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Final

Completion Report for PPI Funded Research Project

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"Availability of Phosphorus Contained in Pulse Crop Residue to a Subsequent Crop"

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Executive Summary:

A combination of controlled environment and replicated field experiments was used to examine the role of pulse crops in recycling of phosphorus to following crops in rotation. Growth chamber experiments were conducted to 1) compare the effect of different crop residues (pea, lentil and cereal) on phosphorus availability; 2) to examine the effect of environmental conditions (wet-dry cycles) on release of phosphorus from crop residues. Field experiments were conducted in 1996, 1997 and 1998 at Central Butte, Swift Current Agriculture Canada, and Kernen and Goodale research sites. These experiments evaluated the effect of different crop stubble types (pea, lentil, chickpea, wheat) on soil phosphorus supply, and phosphorus uptake and yield of wheat grown on the different crop stubbles.

The results of the controlled environment studies revealed that fresh pulse crop residue can release more available phosphorus over the short-term than old, weathered residue. However, above ground residues of all crops including pulses resulted in immobilization of soil phosphorus when added to the soil, consistent with relatively high carbon: phosphorus ratios (>200) of the surface residues. Cereal residues have lower water soluble phosphorus concentrations and higher carbon: phosphorus ratios than pea or chickpea. More phosphorus is leached from crop residues exposed to repeated wet-dry cycles than when kept continuously wet, likely due to more rapid phosphorus mineralization-immobilization turnover under wet-dry conditions. Overall, the phosphorus contained in the above - ground residue of a pulse crop appears to play a relatively minor role in increasing phosphorus availability and may actually be responsible for some decrease when incorporated due to microbial immobilization. Based on our controlled environment studies, the above ground pea residue is expected to contribute at most only 1 to 2 kg P / ha over one to three months and therefore would not be a major factor influencing soil P supplies or growth over the short term.

The field experiment results tended to corroborate the findings in the controlled environment experiments. In the field experiments in the Brown soil zone at Central Butte and Swift Current, no differences in crop phosphorus uptake and yield were detected that could be directly related to phosphorus supplies in the different crop stubble types. Differences in yield among the crop stubble types attributable to nutrients appeared to be mainly related to nitrogen, with wheat yields and nitrogen uptake highest on pea stubble, followed by chickpea stubble and wheat stubble the lowest. At the Dark Brown sites, at Goodale there was slightly but significantly higher soil nitrogen and phosphorus supply rates observed in the pea stubble compared to the lentil stubble.

In addressing the question: Is soil phosphorus availability increased after pulse crops such that it is a major factor contributing to increased cereal yields on pulse stubble as compared to cereal stubble?, the answer is probably not. The phosphorus contents of pulse residues, although higher than cereals, still can contribute to initial net immobilization upon decomposition. Measurements of soil P availability indicate no major differences following pulses compared to cereals in field situations. Observations of greater yields and phosphorus uptake by cereals following pulses are more likely due to improved root-rhizosphere relationships and nutrient absorption area as a result of greater N fertility, disease suppression and improved physical soil characteristics allowing better root growth and plant development. Producers who adopt pulse-cereal rotations over the long-term (several years) and realize yield benefit from the rotation effect early on will need to replace the additional phosphorus removed in harvest with fertilizer in order to maintain production.

Technical Report

Objectives

The focus of the research was to determine the extent to which soil phosphorus supply is influenced by crop residue type, including pulses and cereals, to help explain the nature of the non-nitrogen benefit observed in cereal crops following a pulse as compared to following another cereal.

Main Objectives:

A) Determine the impact of pulse and cereal residues on available soil phosphorus, plant phosphorus uptake and yield under controlled conditions.

B) Determine the nature of phosphorus contributed by pulse and cereal residues to the soil as affected by weathering processes: leaching, wet-dry cycles.

C) Compare soil phosphorus supplies, wheat yield and phosphorus uptake on pulse and cereal stubble under field conditions.

Part A: Growth Chamber Experiment

The objective of this experiment was to isolate and determine the effects of pulse and cereal residue additions on soil phosphorus supplies and yield and uptake of P by wheat and canola.

Experimental Design: Pea, lentil, wheat or no (control) residue was incorporated at 5000 kg/ha in Echo association soil in which the previous crop grown was wheat. Then wheat, canola or no crop (fallow) were set up on the soils. These treatments were allowed to grow for 11 weeks under normal conditions in a growth chamber. All treatments received basal applications of nitrogen, potassium and sulfur. The treatments were replicated four times and set up as a randomized complete block design. Measurements included characterization of total and water soluble nutrient contents of the residues, total and resin available nutrient contents and wheat and canola yield and P uptake.

Results and Discussion: The lentil residue contained the greatest concentrations of phosphorus and had the lowest C:P ratio of the residues studied (Table A.1). Thus the lentil treatment was expected to contribute the greatest amount of P to the soil and following crop, followed by the pea and wheat residue. However, all of the residues were expected to cause some immobilization as C:P ratios exceeded 200:1.

Table A.1. Nutrient content of applied residues.

Residue applied	Pt*, µg g^{-1}	P_{ws}**, µg g^{-1}	Pi_{ws}, µg g^{-1}	C:P	C:N
Pea	740	378	226	592	52
Lentil	1437	484	235	285	30
Wheat	331	186	158	1335	100

* Pt and Pi indicate total and inorganic phosphorus, respectively.

**$_{ws}$ indicates water soluble.

The water soluble inorganic P content of the pea and lentil residue was almost equal. This phosphorus fraction is likely the most immediately available for plant uptake.

The phosphorus supply rates in the soil after 4 and 8 weeks of plant growth (Table A.2) were lower in the residue amended soils than in the no residue (control) treatment, which is attributed to P immobilization induced by the residues. Overall, the presence of plants resulted in increased P supply rates compared to the fallow treatment, possibly due to a rhizosphere effect on enhancing microbial activity and P turnover.

Table A.2 Soil P supply rates of the different treatments at 4 and 8 weeks of incubation.

	P supply rate, µg PO_4 10 cm^{-2} resin					
	4th week of incubation			8th week of incubation		
Treatment	Wheat	Canola	Control	Wheat	Canola	Control
Pea	1.33	7.99	0.30	0.94	2.85	0.91
Lentil	2.00	7.33	0.10	0.60	3.35	0.77
Wheat	1.12	5.61	0.43	0.83	2.99	0.67
Control	2.58	10.85	0.21	1.02	8.28	0.65

Differences among the residue treatments were small. The greatest difference was observed during the fourth week under canola where the pea and lentil treatments had greater supply rates of P than the wheat residue treatment as would be expected according to the P contents of the residues. Consistent with the soil P supply rates, the greatest uptake of phosphorus was by plants growing in the fallow (unamended) soils. Among residue treatments, wheat uptake of N and P was greatest in the lentil treatment,followed by pea and wheat. These trends are consistent with the C:P ratios of the residues and shows that the high C:P ratio of the wheat residue may have limited P uptake by the following wheat crop.

Conclusion: Rather than contributing to P supplies, the addition of residue actually lowered the soil P supply through immobilization. Differences in P uptake by wheat between different residue treatments are explained by differences in residue C:P and the amount of P immobilized.

Part B: Incubation and Residue Decomposition Experiment

The purpose of the incubation experiment was to determine the amount of phosphorus that could potentially be leached from crop residues during the initial growth of a subsequent crop and if the residues were capable of making significant contributions to the subsequent crop phosphorus supply. The residue decomposition experiment evaluated the changes in nutrient composition of residues as they weathered in the field from harvest to the time of seeding the following year, to determine when nutrients are released from the residues and its impact on soil nutrient supplies to the following crop.

Experimental Design: Six samples each of wheat, pea and chickpea residues were collected from plots at Central Butte in the spring of 1998 and sub-samples were characterized for total nutrient content. Remaining portions of the samples were chopped into < 2mm pieces to simulate residue chopping during harvest. Samples were placed in funnels corresponding to a surface residue coverage of about 5000 kg / ha. Each treatment was replicated six times. Two leaching regimes were implemented. The first was an incubation at constant moisture content over a four week interval, with leaching every week. The second regime was the same as the first but with drying of the residue after each incubation period before leaching. The water applied was equivalent to the average growing season precipitation in the Brown soil zone of Saskatchewan (about 230mm).

In the residue decomposition experiment, four sampling points were chosen randomly in each of three stubble plots at Central Butte. The three plots consisted of pea, chickpea and wheat stubble on Echo association, rego-brown Chernozemic soils. Residue samples were removed from the plots in September and November of 1997 and in March and May of 1998. The samples collected in May were used in the leaching- incubation experiment. Samples were dried, ground and analyzed for total P, C, N,S and total and inorganic water soluble P.

Results and Discussion: The nutrient contents of the residues (Table B.1) suggest that the pea residue should supply the greatest amounts of P and N via leaching. The pea residue also contains the lowest C:P ratio and therefore should exhibit the lowest degree of immobilization, followed by chickpea and wheat.

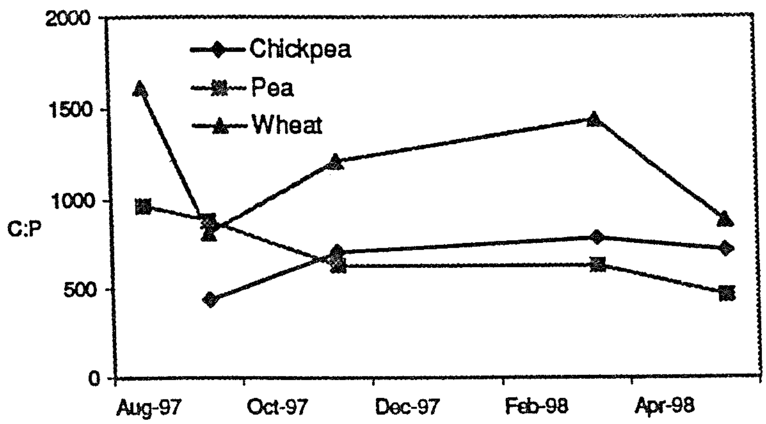
Table B.1. Nutrient content of the residues used in the leaching experiment.

Residue	Pt, µg g^{-1}	Pt_{ws}, µg g^{-1}	Pi_{ws} µg g^{-1}	N, mg g^{-1}	NH_4-N_{ws}, µg g^{-1}	NO_3-N_{ws}, µg g^{-1}	C:P
Pea	769	313	202	6.73	181	0.00	421
Chickpea	508	175	121	4.32	103	0.00	719
Wheat	448	136	105	4.27	110	3.21	799

Nutrient contents of the leachates from continously moist incubation were much lower than in the wet-dry incubation. In the continously moist incubation, most of the nutrients are likely tied up in microbial biomass whereas the drying phase in the moist/dry incubations would cause microbial death and nutrient release. This incubation probably more closely reflects Saskatchewan field conditions. The pea residue leachates contained the highest P amounts, consistent with its highest concentrations of total and water soluble phosphorus. More P was released from the wheat residue than the chickpea. The total P content of the leachates was observed to decrease with each leaching event. This is attributed to loss of water soluble fractions early on leaving behind more resistant P constituents.

Crop residue composition as affected by weathering in the field from fall to spring revealed an increase in C:N ratios of wheat and chickpea and wheat and a decrease in the C:N ratio of pea. The decrease in C:N ratio of the pea residue is attributed to greater microbial decomposition of the pea residue and evolution of carbon as CO_2, resulting in a decrease in residue C:N over time. The C:P ratios (Fig. B.2) followed a similar pattern as the C:N ratios. The C:P ratios of all the residues was high enough such that immobilization would result upon decomposition.

Figure B.2. C:P ratios of residue samples collected overwinter at Central Butte.



Conclusion: Dessication of a crop residue is expected to result in more nutrients being released to the soil via leaching. Using the amounts of phosphorus contained in the leachates and a residue coverage of 5000 kg residue / ha, it was determined that at the most, the crop residue could only supply 1 to 2 kg P / ha by leaching over the short term. This is a small amount that would not be expected to significantly increase soil P supplies or crop growth. In the field, the narrowing of C:P and C:N ratios of pea stubble from fall to spring suggests a more readily decomposible residue than chickpea or wheat.

Part C: Field Experiments

The purpose of the field experiments was to assess the effect of different stubble types on soil P availability and wheat P uptake and yield.

Experimental Design: The field experiment at Central Butte in the 1997 growing season consisted of a comparison of soil P availability, yields and P uptake of wheat on fallow, pea and wheat stubble. A main transect containing ten sampling points spaced at 2m intervals was set up in each of the three plots. One additional transect was added alongside the main transects in the pea and fallow plots to try to isolate the influence of the residue on the measured parameters. Pea residue was transferred from a 2m wide strip along the sub-transect in the pea plot to an equivalent area along the sub-transect in the fallow plot. All plots were fertilized with 100 kgN/ha. The same experiment was repeated again at Central Butte in 1998, except that wheat, pea and chickpea stubble were compared and no sub-plots were implemented and no fertilizer was applied.

The field study at Swift Current in 1997 examined soil P availability, wheat yields and P uptake on plots at SPARC research centre. Plots were set up in a randomized complete block design on wheat, pea, chickpea and lentil stubble and fallow. The plots were fertilized with N and starter P (33 kg 12-51-0 / ha).

Measurements at Central Butte and Swift Current included soil moisture, bicarbonate extractable inorganic P, total soil nutrients, soil P supply rates every two weeks from seeding to July, P release from residue by resin burial under surface thatch, mid-season and final wheat yields and P uptake, and VAM infection of roots at mid-season.

At Kernen and Goodale crop research farms near Saskatoon, an RCBD experiment was used to examine soil phosphorus supply rates under pea and lentil stubble in 1996 and 1997.

Results and Discussion: The pulse crop residues generally contained higher concentrations of phosphorus and nitrogen than the wheat residues in all of the field experiments, with the exception of the chickpea residue at Central Butte in 1998 which has a low concentration of nitrogen.

In the 1997 trials at Central Butte, the wheat grown on pea stubble had a higher yield and phosphorus uptake than wheat grown on fallow. As no differences were detected in soil phosphorus supply rates or plant P concentrations, the greater yield and P uptake by wheat on pea stubble appears to be related to other factors apart from phosphorus availability in the soil itself, perhaps greater VAM infection in the wheat on the pea stubble compared to wheat on fallow which would give the crop greater ability to access soil P. Removal or additions of the surface pulse residue had little effect on soil P supply, wheat yield and phosphorus uptake, pointing to a relatively minor role of the residue in supply of available phosphorus in the spring of the year. At Swift Current in 1997, there were no significant differences in the wheat yield and P uptake among treatments (Table C.1). Any differences associated with the effect of the residue were likely small enough to be overridden by the fertilizer application.

Table C.1. Plant data collected at Swift Current, 1997.

Previous crop	Mid DMY (g m^{-2})	P uptake (mg m^{-2})	Grain yield (kg ha^{-1})	P uptake (kg ha^{-1})
Chickpea	507	1103	2723	9.41
Lentil	479	949	2642	9.00
Pea	369	849	2713	9.61
Wheat	363	774	2645	9.27
Fallow	541	1141	3176	10.37

Wheat yields and nutrient uptake were greatest on pea stubble at Central Butte in 1998. Chickpea stubble produced the next greatest yields, followed by wheat stubble. The lower yields on wheat stubble compared to pulse stubble are attributed to factors apart from phosphorus availability in the soil as the wheat samples at mid - season had the highest concentrations of phosphorus. Wheat on pea stubble had slightly higher P concentrations than wheat on chickpea stubble, suggesting that soil after pea stubble may have slightly higher P availability than after chickpea. Spring soil sampling also revealed lower available P concentrations in the chickpea stubble compared to the pea or wheat stubble.

Comparison of soil phosphate supply rates measured in pea and lentil stubble over the season at Goodale and Kernen in 1996 and 1997 revealed slightly but significantly higher supply rates of phosphate under pea stubble compared to lentil stubble at Goodale only.

Conclusions: It appears that the type of crop stubble could have a small effect on soil phosphorus availability under some conditions but overall the effects are not expected to be large. Overriding factors appear to be the concentration of phosphorus and carbon in the residue along with the amount of residue left behind after the particular crop. Lack of a large effect of crop stubble type on phosphorus availability is not surprising owing to the relatively small contribution that residue phosphorus appears to make over a growing season compared to the indigenous soil P.

Project Outputs:

C.A. MacLeod. 1999. MSc thesis. Influence of pulse crops on soil phosphorus supplies and phosphorus uptake by subsequent crops. In progress, expected completion date March 1999.

D. Adderley. 1999. MSc thesis. Nutrient cycling and herbicide persistence in reduced tillage pulse-cereal rotations. University of Saskatchewan, Saskatoon. 123 pp.

J.J. Schoenau. 1996. Fertility management in conservation crop rotations. Proceedings of Alberta Reduced Tillage Conference, Medicine Hat, Alberta. Dec. 3, 1996.

C.A. MacLeod and J.J. Schoenau. 1997. The influence of crop residues on plant phosphorus uptake. Proceedings of 1997 Soils and Crops Workshop, pp 569-574. Extension Division, Univ. of Sask.

C.A. MacLeod, J.J. Schoenau and P.R. Miller. 1998. The influence of pulse crops on phosphorus supply to a following wheat crop. Proceedings of 1998 Soils and Crops Workshop, pp 345-350.

J.J. Schoenau, D. Adderley, C. MacLeod, R. Holm, A.E. Slinkard, A. Moulin and P. Miller. 1998. Nutrient recycling in pulse-cereal rotations. *In* : Pulse Crops Research volume 3, pp. 33-35, University of Saskatchewan.

J.J. Schoenau, 1998. Fertility Management in Crop Rotations. Presentations at producer and industry meetings. Calgary, Feb. 4; Milestone, Feb. 10; Wakaw, Mar. 2; St. Denis, March 12; Saskatoon, March 18.