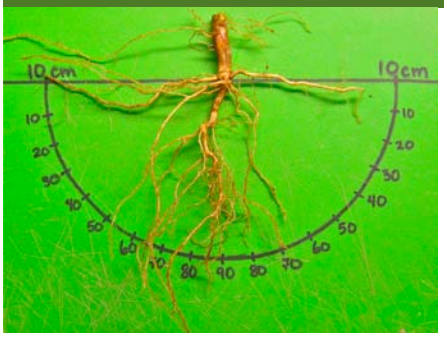
Dig it! Evaluating Crop Root Architecture with a Shovel

Focus on Common Bean



Evaluating the Underground Foundation

Roots explore the soil for water and nutrients providing the foundation for growth and development. Understanding how root traits influence water and nutrient uptake can be important for crop varietal selection and improvement.

Dig it! is an easy method you can use in the field to select for crop varieties with root traits better adapted to abiotic stresses.

Step by step:

1. Select plants

- Choose at least five representative plants from the variety of interest which appear healthy. Mid-flower to mid-pod is the best stage to evaluate bean roots.

2. Dig around plant

- Use a spade shovel to dig out the roots. Start a shovel head distance (~30 cm) away from the stem and loosen the soil on all sides of the plant to a depth of 30 cm.

3. Remove plant

- Gently lift the plant out of the ground with your hands or a shovel, being careful retain as many roots as possible.

4. Clean roots

- If working in heavy clay soil soak root system in moderately soapy water for 10 minutes to loosen the soil, then wash any remaining soil off the roots.

5. Evaluate roots

- Cut root system from the shoot at the soil surface level. Use a score board to evaluate roots (see next page) for traits such as basal angles, lateral branching density, and nodule activity. Count the number of basal and adventitious roots or develop your own visual rating system to document the diversity of root structures in your region.

Evaluating the Roots: Identifying Beneficial Traits

Soil Constraints	Root Traits
Terminal drought	Strong tap Deep basals
Low soil phosphorus	Shallow basals Strong adventitious Long, dense root hairs Higher basal whorl number
Low soil nitrogen	Nodules (nature's nitrogen fixers)

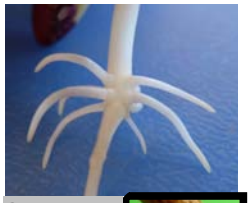
First, determine abiotic constraints to plant production, such as soil nutrient limitations and water availability. Consider also that nutrients and water can be stratified in the soil. For photos of beans with specific nutrient disorders check out roots.psu.edu/en/node/177.

Then, use Dig it! to link root architectural traits to superior stress tolerance and improved production based on local soil conditions. See upper left graphic for examples of specific root traits that enable better resource acquisition. In terminal drought for example, roots that reach deeper into the soil to access water would be beneficial for maintaining growth as the surface soil dries. In low phosphorus soils, the available phosphorus held in the surface soil is best acquired by shallow basal roots, strong adventitious roots and long, dense root hairs.

Basal Root Whorl Number

One

Two



Three

3 weeks in field

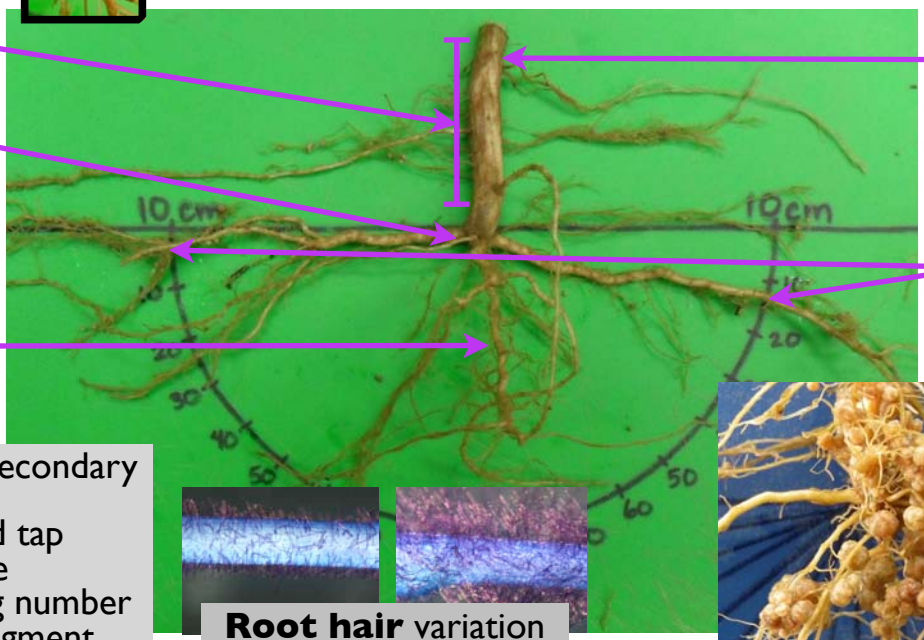
Bean Root Classes

Adventitious roots vary in number and diameter

Basal roots emerge in whorls of four roots, varying in diameter, angle and whorl number

Tap root (Primary root)

Lateral roots all secondary roots coming from adventitious, basal and tap roots, variation can be measured by counting number of laterals in a 2cm segment



Soil surface level

Basal root angle is shallow, between 5° and 15° from horizontal, 10cm from origin

Root hair variation visible with a hand lens

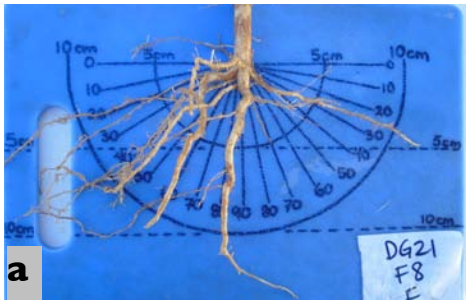
Nitrogen fixing nodules, pinch to see if active:

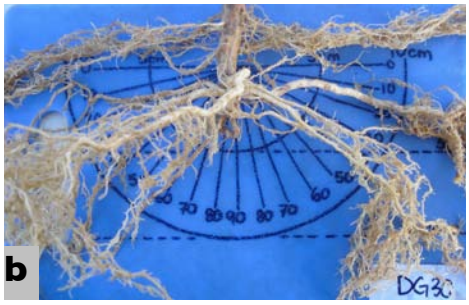
pink = alive

grey = dead

Variation in number and size

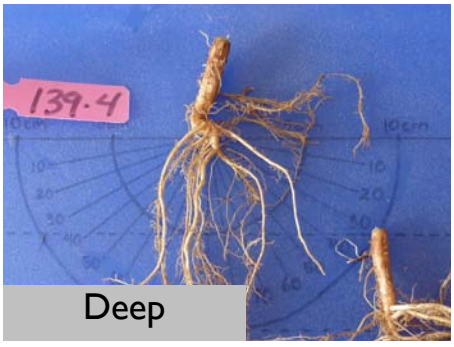
Examples of Common Bean Root Architectural Variation

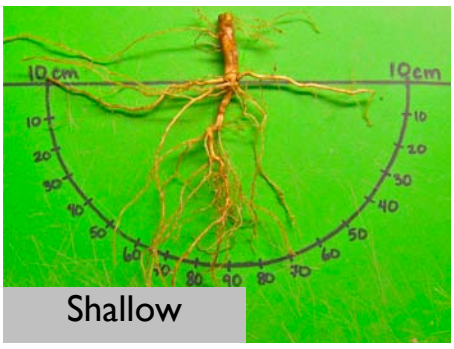




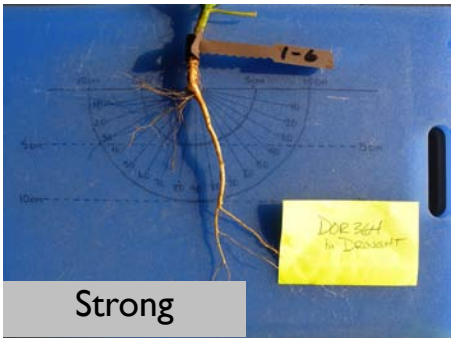
(a) strong tap with few laterals; (b) strong adventitious, basal and lateral roots; (c) deep basal roots with average number of laterals

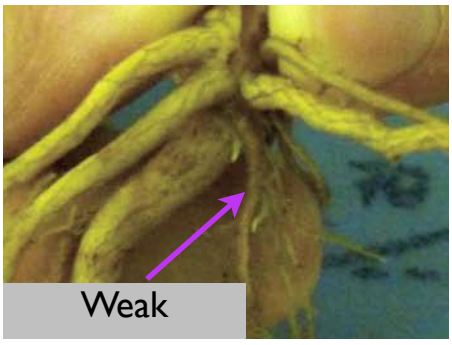
Basal variation



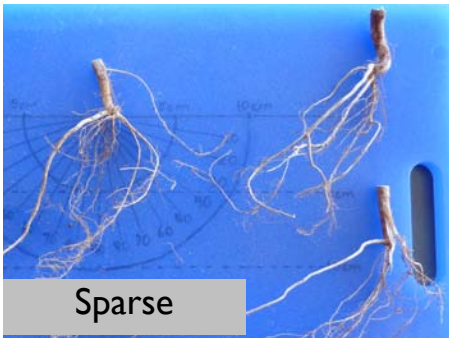


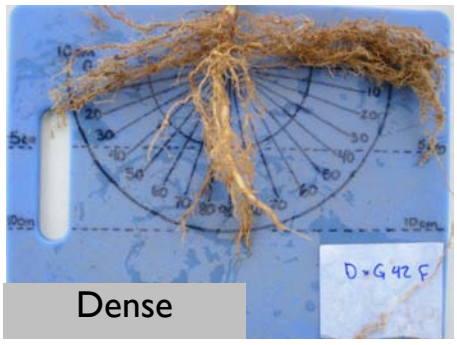
Tap variation

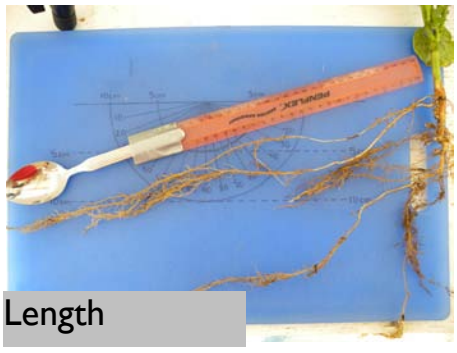




Adventitious variation



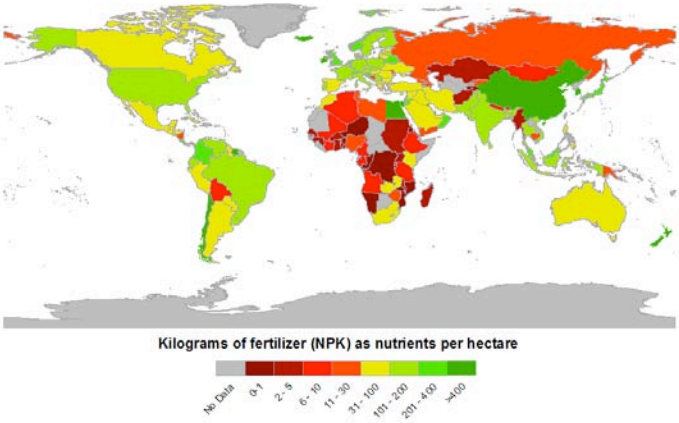




Tool for Participatory Varietal Selection with Small-Holder Farmers

Crop yields for small-holder farmers on marginal land are often far below potential due to limited access to fertilizers and adequate water (see map below). With climate change affecting rain patterns and dwindling mineral resources for fertilizer the emphasis in crop selection should be on traits that improve tolerance to specific abiotic stresses of a particular region. There will be no "silver-bullet" variety for all areas prone to drought, each combination of soils and climates will require a combination of adaptations.

World Fertilizer Use: Limited Access in Africa and Central Asia



York, McCormack, Lynch 2010 from FAO data 2008

Using Dig it! you can investigate with local farmers the array of root traits of the local and commercial varieties of beans grown. Exploring the potential root diversity with farmers, particularly the local varieties, could shed light on the root traits that are well adapted to the region. With a greater awareness of root architectural traits farmers can use this knowledge for selection within local bean varieties or for making interspecific crosses with other bean varieties that have desired traits such as favored seed color and size. Beans are self-pollinated, therefore once the selection has been made the superior line can be maintained from season to season.

Knowledge of beneficial root traits returns the bean improvement control in the hands of the local farmers to make selections they desire at no additional cost or constraints on intellectual property. This method requires no expensive tools or equipment and the basic skills can continue to be a valuable tool for the future in a time of unpredictable climate change.

Where to learn more

Researchers and collaborators of Jonathan Lynch's Root Biology Lab at Penn State University have been working for over 20 years to identify root architectural traits of common bean, maize, and rice that confer tolerance to drought, salinity, and low phosphorus and low nitrogen stress. More details on Dig it! (referred to as "shovelomics"), including articles and score board ideas, and other field methods for exploration of root biology can be found at their website: roots.psu.edu.

For questions please contact Jonathan Lynch at jpl4@psu.edu or Katy Barlow at katy.barlow@gmail.com.

Katy Barlow, Graduate Student, Department of Horticulture, Penn State University, Fall 2010