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NUTRIENT-ENRICHED "GOLDEN RICE" APPROVED FOR COMMERCIAL CULTIVATION BY PHILIPPINES

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GOLDEN RICE AND THE PAST

Rice (*Oryza sativa* L.) is a staple food crop for more than half of the world's population, making up 30-72% of the energy intake for Asian peoples and making it an excellent source for targeting vitamin deficiencies. Golden rice is a variety of rice produced through genetic engineering to biosynthesize beta-carotene (a precursor of vitamin-A) in the edible parts of rice to make it more nutritional. Golden rice is able to combat vitamin-A deficiency (VAD) and thanks to the inclusion of beta-carotene in it. This pigment is red-orange in color and is found in many plants, most famously in carrots (hence the name). The human body converts beta-carotene into vitamin-A, which is an important nutrient for the immune system, for vision and for digestion.

The search for golden rice was started as a **Rockefeller Foundation initiative** in 1982.Peter Bramley discovered in the 1990s that a single phytoene desaturase gene (bacterial *CrtI*) can be used to produce lycopene from phytoene in GM tomato, rather than having to introduce multiple carotene desaturases that are normally used by higher plants. Lycopene is then cyclized to beta-carotene by the endogenous cyclase in golden rice. The scientific details of the rice were first published in *Science* in 2000, the product of an eight-

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year project by **Ingo Potrykus of the Swiss Federal Institute of Technology and Peter Beyer of the University of Freiburg**. At the time of publication, golden rice was considered a significant breakthrough in biotechnology, as the researchers had engineered an entire biosynthetic pathway. The first field trials of golden rice cultivars were conducted by Louisiana State University Agricultural Center in 2004. Additional trials have been conducted in the Philippines, Taiwan, and in Bangladesh (2015). Field testing provides an accurate measurement of nutritional value and enables feeding tests to be performed. Preliminary results from field tests have shown field-grown golden rice produces 4 to 5 times more beta-carotene than golden rice grown under greenhouse conditions. Golden rice differs from its parental strain by the addition of three beta-carotene biosynthesis genes. The parental strain can naturally produce beta-carotene in its leaves, where it is involved in photosynthesis. However, the plant does not normally produce the pigment in the endosperm, where photosynthesis does not occur.

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PHILPPINES IS THE WORLD'S FIRST COUNTRY TO APPROVE GOLDEN RICE

The **Philippines on July 23, 2**021, become the world's first country to approve the commercial production of genetically modified 'golden rice'. Health experts believe that golden rice developed by Philippines will help to fight childhood blindness and save lives in the developing world. Golden Rice was developed by the **Department of Agriculture-Philippine Rice Research Institute (DA-PhilRice)** in partnership with the **International Rice Research Institute (IRRI)** to contain additional levels of beta-carotene, which the body converts into vitamin-A. The Department of Agriculture-Philippine Rice Research Institute and International Rice Research Institute (IRRI) has spent 20 years for developing the golden rice. The rice has been named golden rice because of its bright yellow hue. Golden rice is the first genetically modified rice approved for commercial propagation in South and Southeast Asia. Around one in five children from the poorest communities in the Philippines suffer from vitamin A deficiency (VAD), which affects an estimated 190 million children worldwide. The condition is the most common cause of childhood blindness, as well as a contributing factor to a weakened immune system. Golden Rice is genetically engineered to provide up to 50 per cent of the estimated average requirement (EAR) for vitamin-A of young children, the age group most susceptible to VAD in the Philippines. The regulatory success of Golden Rice demonstrates the research leadership of DA-PhilRice and the robustness of the Philippine biosafety regulatory system. This new variety has already received food safety approvals from regulators in Australia, New Zealand, Canada, and the United States of America but the Philippines is the first country to approve commercial cultivation. Golden Rice is also currently undergoing final regulatory review in Bangladesh.

The Director General of IRRI, Dr. Jean Balie has said that "This milestone puts the Philippines at the global forefront in leveraging agriculture research to address the issues of malnutrition and related health impacts in a safe and sustainable way". "We are committed to ensuring the highest quality of seed for farmers and a safe and nutritious food supply for all Filipinos," said Dr. John de Leon, Executive Director of DA-PhilRice. A comprehensive quality assurance and stewardship program for Golden Rice will be set in place, covering the entire value chain from seed production, to post-harvest processing, to marketing. DA-PhilRice has started working with local partners to identify market- and program-based

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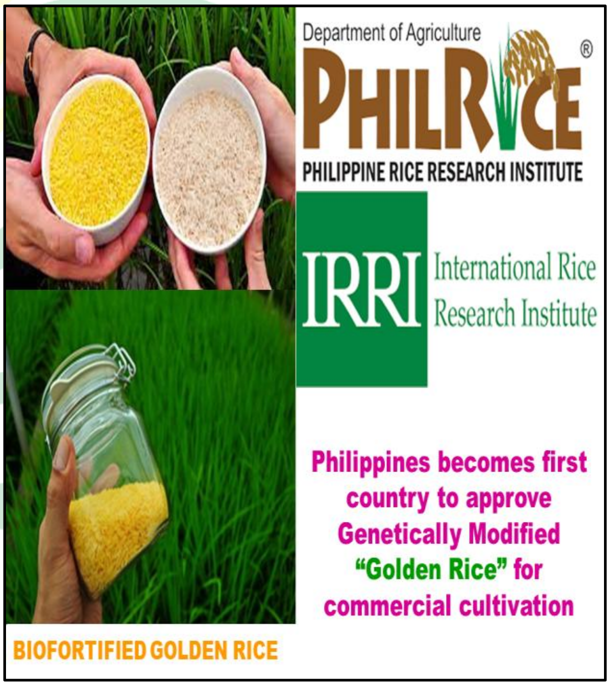
approaches for bringing Golden Rice first to selected communities with a high prevalence of VAD and other associated micronutrient deficiencies. It is also increasing the volume of available seed and other remaining activities necessary for moving Golden Rice into farmers' fields. "The last-mile delivery of Golden Rice is just one component of a food systems approach to nutrition, which also includes community outreach and extension services, and improved market access for farmers," said Dr. Ajay Kohli, IRRI Director for Research. By improving rice varieties that address farmer, consumer, and environment needs, precision breeding innovations such as genetic engineering and gene editing can open up pathways for more inclusive participation in the food system. "It's a really significant step for our project because it means that we are past this regulatory phase and golden rice will be declared as safe as ordinary rice," Russell Reinke of the Philippine-based International Rice Research Institute (IRRI) told. "The only change that we've made is to produce beta-carotene in the grain," Reinke said. The farmers will be able to grow them in exactly the same way as ordinary varieties as it doesn't need additional fertilizer or changes in management and it carries with it the benefit of improved nutrition.

Golden rice Breeder Dr. B.P. Mallikarjuna Swamy examining GOLDEN RICE at the IRRI Transgenic screen house in Los Banos, Laguna province, south of Manila, Philippines

Source: IRRI (AFP)



DESIGNING GOLDEN RICE THROUGH GENETIC ENGINEERING

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Rice endosperm does not naturally produce -carotene; instead, it produces geranylgeranyl diphosphate (GGPP) which is an early precursor of -carotene. Therefore, it was necessary to use recombinant DNA techniques, not conventional breeding, to develop a rice endosperm that would produce -carotene. To convert geranylgeranyl diphosphate to carotene, four additional plant enzymes were needed: phytoene synthase, phytoene desaturase, carotene desaturase, and lycopene -cyclase. These enzymes were identified and their genes were isolated from various plants and bacterium. In 2000, Ye *et al.* put all this information together. The phytoene desaturase and -carotene desaturase were circumvented by using a bacterial enzyme, carotene desaturase, that gave the combined result. The entire -carotene biosynthesis pathway (three genes on three vectors) were transformed into rice endosperm using *Agrobacterium*. The results were yellow endosperms and gained the name Golden Rice. The yellow color was from the -carotene formed in the endosperm. Beyer *et al.* (2002) had refined the technique and were able to transform the -carotene biosynthesis pathway by either single- or co-transformations of cDNA constructs. They used 2 genes from daffodil (*Narcissus psuedonarcissus*) for phytoene synthase (*psy*) and lycopene cyclase (*lcy*) and 1 gene from a soil bacterium (*Erwinia uredovora*) for carotene desaturase (*crt1*). The *psy* and *crtI* genes were transferred into the rice nuclear genome and placed under the control of an endosperm-specific promoter, so that they are only expressed in the endosperm. The exogenous *lcy* gene has a transit peptide sequence attached, so it is targeted to the plastid, where geranylgeranyl diphosphate is formed. The bacterial *crtI* gene was an important inclusion to complete the pathway, since it can catalyze multiple steps in the synthesis of carotenoids up to lycopene, while these steps require more than one enzyme in plants. The resulting Golden Rice yielded 1.6-2.0 µg -carotene/g of dry rice. With a conversion factor of 6 µg of -carotene to 1 µg of retinol, 200 g/day of rice would yield 70 µg /day of retinol which is not enough to fulfill the recommended daily allowance of retinol (1000800 RE).

WHY GOLDEN RICE IS MORE NUTRITIONAL COMPARED TO NORMAL WHITE RICE?

Swamy*et al.* (2019) analysed the grain samples for key nutritional components, including proximates, fiber, polysaccharides, fatty acids, amino acids, minerals, vitamins, and antinutrients. The only biologically meaningful difference between Golden rice eventGR2E

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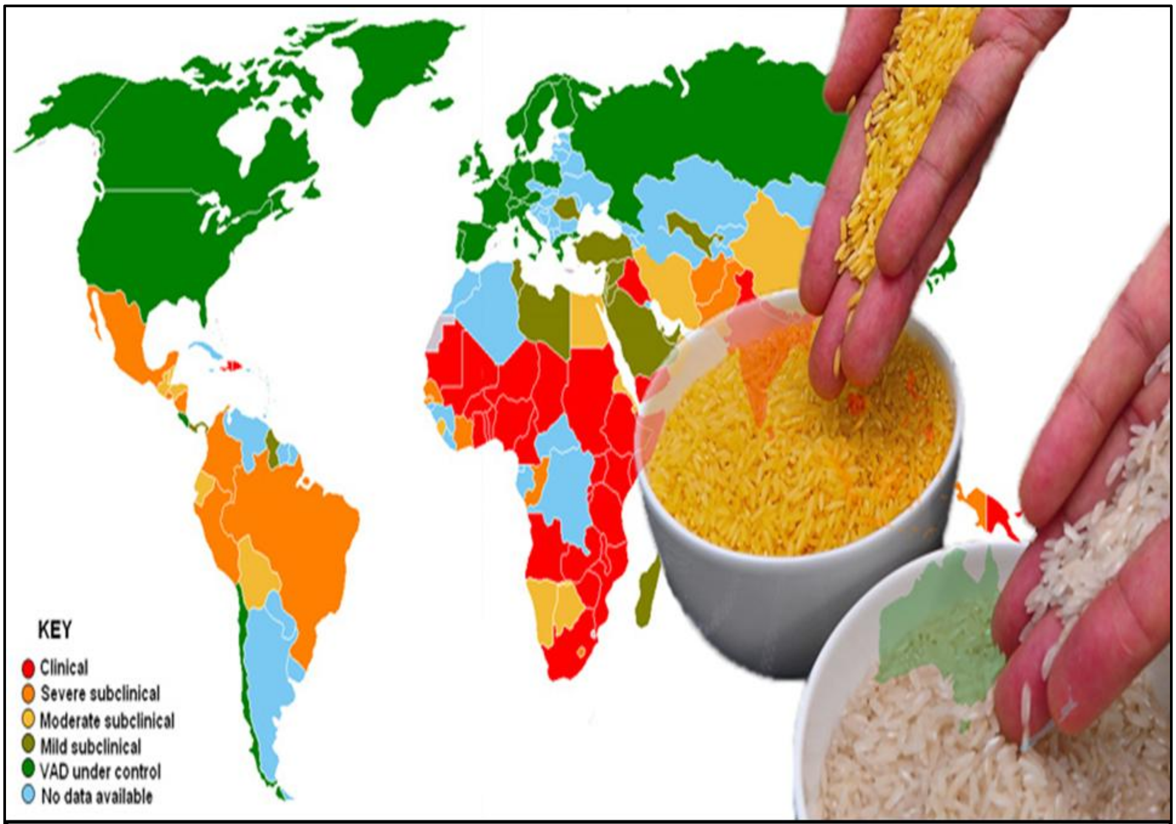
and control rice was in levels of β-carotene and other provitaminA carotenoids in the grain. Except for β-carotene and related carotenoids, the compositional parameters of GR2E rice were within the range of natural variability of those components in conventional rice varieties with a history of safe consumption. Mean provitaminA concentrations in milled rice of GR2E can contribute up to 89-113% and 57-99% of the estimated average requirement for vitamin A for preschool children in Bangladesh and the Philippines, respectively. In normal rice, beta-carotene is produced in the plant but not in the grain. The researchers have developed the golden rice in a way that it produces beta-carotene in the grain. Golden rice has been developed to provide 50 per cent of the estimated requirement for vitamin-A in young children.

GOLDEN RICE: A BEST SUPPLIMENT TO VITAMIN-A DEFICIENCY (VAD)

Vitamin-A (retinol) is crucial for the healthy functioning of the immune system and overall growth and development. Vitamin-A is an essential vitamin used in the retina to create pigment; therefore, it promotes good day and night vision. Vitamin A deficiency can cause visual impairment which can ultimately lead to blindness. It is intended to produce a fortified food to be grown and consumed in areas with a shortage of dietary vitamin A, a deficiency which each year is estimated to kill 670,000 children under the age of 5 and cause an additional 500,000 cases of irreversible childhood blindness and millions of cases of xerophthalmia annually according to the estimate of World Health Organization (WHO).The research that led to golden rice was conducted with the goal of helping children who suffer from vitamin-A deficiency (VAD). In 2005, 190 million children and 19 million pregnant women, in 122 countries, were estimated to be affected by VAD. Because many children in VAD-affected countries rely on rice as a staple food, genetic modification to make rice produce the vitamin A precursor beta-carotene was seen as a simple and less expensive alternative to ongoing vitamin supplements or an increase in the consumption of green vegetables or animal products.



Scenario of Vitamin-A deficiency

Golden Rice can be beneficial because it serves as a source of supplementary vitamin-A and -carotene. High intake of specific vitamins and minerals, such as carotenoids, vitamin-A and -carotene, have been linked with reducing risk of coronary artery disease, specific cancers, and macular degeneration. Therefore, a staple foodlike golden rice, can serve as a means to address the problem of vitamin-A deficiency.