PHOSPHATE ROCKS INFLUENCE GREEN MANURE GROWTH AND SOIL PHOSPHORUS DYNAMICS

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INTRODUCTION

Phosphate rock (PR) has been proposed as an external input of phosphorus (P) in organic farming. If used in conjunction with a green manure crop, any uptake of P from the PR by the green manure may increase the long term effectiveness of the rock. Additions of PR can increase the total P supply to the soil system. However, plants may access P from PR only when the rock is dissolved to release P into the soil solution, a process which is governed by both rock and soil properties. Phosphate rocks that originate from deposits that differ geographically and geologically can also differ greatly in their effectiveness when applied to soils. Generally, rocks of sedimentary origin are more soluble than rocks of igneous origin. Dissolution of PR may be slowed or ineffective in soils with high pH and calcium content, which are typical of many agricultural soils across Canada. With careful crop selection, soil limitations may be overcome. For instance, there is evidence that certain crops, such as canola (rape), white lupin and buckwheat, can extract P from PR through exudation of organic acids and protons into the root zone.

Figure 1. Phosphate rock plots (M. Arcand)

This research proposes to use buckwheat, grown specifically as a green manure, to phyto-extract P from PR. Through uptake of P from the PR, the green manure can transform the P into organic forms (i.e. in the green manure tissue), which may be mineralized and released into the soil following plow-down or mulching.

WHAT WAS DONE

The experiment was conducted from 2004 to 2006 on two organic farms and one conventional farm in Southwestern Ontario. The first part of the study examined the use of phosphate rocks of varying North American origin on the yield and P uptake of a buckwheat green manure crop, conducted on three fields each in the 2004 and 2005 growing seasons. The second part of the experiment examined the residual effects of the mulch and residual PR in the spring following the initial application of those materials.

Application rates of the PRs were standardized based on the total P content of the rock (Table 1). Heavy metal concentrations of PRs are of concern to human and animal health; therefore, total cadmium (Cd) and arsenic (As), which are the most prevalent heavy metals in PRs, were determined for each PR.

The following rocks were applied on the organic farms: VolCanaPhos PR (igneous), Spanish River Carbonatite PR (igneous) and Calphos PR (sedimentary). In addition to the latter PRs, the Pebbled PR (sedimentary) and the Tennessee PR (sedimentary), as well as the conventional fertilizers MAP and TSP were applied on the conventional farm.

Table 1. Phosphate rock deposit locations, characteristics, and field application rates

Rock	Abbr.	Rock deposit location (geologic origin)	Reactivity*	Heavy metals: Cadmium (mg kg^{-1})	Heavy metals: Arsenic (mg kg^{-1})	Total P (%)	Application rate 100** (kg rock ha^{-1})	Application rate 400** (kg rock ha^{-1})	Application rate 800** (kg rock ha^{-1})
VolCanaPhos	VPR	Ontario (igneous)	low	bdl	27.4	16.8	537	2146	4292
Spanish River Carbonatite	SRPR	Ontario (igneous)	no data	bdl	3.9	1.4	6575	26298	52596
Calphos	CPR	Florida (sedimentary)	medium	1.5	5.4	8.7	1031	4123	8245
Pebbled	PPR	North Carolina (sedimentary)	high	6.5	19.4	10.1	892	3569	7138
Tennessee	TPR	Tennessee (sedimentary)	medium	bdl	12.2	12.7	709	2835	5670

*Designations based on crystallographic *a*-axis lengths determined by powder x-ray diffraction of the apatite (P) mineral contained in the phosphate rock. Shorter *a*-axis lengths indicate smaller crystal surface area, which is correlated to increased phosphate rock solubility. Data was not obtained for the SRPR due to low total P content and lack of apatite present in the rock.

**Numbers indicate targeted application rate of rock in kg total P ha^{-1}.

bdl indicates concentrations were below the detection limits of the instrument.

Phosphate rocks were applied to 2.4 m x 5 m plots in early June and incorporated using a rototiller (Fig. 1). Buckwheat was planted at a seeding rate of 67 kg ha^{-1} on all plots within a week of PR application. The crop grew for approximately 7 weeks and was harvested just prior to seed set to determine yield. Aboveground biomass samples were removed from each plot and analyzed for total N and P content.

Immediately following harvest in August, all the aboveground buckwheat material from each plot was returned to half of the plot area (2.4 m x 2.5 m) from which it was grown (Fig. 2). The mulch was left on the soil surface over the fall and winter, then incorporated into the soil with a rototiller in the following spring.

Results: Phosphate Rocks and Green Manure

The phosphate rocks varied considerably in their total P content and reactivity (Table 1). Additionally, the sedimentary rocks CPR and PPR contained the heavy metal cadmium, which would accumulate in soils over time. However, the cadmium content of the rocks is well below the acceptable limit set by the Canadian General Standards Board's Permitted Substances List for Organic Production.

Buckwheat yields did not change with application of any of the phosphate rocks in comparison to the control (no P added) on either the organic fields or the conventional fields. High application rates of an inorganic soluble fertilizer, TSP, were required to obtain a significant yield response on the conventional farm, indicating that P may not have been limiting for buckwheat despite initially low soil test P (3.3 mg kg^{-1}). Buckwheat yields were agronomically adequate (ranging between 3.0 to 3.5 t DM ha^{-1}).

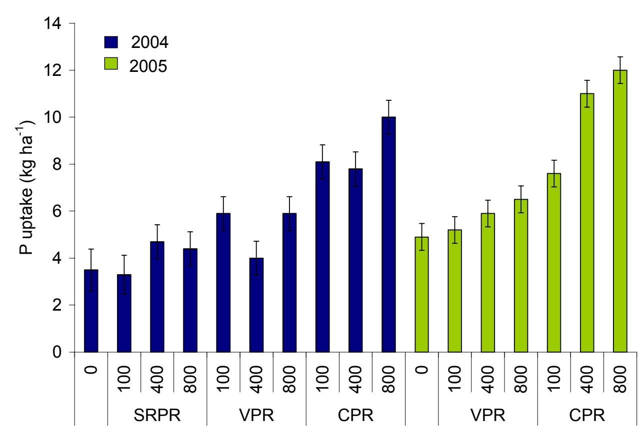

Figure 3. Buckwheat P uptake due to PR treatment and application rate on one of the organic farms in 2004 and 2005.

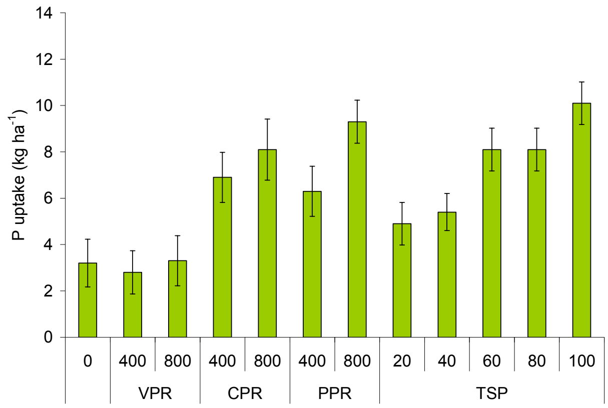

Figure 4. Buckwheat P uptake due to PR and fertilizer (TSP) treatment and application rate on the conventional field in 2005.

Phosphorus uptake was increased with applications of the Calphos PR, indicating enhanced accumulation of P in the buckwheat tissues. The trend in buckwheat P uptake response to PRs was similar across both organic farms in both years. As such, data from only one farm is presented (Fig. 3). The Ontario-derived PRs, Spanish River Carbonatite and the VolCanaPhos, did not influence P uptake of buckwheat grown on any of the fields. On the conventional field in 2005, the Pebbled PR increased P uptake of buckwheat compared to the control (Fig. 4).

Increased P uptake due to Calphos and the Pebbled PRs was likely due to a combination of medium reactivity and small particle size and high reactivity, respectively (Table 1). Calphos comes as large soft aggregates consisting predominantly of clay-sized particles, while the other PRs are coarse grained (Fig. 5).

Figure 5. Phosphate rocks used in the experiment.

Results: Green Manure Residues and Residual PR Effects on Soil P Dynamics

The resulting application rate of P in the buckwheat mulch that was applied to the soil at harvest is shown in Fig. 6. The application rate of the mulch ranged between 15 to 25 kg P ha^{-1}. The amount of P in the mulch applied on plots that had received CPR at the high rates of application was significantly greater than the amount of P applied in the mulch from buckwheat grown on the control plots (no P).

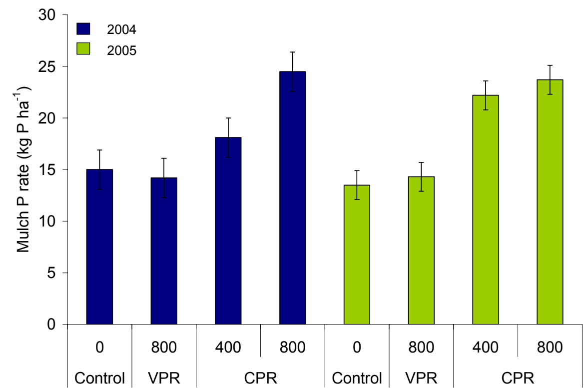

Figure 6. Application rates of P (kg P ha^{-1}) in the buckwheat mulch due to original phosphate rock treatment and rate (kg P ha^{-1}).

Significant mulching and PR treatment effects on soil P flux was found in 2005 only. P flux was increased relative to the control plots left bare in mulched plots that had previously received application of the Calphos PR at 400 and 800 kg P ha^{-1}. This significant effect only occurred within the first two-week PRS^{TM} probe burial period, which corresponded to the time period prior to tillage at the end of April, 2005 (Fig. 7).

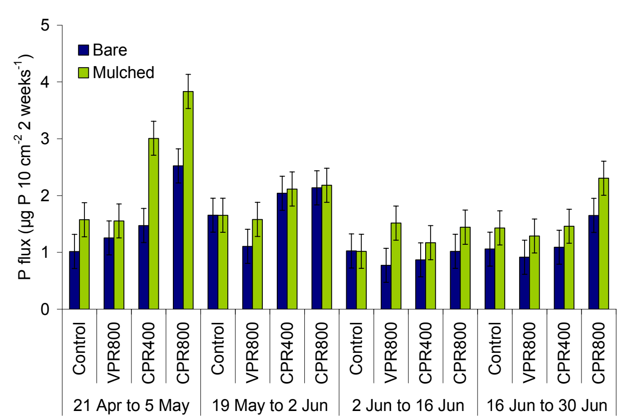

Figure 7. Phosphate flux due to original phosphate rock treatment and rate for each two-week PRS™ probe burial period.

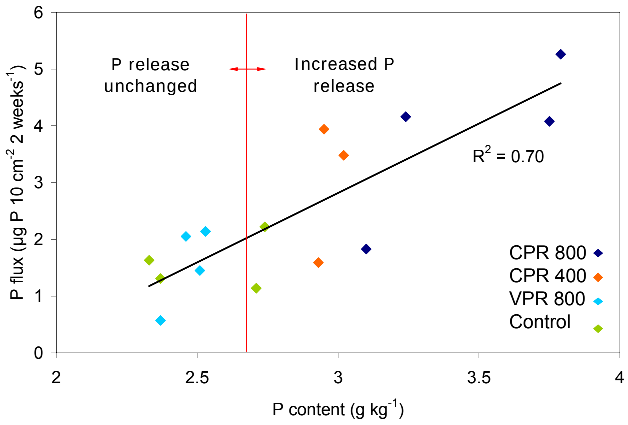

Figure 8. Influence of initial P content of the buckwheat mulch on the P flux in mulched plots in the first two weeks of PRS™ probe burial.

The initial P content of the buckwheat mulch (quality) explained 70% of the variation in P flux in the mulched plots in the first two-week burial period in early spring (Fig. 8), while the amount of P applied in the mulch (quantity) explained 30% of this variation. It was found that buckwheat mulch that contained more than 2.7 g kg^{-1} of P resulted in increased P flux relative to soils left bare, while addition of mulch with total P less than this value resulted in no change in soil P flux (Fig. 8). There was no change in microbial biomass P in soils amended with buckwheat mulch indicating that the release of P from the mulched plots was not due to mineralization by the microbial biomass. The increased P flux may have been due to decreased P adsorption in the soil due to competition for adsorption sites with other decomposition products from the buckwheat mulch.

Phosphate rocks of high reactivity and small particle size increased the P quality of buckwheat, which resulted in increased P flux in soils amended with the buckwheat mulch. Therefore, not all rocks were effective at increasing the P uptake of buckwheat. The subsequent release of P from the buckwheat mulch residues grown with the ineffective rocks was no different in comparison to soils that had not received any mulch at all.

REFERENCES

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THE BOTTOM LINE...

Not all phosphate rocks are the same; current Canadian sources of rock are very insoluble in soils. Increased release of P from buckwheat mulch residues was influenced by the quality of the material. This high quality was achieved by growing the buckwheat with high reactive and fine-grained phosphate rock. Large volumes of rock were required for response, which may be cost prohibitive in the short-term.

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