Magnetic Resonance Imaging and Analysis of Intact Roots Grown in Mineral Soil

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Introduction

The plant root is a specialized organ that provides anchoring support and the means by which plants take up water and mineral nutrients. Root morphology is genetically controlled, but it is also modified by the environment, and the extent of environmental plasticity is also under genetic control. Identification of the genetic determinants of root morphology is essential for the manipulations of root traits. However, the subterranean nature of roots, and their inherent inaccessibility to direct measurements pose a great challenge. Several techniques to measure root traits have been developed, but most are destructive, labor-intensive, and somewhat inaccurate. On the other hand, magnetic resonance imaging is uniquely suitable to study roots grown in mineral soil non-destructively [1]. We have optimized methods to obtain root magnetic resonance images, and developed the means to analyze and obtain quantitative measurements from these images.

Experimental

Phaseolus vulgaris seedlings were grown in 4" cylindrical plastic pots containing Florida sandy soil. Root images were obtained on a 4.7T Oxford magnet with a Bruker Biospin Avance console and ParaVision software. This magnet is housed at the UF Advanced Magnetic Resonance Imaging and Spectroscopy facility which is also an NHMFL facility. 3D-RARE scans were collected with TR=6 sec 1st echo TE=6.6ms, 16 echoes with TEeff = 50ms, single average and 167K spectral width. MRI data were processed with a set of novel algorithms for de-noising while preserving features such points of root branching [2]. Image analysis was carried out to generate root growth curves and quantify root branching.

Results and Discussion

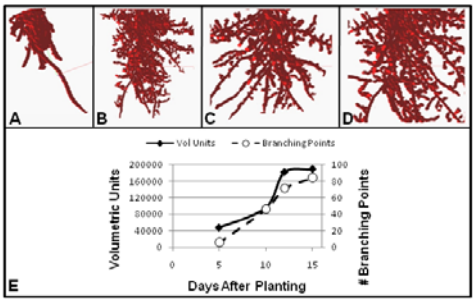

Figure 1. Root growth analysis using MRI . (A-D) 3D surface plots. (E) Growth curve.

3D surface plots of a bean-seedling root, at four different stages of development, are depicted in the adjacent graph (Figure 1, A-D). These plots were obtained from de-noised MRI data. A growth curve was generated after the volumes occupied by the roots were integrated (Figure 1 E). A more detailed analysis of the root includes the number of bifurcations, or branching points, as a function of time. This type of analysis can be used to characterize different genotypes, the effect of nutrient and water availability on root morphology, and to carry out a genetic analysis of root traits in a segregating progeny.

Conclusions

MRI technology and associated image processing algorithm are ideally suited for the genetic analysis of root-growth traits.

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References

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[2] Subakan O., *et al*., Proc. 11th IEEE ICCV07, Alaska, 1-6 (2007).