Introduction

Although organic soil-P can range from 20 to 80% of total P concentration the bioavailability of organic soil-P is not taken into account by routine soil testing methods. Oehl et al. (2001) reported from radio-isotopic experiments that in a soil (pH 6.3; 375 mg organic P kg^{-1} soil) 1.7 mg P kg^{-1} soil d^{-1} were mineralized from the organic soil-P pool. This P content corresponds to 40 kg P ha^{-1}. However, plant roots secrete phosphatase into the rhizosphere for hydrolyzation of organic soil-P (Tarafdar and Claassen, 1988). Dou and Steffens (1993) compared the bioavailability and mobility of inositol-mono-phosphate and single super-phosphate in the rhizosphere of *Lolium perenne* L. The results of this experiment indicate that inositol-mono-phosphate resulted in the same P uptake by the grass as single superphosphate. The objectives of our studies were to determine the bioavailability of phytate in form of sodium hexa-phytate for various plant species and to evaluate different soil-testing methods in measuring organic soil-P.

Material and Methods

This experiment was carried out to determine the bioavailability of organic P for various plant species. Hence summer wheat (*Triticum aestivum* L. cv. Thasos), rape (*Brassica napus* L. cv. Carousel), sugar beet (*Beta vulgaris* L. var. altissima Döll cv. Evita), phacelia (*Phacelia tanacetifolia* L. cv. Angelia), maize (*Zea mays* L. cv. Blizzard), white lupin (*Lupinus albus* L. cv. Amiga), and pigeon pea (*Cajanus cajan* L. cv. ICEAP 0068) were grown in soil culture in a growth chamber. The light phase was 16 h at 22°C and 60% rel. humidity with a photosynthetic active radiation of 500 µ E m^{-1} s^{-1} and the dark phase was 8 h at 16°C and 70% rel. humidity. The plants (three plants /small Mitscherlich pot) were cultivated in a mixture of 3 kg soil and 3 kg quartz sand. The soil was a subsoil (0.40-0.60 m depth) from a luvisol derived from loess (227 g clay kg^{-1}, 450 g silt kg^{-1} and 323 g sand kg^{-1}, 0.28 % total carbon, 0.02 % total N, CEC 11.8 cmol kg^{-1}, pH 6.3 in 0.01 M $CaCl_2$, 6.5 mg plant-available P kg^{-1} [CAL extraction according to *Schüller*, 1969]). The plants were cultivated in a treatment without P application, in a treatment with organic P fertilization, and in a treatment with a P application as $Ca(H_2PO_4)_2$ (100 mg P kg^{-1} each). Organic P was applied as phytic acid dodecasodium salt (Na-hexaphytate, $C_6H_6O_{24}P_6Na_{12}$) from Sigma-Aldrich Co., USA. The soil in the pots was treated with 116 mg N (NH_4NO_3), 400 mg K (K_2SO4), 50 mg Mg ($MgSO_4$) kg^{-1} soil. Sugar beet was additionally supplied with 5 mg B (H_3BO_3) kg^{-1}. In the control and $Ca(H_2PO_4)_2$ treatments, Na was applied as NaCl equivalent to the Na amount in the organic P treatment. Twenty days after sowing, plants were fertilized with 83.3 mg N (NH_4NO_3) kg^{-1} soil. These dressings ensured that the growth of the plants was limited only by P.

Before sowing, soil samples were collected by 2 pricks with a small soil sampler from each pot of a treatment. The collected soil samples were dried at 40°C. Thirty-five days after sowing, plants were harvested, shoot and root biomass were determined and P concentration and P uptake were analyzed according to routine methods.

Various methods were employed for the extraction of P: calcium acetate-calcium lactate-acetic acid method (CAL: Schüller, 1969), double lactate method (DL: Egner and Riehm, 1955), sodium bicarbonate method (Olsen and Sommers, 1982), Mehlich-III method (Mehlich, 1984), electro-ultrafiltration technique (EUF: Nemeth, 1985) and water method (van der Paauw,1967).

Results and Discussion

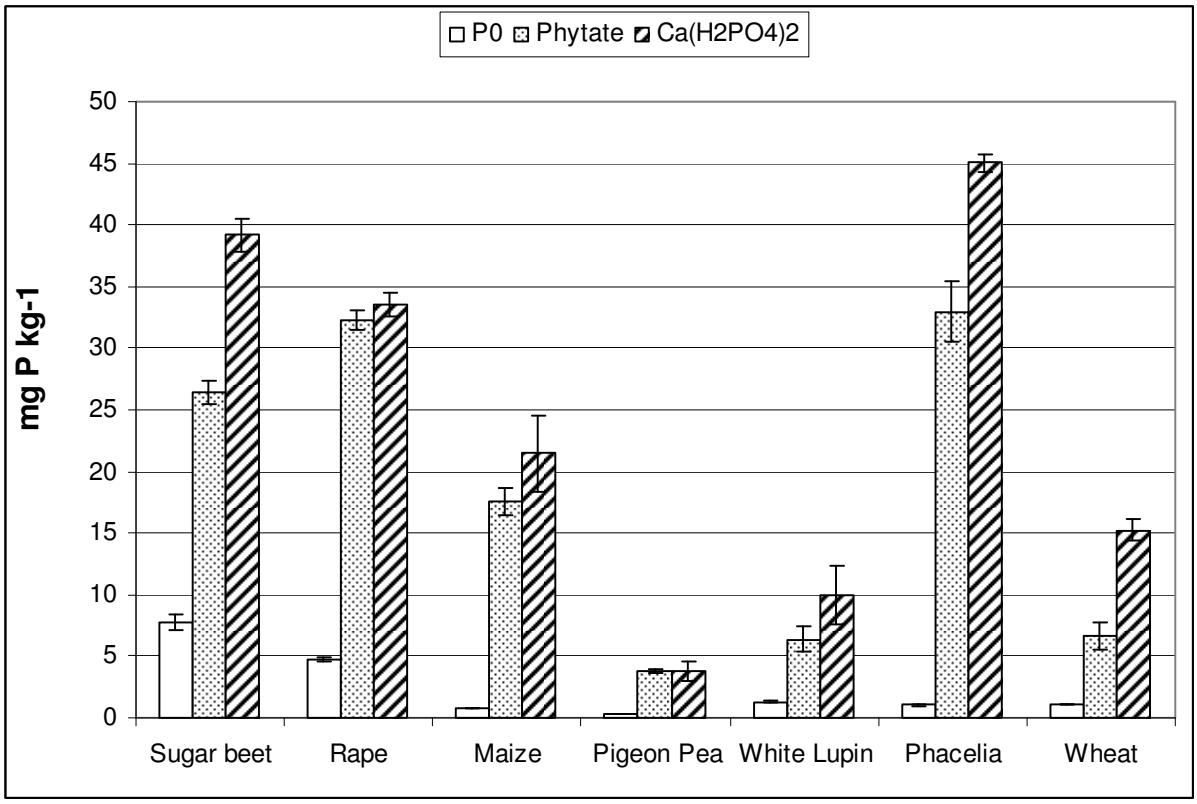

Figure 1: Effect of P fertilization (100 mg P kg^{-1} soil) in form of phytate (Na-hexaphytate $C_6H_6O_{24}P_6Na_{12}$) and Ca $(H_2PO_4)_2$ compared to the treatment without P addition (P0) on the P uptake by various plants

Both, phytate and $Ca(H_2PO_4)_2$ application resulted in an increase of the P uptake of various plants in relation to the P0 treatment (Fig. 1). All of the tested plants used the applied organic P to a considerable extent. The relative P uptake (P uptake in the $Ca(H_2PO_4)_2$ treatment = 100%) was 67% in phytate treatment with sugar beet, 96% with rape, 82% with maize, 99% with pigeon pea, 64% with white lupin, 73 with phacelia and 43% with wheat compared to the P uptake in the $Ca(H_2PO_4)_2$ treatment. The effect of phytate and $Ca(H_2PO_4)_2$ fertilization on shoot and root biomass followed the same trend as the P uptake of the various plants (not shown).

The application of organic P in form of Na-hexaphytate did not result in a significant increase of extractable soil-P in comparison to the control treatment, in which no P was applied (Tab. 1). In general, the highest amounts of P were extracted with the various routine methods in the Ca $(H_2PO_4)_2$ treatment. This result shows that P applied as Na-hexaphytate was not quantified with the methods employed in this study, although the various plants could well utilize the applied organic P.

We conclude that research should be focused on improving soil-testing methods for the analysis of plant available organic soil-P. This approach is more efficient than a genetic engineering of plants in order to optimize phosphatase activity and its release into the rhizosphere.

Table 1: Effect of P fertilization (100 mg P kg^{-1} soil) in form of Na-hexaphytate ($C_6H_6O_{24}P_6Na_{12}$) and Ca $(H_2PO_4)_2$ on the P concentration extracted by various soil- testing methods.

Soil extraction method	P0 mg P kg^{-1}	Phytate	$Ca(H_2PO_4)_2$
Me-III	8.52 (±0,15)	10.01 (± 0,16)	86.20 (± 9,84)
P-Water	1.21 (± 0,06)	1.40 (± 0,07)	31.45 (± 2,74)
Ohlsen	3.33 (± 0,17)	2.71 (± 0,17)	67.06 (±5,22)
CAL	4.53 (± 0,44)	5.12 (± 0,35)	80.42 (± 5,82)
DL	8.46 (±- 0,15)	8.58 (± 0,11)	79.29 (± 5,65)
EUF (1. + 2. fraction)	4.16 (± 0,11)	5.61 (± 0,28)	47.34 (± 3,80)

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