Phytoextraction of Phosphorus for Ecological Restoration

Application of Soil Additives

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Introduction

Depleting soil nutrients for restoration of species-rich natural habitats in Western Europe on abandonned agricultural fields is crucial:

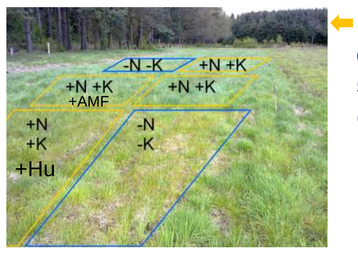
- Common farming practices include excessive P addition, leading to high soil P concentrations[a]
- High soil P concentration is a bottleneck for restoring biodiversity in grasslands[b], heathlands[c], forests[d] and wetlands[e]
- Target soil Olsen P ($NaHCO_3$ extractable P) on species-rich *Nardus* grassland (type 6230): 10 mg P kg^{-1} dry soil

Current restoration methods:

- Topsoil removal is very expensive and can have negative side effects by removing also the soil biota and CEC
- Cutting and removing: decrease of P slows down due to plant growth limitation by other nutrients than P

New potential technique: Phytoextraction of P = P-mining

- = nutrient depletion by cropping with selective fertilization (no P)
- Soil P decreases during first years[f] but this might stagnate



Field experiment on 5 sites (2011-2018)

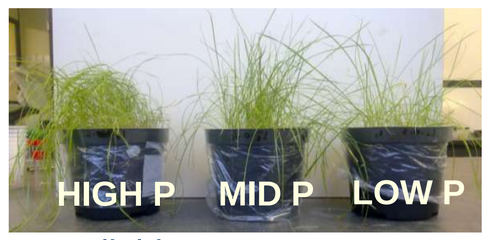
Pot experiment on 3 soil P levels (2011)

Methods

Pot experiment with *Lolium perenne* in a growth chamber:

- Soil P chronosequence (*space for time*) with 3 comparable soils with different P levels relevant for 3 stages in the extraction process

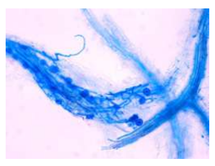
	HIGH P	MID P	LOW P
Olsen P (mg kg^{-1} dry soil)	110	65	35
Oxalate P (mg kg^{-1} dry soil)	328	140	42
Total P (mg kg^{-1} dry soil)	650	330	170



- 4 treatments in order to make P more plant-available

AMF = 1 g pot^{-1} **Arbuscular Mycorrhizal Fungi**

(INOQ Agri: 220 AMF units per cm^3 substrate;
Species: *Glomus etuniatum, G. Intraradices, G. claroideum*)



Hu1 = 7 ml pot^{-1} **Humic substances**

(Humifirst®, elevated dose equivalent to 7000 l ha^{-1})

Hu2 = 0.05 ml pot^{-1} **Humic substances**

(Humifirst®, recommended dose equivalent to 50 l ha^{-1})

PSB = 70 ml pot^{-1} **Phosphate Solubilizing Bacteria**

(*Bacillus brevis*, *B. polymyxa*, *Pseudomonas putida*)

- Monthly harvest of aboveground biomass (n=4)

Chemical analysis P-concentration in DM

P extracted = P-concentration in DM * Biomass

Chemical analysis Olsen P in soil: initial and at 123 days (3th harvest)

Ratio (%) between P extracted (mg P pot^{-1}) and amount of Olsen P (mg P pot^{-1})

Goals

- Is it possible to increase the phytoextraction of P by adding soil additives during different moments in the extraction process?
- Is P extraction at a later stage of the process still attainable?

Results

1. P extracted during four months

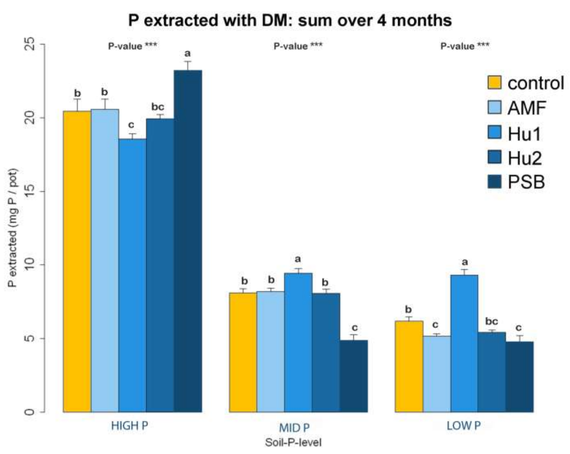


Figure 1: mg P extracted per pot. Significant differences between treatements (ANOVA) are indicated with letters and '*'.

2. Change in soil P

Table: Olsen P (mg P kg^{-1} dry soil) at 123 days (third harvest). Significant differences between treatments are indicated with letters.

TREATMENT	HIGH P	MID P	LOW P
Zero	116.3 ± 3.9 a	57.9 ± 2.4	25.24 ± 2.9 ab
AMF	108.5 ± 2.4 b	57.3 ± 4.1	23.11 ± 3.6 b
Hu1	107.4 ± 5.5 b	56.4 ± 2.5	25.67 ± 2.4 ab
Hu2	107.6 ± 7.5 b	55.84 ± 2.5	23.64 ± 1.2 b
PSB	112.6 ± 4.4 ab	58.74 ± 2.9	28.64 ± 4.0 a
Initial Olsen P	**110**	**65**	**35**

3. P extracted versus initial Olsen P

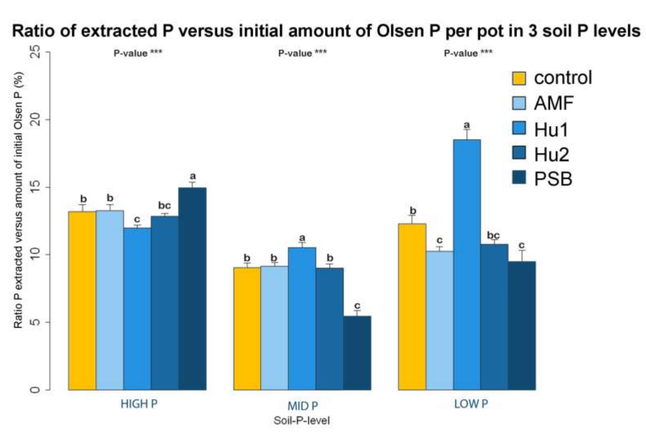


Figure 2: Ratio of extracted P with DM versus initial Olsen P. Significant differences between treatments are indicated with letters and '*'.

4. Nutrient limitation: the vegetation N/P ratio[g]

P-limitation: N/P > 16 In all treatments of the Mid P and Low P soils
Very pronounced (> 30) in the zero, Hu2 and AMF treatments

Conclusions

- Some treatments affects the P extraction depending on the soil P level. P extraction is not enhanced by most treatments in the High P soil. Only the PSB treatment raised the P extraction slightly. P extraction is significantly increased in the Low P and Mid P soils by addition of humic substances in huge doses (Hu1).
- The extraction of P in later stages of the process is much lower than in the initial stages despite the selective fertilization. Limitation by P in the Mid and Low P soils was very pronounced. The time needed to reach the target soil P is possible much longer than first estimations suggested[h].
- The BCF suggest that extracted P is about 10-15% of the Olsen P stock. The phytoextraction of P will slow down with soil P level decreasing in time.
- Validation of these results in the field is necessary, the field experiment is currently ongoing.

References:

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