	2.0a	
44	5.0ab	0.6a	0.8cd	0.2a
52	6.0a	1.3a	2.0a	0.3a
Interaction	ns	ns	Ns	ns

The amounts of P released (Table 3) were all less than the amounts that had been applied with the residues (Table 1), which means that crop residues do not immediately decompose completely, even under conventional tillage. The more resistant parts of the residues, including the nutrients they contain, become soil organic matter, which decomposes slowly. Therefore, although only clover released significant amounts of P, it is advisable that all crop residues be added to the soil because they maintain or increase soil organic matter. Soil organic matter is important not only as a slow-release source of nutrients for crops and soil organisms, but also for maintaining soil structure. Even nutrients added as fertilizers are not utilized efficiently when soil organic matter is low.

Table 4. Available P Concentrations in Soil During Decomposition of Crop Residues.

Treatment	Available P (mg kg^{-1} soil)				
	Clover	Pea	Canola	Wheat	Fallow
Tillage					
CT	29.05a	12.81a	11.27a	28.88a	15.38a
ZT	19.72a	17.74a	28.12a	16.77a	26.14a
Soil depth (cm)					
0-5	37.77a	27.58a	28.71a	32.07a	29.41a
5-10	22.36b	15.98b	21.78b	26.03b	23.02b
10-15	18.11c	9.95c	15.95c	18.10c	17.33c
15-20	19.31bc	7.60c	12.32d	15.10c	13.27d
Time (weeks)					
0	27.20a	15.77a	17.87a	30.90a	22.65a
1	26.46a	17.47a	20.46a	26.68ab	20.86a
2	23.54a	14.25a	17.52a	21.26c	21.01a
3	19.32a	14.54a	19.10a	22.51bc	20.52a
5	22.15a	13.88a	20.00a	17.81c	21.31a
10	25.80a				
32				22.75bc	18.44a
35		14.20a	19.95a		
44	25.64a	15.94a	22.99a	20.49c	22.66a
52	24.98a	16.17a	19.65a	20.18c	18.62a
Tillage x Soil depth	**	**	ns	**	**
Tillage x Time	*	ns	**	ns	**
Soil depth x Time	ns	ns	ns	ns	ns

Soil phosphate contents (sodium bicarbonate- extractable) were not significantly different between tillage systems, and usually not significantly different between sampling times (Table 4). Phosphate contents decreased with soil depth, more so under ZT than under CT as indicated by significant tillage by soil depth interactions. However, there was no such interaction with canola residues, where soil phosphate remained greater (though not significantly) under ZT than under CT at all depths.

There were no significant tillage or crop residue effects on total P uptake. However, P in wheat grain was significantly greater where pea and, to a lesser extent, canola residues had been applied than where clover and wheat residues had been applied (Table 5).

Table 5. P Uptake by Wheat During Decomposition of Crop Residues.

Treatment	P uptake (kg ha^{-1})		
	Straw	Grain	Total
Tillage			
CT	1.70a	9.04a	10.74a
ZT	2.01a	9.79a	11.80a
Crop residue			
Clover	1.60a	8.35b	9.95a
Pea	2.13a	11.47a	13.60a
Canola	1.62a	10.07ab	11.69a
Wheat	2.08a	7.75b	9.83a
Interaction	ns	ns	ns

Conclusion

Crop residues added between 1.7 kg P ha^{-1} (wheat) and 8.5 kg P ha^{-1} (clover) to the soil, with no significant tillage effects. The amounts of applied P released ranged from < 0 kg P ha^{-1} (immobilization) for wheat residues under ZT to 3.8 kg P ha^{-1} for clover residues under CT. Soil phosphate levels were not significantly different between tillage systems, and were actually greater under ZT than under CT in the top 5 cm of soil, where roots usually proliferate. Therefore, adoption of reduced tillage should not have adverse effects on the P nutrition of crops.

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