Researchers identify gene important to adaptation and determine roots are a key to drought-tolerant maize

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Three different maize plants after a drought and subsequent re-irrigation. In the two plants on the right, a gene has been switched off with the effect that fewer seminal roots and more lateral roots grow. They recovered significantly better following a period of drought than the plant with the intact gene (on the left). Credit: AG Hochholdinger/Uni Bonn

An international study headed by the University of Bonn has now demonstrated the important role of the plant root system in maize, a crop that can grow successfully in very different local conditions.

For the study, the researchers analyzed more than 9,000 varieties and were able to show that their roots varied considerably—depending on how dry the location is where each variety was cultivated.

They were also able to identify an important gene that plays a role in the plant's ability to adapt. This gene could be the key to developing varieties of maize that cope better with climate change.

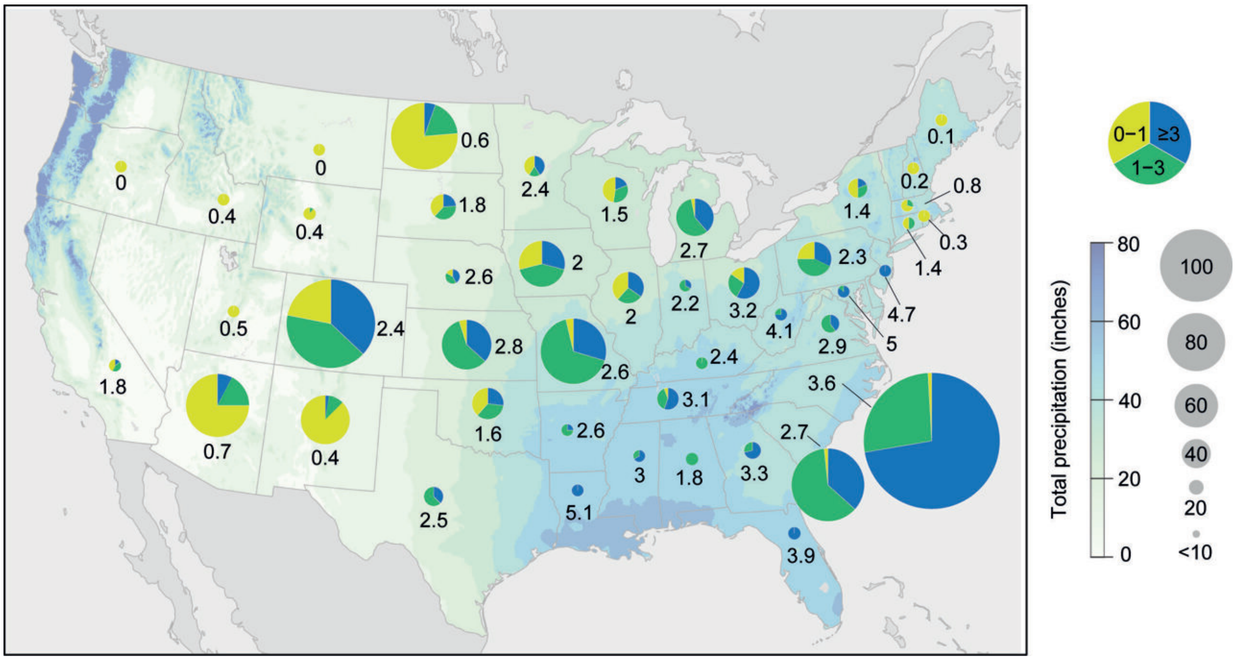
These results were recently published in *Nature Genetics*.

It is a bushy plant with highly branched stems. Finger-length ears grow from the axils of their elongated leaves and every one of them consists of a dozen rock-hard seeds. You have to look very closely to recognize kinship with one of the world's most important cultivated plants. And yet experts all agree that the genus teosinte is the ancestral form of all modern varieties of maize.

Farmers in southwest Mexico began to select the progeny of teosinte plants that produced the most grains, and the tastiest grains, more than 9,000 years ago. Modern maize crops were cultivated in this way over the course of many generations, and now maize is cultivated across all the continents.

"We know that the appearance of the plants changed significantly during this time and, for example, the cobs have become much bigger and more prolific," explains Prof. Dr. Frank Hochholdinger from the Institute of Crop Science and Resource Conservation (INRES) at the University of Bonn.

"Up to now relatively little has been known, however, about how the root system developed over this period of domestication and afterwards."



The drier the region, the fewer seminal roots the maize varieties cultivated there had on average (black figure; the pie chart shows the proportion of varieties with up to one seminal root in yellow, with up to three seminal roots in green and with more than three seminal roots in blue). Credit: AG Hochholdinger/University of Bonn

Roots in paper cigars

This has now changed thanks to the new study. Over the last eight years, the participating research groups have investigated about 9,000 varieties of maize and 170 varieties of teosinte around the world. The researchers collected seeds and placed them onto special brown paper, which was then rolled into a cigar shape and stored upright in narrow glass beakers.

"Around 14 days after germination, we unrolled the paper so that we could observe the early development of the roots without the interference of any soil adhered to them," says Hochholdinger.

In cooperation with a research group headed by Dr. Robert Koller (Forschungszentrum Jülich), the researchers also studied root growth in soil. They used a method that is more commonly known from the field of medicine for this purpose—magnetic resonance imaging.

The results showed how the root structure has radically changed during the domestication of teosinte to cultivated maize.

"In the maize varieties, we often find seminal roots shortly after germination—with as many as 10 or more of these roots in some varieties," explains Dr. Peng Yu, who is head of an Emmy Noether research group at INRES and has recently accepted the offer of a professorship at TU Munich. "This is not the case with teosinte."

Seminal roots give the seedlings an initial advantage under optimal conditions: They enable them to absorb large amounts of nutrients from the soil very rapidly. "However, we noticed that another type of root—the lateral roots—suffer as a consequence," says Yu.

Lateral roots are especially important for the uptake of water because they greatly enlarge the root surface. This is probably the reason why the number of seminal roots varies considerably depending on the variety: Maize varieties that have adapted to dry conditions grow significantly fewer seminal roots and more lateral roots. When breeding these varieties, farmers in the past were unknowingly selecting plants that have led to the development of this root structure.

160 candidate genes identified

The researchers also investigated which genetic material was responsible for the growth of seminal roots and were able to identify more than 160 candidate genes. "We then studied one of these genes named ZmHb77 in more detail," says Hochholdinger. "We noticed that plants with this gene grew more seminal and at the same time fewer lateral roots."

The researchers deliberately switched off this gene in some plants and were able to change the root structure so that they could better tolerate periods of drought. "This gene is thus important for breeding drought-tolerant varieties," explains the researcher. "In view of climate change, these varieties will become increasingly important if we want to avoid more and more crop failures in the future."

More information: Peng Yu et al, Seedling root system adaptation to water availability during maize domestication and global expansion, *Nature Genetics* (2024). DOI: 10.1038/s41588-024-01761-3

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