FIRST DIRECT OBSERVATIONS OF HOW ROOTS GROW

Researchers have found ways to watch the roots of plants as they grow

As scientists look at crops to find ways to help them deal with climate change stress and growing populations, a tool has emerged to give them a new perspective: the view from underground.

Plants are a lot like icebergs: A bulk of their mass is invisible to the naked eye, buried in their roots. Roots allow plants to compensate for their stationary role in life, hunting for nutrients and diving to mine for water in times of drought.

These are abilities food security researchers would like to be able to enhance to develop more durable crops, but laboratory conditions currently confine experiments to the first few days or weeks of a sprouting plant's life.

Alexander Bucksch, a computer scientist turned plant genetic mathematician, said he was driven to find a way to shed light on roots in his postdoctoral work at the Georgia Institute of Technology. He was struck by how little is known about their growth and how similar the scale, overlap and diversity of branching was to other systems he had created visual models for in his previous work.

"I had an immediate interest in going underground," he said. "We knew hardly anything about mature root systems, even less how to control traits. I realized I could take my technical side and apply it to biology, to get the best of both."

Bringing together specialists in root genetics, plant physiology and agro-ecology, Bucksch built a computer program that uses an algorithm to interpret digital images of mature roots extracted from the field. It allowed him to analyze enough root samples with a high degree of uniformity to allow statistically significant results. This could give future researchers the ability to manipulate traits of crops that have been concealed, explained Malcolm Bennett, a professor of plant sciences at the University of Nottingham in the United Kingdom.

"For 10,000 years we've selected for aerial traits directly, but we haven't directly been able to select for the hidden half, though we know roots can greatly impact the very things we're trying to select for," he said. "This is an impressive gain towards being able to do what we've wanted to for a long time."

Measuring the unseen in a standardized way

Understanding the challenges presented to root researchers is fairly easy, Bucksch explained. Current methods either grow seedlings in clay pots that can be analyzed using magnetic resonance imaging (MRI) or grow them in glass pots using a clear medium instead of soil. While these techniques are highly advanced, they observe only a small, unrepresentative portion of plant life, which restricts root study as many develop or are modified later in life.


Prop roots of Maize plant

"In maize [corn], you don't even see top roots grow within current studies," Bucksch said. "Before, the time scale people were working with was within a few weeks to a month at best; now we're talking about being able to see the growth of months, maybe even more."

Bennett explained that this limited how quickly researchers could process their samples, which with a living subject that continues to grow makes comparing data collected days apart tricky.

In the 1980s, image-based techniques were applied to the study of roots to better predict how they might grow, but this process still didn't allow the kind of certainty needed for genetic study and was very time-consuming.

In 2011, Jonathan Lynch from Pennsylvania State University, now part of Bucksch's team, helped create an alternative, a way to standardize root sampling and generate more precise results, which he called "shovelomics." It called for roots to be extracted, washed and then measured against a protractor board for classification in a specific manner.

But there were still subjective factors that remained a problem. "Each person brings with them different levels of expertise, field knowledge and training into their interpretation, making scores subjective," Bucksch said. "We wanted to take counting and measuring out of the researcher's hands altogether to avoid this."

Speaking the same language

The new method, published last week in **Plant Physiology**, has researchers photographing their root samples against a black background board alongside a circle to scale the image. This image is then uploaded to a computer that uses the algorithm to analyze fine and large-scale aspects of the samples. For many root systems, this was previously impossible given their high degree of complexity.

Within these additions also come the tools to match the visible traits of the plant with the genetic makeup of the trait. This was needed to unlock and explore root adaptive potential.

"What we can learn now is how plants change to meet their environment," Bucksch said. "What things have worked in the past for the plant is reflected in the angle, the branching and the dynamics of its root system."

Continued on Page 18