Root Border Cells Defend Plants

UA researcher first to describe mechanism

by Susan McGinley

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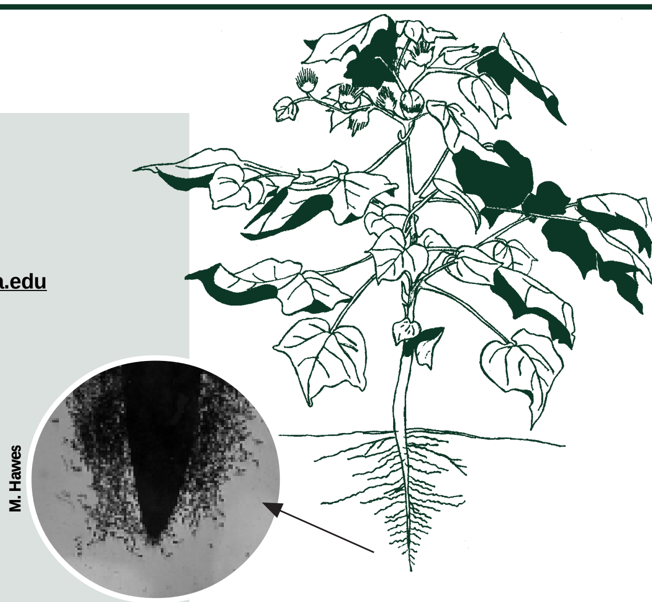

Border cells clustering around cotton root tip.

Most of us think plant roots end with the cells that are attached to the outer surface of the root tip, but Martha Hawes knows better. She has spent more than 20 years researching and describing root border cells: a floating, separate "phalanx of biological 'goalies'" that guards the outer tip of most plant roots.

"The plant puts a huge amount of energy into producing border cells, which confer the root's ability to engineer the chemical and physical properties of the external environment," says Hawes, a plant pathologist in the University of Arizona College of Agriculture and Life Sciences. Her work is unique in the field; no one has described this system in detail before. "We think border cells are behaving as foot soldiers that have to be able to fall away to protect the plant. This energy may be worth the cost because it enables the plant to dictate which species will share its ecological niche."

Border root cells consist of tissue that is different from anything else in the plant. In laboratory studies Hawes has watched detached root cap cells divide and multiply independent of the plant that generated them. They can even differentiate into organized tissue.

Before the cells separate from the root cap, they secrete mucilage and sense gravity, but as they detach, their metabolic activity increases and the gene expression switches. They begin to produce anthocyanins, antibiotics, special enzymes and other substances that either inhibit or promote the growth of other entities in the soil around the root. These can include bacteria, fungi, viruses, parasites, nematodes, mites, insects and other invaders.

"Border cells of species like cereals, cotton, nicotiana, and pine produce specific chemicals that dramatically alter the behavior of populations of soil-borne microflora," Hawes says. (Only species in the cabbage family do not appear to produce border cells.) In one experiment, border cells were washed off one set of legume roots and were left attached to another set. All of the roots were placed into a plate of nematodes. "They went straight to the plant with the border cells," Hawes says. "Within a half hour they had all stopped moving, but did not die. The nematodes were able to 'come back to life' even after days of not moving."

When the stunned nematodes sobered up from their encounter with the root border cells' chemicals, they were able to infect behind the root tip, but not the meristem. "We think it's another example of how the system allows the plant to be invaded, to tolerate some colonization without being killed," Hawes explains. "It's the specific gene expression in these border cells that enable the plant to define how it's going to interact with infectious agents. So that affects how, when and where and by whom it gets infected."

Hawes speculates that previous investigators often overlook border cells because without free water, these cells adhere so tightly to the root periphery that their presence is difficult to detect. In contrast, when free water is present, the cells disperse away from the root in seconds.

She began this work in 1980 as a graduate student at the University of Kentucky. She spent the first ten years describing the biology of this system—at times working on it for free because she believed so strongly in its usefulness—using organisms that couldn't be attracted to a border cell. In 1986 Hawes accepted a shared appointment in the UA Departments of Plant Pathology and of Molecular and Cellular Biology, and has worked to engineer changes in the border cells of transgenic plants that can be placed into soil to monitor effects on plant-microbe relationships.

Since border cells have the capacity to express whatever they're programmed to do, Hawes hopes to find products in their secretions that can be amplified and transferred to regions of the plant where infection is occurring. She has applied for a patent on this process and is interested in seeing it turn into a product that will have worldwide applications.

"If these cells can immobilize a nematode, it's not a great stretch to propose expressing a chemical that knocks them out and keeps them knocked out a little longer," Hawes says. Soil bioremediation, where a natural organism released into the soil neutralizes a contaminant, is another application for this mechanism. "There are genes and microorganisms that will bioremediate anything we come up with. The trick is to introduce them at the right time and place in the environment, and that's what border cells are programmed to do naturally."

Hawes and her team are also collaborating with a professor in Hawaii on using this biological technology to improve the tolerance of plant roots to naturally occurring aluminum in tropical soils. ❖