Automated phenotyping of root hair traits from microscopy images

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Introduction

• Improving nutrient and water uptake in resource limited soils is a major challenge for agricultural research.
• Root hairs are specialized epidermal cells that are important for nutrient uptake from the soil by increasing the root-surface area.
• Digital microscopy can record root hairs as images, but has never been used for automated analysis.
• We present a methodology to automatically quantify the geometric complexity and spatial arrangement of root hairs.

Conclusions

• Our results suggest that our algorithms distinguish the set of test genotypes and potentially enable to identify genetic control of root hair traits.
• Maledfai, Suphan Buri and Phitsanulok 2 were successfully distinguished.
• KDM1105, Lon and San Pa Tong are a suited test set for further improvement of algorithm sensitivity.
• Significant variation in root hair diameter was observed for Maledfai.
• A bias is introduced to the results, because the current implementation is sensitive to intersecting root hairs.

Growth Conditions

• Six commercial and traditional Thai rice varieties.
• 3-4 images were taken per variety.
• Each variety was grown in a roll-up system using a germination paper soaked with 0.5 mM calcium sulfate.
• Samples for imaging were taken seven days after starting the roll-up.
• Roots were preserved in 75% EtOH and stained with 0.25% toluidine blue for collecting digital microscopy images.

Computational Methods

• We use machine learning to classify root hairs, the lateral root from which root hairs emerge and the image's background.
• Six training images were used to generate statistics to automatically classify all root hair images taken with the same imaging protocol.
• We developed first algorithms to measure length, density and diameter of separate root hairs.

Outlook

• Improvement of our algorithm to distinguish intersecting root hairs or clusters of two or more hairs.
• Computing the traits root hair surface area, tip to main root distance, root hair orientation provides ways to distinguish genotypes in full diversity panels.
• Extending our study to root hairs of maize and common bean is planned.
• Modification of the experiment setup allows to determine influence of N/P/K stress on root hairs.
• Integration of our algorithms into DIRT (dirt.iplantcollaborative.org)

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Peter’s phenotyping interest is to develop imaging algorithms that characterize the variability across multiple architectural scales in various crop roots. He has a background in Aerospace Engineering (B.sc.) and Geomatics (M.sc.).
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