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Grains Of Hope

Genetically engineered crops could revolutionize farming. Protesters fear they could also destroy the ecosystem. You decide

BY J. MADELEINE NASH/ZURICH

At first, the grains of rice that Ingo Potrykus sifted through his fingers did not seem at all special, but that was because they were still encased in their dark, crinkly husks. Once those drab coverings were stripped away and the interiors polished to a glossy sheen, Potrykus and his colleagues would behold the seeds' golden secret. At their core, these grains were not pearly white, as ordinary rice is, but a very pale yellow--courtesy of beta-carotene, the nutrient that serves as a building block for vitamin A.

Potrykus was elated. For more than a decade he had dreamed of creating such a rice: a golden rice that would improve the lives of millions of the poorest people in the world. He'd visualized peasant farmers wading into paddies to set out the tender seedlings and winnowing the grain at harvest time in handwoven baskets. He'd pictured small children consuming the golden gruel their mothers would make, knowing that it would sharpen their eyesight and strengthen their resistance to infectious diseases.

And he saw his rice as the first modest start of a new green revolution, in which ancient food crops would acquire all manner of useful properties: bananas that wouldn't rot on the way to market; corn that could supply its own fertilizer; wheat that could thrive in drought-ridden soil.

But imagining a golden rice, Potrykus soon found, was one thing and bringing one into existence quite another. Year after year, he and his colleagues ran into one unexpected obstacle after another, beginning with the finicky growing habits of the rice they transplanted to a greenhouse near the foothills of the Swiss Alps. When success finally came, in the spring of 1999, Potrykus was 65 and about to retire as a full professor at the Swiss Federal Institute of Technology in Zurich. At that point, he tackled an even more formidable challenge.

Having created golden rice, Potrykus wanted to make sure it reached those for whom it was intended: malnourished children of the developing world. And that, he knew, was not likely to be easy. Why? Because in addition to a full complement of genes from Oryza sativa--the Latin name for the most commonly consumed species of rice--the golden grains also contained snippets of DNA borrowed from bacteria and daffodils. It was what some would call Frankenfood, a product of genetic engineering. As such, it was entangled in a web of hopes and fears and political baggage, not to mention a fistful of ironclad patents.

For about a year now--ever since Potrykus and his chief collaborator, Peter Beyer of the University of Freiburg in Germany, announced their achievement --their golden grain has illuminated an increasingly polarized public debate. At issue is the question of what genetically engineered crops represent. Are they, as their proponents argue, a technological leap forward that will bestow incalculable benefits on the world and its people? Or do they represent a perilous step down a slippery slope that will lead to ecological and agricultural ruin? Is genetic engineering just a more efficient way to do the business of conventional crossbreeding? Or does the ability to mix the genes of any species--even plants and animals--give man more power than he should have?

The debate erupted the moment genetically engineered crops made their commercial debut in the mid-1990s, and it has escalated ever since. First to launch major protests against biotechnology were European environmentalists and consumer-advocacy groups. They were soon followed by their U.S. counterparts, who made a big splash at last fall's World Trade Organization meeting in Seattle and last week launched an offensive designed to target one company after another (see accompanying story). Over the coming months, charges that transgenic crops pose grave dangers will be raised in petitions, editorials, mass mailings and protest marches. As a result, golden rice, despite its humanitarian intent, will probably be subjected to the same kind of hostile scrutiny that has already led to curbs on the commercialization of these crops in Britain, Germany, Switzerland and Brazil.

The hostility is understandable. Most of the genetically engineered crops introduced so far represent minor variations on the same two themes: resistance to insect pests and to herbicides used to control the growth of weeds. And they are often marketed by large, multinational corporations that produce and sell the very agricultural chemicals farmers are spraying on their fields. So while many farmers have embraced such crops as Monsanto's Roundup Ready soybeans, with their genetically engineered resistance to Monsanto's Roundup-brand herbicide, that let them spray weed killer without harming crops, consumers have come to regard such things with mounting suspicion. Why resort to a strange new technology that might harm the biosphere, they ask, when the benefits of doing so seem small?

Indeed, the benefits have seemed small--until golden rice came along to suggest otherwise. Golden rice is clearly not the moral equivalent of Roundup Ready beans. Quite the contrary, it is an example--the first compelling example--of a genetically engineered crop that may benefit not just the farmers who grow it but also the consumers who eat it. In this case, the consumers include at least a million children who die every year because they are weakened by vitamin-A deficiency and an additional 350,000 who go blind.

No wonder the biotech industry sees golden rice as a powerful ally in its struggle to win public acceptance. No wonder its critics see it as a cynical ploy. And no wonder so many of those concerned about the twin evils of poverty and hunger look at golden rice and see reflected in it their own passionate conviction that genetically engineered crops can be made to serve the greater public good--that in fact such crops have a critical role to play in feeding a world that is about to add to its present population of 6 billion. As former President Jimmy Carter put it, "Responsible biotechnology is not the enemy; starvation is."

Indeed, by the year 2020, the demand for grain, both for human consumption and for animal feed, is projected to go up by nearly half, while the amount of arable land available to satisfy that demand will not only grow much more slowly but also, in some areas, will probably dwindle. Add to that the need to conserve overstressed water resources and reduce the use of polluting chemicals, and the enormity of the challenge becomes apparent. In order to meet it, believes Gordon Conway, the agricultural ecologist who heads the Rockefeller Foundation, 21st century farmers will have to draw on every arrow in their agricultural quiver, including genetic engineering. And contrary to public perception, he says, those who have the least to lose and the most to gain are not well-fed Americans and Europeans but the hollow-bellied citizens of the developing world.

Going for the Gold
It was in the late 1980s, after he became a full professor of plant science at the Swiss Federal Institute of Technology, that Ingo Potrykus started to think about using genetic engineering to improve the nutritional qualities of rice. He knew that of some 3 billion

people who depend on rice as their major staple, around 10% risk some degree of vitamin-A deficiency and the health problems that result. The reason, some alleged, was an overreliance on rice ushered in by the green revolution. Whatever its cause, the result was distressing: these people were so poor that they ate a few bowls of rice a day and almost nothing more.

The problem interested Potrykus for a number of reasons. For starters, he was attracted by the scientific challenge of transferring not just a single gene, as many had already done, but a group of genes that represented a key part of a biochemical pathway. He was also motivated by complex emotions, among them empathy. Potrykus knew more than most what it meant not to have enough to eat. As a child growing up in war-ravaged Germany, he and his brothers were often so desperately hungry that they ate what they could steal.

Around 1990, Potrykus hooked up with Gary Toenniessen, director of food security for the Rockefeller Foundation. Toenniessen had identified the lack of beta-carotene in polished rice grains as an appropriate target for gene scientists like Potrykus to tackle because it lay beyond the ability of traditional plant breeding to address. For while rice, like other green plants, contains light-trapping beta-carotene in its external tissues, no plant in the entire Oryza genus--as far as anyone knew--produced beta-carotene in its endosperm (the starchy interior part of the rice grain that is all most people eat).

It was at a Rockefeller-sponsored meeting that Potrykus met the University of Freiburg's Peter Beyer, an expert on the beta-carotene pathway in daffodils. By combining their expertise, the two scientists figured, they might be able to remedy this unfortunate oversight in nature. So in 1993, with some $100,000 in seed money from the Rockefeller Foundation, Potrykus and Beyer launched what turned into a seven-year, $2.6 million project, backed also by the Swiss government and the European Union. "I was in a privileged situation," reflects Potrykus, "because I was able to operate without industrial support. Only in that situation can you think of giving away your work free."

That indeed is what Potrykus announced he and Beyer planned to do. The two scientists soon discovered, however, that giving away golden rice was not going to be as easy as they thought. The genes they transferred and the bacteria they used to transfer those genes were all encumbered by patents and proprietary rights. Three months ago, the two scientists struck a deal with AstraZeneca, which is based in London and holds an exclusive license to one of the genes Potrykus and Beyer used to create golden rice. In exchange for commercial marketing rights in the U.S. and other affluent markets, AstraZeneca agreed to lend its financial muscle and legal expertise to the cause of putting the seeds into the hands of poor farmers at no charge.

No sooner had the deal been made than the critics of agricultural biotechnology erupted. "A rip-off of the public trust," grumbled the Rural Advancement Foundation International, an advocacy group based in Winnipeg, Canada. "Asian farmers get (unproved) genetically modified rice, and AstraZeneca gets the 'gold.'" Potrykus was dismayed by such negative reaction. "It would be irresponsible," he exclaimed, "not to say immoral, not to use biotechnology to try to solve this problem!" But such expressions of good intentions would not be enough to allay his opponents' fears.

Weighing the Perils

Beneath the hyperbolic talk of Frankenfoods and Superweeds, even proponents of agricultural biotechnology agree, lie a number of real concerns. To begin with, all foods, including the transgenic foods created through genetic engineering, are potential sources of allergens. That's because the transferred genes contain instructions for making proteins, and not all proteins are equal. Some--those in peanuts, for example--are well known for causing allergic reactions. To many, the possibility that golden rice might cause such a problem seems farfetched, but it nonetheless needs to be considered.

Then there is the problem of "genetic pollution," as opponents of biotechnology term it. Pollen grains from such wind-pollinated plants as corn and canola, for instance, are

carried far and wide. To farmers, this mainly poses a nuisance. Transgenic canola grown in one field, for example, can very easily pollinate nontransgenic plants grown in the next. Indeed this is the reason behind the furor that recently erupted in Europe when it was discovered that canola seeds from Canada--unwittingly planted by farmers in England, France, Germany and Sweden--contained transgenic contaminants.

The continuing flap over Bt corn and cotton--now grown not only in the U.S. but also in Argentina and China--has provided more fodder for debate. Bt stands for a common soil bacteria, Bacillus thuringiensis, different strains of which produce toxins that target specific insects. By transferring to corn and cotton the bacterial gene responsible for making this toxin, Monsanto and other companies have produced crops that are resistant to the European corn borer and the cotton bollworm. An immediate concern, raised by a number of ecologists, is whether or not widespread planting of these crops will spur the development of resistance to Bt among crop pests. That would be unfortunate, they point out, because Bt is a safe and effective natural insecticide that is popular with organic farmers.

Even more worrisome are ecological concerns. In 1999 Cornell University entomologist John Losey performed a provocative, "seat-of-the-pants" laboratory experiment. He dusted Bt corn pollen on plants populated by monarch-butterfly caterpillars. Many of the caterpillars died. Could what happened in Losey's laboratory happen in cornfields across the Midwest? Were these lovely butterflies, already under pressure owing to human encroachment on their Mexican wintering grounds, about to face a new threat from high-tech farmers in the north?

The upshot: despite studies pro and con--and countless save-the-monarch protests acted out by children dressed in butterfly costumes--a conclusive answer to this question has yet to come. Losey himself is not yet convinced that Bt corn poses a grave danger to North America's monarch-butterfly population, but he does think the issue deserves attention. And others agree. "I'm not anti biotechnology per se," says biologist Rebecca Goldberg, a senior scientist with the Environmental Defense Fund, "but I would like to have a tougher regulatory regime. These crops should be subject to more careful screening before they are released."

Are there more potential pitfalls? There are. Among other things, there is the possibility that as transgenes in pollen drift, they will fertilize wild plants, and weeds will emerge that are hardier and even more difficult to control. No one knows how common the exchange of genes between domestic plants and their wild relatives really is, but Margaret Mellon, director of the Union of Concerned Scientists' agriculture and biotechnology program, is certainly not alone in thinking that it's high time we find out. Says she: "People should be responding to these concerns with experiments, not assurances."

And that is beginning to happen, although--contrary to expectations--the reports coming in are not necessarily that scary. For three years now, University of Arizona entomologist Bruce Tabashnik has been monitoring fields of Bt cotton that farmers have planted in his state. And in this instance at least, he says, "the environmental risks seem minimal, and the benefits seem great." First of all, cotton is self-pollinated rather than wind-pollinated, so that the spread of the Bt gene is of less concern. And because the Bt gene is so effective, he notes, Arizona farmers have reduced their use of chemical insecticides 75%. So far, the pink bollworm population has not rebounded, indicating that the feared resistance to Bt has not yet developed.

Assessing the Promise

Are the critics of agricultural biotechnology right? Is biotech's promise nothing more than overblown corporate hype? The papaya growers in Hawaii's Puna district clamor to disagree. In 1992 a wildfire epidemic of papaya ringspot virus threatened to destroy the state's papaya industry; by 1994, nearly half the state's papaya acreage had been infected, their owners forced to seek outside employment. But then help arrived, in the form of a virus-resistant transgenic papaya developed by Cornell University plant pathologist

Dennis Gonsalves.

In 1995 a team of scientists set up a field trial of two transgenic lines--UH SunUP and UH Rainbow--and by 1996, the verdict had been rendered. As everyone could see, the nontransgenic plants in the field trial were a stunted mess, and the transgenic plants were healthy. In 1998, after negotiations with four patent holders, the papaya growers switched en masse to the transgenic seeds and reclaimed their orchards. "Consumer acceptance has been great," reports Rusty Perry, who runs a papaya farm near Puna. "We've found that customers are more concerned with how the fruits look and taste than with whether they are transgenic or not."

Viral diseases, along with insect infestations, are a major cause of crop loss in Africa, observes Kenyan plant scientist Florence Wambugu. African sweet-potato fields, for example, yield only 2.4 tons per acre, vs. more than double that in the rest of the world. Soon Wambugu hopes to start raising those yields by introducing a transgenic sweet potato that is resistant to the feathery mottle virus. There really is no other option, explains Wambugu, who currently directs the International Service for the Acquisition of Agri-biotech Applications in Nairobi. "You can't control the virus in the field, and you can't breed in resistance through conventional means."

To Wambugu, the flap in the U.S. and Europe over genetically engineered crops seems almost ludicrous. In Africa, she notes, nearly half the fruit and vegetable harvest is lost because it rots on the way to market. "If we had a transgenic banana that ripened more slowly," she says, "we could have 40% more bananas than now." Wambugu also dreams of getting access to herbicide-resistant crops. Says she: "We could liberate so many people if our crops were resistant to herbicides that we could then spray on the surrounding weeds. Weeding enslaves Africans; it keeps children from school."

In Wambugu's view, there are more benefits to be derived from agricultural biotechnology in Africa than practically anywhere else on the planet--and this may be so. Among the genetic-engineering projects funded by the Rockefeller Foundation is one aimed at controlling striga, a weed that parasitizes the roots of African corn plants. At present there is little farmers can do about striga infestation, so tightly intertwined are the weed's roots with the roots of the corn plants it targets. But scientists have come to understand the source of the problem: corn roots exude chemicals that attract striga. So it may prove possible to identify the genes that are responsible and turn them off.

The widespread perception that agricultural biotechnology is intrinsically inimical to the environment perplexes the Rockefeller Foundation's Conway, who views genetic engineering as an important tool for achieving what he has termed a "doubly green revolution." If the technology can marshal a plant's natural defenses against weeds and viruses, if it can induce crops to flourish with minimal application of chemical fertilizers, if it can make dryland agriculture more productive without straining local water supplies, then what's wrong with it?

Of course, these particular breakthroughs have not happened yet. But as the genomes of major crops are ever more finely mapped, and as the tools for transferring genes become ever more precise, the possibility for tinkering with complex biochemical pathways can be expected to expand rapidly. As Potrykus sees it, there is no question that agricultural biotechnology can be harnessed for the good of humankind. The only question is whether there is the collective will to do so. And the answer may well emerge as the people of the world weigh the future of golden rice.

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