CASE STUDY: GOLDEN RICE

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(http://www.biotech.iastate.edu/)
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BACKGROUND

The World Health Organization (WHO) estimates that vitamin A deficiency affects 230 million children worldwide, and at least one million children per year are dying of diseases related to this deficiency. Ingo Potrykus and his collaborator Peter Beyer, with financial support from the Rockefeller Foundation, led the effort to develop a variety of rice that contains beta-carotene, the plant pigment that is the precursor of Vitamin A. This rice, called "golden" rice because the inserted beta-carotene turns the grain a golden yellow color, could supply enough beta-carotene in a typical serving to supply 10% of the daily requirement for Vitamin A. The co-developers have provided samples of golden rice to the International Rice Research Institute (IRRI) in the Philippines, which will join with other research organizations to try to develop new varieties of rice that they hope will be rich in vitamin A. But before making such seeds available to the rice farmers of the developing world, IRRI also will ensure Golden Rice is completely safe for human consumption and the environment.

IRRI has been doing traditional rice breeding for decades, but with the recent development of biotechnology tools, the institute has been able to accelerate processes that used to take many years into only a few years. Because IRRI is supported by the governments of more than 20 nations, its services are provided without charge to the poor farmers and consumers it was set up to serve.

Many people regard golden rice as an example of how biotechnology can be used to help developing nations, while others consider it a smokescreen to divert attention away from biotechnology companies' attempts to dominate the food supply.

ACTIVITY

Your assignment is to write a letter to the Rockefeller Foundation either supporting or opposing their funding of golden rice research. The Rockefeller Foundation describes itself as "a knowledge-based global foundation with a commitment to enrich and sustain the lives and livelihoods of poor and excluded people throughout the world." In its mission statement, the Foundation says that it will "continue to join with governments, industry, other foundations and nongovernmental organizations to ensure that poor people are included in decisions that affect their lives." For more information about the Rockefeller Foundation, see http://www.rockfound.org/.

To help you decide whether to support or oppose the Foundation's funding of golden rice research, you will hear reports from various witness groups involved in the current debate about golden rice.

Witness Groups

Friends of the Earth -- FoE is an organization dedicated to protecting the environment and promoting sustainable development. FoE believes that solutions to the problem of vitamin A deficiency are available that are more effective, less risky, and less expensive than golden rice, but that the introduction of genetically modified organisms continues because of the power wielded by large agribusiness companies. You will argue that golden rice research should not continue to be funded.

Philippine Partnership for Development Farmer-Research Scientists (MASIPAG) -- MASIPAG is a collaboration between farmers and researchers working together on issues concerning the improvement of rice. MASIPAG trains farmers in cultivation methods that aim to make them independent of loans and chemicals. In your view, biotechnology companies, not poor Asian farmers, are the ones most likely to benefit from golden rice. Accordingly you will argue against continued support for golden rice research.

International Rice Research Institute (IRRI) Scientists -- IRRI describes itself as "a nonprofit agricultural research and training center established to improve the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes. It is dedicated to helping farmers in developing countries produce more food on limited land using less water, less labor, and fewer chemical inputs, without harming the environment." You will argue that continued research is necessary to ascertain whether golden rice might be able to help solve the problem of vitamin A deficiency.

Ingo Potrykus

The Humanitarian Board for Golden Rice-- The Humanitarian Board is chaired by Ingo Potrykus, the co-inventor of golden rice. The aims of the Humanitarian Board include facilitating further golden rice research and the introduction of golden rice to developing countries. Other members of the Board include: Peter Beyer, also co-inventor of golden rice; Dr. Ronnie Coffman from Cornell University; Dr. Adrian, Dubock from Syngenta Corporation; Dr. William Padolina from IRRI; Dr. Ashok Seth, from the Rural Development Unit of the South Asia Region of the World Bank; and Dr. Gary Toenniessen, Director of Food Security at the Rockefeller Foundation. You will argue that golden rice research should continue to be funded because it promises significant humanitarian benefits.

Index of Readings

For all groups:

1. Rockefeller Foundation, "Program Goals"
2. Rockefeller Foundation, "Food Security"

Friends of the Earth:

1. Friends of the Earth: "Golden Rice: Blind Ambition?"
2. Friends of the Earth: 'Golden Rice' and Vitamin A Deficiency

MASIPAG:

1. "Grains of delusion: Golden rice seen from the ground," by BIOTHAI (Thailand), CEDAC (Cambodia), DRCSC (India), GRAIN, MASIPAG (Phillipines), PAN-Indonesia and UBINIG (Bangladesh).

IRRI:

1. Brief
2. "Golden Rice Background," from the Council for Biotechnology Information
3. "Golden Rice: The Eyes of the World are Watching," from the IRRI Annual Report 2000-2001, *Rice Research: The Way Forward*.

Humanitarian Board:

1. Ingo Potrykus, "Development of Golden Rice and Free Transfer for Humanitarian Use in Developing Countries" (abstract), from the Tufts University conference Agricultural Biotechnology: The Road to Improved Nutrition and Increased Production?, November 1-2, 2001.
2. Ingo Potrykus, "Golden Rice and Beyond," *Plant Physiology* March 2001, Vol. 125, pp. 1157-1161.

Program Goals

The Rockefeller Foundation is a knowledge-based global foundation with a commitment to enrich and sustain the lives and livelihoods of poor and excluded people throughout the world.

In order to maximize its resources and leverage the Foundation's strengths, grantmaking is organized around four thematic lines of work: Creativity & Culture, Food Security, Health Equity and Working Communities. A cross-theme of Global Inclusion supports, promotes and supplements the work of these themes.

In addition, the Foundation supports various regional and special programs, among them the Africa Regional Program, Southeast Asia Regional Program, Communication for Social Change, Public/Private Partnerships and Global Philanthropy. We also offer a unique place for study and creative endeavor through our Bellagio Study and Conference Center in northern Italy.

The Foundation's strategic direction focuses explicitly on the challenges faced by poor and excluded people and affirms our assumptions about development, most notably that:

- For the Foundation's strategies to be most effective, poor and excluded people should have a voice in the process, we should actively find ways to unleash those voices, and such voices should be heeded; that
- The poor and excluded people themselves should participate in researching, planning and doing the work; and that
- We must seek creative ways to leverage our limited dollars in order to attract new funding from the private sector, international aid organizations, and national, state and provincial governments.

The challenges confronting poor and excluded people are too numerous, complex and massive to be addressed by any single foundation alone. A $15 million grant, or even a $50 million grant, cannot begin to address a cure for AIDS or development of new tuberculosis drugs, for example. We must continue to emphasize the creation and support of global partnerships, alliances and collaboratives to effect positive change in the daily lives of poor people.

The Foundation will continue to join forces with governments, industry, other foundations and nongovernmental organizations to ensure that poor people are included in decisions that affect their lives.

Goal: To improve the food security of the rural poor through the generation of agricultural technologies, institutions and policies that will provide sustainable livelihoods in areas of sub-Saharan Africa and Asia bypassed by the Green Revolution.

Food security--all people having enough food at all times to live normal, active lives--will continue to be a central challenge for millions of households, numerous countries and at least one continent, Africa, over the next half century. When people lack the calories and micronutrients, such as iron and vitamin A, that enable the body to develop, the lifelong effects can be devastating. Undernourished children are more susceptible to disease and are often stunted both physically and mentally, impacting their school performance and their potential for productive adult lives.

Of the more than 5 billion people living in developing countries, 3 billion live in rural areas, most of them dependent on agriculture for their livelihoods. Currently, about 800 million people remain undernourished and roughly 24,000 people die each day from hunger and hunger-related causes. Yet hunger's corrosive effect extends beyond those immediately impacted, often leading to social and economic instability in a region, country and even an entire continent.

Most of those who remain undernourished live in regions bypassed by the agricultural advances of the Green Revolution that contributed to dramatic improvements in food security for the majority of the world's people. Living on land that is often lower in natural agricultural potential, having few formal educational opportunities and little access to technology, these farming families, concentrated in sub-Saharan Africa and less-favored parts of Asia, remain in poverty.

To help these farm families move out of poverty, Foundation grantees are working to improve access to markets and provide better and more locally appropriate teaching of farming skills. Research is aimed at generating agricultural innovations, including more dependable and sustainable farming practices, and new crop varieties developed for the specific environmental and socioeconomic conditions under which the poor farm. The National Agricultural Research Organisation of Uganda, for example, has released new maize varieties that have improved disease resistance, more efficient nitrogen utilization and that breed true, so farmers can save seed from their harvest for the next planting.

Our grantees are engaging the farmers themselves as participants in scientific investigations and in the development of new technologies to meet their needs. This is illustrated by the central role of farmer participation in research on soil-fertility management being conducted in western Kenya where several nongovernmental organizations have recommended alternative maize/legume intercrops in an effort to determine the approach that is best suited to the region's diverse agroecological and

social settings. Under the leadership of SACRED-Africa (Sustainable Agriculture Centre for Research, Extension and Development in Africa) the nongovernmental organizations have come together to facilitate on-farm testing and comparison of these technologies. The trials are farmer managed and a deliberate effort is made to capture the farmer's impressions and to encourage further farmer innovation in use of the technologies. The results are presented at widely promoted "field days" where participating farmers play a key role in teaching other farmers the "best bet" practices for each subregion.

The ability of local organizations to access and move key institutional, policy and technological levers is critical to the success of this process. To foster development of local, national and international policies that will increase the productivity, stability and sustainability of smallholder agriculture, the Foundation seeks to empower and invigorate institutions that provide goods and services to poor farmers. In Africa, for example, the Foundation provides funding to the Ministry of Agriculture and Irrigation in Malawi, to assist the government's development of a long-term strategy for sustainable soil-fertility management and food security for smallholder farmers; to the African Centre for Fertilizer Development to facilitate greater private-sector participation in the dissemination of soil-fertility technologies to smallholder farmers; and to the University of Pretoria to conduct research on the risks and benefits associated with the adoption of agricultural biotechnologies by smallholder farmers in Africa. At the international level the Foundation helped support establishment of an African Agricultural Technology Foundation that will facilitate public/private partnerships designed to provide smallholder farmers in Africa with greater access to new agricultural technologies, materials and know-how, including proprietary technologies.

Our work addresses the root causes of food insecurity through the following areas of work:

- To develop improved crop varieties for Africa and Asia.
- To enhance soil productivity in Africa.
- To improve the efficiency and equity of markets to raise the income of poor farmers in Africa.
- To generate international public goods that can help developing countries better serve poor farmers.

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Friends of the Earth International

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GOLDEN RICE: BLIND AMBITION?

“It is ironic that some of the worst concentrations of xeropthalmia and blindness due to Vitamin A deficiency occur in populations surrounded by abundant sources of the vitamins and minerals in local vegetables and fruits, yet no country has yet mounted a successful campaign to solve the Vitamin A problem in this way.”
Dr. Nevin Scrimshaw, 1991 Laureate of the World Food Prize

Golden Rice could prevent blindness in half a million children each year, and every month that we delay the use of this sight-saving transgenic crop means that about 50,000 more children go blind. This claim by biotech industry representatives was greeted with skepticism and anger at FoE Europe's "Sustainable Agriculture in the New Millennium" conference in May (see article this issue).

UK biotech company Zeneca's agreement to help make Golden Rice available to the developing world's poor farmers was a hotly debated topic throughout the conference. Is Golden Rice a triumph of biotechnology that could eradicate unnecessary suffering? Or is it merely a PR maneuver by a threatened industry that would thrust an unproven, unwanted and perhaps even harmful technology upon the developing world?

In fact, it was revealed that the gift of transgenic rice had strings attached -- seventy of them to be precise. Transgenic manipulation is an extremely complex process. The creation of Vitamin A rice requires numerous genes, DNA sequences and genetic constructs, and each of these processes may be separately patented. Ingo Potrykus and Peter Beyer, the scientists who invented the Vitamin A rice, agreed to make their share of the Golden Rice intellectual property available to poor farmers for free. But truly “free” Golden Rice would require similar releases from all 70 patent claimants.

Many other questions remain. How would the programme be selectively administered to poor farmers, defined by Zeneca to be those earning less than US$10,000 per year? And although farmers are permitted to sell Golden Rice locally, would they be required to pay royalties on exports? Would farmers be able to use the seeds for replanting? Is the science as sound as GM food proponents claim?

“Golden Rice is the answer, but what was the question?” was an oft-heard quip from NGO representatives at the conference. It seems that Third World consumers have not been asked if they want to eat Golden Rice, or any other genetically modified foods for that matter. Auxillia Motsi of the Zimbabwe Consumers International regional office in Africa was not convinced that Africans would be any keener to adopt GMOs than the Europeans who have almost universally rejected them. Also unaddressed were cultural food preferences. “You change the flavour of Coca Cola, and nobody accepts it because it's culturally linked and people grew up with it from their childhood,” says University of California Berkeley agroecologist Miguel Altieri, “It's the same thing with colour. People in Asia are not going to adopt a yellow rice.”

Ironically, dozens of varieties of Vitamin A rice already exist. “In India the red rice, which is found in the southern states, already has Vitamin A in it,” says Anuradha Mittal of the US Institute for Food and Development Policy. “But the problem is very closely linked to what we have been told constitutes good rice. Good rice is supposed to be this gleaming white rice which has been provided to us, basically making sticky rice and other varieties that people used to eat something that is not good enough for consumption, and deemed as inferior. Never mind that it has all the virtues!”

“Green Revolution II,” the GM food revolution, may simply be dealing with deficiencies caused, in part, by Green Revolution I, says Malaysian activist Chee Yoke Ling of the Third World Network. “The Green Revolution introduced the technology of polishing and milling the rice. Before that, we did not eat polished rice. It was not part of the rice culture. Now they tell us that we don't have enough Vitamin A,” says Chee. Rice is polished to prolong its storage for export and to suit the tastes of the developed world, according to geneticist Dr. Mae-Wan Ho of the Institute of Science and Society at the Open University in the UK. Making unpolished rice available for free or at low cost to undernourished people would go a long way in solving this deficiency, according to Ho.

This and other solutions to micronutrient deficiencies are readily available, says Mittal, “and we've known it forever. But there's been a complete absence of political will on behalf of those same foundations, those same corporations that now claim that they want to end blindness. What they want is more and more corporate interest.”

blind to solutions

UNICEF currently has solutions to Vitamin A deficiency, Mittal says, some of which cost mere pennies per person. Available solutions include Vitamin A tablets, food fortification (for example, adding the vitamin to sugar), and dietary approaches to educate people -- who may be completely unaware of the deficiency – about healthy diets. Moreover, unlike Golden Rice, these solutions will solve a whole range of micronutrient deficiencies. Furthermore, people's ability to absorb Vitamin A depends on their overall nutrition status. This underlines the need for global improvements in nutrition, not “magic bullets” of Vitamin A. “Are they going to give us a miracle rice that will be engineered with everything?” asks Chee.

spin for dollars

Mittal and Chee say that all the hype and millions of funding dollars injected into Golden Rice, a product still five or even ten years in the future, is diverting much-needed resources from

currently available solutions. “They keep telling us 'we are giving you one more tool.' They are not,” says Chee. As much as US$100 million has been spent on Golden Rice thus far, with funds from the Rockefeller Foundation, the Swiss Federal Institute of Technology, the European Community Biotech Programme and the Swiss Federal Office for Education and Science.

Golden Rice may never help poor farmers, but it could give the beleaguered European biotech industry a new grasp on life. “One can only hope that this application of plant genetic engineering to ameliorate human misery without regard to short-term profit will restore this technology to political acceptability,” wrote the respected journal Science in a commentary piece on Golden Rice. The magazine sent pre-prints of the article to 1700 journalists around the world.

“They've become really good at putting a human face to their corporate interest,” says Mittal, “rather than admitting their motive is profits.” Mittal feels that this layer of “spin” makes it difficult for concerned citizens and agencies to have an honest debate about the real pros and cons of the technology.

science or fiction?

One essential debate is on the science of biotechnology. “This will never be a precise technology,” says Chee. “They can't defend it from a scientific basis because they haven't shown us good science yet.” Golden Rice is a so-called “Second Generation” GM product, meaning it purports to have benefits for consumers, not just for producers. Yet from a scientific perspective, Golden Rice has the same drawbacks as the “First Generation” GM products, according to Ho.

Golden Rice is an unstable construct, says Ho, made from a combination of genetic material from viruses and bacteria that are associated with diseases in plants, as well as genes from non-food species. For example, each Golden Rice plant contains two promoters from the hazardous cauliflower mosaic virus, which Ho believes could spread by cross pollination or gene transfer and have enormous impacts on health and biodiversity. The product's instability also means that there is no guarantee that seeds from Golden Rice plants will retain the desirable traits over successive generations, according to Ho.

Others feel that Golden Rice and other GMOs must be flatly rejected on ideological grounds. “It's a Trojan Horse,” argues Altieri, who says the biotech industry is already working to penetrate markets in developing nations and even directing national research priorities in some countries. In an atmosphere of little or no regulation and little or no public debate, Third World consumers may never have the luxury of choice when it comes to GMOs.

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‘Golden Rice’ and Vitamin A Deficiency

"If anyone tells you that GM is going to feed the world, tell them that it is not… To feed the world takes political and financial will – it’s not about production and distribution."

Steve Smith, head of Novartis Seeds

High-tech cure for Vitamin A deficiency?

"Biotechnology and GM crops are taking us down a dangerous road, creating the classic conditions for hunger, poverty and even famine. Ownership and control concentrated in too few hands and a food supply based on too few varieties planted widely are the worst option for food security."

Christian Aid Report: "Biotechnology and GMOs"

In 1999, Swiss and German scientists announced the development of a "golden rice" genetically engineered to produce beta-carotene, a substance which the body can convert to Vitamin A. The new rice was quickly heralded as a miracle cure for vitamin A deficiency (VAD), a condition which afflicts millions of people in developing countries, especially children and pregnant women. Severe VAD can cause partial or total blindness; less severe deficiencies weaken the immune system, increasing the risk of infections such as measles and malaria. Women with VAD are more likely to die during or after childbirth. Each year, it is estimated that VAD causes blindness in 350,000 pre-school age children, and it is implicated in over one million deaths. At first glance, then, golden rice would seem to be a godsend. But a closer look reveals a different picture.

A long road from lab to field

"…the public relations uses of Golden Rice have gone too far. The industry’s advertisements and the media in general seem to forget that it is a research product that needs considerable further development before it will be available to farmers and consumers."

Gordon Conway, President of the Rockefeller Foundation, the chief funder of the Golden Rice project

Golden rice is produced by splicing three foreign genes – two from the daffodil and one from a bacterium – into japonica rice, a variety adapted for *temperate* climates. The developers anticipate at least five more years will be required to breed the Vitamin A trait into rice varieties adapted to local climates in developing countries. This is probably overly optimistic, given the unprecedented difficulties presented by engineering a complex three-gene trait (all current GE crops are spliced with single-gene constructs), and the need for safety and environmental testing before field introduction.

Too little, too late

Even if golden rice is successfully introduced, it will likely do little to ameliorate VAD because it produces so little beta-carotene – just 1.6 micrograms per gram rice (µg/g) at present, with a goal of 2.0 µg/g. Even if scientists reach this goal, a woman would need to eat 16 lbs. of cooked rice every day in order to get sufficient Vitamin A, if golden rice were her only source of the nutrient. A child would need 12 lbs. More realistically, three servings of ½ lb. cooked golden rice per day would provide only 10% of her daily Vitamin A requirement, and less than 6% if she were breast-feeding. Yet even these modest contributions are uncertain. In order to absorb beta carotene, the human body requires adequate amounts of zinc, protein and fats, elements often lacking in the diets of poor people. Those with diarrhea – common in developing countries – are also unable to obtain vitamin A from golden rice.

Magic bullets miss the mark

"A single nutrient approach towards a nutrition-related public health problem is usually, with the exception of perhaps iodine or selenium deficiencies, neither feasible nor desirable."

John R. Lupien, Director, Food and Nutrition Division, Food and Agricultural Organization, United Nations

Nutrition experts thus confirm what common sense tells us – a balanced, diverse diet supplying a *full range* of foods and nutrients is the only sound way to promote health and prevent VAD and other nutritional deficiencies. According to Dr. Samson Tsou of the Asian Vegetable Research and Development Center, VAD is not a major problem in countries with vegetable consumption of more than 200 grams per day. A pre-school child’s daily requirement of vitamin A can be met with just two tablespoons of yellow sweet potatoes, half a cup of dark green leafy vegetables, or two-thirds of a medium-sized mango. And unlike golden rice, these vegetables supply other micronutrients as well.

Shall man live by rice alone?

"Seeking a technological food fix for world hunger may be…the most commercially malevolent wild goose chase of the new century." Dr. Richard Horton, editor of the British science journal *The Lancet*

The Green Revolution of the 1960s and 70s replaced diverse cropping systems with monocultures of new wheat and rice varieties. These new hybrids required irrigation, fertilizers and herbicides to deliver increased yields. These herbicides killed off many green, leafy vegetables that had been important sources of Vitamin A. They also poisoned rice paddy waters, causing steep declines in fish and shrimp populations in areas such as Bangladesh, where integrated rice-fish farming is practiced. Monoculture in the fields predictably led to less diverse diets. In India, household consumption of vegetables has decreased 12% over the past two decades. In Thailand, 80% of caloric intake now comes from rice, up from less than 50% before the Green Revolution. An impoverished diet that consists of little else but rice (golden or not) will never provide a solution to world hunger or malnutrition.

Alternatives to golden rice

"If it were not for the vast array of alternatives on offer, the arguments for the GM approach might be genuinely compelling." Hugh Warwick, Splice, magazine of the Genetics Forum, March/April 2000

Even if golden rice is successfully developed, many question whether it is an efficient use of scarce public funds. An educational project in Bangladesh begun in 1993 by the UN’s Food and Agriculture Organization has helped landless families develop home gardens with vitamin A-rich crops such as beans and pumpkins. This successful program grew to involve at least three million people by 1998. A public education campaign in Thailand that utilized radio, posters and street theater taught farmers the advantages of growing the ivy gourd, another good source of vitamin A. A project in the Jiangsu province of China has helped spawn a huge increase in rice/aquaculture systems, which resulted in 10-15% increases in rice yields and, more importantly, 750 kg of fish per hectare of rice paddy. The fish also helped reduce the incidence of malaria by consuming mosquito larvae.

There are innumerable small-scale projects such as these throughout the developing world, only we rarely hear about them. And they don’t get nearly the amount of funding that they deserve. According to Hans Herren, Director of the Kenyan-based International Centre of Insect Physiology and Ecology, "half of Rockefeller’s agricultural money now goes to biotechnology." Herren, recipient of the World Food Prize in 1995, helped avert famine in Africa through introduction of a natural predator that eliminated a serious cassava pest. And this elegant solution didn’t cost farmers anything. One must wonder how many other low-tech, sustainable, people-centered solutions to hunger and malnutrition go unfunded thanks to government and biotech industry obsession with the hugely expensive technology of genetic engineering.

Grains of delusion:
Golden rice seen from the ground

February 2001

www.grain.org/publications/delusion-en-p.htm

INTRODUCTION

Rice does not normally contain vitamin A or its precursor, beta-carotene. But a group of European scientists have spent the last decade trying to change this. By inserting two genes from daffodil and one gene from a bacterium, Dr. Ingo Potrykus of the Swiss Federal Institute of Technology and Dr. Peter Beyer of the University of Freiburg in Germany have managed to engineer a beta-carotene pathway into Taipei 309, a japonica rice variety. In August 1999, they unveiled the fruit of their research and named it "golden rice." Shortly afterwards, they signed a deal with AstraZeneca, which agreed to waive technological fees to enable the development of the rice for "humanitarian" purposes. Monsanto was quick to jump on the humanitarian bandwagon by announcing royalty-free licenses for any of its technologies used to further the development of the rice. The small handful of transgenic rice grains produced in Potrykus’ laboratory provided a much-needed public relations boost for the biotech industry at a time when genetic engineering is under siege in Europe, Japan, Brazil and other developing countries.

The biotech lobby is selling the idea that genetically engineered (GE) crops, starting with golden rice, will solve problems of malnutrition. This is an ambitious goal for a small grain of rice. The malnutrition agenda is drawing in support from every major agricultural biotech company, the Consultative Group on International Agricultural Research (CGIAR), the US Agency for International Development (USAID), and its main funder, the Rockefeller Foundation. But at the end of the day, the main agenda for golden rice is not malnutrition but garnering greater support and acceptance for genetic engineering amongst the public, the scientific community and funding agencies[1]. Given this reality, the promise of golden rice should be taken with a pinch of salt.

1. PROMISES, PROMISES …

Golden rice has been met with excitement in every corner of the world. It has become a symbol of all the goodness biotechnology has to offer. Among other things, it is supposed to exemplify how genetic engineering can directly benefit consumers, which the first generation of genetically engineered crops has failed to do. It claims to provide a more sustainable, inexpensive and effective solution to vitamin A deficiency in poor, rice eating countries where drug-based supplementation and fortification have been ineffective. And in a climate where intellectual property rights (IPR) are the subject of controversy and uncertainty, it promises to provide the IPR-laden golden rice technology free of charge to subsistence farmers.

Examples of other nutritionally enhanced crops in the pipeline[2]

Increased levels of beta-carotene in oil-seed rape	Monsanto
Increased bioavailable iron in rice	Swiss Federal Institute of Technology (Zurich)
Improving nutritive value of Andean potatoes by manipulating potato’s own genes to block natural but bitter compounds called glycoalkaloids	USDA Agricultural Research Service (ARS); International Potato Center (La Molina, Peru)
High iron corn with less phytic acid, or phytate, than most common varieties (phytic acid is thought to reduce the body's ability to use certain nutrients like iron)	USDA ARS
Low glutenin rice	Orynova (Japan Tobacco)
Lactoferrin-producing rice	Japan Agricultural Cooperatives
Ferritin-rich lettuce	Central Research Institute of Electric Power Industry (Japan)

Freedom to operate or an excuse to corporate?

One of the major selling points of this golden rice technology is that the work has been done within the realm of public research using public funding. But the fact that golden rice has not been developed by and for the industry has come about not by design but default. Dr. Potrykus initially approached Nestle, the world’s biggest food company, for funding but was rejected. In retrospect, Dr. Potrykus describes this as "fortunate" because it kept the project open for public funding and the potential for free distribution[3]. But it was more of an afterthought than a plan.

Despite being the result of public research, golden rice is enmeshed in around seventy patents owned by some thirty-two companies and institutions, according to the US-based International Service for the Acquisition of Agri-biotech Applications (ISAAA)[4]. Because of the complexity of licensing arrangements, the inventors ceded their rights to Greenovation, a biotech spin-off company from the University of Freiburg, which then struck a deal with AstraZeneca (now Syngenta). According to Dr. Potrykus, a veteran in dealing with multinational companies and an inventor of a number of patented technologies, forging an alliance with AstraZeneca seemed to be the only option available to gain "freedom-to-operate" and speed up the transfer of the technology to developing countries. Hence by a stroke of a pen, AstraZeneca was able to acquire exclusive commercial control over a technology that was developed with public funding and purportedly pursued for a humanitarian cause.

Tangled up in patents

The AstraZeneca deal gives the corporation full commercial rights to the invention worldwide and "non-commercial" rights to the inventors for license-free use by national and international research institutes and resource-poor farmers in developing countries. A resource-poor farmer may sell the golden rice so long as s/he does not earn more than $10,000 a year from it. Any other commercial use of the golden rice technology – using public or private germplasm – and any export from a producer country requires a license from Zeneca on commercial terms.

Many see the deal with AstraZeneca as a rip-off. Despite of the huge number of patents involved, no more than 11 have the potential to serve as a barrier to the deployment of golden rice in countries with the highest levels of vitamin A deficiency, according to the Rural Advancement Foundation International (RAFI). The deal with AstraZeneca not only surrendered a decade of publicly-funded research to commercial control, but – more importantly – it strengthened the North’s patent hegemony worldwide.[5]

According to a press release jointly issued by IRRI, the Rockefeller Foundation and Syngenta in January 2001, six out of the 32 or so companies and institutions which own patents on certain technologies used to develop golden rice, had each licensed the technology free of charge. The companies are Syngenta Seeds, Syngenta, Bayer, Monsanto, Orynova, and Zeneca Mogen. Subject to further research, initially in the developing countries of Asia, as well as local regulatory clearances, golden rice will be made available free of charge for humanitarian uses in any developing nation. However, the terms of the free license agreements are still unclear: they appear to cover research, but not release or commercialization. This lack of clarity casts a huge question mark over how "free" the agreement really is and has huge implications for the accessibility, availability and affordability of golden rice to farmers around the world. Instead of resolving the intellectual property issues around golden rice, the inventors have passed the buck to developing countries and public institutions to sort out the mess themselves.

A "Humanitarian Board" has been established "to help make the right decisions" in any technology transfer agreement pertaining to golden rice. But the ‘humanitarian’ credentials of board members and their ability to judge the appropriate use of golden rice amongst resource-poor farmers are extremely questionable. They include the Rockefeller Foundation (New York), Zeneca Agrochemicals, the World Bank (Washington), IRRI (the Philippines) and the inventors themselves. Adrian Dubock, who was formerly the commercial biotechnology manager of Zeneca and is now with Syngenta, serves as the secretary of the board. The board also receives support from ISCB or the Indo-Swiss Collaboration in Biotechnology, which is jointly financed by the Indian Department of Biotechnology (DBT) and the Swiss Development Corporation (SDC).

From Bt rice to golden rice[6]

The first ever genetically engineered insect resistant indica rice variety also came out of the lab of Dr. Potrykus in the Swiss Federal Institute of

Technology (ETH). In April 1995, Dr. Potrykus sent Bt rice seeds containing a gene owned by Ciba Geigy (now Novartis) to IRRI in the Philippines. The package was intercepted by Greenpeace on the grounds that the necessary permit to export the genetically engineered seeds to the Philippines had not been obtained. But a week later, more Bt rice seeds were on their way to IRRI – this time via diplomatic pouch. IRRI’s Bt research faced strong opposition from many NGOs in Asia and around the world and also caused tension even within IRRI itself where some of its more ecology-oriented scientists question the usefulness of Bt rice in farmers’ fields. According to an IRRI scientist, Bt rice strains have also been sent to India, but up to now no field-testing has been conducted in the Philippines or India.

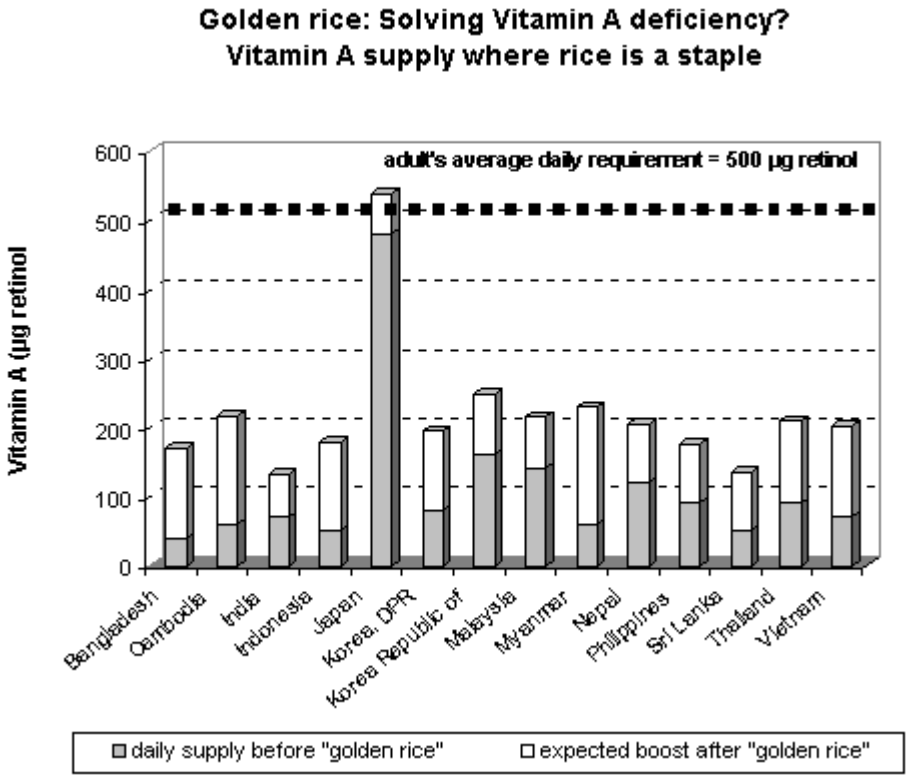
According to Dr. Potrykus, agreements have already been established with several institutions in Southeast Asia, China, Africa and Latin America and are only awaiting submission of a written confirmation of the "freedom to operate" to the humanitarian board[7]. However, Dr. Dubock refuses to give further information on these agreements. India is being looked upon as a possible model for technology transfer of the golden rice. Golden rice will be introduced in India through ISCB with possible funding from DBT, the Indian Council for Agricultural Research (ICAR) and the World Bank. Last 19 January 2001, Dr. Potrykus arrived at IRRI with the golden rice, where scientists will start transferring the golden rice trait to commercial varieties.

2. A REALITY-BASED ASSESSMENT

Malnutrition is said to be high in rice-eating populations. But these nutritional problems are not caused directly by the consumption of rice. They reflect an overall impact of multiple causative factors similar to those of other developing countries where rice is not a major staple[8]. Various deficiencies including zinc, vitamin C and D, folate, riboflavin, selenium and calcium occur in the context of poverty, environmental degradation, lack of public health systems and sanitation, lack of proper education and social disparity. Poverty and lack of purchasing power is identified as a major cause of malnutrition[9]. These underlying issues that can never be addressed by golden rice.

The Green Revolution with its inherent bias towards monocultures of staple crops has led to unbalanced patterns of food production in many places. As the UN Food and Agriculture Organization (FAO) has stated, variety is the key and should be the norm rather than the exception in farming systems. According to Dr. Samson Tsou of the Asian Vegetable Research and Development Center (AVRDC), countries with vegetable consumption of more than 200 grams of vegetables per day do not have vitamin A deficiency as a major problem[10]. Although animal sources are expensive, inexpensive plant food sources are widely available. It only takes two tablespoonfuls of yellow sweet potatoes, half a cup of dark green leafy vegetables or two-thirds of a medium-sized mango in a day to meet the vitamin A requirement of a pre-school child[11]. This way, not only is the vitamin A requirement being addressed, but a whole range of other micronutrients as well.

With what has been shown so far, 300 grams of golden rice can only provide *at most* 20% of an adult’s daily vitamin A requirement (see graph). A child would have a lower requirement of 450 µg retinol as against 500-600 µg retinol for adults[12]. But 300 g of rice a day is way too much for a child. In the Philippines, pre-school children consume less than 150 grams of rice a day. In principle then golden rice will only supply a little over 10% of the daily vitamin A needed by pre-school children. And children are the target population in this case.



Whether the beta-carotene contained in golden rice will be bioavailable is yet another question. Dietary fat is needed for it to be absorbed by the body. Unfortunately dietary fat is also limited in rice-eating countries and in fact is being looked at as one possible "hidden" causes of vitamin A deficiency itself[13]. There are also important interactions between different nutrients and minerals, which further warrants variety in food intake. Zinc deficiency, for example, may lead to an impairment of vitamin A metabolism. Disease control and hygiene, food selection and preparation will significantly influence absorption and utilization of vitamin A (and iron). Furthermore, there has been debate over the bioconversion of beta-carotene from green leafy vegetables into vitamin A. Some reports claim that the conversion rate is less than one-quarter of what has been assumed up to now. Should this be the case, the amount of vitamin A made available from golden rice would be almost negligible.

Despite statements being made that there is not a slightest risk of overdose from golden rice and conceivable risk to consumer health and the environment[14], no testing has been conducted. According to Dr. Mae Wan Ho, vitamin A poisoning has been known to result from excessive beta-carotene intake in food. Allergenicity has also been raised as a possible

issue. Daffodil, which is the source of the genes for the beta-carotene rice, is responsible for an allergic reaction which manifests as "daffodil picker’s rash" in some people.[15]

3. CLASHING PERSPECTIVES

According to Gary Toenniessen of the Rockefeller Foundation, "The benefit of having the beta-carotene in the crop is that the delivery system is already there. The current generation of improved varieties is being grown in rural areas not being reached by supplements." But we know too well that the Green Revolution did not reach marginal areas where many of the poor reside, so golden rice is not likely to go there either. According to Dr. Gurdev Khush of IRRI, the golden rice trait will be inserted in commercially grown rice varieties (such as IR64) since these varieties provide 80% of the rice in cities. Will it reach the rural poor? Or will it create a segmented market where golden rice captures a premium due to its added "nutritive" claim? It may be that golden rice will develop as a "specialty crop" in the Philippine market according to one of the leading rice breeders in the Philippine Rice Research Institute. Dr. Emorn Wasantwisut of the Institute of Nutrition at Mahidol University in Thailand goes as far as saying that it may initially start off as a "brand name" crop, in which case accessibility to the poor may be limited.

"Malnutrition is not merely a nutrition problem, it is also a social problem," says Dr. Samson Tsou, Director General of AVRDC. "Income generation, healthy diet and proper education needs to be improved simultaneously for sustainable development," he adds. In terms of priorities, increasing vegetable production may be more effective than improving vitamin A content. In Tsou’s view, "The adoption rate of the so called modern varieties of cereal crops is still not very high after 30 years of Green Revolution. To introduce a new type of staple food with color will even take a longer time to be popularized. Just take any other technology, the engineered crop will benefit certain growers and consumers but the vitamin A deficiency will not be resolved by any single technology."[16]

According to Riza Tjahjadi of the Pesticide Action Network – Indonesia, nutrient-enhanced GE crops, such as beta-carotene-enriched or high-iron rice, made available "freely" to poor farmers in the South will not automatically increase rice farmers income. "We can see this because the terms of trade for small-scale farmers in Indonesia have not improved since the Green Revolution, which focused so much on increasing yields of a few selected grains. In reality, we keep facing a crude mismatch when people try to make poverty the target of agricultural technology. Farmers get the rhetoric thrown at them, but the livelihood improvements don't follow."

For local groups like MASIPAG (The Farmer Scientist Partnership for Development Inc.) in the Philippines, combating a socio-economic problem with a technofix solution is reliving the Green Revolution – which they have totally turned their backs on. "Pro-vitamin A rice or golden rice is but a prescriptive approach to malnutrition wherein only a few varieties will contain the trait thereby further worsening genetic erosion" warms MASIPAG. "Malnutrition will even reach greater heights, as people will have more unbalanced diets based only on few foods," it adds.

Golden rice will supposedly be freely available to poor farmers. Although the notion of "free distribution" means free from royalties or added cost for the technology, for many farmers, cost does not only translate into monetary terms. For Mr. Afsar Ali Miah, a Bangladeshi farmer, "Nothing comes in free anymore, without its consequence, especially if it is driven by profit motives." He relates this vividly with his experience in the 1960s when Green Revolution seeds were introduced. At that time, the technology was started with all out support from the government and many farmers responded positively making use of the packaged technology of modern high-yielding varieties together with pesticides, and chemical fertilizers and a certain amount of credit. But when the uncertainty and fear of new was mitigated, the government slowly started withdrawing support and the farmers were left to deal with poor soil, lost seeds and declining diversity in the field, and dependency on pesticides and fertilizers. In the process, farmers lost control of their food system. According to Mr. Ali Miah, "Because of pesticides, people are no longer eating what little edible green leafy vegetables (and fishes) there are left in the fields anymore. If we allow this golden rice, and depend for nutrition on it, we might further lose these crops, our children losing knowledge of the importance of other crops such as green leafy vegetables."

CGIAR's Technical Advisory Committee, IRRI should "Continue to campaign for GE as a legitimate breeders' tool, using the 'golden' rice as a flagship."[17] In an interview with Dr. Potrykus, he said, "If some people decide that they want blind children and white rice, it’s their decision. I’m offering the possibility of yellow rice and no blind children. But the decision what people want to eat is theirs."[18]

However, Farida Akhter of UBINIG, an organization working with marginalized farmers and weavers in Bangladesh is quick to point out that biotech companies are looking to the poor in developing countries because of the strong opposition to GE crops in developed countries, such as the EU and Japan. According to Akhter, the poor are a good target because they are less powerful and less able to make technology choices. She adds that, "While golden rice is still in its pre-introductory stage, it is being promoted as if the poor have been asked if they wanted it and said ‘yes’."

According to Daycha Siripatra of the Alternative Agriculture Network in Thailand and the director of Technology for Rural and Ecological Enrichment, vitamin A deficiency will not be solved by golden rice technology since it does not address the key to the problem of poverty, which is landlessness. "They're cheating us. If the poor had land, they would have better diets. The poor don't need vitamin A. They need vitamin L, that's Vitamin Land. And they need Vitamin M, that's Vitamin Money. Malnutrition is because of poverty, not [a lack of] technology."

4. ALTERNATIVES

IRRI says that the Green Revolution may have actually increased malnutrition among the poor[19]. Consumption of vegetables in most Asian countries has remained stagnant since the Green Revolution and vegetable prices have increased in both real and relative terms[20]. In India, annual rice and wheat production has more than tripled from pre-Green Revolution levels. On the other hand, household consumption of vegetables has dropped 12 percent over

the last two decades. Pulse and legume consumption is down even more and is becoming more and more costly, and malnutrition remains high.[21]

Reclaiming the drylands….[22]

Golden rice proponents say that it will be particularly useful in marginal areas such as drought-prone regions where vegetables usually cannot be grown. But the Development Resource and Service Center (DRCSC) in Calcutta has demonstrated that such regions can be made to produce a rich and varied diet and should not simply be written off in this way.

In many drought-prone areas of Purulia, Bankura, part of Birbhum and Baduria, farmers often migrate to nearby villages after every cropping to earn their living as laborers. In some parts of these districts, rainfall only ranges from 800-1,200 mm and only one rice cropping is possible. Through the efforts of local farmers and the interventions of DRCSC, these arid lands have been transformed into productive and diverse farmland. In home gardens, vegetables are grown year-round. In the fields, rice or corn and pulses are grown during the rainy season; legumes and oilseeds are the main focus in winter. In early summer, some farmers cultivate cowpea, but many leave their lands fallow for at least 2 to 3 months. Farmers were able to bring back life to a once barren land left only to fallow or as grazing land for cattle.

But it wasn’t an easy task for the farmers and DRCSC. Careful planning, and the promotion of sustainable agricultural practices such as soil and water conservation techniques, mixed cropping and appropriate crop varieties were critical to achieving success. These interventions helped to increase soil water retention and organic matter content and help prevent the little topsoil there was from draining off to the lowlands.

There are a variety of food plants available in conjunction with other non-plant based food sources that can provide a rich and healthy diet for many people in Asia. To meet the average daily requirement of vitamin A, requires the consumption of only 50 grams of cassava leaves, 73 g of dark green vegetable leaves, 78 g of sweet potato leaves or 133 g of taro leaves[23]. A far more effective approach to treating vitamin A deficiency is surely to focus on the utilization of these food plants, especially since many of them are fast disappearing in the fields.

According to Ardhendu Chaterjee of the Development Resource and Service Center (DRCSC) in Calcutta, India, the problem of malnutrition is linked not with rice per se, but with the way rice is produced now[24]. ″In the past, integrated rice-fish-duck-tree farming was a common

practice in wetlands. This does not only meet peoples’ food, fodder and fuelwood needs, but it provides superior energy-protein output to that obtained from today’s monoculture practice of growing high-yielding varieties. These fields also serve as the hatcheries for many fishes and aquatic organisms, which multiplied and spread to other wetlands. In the rainy season, these lowland rice fields often become connected to the water bodies like lakes and rivers. Agrochemicals applied in the paddy pollute these water-bodies and hence affect the entire food chain, thereby causing a decline in the overall fish, shrimp and frog supply – a resource freely available to the poor. Aquatic weeds which are rich in vitamin A are also becoming scarce." Sadly this is a scenario fast becoming common in most of Calcutta and over the whole Asian region.

In Bangladesh, UBINIG has been working with farmers to seek alternatives to chemical agriculture. Nayakrishi Andolon is a community-based system of organic farming being promoted by UBINIG and being practiced by more than 60,000 families in Bangladesh[25]. Many of these farmers, especially women, are aware of the nutritional importance of green leafy vegetables including wild species, and are strongly campaigning against the indiscriminate spraying of pesticides. In the villages, a wide range of uncultivated and cultivated plants and fishes are available which have been raised or harvested without the use of chemical fertilizers and pesticides.

Dr. Romy Quijano, a medical doctor who heads the Philippine Action Network, also believes that the sensible approach to preventing vitamin A deficiency is to see that the vulnerable sectors of the population are empowered enough to access natural sources of vitamin A. "Effective nutrition education is much better than adding yet another source of vitamin A which most likely will not be equitably distributed anyway; improving livelihood; providing better health care system; addressing malnutrition, communicable diseases and other illnesses that make children more vulnerable to vitamin A deficiency."[26]

Growing your vitamins[27]

Promoting kitchen gardens can be an effective way of addressing malnutrition. Traditional gardens provide valuable minerals, vitamins and amino acids, which make a substantial contribution to household food security. However, according to FAO’s 1996 State of the World Report on Plant Genetic Resources for Food and Agriculture, the contribution of such plants and systems to alleviating micronutrient deficiencies is greatly underappreciated.

SWANIRVAR, an NGO engaged in rural development, has been keen in promoting kitchen gardening for the past 5 years in 9 villages in 24 Parganas, West Bengal. Women were encouraged to grow fruits and vegetables in their backyards to supply or augment the nutritional needs of their families. After just two seasons of her garden, Kobita Mondall relates that, "We have already consumed all that we can, have given some to the neighbours and sold some in the market, and still we’re getting something from our backyard." Kobita’s garden consists of a 300 square foot plot near their home, planted with more than 30 kinds of fruits and vegetables.

CONCLUSION

While many doubt the ability of golden rice to eliminate vitamin A deficiency, the machinery is being set in motion to promote a GE strategy at the expense of more relevant approaches. The best chance of success in fighting vitamin A deficiency and malnutrition is to better use the inexpensive and nutritious foods already available, and in diversifying food production systems in the fields and in the household. The euphoria created by the Green Revolution greatly stifled research to develop and promote these efforts, and the introduction of golden rice will further compromise them. Golden rice is merely a marketing event. But international and national research agendas will be taken by it. The promoters of golden rice say that they do not want to deprive the poor of the right to choose and the potential to benefit from golden rice. But the poor, and especially poor farmers, have long been deprived of the right to choose their means of production and survival. Golden rice is not going to change that, and nor will any other corporately-pushed GE crop. Hence, any further attempts at the commercial exploitation of hunger and malnutrition through the promotion of genetically modified foods should be strongly resisted.

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CASE STUDY: GOLDEN RICE
The Biotechnology Outreach Education Center
At Iowa State University

IRRI Resources

Golden Rice Background

Golden Rice: The Eyes of the World are Watching
Download the PDF of this name from the linked site

Rice Research and Biotechnology

(The following is a statement on rice research involving biotechnology by Dr. Ronald Cantrell, the Director General of the Philippines-based International Rice Research Institute (IRRI). It may be freely reproduced and quoted.) From IRRI web site: www.irri.org/vis/line2001.htm

Rice, which helps feed almost half the people on the planet, is clearly not only the most important food staple in Asia, but also in the world today. The respected Washington Post newspaper recently described rice production as the world's single most important economic activity. Therefore, the present debate on the impact of biotechnology on rice production and rice cultures is clearly of crucial importance, not just to rice consumers and farmers but also to governments, nations and societies.

For 40 years, the International Rice Research Institute (IRRI) has been committed to evaluating different options and technologies that could help improve the lives of poor rice farmers and consumers via sustainable increases in production, improved management and fewer problems. Without doubt, biotechnology appears to provide exciting new opportunities in many of these areas.

However, IRRI's role is not to promote biotechnology or genetically modified organisms (GMOs). Its role is to objectively evaluate the new strategies and options that biotechnology may offer the rice industry and work with its partners in the National Agricultural Research Systems (NARS) of rice producing nations to see if such strategies are suitable and sustainable in different countries.

Put simply, IRRI seeks the freedom to find factual answers to the very questions posed by the debate on biotechnology, especially in relation to rice. While societies in Europe, North American and Japan must have the freedom to debate the pro and cons of their development and consumption of GMOs; it would be wrong for such debate to impede basic research to study whether such technologies are safe, sustainable and suitable for rice producing nations in the developing world. Such countries must be allowed the right to make their own decisions on biotechnology, which they cannot do if access to such technology is denied to them.

An excellent example of the perils of the biotechnology debate is Vitamin A rice. IRRI considers rice enriched with Vitamin A through genetic modification an exciting new option provided by biotechnology. However, many months of research are still required to establish if this so-called Golden Rice will ever make it into the bowls of rice consumers. Even before we get to questions on food safety we must find out if rice enriched with Vitamin A will yield well; will it be susceptible to pests and diseases; and will it be palatable. Then there are still more important questions in relation to food safety, consumer acceptability and biodigestability to be answered.

However, such is the media hype over Vitamin A rice that the debate is increasingly focused on whether it should be allowed on consumer tables, when we still have not answered far more basic production and development questions. Unless common sense prevails, Vitamin A rice may be an idea proposed and rejected, even before we know if it is possible.

Food safety is rightly a crucial issue in the biotechnology debate and must be fully addressed and resolved to the satisfaction of all sides. But it is vital that any concerns do not prevent the basic research we will need to answer the very questions such debate will generate. All the questions being raised by the biotechnology debate are far too important for us to guess the answers, or allow them to come from newspaper headlines and Internet campaigns.

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Golden Rice Background

(September 2000)

The inventors of ‘Golden Rice’ reached an agreement with Greenovation and Zeneca Agra Chemicals (now part of Syngenta), and are working with agencies throughout the world to enable the delivery of this technology free-of-charge for humanitarian purposes in the developing world. This will bring closer the 1982 vision of the Rockefeller Foundation who stimulated and funded this research into rice varieties which might offer global public health benefits. The collaboration will help the inventors of ‘Golden Rice’ to deliver their gift of nutritionally-enhanced rice to the developing nations of the world, bringing closer the health benefits for countries where vitamin A deficiency is the cause of 500,000 cases of irreversible blindness each year.

Dr. Gary Toenniessen, Director for Food Security at the Rockefeller Foundation, endorsed the agreement, saying, "this collaboration will speed the process of conducting all appropriate nutritional and safety testing and obtaining regulatory approvals. The agreement should help assure that ‘Golden Rice’ reaches those people it can help most as quickly as possible. We look forward to following the progress of this agreement as a possible model for other public-private partnerships designed to benefit poor people in developing countries."

The inventors of ‘Golden Rice,’ Professor Ingo Potrykus and Dr. Peter Beyer, will fulfill their commitment to give this technology to resource-poor farmers in developing countries, and contribute to poverty alleviation by increasing nutritional benefit from crops and income generation. They will be supported by Syngenta, which has contributed since 1996 to the EU carotenoid research project of which ‘Golden Rice’ was a part. Other specialist organizations, in Asia and elsewhere, are being requested to assist in the development and free delivery of ‘Golden Rice.’

Syngenta will explore commercial opportunities for sales of ‘Golden Rice’ into the growing market for healthy foods in developed countries, particularly in Japan and in North America. At the same time, Syngenta will provide regulatory, advisory and research expertise to assist in making ‘Golden Rice’ available in developing countries. ‘Golden Rice’ has the potential to provide massive benefit countering vitamin A deficiency-related diseases including irreversible blindness.

Other biotechnology companies are also supporting this project; for example, Monsanto will provide royalty-free licenses for all of its technology that can help further development of 'golden rice' and other pro- vitamin A-enhanced rice varieties.

The collaborators anticipate that ‘Golden Rice’ will not be available for local planting and consumption until 2003 at the earliest.

- ‘Golden Rice’ is a genetically modified rice with high levels of beta-carotene and other carotenoids. These are precursors to vitamin A which is deficient in the diet of people in highly populated areas of Asia, Africa

and Latin America. This agreement facilitates the delivery of a public health program aimed at countering deficiency diseases associated with vitamin A, which accounts for irreversible blindness in 500,000 children each year (Source: FAO).

- The inventors of ‘Golden Rice’ are Professor Ingo Potrykus of the Institute for Plant Sciences, Swiss Federal Institute of Technology, Zurich, Switzerland, and Dr. Peter Beyer of the Centre for Applied Biosciences, University of Freiburg, Germany.

- The ‘Golden Rice’ technology was developed with funding from the Rockefeller Foundation (1991-2002), the Swiss Federal Institute of Technology (1993-1996), the European Union under a European Community Biotech Programme (FAIR CT96 1633)(1996-2000) and the Swiss Federal Office for Education and Science (1996-2000).

- Syngenta is one of the world's leading agribusinesses. Syngenta ranks first in crop protection, and third in the high-value commercial seeds market. Pro forma sales in 1999 were approximately US $7 billion. Syngenta employs more than 20 000 people in over 50 countries. The company is committed to sustainable agriculture through innovative Research and Technology. Formed in November 2000 by the merger of Novartis Agribusiness and Zeneca Agrochemicals, Syngenta is listed on the Swiss stock exchange, in London, New York, Stockholm. Further information is available at www.syngenta.com.

- Greenovation (http://www.greenovation.com) was founded in Freiburg, Germany in September 1999. This university spin-off biotechnology company performs and funds research and development in plant biotechnology for agricultural and phytopharmaceutical applications. Agribiotech projects focus on metabolic engineering for increasing nutritional value and on stress tolerance. Greenovation also performs contract research and serves as a platform for development and out-licensing of university research projects to the life science industry.

- The Rockefeller Foundation is a philanthropic foundation (www.rockfound.org) affirming John D. Rockefeller's original mandate "to promote the well-being of mankind throughout the world." The Rockefeller Foundation is a knowledge-based, global foundation with a commitment to enrich and sustain the lives and livelihoods of poor and excluded people throughout the world.

Golden Rice: “The Eyes of the World Are Watching”

A major new chapter in IRRI′s work for the well-being of present and future generations of rice farmers and consumers opened up on 19 January 2001. The first research samples of the genetically modified provitamin A-enriched ″golden rice″ were delivered to the Institute′s researchers by their German coinventor, Dr. Ingo Potrykus. At the same time, the three genes that were used to achieve the transformation were also handed over to IRRI′s plant biotechnologists by the other co-inventor, Dr. Peter Beyer, from Germany.

Work began immediately on what amounts to a race against time, and golden rice is just a start: IRRI′s biotechnologists hope they will be able to create rice plants that deliver not only vitamin A but also iron and zinc *(see following story)* and, later, increased levels of protein.

The project stirs additional excitement because it represents the first major collaborative effort between the private-sector corporations that own many of the technologies and public-sector institutions such as IRRI that are capable of delivering their benefits, free of charge, to the poorest of the world′s poor.

The genetically modified golden rice contains beta-carotene, the precursor of vitamin A. It was developed with the sole intention of combating vitamin A deficiency, which is responsible for about half a million cases of irreversible blindness and up to one million deaths per year among the poorest people in the world.

Back to Basics

The first job is to investigate the safety and efficacy of golden rice. In charge of the pioneering project is IRRI′s chief plant biotechnologist, Dr. Swapan K. Datta. Although his work involves state-of- the-art genetic engineering, his first step involved a return to a basic understanding of the relationship between plants and their natural environment. From hundreds of popular, high-yielding indica rice varieties, he had to select the first candidates for genetic transformation. ″We don′t choose these plants randomly, with nothing more in mind than a successful transfer of genes,″ Dr. Datta explains. ″These must be popular and successful plants within particular environments, plants with which we are totally familiar, plants that we understand in totality.″

The first move was to identify those parts of Asia most in need of a vitamin A dietary boost. Then local plant breeders were asked to help.

″One plant that we have chosen is BR29, from Bangladesh. It has good cooking quality and moderate disease and pest resistance, and it is well and truly adapted to its environment. The farmers are happy with it, the market is happy with it, consumers are happy with it. We, and our counterparts in Bangladesh, know this plant through and through. All we have to do is engineer BR29 with the beta-carotene pathway and, since we are totally familiar with the original plant, we will be able to quickly but thoroughly analyze the outcome of the genetic modification, and make sure nothing else has changed. We won′t have to worry about pest and disease resistance, grain flavor, acceptability, or anything like that.″

Dr. Datta points out that biotechnology research is, in many respects, the same as any other field of plant science, in that it demands a thorough understanding of both the living raw material and its relationship with the natural, social, and commercial environments in which it is grown.

As well as Bangladesh, the search for candidate plants has centered on Vietnam, India, the Philippines, and Mozambique in East Africa. Between six and ten varieties will be chosen for the first batch.

″We have a fundamental responsibility,″ Dr. Datta says. ″We must be absolutely sure of the food safety and biosafety of the plants we produce.″ For each of the varieties chosen for transformation, large numbers of different ″lines″ will be engineered. Some may be unhealthy, others may not produce enough seed, some may not produce enough beta-carotene, but some will have the desired characteristics.

When acceptable plants have been developed, they will be released to the national agricultural research and extension systems in their countries of origin so that they can proceed with their own analyses.

Within One Year

Dr. Datta believes that, within one year, his team at IRRI will have the first batch of transgenic golden rice plants. They will probably still be at the tissue culture level, but some may be growing in soil within secure greenhouses.

The three vital genes, meanwhile, have been "stored" in living bacteria, which are also busily multiplying their number. When the time comes, a speck of tissue weighing about one millionth of a gram will be transferred from the bacteria to the chromosomes of rice embryos, and researchers will begin the process of coaxing new life from the resulting tissue.

Dr. Datta explains that rice plants already have the pathway for producing beta-carotene. "It exists in the roots, stems, and leaves, but not in the seeds, so by adding appropriate genes we are directing the pathway to accumulate beta-carotene in the rice seeds." The inventors, Drs. Ingo Potrykus and Peter Beyer, created their original vitamin A-enriched rice by implanting two genes from a daffodil and one more from a bacterium into a japonica rice variety called T309. It is not a commercial variety, but it is regularly used in biotechnology experiments because it is very responsive to tissue cultures.

Never Seen Such a Project

For the IRRI researchers involved, the golden rice project is already unlike anything they've ever worked on before. "I've never seen such a project, ever," Dr. Datta says. "The eyes of the world are watching. Everyone wants to know about the work. We all know that if this is successful it may open up a new dimension in research collaboration with the private sector.

"Frankly, I enjoy the pressure. I think the private companies who handed us this technology have adopted a fantastic humanitarian attitude. We now have the responsibility of carrying the work forward."

A humanitarian board, composed of several public- and private-sector organizations, has also been formed to help expedite the introduction of golden rice to developing countries. One of its seven members is IRRI's deputy director general for partnerships, Dr. William Padolina.

Drs. Karabi Datta, Swapan Datta, Ingo Potrykus, and Peter Beyer.

Development of Golden Rice and Free Transfer for Humanitarian Use in Developing Countries Abstract

by Ingo Potrykus

The social and the scientific challenge

Golden Rice represents a genetic engineering concept for the development of nutrient-dense staple crops to reduce malnutrition in developing countries. Major micronutrient deficiencies concern iron (1.4 billion women suffering from anemia) and vitamin A (134 million deficient and 500 000 blind children p.a.). Both deficiencies are especially severe, where rice is the major staple food.

Iron deficiency is the consequence of low amounts in rice of iron, presence of an inhibitor, and lack of iron re-sorption enhancing factors. Our task was, therefore, to increase iron content, to reduce the inhibitor, and to add a re-sorption-enhancing factor. The transgenic plants have, so far, a two-fold increase in iron, a seven-fold increase in re-sorption-enhancing cystein, and high inhibitor-degrading phytase activity.(*P. Lucca et al. TAG 102: 392-396, 2001*).

Rice endosperm is devoid of provitamin A. Introduction of transgenes for phytoene synthase, a phytoene / x-carotene double-desaturase, and lycopene cyclase completed the biochemical pathway to pro-vitamin A. Biochemical analysis of the polished rice kernels confirmed, that the yellow endosperm colour was due to varying amounts of provitamin A and further terpenoids of dietary interest. The present concentration of 2m/g b-carotene is already in the range of fortification levels, and will be further improved. (*Xudong Ye et al., Science 287: 303-305, 2000*).

The challenge of free donation to developing countries

To contribute to relieve from malnutrition in developing countries, Golden Rice must reach the poor free of charge and limitations. As the technology had used 70 IPR's, "freedom-to-operate for humanitarian use" became a major undertaking. The inventors solved the problem thanks to an alliance with Zeneca. The rights for commercial use were transferred to company which, in turn, supports the

humanitarian project. Thanks to this agreement the technology is now available via free licences to public research institutions for breeding and variety development. Transfer was, so far, to IRRI and PhilRice, and further arrangements are in progress with institutions China, India, Vietnam, Africa, and Latin America. This example of public-private partnership hopefully encourages others to follow.

The challenge of safe technology transfer and variety development

To ensure proper handling of the GMO material, a "Humanitarian Board" has been set up, to supervise the choice of partners, to support further improvement, to overlook needs, availability, biosafety, and socio-economic assessments, to coordinate the activities in the different countries, to support fund raising from public resources, to support deregulation, to facilitate exchange of information, and to mediate information of the public and general support for the humanitarian project.

The challenge of radical GMO opposition and consumer acceptance

A radical GMO opposition is the last major stumbling block, which might prevent that the poor in developing countries benefit from the project. Greenpeace is determined to prevent the use of Golden Rice, which it sees as a Trojan Horse. Greenpeace uses the tactics, to bypass the moral obligation, by claiming that Golden Rice is useless, because children would have to eat 9 kg/day, which is definitely wrong. The project will provide rice which is efficient on a 300 g/day basis. How much rice per day children would have to eat at the present prototype state, to prevent mortality and blindness, can only be determined in nutrition studies, which require field-grown material, and this is exactly what Greenpeace tries to prevent to date.

"Golden Rice and Beyond"

Ingo Potrykus, *Plant Physiol*, March 2001, Vol. 125, pp. 1157-1161

The GMO opposition, especially in Europe, has been extraordinarily successful in channeling all negative emotions associated with the supposed dangers of all new technologies as well as economic "globalization" onto the alleged hazards presented by the release of GMOs into the food chain. This is one reason why the story of "golden rice" is so important: In the short history of GMO research, "golden rice" is unique in having been embraced by the public-at-large.

INTRODUCTION

EMOTIONS ARE THE PROBLEM, NOT RATIONAL DISCOURSE

The term "golden rice" was coined by a Thai businessman who is active in initiatives aimed at reducing the birth rate, a major cause of the food security problem. As it turned out, the term "golden rice" has proven to be enormously successful in piquing the interest of the public. (I gave up tallying its mention in the popular media after more than 30 television broadcasts and 300 newspaper articles, but I am still busy with requests for interviews every week.) It is difficult to estimate how much of its celebrity stems from its catchy moniker and how much is from the technological breakthrough it represents. Needless to say, we live in a society that is strongly influenced (not to say manipulated) by the media. As the popular media live by selling news, "catchy" names are especially useful in attracting the interest of media consumers. The "story," however, must also be accompanied by an important message, in this case, that the purely altruistic use of genetic engineering technology has potentially solved an urgent and previously intractable health problem for the poor of the developing world. And this is my first message and my response to Chris Somerville's (2000) contribution: I, too, believe in the power of education and rational discourse. However, after more then 10 years on the frontlines of the public debate concerning genetically modified organisms (GMOs), I have learned that even with the help of the media, rational arguments succeed in influencing only a small minority of the public-at-large. In short, rational arguments are poor ammunition against the emotional appeals of the opposition. The reason for this, I believe, lies in its emotional appeal: People are truly concerned about the fate of blind children, and they are willing to support a technology that offers the children at risk the opportunity to avoid blindness.

I fully agree with the opinion of Maarten Chrispeels (2000) that "food security" for developing countries is one of the major challenges for mankind. I believe that scientists, as a privileged group of citizens, have more than an academic responsibility to advance

science: They must also accept a higher social responsibility and, wherever possible, use science to help solve the important problems not of industry, but of humanity. In this respect our scientific community is not in balance, and the public senses this intuitively. This, in turn, has made it easy for the GMO opposition to wage a war of propaganda against our work with arguments to the effect that we are only pretending to work for mankind, or are only satisfying our own egos, or are working merely for the profits of industry. For example, laypeople often ask if food security for developing countries is such a dire problem, and if scientists feel that GMO technology should be developed to contribute to a solution, then why are so many scientists working on Arabidopsis and so few on those plants that feed the poor? Of course, one can pontificate about the importance of basic research and how all the knowledge gained from Arabidopsis will ultimately expedite the improvement of major crops, but one realizes that the average citizen remains emotionally unswayed by such arguments. The public's skepticism is heightened by the fact that many scientists do have funds from industry and, therefore, have their sensibilities attuned to solutions of problems of interest to industry. Press releases from the agrobiotechnology industry relating to work on food security in developing countries are taken as disingenuous and serve only to foster ill will against the technology. So what can we do to improve the public sentiment about the technology? We need more examples of the "golden rice" type; namely, successful projects that were developed in public institutions using public funding that address an urgent need, are not solvable with traditional techniques, are being made available free of charge and limitations to the poor, and have no deleterious effects on the environment or human health.

GOLDEN RICE: THE SCIENTIFIC CHALLENGE

In the early 1990s, when we proposed to the Rockefeller Biotechnology Program (New York) to initiate a project to genetically engineer the provitamin-A pathway into the rice endosperm, we were fortunate that the Rockefeller Foundation had already had similar thoughts. The Foundation responded readily by organizing a brainstorming session. The verdict of this initial session was that such a project had a low probability of success, but that it was worth trying because of its high potential benefit. That is how Peter Beyer (University of Freiburg, Germany) and I got together, and this collaboration turned out to represent an ideal combination of skills. Peter Beyer was studying the regulation of the terpenoid pathway in daffodil and was working on the isolation of those genes we would need to establish the pathway in rice endosperm, whereas I had the engineering technology and was naïve enough to believe that the project was feasible. Naïveté was an important component because all those with appropriate knowledge had cited numerous reasons for skepticism. Our research determined that the last precursor of the pathway in endosperm was geranlygeranyl-pyrro-phosphate and, as a consequence, it theoretically should be possible to reach -carotene via four enzymes: phytoene synthase, phytoene desaturase, -carotene desaturase, and lycopene cyclase (Burkhardt et al., 1997). There were hundreds of scientific reasons why the introduction and coordinated function of these enzymes would not be expected to work. Those with the necessary scientific knowledge were right in not believing in the experiment. When we finally had "golden rice" I learned that even my partner, Peter Beyer, and the scientific advisory board of The

Rockefeller Foundation, except for Ralph Quatrano, had not believed that it could work. This exemplifies the advantage of my ignorance and naïveté: With my simple engineering mind I was optimistic throughout and therefore carried the project through, even when Rockefeller stopped funding Peter Beyer's group. Altogether it took 8 years, but the first breakthrough came when Peter Burkhardt of my laboratory recovered phenotypically normal, fertile, phytoene synthase-transgenic rice plants, which produced good quantities of phytoene in their endosperm (Burkhardt et al., 1997). This demonstrated two important facts: It was possible to specifically divert the pathway toward -carotene, and channeling a considerable amount of geranlygeranyl-pyrrophosphate away from the other important pathways had no severe consequences on the physiology and development. Xudong Ye of my laboratory did the crucial experiment: cotransformation with two Agrobacterium strains containing all the necessary genes plus a selectable marker. The resulting yellow-colored endosperm contained provitamin A and other terpenoids of nutritional importance and to everybody's surprise demonstrated that it was possible to engineer the entire biochemical pathway (Ye et al., 2000). A further key figure in our research was Salim Al-Babili from Peter Beyer's group who supplied all the successful constructs. The highest provitamin-A-producing line contains enough provitamin A (1.6 µg g1 endosperm) to expect a positive effect in relieving vitamin-A deficiency, but of course this has to be tested with bioavailability and feeding studies. However, these cannot be performed with the few grams of rice we can produce in our containment greenhouse. This will require hundreds of kilograms, which can be produced only in the field, and field release is still a problem in Europe, as it is in developing countries. (We are faced with a strong political movement for a 10-year moratorium in Switzerland.)

GOLDEN RICE: THE CHALLENGE OF INTELLECTUAL PROPERTY RIGHTS (IPRs)

"Golden rice" was developed to prevent vitamin-A deficiency in the poor and disadvantaged of developing countries. To fulfill this goal it has to reach the subsistence farmers free of charge and restrictions. Peter Beyer had written up a patent application, and Peter and I were determined to make the technology freely available. Because only public funding was involved, this was not considered too difficult. The Rockefeller Foundation had the same concept and the Swiss Federal Institute of Technology (Zurich) supported it, but the European Commission had a clause in its financial support to Peter Beyer, stating that industrial partners of the "Carotene Plus" project, of which our rice project was a small part, would have rights to project results. (The framework [IV and V] of European Union [EU] funding forces public research into coalitions with industry and thus is responsible for two very questionable consequences: Public research is oriented toward problems of interest to industry, and public research is losing its independence.) We did not consider this to be too big a problem because the EU funding was only a small contribution at the end of the project, but we soon realized that the task of technology transfer to developing countries, the international patent application, and the numerous IPRs and technical property rights (TPRs) we had used in our experiments were too much for two private persons to handle properly. We urgently needed a powerful partner (because of the deadline of the international patent application). In discussions with industry the definitions of "subsistence farmer" and "humanitarian use" were the most

difficult problems to be solved. We wanted a definition as generous as possible, because we not only wanted the technology to be free for small-scale farmers, but we also wanted to contribute to poverty alleviation via local commercial development. It is very fortunate that the company that agreed to the most generous definition was also the company that had legal rights because of its involvement in the EU project. This facilitated the agreement, via a small licensing company (Greenovation, Freiburg, Germany), with Zeneca (Fernhurst, UK). Zeneca received an exclusive license for commercial use and in return supports the humanitarian use via the inventors for developing countries. The cutoff line between humanitarian and commercial use is $10,000 (income from "golden rice"). This agreement also applies for all subsequent applications of this technology to other crop plants. It turned out that our agreement with Zeneca and the involvement of our partner in Zeneca, Adrian Dubock, were real assets in developing the humanitarian aspect of the project. Adrian was very helpful in reducing the frightening number of IPRs and TPRs. He also organized most of the free licenses for the relevant IPRs and TPRs such that we are now in the position of granting "freedom to operate" to those public research institutions in developing countries to proceed in introducing the trait into local varieties. Publicity sometimes can be helpful: Only a few days after the cover story about "golden rice" had appeared in Time, I had a phone call from Monsanto offering free licenses for the company's IPR involved.

MAKING BEST USE OF (NOT FIGHTING ABOUT) PATENTS HELPS THE POOR AND UNDERPRIVILEGED

At this point it is appropriate to add a more general comment on patents and the heavy opposition against patenting in life sciences. Because we did not know how many and which IPRs we had used in developing the "golden rice," and because further development for the humanitarian purpose required "freedom to operate" for the institutions involved, The Rockefeller Foundation commissioned an IPR audit through the International Service for the Acquisition of Agri-Biotech Applications. The outcome was shocking (International Service for the Acquisition of Agri-Biotech Applications brief nos. 20-2,000). There were 70 IPRs and TPRs belonging to 32 different companies and universities, which we had used in our experiments and for which we would need free licenses to be able to establish a "freedom to operate" situation for our partners, who were keen to begin further variety development. Because I was also blocked by an unfair use of a material transfer agreement, which had no causal relation to "golden rice" development, I was initially upset. It seemed to me unacceptable, even immoral, that an achievement based on research in a public institution and exclusively with public funding and designed for a humanitarian purpose was in the hands of those who had patented enabling technology earlier or who had sneaked in a material transfer agreement in the context of an earlier experiment. It turned out that whatever public research one was doing, it was all in the hands of industry (and some universities). At that time I was much tempted to join those who fight patenting. Upon further reflection, however, I realized that the development of "golden rice" was only possible because of the existence of patents. Much of the technology that I had been using was publicly available only because the inventors, by patenting, could protect their rights. Without patents, much of this technology would have remained secret. To take full advantage of available knowledge to benefit the poor, it

does not make sense to fight against patenting. It makes far more sense to fight for a sensible use of IPRs. Thanks to public pressure there is much goodwill in the leading companies to come to an agreement on the use of IPR/TPR for humanitarian use that does not interfere with commercial interests of the companies. An interesting discussion of this issue was part of a recent satellite meeting associated with the World Food Prize Symposium 2000 in Des Moines, Iowa (for more information, contact C.S. Prakash, e-mail: prakash@acd.tusk.edu).

We are now in a situation in which we have verbal confirmation for free licenses for humanitarian use for all intellectual and technical property involved. To date, details cannot yet be disclosed because some IPR owners prefer anonymity. Thanks to the interest of the agbiotech companies to use "golden rice" for better acceptance of the GMO technology, and thanks to the pressure against GMOs built up by the opposition, the IPR situation was easier to solve than expected.

GOLDEN RICE: THE CHALLENGE OF TECHNOLOGY TRANSFER

Having overcome the scientific problems, and having achieved freedom to operate, leaves technology transfer as the next hurdle. This is a far bigger task that anyone having no personal experience should assume. "Golden rice" so far consists of a series of provitamin-A-producing laboratory lines (TP 309). The characters of these lines must be transferred to as many locally adapted varieties and ecotypes in as many rice-growing countries as quickly as possible, and this transfer has to be organized such that all rules and regulations concerning the handling and use of GMOs will be strictly followed. Although we have had requests from many institutions in many countries, we believed it would be unwise to start the technology transfer on too large a scale. To aid in this endeavor, we have established a "Golden Rice Humanitarian Board" to help make the right decisions and to provide secretarial support. Again, our decision to work with Zeneca was extremely helpful. Adrian Dubock was willing to care for the task of the secretary. We have additional invaluable help from Katharina Jenny from the Indo-Swiss Collaboration in Biotechnology (ETH Zurich), an institution jointly financed by the Indian Department of Biotechnology (DBT; New Delhi, India) and the Swiss Development Corporation (Bern, Switzerland). Golden rice will be introduced into India in the established organizational framework of the Indo-Swiss Collaboration in Biotechnology, which has 10 years of experience in technology transfer. Thanks to this situation and thanks to the strong commitment of the DBT and the Indian Council for Agricultural Research (New Delhi, India), India will take a leading role and can serve as a model for other countries. The project will begin with a careful assessment of needs, an analysis and comparisons of the pros and cons of alternative measures, and setting a framework for the optimal and complementary use of "golden rice." Of course, there will be bioavailability, substantial equivalence, toxicology, and allergenicity assessments and we are grateful for offers from specialists to help. Careful socioeconomic and environmental impact studies will help to avoid any possible risk and make sure that the technology reaches the poor. Care will be taken that the material is given only to institutions that ensure proper handling according to rules and regulations. Traditional breeding will transfer the trait into locally best adapted lines, and again will make sure

that varieties important to the poor will be used and not fashionable varieties for the urban middle class. There will be also direct de novo transformation into important varieties, and this will be done with Man selection (Lucca et al., 2000). It is fortunate that the World Bank, the Indian Council for Agricultural Research, and DBT will probably share the costs for this development in India. Agreements have been established with several institutions in Southeast Asia, China, Africa, and Latin America and as soon as the written confirmation of the "freedom to operate" is in the hands of the "Humanitarian Board," material will be transferred.

GOLDEN RICE: THE CHALLENGE OF THE GMO OPPOSITION

A scientific breakthrough promises to add an essential dietary component (provitamin A) to one of the major food staples of the poor and developing world. Against all expectations, "freedom to operate" for humanitarian use has been achieved, enabling us to provide this technology free of charge and limitations, via national and international public research institutions and local rice breeders to the subsistence farmers in developing countries. Numerous rice-growing countries have expressed great interest in embracing this novel opportunity to help reduce malnutrition, and there is the institutional organization and the technical expertise to further develop this technology within the rice-growing countries. Is there any problem left that could interfere with the exploitation of "golden rice" to the benefit of the poor and disadvantaged in developing countries? It is unfortunate that the answer is yes: Greenpeace (www.greenpeace.org) and associated GMO opponents regard "golden rice" as a "Trojan horse" that may open the route for other GMO applications. As a consequence, by their singular logic, the success of "golden rice" has to be prevented under all circumstances, irrespective of the damage to those for whose interest Greenpeace pretends to act. The strategy is simple and has proven effective in Europe: undermining the acceptance of the consumer.

- "Golden rice" fulfills all the wishes the GMO opposition had earlier expressed in their criticism of the use of the technology, and it thus nullifies all the arguments against genetic engineering with plants in this specific example. Golden rice has not been developed by or for industry.
- It fulfills an urgent need by complementing traditional interventions.
- It presents a sustainable, cost-free solution, not requiring other resources.
- It avoids the unfortunate negative side effects of the Green Revolution.
- Industry does not benefit from it.
- Those who benefit are the poor and disadvantaged.
- It is given free of charge and restrictions to subsistence farmers.
- It does not create any new dependencies.
- It will be grown without any additional inputs.
- It does not create advantages for rich landowners.
- It can be resown every year from the saved harvest.
- It does not reduce agricultural biodiversity.
- It does not affect natural biodiversity.
- There is, so far, no conceptual negative effect on the environment.
- There is, so far, no conceivable risk to consumer health.

- It was not possible to develop the trait with traditional methods, etc.

Optimists might have expected, therefore, that the GMO opposition would have welcomed the advent of "golden rice." The GMO opposition, however, has been doing everything in its power to prevent "golden rice" from reaching subsistence farmers. This is because the GMO opposition has a hidden, political agenda. It is not so much the concern about the environment, or the health of the consumer, or the help for the poor and disadvantaged. It is a radical fight against a technology and for political success. This could be tolerated in rich countries where people have a luxurious life even without the new technology. However, it cannot be tolerated in poor countries, where the technology can make the difference between life and death or between health and severe illness.

However, because its acceptance has to be prevented under all circumstances, new arguments had to be invented. Thus, the opposition has argued that there is no need for "golden rice" because distribution of synthetic vitamin A works perfectly, or that nobody wants it because it tastes awful, or that people who eat "golden rice" will lose their hair and sexual potential! If you are interested in further misinformation of this kind, please consult various anti-GMO Web sites on the Internet.

One is tempted to ignore these aspersions, but this would be the wrong strategy. I am afraid that Greenpeace's specious arguments against "golden rice" will lead to unwarranted opposition in some developing countries. The consequence will be millions of unnecessarily blind children and vitamin-A deficiency-related deaths. For these reasons, we have the moral obligation to enlighten the public concerning the dangerous and immoral game the GMO opposition is playing. Anti-GMO activists are using all their political power (and funds collected ostensibly to protect whales and baby seals) to prevent a humanitarian project aimed toward helping millions of people who are malnourished and in grave danger of going blind. The GMO opposition often demands that scientists be held responsible for their actions. At the same time, however, they sidestep responsibility for the harm they cause to the disadvantaged and poor with their creation of a most hostile atmosphere against GMOs in Europe and elsewhere. In my judgment, hindering a person's access to life- or sight-saving food is criminal. To do this to millions of children is so criminal that it should not be tolerated by any society. It is unfortunate that our society, especially in Europe, is unable to recognize the true face of an organization that is using the mask of a few idealists risking their lives to save a few whales. The extent to which Greenpeace can act outside the law with impunity, and how skewed the mind of a European judge can be, was recently demonstrated in a judicial court in Nottingham, UK. The vandalism by Greenpeace activists of a government-supported experimental plot examining the possible effects of transgenic maize on the environment was ruled justifiable because it had been done "in the higher interest of mankind." In my view, the Greenpeace management has but one real interest: to organize media-effective actions for fund raising. The "golden rice" case hopefully may help to unmask the true and shameful face of Greenpeace, but only if the media are willing to take them to task.

I share the optimism of Norman Borlaug (2000) concerning the potential that GMO

technology has for improving the living conditions of the poor and underprivileged in developing countries. I admire his "standing up to the antiscience crowd." I wish that more internationally recognized personalities would demonstrate similar civil courage and that the scientific community (and the granting agencies) would find a bit more interest in contributing to solutions of the problems of food security. In the long run, our science has the best chance to survive if we win the support of the public. For this, it is no longer sufficient simply to do good science we must also be activists for and popularizers of the new technology.

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