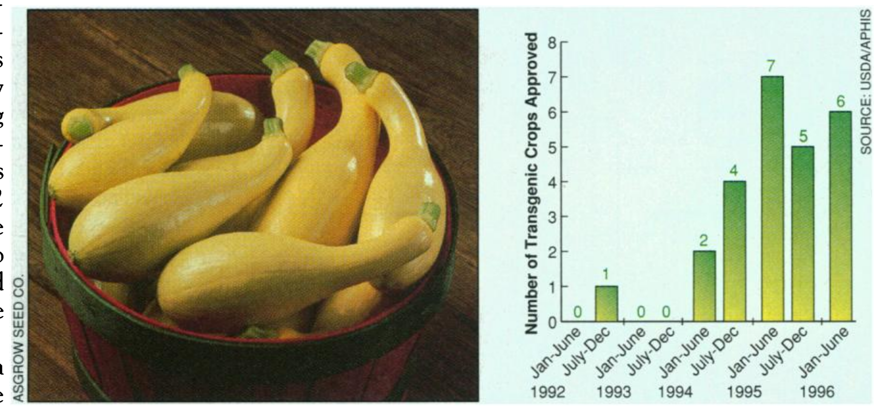
AGRICULTURAL ECOLOGY

Could Transgenic Supercrops One Day Breed Superweeds?

SEATTLE—The Freedom2 Squash and its cousins look like any other plump yellow squash, but actually, they're better: They have been genetically engineered by the Asgrow Seed Co. of Kalamazoo, Michigan, to resist two common plant viruses. In large-scale field trials in Texas over the last 2 years, Freedom2 has significantly outproduced lesser squash. Yet despite Freedom2's virtues, a debate has begun swirling about this and other transgenic crops. The public's original fears about genetically engineered crops have subsided, but now some biologists are raising a new concern: that advantageous genes, such as those that make Freedom2 resist viruses, may escape from transgenic crops to their weedy relatives and thus create a hardy race of weeds.

New ecological data show that genes can move from transgenic crops to wild relatives more often than once thought, says evolutionary ecologist Allison Snow of Ohio State University, who co-organized a recent symposium on this topic at the meeting of the Botanical Society of America here in August. As more and more transgenic varieties are planted, Snow and others worry that it is only a matter of time before the transfer of an engineered gene creates a new weed or invigorates an old one. This year alone, eight new transgenic crops have been approved for wide-scale field tests, including a cousin of Freedom2 that resists even more viruses (see chart). Even rare genetic transfers to wild plants could have devastating effects, warns ecological geneticist Norm Ellstrand of the University of California, Riverside. "It will probably happen in far less than 1% of the products ... but within 10 years we will have a moderate- to large-scale ecological or economic catastrophe, because there will be so many products being released."

Agricultural officials say that they already assume that gene flow may occur to wild populations, and that they approve field trials only when they are convinced that there is no hazard. And they note that the dangers of creating a "superweed" are at the moment hypothetical. After all, the Freedom2 Squash, which was approved 2 years ago, and its weedy relative, the Texas gourd, haven't taken over Texas yet. "We don't assume a priori that [a transgene] is a hazard," says Terry Medley, administrator of the Animal and Plant Health Inspection Service (APHIS), which is the division of U.S. Department of Agriculture (USDA) that regulates transgenic crops. Agriculture experts also say that any risk has to be weighed against the benefits of transgenic crops—especially in developing countries, where nonprofit agencies are trying to introduce the new varieties to nations that need them most.



Transgenic crops take root. More genetically engineered crops, like these squash, are earning regulatory approval.

First-generation hybrids between crops and wild plants are often sterile, so researchers once thought that gene flow from transgenic crops to weeds would be minimal, says Ellstrand. But at the Botanical Society of America session, which was devoted to this issue, evolutionary geneticist Loren Rieseberg of Indiana University in Bloomington documented unusually high rates of such gene flow by studying 12 marker genes in cultivated and wild sunflowers. For example, near fields where sunflowers had been growing for 10 years, the frequencies of the marker genes in wild sunflowers averaged about 28%; in a 35-year-old system, the figure was 38%. "Neutral or favorable cultivar genes will invade and persist in [wild sunflower] populations," concludes Rieseberg. At the same session, plant ecologist Tim Spira of Clemson University in South Carolina reported that in a population of wild strawberries growing within 50 meters of a strawberry field, more than 50% of the wild plants contained marker genes from the cultivated strawberries.

And in work published earlier this year in *Nature*, plant geneticist Rikke Jørgensen of the Risø National Laboratory in Roskilde, Denmark, showed, not surprisingly, that the same thing can happen with genes from transgenic crops. Her group grew and then examined hybrids of transgenic oilseed rape, which carried a gene for herbicide resistance, and a weedy relative in the canola family, *Brassica campestris*, or field mustard. They found that first-generation crosses resisted herbicides—and so apparently had retained the transgene—and had highly fertile pollen. The take-home message of all this, says Ellstrand, "is that gene flow beyond the initial hybrid does occur; it has occurred."

Even so, ecologists say, there is no need to worry about most transgenic crops. Many transgenes, such as those that make tomatoes ripen more slowly, wouldn't give wild plants an advantage. And many crops don't have native relatives that could hybridize with transgenic strains. Freedom2 was the first U.S. transgenic crop with a weedy relative to be approved, and USDA officials say they took special care in the case. "We took 2 years [to make the decision]. We deliberately let our statutory deadline [of 180 days] slip to make sure we were comfortable with the decision we made," says Val Giddings, international team leader at APHIS. After looking at data from Asgrow and outside reviewers, they decided to deregulate, explains Giddings, because they concluded that the virus doesn't infect the Texas gourd in the wild, so the transgene wouldn't confer a special advantage.

But plant taxonomist Hugh Wilson of Texas A&M University, who was one of the reviewers—and who recommended against deregulation—isn't convinced. He thinks more evidence is needed to establish that the viruses don't affect the wild Texas gourd, noting that the crucial data came only from Asgrow and were not an exhaustive survey of wild populations. Wilson and others say they don't want to stop transgenic crops cold, but they fear that the Freedom2 has established a precedent and that ecological concerns will be swept aside as more and more crops are approved. "I see [transgenic crops] getting approved when more information is needed," says Ohio State's Snow.

Federal officials counter that there should be limits to regulation, and that in many cases, it's the company's responsibility to protect their investments by making sure that transgenic crops don't lend their genetic strengths to weeds. Herbicide-resistant crops are usually developed by the herbicide marketers themselves, so if the transgene escapes into a wild population and eventually renders the herbicide obsolete, the company will lose a portion of its herbicide market. "I do not believe it's the role of the USDA to mandate the monitoring of [resistance] ... it is the developer of the product that has the interest in assuring that resistance does not build up," says John Payne, acting director of the Biotechnology, Biologics, and Environmental Protection Division of APHIS.

As ecologists and regulators debate these issues, the stakes surrounding transgenic crops are rising. Developing nations—where crops may have more native relatives—are beginning to test and adopt the new varieties. For example, a potato genetically engineered for virus resistance has been in field trials in Mexico since 1992. If this year's large-scale trials go well, the potato could come up for deregulation in mid-1997, according to Ariel Alvarez-Morales, principal investigator on the potato project at CINVESTAV, a federally funded Mexican research organization in Iracuato, Guanajuato.

The introduction of transgenic crops to regions where many crops originated raises another concern. One of the centers of diversity for the potato is central Mexico, for example, and many wild potatoes still grow there. Traditional breeders and transgenic crop critics worry that transgenic varieties could introduce a potentially dominant genotype into the wild. Such a takeover would reduce the genetic pool available to breeders who currently tap these diverse populations to develop new crop strains. "It's all hypothetical ... but everybody agrees that the release of [a transgenic crop] in its center of origin is not a good idea," admits R. James Cook, a research pathologist with the USDA Agricultural Research Service at Washington State University in Pullman.

But Cook notes that existing rules for selling seed crops would prevent such a takeover, by guarding against hybridization. Most widely grown crops go through a rigorous certification process, in which fields are monitored for signs of hybridization. Cook and others insist that it is important for developing nations to get the benefit of these new technologies, and say that careful seed certification in these countries can prevent the shadowy dangers of gene flow. "Unfortunately, the benefit side of these equations gets far too little press," says Judith Chambers, senior biotechnology adviser at the U.S. Agency for International Development. "We're talking about many nations with limited arable land and burgeoning populations, and they are going to need some infusion of technology in order to meet their food needs."

Whether or not transgenic crops spawn superweeds, they are likely to generate continued debate, as the opinions of officials like Chambers sometimes clash with those of research ecologists. In Jørgensen's view, "If you want to deregulate transgenic crops, you have to take a chance."

–James Kling

James Kling is a science writer in Bellingham, WA.

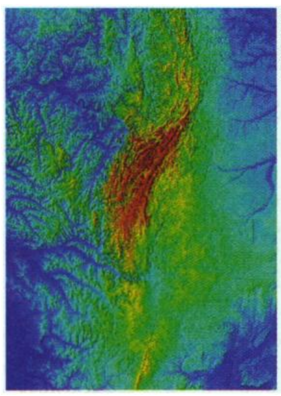
PLATE TECTONICS

Urals Yield Secret of a Lasting Bond

Like modern marriages, geologic unions have a disconcerting tendency to fail. Two great tectonic plates collide, driving up a mountain belt like the Appalachians, only to rift apart again, forming an ocean-filled breach. The Atlantic in fact marks the latest failed marriage between the continents flanking it. Now an international team of researchers from Russia, Germany, the United States, and Spain has drawn a portrait of a geologic union that has stood the test of time, revealing the deep underpinnings that, for 250 million years, have preserved the bond between Europe and Asia marked by the Ural Mountains of central Russia.

Beginning on page 220, researchers recount the findings of URSEIS '95, a multipronged effort to image the rock beneath the Urals to a depth of a couple of hundred kilometers by probing it with artificial seismic waves. "It was a tremendous success," says deep-crustal specialist Walter Mooney of the U.S. Geological Survey in Menlo Park, California, who followed the project closely. "It's as close as they're going to get to a [geologic] cross section." And it shows a sharp contrast to most collisional mountain ranges, where the plate thickened by the collision eventually sheds its deepest layers into the mantle, weakening the continental bond. Under the Urals, the thickened plate is intact. "We see now that the [crustal] root really has survived," says Rolf Meissner, professor emeritus at Kiel University. The question now is why.

The URSEIS '95 researchers aren't the first to glimpse that puzzle. A variety of studies by Soviet researchers, including ones that used seismic waves generated by underground nuclear explosions spread across the country to probe the crust, convinced them that the Urals had retained a crustal root, but Western scientists were less certain. "We didn't have direct access to these data," says James Knapp of Cornell University, a member of the U.S. URSEIS '95 team. In addition, the concept of a mountain belt with a thick crust was "very foreign to our experience in the West," where seismic studies beneath older mountains tend to show that the crust has thinned back to normal thickness.



URSEIS '95

Strong union. Urals (seen in a color-coded topographic map) have held together for 250 million years.

So URSEIS '95 took a new look by generating seismic waves—this time with truck-mounted "thumpers" and conventional explosives, not nukes—and exploiting them in two imaging techniques. One, called seismic refraction, maps out structure based on variations in the speed of the waves; the other, called seismic reflection profiling, creates an image from seismic waves reflected by subtle boundaries within the rock.

Based on the picture that emerged, says Knapp, "we can definitely say that we have a preserved example of a collision that is 250 [million] to 300 million years old." The crust thickens from about 40 kilometers on either side of the Urals to more than 55 kilometers beneath them. And the gently sloping faults created by the compression that raised the Urals are still there. At the same time, the suture shows none of the signs of weakening so familiar under other mountain ranges, such as churning of the deep crust and crustal melting.

Why the Urals and the plate suture they represent have held together so long is not so obvious from the seismic data, but the URSEIS '95 group thinks the answer may lie in the suture's modest thickness. Today, as India plows into Asia, it not only squeezes up the Himalayas but also dives beneath the Asian plate, doubling its thickness to 75 kilometers and raising the broad Tibetan plateau. Such thickening can pile up more cold, dense rock than can float on the underlying mantle. Eventually, the extra plate thickness will fall away, allowing plate-weakening magma to intrude—a process that will thin and weaken the suture and allow it to rupture as soon as the plates change direction and start to pull apart.

The URSEIS researchers suggest that Asia and Europe never had a chance to go that far. The Uralian suture is a hodgepodge of different rock types, indicating that when Europe and Asia converged, bits and pieces of new crust—like the volcanic island arcs now common in the southwest Pacific—became caught between them. These crustal fragments may have acted as spacers, keeping the plates far enough apart that their union did not deepen to the point of instability. Make your own parallels with marriages that last.

–Richard A. Kerr