

The background of the image is a close-up, slightly blurred photograph of Golden Rice. On the left side, there are green rice stalks with long, slender leaves and clusters of golden-yellow rice grains. The right side of the image is dominated by a dense, out-of-focus field of golden-yellow rice grains, creating a warm, textured background.

Golden Rice

What is Golden Rice ?

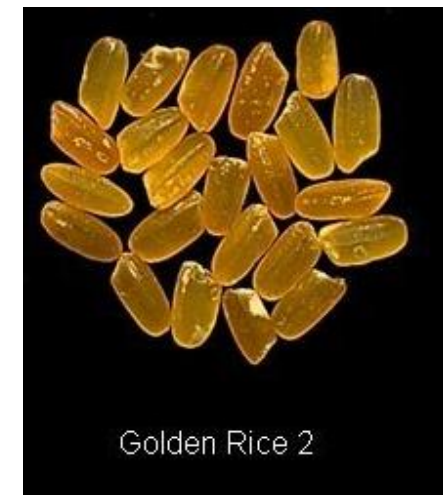
- Golden rice is a form of rice with biosynthesis of beta-carotene (a form of vitamin A).
- Golden rice is produced through genetic engineering.
- Beta-carotene gives golden rice its “golden” or “yellow” colouring. White rice, on the other hand, does not contain carotenoids (i.e. beta carotene) and therefore lacks that “golden” colouring.
- When we consume golden rice, the beta-carotene either accumulates in our fatty tissues or is transformed into vitamin A.
- Golden rice is rich in beta-carotene and also easily processed by your digestive system.
- The natural fatty lipids in golden rice aid in the absorption of beta-carotene, even when little or no oil is added to it.
- Other benefits of golden rice include: increased energy (which comes from the starch located within the rice) and a low fat content.



Golden rice and Vitamin A

- It is important to understand that golden rice is considered a type of genetically modified rice (GMO).
- It is a fortified food that is produced to combat a vitamin A deficiency in areas where this vitamin is scarce.
- More and more people are being diagnosed with a vitamin A deficiency. In fact, young children are the most vulnerable to vitamin-related deficiencies.
- Approximately 1 million children die of a vitamin A deficiency each year. A vitamin A deficiency can severely affect a child's eyesight; weaken his/her immune system function and increase his/her risk of chronic conditions.
- Moreover, in underdeveloped countries, approximately half-a-million people, mostly children, develop blindness, associated with a vitamin A deficiency.
- Approximately 50% of those diagnosed with this type of deficiency related blindness die a year or two after becoming blind (Wright, Hinchliffe & Adams, 2005).
- To make matters worse, approximately 10 million children suffer from malnutrition every year. In severe cases, the malnutrition turns deadly (Wright, Hinchliffe & Adams, 2005).

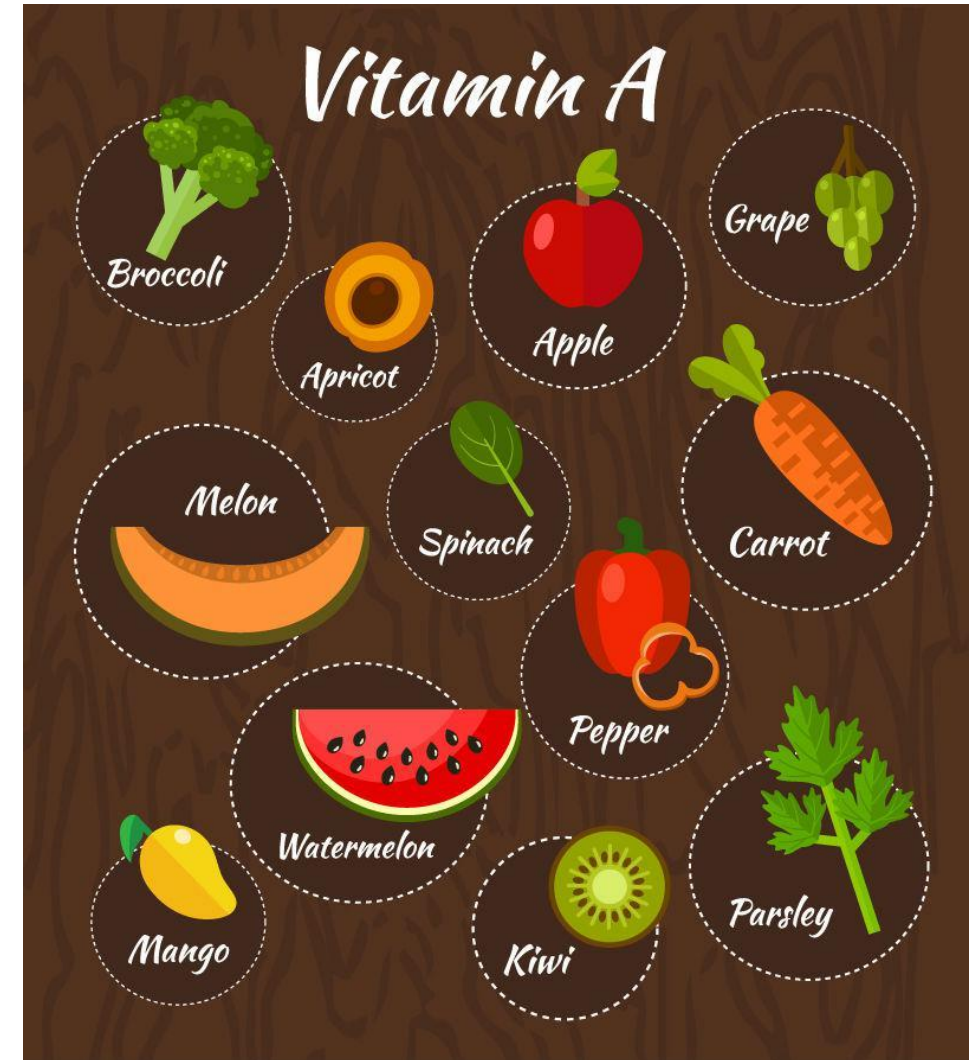
- Low levels of vitamin A can negatively affect our immune system and cause serious illnesses and/or death.
- In the last few years, an increase in child deaths (under the age of five) has been linked to deficiencies in vitamin A, protein and zinc.
- The newest form of golden rice varies from the original strain through the addition of three new beta-carotene genes.
- In addition, this newest form of golden rice (invented in 2005) is referred to as Golden Rice 2 because it contains higher levels of beta-carotene than the original golden rice.
- Golden rice was originally developed, with the support of environmental activists, to improve, enrich, support and enhance health and well-being and it has accomplished its goals.
- The invention of golden rice has lowered the risk of a variety of health conditions and ailments. Golden rice has been tested in the Philippines for over two seasons on two different locations in 2012.



White rice vs Golden Rice

Carotenoids and Vitamin A

- Carotenoids, like beta-carotene, are the colourful plant pigments normally found in a variety of fruits and vegetables (carrots, tomatoes, broccoli, cantaloupe, sweet potatoes, etc.).
- It is important to note that plants lack the direct form of vitamin A, but do contain beta-carotene, a form of vitamin A.
- Our body metabolizes vitamin A when we consume foods rich in beta-carotene.
- Vibrant fruits and vegetables, along with meats contain vitamin A.
- If we adhere to a poor diet, we have an increased risk of life-threatening medical conditions and diseases associated with a vitamin A deficiency.



Golden Rice History

- Golden rice was invented in 1999 by **Peter Beyer**, professor at the University of Freiburg, Germany and **Ingo Potrykus**, professor at the Swiss Federal Institute of Technology at the Institute for Plant Sciences.
- Golden rice was originally produced in 1982 as an initiative for the Rockefeller Foundation.
- Beyer and Potrykus developed a rather complex biosynthetic crop that could be altered to produce healthier and more abundant grains like rice.



Peter Beyer and Ingo Potrykus

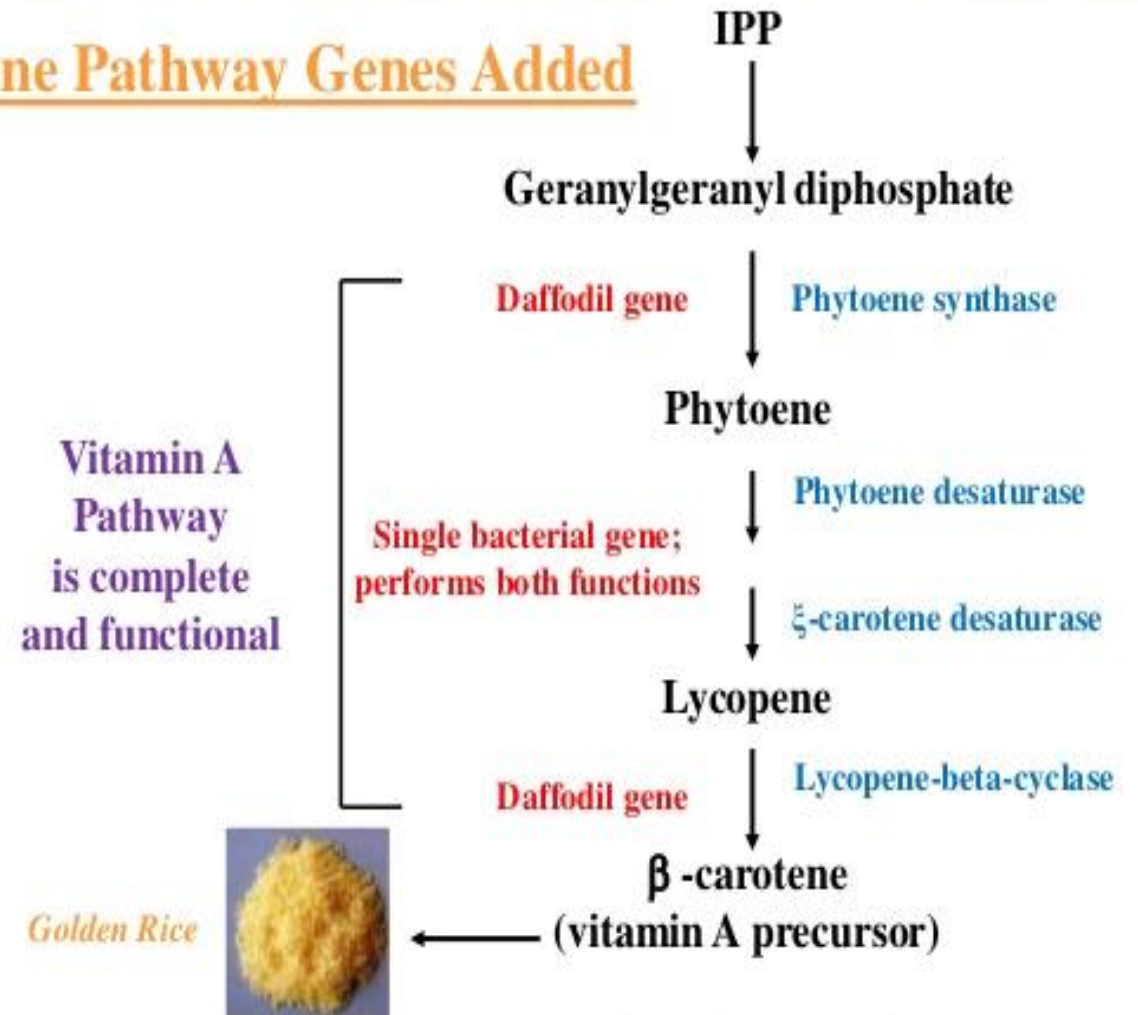
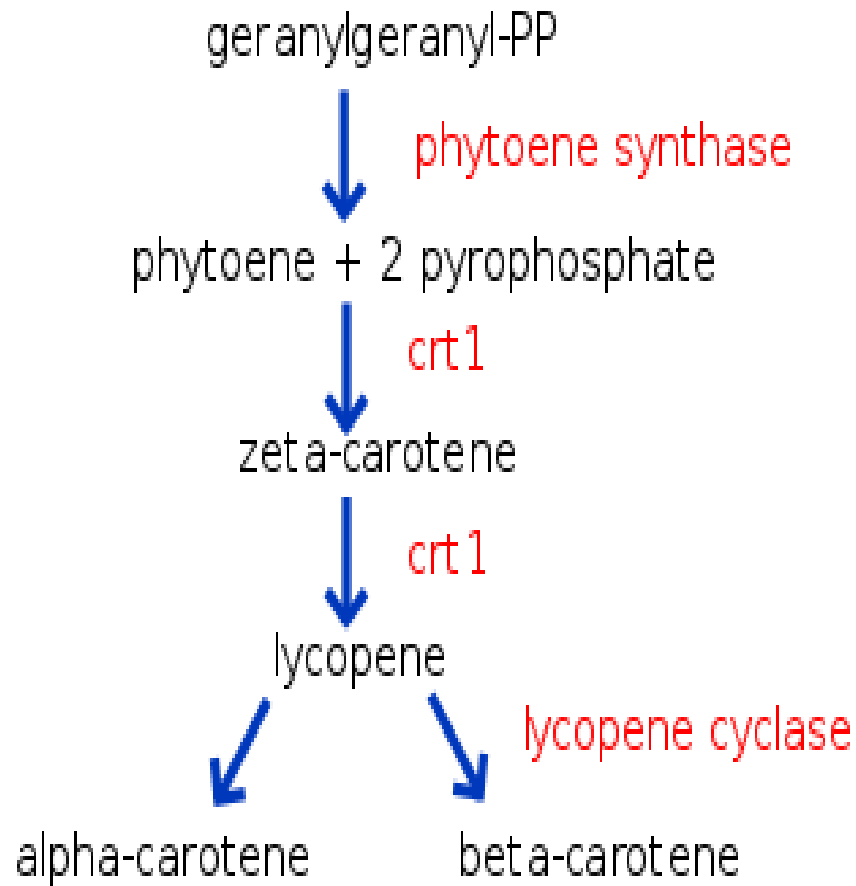
The Science of *Golden Rice*

Metabolic engineering

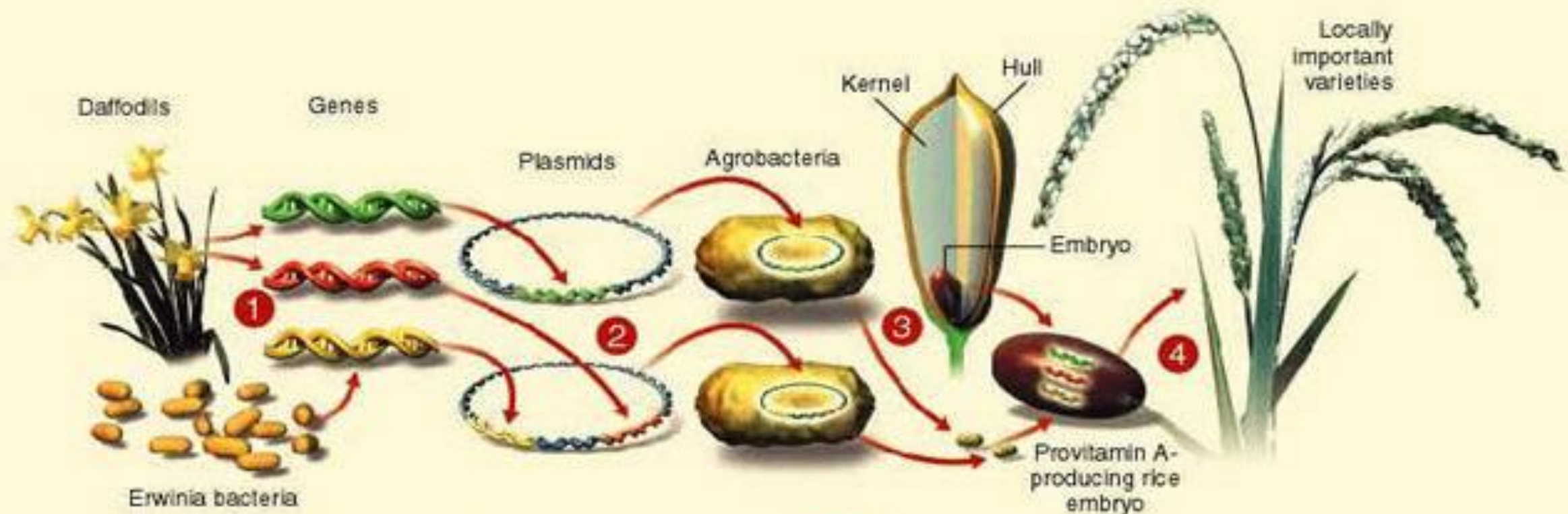
- *Golden Rice* technology is based on the simple principle that rice plants possess the whole machinery to synthesise β -carotene, and while this machinery is fully active in leaves, parts of it are turned off in the grain.
- By adding only two genes, **a plant phytoene synthase (psy)** and **a bacterial phytoene desaturase (crt I)**, the pathway is turned back on and β -carotene consequently accumulates in the grain.
- Carotenoids and their derivatives include a vast number of molecules and accordingly a great number of enzymes and cofactors.
- Only a small number of carotenoids namely those with at least one unsubstituted β -ionone ring, such as β -carotene have provitamin A activity.
- Compounds derived from this important pathway include plant hormones, like abscisic acid, the strigolactones and gibberellins.
- Tocopherols (vitamin E), chlorophylls and quinones employ the pathway intermediate GGPP as a building block for their synthesis.

The Golden Rice: Solution

β -Carotene Pathway Genes Added



Presence of pro-vitamin -A gives rice grains a **yellowish-orange** color, thus, the name '**Golden Rice**.'

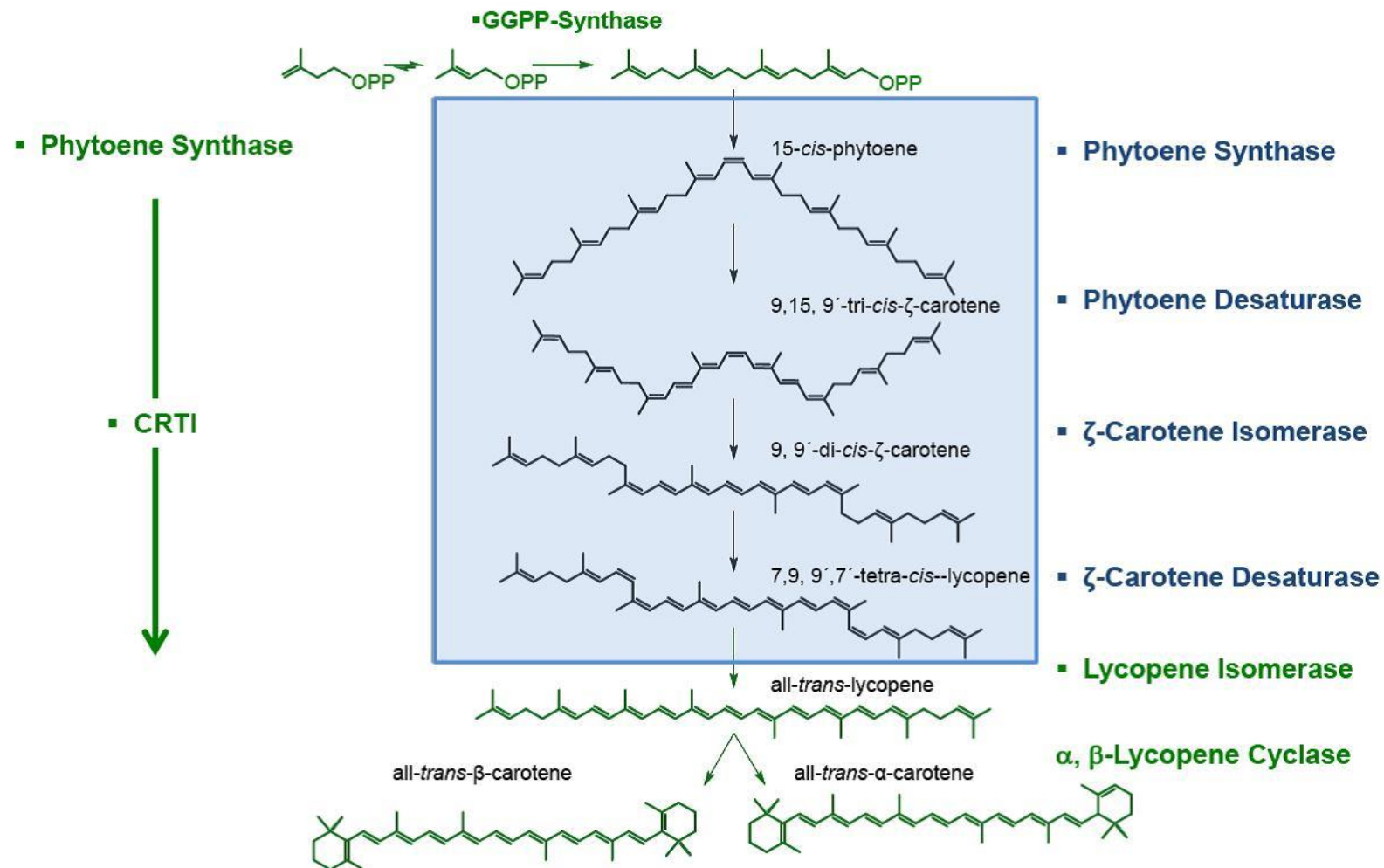


1 The genes that give golden rice its ability to make beta-carotene in its endosperm (the interior of the kernel) come from daffodils and a bacterium called *Erwinia ureidovora*.

2 These genes, along with promoters (segments of DNA that activate genes), are inserted into plasmids (small loops of DNA) that occur inside a species of bacterium known as *Agrobacterium tumefaciens*.

3 These *Agrobacteria* are then added to a Petri dish containing rice embryos. As they "infect" the embryos, they also transfer the genes that encode the instructions for making beta-carotene.

4 The transgenic rice plants must now be crossed with strains of rice that are grown locally and are suited to a particular region's climate and growing conditions.



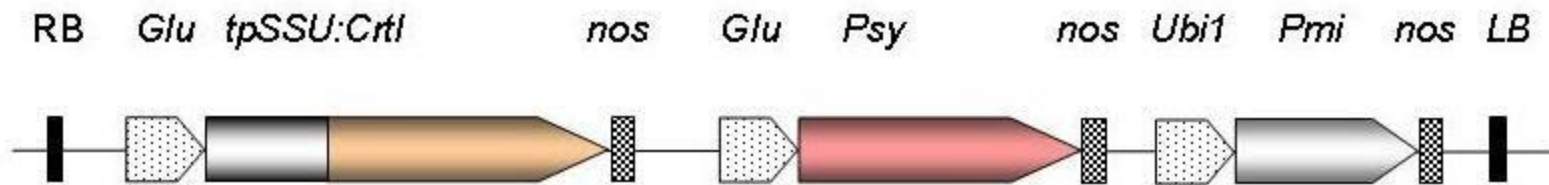
Filling a biosynthetic gap: Pathway elements in green are functional in wild-type rice grains. Thus the GGPP precursor molecule is being synthesized and lycopene can be cyclized. Elements in blue, including the blue box, are effectively absent. Introduction of the enzymes phytoene-synthase and the bacterial desaturase CRTI fills the biosynthetic gap created by the absence of the blue elements.

The underlying science

- Early research by 1990's proved that 2 transgenes required
- Phytoene synthase (PSY) and Phytoene desaturase and zeta carotene desaturase (CRT1). Lycopene cyclase .
- Later studies proved that Lycopene cyclase is not required as rice contains this enzyme.
- the advantage of the CRT1 desaturase lies in the fact that it can perform the entire reaction sequence from phytoene to lycopene on its own, while plants employ two desaturases and two cis-trans isomerases to achieve the same outcome. This reduces the number of transgenes required to only two.

Golden Rice

- The first generation of *Golden Rice* is SGR1 (1999)
- SGR1 contained the phytoene synthase (*psy*) gene from daffodil and the carotene desaturase (*crtl*) gene from the bacterium *Erwinia uredovora*
- Both genes were expressed only in the rice endosperm.
- The carotenoids level in field production of SGR1 were up to 1.6 $\mu\text{g/g}$



- The end product of the engineered pathway is **lycopene**, but if the plant accumulated lycopene, the rice would be red.
- Recent analysis has shown the plant's endogenous enzymes process the lycopene to beta-carotene in the endosperm, giving the rice the distinctive yellow color for which it is named. The original golden rice was called SGR1, and under greenhouse conditions it produced 1.6 $\mu\text{g/g}$ of carotenoids.



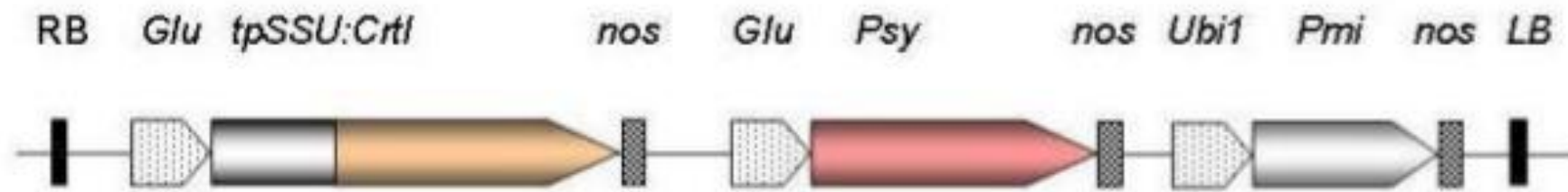


Figure: Gene construct used to generate *Golden Rice-1*.

RB, T-DNA right border sequence; **Glu**, rice endosperm-specific glutelin promoter; **tpSSU**, pea ribulose bis-phosphate carboxylase small subunit transit peptide for chloroplast localisation; **crtI** *Carotene desaturase* from the soil bacterium *Erwinia uredovora*; **nos**, nopaline synthase terminator; **Psy**, phytoene synthase gene from *Narcissus pseudonarcissus* (GR1) or *Zea mays* (GR2); **Ubi1**, maize polyubiquitin promoter; **Pmi**, phosphomannose isomerase gene from *E. coli* for positive selection (GR2); **LB**, T-DNA left border sequence.

- Lycopene is then cyclized to beta-carotene by the endogenous cyclase in Golden Rice.

(The insertion of a *lcy* (lycopene cyclase) gene was thought to be needed, but further research showed it is already being produced in wild-type rice endosperm.)

Golden Rice 2

- In 2005, **Syngenta**, produced a variety of golden rice called "Golden Rice 2".
- They combined the **phytoene synthase**(*psy*) gene from maize with **carotene desaturase** (*crt1*) from the original Golden rice-1.
- Both genes are under **endosperm specific promoter** control and the **mannose** act as **selectable marker**.
- Golden rice 2 produces 23 times more carotenoids than golden rice (up to **37 µg/g**), and preferentially accumulates β-carotene (up to **31 µg/g** of the 37 µg/g of carotenoids).
- To receive the **Recommended Dietary Allowance** (RDA), it is estimated that people who eat about **75g of golden rice per day**.
- In June 2005, researcher Peter Beyer received funding from the **Bill and Melinda Gates Foundation** to further improve golden rice by increasing the levels of or the bioavailability of pro-vitamin A, vitamin E, iron, and zinc, and to improve protein quality.

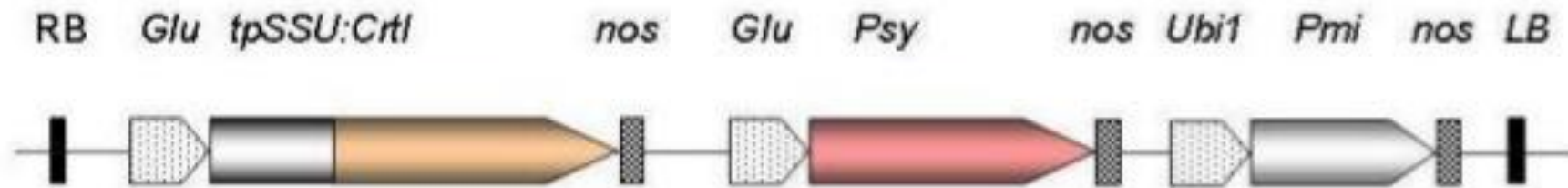


Figure: Gene construct used to generate *Golden Rice-2*.

RB, T-DNA right border sequence; **Glu**, rice endosperm-specific glutelin promoter; **tpSSU**, pea ribulose bis-phosphate carboxylase small subunit transit peptide for chloroplast localisation; **crtI** *Carotene desaturase* from the soil bacterium *Erwinia uredovora*; **nos**, *nopaline synthase terminator*; **Psy**, phytoene synthase gene from *Narcissus pseudonarcissus* (GR1) or *Zea mays* (GR2); **Ubi1**, maize polyubiquitin promoter; **Pmi**, *phosphomannose isomerase gene* from *E. coli* for positive selection (GR2); **LB**, T-DNA left border sequence.

Transform long grain rice variety (Kaybonnet) Sugar selectable marker

↓
619 individual GM rice plants

Golden Rice-2

↓
Screen for seed colour, gene copy number, fertility

↓
Select 6 “Golden Rice 2” events for further screening and development

Golden rice 2



Schematic diagram of the T-DNA in pSYN12424 used to create Golden Rice 2. The T-DNA components with a selectable marker cassette comprising the maize polyubiquitin (*Ubi1*) promoter with intron, phosphomannose isomerase gene (*pmi*) and *nos* terminator. The use of an intron was abandoned because it was shown to have no effect on carotenoid accumulation.

The golden rice reported here has up to 37 $\mu\text{g/g}$ carotenoid of which 31 $\mu\text{g/g}$ is β -carotene (23 fold increase).

Golden Rice Benefits

1. Lowers Risk of Blindness, Infections, Cancers and Diseases

- Golden rice has the ability to lower your risk of blindness, infections and cancers.
- A vitamin A deficiency can increase our risk of vision impairments, age-related macular degeneration and blindness.
- It can also worsen infections (measles, HIV, AIDS, chicken pox, etc.), especially in children.
- Approximately 125 million children, worldwide, exhibit chronically low levels of vitamin A (Wright, Hinchliffe & Adams, 2005).
- The carotenoids found in golden rice can combat adult degenerative diseases.
- Other benefits of golden rice include: a lower risk of both a variety of heart diseases and prostate, breast and skin cancers.

2. Reduces Gastrointestinal Distress

- Another one of the benefits of golden rice is that it can reduce gastrointestinal distress.
- In fact, it is considered a beneficial food to eat following an episode of diarrhoea, regardless of the cause.
- Golden rice behaves like a mild astringent in your gastrointestinal system, which supports easy digestion and restores your intestinal mucus following an episode of gastroenteritis and colitis.

3. Reduces High Blood Pressure and High Cholesterol

- Golden rice is a low-fat and low-sodium food; therefore it is especially beneficial for lowering high blood pressure and cholesterol.
- High levels of sodium, a mineral, can lead to fluid accumulation, edema (fluid retention) and a spike in blood volume.
- The excess fluid can increase your risk of high blood pressure. In other words, the more sodium you consume, the higher your blood pressure may soar.
- Moreover, one of the most valuable benefits of golden rice is that it prevents fiber-related biliary acids from accumulating in your intestines.
- Biliary acids found in the liver and transported to your intestines, aid cholesterol production.
- Golden rice contains no fat (i.e. no cholesterol); therefore it has the ability to regulate your unhealthy blood cholesterol levels.

Problems with Golden Rice

- Controversy has surrounded the production of golden rice because it is considered genetically modified rice (GMO).
- Critics have raised concerns of using genetically engineered foods to combat vitamin deficiencies like vitamin A.
- One of the main problems with the original form of golden rice was that it did not contain enough vitamin A to be beneficially for reducing disease risks.
- This problem was rectified when the new form of golden rice, Golden Rice 2 was developed in 2005.
- Critics continue to not only question the effectiveness of using genetically modified rice to improve health, but also the degree to which the nutrients persist once the rice has been cooked.
- In a recent study (2009), it was found that golden rice was just as beneficial and effective as supplementing with vitamin A.
- An organization called Greenpeace, vehemently opposes the production and use of golden rice citing this GMO will encourage the development of more GMOs in the future.
- Anti-GMO activists argue that an increase in GMOs will cause the degradation of foods to the point where everything that we eat will be artificial and genetically engineered.

- In the long run these types of non-natural foods will cause a variety of health problems
- These activists also argue that a balanced diet that contains beta-carotene (kale, mustard, greens, carrots, broccoli, sweet potatoes, etc.) provides an adequate amount of vitamin A and should therefore be utilized first and foremost.
- Supporters of GMOs argue that although it would be nice if everyone could adhere to a balanced diet rich in vitamin A, it just is not possible for some people.
- These supporters cite a lack of available resources and poverty as two of the main reasons why some people have developed nutritional deficiencies.
- They state that it is important to have alternative food sources to eliminate vitamin deficiencies and improve health and wellbeing.
- More research is needed to get a full understanding of golden rice pros and cons.

STATUS OF GOLDEN RICE

Golden Rice meets food safety standards in three global leading regulatory agencies. Los Baños, Philippines, 25 MAY 2018 – GR2E Golden Rice, a provitamin-A biofortified rice variety, completed its third positive food safety evaluation, this time from the United States Food and Drug **Administration** (US FDA).

Golden Rice is at different stages of regulatory review in the Philippines and Bangladesh, and Golden Rice will only be made available to the public once all necessary permits have been received.

In 2018, Golden Rice received three successive positive food safety evaluations from leading regulatory agencies: [Food Standards Australia New Zealand \(22 February 2018\)](#), [Health Canada \(16 March 2018\)](#), and the [United States Food and Drug Administration \(24 May 2018\)](#).



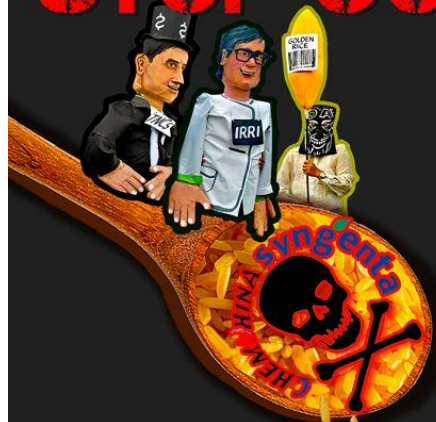
IRRI's work with Golden Rice

IRRI is working with partners to develop Golden Rice as a potential new food-based approach to improve vitamin A status. Our work will:

Develop varieties suitable for Asian farmers



STOP GOLDEN RICE!



WHAT IS GOLDEN RICE?

Golden Rice is a genetically engineered rice that contains beta-carotene whose main proponents are IRRI, Syngenta, BMFC, PhilRice, along with philanthropic organizations and government agencies. It was hailed as an effective solution to Vitamin A deficiency (VAD) particularly in poor, rice-eating countries in Asia.

WHY DO WE OPPOSE GOLDEN RICE?

- GMOs are clouded with uncertainties and threats to health.
- Golden Rice pose possible contamination of traditional rice varieties.
- Unfit for commercial cultivation due to low yield brought by unintended effects of genetic modification.
- Golden Rice is only an instrument for TNCs to gain more corporate control over food and agriculture.
- Unresolved issues on liability, 70 competing patents of Golden Rice, and ownership of GMO seeds
- Golden Rice were used in unethical experiments and uninformed feeding trials to children.

MALNUTRITION IS NOT JUST VAD, IT IS A SOCIAL PROBLEM

GOLDEN RICE IS NOT TESTED!

RISKS TO CONSUMER HEALTH

RISKS TO ENVIRONMENT

Daily Vit A requirement is readily available in various natural, accessible, and inexpensive food sources.



HOW DO WE ALLEVIATE MALNUTRITION AND POVERTY?

- Diversify food sources
- Uphold farmers' rights and protection/use of traditional seeds varieties
- Pursue Sustainable Agriculture
- Fight for social equity and food sovereignty



NO TO GMOs! DEFEND FARMERS' RIGHTS!



STOP GOLDEN RICE! NETWORK

Conclusion



“Public sentiment is everything. With public sentiment, nothing can fail. Without it, nothing can succeed.” – Abraham Lincoln.