Genetically Modified Rice

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Plant breeding, the science of crop production, has traditionally developed new cultivars through selective breeding in the spirit of Gregor Mendel (1965) and his peas. Plant breeders hybridize plants that have been selected for some desired trait. By hybridizing desirable plants, desirable alleles—and combinations of alleles—are concentrated, thereby improving the fitness of the offspring. Plant breeders then test the new genotypes in different environments in order to compare the fitness of offspring against their parents in hope of improving the progeny’s performance across a greater range of environmental conditions.

Now, with the advent of sophisticated genetic technology, plant improvement often involves the direct manipulation of the genetic code of plants by activating or deactivating genes or by inserting genes from other organisms.

The list of genetically modified organisms (GMOs) developed for agriculture is sizable and growing. Roundup-Ready® soybean is genetically engineered to withstand glyphosate, an inexpensive herbicide trademarked as Roundup® which allows farmers to kill “weeds” but not their genetically modified crops (Stokstad 2004); Bt corn and cotton contains deoxyribonucleic acid (DNA) from a common soil bacteria (Bacillus thuringiensis) which produces an endotoxin repellent to European corn borer and cotton bollworm (Linacre and Thompson 2004) obviating the need for pesticide (Brody 2000); genetically modified papaya resists ringspot virus (Gonsalves 1998); snippets of bacterial genes inserted into potatoes repel the voracious Colorado Potato Beetle (New York Times 1995); genetically modified strawberries tolerate frost much better than their natural counterparts (Houde et al. 2004).

The idea to manipulate the genetic code of a common strain of rice (Oryza sativa) arose from determination to solve an acute nutritional problem. The World Health Organization (2007) estimates that between a quarter and a half million children go blind each year due to Vitamin A Deficiency (VAD) syndrome. Half of these children die. When adults are included, the annual VAD death toll exceeds 1 million (Baggott 2006, p. 28). The unnerving fact
for humanitarian activists is that VAD is completely preventable; better nutrition is all that is needed.

Upwards of 3 billion people depend upon rice as their main staple. Beta-carotene (β-carotene), a natural plant pigment, provides the chemical precursor for the body to produce Vitamin A. For this reason beta-carotene is also called provitamin A. In rice, beta-carotene is present only in the outer grain layers. Unfortunately, in order to keep the grain from rotting, these layers are removed during milling and polishing. The kernel that most people eat—the starchy interior called the endosperm—does not contain beta-carotene. Since no species in the entire Oryza family produces beta-carotene in its endosperm, hybridization of Oryza lines—the traditional crop improvement approach—is not considered feasible.

Since normal plant breeding techniques were unpromising, Gary Toenniessen, Director of Food Security of the Rockefeller Foundation, looked elsewhere. If genetic technology could produce a rice that contained provitamin A in the part of the plant that people eat, VAD might be vanquished and human suffering greatly alleviated (Nash and Robinson 2000). With the support of Toenniessen and a Rockefeller Foundation grant, Ingo Potrykus, Professor of Plant Science at the Swiss Institute of Technology, began collaborating with Peter Beyer, Professor at the Department of Cell Biology at the University of Freiberg, an expert on the beta-carotene pathway in daffodils, on the genetic modification of rice. Potrykus (2001) has been adamant about the humanitarian origin of this project. It began at public institutions with public funding independently of industry influence. The hope, Potrykus said, was that the technology would be transferred to other major human food staples such as banana, cassava, grain, legumes, sweet potato, and wheat (ibid.).

The outcome of their research was “Golden Rice,” so-called because the endosperm contains 3 genes (ibid.) which produce beta-carotene, giving it a yellowish, rather than whitish, color (Schaub et al. 2005). This triumph of genetic engineering was accomplished by splicing DNA from common soil bacterium (Erwinia uredovora) and wild daffodil (Narcissus pseudonarcissus) into Oryza sativa (Al-Babili and Beyer 2005). These genetic modifications created provitamin A pathways in the endosperm of the rice (Beyer et al. 2002).

This extraordinary scientific achievement did not mark victory for the eradication of VAD but the beginning of stumbling over a series of blocks in getting the rice to the people for whom it was intended. The first unforeseen
obstacle was intellectual property rights: the genes and technology Potrykus and Beyer used to transfer DNA from bacteria and daffodils to rice were encumbered by 70 patents! (Potrykus 2001).

Intellectual property rights automatically brought corporations into the mix. Greenovation, a German company specializing in orchestrating academic discoveries with the biotechnology industry, brokered a deal between the professors and Zeneca Agrichemicals, which held crucial patents (Christensen 2000). Through a corporate merger, Zeneca became Syngenta in 2000 (ibid.). St. Louis-based Monsanto, the largest agricultural biotechnology company in the world and a darling of investors because of aggressive research and development (Stewart 2005), also held key patents.

With huge multinational corporations now involved, Potrykus and Beyer quickly realized they needed the expertise of a partner to deal with the legal and commercial dimensions that they as academics were ill-equipped to handle. These partners they found were in the private sector (Potrykus 2001). With legal advice, the number of patents impeding distribution was brought to 12 from 70 (ibid.). Zeneca agreed to support the project on the basis of its humanitarian intent by allowing the remaining patents to be used if the profits accrued by its use did not exceed $10,000 per year, a cap well above the income of poor farmers (Christensen 2000). In a similar gesture of good-will, Hendrick Verfaillie, President and Chief Executive of Monsanto, proclaimed “The purpose of golden rice is to bring Vitamin A where people suffer” (Marquis 2000) and waived all fees associated with patents on Golden Rice technology (Wall Street Journal 2000). Surmounting these obstacles cleared the way for shipment of Golden Rice to the International Rice Research Institute (IRRI) in Los Banos, Philippines, for greenhouse research (Schiermeier 2001). Four years later Golden Rice was harvested for the first time outdoors in Louisiana (Treadway 2005) as the U.S. is one of the few countries with clearly-delineated regulations for growing genetically modified plants (History of the Golden Rice Programme).

But another, more imposing obstacle loomed: adverse public opinion. Americans are customarily more trusting of governmental oversight than Europeans (Baggott 2006, p. 29), and the most intense reproach of Golden Rice has come from Europe driven by environmental groups, most notably, Greenpeace.

Greenpeace dismissed Golden Rice as “fool’s gold” (Connor 2001) and condemned it as unecological and unjust. As the controversy was heating up in 2001, Charlie Kronick, Chief Policy Adviser for Greenpeace, wrote: “We oppose GM crops because the technology is unpredictable, imprecise and
irretrievable. The fundamental environmental safety issues remain unresolved for ‘golden rice’ just as for any other GM organism. We and others also oppose it for specific reasons: nutritionists say that it won’t solve Vitamin A deficiency because the absence of fat in diet of the poor won’t allow the uptake of pro-Vitamin A in the rice. We believe it is based on unsound nutritional science—a genetic engineer’s approach to hunger. The only function that GM crops such as golden rice can be guaranteed to perform is to divert attention and resources from the challenge of creating a genuinely sustainable future for agriculture in both the developed and developing worlds. A technical ‘fix’ to economic and social problems such as poverty is no solution” (loc. cit.).

The health benefits initially touted by biotechnology proponents were dismissed as overrated (Schnapp and Schiermeier 2001). The rice consumption of an average Asian adult would provide only 8% of the needed daily intake of Vitamin A. That adult would need to consume nearly 20 pounds of uncooked rice—twice that amount for pregnant women—to meet daily Vitamin A requirements (Brown 2001). This prompted Kronick to claim: “It is clear that the GM industry has been making false claims about golden rice” (ibid.).

This criticism, however, was blunted in 2005 with the development of “Golden Rice-2” which substituted daffodil DNA for maize DNA (Paine et al. 2005). The new rice contained 23 times the beta-carotene than its prototype (Mayer 2005) and in the minds of some observers resolved the dispute about provitamin A content (Baggott 2006, p. 30).

There remained other nutritional concerns, however. Some claimed that elevated levels of beta-carotene did not necessarily improve health, because in order to absorb beta-carotene the body must be fairly fit. People suffering from poor nutrition have trouble absorbing beta-carotene in the first place. The scourge of malnutrition, nutritionists maintain, is complex and cannot be solved by simply inventing a new strain of rice. The real problem is the whole diet, particularly the lack of green vegetables (Cavendish 2004).

Others raised psychological issues, suspicious that European men in white lab coats had not considered cultural factors. Asians, for example, prefer white rice to brown rice even though brown rice is known to be more nutritive. An American writer wondered whether Asians even wanted to eat yellow rice (Pollan 2001).

In terms of straightforward economic cost/benefit analysis, skeptics speculated that the money gone into developing and marketing Golden Rice
might have been better spent by handing out Vitamin A supplements and teaching farmers how to grow green leafy vegetables on the margins of their rice paddies (ibid.).

The conspicuous emphasis on the humanitarian potential of Golden Rice by biotechnology acolytes, in spite of seemingly obvious economic evidence against its continued promotion, caused considerable suspicion that it was being used as a public relations stunt to win widespread acceptance for GMO use in agriculture. Critics snubbed Golden Rice as a poster child, a “Trojan horse” (Pollack 2001a) to bolster biotechnology profits which had been failing to meet the rosy expectations of investors (Stewart 2005).

If humanitarian arguments were enlisted by biotechnology interests in an intentional propaganda ploy, it worked. Benedikt Haerlin, Genetic Engineering Campaign Coordinator for Greenpeace International, had categorically maintained a “permanent and definite and complete opposition” to GMOs (Taverne 2003)—except in the case of Golden Rice. “I feel that ‘golden rice’ is a moral challenge to our position,” Haerlin conceded. “It is true there is a different moral context, whether you have an insecticidal or pesticide-resistant GM, or whether you have a GM product that serves a good purpose” (Connor 2001).

Questioning the veracity of the biotechnology industry’s good intentions, American journalist Michael Pollan posed a rhetorical question after an ordinary observation: “Granted, it would be immoral for finicky Americans to thwart a technology that could rescue malnourished children. But wouldn’t it also be immoral for an industry to use those children’s suffering in order to rescue itself?” (Pollan 2001). This worry seemed to be echoed in the comments of Rockefeller Foundation President Gordon Conway who judged that “…the public relations uses of golden rice have gone too far” (Brown 2001).

It is clear that much of the opposition to Golden Rice has really been opposition to GMOs in general. Lingering suspicion of the altruistic intentions of big corporations induced many to worry that acceptance of Golden Rice may lead down a slippery slope to the acceptance of other GMOs with less noble purposes, a “dangerous domino” in a larger agricultural game (Baggott 2006, p. 30).

For untold people, messing around with the genetic infrastructure of the human foodstuff defies common sense. Justifiable anxiety exists over unwittingly subjecting people to allergens. Transferred genes (transgenes)
contain information for making proteins, and some proteins—such as those in peanuts—can cause death (Nash and Robinson 2000).

Apprehension extends from diet to ecology. There is worry about “genetic pollution” or “contamination” cascading through ecosystems, “the consequence of dumping genes into genomes” (Cavendish 2004). Biologists emphasize that gene flow is a natural property of ecological systems. Genetically modified wind-pollinated cultivars spread transgenes through ecosystems. A furor flared up when farmers in England, France, Germany, and Sweden unknowingly planted genetically modified canola from Canada which interbred with non-genetically modified canola in adjacent fields, consequently “contaminating” the natural stock (Nash and Robinson 2000). Ecologists point out that the immanent implementation of Golden Rice will invariably disseminate modified genes to nearby wild populations. These ecological effects are uncertain and call for further study (Lu and Snow 2005).

In light of all this ecological uncertainty, European Union public policy makers have adopted a “precautionary principle” which holds that if the consequences of some action, like using GMOs in food production, are undetermined and potentially dangerous, implementation ought to be avoided (Baggott 2006, p. 29). Given current knowledge, this principle weighs against use of GMOs as cultivars.

For anti-globalization activists, the feared outcome of GMO agriculture is loss of local autonomy (Pearce 2001) and consequent corporate control of the world’s food market (Pollack 2001b). In the words of English journalist Camilla Cavendish, “GM crops will not solve world hunger. In fact they could worsen it, by enabling a few giant conglomerates to monopolize the food chain[,] the surrender of poor farmers into a new form of slavery” (op. cit. 2004).

The frustration of scientists to this discourse has been palpable. Many exhibit exasperation that the issue is no longer about helping the impoverished or sound science but about anti-technology politics. As Potrykus complained, “It is not so much the concern about the environment, or the health of the consumer, or help for the poor and disadvantaged. It is a radical fight against a technology and for political success” (Pollack 2001a).

To counter politics which many scientists feel is based more on emotion than agronomy and genetics and humanitarianism, over 3 thousand scientists, including 25 Noble Laureates, signed a “Declaration in Support Of Agricultural Biotechnology” which asserts “recombinant DNA techniques
constitute powerful and safe means for the modification of organisms and can contribute substantially in enhancing quality of life by improving agriculture, health care, and the environment. The responsible genetic modification of plants is neither new nor dangerous. Through judicious deployment, biotechnology can also address environmental degradation, hunger, and poverty in the developing world by providing improved agricultural productivity and greater nutritional security” (op. cit.).

Golden Rice, these scientists argue, is not a ruse to addict the world’s population to a monoculture controlled by multinational corporations. Rather, introgression of Golden Rice into local varieties can occur within 2 years, thus preserving biodiversity (Mayer 2005). Nor is Golden Rice intended to be the final solution to VAD, but rather an additional arrow in the humanitarian quiver of weapons aimed at mitigating malnutrition (Nash and Robinson 2000). It effectively delivers a beneficial natural trait (beta-carotene) in a standard crop plant (Mayer 2005). Therefore Golden Rice is meant to complement, not replace, existing strategies (Dawe et al. 2002).

For proponents of Golden Rice, it is time to shift attention from debate to implementation (Al-Babili and Beyer 2005, p. 571). A U.S. Department of Agriculture research geneticist recently exhorted, “The current resistance to acceptance of this novel technology should be assessed and overcome so that its full potential in crop improvement can be realized” (Jauhar 2006, p. 1841). And in the words of former U.S. President Jimmy Carter, “Responsible biotechnology is not the enemy; starvation is” (Nash and Robinson 2000).

Whatever the case may be, two things are for certain. One it that genetically modified cultivars are and will continue to be part of the human foodstuff. The other is that malnutrition will persist and genetic technology could have some role in addressing this humanitarian crisis. The open question is the extent of biotechnology’s future role in confronting chronic malnutrition, and the guiding principles that will direct the strategy.

References
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