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P uptake, root properties and biomass of six cover-crops

Sebastian Radlwimmer, Jürgen Kurt Friedel*

University of Natural Resources and Life Sciences, Department of Sustainable Agricultural Systems, Vienna, Austria

Phosphorus (P) is an essential and limited nutrient. To avoid shortages in the coming decades, P recycling and efficiency of P use will have to be enhanced. Cover crops may help to transform less available P forms into bioavailable P forms. The aim of this investigation was the comparison of P uptake with root traits of six cover crops. Root and shoot biomass was analysed for P content. Root hair length and root length was measured on the basis of 6400 dpi root scans using ImageJ and WinRhizo. In addition, the root hair cylinder was calculated. P uptake was found to be strongly correlated with the root hair cylinder and the total crop biomass.

Keywords: cover crops, phosphorus uptake, root hair cylinder, root length, root hairs

1 Introduction

Phosphorus (P) is an essential nutrient. Today, most of it is being used in fertilizers. Hence P is a scarce resource, and in the coming decades there could be a lack of P-supply worldwide. This ist why there is a need to develop technologies for a more sustainable and efficient use of P (Cordell et al., 2011). For ecological agriculture one possible approach for enhancing nutrient mobilization and therefore nutrient efficiency is the use of cover crops which may help to transform less available P forms like tricalcium phosphates into bioavailable P forms.

P-uptake highly depends on soil as well as on plant properties (Schachtman et al. 1998). In order to design P-efficient crop-rotations, P uptake, under different environmental conditions and related plant properties, should be documented because plants have developed different strategies for different environments to gain P from soil including enhanced root growth and development of root hairs (Gahoonia and Nielsen 2004). The aim of this study was to measure the P uptake, root length and root hair length of six cover crops under field conditions, to correlate the data and to determine if linear relationships can be observed.

2 Material and Methods

The six cover crops, mustard, buckwheat, phacelia, common vetch, false flax and oil radish, were field grown in a completely randomized block design in four replicates from March respectively late April (in case of buckwheat) to June 2012 under semi-humid conditions on a calcareous soil with good P supply.

Harvesting of the roots was carried out in the second part of May with a soil-sampler (2.5 cm diameter) at 20 cm depth. For each repetition, two times five samples were harvested. The roots were gently washed out of the soil, and subsequently root scans were performed with an Epson V700 at 6400 dpi. The root hair length was determined manually with ImageJ by measuring 100 hairs per sample on at least 10 root segments. Root length and diameter analysis was performed on downscaled 1600 dpi images with WinRhizo2012b. The root hair cylinder was calculated for each root sample considering the root length, the root diameter

* **Correspondence:** Jürgen Kurt Friedel, University of Natural Resources and Life Sciences, Wien, Department of Sustainable Agricultural Systems, Gregor Mendel Straße 33, 1180, Wien, Austria. E-mail: juergen.friedel@boku.ac.at

distribution and the mean root hair length (Radlwimmer, 2014). At the beginning of June, 1 m^2 of shoot biomass for each repetition was harvested and dried at 60 °C for further analysis. At the same time, root biomass was taken two times per repetition with a soil-corer (10 cm diameter) on 20 cm depth. Again, the roots were washed out of the soil and dried at 60 °C. Plant biomass was dissolved with a HNO_3-H_2O_2-digestion (modified after Zhao et al., 1994) and the P content was measured spectroscopically according to Zhang (2003). The statistical analysis was conducted using spearman's correlation.

3 Results

Because of extreme weather events (draught in April and late frost in May), buckwheat, false flax and common vetch showed a very poor growth. When observing the poorly grown or all cover crops, the correlations between root parameters respectively biomass and P uptake were higher for the poorly grown than for the normally grown cover crops (Fig. 1). Only the correlation between shoot biomass and P uptake of the poorly grown plants was lower compared with the normally grown cover crops. It is assumed that this was mainly caused through the poor growth of the shoots in relation to the roots of the poorly grown cover crops. Among the root parameters, the root hair cylinder was found to have the most significant correlation with the P uptake of the cover crops (Fig. 1, Fig. 2). Nevertheless, when observing all cover crops or only the poorly grown, significant linear correlations were found between root length and P uptake as well as between root hair length and P-uptake, but with less significance than for the root hair cylinder (Fig. 1).

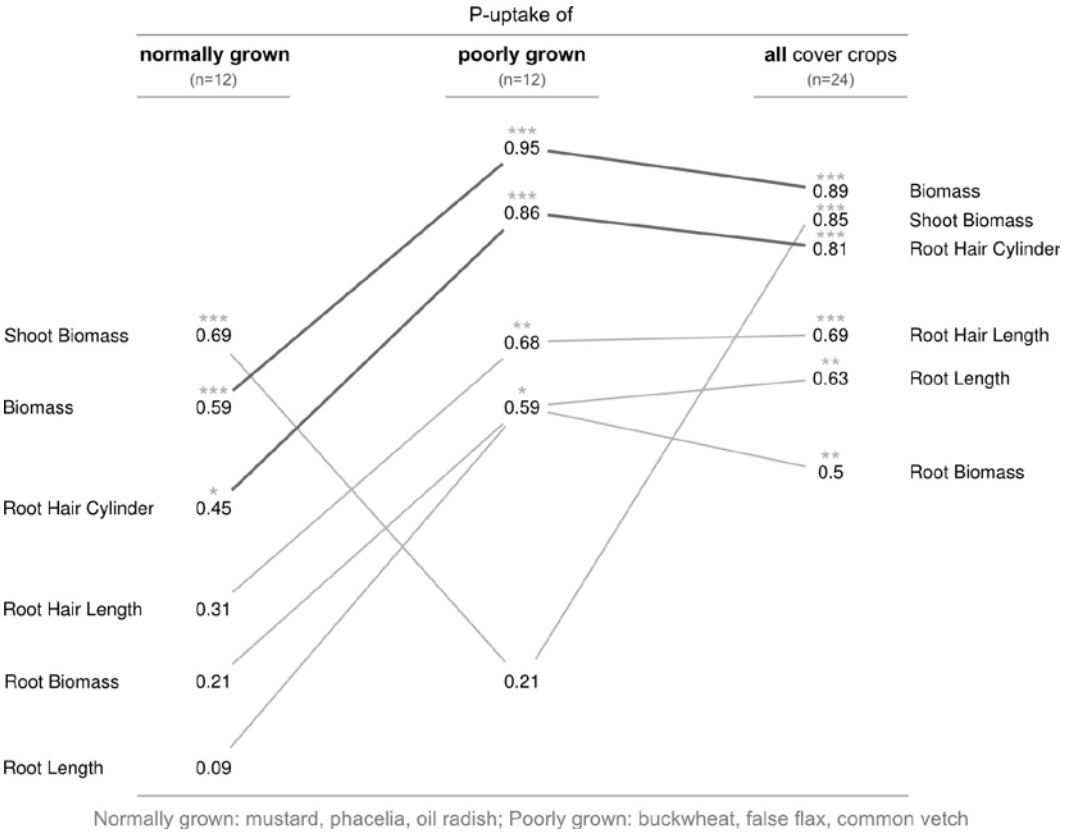

Figure 1 Spearman's correlation coefficients for the linear correlation of root properties and cover crop biomass with P-uptake: * P < 0.05,** P < 0.01, *** P < 0.001

The strongest correlation at all was found between total plant biomass (root biomass + shoot biomass) and P uptake (Fig.1, Fig. 2). Again the only exception was found for the normal grown cover crops, where the P uptake was more dominantly related to the shoot biomass than to the total biomass (Fig. 1).

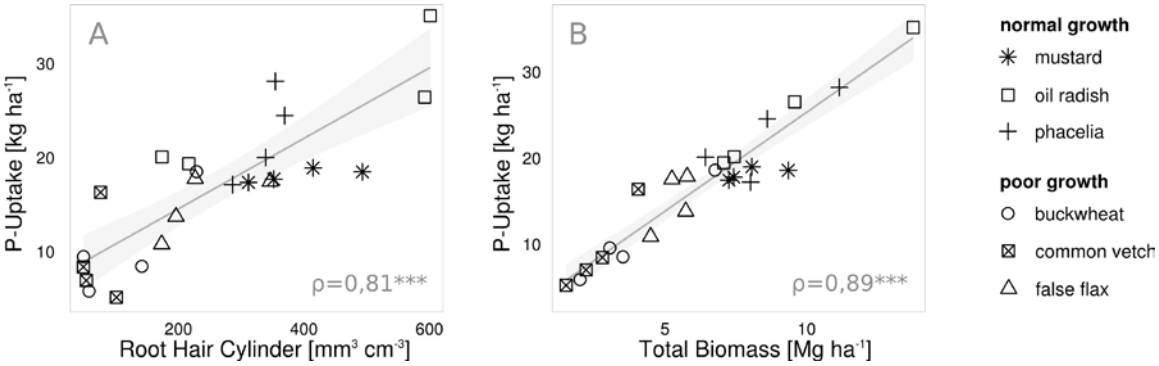

Figure 2 Spearman's linear correlation and standard error for (A) root hair cylinder with P uptake and (B) biomass with P uptake for the six cover crops. *** P < 0.001

4 Conclusions

It is yet unclear why there were much lower correlations found for the normally grown than for the poorly grown cover crops, although this could be explained by the limited depth of the soil and root sampling down to 20 cm: If there was a difference between the rooting depth of the poorly and the normally grown cover crops, essential amounts of P bound in deeper root layers and root parameters like root density changes along with soil depth may not have been considered adequately. Furthermore other parameters like root exudations were not measured but may have had a substantial influence on P uptake of some cover crops. When assuming that the observed correlations are based on causality, which can be expected (e.g. Gohoonia et al., 2004), the total tendency points out that the root hair cylinder and therefore the combined effect of root length and root hair length is of vital importance for P uptake of plants, and therefore indicates that selecting both traits may be useful in future breeding programs. As the strongest correlation was found between biomass and P uptake, the biomass could act as a simple indicator for identifying P efficient cover crops.

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