the gene for a viral coat protein, which interferes with the replication of invading viruses in ways that are not fully understood.

Herrera-Estrella, with Rafael Rivera and other CINVESTAV colleagues, has now applied that technique to immunize "Alpha" potatoes, a variety common in Mexico, against infection by two potato viruses, simply known as X and Y. Field testing of these transgenic potatoes began last year, and it has shown promising results, according to Rivera: Average potato crop losses to the viruses range from 15% to 20%, but the transgenic varieties had losses ranging from 0% to 15%.

In addition to working on traditional crops, developing nations are using biotechnology to improve native species, including sweet potatoes, papaya, banana, and palm—the plants on which many subsistence farmers depend. Richard Sawyer, president of the International Fund for Agricultural Research in Arlington, Virginia, says that, in the West, researchers and farmers "have a cereal mentality, but there are alternative crops, such as fruits and vegetables, that are of more interest to small farmers in developing nations."

Take papaya. This staple of tropical diets is infected almost worldwide by the ringspot virus, an RNA virus that is transmitted by aphids to papaya, squash, and related plants and greatly reduces their yields. About 7 years ago, Dennis Gonsalves of Cornell University's Agricultural Experiment Station in Geneva, New York, began a collaboration with Richard Manshardt and Maureen Fitch of the University of Hawaii and Jerry Slightom of Upjohn to see whether genetically engineering papaya plants to express ringspot viral coat proteins could make them resistant to the virus. Field trials with the genetically modified plants began in 1992. The results, Gonsalves says, are dramatic: "We had 100% protection. It's one of the most impressive field trials you will see."

A problem remains, however. The protection conferred by the coat-protein gene appears to be specific to the viral strain from which the gene came. This may mean, Gonsalves says, that transgenic papaya plants will have to be specifically tailored to resist strains indigenous to the areas where they will be grown.

Papaya isn't the only developing-world crop that's being modified to protect it from disease. International Services for the Acquisition of Biotech Applications, a not-for-profit international organization based at Cornell University that encourages the transfer of agricultural biotechnology to developing countries, is funding efforts by Marto Valdez and Gabriel Macayo of the University of Costa Rica to genetically engineer resistance to viruses into several varieties of the criollo melon, grown by small farmers in Costa Rica, Mexico, and Guatemala. And Magdy Madkour and his colleagues at AGERI are using transgenic techniques to improve disease resistance and nutritional qualities of the fava bean, a food eaten in many Mediterranean countries.

As these examples show, biotechnology holds great promise for improving many crops in developing countries. Yet, ironically, it also has the potential to harm economies of some developing countries—by reducing the demand for their specialized export crops. One negative impact could come from the efforts of companies in the developed world to use plant cell culture techniques to make high-value materials, such as vanilla and cocoa butter, that now must be extracted from tropical plants. Experts such as Michigan State University sociologist Lawrence Busch say that if it becomes economically feasible to make these materials by biotech methods, agricultural production in some developing countries will be harmed, much as the development of high-fructose sweetener from corn devastated the sugar industry in the early 1980s.

But biotech itself could provide an appropriate response, says Ralph Hardy, president of the Boyce Thompson Institute for Plant Research in Ithaca, New York, and an NABC founder. Developing nations could profit, he says, "by using biotechnology to export a more finished product instead of raw commodities." They might, for example, use genetically engineered coffee plants to produce beans that are naturally decaffeinated. Innovative products like these would help to ensure that the overall outcome of biotech on the developing world, where it is fast acquiring a firm foothold, will be positive.

–Anne Simon Moffat

ATOMIC PHYSICS

Making and Trapping the Ultimate Ion

Uranium likes to hang on to its electrons. By stripping away most or all of the 92 electrons surrounding a uranium atom, scientists can turn it into a valuable testing ground for atomic physics, but the 92 positive charges in its nucleus—the most of any natural element—exert a tenacious grip. The last few electrons, bound close to the nucleus, are exceptionally hard to dislodge. Until recently, the only way to do so was to whirl the uranium atoms at half the speed of light in a particle accelerator, smash them into a thin foil, and look for bare nuclei in the debris streaming out the other side. But Ross Marrs and his colleagues at Lawrence Livermore National Laboratory have a subtler strategy.

He and his colleagues Steven Elliott and David Knapp report in the 27 June *Physical Review Letters* that they suspended uranium atoms in a high-speed stream of electrons, which erodes away the uranium's own electrons like a sandblaster stripping paint, all the way down to bare nuclei. As a bonus, the beam conveniently traps the ions for study. "We're the first people to make [bare uranium] sitting still in the laboratory," says Marrs.

That achievement has already opened the way to measuring the rate at which collisions dislodge the last few electrons, a test of theorists' understanding of how high-speed electrons interact with massive nuclei. It's also a proof-of-principle of the Livermore workers' technique for studying heavy, highly charged ions, where quantum mechanical effects that are muted in lighter ions should come through loud and clear. As physicist Michael Prior of Lawrence Berkeley Laboratory puts it, if you can make and trap fully ionized uranium—"the ultimate ion," he calls it—"you've demonstrated the ability to ionize essentially anything."

The key, Marrs explains, is a device called the electron-beam ion trap (EBIT). Originally developed in 1984 to study atomic physics processes for Strategic Defense Initiative beam weapons (*Science*, 4 February, p. 620), the device is built around a tightly focused, high-energy electron beam. The beam not only strips away the electrons from any atoms it encounters but also generates a powerful electric field that holds the resulting positive ions dead center in the beam.

In the work Marrs and his colleagues reported last week, the electron beam also served a third purpose: probing the contents of the trap. An occasional high-speed electron from the beam recombines with a uranium ion, which signals the event by giving off an x-ray photon. The photon's energy depends on whether the ion was fully stripped or had one electron or more left. By measuring the number of photons at each energy, Marrs and his colleagues were able to do a census of their trap to find out the ratio of bare uranium ions to ions still clothed in a single electron. And from that ratio (about 1-to-50), the Livermore workers calculated the rate at which the electron-stripping collisions were taking place.

That rate is about 50% higher than theorists had predicted, which may imply that they need to do some tinkering, says Marrs. But he and his colleagues are just as excited about future EBIT experiments that will probe quantum electrodynamics (QED), the reigning theory of how charged particles interact. "We'd like to see how QED plays out in the environment of these highly charged ions," says Marrs, and the EBIT may give him a front-row seat.

–Tim Appenzeller