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

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Background:

The effect of pulse crop (pea and lentil) residue on availability of phosphorus to following crops was examined in two replicated growth chamber experiments in 1996. The purpose of the growth chamber experiments was to examine the effect of the residue itself on phosphorus availability to a following cereal or oilseed crop under controlled conditions. In 1997, the effects of a previous pulse crop on phosphorus availability will be examined under field conditions in order to determine the overall impact of the pulse crop on phosphorus availability and better understand long term impacts of pulse crops on soil phosphorus fertility.

Objectives:

The objectives of the 1996 growth chamber studies were 1) to examine the effect of surface - placed pea residue of differing age and phosphorus contents on phosphorus availability to spring wheat and 2) to compare the impact of lentil, pea and cereal residues on phosphorus availability to spring wheat and canola.

Materials and Methods:

1st Growth Chamber Study

Pea residue was collected from the field at three different stages of growth to provide pea residue of different phosphorus concentrations (young 0.31% P, medium 0.21%P, old 0.10%P). The residue was added to flats of Haverhill association soil (Brown soil zone, medium texture) taken from a wheat stubble field which had never received P fertilizer or had a pulse crop grown on it before. Residue was added to the soil surface at a rate of 5000 kg residue / ha. The growth chamber experiment consisted of a control and each of the three residue types added in both the presence and absence of wheat plants. Each treatment was replicated three times. Columbus var. hard red spring wheat was grown on half the flats. All treatments received a basal application of nitrogen, potassium and sulfur.

Plant available phosphorus in the treatments was determined as a potential phosphorus supply rate using 24 hour burial of anion exchange membrane as an available phosphate sink. Measurements were made initially, 4 weeks and 8 weeks after seeding. The content of total and water soluble phosphorus was measured in the residues prior to residue addition. Whole wheat plants were harvested after 55 days and analyzed for total dry matter yield as well as phosphorus, nitrogen and sulfur contents.

2nd Growth Chamber Study

In the second growth chamber study, soil was collected again from the same field used in the first growth chamber study. Lentil, pea and wheat residue were collected from a field near Saskatoon and characterized for phosphorus content. The residues were then mixed with the soil in flats, a basal N,K,S nutrient application was made and canola and spring wheat plants seeded and grown on the soils to maturity. Treatments consisted of the three different residue types added plus a control for each of the two crops. Measurements of phosphate supply rate were made initially, at four and eight weeks using anion exchange membrane burial as described for the 1st growth chamber experiment. At harvest, seed and straw yield was determined and the seed and straw analyzed for phosphorus and nitrogen concentration.

Results and Discussion:

1st Growth Chamber Study

The initial phosphate supply rate in the Haverhill soil used in the growth chamber study was 0.18 $ug/10cm^2/24$ hrs. The soil was therefore initially low in available P, as amounts less than about 0.3 $ug / 10cm^2/24$ hrs are generally considered deficient. In the pea residue, upwards of 85% of the total phosphorus in the residue was present in a water soluble form. Due to the large proportion of water soluble phosphorus, much of the P in the residue would be expected to be readily removed by leaching and therefore be available for uptake by a subsequent crop. Overall, the pea residue P concentrations are similar to that reported for barley and alfalfa residue. The young P residue had the highest concentrations of total P. The carbon to phosphorus ratios were 137:1 in the young residue, 208:1 in the medium and 416:1 in the old residue. Since each flat received the same amount of added residue, the total amount of P added as residue was highest in the treatments with the young residues added. As immobilization is reported to occur when C:P ratios in residues exceeds 200:1 (Hannapel et al., 1964), the medium and old residues have the potential to immobilize some available P upon decomposition.

Overall, final dry matter spring wheat yields were not significantly affected by the residue additions. The control treatment without added residue gave rise to the highest dry matter yield. Tissue phosphorus concentrations were significantly higher in the treatments receiving the young and medium aged residue additions (Figure 1). However, there was no significant difference in phosphorus uptake among the treatments.

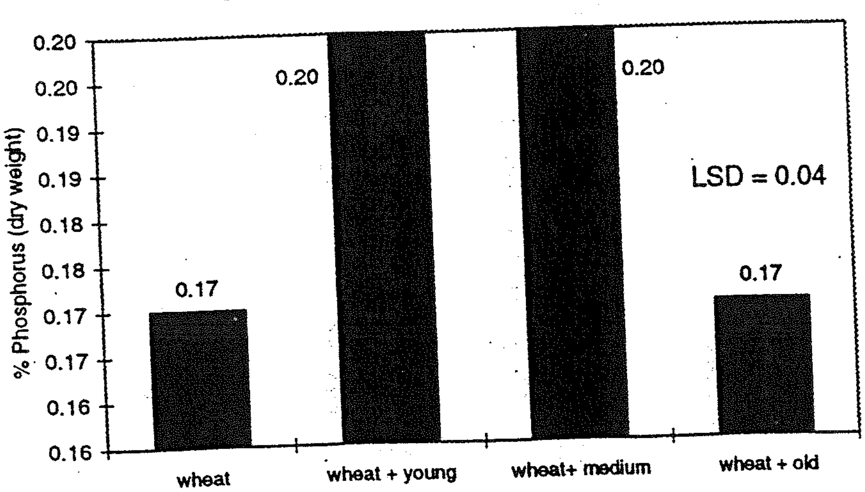

Figure 1

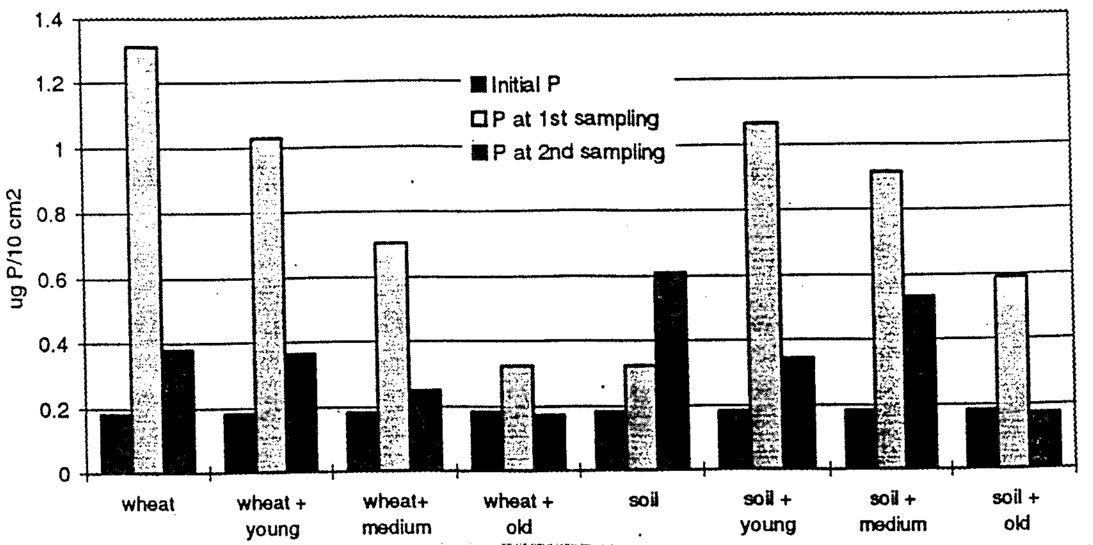

Figure 2

In the treatments where pea residue was added to the soil, significantly higher soil phosphate supply rates were observed at the four week sampling time (Figure 2), with the highest supply rates observed in the treatments where the young pea residue was added. Generally, all residue treatments had a positive effect on soil phosphate supply rate at the 4 week sampling period, indicating that more phosphate was released than immobilized by this time. It seems likely that the early initial increase in phosphate supply in the soil is related to the release of water soluble inorganic phosphate forms from the residue. As more residue phosphorus is added in the young residue treatments, it is not surprising that these treatments gave rise to the highest supply rates. As the supply rates decreased and the differences among treatments diminished in the 8 week sampling, it seems likely that either immobilization or fixation of the released phosphate occurred over the next four weeks.

An interesting finding of this study was that the phosphate supply rate after 4 weeks was significantly higher in the no-residue treatment in the presence of wheat plants versus when the plants were absent. This may be related to rhizosphere effects in that the root density in the flats used to grow the plants is so great that essentially all of the soil may be considered rhizosphere soil. P availability is increased in the rhizosphere by secretion of H^+ and organic acids. Stimulation of microbial activity by the addition of residue in the may enhance microbial immobilization of phosphate in the rhizosphere as indicated by lower available P supply in residue - amended treatments. It is also possible that increased microbial activity and associated CO_2 production could have resulted in HCO_3 competition with phosphate for adsorption sites on the resin membrane in residue-amended treatments.

2nd Growth Chamber Study

In the second growth chamber study, the three residues used differed considerably in total P concentration: lentil .14%P; wheat 0.033%P and pea 0.074%P. The residues collected for this study were residues from the previous crop year collected in the spring of 1996 and so had experienced over-winter weathering and nutrient loss, thus explaining the lower P concentrations compared to the 1st growth chamber study in which fresh pea residue was harvested from the field. In the absence of plants, the phosphate supply rate was higher in the residue amended soils than in the unamended soils (Figure 3). However, the differences were much less than in the 1st growth chamber study, probably as a result of losses of P from the residue that had occurred in the field. Again, as in the first growth chamber study, in the presence of both canola and wheat plants, the phosphate supply rate was lower in the residue amended treatments compared to unamended. Much higher (5 to 7 times higher) phosphate supply rates were observed in soils in which canola was grown compared to wheat, indicating that these two crops produce very different conditions in their rhizosphere which may subsequently impact upon P availability.

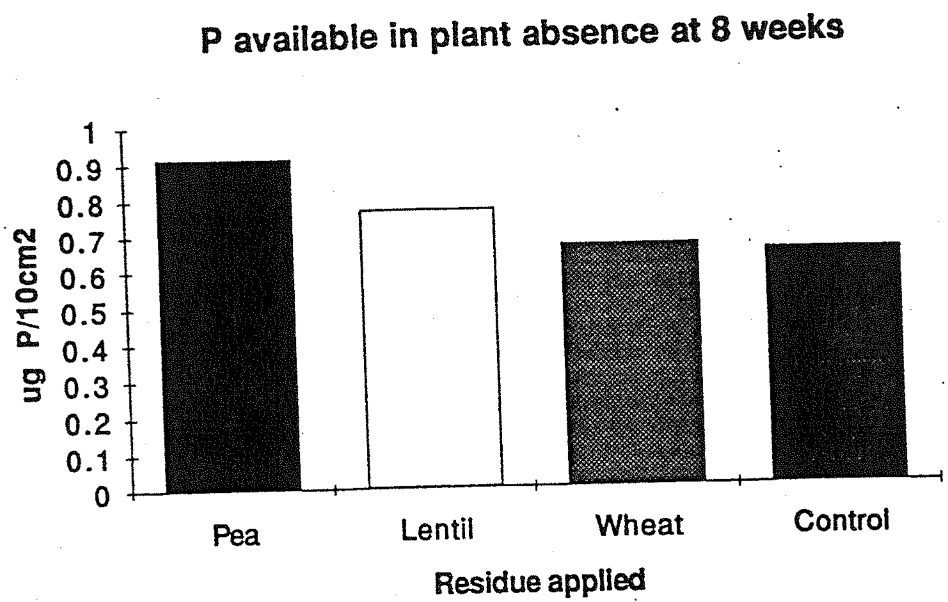

Figure 3

Both the grain and straw yield of canola amended with residues was lower compared to unamended, indicating that the residues were having a negative impact upon yield. This does not appear to be related to nitrogen,potassium or sulfur availability as all treatments received a blanket application of these nutrients. In wheat, the straw phosphorus concentrations were lower in residue amended treatments compared to unamended. With canola, straw P concentrations were highest in the lentil residue amended treatment. Overall, the addition of pea, lentil and wheat residue reduced the phosphorus uptake compared to the control for both wheat and canola.

Conclusions:

The results of the two controlled environment studies on the effect of pulse crop residues on phosphorus availability leads to the following conclusions:

1) The ability of a pulse crop residue to act as a source of available P is dependent upon the age of the residue. Young, unweathered residue appears to have the greatest impact on increasing available P, likely through the release of unbound water - soluble phosphate forms.

2) Overall, the phosphorus contained in pulse crop residue itself appears to play a relatively minor role in increasing phosphorus availability to a following crop. If significant increases in crop yield and phosphorus uptake are observed in cereals and oilseeds following a pulse crop versus a cereal in the field, this increase in P uptake is likely associated with a better rooting system present in the crop following the pulse, which allows it to better access indigenous soil phosphorus.

3) The relative effects of cereal residue and different types of pulse crop residues on phosphorus availability are complex. The effects of the residue on P availability as revealed in soil P supply rate and plant uptake were not closely related to the total P content of the residue itself. Wheat and canola appear to have very different rhizosphere conditions which interact with the residue additions to influence P availability.