Computer modeling breaks new ground in study of root architecture

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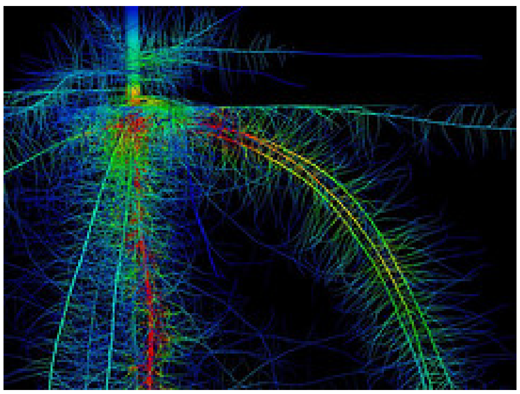

Jonathan Lynch uses computer simulations to study root characteristics.

(Phys.org)—The UN estimates that one in every seven people around the world are hungry. Fortunately, Jonathan Lynch uses Information Technology (IT) to get to the root of this problem.

Lynch is a professor of plant nutrition in the Penn State College of Agricultural Sciences. His research focuses on plant root architecture, and how the study of plant roots can increase crop yields and improve global food security. Lynch conducts research on five continents, where he uses computer simulations to study root characteristics.

Along with his colleague Kathleen Brown and their team of researchers, Lynch works to breed plants that thrive in low-phosphorus soils with limited water and nutrient availability, specifically among poor nations in Africa, Asia and Latin America.

Traditionally, the key to improving crop yields has been to increase soil inputs like fertilizer and irrigation, but in Africa, farmers cannot afford fertilizer and must work with poor soil. Given these circumstances, Lynch believes the roots themselves must be improved.

"All plants need nutrients," he explained. "What we're dealing with, really, is acquisition efficiency. Getting those nutrients out of the soil better. What we need, instead of plants that respond well to fertilizers, are plants that can do well in low-input, low-fertility environments."

Across the globe more than 1 billion people are malnourished, and the number of undernourished people continues to grow. Improving soil resource acquisition helps to feed the world, and this research has been greatly aided by computer technology.

The characteristics and shapes of roots play a crucial role in the acquisition of water and essential nutrients, such as phosphorus and nitrogen. In order to study these important traits, Lynch and his colleagues use computer modeling to simulate the roots of two of the world's most important staple crops: beans and corn. Computer modeling helps to pinpoint critical factors that are difficult to measure on real roots growing in soil.

"To just say that you want more roots—that's the wrong answer. What you really want is a root system that's doing just the right thing at the right time in the right place – but what is that exactly?" said Lynch.

The answer can be found through computer simulations, using Penn State-developed programs like SimRoot, RootScan and RootSlice.

SimRoot is an essential aspect of Lynch's research. The simulation was created entirely by students and post-doctoral researchers in the Lynch lab, with help and guidance from IT staff. SimRoot uses three-dimensional root models to provide a comprehensive picture of the relationships between root shapes and their functions. The program simulates different root systems and the quantification of root related factors, such as phosphorous absorption. Studies conducted using SimRoot have examined the effectiveness of shallow versus deep roots, and the importance of root angles, root hairs, root hair density and root hair length. Currently, Lynch and his researchers are using SimRoot to study root cortical aerenchyma, an anatomical quality that improves drought resistance in corn.

Researchers in the Lynch and Brown Labs also have developed a program called RootScan, an image analysis system capable of extracting quantitative anatomical information from root cross sections. RootSlice explicitly models this information in 3-D, permitting functional analysis of cellular and subcellular biology in silico.

Many of the discoveries made using computer simulations can be applied to the practical aspects of farming and can improve crop yields. For example, shallow roots fare better in topsoil, and longer root hairs absorb more phosphorus. When growing corn, deep roots are best, because essential nutrients like nitrogen are easily washed out of the soil.

In his interactions with farmers around the globe, Lynch advocates a simple approach: Study the visuals of roots, rather than their genetic makeup.

"In Africa, breeders may not have sophisticated tools to look at molecular markers," Lynch said. "If they can use a shovel, dig up a root system and notice it has certain traits, that's something they can use. It's what we call 'shovelomics.' And that may be more important than genomics in promoting food security in poor nations."

Through collaboration with plant breeders, Lynch's work has led to the creation of new genotypes of beans and soybeans, and has resulted in improved crop yield in the low phosphorus soils of Africa, Asia and Latin America. Other countries stand to benefit from Lynch's work as well, with projects under way with colleagues in Mozambique, Malawi, South Africa, China, Ecuador, Honduras, Nicaragua and Colombia.

More information: To learn more about Lynch's research, visit roots.psu.edu

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