# Quantification of Phenotypic Responses to Root-Root Interactions Among Common Beans in a Specialized Mesocosm

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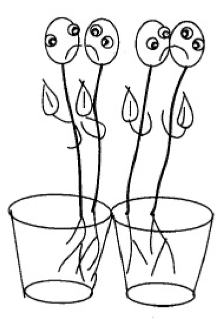
## Abstract

Root-root interactions alter the architectural organization of individual root systems and therefore, affect nutrient foraging (O'Brien et al., 2005). Past reports have shown detrimental and beneficial effects to the amount of yield in crops as they avoid or prefer belowground competition (Li et al., 2006; O'Brien et al., 2005). With little research done into root-root interactions there is still much to discover about the root phenotypes arising from root-root interactions and functions. Quantifying architectural traits of root system interactions would provide insight for researchers into the benefit of a cooperation vs. competition trade-off belowground. We have begun to develop a soil filled mesocosm system to perform a series of preliminary studies using 3D imaging to develop metrics of root-root interaction using common beans (*Phaseolus vulgaris*). Common beans have a relatively fast growing and sparse adventitious and basal root system, making them a suitable organism for this imaging study. Our second revision of the mesocosm focused on improving and fine tuning a mesh system that provides better support for the root architecture during the soil removal process. We use a light-weight, low-visibility plastic mesh originally used as bird netting to allow image capture from all sides. Traits that we aim to extract include root growth angle, rooting depth, and root volume relative to neighbors, because these spatial qualities determine the soil areas that the root system will be foraging in. Our data will allow for the quantification and association of root plasticity in the presence of belowground competition.

## Background

Ecologists hypothesize acclimatization to adverse growing conditions (climate change) occurs at the population level. With limited resources, efficient distribution would benefit overall field health.



Maina et al., 2002

In small pot experiments neighbors compete for belowground nutrients, they over proliferate roots reducing reproductive mass and field production.

Rubio et al., 2001

Simulated root growth demonstrated varied rooting depths lead to the least amount of nutrient depletion zones overlapping with neighbors.

Fang et al., 2013

3D imaging of rice seedlings grown in a clear gel growing medium show that the same genotypes tend to have more overlap in their root system than different genotypes.

There have been several attempts to analyze the effects of root-root interactions on the root system and plant health. However, most of these studies are limited to small potted experiments, simulations, or young plants in a gel media. At this point there has been no in-depth research in real soil. We propose a system that can utilize 3D imaging paired with intricate pipelines to accurately quantify the response of architectural root traits during root-root interactions.

## References

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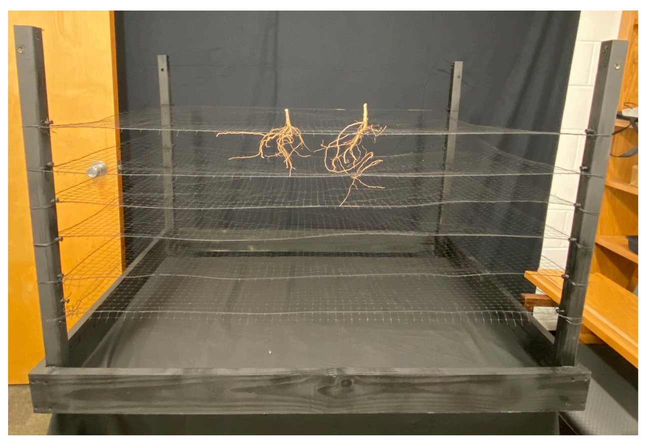
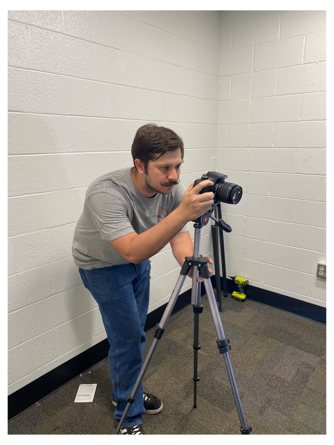
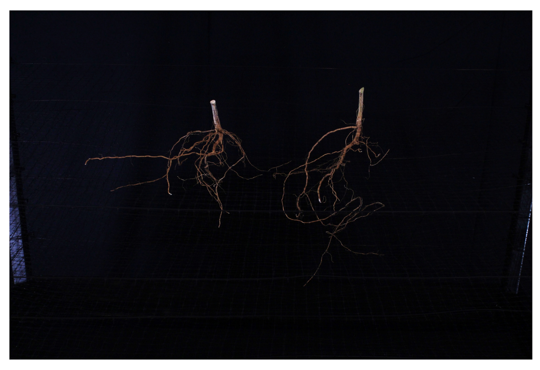
## Experimental Design

1. We developed a mesh frame that can be inserted into a mesocosm system. Must remain lightweight and minimal to allow for taking photographs from all point of views, while providing enough support to keep the roots in place when soil gets removed.



2. Using dried out roots we tested our system by taking hundreds of high-quality images with a Canon Rebel T6 camera as input to our 3D reconstruction pipeline.





3. Our pipeline uses a previously developed structure-from-motion algorithm to generate a 3D model of the 3D root-root interaction.

4. After the successful preliminary tests, we began preliminary experiments in a full-sized mesocosm. We currently grow a first experiment of two interacting roots to test the 3D reconstruction in a full experiment setting. Soil will be removed after 8 weeks, and the state of root-root interaction will be reconstructed and quantified in 3D.

## Future Work

With our preliminary experiment underway we are waiting to harvest. To harvest the mesocosm will be deconstructed and soil can be rinsed from the mesh frame and roots. Roots can then be imaged and modeled to extract traits of interest.

This preliminary work can help us adapt already in use data pipelines like DIRT/3D to extract architectural traits such as root growth angle, rooting depth, and root volume relative to neighbors. These spatial traits relate to the soil areas that individual root systems are foraging in with respects to their neighbors.

When we are ready to scale up our experiments and our extraction pipelines have been modified, we will have developed a reliable platform to accurately quantify the effects of root-root interactions on root architectural plasticity. This will provide valuable insight into how root systems respond to one another and allow for the identification of traits that are favorable to population fitness, instead of focusing on a high-performing individual.

## Acknowledgements

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