

EFFECT OF FIVE PHOSPHATE ROCKS ON THE BIO-AVAILABILITY OF PHOSPHORUS AND CADMIUM

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Introduction

Red clover (*Trifolium pratense* L.) as a forage legume is often the first step of the food chain for substances those accumulate from soil via herbage and livestock into the human body. Red clover is a cool-season, perennial crop with a bunch growth habit, yielding 4-14 t per ha of herbage that is used principally as hay and silage. It thrives even on acid soils, though low soil pH usually decrease N fixation by hindering nodulation.

Low soil pH decreases the bioavailability of essential nutrients such as phosphorus, and increases the availability of toxic elements such as cadmium in the root zone (Kádár 1991). On acid soils the direct use of a CaCO_3 -containing reactive phosphate rock (PR) as P fertilizer may be recommended concerning the growing costs of superphosphate application. However, Cd mobilization is also possible from PRs in course of their dissolution, resulted in Cd accumulation in the forage.

In this study we focused on the effects of five phosphate rocks with various P-solubility on the bioavailability of phosphorus for red clover. The accumulation of Cd by plants mobilized from PR in an acidic root environment has been also studied.

Methods

In a pot experiment five PRs, originating from Algeria (1), North Florida (2), North Carolina (3), Senegal (4) and Morocco (5), Hyperphosphate (6) and single superphosphate (SSP, 7), as well as $\text{SSP} + \text{CaCO}_3$ (8) were applied in 0-100-400-1600 $\text{mg P}_2\text{O}_5 \text{ kg}^{-1}$ rates, with particle size of $<160\mu\text{m}$, on a strongly acidic sandy soil with very low available P content (Table 1.).

Table 1. Chemical properties of the experimental soil

$\text{pH}_{\text{H}_2\text{O}}$	pH_{KCl}	AL-P mg kg^{-1}	Olsen-P mg kg^{-1}	$\text{H}_2\text{O-P}$ mg kg^{-1}	CEC cmol kg^{-1}	Hydr.ac. (y_1) %	Exch. ac.(y_2)	OM %
5.01	3.83	23.4	16.2	8.5	3.0	11	3.7	0.6

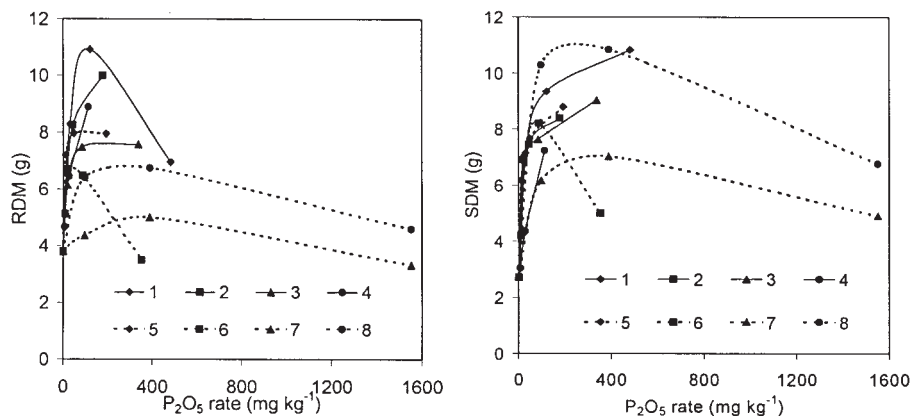
100 mg N and 200 $\text{mg K}_2\text{O kg}^{-1}$ soil was added to supply adequate N and K. All P sources and the N and K fertilizers were mixed into 1, 6 kg of soil in each pot before sowing. Pots were watered according to the requirement of plants. Shoots were harvested three times during the three-month growing period. At the end of the experiment the whole root system was separated from the soil, the biomass, P and Cd content of shoots and roots were measured. The available P contents of PRs were characterized by neutral ammonium citrate extraction.

Results and discussion

The specific surface of PRs varied in a range from 5,7 m^2g^{-1} (for Senegal Pr) to 20 m^2g^{-1} (for North Carolina PR) (Csathó *et al.* 2005). Neutral ammonium citrate was the best solvent for determining the solubility of the different PRs (Csathó *et al.* 2005). Algerian PR (PR1) showed the highest solubility in neutral ammonium citrate extractant. The solubility ratio for

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When averaged over P sources, the $1600 \text{ mg total P}_2\text{O}_5 \text{ kg}^{-1}$ of soil rate increased red clover yield more than 2.5 times in the acid sandy soil compared to the zero P treatment by the first harvest. The sum of the three-harvest yields of shoot and root biomass (Figure 1) was significantly affected by PR type ($p < 0.001$) whereas P availability did not affect root dry mass (RDM), but affected shoot dry mass (SDM) significantly ($p < 0.01$).

Figure 1. Shoot and root dry mass as affected by the soluble P content of PRs.

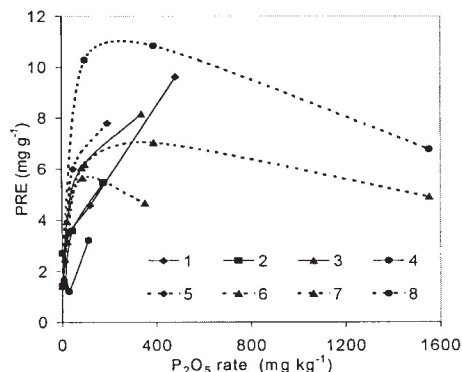
The lowest rate of biomass accumulation was shown for PR4 (Senegal) that can be explained by its lowest specific surface, P-solubility and CaCO_3 content among the PRs studied (Osztoics *et al.*, 2006).

Both shoot and root growth was strongly depressed by the increasing rate of applied P fertilizers above a critical dosage. Root growth was more sensitive to the P added than shoot growth, i.e. biomass accumulation ceased preceding the decline in shoot growth by lower P treatments of the most soluble P fertilizers (SSP, SSP+Ca, Algeria and North Carolina PR). Moreover, the death rate of roots exceeded growth rate in these treatments, as clearly shown on decreasing RDM in Figure 1. Critical rate of fertilizer application was about $100 \text{ mg added P kg}^{-1}$ soil for root growth, consequently it was unlikely an effect of P availability, but of other factors, possibly dissolution of some toxic substances such as Cd from the PRs.

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The bioavailability of P mobilized from the various PRs and transported to the root surface was characterized by using the parameter “phosphorus root uptake efficiency” (PRE, mg shoots P per unit root mass). Both the type of applied P fertilizer and its rate of application are markedly affected PRE of the red clover crops ($p < 0.001$).

Figure 2. P uptake efficiency of red clover as affected by PR treatments



Enhancement of P availability on low supply induced both root growth and more efficient P acquisition. Dissolution rate of phosphorus from PR4 (Senegal), and the availability and uptake of the P content of PR4 is much lower than that of the other P sources.

Critical rates of P fertilizers, where the efficiency of clover P uptake starts to decrease, proved to be above the highest application level for PRs, but not for SSP and SSP+CaCO₃, as shown in Figure 2.

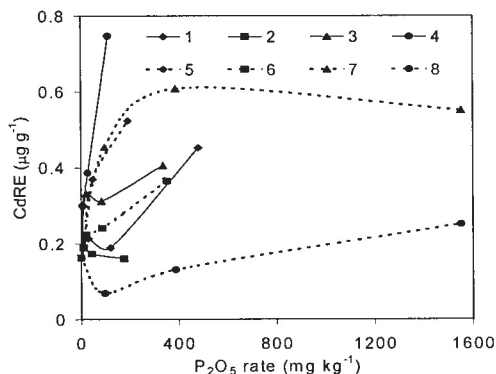
The amount of P taken up by shoots varied between 7 to 72 mg per plant and was controlled by the type of P source and P availability ($p < 0.001$) on low P supply, and by other factors above the critical supplying level, where similarly to shoot and root growth uptake rate decreased.

PR4 (Senegal) treatment gave the lowest plant P uptake and the highest Cd uptake, which was more than three times higher, than Cd uptake from any other P source. Cd uptake ranged from 0.9 μg up to 7 μg measured for the highest application rate. Unlikely to the P uptake, no any depression in Cd uptake was observed in the high P fertilizer treatments. Both the origin and application rate of P source significantly affected on the rate of Cd uptake of red clover shoots, determining Cd availability and also root acquisition efficiency in the given soil environment ($p < 0.001$).

Cd availability is likely promoted by the acidification of the root environment due to biological nitrogen fixation in the root nodules of red clover plants.

In Figure 3. cadmium uptake efficiency is shown as influenced by the different P sources and rates. The bioavailability of Cd differed for RPs ($p < 0.001$) and increased markedly with increasing P rates ($p < 0.001$), except of the more buffered SSP+CaCO₃ treatment.

Figure 3. Cd uptake efficiency in various P fertilizer treatments.



Conclusions

Shoot and root growth, P uptake and P acquisition efficiency were strongly depressed by the increasing rate of applied P fertilizers above a critical rate, which was around 100 mg P₂O₅ kg⁻¹ of soil for red clover for the PRs and soil conditions of the experiment.

Both the type of applied P fertilizer and its rate of application markedly affected the P acquisition efficiency (PRE) of the red clover crops.

PR4 (Senegal) treatment gave the lowest plant phosphorus uptake and the highest Cd uptake, which was more than three times higher, than Cd uptake from any other P source.

The bioavailability of Cd increased with increasing P rates, except of the more buffered SSP+CaCO₃ treatment.

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