Golden Rice is coming. Finally! Will it be the game-changer hinted at for almost 20 years?

Comes the news that the government of Bangladesh is about to approve Golden Rice for commercial release some time in the next three months.

First and foremost this is fantastic news for Southeast Asia for humanitarian and economic development reasons. On a less consequential level this is great news for the overall debate surrounding the use of biotech in agriculture. Golden Rice occupied a space in the debate as the *Great Golden Hope of Biotech Crops*, a wholly virtuous crop devoid of the grubby commercial concerns of intellectual property or profit motive. In this case, the IP had been donated, the rice was being developed by a non-profit NGO and the rice will be given freely to farmers and local breeding programs—a trait of value directly to consumers, among them some of the most vulnerable people on the planet. Because of this history, it is a crop not linked to so-called 'industrial agriculture' and its key trait is not tied to pesticide use.

Golden Rice has long been promoted as an application of biotech that is seemingly beyond reproach, although that didn't stop critics from coming up with cynical and loopy objections: e.g. Golden Rice is a stalking horse for corporate control of agriculture in Southeast Asia; it is a distraction from solving the problems of poverty and equitable food distribution, etc, etc. But the halo that surrounded Golden Rice had faded considerably in recent years, as its release date, which has been 'just around the corner' for the last decade and a half kept getting pushed back into what seemed like a permanently receding future.

For the entire time that I've been paying close attention to the GMO debate, beginning around 2011, Golden Rice has been both just around the corner and long overdue, which has made it an easy target for environmental NGO critics. Advocates often had an unfortunate way of referring to Golden Rice in a weirdly liminal space between a pipeline crop with theoretical benefits that would probably bear out and a already existing commercially released crop already in production. There has also been an unfortunate tendency to over-estimate how much the destruction of crop trials set back the time-line and impute them with genocidal consequences. One 2014 paper calculated "1.4 million life years lost over the past decade in India" but was predicated on the idea that Golden Rice had been available since 2000 and was entirely held back by critics of genetic engineering, in the form of overly precautionary regulations of field trials. This became a trope that circulated widely in pro-GMO circles and formed the foundation for many a hysterical charge of genocide against GMO critics, even those who questioned the wisdom of herbicide tolerant crops who'd registered no objection to Golden Rice. But it is not the case that Golden Rice has been available since 2000 or that regulation rather than formidable technical challenges have been the main bottleneck.

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Golden Rice, soon. Or not.

We have a new E.T.A. on Golden Rice. Well, sort of: the institutes in the Philippines that have been conducting field tests since 2008 say they may be able to submit the needed data for regulatory approval by 2013 in the Philippines and 2015 for Bangla Desh. So maybe a 2014 release in the Philippines.

This anti-biotech blog post from 2011 highlights the way appeals to the potential of Golden Rice became less and less persuasive as the release date seemed to perpetually recede into the future.

The most straightforward criticism from opponents became increasingly difficult to parry over time, “If genetic engineering is so great, why is Golden Rice taking forever to get right?” The appropriate response to that question illustrates the quandary faced by biotech advocates, for it is both reasonable and factually correct, but to the ears of an opponent of biotech in agriculture, unpersuasive.

First, the International Rice Research Institute (IRRI) should be applauded for setting a high bar in terms of the amount of beta-carotene and yield required for them to seek commercial release. They apparently have never felt pressure to release a product not up to the task at hand simply to “get something out there”. Most outrageously, its rich for critics to blame shortcomings of the technology for the delay when the most extreme critics have been destroying test fields of Golden Rice for decades, with each destruction setting researcher back a full growing season, sometimes back years for a given cultivar/trait pairing. But most consequentially, the main reason that Golden Rice has taken so long is that ambitious crop breeding programs take a long time.

Consider. The world conquering Honeycrisp apple took 31 years to go from the first crosses made in 1960 to an official test designation in 1974 by the University of Minnesota apple breeder David Bedford to the patent in 1988 (a patent, BTW, for a conventionally breed apple 6 years before the first GE crop hit the market) to the commercial release in 1991. A sweet crunchy apple is a truly wonderful thing, but nowhere near the ambition of coaxing a cornerstone, staple crop to express beta-carotene in its endosperm without giving up any agronomic characteristics.

Likewise, when founder of the Land Institute, Wes Jackson, talks about their progress over 40 years in attempting to develop a commercially viable perennial wheat, he is lauded in food movement circles as a sage, and far seeing prophet:

> When I first started working on this 40 years ago, I said this is going to take 50 to 100 years. The yields are lower now, but my bet is that in the long run perennial grains will out-yield annuals. Remember, the annual grains we have now have been 10,000 years in the making [since farmers first started breeding wild grains]. We've been at this less than half a century. So I think we are ahead of the curve.

rteen years after Jackson's and is ready for full, rather than orn for taking so long.

Granted, Jackson has done a much better job of managing expectations. When he started 40 years ago, he was up front that he was beginning a half century project. Now it's a century project, but who's going to quibble over another a half century given the current crisis of soil degradation and erosion? Golden Rice has been perpetually just around the corner nearly from its inception.

Ingo Potrykus, the Swiss scientist who first conceived of Golden Rice, began thinking about using genetic engineering to improve the nutrition of rice in the 1980s. In 1993 he received a grant from the Rockefeller Foundation to begin work on Golden Rice. By the time he was featured on the cover of Time Magazine in

July of 2000 with the headline "This Rice Could Save a Million Kids a Year" he and his research partner Peter Beyer had successfully introgressed genes from bacteria and daffodils into *Oryza sativa* — the most commonly consumed species of rice — and coaxed the plant into producing beta-carotene in the endosperm. Golden Rice was presented in the article as more or less complete in its development. That wasn't the case, but it certainly was the impression one got from reading the article.

One person who apparently got that impression was organic food writer Michael Pollan, who by March of 2001, was already braying in a New York Times article titled "The Great Yellow Hype" that Golden Rice was taking too long, the rice didn't yet deliver enough beta-carotene, and the money invested in its development could be better spent on other solutions. The whole thing was just an elaborate public relations scheme for corporate biotech.

Eventually the daffodil genes were abandoned in favor of genes from maize which brought the amount of beta-carotene. By 2005, Golden Rice 2 delivered up to 23 times the amount of beta-carotene as the daffodil gene based rice. A 2009 study found that a cup of cooked Golden Rice delivered the equivalent of half a days worth of required vitamin A for adults. Getting the biofortified rice to maintain the same yield as its non-biofortified parent continued to be a challenge, a yield gap they only recently seemed to have closed. As recently as 2016, they were on record as still facing yield drag. A thoughtful, well researched article in February 2016 by environmental agriculture writer Tom Philpott of Mother Jones asked the question, "WTF Happened to Golden Rice?":

> On its website, the IRRI reports that in the latest field trials, golden rice varieties "showed that beta carotene was produced at consistently high levels in the grain, and that grain quality was comparable to the conventional variety." However, the website continues, "yields of candidate lines were not consistent across locations and seasons." Translation: The golden rice varieties exhibited what's known in agronomy circles as a "yield drag"—they didn't produce as much rice as the non-GM varieties they'd need to compete with in farm fields. So the IRRI researchers are going back to the drawing board.
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> Via email, I asked the IRRI how that effort is going. "So far, both agronomic and laboratory data look very promising," a spokeswoman replied. But she declined to give a time frame for when the IRRI thinks it will have a variety that's ready for prime time.

He went on to conclude:

> Meanwhile, as the IRRI scrambles to perfect golden rice, the prevalence of vitamin A deficiency is declining in the Philippines—according to the IRRI itself— from 40 percent of children aged six months to five years in 2003, to 15.2 percent in 2008. "The exact reasons for

> these improvements have not been determined, but they may be the results of proven approaches to preventing vitamin A deficiency, such as vitamin A supplementation, dietary diversification, food fortification and promotion of optimal breastfeeding," the group noted. That drop is part of a long-term trend that involves all of Southeast Asia. According to a 2015 Lancet study funded by the Bill & Melinda Gates Foundation, vitamin A deficiency plagued 39 percent of children in the region in 1991 but only 6 percent in 2013—without the help of golden rice.
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> But VAD, as the deficiency's known, remains a huge scourge on the Indian subcontinent and in Africa, the study found, affecting more than 40 percent of children in both regions. Whether golden rice will ever help mitigate that ongoing tragedy won't likely be known for some time. But the technology's hardly the slam-dunk panacea its advocates insist it is.

Beyond the fact that big ambitious breeding projects take decades, we need to address what I think Golden Rice's naysayers miss about the potential of Golden Rice when they raise the sort of counterfactual that Pollan raised in his 2001 article:

> This begs a rather obvious question. Why not simply a campaign to persuade them to eat brown rice? Or how about teaching people how to grow green vegetables on the margins of their rice fields, and maybe even give them the seeds to do so? Or what about handing out vitamin-A supplements to children so severely malnourished their bodies can't metabolize beta-carotene?
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> As it happens, these ridiculously obvious, unglamorous, low-tech schemes are being tried today, and according to the aid groups behind them, all they need to work are political will and money.

In their remarkable documentary *Well Fed*, Dutch film-maker Karsten de Vreug and Hidde Boersma, a science journalist with a PhD in molecular biology, travel the world as Boersma challenges de Vreug's standard urban foodie's litany of objections to biotech crops. In the section on Golden Rice (beginning at the 39 minute mark), they visit the IRRI, where the challenges are laid out for them by a researcher.

But then the lightbulb moment for de Vreug happens in the city as they get a sense of street life and street food. It becomes clear just how restrained people at the bottom are in their choices and how big a role rice plays in their food culture. He realizes just how immense the inherent leverage actually is in transforming their staple crop into one that delivers adequate nutrition.

screenshot at pm

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And here’s what I think people miss in their calls to just fix poverty or teach people to plant kitchen gardens— having a staple crop that delivers adequate nutrition is a necessary precondition to fixing poverty.

In the second lecture on Poverty Trap Economics in the MIT economics course, The Challenge of World Poverty, professor Esther Duflo explains the capacity curve.

screenshot at pm

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In the standard S-shape of the curve you can see the early plateau on the left hand side at the bottom of the S. Even as income increases, at first work capacity is unaffected. Even as you start to make more money, instead of diverting all new income into procuring adequate nutrition (calories and micronutrients), other needs begin to compete for your resources, leaving you providing yourself subsistence levels of nutrition while you divert new resources towards shelter or your child’s needs or a medical emergency or a hundred other pressing needs. What you desperately need is a cheap staple crop that delivers the calories and micronutrients you need to work and avoid deficiencies on the least amount of income possible so that capacity curve can begin to slope upwards towards greater capacity to work as quickly as possible.

What naysayers fail to acknowledge is the enormous leverage in having a staple food that delivers

adequate nutrition. While it would be great if we could fix poverty first, it would be far easier to fix poverty with a rice that solved a major vitamin deficiency. There is a reason why certain crops become staple crops. They are high yielding in local production, they deliver plenty of energy, and they are less perishable than fresh fruits and vegetables. In the case of grains, far, far less perishable. In the case of roots and tubers, significantly less perishable.

Pollan asks why we can't just teach people to eat brown rice? It isn't a source of beta-carotene or vitamin A. Why not have farmers grow green vegetable on the edges of their fields? That might work for farmers, but what about urban citizens with little or no access to refrigeration? What about administering supplementation to kids who need it? UNICEF does this already, dropping what they do in the region and carrying out supplementation twice a year. But that is an open-ended program that requires ongoing resources in perpetuity and at the expense of other things UNICEF could be doing. Wouldn't it be much easier to have a cheap, staple grain that accomplished the same thing? Kitchen gardens are a useful intervention that the Hellen Keller Foundation is engaged in. But kitchen gardens assume kitchens, space for gardens, and time. Not everybody has those. Likewise there is a built-in entropy as some of the folks you invested time and resources in helping to start gardens abandon them as life interferes or interest wanes.

As Philpott mentioned in his piece, while incidence of VAD and associated blindness has been dropping in the Philippines, it remains a huge challenge in other places. It may have taken longer than hoped for, but Golden Rice addresses the problem at its roots in ways the naysayers deny.

Marc Brazeau is the GLP's senior contributing writer focusing on agricultural biotechnology. He also is the editor of Food and Farm Discussion Lab. Follow him on Twitter @eatcookwrite