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From the root's point of view: understanding the plant response to beneficial microbes, with primary aim of improved plant nutrient uptake

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The use of microorganisms for improving plant performance under limiting conditions can be traced throughout history. Interestingly the first commercial biological plant growth promotor was patented in 1896. However, the understanding how the organisms interact on molecular level really took off after the advent of the genomic era which produced the tools needed for understanding how plants and microorganisms modulate each-other's gene expression and metabolism. Today more than ever, the holistic understanding of plant nutrient uptake and novel strategies to improve nutrient uptake are of utmost importance. Our work focuses on nitrogen (N) – the second most abundant nutrient in plants and phosphorus (P) – a finite global resource. We present studies where use of plant growth promoting rhizobacteria (PGPR) resulted in improved plant performance under limited N or P in Brachypodium - a model plant for cereals. Plant roots were analyzed with the non-invasive root phenotyping platform GrowScreen Page [1], or with the 3D printed EcoFab microcosms [2]. The latter was adapted and used in combination with Plant Screen Mobile [3], for non-invasive shoot area estimation, in conjunction with root scanning, over time. On the other hand, the performance of barley plants under the influence of 2 fungal interaction partners were investigated in soil system, using magnetic resonance imaging [4].

The plant response to a micro-organism is largely dependent on the surrounding conditions. Examples of plants treated with plant growth promoting rhizobacteria (PGPR) and grown under high and low N show that: the plant phenotype, N content within the plant and molecular response vary depending on the N availability in the surrounding medium.

Furthermore, we were able to dissect the plant phenotype of plants grown under limiting P in soil-less medium, and found that plant biomass was higher in plants inoculated with PGPR. A time series image-analysis of root phenotype showed the changes in root architecture, pin-pointing the time-window when growth promotion took effect after inoculation. A sand experiment confirmed these results.

Finally, the interaction between Barley roots and two fungi (a pathogen and a putative beneficial partner) was investigated to find dynamic response in root growth in soil that varied in soil depth, and had a different progression through time based on treatment.

We argue that for successful use of PGPR in context of nutrient uptake we need to account for: time in context of plant developmental stage [5] and moment of application, the organisms in question and the surrounding condition. Efforts are needed to elucidate the proper interaction partners and application points to result in a sustainable solution for agriculture.

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