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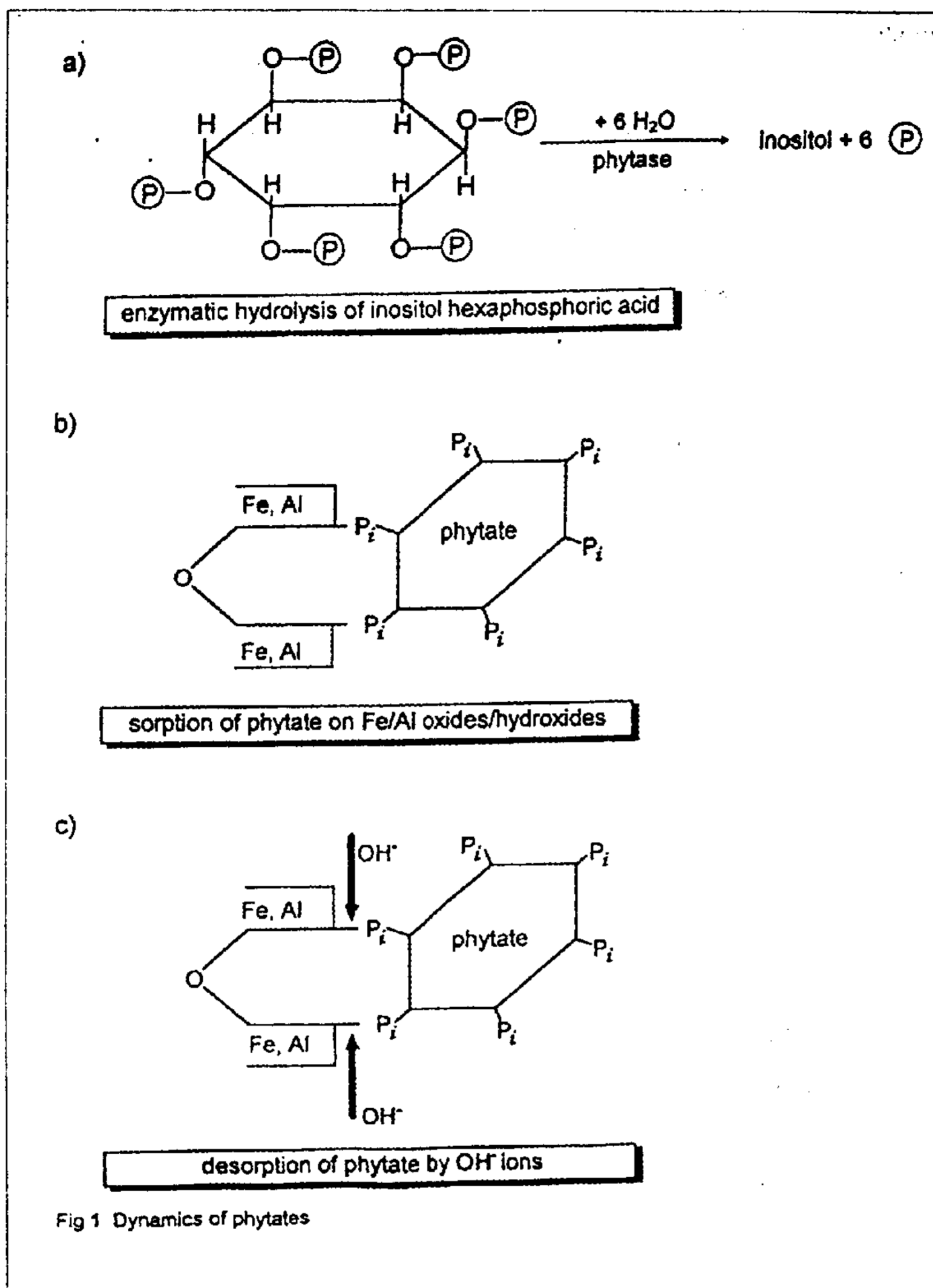
ABSTRACT

Incubating a soil (Niederhummel) of low P adsorption capacity and low oxalate-soluble Fe with Na-phytate let release up to 30-25% of the added phytate-P by enzymatic dephosphorylation, which increases with dose (8.8/ 17.5 mg phytate P/100 g soil) and temperature (12 and 25° C) but is eliminated by γ -radiation. With a soil (Gartelshausen) of high P ads. cap. and ox.-sol. Fe the crucial factor is the availability of phytate-P, which is adsorbed much stronger than orthophosphate and can displace the latter from the adsorption sites. Adsorbed phytate-P can be desorbed by OH⁻ ions (e.g. by liming). This was confirmed in pot experiments, where phytate-P and di-Ca phosphate as P sources behave similarly for total uptake of P by plants in different rotations, ryegrass excepted.

INTRODUCTION

Inositol hexaphosphates (salts of phytic acid), originating mainly from plant residues and partly from microbial biosynthesis (Caldwell and Black, 1958), are the largest fraction ($\geq 50\%$) of the organically bound P in soils (McKercher and Anderson, 1968). Their plant availability depends primarily on their hydrolysis to inositol and P_i by the phytase present in roots, mycorrhizae and microorganisms (Fig. 1a). However enzyme activity is very often not decisive for the acquisition of phytate-P by plant roots in agricultural soils, where several parameters significantly influence its availability. One major factor is the adsorption capacity of soil aggregates, since by its 6 P_i groups (Fig. 1b) phytate is more strongly fixed than P_i to Fe/Al oxides/hydroxides and to a smaller extent clay minerals (Anderson et al., 1974, Ivanov and Sauerbeck, 1971, Martin and Cartwright, 1971). When considering the P status of soils; sorption and desorption curves describe much better P availability than either buffer soluble or precipitated with Ca or sorbed to CaCO₃ (Jungk and Claassen, 1989). Results by Schwertmann and Schieck (1980), Welp and Brijm/ner. (1983) and Soltan et al. (1993) are consistent with this notion, indicating a close positive correlation between phosphate sorption on Fe oxides and oxalate extractable Fe. Goethite was considered to be the most important adsorbent in soils.

Presented experiments (Weigl, 1989) were aimed to determine sorption and desorption of Na phytate (*Na-phy.*) added to two soils with similar texture but different pH, phosphate (*php.*) adsorption and oxalate extractable Fe (*ox-ex-Fe*, i.e. labile Fe). Methodological problems led us to prefer to monitor the difference of P concentration in the water extract of the soil against the control as the parameter for the availability of phytate-P (*phy-P*), instead of direct phytate determination.



MATERIALS AND METHODS

Soil samples were taken from the A, horizon (0-20 cm), air dried, and sieved at 2 mm. Their characteristics were as follows :

Niederhummel Soil: texture: 20% clay, 70% silt, 10% sand, org. matter 2.4%
 $\text{pH}_{\text{CaCl}_2}$ 7.2; total P 91.5, CAL-P 18.5, $\text{H}_2\text{O-P}$ 6.6 mg/100 g soil

Gartelshausen Soil: texture: 21% clay, 69% silt, 10% sand, org, matter 2.6%
 $\text{pH}_{\text{CaCl}_2}$ 5.5; total P 70.0, CAL-P 2.0, $\text{H}_2\text{O-P}$ 0.6 mg/100 g soil

pH was determined with 0.0125 N CaCl_2 solution (soil : solution = 1 : 25, w/v)

P_w = water extraction (van der Paauw and Sissingh as modified by Amann 1980), determination according to Murphy and Riley modified by John (1970)

P-fractionation (Scharafat modified by Kurmies, 1972); total P after digestion with perchloric and sulfuric acids

P-sorption according to the Weihenstephan manual (1 g soil shaken with 50 ml P solution (0-500 $\mu\text{mol P/l}$), calculation and evaluation by isotherm curves according to the Langmuir adsorption equation (Syers et al., 1973).

Ox-ex-Fe = Fe ammonium oxalate soluble in soils according to Fischer (1976)

P content in plants: digestion with conc. $\text{HNO}_3/\text{HClO}_4$ and colorimetric determination by vanadomolybdate.

Incubation conditions of the individual experiments are indicated in next chapter.

RESULTS AND DISCUSSION

I. Niederhummel, silty loam, pH 7.2.- Incubation at 12/25°C and 60% of maximum water holding capacity with 8.8/17.5 mg added ph-P/100 g soil, corresponding to natural phytate contents of soils, produced a biological dephosphorylation increasing with phytate concentration and temperature (Fig. 2). After 8 weeks, 30%/25% of the added phytate were mineralized. The adsorption isotherms followed roughly a Langmuir equation and demonstrated a low P sorption capacity. In addition, a low ox-ex-Fe content was noticed. Soil sterilization by γ -radiation at 25 kGy completely blocked the enzymatic hydrolysis.

II. Gartelshausen, silty loam, pH 5.5.- Its very low original water soluble P content (0.6 mg/100 g soil) still slightly dropped after 8 weeks preincubation with Na-phy. at 25° C (Fig. 3), due to the soil higher P adsorption capacity and its high content of ox-ex-Fe (Fig. 1 b). P fractionation (table 1) supported these results, indicating that no increase of P occurred in both NH_4Cl (easily sol. P) and H_2SO_4 (Ca-php.) fractions. However 100/90% resp. were recovered in the 0.01 N NaOH fraction which is generally used to characterize phosphates adsorbed on Fe/Al oxides or -hydroxides.

Langmuir sorption isotherms are able to describe the P concentration at the point of equilibrium (adsorbed and released P). The sorption buffer capacity of the soil is indicated by the y-value at equilibrium. Fig. 4 shows that there is a much higher adsorption capacity for phy-P when compared to inorganic P from KH_2PO_4

Inositol php. were shown to strongly compete with ortho-php. for adsorption sites (Mc Kercher and Anderson, 1989). In the next experiment, Gartelshausen soil was preincubated 5 days with Na-phy. (28 $\mu\text{g P/g}$ soil), ensuring complete coverage of the adsorption sites with phytate after displacing original o-php. from the exchanger into the soil solution. This resulted in negative P sorption values, i.e. php. was released (fig.5).

Next experiment aimed to desorb phy-P by exchange against OH^- anions by liming. Gartelshausen soil was preincubated 5 days with Na-phy. (28 $\mu\text{mol P/g}$ soil.) to cover all adsorbing sites, followed by a second incubation (5 days) with $\text{Ca}(\text{OH})_2$, in a dose equal to 72 $\mu\text{mol OH}^-/\text{g}$ soil. Finally P sorption was determined in the equilibrium solution (fig. 6).

It is obvious that the adsorbed phytate-P was completely exchanged by OH^- anions after liming with CaO (see fig. 1 c). Thus, the soil regained its high P sorption capacity for orthophosphate. These results are in good

agreement with observations of isotopic exchange and desorption in the presence of competing ligands such as hydroxyl, bicarbonate or citrate depending on their specific affinity and concentration (He et al., 1992).

III.- Based on these results, parallel pot experiments were carried out with the Gartelshausen soil (in part limed to pH 7.0) with different crops resp. rotations in order to test the liming effect on desorption and mobilization of phytate-P (Table 2). In control pots without added P, Ca(OH)₂ at 11 g CaO/5.5 kg soil mobilized significant amounts of soil P for all crops. In the unlimed treatments there were great differences of total P uptake between di-Ca-php. and phytate on both levels of added P (0.2 and 0.4 g P/pot). Liming leveled off these differences and resulted in a largely similar P utilization except for ryegrass in monoculture. Thus, the results of the pot experiments confirmed the *in vitro* experiments.

CONCLUSIONS

The experiments with two soils of nearly equal texture but differing in pH, P adsorption, and oxalate soluble Fe, show that the plant availability of phytate-P :

- depends on enzymatic dephosphorylation and poses no problem in soils of low P adsorption and low oxalate soluble Fe
- however is primarily limited in soils with high P sorption and high oxalate soluble Fe.

Liming desorbes phytate P and makes it available to plants.

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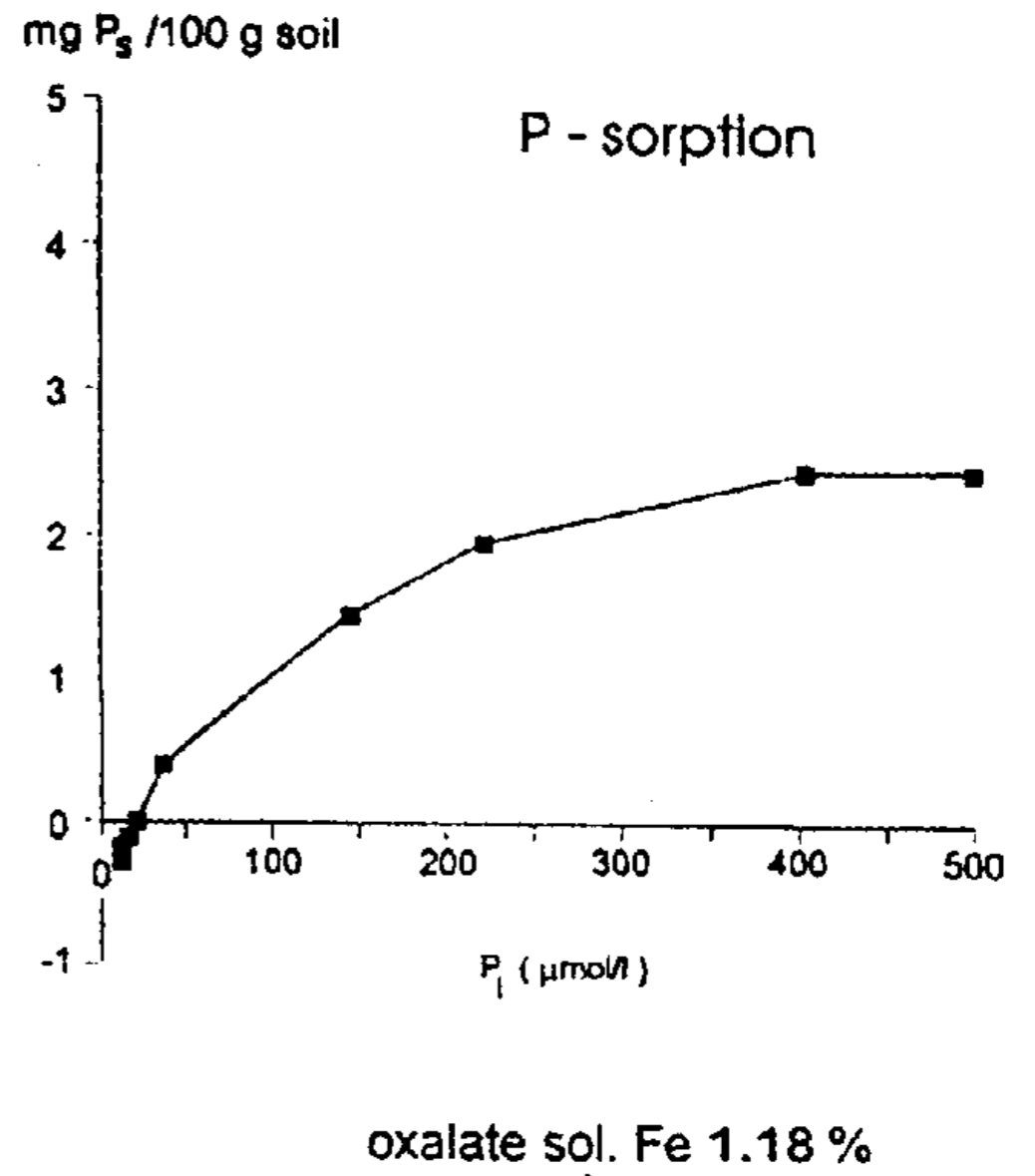
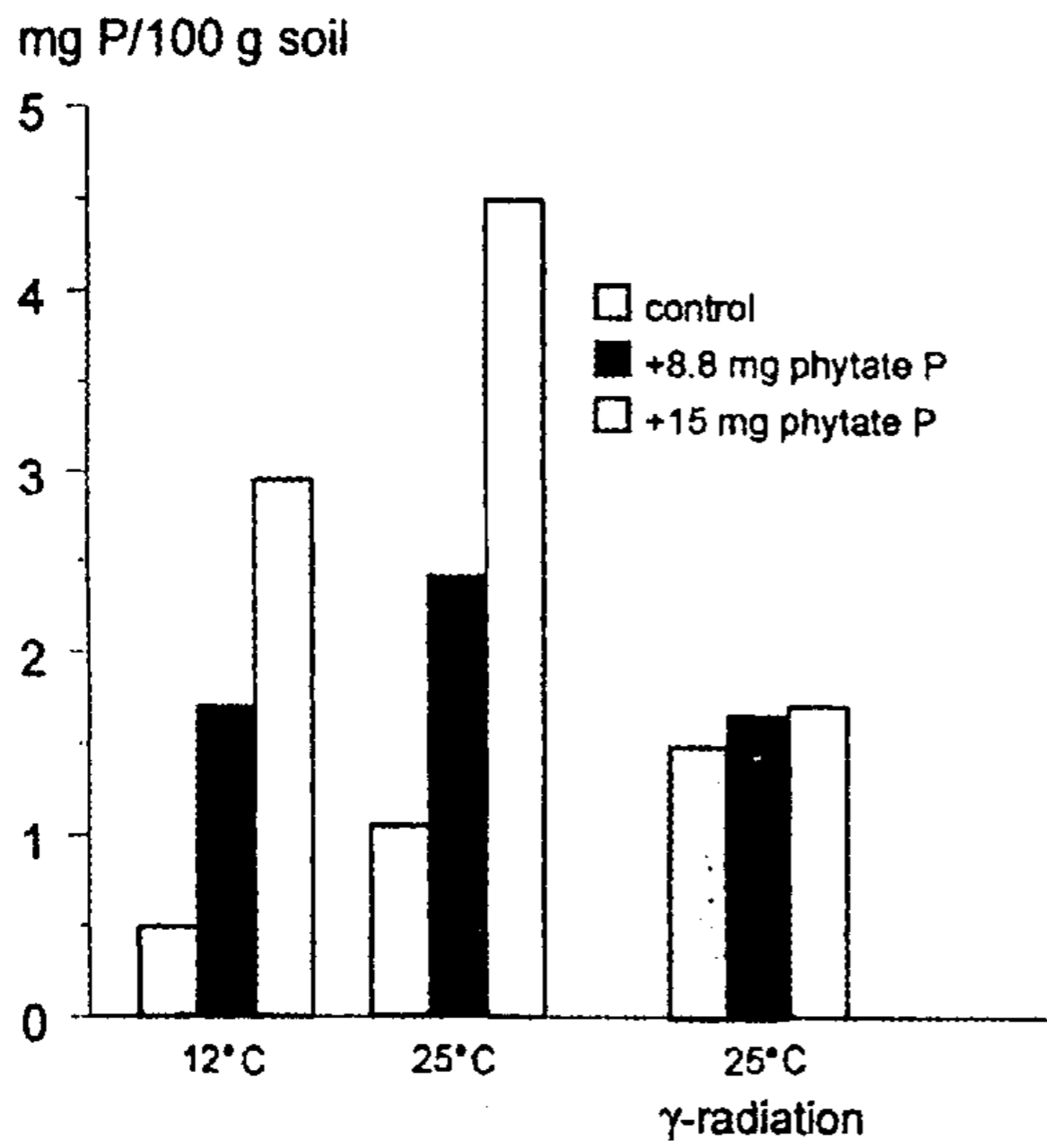


Fig.2 Water soluble P in Niederhummel silty loam after 8 weeks incubation with phytate

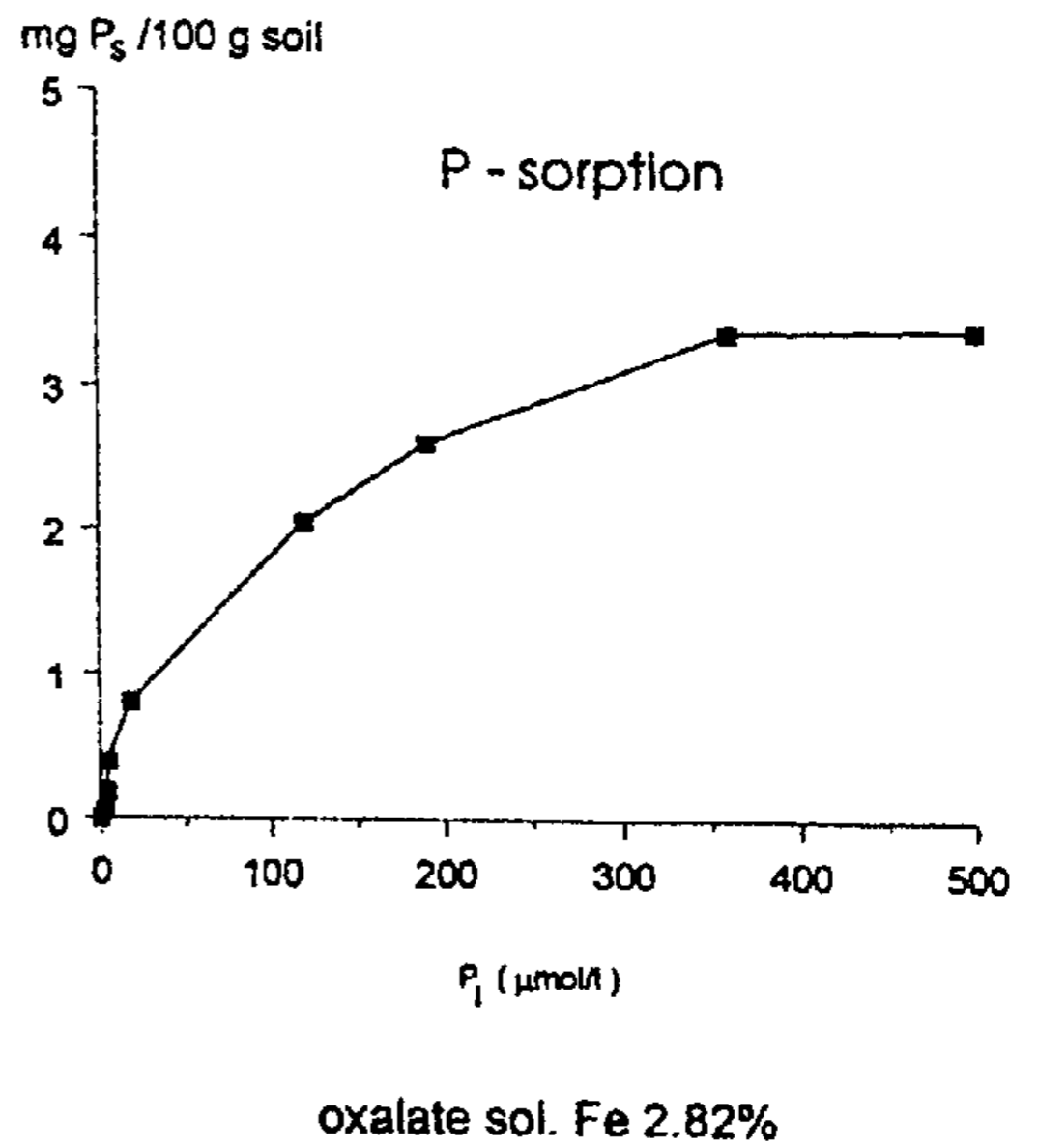
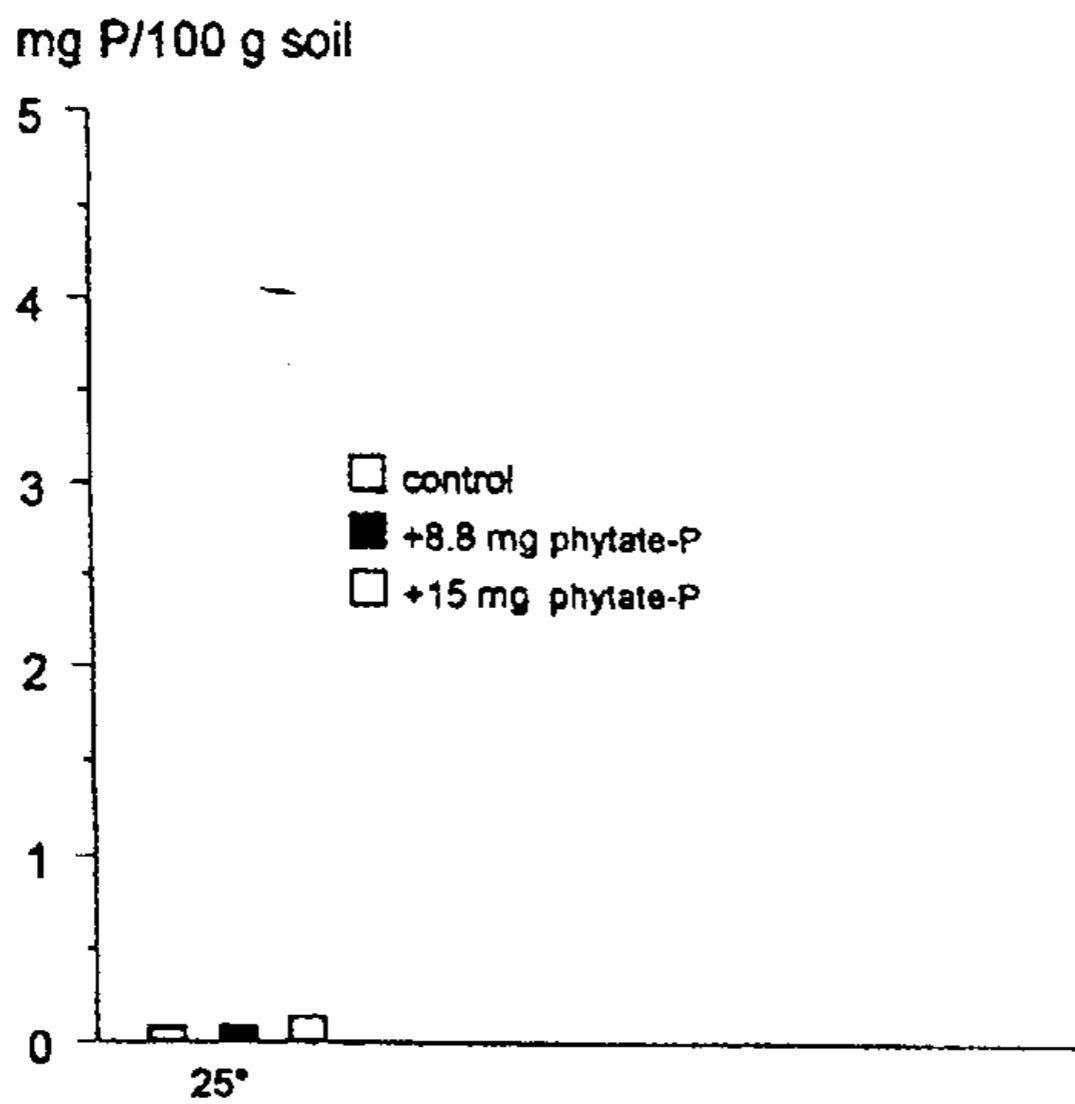
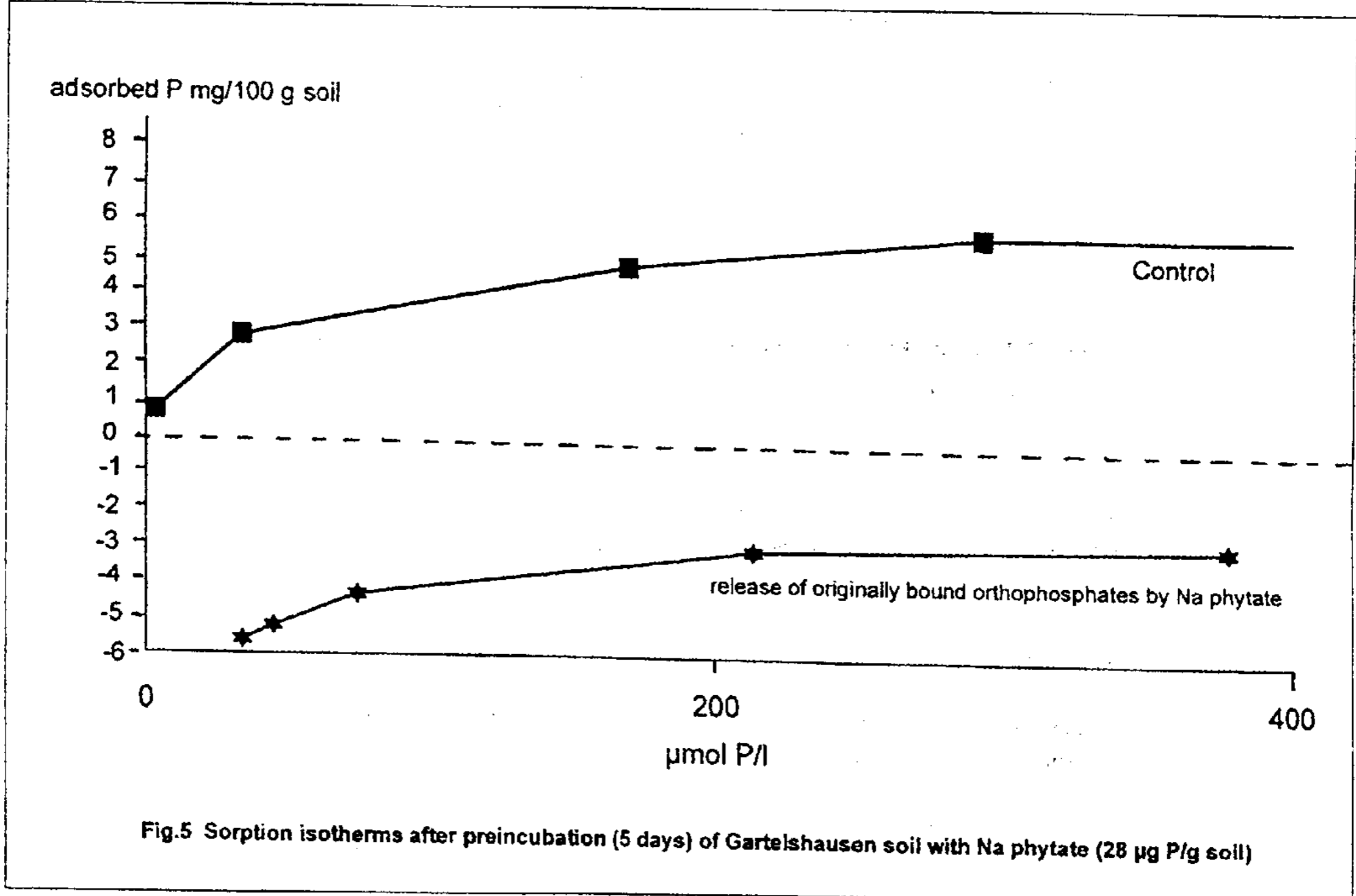
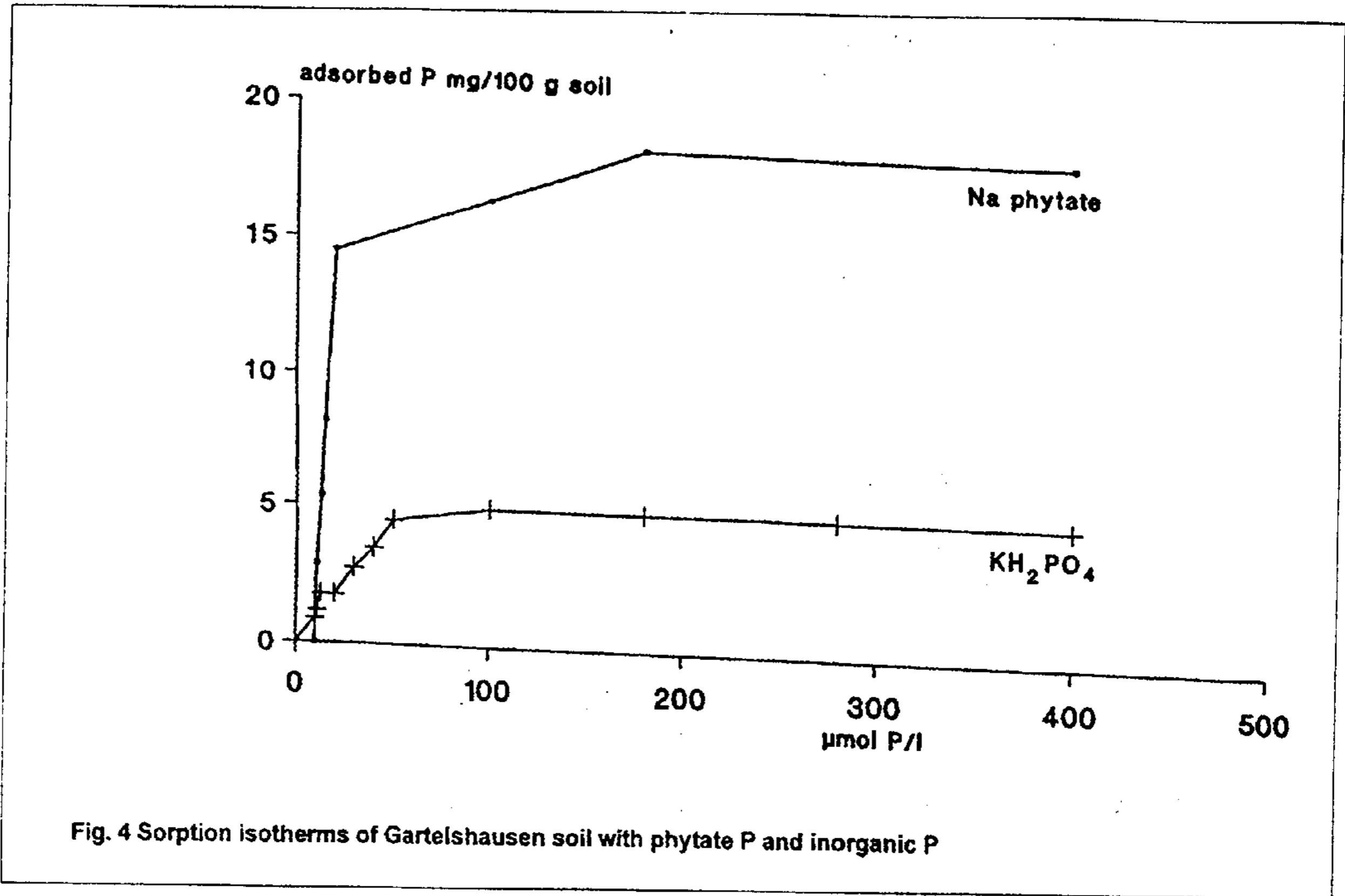


Fig.3 Water soluble P in Gartelshausen silty loam after 8 weeks incubation with phytate



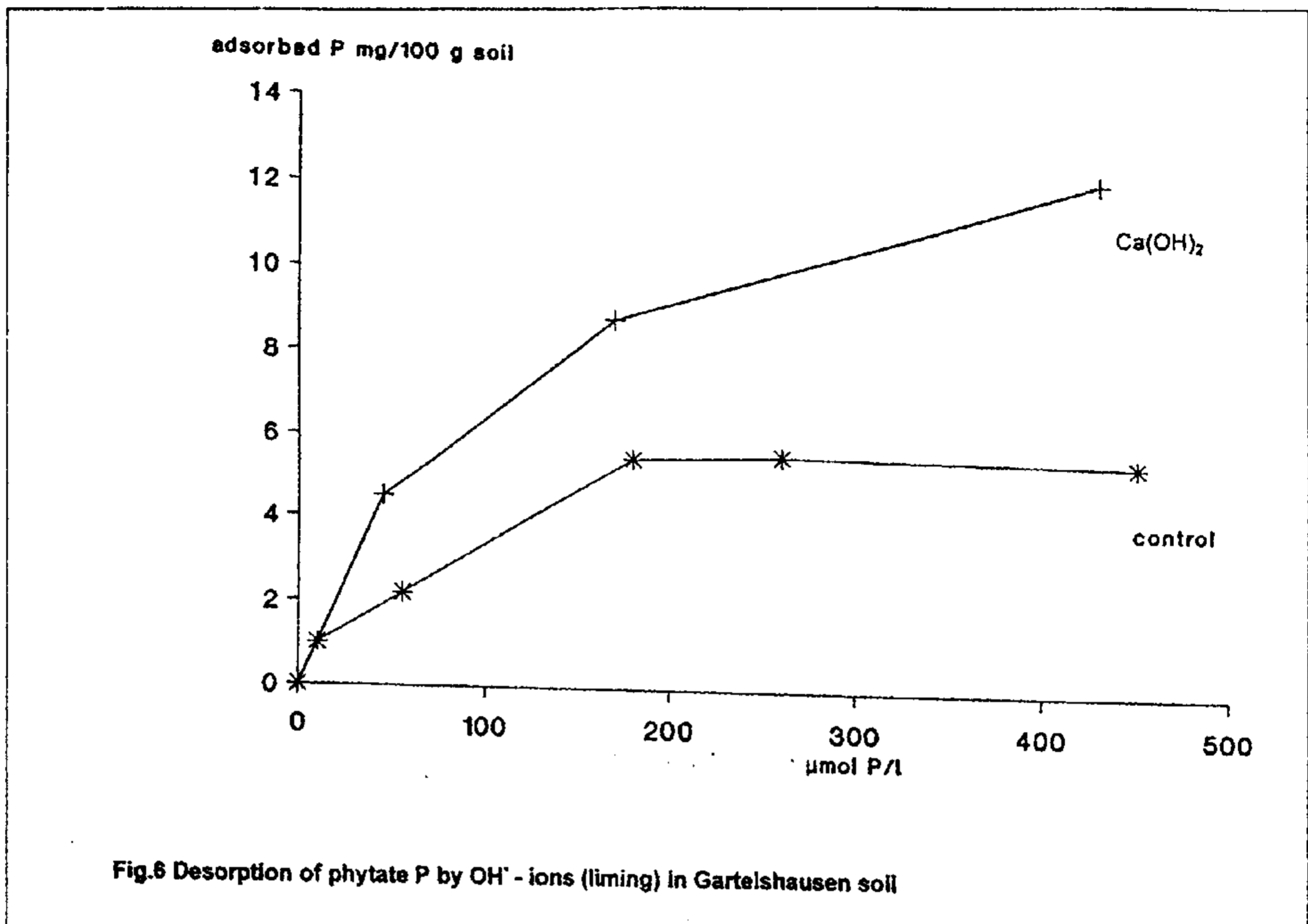


Fig.6 Desorption of phytate P by OH⁻ ions (liming) in Gartelshausen soil

Table 1: P fractionation of Gartelshausen silty loam after 8 weeks incubation (25°C) with Na phytate mg P/100 g soil as difference to control (without phytate)

P-fraction soluble in	mg added phytate P/100 g soil	
	5.8	17.5
1 N NH ₄ Cl	0	0
0.01 N NaOH	5.8	15.1
0.1 N NaOH	2.4	3.0
0.5 N H ₂ SO ₄	0	0

Table 2: Total P uptake of different crops from Gartelshausen soil as influenced by liming (optimal NPK according to requirements of crops) (mg P/pot)

treatment g P/pot	spring wheat/maize		red clover/ spring rye		rye grass	
	spring rye		spring rye			
	-	lime +	-	lime +	-	lime +
without P	217	304	293	344	224	254
dicalcium-phosphate	0.2	293	376	400	414	309
	0.4	365	399	513	498	399
Na phytate	0.2	265	361	347	420	244
	0.4	301	413	380	481	268
LSD _{5%}		7		15		9