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EFFECT OF SOIL PROPERTIES AND P FERTILIZERS ON TRACE ELEMENT UPTAKE OF RED CLOVER IN A POT EXPERIMENT

E. OSZTOICS and K. BUJTAS

Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest, Hungary

TRACE ELEMENTS UPTAKE PHOSPHATES CLOVER PLANTS ENVIRONMENTAL EFFECTS ENVIRONMENT POLLUTION ACIDIFICATION

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Summary

The impacts of superphosphate and Algerian phosphate rock and their various application rates on soil pH and on the availability of trace elements by red clover were studied in a pot experiment on several types of acidic soils from the Carpathian basin. The differences among the soils' original pH and texture, and those differences in soil pH, which resulted from the application of different P forms and rates were reflected in the Mn, Ni, Al, Co, Sr, Cd and Cr contents of red clover. Plant concentrations of these elements were smaller on the slightly acidic than on the strongly and extremely strongly acidic soils. Elemental concentrations were generally higher when there was less time between two cuts, and decreased in the later cuts.

Introduction

Strongly acidic soils cover about 13 % of Hungary, and nearly 43 % of the soils are slightly acidic (Várallyay,1990). Acidification of the soils is on the increase. In the past decades, superphosphate was the main P fertilizer source on both calcareous and acidic soils. As soils are becoming more acidic and the costs of superphosphate application are growing, attention should be drawn to the direct use of reactive phosphate rock as P fertilizer. Soil acidification and its harmful effects (mobilization of Al, Mn, and heavy metals) can be diminished by regular application of phosphate rock.

Plant roots absorb only phosphate ions (Barber, 1984) as a source of phosphorus to satisfy their needs. Therefore phosphate rocks, which are considered as insoluble P fertilizers, must first be dissolved in soils to yield phosphate ions. Dissolution of a given phosphate rock depends mainly on soil characteristics, climate and the properties of the phosphate rock (chemical reaction, size of particles). The solubility of phosphate rock in

soil is influenced favourably by low pH (<pH 6), low available P, low exchangeable Ca, low base saturation, high cation exchange capacity, high humus content (Khasawneh & Doll, 1978; Hammond et al., 1986; Chien & Mennon, 1995).

The differences among the soils' properties, and the differences in soil pH resulting from the application the different P fertilizers may reflect in the nutrient and trace element uptake of the plants.

.In the study presented here, the impacts of superphosphate and Algerian phosphate rock and their various application rates on soil pH and on the availability of Mn, Ni, Al, Co, Sr, Cd and Cr by red clover (in 5 cuts) were studied in a pot experiment on 6 different types of acidic soils from the Carpathian basin.

Materials and Methods

The main characteristics of the acidic soils from Hungary, Romania, Slovakia and Algeria are presented in Table 1. Total content of trace elements in the soils were determined by inductively coupled plasma emission spectrometry (ICP) after digestion of soil samples by cc. HNO_3+H_2O_2. Available trace elements were determined by ICP after acidic ammonium acetate + EDTA (AAAc-EDTA) extraction (Lakanen and Erviö, 1971, Sillanpää, 1982). Limits of ICP detection were: Mn 0.50, Ni 0.75, Al 1.4, Co 0.35, Sr 0.02, Cd 0.135, Cr 0.305 mg/kg.

The experimental set-up:

1.7 kg soil was used per pots in a randomized block experiment with 3 replications. 100 mg N in the form of NH_4NO_3, and 400 mg K as aqueous solution of KCl per kg soil were given uniformly in all treatments. Similar P active ingredient contents (50, 200, and 400 mg P_2O_5/kg soil) were applied as superphosphate and phosphate rock in powdery form. Extra phosphate rock doses (600 and 800 mg P_2O_5/kg soil) were also included. Soil pH was assessed and 40 seeds of red clover per pot were sown one day after fertilizer application. Red clover was cut 5 times (on some soils only three times because of the poor development of the plants) and each cut was analysed separately. Elemental composition of the air-dried and ground plant parts were determined by ICP after wet digestion of the samples in cc. HNO_3+H_2O_2..

Table 1. Characteristics of the soils used in the pot experiment

	Hungarian soils			Rumanian soil	Slovakian soil	Algerian soil
	1.	**2.**	**3.**	**4.**	**5.**	**6.**
pH_{H2O}	5.59	6.50	4.38	3.62	5.24	6.02
pH_{KCl}	4.25	5.56	3.71	3.40	4.03	5.55
hydrolytic acidity (y_1)	13.3	9.3	19.5	26.5	21.6	7.7
humus, %	1.67	3.81	1.06	1.54	2.7	1.53
CEC, meq/100g	9.31	30.1	8.5	8.1	11.0	4.9
base sat., meq/100g	8.7	29.4	4.2	0.74	3.7	4.4
total **P**, mg/kg	801	525	493	688	211	198
water sol.-**P**, mgP/kg	5.1	6.9	5.4	2.4	2.1	6.9
Mn, total, mg/kg	941	904	368	668	1177	64
Mn, AAAc-EDTA sol., mg/kg	198	162	87	68	361	8.6
Ni, total, mg/kg	20.3	31.3	17.8	14.3	9.5	10.3
Ni, AAAc-EDTA sol., mg/kg	1.0	6.0	0.9	0.6	2.1	0.4
Al, total ,%	1.4	1.69	0.9	0.7	0.6	0.5
Al, AAAc-EDTA sol, mg/kg	124	100	195	360	277	59
Co, total, mg/kg	14	13.6	5.7	6.6	9.7	3.9
Co, AAAc-EDTA sol., mg/kg	2.8	1.9	0.9	0.7	1.8	0.3
Sr, total, mg/kg	33.9	25.9	5.1	2.9	3.6	6.8
Sr, AAAc-EDTA sol., mg/kg	23.0	11.0	1.9	0.5	1.3	4.0
Cd, total, mg/kg	0.30	0.22	0.16	*	0.38	*
Cd, AAAc-EDTA sol., mg/kg	*	*	*	*	*	*
Cr, total ,mg/kg	28.4	25.3	15.1	14.5	12.6	12.6
Cr, AAAc-EDTA sol., mg/kg	*	*	*	*	*	*

Hungarian soils: 1. **moderately acidic** pseudogley brown forest soil (Szentgyörgyvölgy)
2. **slightly acidic** chernozem brown forest soil (Kompolt)
3. **extremely acidic** sandy brown forest soil with thin interstratified layers of colloid and sesquioxide accumulation (Nagykorpád)

Rumanian soil 4.: **extremely acidic** podzol soil (Livada)
Slovakian soil: 5. **strongly acidic** typical podzol soil (Lucenec)
Algerian soil: 6. **slightly acidic** sandy soil

* < limit of detection

Results and discussion

At increasing P application rates (with addition of the same amount of NK), the original soil pH decreased by 0.1-0.7 units when superphosphate was applied but increased by 0.3-1.0 units when P was given in the form of phosphate rock. The extent of these changes was different for the 6 soils, depending on original pH and texture (Fig.1.)

In the first cut of red clover the concentrations of the various trace elements were different: Mn contents were the highest (50-2600 mg/kg), Sr and Al concentrations were

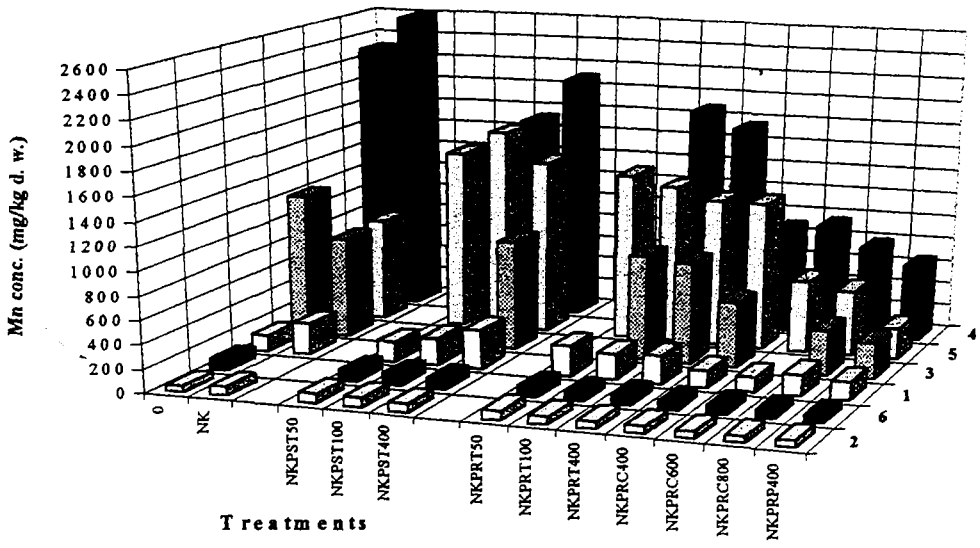

Fig. 2. Changes in Mn concentration in the first cut of red clover

For 1,2,3,4,5,6 soils: See table 1. Treatments: See Fig. 1.

Uptake of Al and Sr were determined basically by the original properties of the soils, but soil acidity had not such a dominant influence than in the case of the previously discussed elements. Influence of P form on the uptake of Al was observed only on the podzol soil from Slovakia. Strontium content of the plants increased on all soils with increasing superphosphate rates because of the high Sr content of the superphosphate. On the other hand, phosphate rock hardly increased the Sr content as compared to the control plants, and the increasing P rates of phosphate rock also had no effect. Changes in Sr, Al, and Ni contents of plants on the podzol soil from Slovakia (soil No. 5.) are shown on Fig. 3., and Co, Cr, Cd contents on the same soil on Fig. 4. Changes of pH in this soil reacted the most sensitively to P forms and P rates (see Fig. 1.).

In the later cuts of red clover effects of soil properties, of P forms and rates were similar to those observed in the first cut.

between 50 and 300 mg/kg, Ni and Co contents between 0.3 and 10 mg/kg. Chromium contents were below 1.0, Cd contents below 0.5 mg/kg.

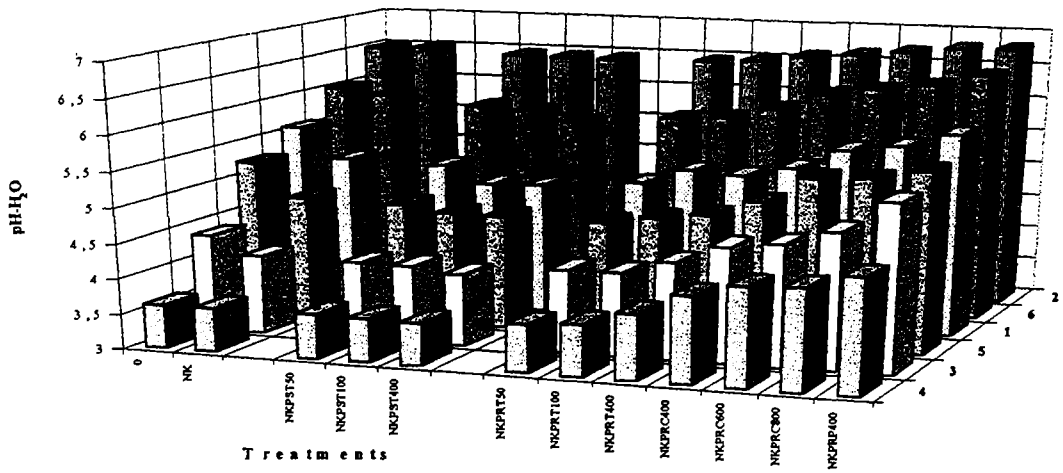

Fig. 1. Effect of P fertilizer treatments on soil pH-H_2O

For 1,2,3,4,5,6 soils: See Table 1.
Treatments: PS= Superphosphate, PR= Phosphate Rock
50, 100, 400...= Active P ingredients, mg P_2O_5/kg soil
calculation of active ingredient based on
total (mineral acid-soluble-) P_2O_5 content (PS_T and PR_T) (Int. Stand., 1984),
2 % citric acid-soluble- P_2O_5 content (PR_C) and
alkaline ammonium citrate- soluble-P_2O_5 content according to Petermann (PR_P)
(Offic.J.EC, 1977).

Uptake of Mn, Ni, Co, and Cr was differently affected by the original soil properties (pH, texture, trace element content) and by the form and extent of P fertilization. These effects are shown in Fig. 2. for Mn. On the slightly and moderately acidic soils uptake of Mn and Ni was much lower (50-300 and 1-4 mg/kg, resp.) than on the strongly acidic soils, and the P fertilization had no effect on the uptake. On acidic soils Mn phytotoxicity is held to be at least partly responsible for yield decreases, in agreement with the higher Mn content of the soil solution at lower pH (Cseh and Zsoldos, 1990). In an FAO study, plant Mn contents decreased steadily with rising pH (Sillanpää, 1982). No cobalt, Cr, and Cd were measured in the plants on the slightly acidic soils. In contrast, the higher Mn, Ni, Co, and Cr content of the plants on the strongly acidic soils were substantially influenced by the form and extent of P fertilization, but such P effects were not observed in Cd uptake. Mitchell (1957) found decrease of Ni and Co contents in red clover with increasing soil pH.

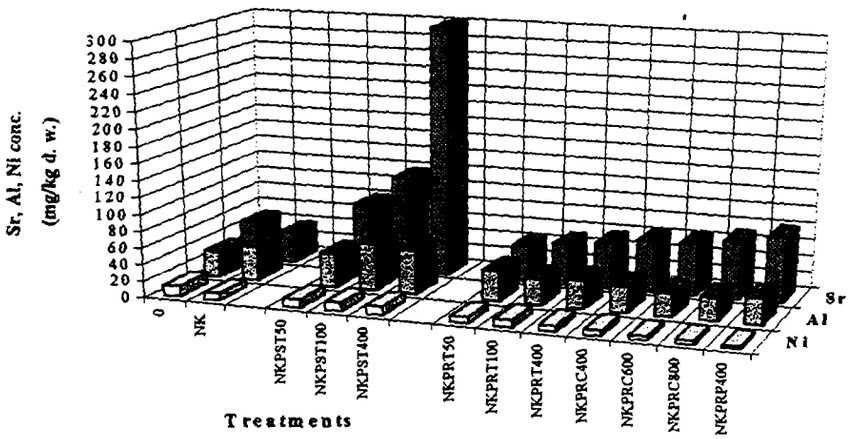

Fig. 3. Changes in Sr, Al and Ni uptake in the first cut of red clover on strongly acidic typical podzol soil, No. 5.

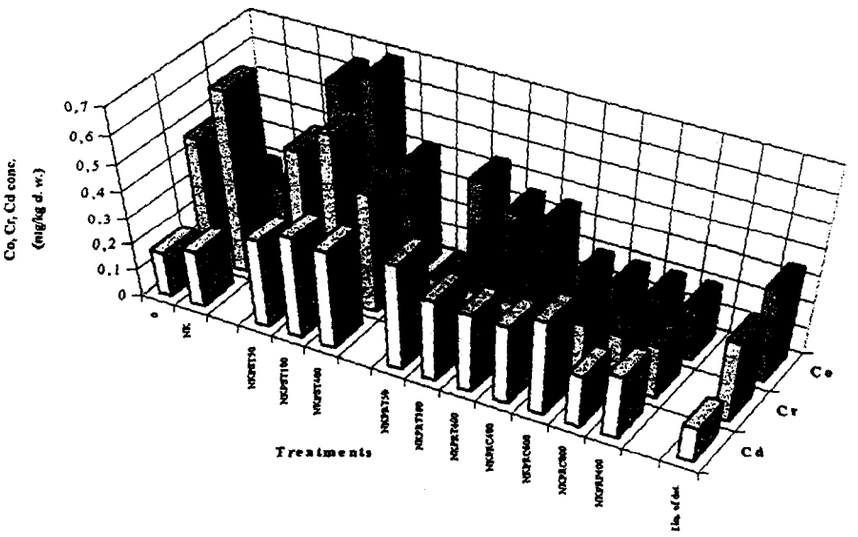

Fig. 4. Changes in Co, Cr and Cd uptake in the first cut of red clover on strongly acidic typical podzol soil, No. 5.

Elemental concentrations were generally higher when there was less time between two cuts, and decreased in later cuts, with the exception of Cr. In the last cut, when the plants grew under slightly stressed conditions (lower temperature, less light), cocentrations of several elments (Cr, Al) increased. This increase was greater on strongly and extremely strongly acidic soils.

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