Remarkable Kazak Apples

Their resistance to disease may boost an entire industry

Horticulturist Phil Forsline steps from his pickup truck on a cool spring morning, mulling where to start his day's work. "Let's see, that's Kazakhstan over to the right," he says. "To the left, that's China.

"We'll start in Kazakhstan and work our way over."

Though said tongue-in-cheek, it's still a sweeping statement. After all, thousands of miles separate the Kazak nation, which spreads away from the Caspian Sea's northeastern shores, and Sichuan, the Chinese province near the Himalayas that Forsline is referring to.

In actuality, Forsline stands on a dirt road bisecting apple orchards north of the Finger Lakes community of Geneva, New York. But the studies he and colleagues are bringing to a climax bridge not only far-apart Asian regions, but places in time as well.

Forsline is curator of ARS's Plant Genetic Resources Unit (PGRU), located on Cornell University's Geneva campus. And the genetic makeup of the trees he attends to may revolutionize the nation's—and perhaps the world's—apple industry.

These trees come from seeds and grafts Forsline and other researchers collected mostly during the 1990s in central Asia and Europe. Their material was gathered during seven expeditions sponsored by USDA and the U.S. National Plant Germplasm System aimed at expanding the known genetic diversity of apples.

Tapping the Apple's Ancestral Home

Back in his office, Forsline explains that central Asia—Kazakhstan and Kyrgyzstan in particular—is likely the ancestral home of familiar domestic apples (*Malus* x *domestica*) such as Red Delicious, Golden Delicious, and McIntosh.

"We tapped millions of years of adaptations to improve today's apple," he says.

Forsline went on seven of the trips, including four to central Asia, to collect apple material, conserve it, and, after evaluation, distribute it to breeders and geneticists worldwide. Other trips were to Sichuan, Russian, and Turkish sectors of the Caucasus region, and Germany.

He recalls the expeditions as hard work. Often, the only way of getting to remote mountain areas was by helicopter, long hikes, or half-day-long jeep rides down bumpy, dusty roads.

"What we collected made possible our re-creation of Kazakhstan and China here in Geneva," he says. "All that effort is now bearing fruit, literally and scientifically."

He says the trips resulted in "at least a doubling of the known genetic diversity of apples. It turns out that this gene pool is much more diverse than we had originally thought. And what we've found may help make the trees stand up better to diseases."

Among all this material, it is the Kazak samples that have become the apple of Forsline's eye, so to speak. Especially noteworthy are accessions collected there of *M. sieversii,* an important forerunner of

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Plant geneticist Gennaro Fazio (left) and horticulturist Phil Forsline observe fruit diversity from seedling trees of *M. sieversii.*

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the domestic apple. (See Forum, p. 2.)

In all, the scientists returned from central Asia with 949 apple tree accessions. Most of the specimens were brought here as seed, but 50 were cataloged as "elite clones"—grafts of the original trees.

Widening a Narrow Base

"Silk Road traders and their predecessors started the spread of apples from there to other parts of the world," he says. "But the seeds they carried likely represented a narrow genetic sampling. That's probably why today's American domestic apples have a fairly narrow genetic base that makes them susceptible to many diseases."

Forsline says that many of the Kazak apples lack the size and flavor needed for commercial success. "But it's the trees' ability to resist diseases that sets them apart. Breeders will be able to cross them with palatable varieties."

The curator and colleagues from PGRU and other institutions—the main collaborators include ARS plant geneticist Gennaro Fazio and Cornell University plant pathologist Herb Aldwinkle—are paying particular attention to the trees' germplasm and rootstocks.

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Success Against Plant Diseases

Forsline says the Kazak trees showed significant resistance to apple scab, the most important fungal disease of apples, whose outbreaks blemish fruit and defoliate trees. "Twenty-seven percent of the Kazak accessions were resistant to it," he says. "This makes sense, because the tree co-evolved with the disease, through natural selection."

In addition, he led a project in which the popular Gala apple variety was crossbred with seven Kazak accessions. "This produced 7 populations of 250 seedlings each," he says. "In one of these populations, we achieved a 67-percent resistance rate against apple scab.

Forsline says this study, which involved scientists from Cornell and the University of Minnesota, as well as collaborators from New Zealand and South Africa, "may be the source of a more durable, scab-resistant apple.

"Also, about 30 percent of samples inoculated with fire blight resisted that disease," he adds. Fire blight destroys apples, pears, and woody ornamentals in the Rosaceae family.

And researchers have found genes in these apples that allow them to adapt to mountainous, near-desert, and cold and dry regions.

Samples from species collected in other expedition sites have provided promising news in the fight against fire blight. Aldwinckle reports that seedlings from different populations of *M. orientalis* from the Russian Caucasus and Sichuan regions effectively resisted the disease, with Russian accessions scoring 50- to 93-percent resistance.

Rootstocks, Too

"Russian *M. orientalis* may convey resistance to fire blight and less sensitivity to latent viruses than small-fruited *Malus* species," says Aldwinckle. "This would be especially useful for breeding fire blight-resistant rootstocks."

And it is in rootstocks that Fazio, director of PGRU's apple rootstock breeding project, also sees great potential—especially with crosses between Kazak apples and elite American material. "This is the future of the apple industry," he says. "Give it 5 to 7 years."

Walking through greenhouses at Geneva devoted to rootstock studies, Fazio

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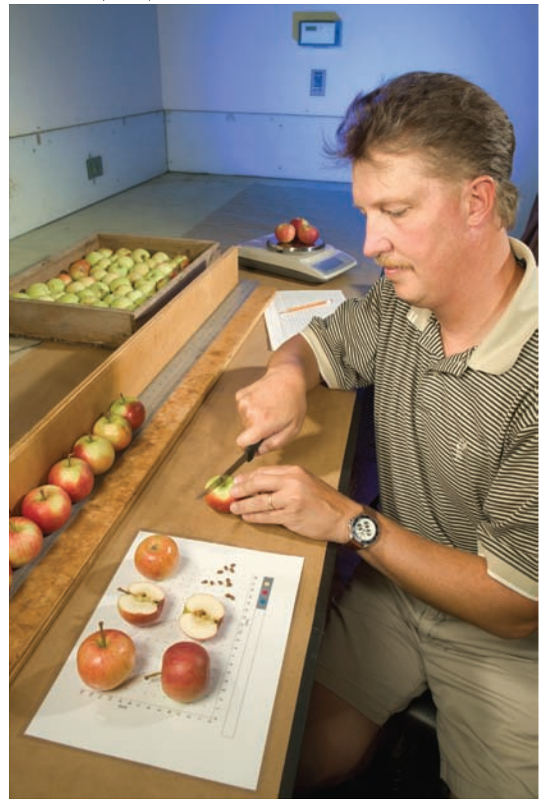

Technician Greg Noden characterizes morphological traits of *M. sieversii* fruit and cuts the fruit in preparation for taking a digital image for the website www.ars-grin.gov/gen.

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Herb Aldwinckle, plant pathologist from Cornell University, observes a susceptible seedling of *M. sieversii* inoculated with the bacterium *(Erwinia amylovora)* that causes fire blight.

says that natural selection that occurs in the central Asian forests seems to have helped the Kazak trees develop resistance to soil pathogens that can otherwise stunt young apple orchards and lead to poor growth and lost production. He says this material is "a treasure trove" of new genetic variants for resistance to *Phytophthora cactorum,* which causes collar rot, and *Rhizoctonia solani,* an agent of apple replant disease.

The progeny of two of the Kazak trees have stood up particularly well to disease. "We put them through what we call 'The Gauntlet,'" Fazio says, referring to exposure in the greenhouse to a series of pathogens that include fire blight and *Phytophthora*. "It usually kills 70 to 80 percent of seedlings. The first hint I had that this material was special was when I got 70- to 80-percent survival rates."

Fazio sent rootstock samples to plant pathologist Mark Mazzola of ARS's Tree Fruit Research Laboratory in Wenatchee, Washington. Mazzola, who specializes in soilborne diseases of apples, tested it for resistance to *R. solani* and found it to be significantly more resistant than all the controls he was using.

"The reduction in root mass due to infection was 30 percent, compared to 70 percent for the controls," says Fazio. "We are considering seeking the inheritance of this resistance by following it—and the genes causing it—in the progenies of these plants. This step will take us closer to cloning and isolating genes responsible for this resistance."

Fazio says that these seedlings have already become part of PGRU's rootstock-breeding program. "With the aid of marker-assisted selection, they will become the resistant rootstocks of the future," he adds. "Also, root tissue from the survivors of the *Phytophthora* inoculation has been used to create a cDNA library that will be sequenced as part of an ongoing National Science Foundation Expressed Sequence Tag project. The goal is to find the genes that are expressed only in resistant individuals."

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A grafted tree produced in Geneva, New York, from a scion taken from a tree in a Kazakh apple forest. William Srmack, farm manager at Geneva, displays the quality fruit of this genotype that has potential use by breeders.

Forsline, meanwhile, realizes the importance of his new role within this project. "The work is here now—in and close to the lab," he says. "It is more productive to be here and help spread the word about these apples than to be traveling on the other side of the world."

He says a goal now is to release germplasm lines from the collected materials within 5 years. "These collections are now being offered to breeders to develop diverse and useful hybrids for fruit, ornamental, and rootstock value."—By **Luis Pons,** ARS.

This research is part of Plant, Microbial, and Insect Genetic Research, Genomics, and Genetic Improvement, an ARS National Program (#301) described on the World Wide Web at www.nps.ars.usda.gov.

Philip L. Forsline and Gennaro Fazio are in the USDA-ARS Plant Genetic Resources Unit, Cornell University, Collier Dr., Geneva, NY 14456; phone (315) 787-2390 [Forsline], (315) 787-2480 [Fazio]; fax (315) 787-2339 [Forsline], (315) 787-2216 [Fazio]; e-mail philip.forsline@ars.usda.gov. ✷

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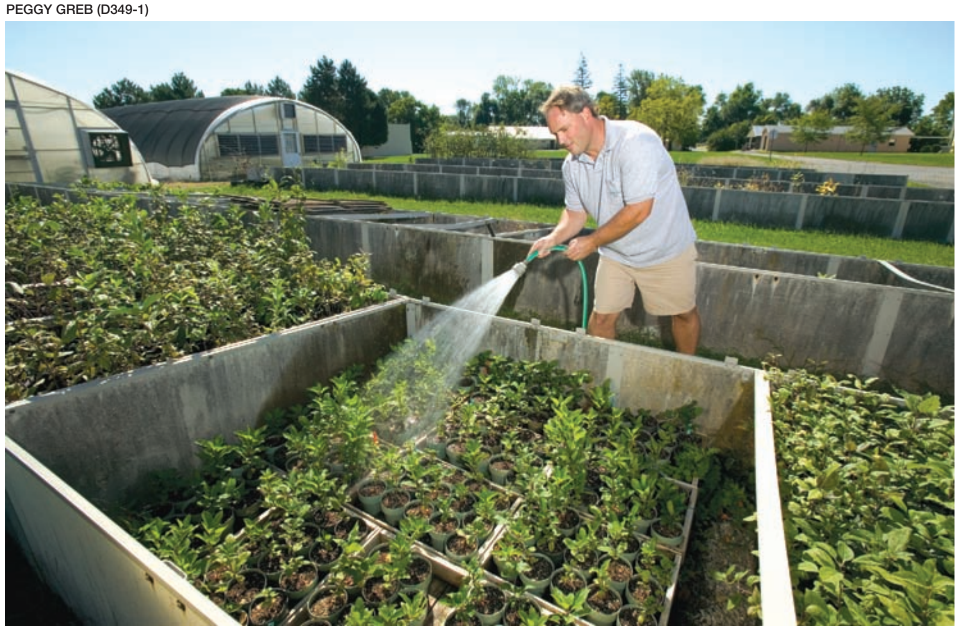

Technician Todd Holleran waters young apple rootstock seedlings that have survived the "gauntlet" of disease screens. These disease-resistant seedlings are derived from a cross between resistant wild *M. sieversii* selections and elite apple rootstocks from the Geneva breeding program.