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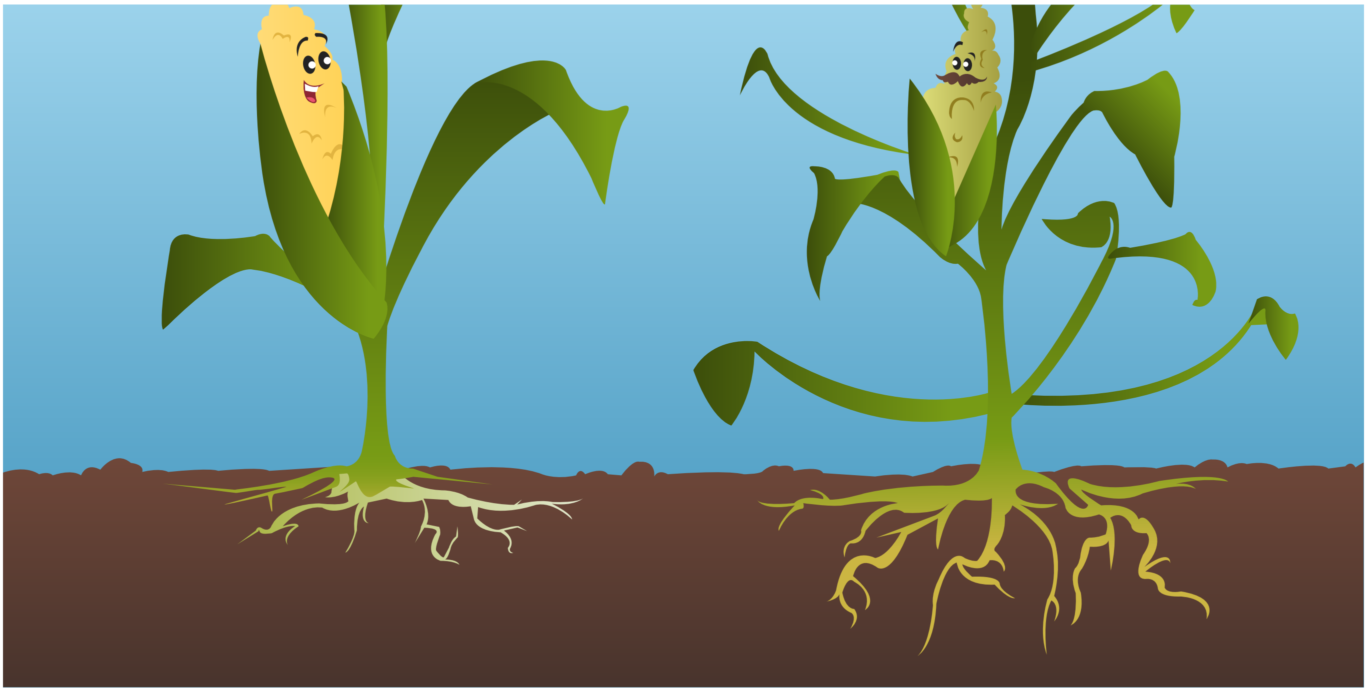

"WHERE DID MY FRIENDS GO?": HOW CORN'S MICROBE PARTNERS HAVE CHANGED OVER TIME

Jennifer E. Schmidt and Amélie C. M. Gaudin*

Department of Plant Sciences, University of California, Davis, Davis, CA, United States

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WISH BILINGUAL SCHOOL
10–11 YEARS OLD

Many of the foods we eat today look very different than they did in the past. Corn, or maize, did not exist 10,000 years ago: it descended from a weedy grass with tiny hard-shelled seeds that we would not recognize as corn kernels. That wild ancestor of corn, called teosinte, grew in mixtures of many other plants, instead of grows in cornfields like today. Big changes between teosinte and corn that we can see aboveground lead us to think that there have been changes belowground too. Plants form partnerships with microbes, such as bacteria and fungi, to get the nutrients that they need to grow. Scientists are finding that microbes near the roots of teosinte are different than microbes that live around corn roots. Understanding how corn's microbe partners have changed can help us make corn varieties that are better for the environment.

PLANTS AND THEIR MICROBE PARTNERS

What do corn roots have in common with your Facebook profile?

No, that was not the beginning of a joke. The two have more in common than you might think. We often think of a corn plant as a single organism. But plants are part of a network of relationships, sort of such as Facebook. These plant relationships are easy to overlook because they are hard to study. Still, they are very important because they affect how healthy plants are.

Soil is full of millions of microscopic bacteria and fungi. These microscopic organisms are collectively called microbes. Some of these microbes form close partnerships with plants. Plants can rely on microbes to help them get nutrients that are scarce in soil. Microbes break down dead plants and animals, and this process slowly releases nitrogen, phosphorus, and other elements that plants need to grow. When plants cannot get enough of these nutrients on their own, they can send out sugars from their roots. The energy microbes get from these sugars helps them break down even more dead plants and animals. If enough nutrients are available in the soil, though, plants would rather keep their sugars for themselves. They only ask for help from microbe partners when they need it.

Here is how we could compare the relationships between corn and its microbes to a Facebook profile. You know lots of people through school and activities, but you are only Facebook friends with some of them. In the same way, there are millions of microbes in the soil, but corn only interacts with some of them. The area near plant roots, called the **rhizosphere**, has fewer types of microbes than the rest of the soil. Plants attract specific microbes to the rhizosphere by sending out signals and sugars from their roots.

RHIZOSPHERE

The area of soil near plant roots.

Your group of Facebook friends could change as you change. This might happen as you grow older or move and meet new people. Corn's microbes change too. Different microbes live in the rhizosphere when corn is a seed than when it is a full-grown cornstalk. Corn in Mexico has different microbes in the rhizosphere than does corn in California.

We know that microbes change over the course of a single plant's life cycle. But what about the long term? How has corn's social network changed over the past 10,000 years?

TEOSINTE, THE WILD ANCESTOR OF CORN

Humans evolved from apes. Birds evolved from dinosaurs. Corn evolved from... **teosinte**?

TEOSINTE

A Mexican grass that is the wild ancestor of corn.

Corn on the cob did not exist 10,000 years ago. Modern corn comes from a weedy grass, called teosinte, that grew in Mexico. Teosinte's tiny seeds do not look anything like corn kernels. These seeds had a hard shell that kept them from being eaten by animals. In fact, we would not recognize teosinte as related to corn just from looking at it! Scientists had to look at the DNA of teosinte and corn to figure out that the two plants are related. They compared DNA from corn to DNA from lots of its wild relatives, collected in different regions of Mexico. Teosinte from the Balsas Valley was the best match, telling us that it is the direct ancestor of corn [1].

Teosinte lived in a challenging environment. Nutrients were scarce. Other plants competed for sunlight and water. Teosinte looked very different from corn because it needed to survive in this challenging environment (Figure 1). Large roots helped teosinte get nutrients and water and many stalks helped it compete with other plants for light.

Humans slowly created corn from teosinte. Thousands of years ago, people began to grow food instead of hunting and gathering. They selected seeds from their best plants at harvest time to plant the next year. Large kernels without hard shells were easier to eat, so every year farmers saved the largest, softest seeds. Over thousands of years, this selection process created corn from teosinte. Corn began to spread throughout Mexico and to the rest of the world. Early **varieties**, called **landraces**, were as different from one another as they were from teosinte. Each variety of corn had qualities that helped it grow in its particular location.

Corn has changed even more over the last 80 years. Modern farming is very different from early agriculture. Today, cornrows are planted very close together and farmers apply nitrogen and phosphorus fertilizer to the soil. Modern varieties of corn need to be able to grow well in these conditions.

VARIETY

A type of corn (or another crop) with unique characteristics that make it different from other types of the same plant. For example, one variety might be ready to harvest earlier than others and another variety might resist diseases better.

LANDRACE

An early domesticated variety of a crop that grows well in a particular location.

FIGURE 1

FIGURE 1

Teosinte and modern corn. Teosinte (left) is much shorter than modern corn (right) and has many more stalks, but only tiny, hard-shelled seeds instead of corn cobs. Teosinte's many roots are narrow and short and have lots of branches. Corn roots are longer and thicker, which helps them get nutrients that are deep in the soil, and the corn stalks are much taller than the stalks of teosinte.

OOPS, WE SHRUNK THE ROOTS: INDIRECT SELECTION ON ROOTS

TRAIT

A characteristic, like a particular leaf shape or seed color.

We often focus on aboveground plant characteristics, or **traits**, such as height or leaf shape, because they are easier to see. But characteristics of the plants that lie belowground are important too. Plants depend on roots to find nutrients and water in the soil and take them up. Roots also transport those resources up to the stem so that they can go to the leaves. And plants send out signals from roots to interact with their social network of microbes.

When early farmers chose which seeds to save, they were not thinking about the roots. They wanted plants that produced a lot of large, soft, tasty seeds. Plants with these kinds of seeds did not necessarily have the biggest, strongest roots. In fact, they might have had tiny roots because they used the energy that could have gone into growing roots to make large seeds instead. But roots and seeds are part of the same plant. By saving the seeds from these plants, humans might have chosen certain root traits without planning to. We call this **indirect selection**.

INDIRECT SELECTION

Choosing certain characteristics without meaning to, because they are linked to characteristics that are being selected.

Modern corn roots look very different from teosinte roots because of indirect selection [2] (Figure 1). Teosinte needed roots that were good at getting nutrients and water. It produced many more roots than corn. The roots coming out of the main stalk of teosinte were narrow and short, with many branches. These roots spread out close to the surface of the soil. All of these traits helped teosinte find and take up scarce nutrients. But a cornfield is very different from the wild environment of teosinte. On a farm, humans provide fertilizer and water (if there is not enough rain), and keep weeds out. Modern corn does not have to work very hard to find nutrients. It produces fewer roots that do not have as many branches. Modern corn roots are thicker and can transport lots of nutrients quickly. They go deeper into the soil instead of spreading out near the surface. Since corn rows are planted very close together, deep roots can help plants find nutrients without competing with their neighbors [3].

We can see that corn has changed both aboveground and belowground. But what about the part we cannot see: its soil microbes?

HAS CORN GOTTEN LAZY?

It is clear that corn is very different from teosinte and a cornfield is very different from a river valley filled with many different wild plants. Even though corn is related to teosinte, these changes make us think that corn might have picked up new microbes or lost some of the old ones as it evolved.

We know that corn varieties have many of the same microbes as their relatives. One corn plant can pass some of its microbes on to the next generation through seeds [4]. The next generation can also attract similar microbes because the plants send out the same signals into the soil as their parents did. This makes us think that corn and teosinte might have some of the same microbes, even though teosinte is more like corn's great-great-great-grandparent than its parent.

But we also know that different kinds of corn can attract different microbes. We still do not understand exactly why this is, but we think it has to do with their roots and the signals the roots send. Just like human kids, corn plants are not exact copies of their parents. Their roots can be different, or they can send out different signals. This means a corn plant can have different microbes than its parents, especially if its roots are different in other ways. One variety of corn can attract more microbes than another, even when both varieties grow in the same soil. Some varieties might have more active microbes, which provide the plant with more nutrients.

Differences between corn and teosinte roots make us think that corn might have fewer, less active microbes. Microbes would rather live near roots than in the soil. Both living and dead roots provide food and protection from the harsh soil environment. Since modern corn has fewer roots, it may not be able to support as many microbes. These microbes might also be less active than microbes in the rhizosphere of teosinte. Since modern corn gets all the nutrients it needs in fertilizer instead of relying on microbes, it might send out fewer sugars for the microbes to eat. This means microbes near modern corn might be less active. To see if this is true, scientists are starting to compare microbes around the roots of teosinte and corn.

YOU WIN SOME, YOU LOSE SOME: CORN'S CHANGING MICROBE COMPANIONS

Does modern corn have different microbes than teosinte? And even if the same microbes are there, are they doing different things?

Recently, scientists have found some differences in the microbes around corn and teosinte roots. Modern sweet corn has fewer microbes than teosinte and fewer different kinds of bacteria and fungi [5]. This supports the idea that modern corn may have lost some microbes over time and gained new ones. However, some of the same microbes can be found around the roots of both teosinte and corn. This shows that a core group of microbes has stayed the same over time.

We still have a lot of questions to answer, though. When, during the thousands of years between teosinte and corn, did these changes occur? Does modern corn send out different signals than teosinte sent out? Do different microbes mean that modern corn can get more nutrients from soil, or fewer?

MICROBES AND THE SUPER-CORN OF THE FUTURE

Studying corn's roots and its microbes can help us make farming more efficient. The first step is to identify desirable traits of the roots and microbes. We may find that teosinte roots are better at getting nutrients. Or modern corn might have microbes that provide more nitrogen. Once we find those good traits, we can trace them to the plant genes that control them. Plant breeders can combine these genes to make corn plants that are better at getting nutrients from soil and from microbes. These plants would need less chemical fertilizer. Producing fertilizer uses lots of energy, and pollution from fertilizer sometimes hurts water quality, the animals in the water, and the humans who drink it. We still have many questions, but research on how corn's roots and microbes have changed will help lead to making corn varieties that use less fertilizer and that would be better for the environment.

ORIGINAL SOURCE ARTICLE

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WISH BILINGUAL SCHOOL, 10–11 YEARS OLD

We are the "Raios" ("lightning" in English) class. In our classroom, there are 12 students – 8 students are 11 years old and 4 students are 10 years old. We like very much to play soccer and to make activities together with each other. We are happy, handsome, funny, lazy, creative, and comical. But we feel sleepy at school sometimes. Our first names: Isabelle, Luana, Isabela, Gabriel, Thomas, Pedro, Enrico, Heitor, Rodrigo, Gustavo, Rafael, Laion.

AUTHORS

JENNIFER E. SCHMIDT

Jennifer E. Schmidt is a Ph.D. student at the University of California, Davis. Her focus is on plant–microbe interactions in the rhizosphere and she is currently working with corn. She plans to use research on these interactions to help develop sustainable agricultural systems that are better for the environment. *jenschmidt@ucdavis.edu

AMÉLIE C. M. GAUDIN

Amélie C. M. Gaudin is an Assistant Professor of Agroecology at the University of California, Davis. Her research focuses on the important role roots play in agricultural systems and ways to make farms more resilient in a changing climate. She has studied cropping systems, roots, and rhizosphere ecology in France, Peru, the Philippines, Canada, and the United States.