

# Golden Rice Project

Golden Rice Humanitarian Board

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## Golden Rice is part of the solution

### Biofortified rice as a contribution to the alleviation of life-threatening micronutrient deficiencies in developing countries

#### A good start is a food start!

Dietary micronutrient deficiencies, such as the lack of vitamin A, iodine, iron or zinc, are a major source of morbidity (increased susceptibility to disease) and mortality worldwide. These deficiencies affect particularly children, impairing their immune system and normal development, causing disease and ultimately death. The best way to avoid micronutrient deficiencies is by way of a varied diet, rich in vegetables, fruits and animal products.

The second best approach, especially for those who cannot afford a balanced diet, is by way of nutrient-dense staple crops. Sweet potatoes, for example, are available as varieties that are either rich or poor in provitamin A. Those producing and accumulating provitamin A (orange-fleshed sweetpotatoes) are called *biofortified*,\* as opposed to the white-fleshed sweet potatoes, which do not accumulate provitamin A. In this case, what needs to be done is to introduce the biofortified varieties to people used to the white-fleshed varieties, as is happening at present in southern Africa by introducing South American varieties of orange-fleshed sweetpotatoes.

Unfortunately, there are no natural provitamin A-containing rice varieties. In rice-based societies, the absence of  $\beta$ -carotene in rice grains manifests itself in a marked incidence of blindness and susceptibility to disease, leading to an increased incidence of premature death of small children, the weakest link in the chain.

Rice plants produce  $\beta$ -carotene (provitamin A) in green tissues but not in the endosperm (the edible part of the seed). The outer coat of the dehusked grains—the so-called aleurone layer—contains a number of valuable nutrients, e.g. vitamin B and nutritious fats, but no provitamin A. These nutrients are lost with the bran fraction in the process of milling and polishing. While it would be desirable to keep those nutrients with the grain, the fatty components are affected by oxidative processes that make the grain turn rancid when exposed to air. Thus, unprocessed rice—also known as brown rice—is not apt for long-term storage.

Even though all required genes to produce provitamin A are present in the grain, some of them are turned off during development. This is where the ingenuity of the *Golden Rice* inventors, Profs Ingo Potrykus (formerly ETH Zurich) and Peter Beyer (University of Freiburg) comes into play. They figured out how to turn on this complex pathway again with a minor intervention.



The shocking fact is that, far from reaching the envisaged Millenium Development Goals, more than 10 million children under the age of five are still dying every year. A high proportion of those children die victims of common diseases that could be prevented through a better nutrition. This number has been equated with a '[Nutritional Holocaust](#)'. It is unfortunate that the world is not embracing more readily a number of approaches with the potential to substantially reduce the number of deaths. It has been calculated that the life of 25 percent of those children could be spared by providing them with diets that included crops biofortified with provitamin A (beta-carotene) and zinc. *Golden Rice* is such a biofortified crop. Those involved in the project are hopeful that in a near future *Golden Rice* will be growing in farmers' fields and helping to improve the diets of millions of people.



### Golden Rice is an effective source of vitamin A

#### $\beta$ -Carotene in *Golden Rice* is as good as $\beta$ -carotene in oil at providing vitamin A to children

August 2012. Researchers from USDA (Boston and Houston), Chinese institutions in Hunan, Beijing, and Hangzhou, and NIH (Bethesda), have determined that the  $\beta$ -carotene in *Golden Rice* is as effective as pure  $\beta$ -carotene in oil and better than that in spinach at providing vitamin A to children. A bowl of ~100 to 150 g cooked *Golden Rice* (50 g dry weight) can provide ~60% of the Chinese Recommended Nutrient Intake of vitamin A for 6-8-year-old children. The paper, with data based on a registered clinal trial, has been published by the [American Journal of Clinical Nutrition](#). And there is good reason to conduct these studies in China, considering the low vitamin A status of a great proportion of Chinese children (see [Nutrition and Health Status Report](#)).

#### Golden Rice has got what it takes

Back in 2009, researchers were able to demonstrate that *Golden Rice* was an effective source of vitamin A. This investigation was done with a group of healthy adult volunteers in the USA. The study showed that the  $\beta$ -carotene contained in *Golden Rice* was highly available and easily taken up into the bloodstream by the human digestive system. While foodstuffs of plant origin are the major contributors of  $\beta$ -carotene in the diet, these are often absent from the diet, for customary and economic reasons. And moreover, conversion of the provitamin A carotenoids contained in them is generally inefficient. Conversion factors for provitamin A carotenoids from various fruits is in the range of 13:1 for sweet potato, 15:1 for carrots, and between 10:1 and 28:1 for green leafy vegetables. With a conversion factor of 4:1 *Golden Rice* displays a comparatively very favourable conversion ratio. This study was published in the [American Journal of Clinical Nutrition](#) in 2009.

#### Biotechnologie Seiten

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*Golden Rice* grains are easily recognisable by their yellow to orange colour. The stronger the colour the more  $\beta$ -carotene. While a yellow rice is still unfamiliar to most of us, it is hoped that the pleasant colour will help promote its adoption. Would you believe that once upon a time carrots were white or purple? Orange-coloured carrots are the product of a mutation selected by a Dutch horticulturist a few hundred years ago, because it was the colour of the Dutch Royal House of Orange-Nassau!

\*Welch RM and Graham RD (2004) Breeding for micronutrients in staple food crops from a human nutrition perspective. *J Exp Bot* 55:353-364.

## Quantum leap:

### *Golden Rice* accumulates provitamin A ( $\beta$ -carotene) in the grain

Rice produces  $\beta$ -carotene in the leaves but not in the grain, where the biosynthetic pathway is turned off during plant development. In *Golden Rice* two genes have been inserted into the rice genome by genetic engineering, to restart the carotenoid biosynthetic pathway leading to the production and accumulation of  $\beta$ -carotene in the grains. Both genes are naturally involved in carotene biosynthesis. The difference here is that the reconstructed pathway is not subject to downregulation, as usually happens in the grain.

Since a prototype of *Golden Rice* was developed in the year 2000, new lines with higher  $\beta$ -carotene content have been generated. The intensity of the golden colour is a visual indicator of the concentration of  $\beta$ -carotene in the endosperm. Our goal is to make sure that people living in rice-based societies get a full complement of provitamin A from their traditional diets. This would apply to countries such as India, Vietnam, Bangladesh, the Philippines, and Indonesia. *Golden Rice* could still be a valuable complement to children's diets in many countries by contributing to the reduction of clinical and sub-clinical vitamin A deficiency-related diseases.

Many people are aware that vitamin A has something to do with vision, especially at night. But many are not aware of the central role it plays in maintaining the integrity of the immune system. According to the World Health Organization, dietary vitamin A deficiency (VAD) compromises the immune systems of approximately 40 percent of children under the age of five in the developing world, greatly increasing the risk of severe illnesses from common childhood infections, thus causing hundreds of thousands of unnecessary deaths among them.

In remote rural areas *Golden Rice* could constitute a major contribution towards sustainable vitamin A delivery. To achieve this goal a strong, concerted, and interdisciplinary effort is needed. This effort must include scientists, breeders, farmers, regulators, policy-makers, and extensionists. The latter will play a central role in educating farmers and consumers as to their available options. While the most desirable option would be a varied and adequate diet, this goal is not always achievable, at least not in the short term. The reasons are manifold, ranging from tradition to geographical and economical limitations. *Golden Rice* is a step in the right direction in that it does not create new dependencies or displace traditional foodstuff.

## Golden Rice, the real thing

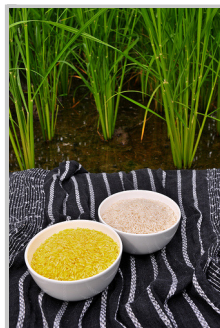
### Who is behind *Golden Rice*



*Golden Rice* is the brainchild of Profs Ingo Potrykus (ETH Zurich) and Peter Beyer (Univ of Freiburg), who in a

collaborative effort were able to show that production of  $\beta$ -carotene could be turned on in rice grains using a minimum set of transgenes. From the beginning *Golden Rice* was conceived as a public-good project under the guidance of the [Golden Rice Humanitarian Board](#). The initial prototype ([Science 2000](#)) was further improved in terms of provitamin A ( $\beta$ -carotene) content by a research team at Syngenta ([Nature Biotechnology 2005](#)). From 2005 to 2010 the project dealt mainly with breeding the novel trait into locally adapted rice varieties. Along its way the project has been funded by a number of donors, including the Rockefeller Foundation, the Bill & Melinda Gates Foundation (Grand Challenges in Global Health Initiative), USAID, the Philippine Department of Agriculture, HarvestPlus, the European Commission, Swiss Federal Funding, and the Syngenta Foundation. Several companies have provided free access to their patented technologies necessary to generate *Golden Rice*. Current breeding and field trialling work is being carried out by the [International Rice Research Institute \(IRRI\)](#) in the Philippines together with PhilRice, the [Philippine Rice Research Institute](#). PhilRice is preparing a submission to the regulatory authority of the Philippines in 2013, which could lead to initial releases to farmers in 2014. And the work doesn't stop there. If the first hurdles are taken successfully, then *Golden Rice* will be heading towards China, India, Bangladesh, Indonesia, and Vietnam. In those countries national programs are already involved in laying out the necessary groundwork.

### Helen Keller International



[Helen Keller International \(HKI\)](#) has been working to address vitamin A deficiency (VAD) for well over 30 years and continues to work with local partners to deliver vitamin A to those in need through implementation of complementary interventions including vitamin A supplementation, promotion of optimal

breastfeeding, dietary diversification and food fortification. HKI considers that *Golden Rice* may have the potential to be another complementary vehicle to combat vitamin A deficiency, particularly among those who are not reached by other mechanisms. Hence, HKI is working on determining the efficacy of *Golden Rice* to improve the vitamin A status in deficient individuals. If proved efficacious and once approved by the regulatory bodies, HKI would proceed to include *Golden Rice* in their VAD combatting toolbox. According to HKI 190 million pre-school children and 19 million pregnant women are currently vitamin A deficient. Each year, an estimated 670,000 children will die from VAD, and 350,000 will go blind. In the Philippines, approximately 1.7 million children aged 6 months to 5 years and an additional three out of every ten school-aged children have VAD, as do one out of every five pregnant and lactating mothers. In Bangladesh, one in every five of pre-school aged children are estimated to have VAD. In these, as almost in all developing countries, effective distribution systems for vitamin A supplementation are not in place to reach all people in need adequately and consistently. Supplementation programs incur high logistic costs that not every region can afford.

## *Golden Rice* will reach those who need it at no additional cost

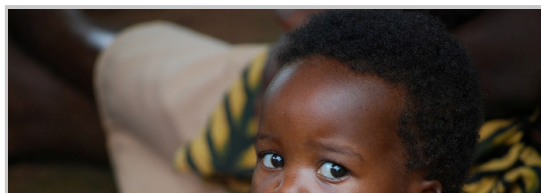
### Growers will be able to reuse their seed as they please

Those most in need of this new seed-based technology are those who can least afford buying an adequate diet, rich in essential nutrients. This has been taken into consideration by the creators of *Golden Rice*, Profs Peter Beyer and Ingo Potrykus, and the crop protection company Syngenta, who have worked together to make the latest, improved version of *Golden Rice* available for humanitarian use in developing countries, free of charge.

The *Golden Rice* Humanitarian Board encourages further research to determine how the technology may play a part in the ongoing global effort to fight Vitamin A Deficiency in poor countries. While *Golden Rice* is an exciting development, it is important to keep in mind that malnutrition is to a great extent rooted in political, economic and cultural issues that will not be solved by a technical fix. Yet *Golden Rice* offers people in developing countries a valuable and affordable choice in the fight against the scourge of malnutrition.

This site is maintained by the *Golden Rice* Humanitarian Board for the purpose of providing information on the background and progress of the *Golden Rice* Humanitarian Project.

**Eat orange! We really mean it!**





Eat orange! A motto promoted by [HarvestPlus](#)

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