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Bioaccessibility of phosphorus sorbed to amorphous oxides: Evaluation of plant supply potential

Maximilian Koch[1], Stella Gypser[2], Nina Siebers[1], Wulf Amelung[3]
[1] Institute for Bio- and Geosciences – IBG-3, Agrosphere, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany
[2] Brandenburg University of Technology Cottbus-Senftenberg, Chair of Soil Protection and Recultivation, 03046 Cottbus, Germany
[3] Institute for Crop Science and Resource Conservation (INRES) – Soil Science and Soil Ecology, University of Bonn, Nussallee 13, 53115 Bonn, Germany

Introduction and Objectives

In sparsely rooted subsoils secondary minerals, such as iron and aluminum oxides are predominant sorption sites for phosphorus (P) and thus important sinks for P fertilizers. P supply from these oxides can contribute to effective strategies for a sustainable future use of P fertilizers. Here we are going to combine (1) P radio-isotope tracing and imaging techniques, (2) diffuse gradient in thin films technology (DGT), and (3) magnetic resonance imaging (MRI) with the **objective** to assess the P accessibility and use efficiency from stable P reservoirs.

Bioimaging technology – Radioluminography

Using radioimaging it is possible to locate ^{33}P labelled P within the plant and roots. The CR 35 Bio is a compact high-speed image plate scanner (Figure 1) to detect a variety of different radio nucleotides (radioluminographic imaging). The Imaging plate (IP) is a flexible, coated radiation sensor plates, which contains fine crystals (< 5 µm) of photo-stimulable barium fluorobromide spiked with bivalent europium as luminescence center (Nakajima, 1993). By comparison with conventional X-ray imaging, referred to as autoradiography, this technique enables shorter exposition times, high resolutions (till 30 µm) and an easy handling due to digital processing.

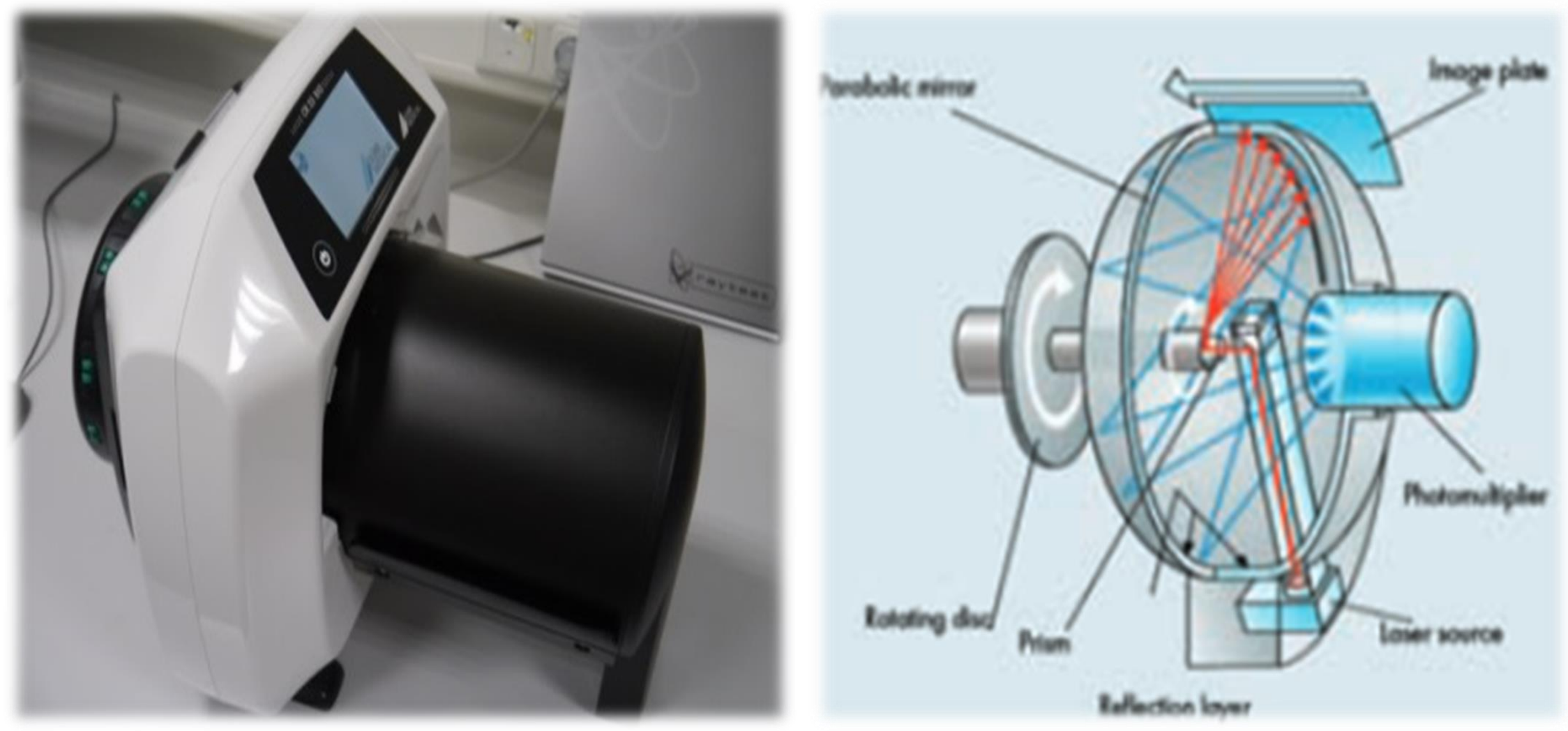

Figure 1: Left: CR 35 Bio compact high-speed image plate scanner (Photo: Koch; 2015). Right: Insights of a scanner unit with activated laser beam (red lines) reading an image plate (blue) (Picture: www.biostep.de).

Study design and first results

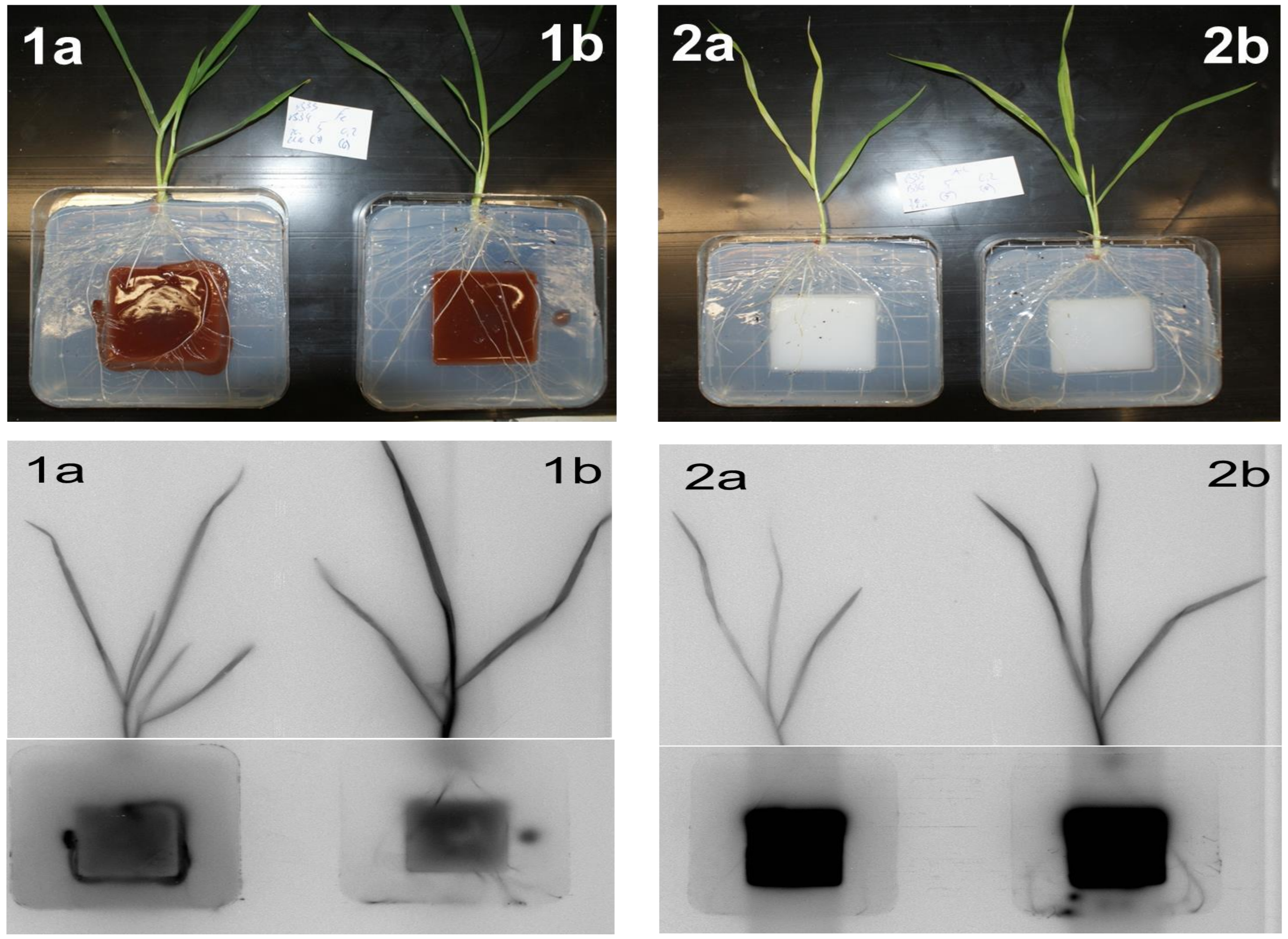

Figure 2: Photo and bioimager image of plant-agar system after 18 d of growth. P sources were provided as (1) P sorbed on to amorphous iron oxide and (2) on to amorphous aluminum oxide, both labelled with ^{32}P-Orthophosphate mixed in agar gel and implemented in surrounding agar gel with basal nutrition solution containing (a) 5mM and (b) 0,2 mM of KH_2PO_4. The experiment was performed in a growth chamber with 16 h day-length at a light intensity of 320 µmol m-2 s-1 (PAR). Day-time conditions were 20 °C and 60% relative air humidity, while at night temperature decreased to 12 °C at 80% relative air humidity. IPs was exposed for 6 h and scanned with 100µm sensitivity.

In a plant-agar system ^{32}P labelled Fe-P and Al-P oxides are applied in agar gel (Figure 2; brown and white boxes in the square petri dishes). Wheat plants were grown in the agar for 18 d, afterwards ^{32}P plant up take was quantified via liquid scintillation counting (LSC).

The **hypothesis** of this study was to analyse
(1)whether the plants take up more ^{32}P in the low P concentration agar medium (0,2 mM) than in the high P medium (5mM)?
(2)what is the P supply potential of Fe-P and Al-P oxides? Is the plant able to adapt strategies for P supply to different soil minerals?

Table 1: Dry weights (DW) and ^{32}P proportions of selected plant compartments and agar nutrition medium after 18 d of growth. ^{32}P recovery was between 96% and 100%. Significant at * $P < 0.05$. n = 3

	Iron oxide		**Aluminium oxide**		**Control**
P concentration	5mM (1a)	0,2 mM (1b)	5mM (2a)	0,2 mM (2b)	0,6 mM
Shoot DW [mg]	178±33	183±28	120±6	146±15	176±39
Root DW [mg]	42±20	37±3	36±3	41±2	45±9
Shoot ^{32}P (%)	1.1±0.3	**3.9±0.7***	0.1±0.0	0.3±0.0	-
Root ^{32}P (%)	1.2±1.0	1.9±0.0	1.1±0.2	1.8±0.3	-
Agar ^{32}P (%)	98±1.1	94±0.7	99±0.4	98±0.2	-

The results illustrated that it is possible to quantify P plant acquisition from dominant soil P sources via radio-isotopic labelling. Plants grown in 0,2 mM P agar medium showed higher specific ^{32}P activities. Further, P sorbed to iron oxide was significantly better accessible than from aluminum oxide due to adapted acquisition strategies of the plant to utilize the Fe-P as available P source.

Outlook

(1) Plant - Soil System - P Uptake

^{33}P sorbed oxide uptake studies allow to evaluate P utilization potential from P associated with soil minerals in a natural environment.

Figure 3 : Design of soil filled rhizotron for analysing Fe-P/ Al-P accessibility in subsoil by wheat plants

(2) Oxid-P desorption isothermes - DGT

To unambiguously analyse exchange - and desorption potentials in soils compared to plant acquisition strategies of Fe-P and Al-P oxides.

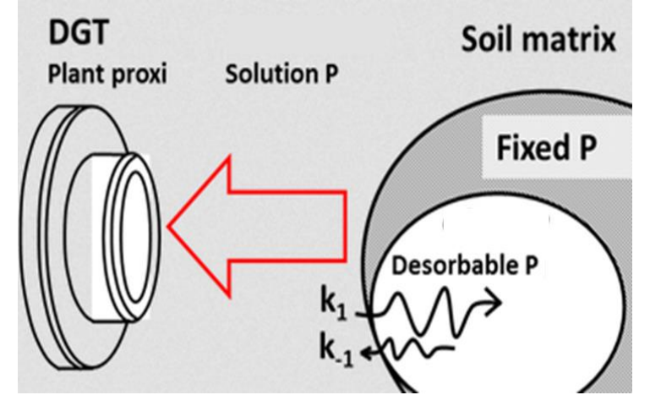

Figure 4 : Functional design of the DGT method. Illustrating the trapping of soil desorable P in the soil solution (modified Picture: soilpforum.com)

(3) Root morphology - MRI

MRI experiments (Figure 5) for analysing root morphology and to obtain a structural model of plant root systems. This allows to evaluate P acquisition strategies by plant roots at the soil profile scale.

Figure 5 : MRI picture of a Lupine root (Oswald et al., 2015)

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