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Toxicity-Resistant Crops

Researchers have engineered aluminum-tolerant crops.
By Mason Inman

Much of the world's cropland contains aluminum that stunts crops. But a new study has found a way to make plants grow tall in spite of the metal's toxic effects. The discovery, by plant biologists at the University of California, Riverside, suggests that genetic engineering could boost yields from fields that today are not ideal for growing crops.

Aluminum is common in soils--it's a major component of clay--but only in acidic soils does the metal form an ion that can dissolve into liquids and that's toxic to plants. Acidic soils make up as much as half the world's croplands, however, and aluminum toxicity is the main factor holding back crop growth in nearly 20 percent of the world's arable soils, including large areas of the United States east of the Mississippi River and northwestern Europe.

"The problem is, we have all these crop plants--wheat and corn and barley and so on--that didn't evolve or get developed on aluminum-toxic soils," study leader and professor of biochemistry Paul Larsen says. "They don't have natural resistance or tolerance to aluminum." Plant breeders are working on developing strains that can cope better with toxic aluminum, but they have only been able to make incremental improvements, Larsen says.

In a study in *Current Biology*, Larsen and his colleague Megan Rounds have uncovered a simple mutation to a single gene that makes plants thrive in spite of levels of aluminum that would normally be toxic. Larsen and Rounds found the gene, called AtATR, by combing through mutants of *Arabidopsis*, a member of the mustard family that's commonly used in plant-genetics studies. The gene is related to a family of proteins known to help with finding and responding to DNA damage in nearly all multicellular organisms.

Toxic aluminum ions are known to damage DNA, and the new study suggests that plants respond by shutting down growth of cells in the tips of their roots when they accumulate too much DNA damage. Plants may have evolved this response to help them, over generations, cope with aluminum's toxic effects, Larsen speculates. But in the short run, it means that the plants are less healthy and are stunted and more vulnerable to stressors such as droughts.

But the newly identified mutation inactivates the AtATR protein, so cells don't respond to DNA damage by shutting down cell division, thereby bypassing that checkpoint, Larsen says. "The plant is effectively blind to what's happening in the cell." So the mutant plants can maintain high levels of growth in the presence of toxic levels of aluminum, even if they sustain some DNA damage.

It is not yet clear how much DNA damage the plants sustain, Larsen says. But the strategy could work to promote short-term growth even if it would sacrifice the plants' DNA. To avoid DNA damage accumulating over generations of growing on aluminum-rich soils, farmers could obtain seeds from mutant plants grown on aluminum-free soil. This would mirror how farmers in industrialized countries use hybrid seeds from agribusinesses rather than saving their own seeds for planting further generations of crops.

"The work provides the first compelling evidence for a mechanism that explains the toxic effect of [aluminum] on root growth," says plant biologist Manny Delhaize of the Commonwealth Scientific and Industrial Research Organisation Plant Industry Center, in Canberra, Australia. "There have been numerous theories about how aluminum arrests root growth, and this work provides convincing evidence regarding the molecular process involved." Delhaize says that another method of keeping the growth rates high, while limiting any DNA damage, might be to engineer plants so that their root tips express molecules that would inactivate AtATR.

However, such a targeted approach may not be necessary, Larsen argues. Even after growing the mutant plants on aluminum-containing soils for several generations, there are "no obvious deleterious effects on growth, viability, [or] seed production," he says.