

METHODOLOGY

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# Golden Rice: instructions for use

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## Abstract

Golden Rice is any variety of rice which makes beta-carotene, thus giving the rice a yellow (Golden) colour. It was created as an additional intervention for vitamin A deficiency. This dietary deficiency is the most significant cause of childhood blindness, and also the biggest killer of children under 5 year's old, globally. White rice contains no beta-carotene, and no vitamin A. Vitamin A deficiency is common in countries where rice is the staple diet. The Golden Rice technology, adding two genes to white rice in 2004, has been donated by its inventors for use in developing countries as an additional intervention against vitamin A deficiency. When Golden Rice is approved for use in a country, that country's Government will have decided that it is safe for the environment to grow the crop, and safe for humans, and animals, to consume it. Regular consumption of Golden Rice by people is expected, with time, to deliver health benefits by reducing cases of partial or complete blindness, and reducing preventable deaths, especially of young children and mothers. Any amount of daily white rice consumption can be replaced by Golden Rice consumption without ill effect. This document suggests how people can organise themselves to contribute to Golden Rice's adoption for growth and consumption by populations in their own country. Without adoption, Golden Rice cannot be an intervention for vitamin A deficiency, which is a major public health problem.

**Keywords:** Public health, Vitamin A deficiency, Golden Rice, Instructions, Self-help, Preventable death, Preventable blindness

## Vitamin A deficiency and Golden Rice

Vitamin A deficiency is the most important cause of childhood blindness. Lack of sufficient vitamin A also reduces the human body's ability to fight common diseases. For this reason, vitamin A deficiency is a very important killer, especially of young children and their mothers. Vitamin A itself is only found in animal products: milk, butter, cheese, eggs and liver are good sources. No plants contain vitamin A. White rice contains carbohydrate, an excellent source of energy, but no beta-carotene.

Beta-carotene is responsible for the colour of Golden Rice (and carrots, and the colour of many fruits and vegetables). The human body makes vitamin A from beta-carotene.

The technology in Golden Rice varieties has been donated by its inventors Professors Ingo Potrykus and Peter Beyer, and so is owned by the public in countries where rice is the staple crop. No one involved with the development or promotion of Golden Rice has any financial interest in its use: the project is completely not for profit. The technology

used to make Golden Rice involved newly introducing genes from maize and a common soil bacterium to white rice in around 2004. All the other stages of development have involved conventional plant breeding.

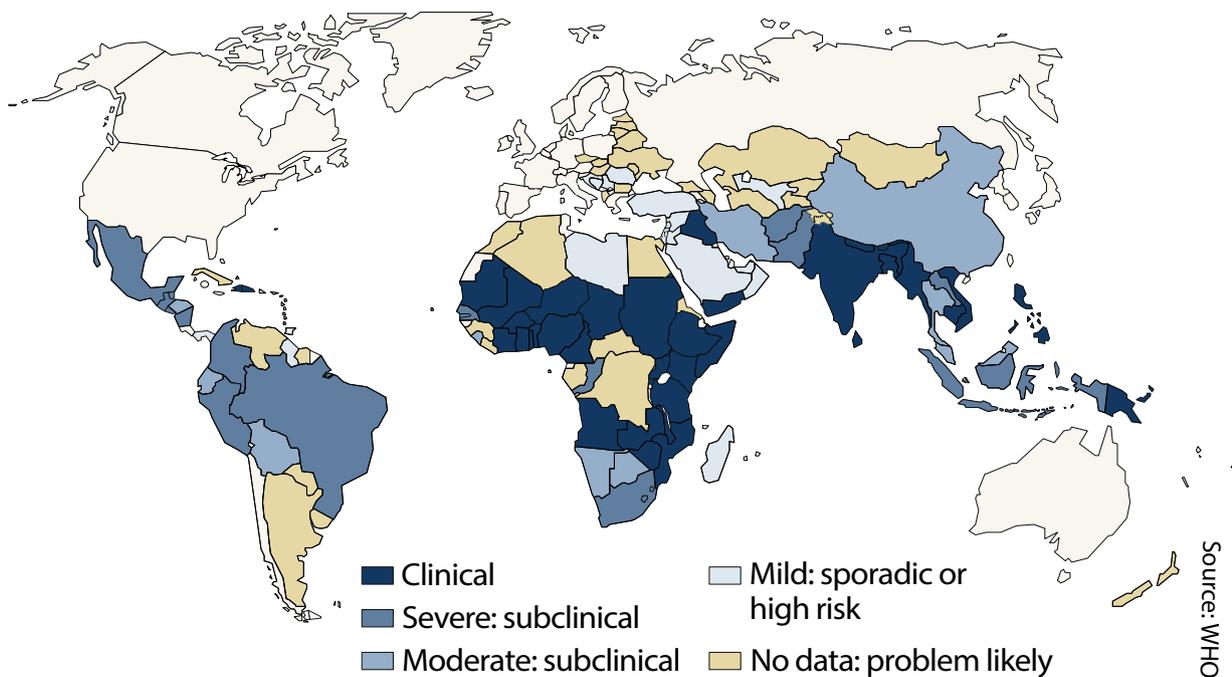
Because of the terms of the technology donation, and development by the public sector, Golden Rice will not cost more than the equivalent white rice variety. It is planted, grows, is processed, stored and is cooked in the same way. Harvested seeds can be planted again, without limitation, to produce more Golden Rice. The Golden Rice version of any variety of rice will have the same yield as the 'parent' white rice variety that the nutritional trait has been bred into (the Governments registration will have confirmed this.)

## Your fellow citizens need you!

The time is approaching when Golden Rice will be available for its intended use: to help combat vitamin A deficiency.

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## Public health importance of vitamin A deficiency, by country



Do you live in one of the countries highlighted in the map above? Is rice an important staple food crop in your country? Do you care about improving the well-being of mothers and children in your country? Do you want to help to improve the country’s economy and economic development? Do you have, or can you exert some, influence on the use of public resources in your country?

If the answer to any of the questions above is ‘yes’, this document is for you. Especially if ‘yes’ is your answer to all the questions above, this document is for you. Your country needs your assistance to make Golden Rice an effective additional intervention for vitamin A deficiency.

I want to simply explain what needs to be done. You will recognise how you can assist. Then you need to take up your challenge, organise yourself with like-minded individuals and persist until you are all successful together. No set of circumstances will be the same. There will be obstacles. Nothing worthwhile is achieved without effort. And this effort is worthwhile.

The main text here will be to outline practical steps to facilitate adoption of Golden Rice as an additional intervention for vitamin A deficiency.

### Background

Golden Rice offers the hope of sustainable improvement to a long recognised but hitherto rather intractable problem: vitamin A deficiency. For this hope to translate into

reality, Golden Rice has to be consumed regularly by affected populations. To be available for consumption, it has to be grown by rice farmers and offered for sale, and purchased by families. For very poor families, especially those living away from agricultural centres, governments, local or central, will probably need to be involved in the supply chain of Golden Rice to families.

The licence terms, to each Government, of the inventors donation of the nutritional component of Golden Rice mean that there is no agronomic difference, no processing or storage or cooking difference, and will be no cost difference, between white rice and the same variety of rice with the nutritional component: now called Golden Rice.

The process to get Golden Rice from the intent of the inventors, from public-sector laboratory to public-sector rice-breeding institutions, and to be approved for use by national Governments on a nation-by-nation basis has taken longer than anticipated. The private sector has assisted the public-sector project, especially in its initial stages. This is all described elsewhere.

The public sector has principal responsibility for public health. Up to this point, the Golden Rice project has mainly involved public-sector rice breeders in Asian countries, with some global coordination. The work has been supported by the unpaid Golden Rice Humanitarian Board where several key roles have been filled by

individuals from countries where vitamin A deficiency is not a problem. The Golden Rice project received technical support from the private sector, especially in the early years. The private sector has not been involved with the management of the project since 2008, and has had no commercial interest since 2004. The research and development of Golden Rice has been paid for by philanthropic grants and public-sector science budgets used principally by rice-breeding institutes.

Agriculture is very important as the Golden Rice delivery vehicle. The 'new' property of Golden Rice, as a result of its colour, is nutrition: it contains beta-carotene (an important source of vitamin A) additional to the carbohydrate energy source of white rice, which is unchanged. Golden Rice is above all a well-being, a nutritional, a medical project.

*Golden Rice can easily be recognised by its solid golden colour. Eating at least 40 g a day will improve health.*



Rice feeds half the world daily. In many countries, rice provides more than 60%, perhaps 80%, of calories daily. Vitamin A deficiency is widespread, and is particularly severe in those countries where rice is the staple food. For these reasons, the leadership of the project to encourage and facilitate local adoption of Golden Rice has to pass from global to local. And local must include national level, and local government and village level organisation, and family organisation.

The first step is recognising what role you, individually, can play, taking personal responsibility for it, and striving continually to achieve it with your fellow citizens, until you are successful. National and local priorities need to be reassessed. Budgets need to be allocated, probably reallocated and harnessed to pay for the task. The payback will be more beneficial than almost any other use of the money.

The payback will be huge: economically and from a population and family welfare perspective. And following widespread adoption of Golden Rice in a country the project will be largely self-sustaining, requiring little or no budgetary support. It will also need no philanthropy and no aid-agency support. Each country will have the dignity and pride of delivering its own populations improved well-being. But we, by which I mean you, have to get to that enviable position, from today's interest in reading an article!

The most important part of the Golden Rice project is concerned with ensuring that it is available to those that want to grow or consume it. 'Adoption' of Golden Rice into daily diet is essential for the potential health and welfare benefits to be realised. Adoption of Golden Rice in a country can only follow that country's official written Government approval of Golden Rice as safe to grow and consume: only then can farmers access the seed and grow the crop. And they will only want to grow it if it is at least as productive as the white rice they previously grew. Growers also need to sell the Golden Rice after harvest, which requires consumer, or Government demand, to be clear to the growers when they decide to purchase the Golden Rice seed.

All the seed breeding of the locally agronomically adapted and farmer- and consumer-preferred Golden Rice varieties will have been developed by the national rice-breeding institutes, and it is expected that one national rice-breeding institute in each country will have applied for and will hold the formal regulatory approval allowing the crop to be grown and consumed in that country. These institutes will have generated some of the data needed for the regulatory clearance, and other regulatory data will have been generated and provided (free of charge) by the global elements of the public-sector Golden Rice project. The national rice-breeding institutes will have the opportunity to continue to introduce the Golden Rice nutritional trait into more locally preferred rice varieties, and to also introduce other nutritional traits, for example high iron, zinc and folate varieties.

But for now, let us concentrate on achieving adoption of the first nationally approved Golden Rice variety in your country. The steps below could usefully and ideally be initiated in anticipation of this 'registration', or follow it.

## How?

### a. Organisation

It will be clear by now that Golden Rice adoption in a country requires the engagement of several functions of Government, many of whom may not be used to working together. These include agriculture, health, nutrition, medical, women and child welfare, communications,

budget and strategic planning. There may be others, including subgroupings within the main functions.

For example, within 'Agriculture' are represented the national rice seed-breeding institutes already mentioned, and extension services to assist farmers and growers. Additionally, there are Government rice seed multiplication and distribution systems. In some countries, these functions are performed solely by Government-funded units, in others the Government contracts with the private sector to provide part or all of the required service.

Cooperation in planning and running public meetings may be appropriate, for example, between agricultural extension services, and local government health and nutritional education specialists, with all specialists benefiting by working with communications specialists.

In some of these functions, government routinely benefits from the assistance of NGOs, and/or the private sector, to help Government deliver its service to the people, and there is no reason for change within an overall strategy chosen for Golden Rice adoption.

There are also roles for different levels of government: village, region, city and national. It would be extremely helpful, in each country and at each level of government and in each necessary function, for interested individuals to announce their interest, reach out to other functions and individuals in the same and the other functions, at the same level of government, whom they may not previously know, and bring people together to discuss how to coordinate their activities for the common purpose: improved health and welfare through Golden Rice adoption.

It would be useful for each appropriate level of government, for the relevant group to elect a leader through discussion. And then to invite participation from all other functions needed for efficient and timely decision-making and management of resources needed or controlled by the group to facilitate adoption of Golden Rice.

The relevant leaders from each level of government then need to establish linkages with the corresponding leaders of groups in the other levels of government.

From these responsible self-help initiatives, a national coordinating system should develop to allocate, prioritise and direct the use of relevant resources to improved health and welfare through Golden Rice adoption.

#### b. Priority setting

In theory, one seed grain of rice can result in 20,000 tonnes of rice in a few years if all the seed produced is replanted after harvesting each crop cycle. Rice has a tremendous capacity for multiplication. But practically, Golden Rice seed cannot be made available to all farmers

in a country at the same time. Seed multiplication output and dissemination have to be prioritised.

The most rational way to address this is to identify the regions within the country where the need and/or demand for Golden Rice is highest, and supply seed to those areas first. This could be related to where the incidence of vitamin A deficiency is highest, which in turn could be related to the areas where childhood blindness is most prevalent, and/or where child or maternal mortality remains stubbornly high, or where, for any reason existing interventions, such as vitamin A capsules, cannot be reliably and routinely delivered.

Conversely, Golden Rice communication and support services to growers and consumers may be the most difficult to manage in very remote areas. The Golden Rice seed multiplication and distribution system will be able to advise on what production can be expected in what time scale. It will be necessary to integrate need with practicality in determining which areas in a country should be the first recipients of Golden Rice seed for farmers to grow. Locally discussed and informed decisions will be the best way to decide on priorities.

#### c. Social marketing

The Golden Rice nutritional trait has been introduced into locally adapted and preferred rice varieties (and such work will continue). These Golden Rice varieties grow the same as the equivalent white rice variety. Before farmers will grow Golden Rice, they will need to know that they will be able to sell it and that their profitability will not be adversely affected compared to growing white rice. The rice breeders need to communicate these facts to local growers. 'Field days' may need to be organised with the involvement of locally influential growers and perhaps agricultural extension services: 'seeing is believing'. Other communication methods may be required, all of course in local language.

For consumers to want to buy and consume Golden Rice, they will need initial encouragement. They need to be reassured that there can be no adverse effects of consuming Golden Rice as a source of vitamin A, which is essential for maintenance of healthy sight and a healthy immune system to combat disease. They need to understand that the only possible effect of consumption is beneficial and that independent local scientists (as well as foreign scientists and clinicians) have reviewed all the relevant data and found Golden Rice to be safe to humans and the environment. They need to understand that each Golden Rice grain is uniformly labelled with its colour, which is different from spoiled rice and rice which fraudsters may have coloured in imitation of Golden Rice. This

uniform colour of Golden Rice, which shows that it contains beta-carotene, is the only difference from the same white rice variety. The taste is the same as the white rice variety, and of course consumers will need to become used to eating it regularly, for it to be effective. They need to understand that there is no charge for the nutritional trait and that the inventor's donation is without any financial benefit to those involved with the development or distribution of Golden Rice. The nutritional trait has been developed as a 'public good,' with the assistance of their Government, and others in other countries.

It is necessary to understand how to reach consumers, and tailor the approach to local circumstance, for effective communication. In some places, it may be via radio, it could be via text message, or TV, or newspapers or other social media. Who do consumers trust? Perhaps it is the local health workers? Perhaps a popular health programme, perhaps celebrity sports, film or TV personalities?

Focus groups probably need to be run to establish which would be the most effective, and the most cost-effective, communication messages and channels. Maybe the local business school can provide training in how to organise these, and record the results to influence strategy. When systems have been tried, results should be measured, and learning applied to future iterations of the systems so that they become more and more efficient at message delivery.

The aim is, at a low per capita cost, to establish demand for Golden Rice from consumers as encouragement to farmers to grow and harvest it. After such demand has been created, after a few cycles it will then continue without continuous social marketing.

Of course, grower interest and consumer demand have to be developed together, which is more challenging than introducing a new rice variety which only benefits the grower. The grower needs to understand that s/he can assist in, indeed is essential to, the well-being of the people who eat the crop.

For initial crops of Golden Rice, perhaps Government, local or central, needs to guarantee to purchase the crop, to start the cycle of availability and consumption. Whereas in rural setting this will probably not be needed for many crop cycles, there are other settings where government purchase and distribution programmes for Golden Rice may usefully continue.

Vitamin A deficiency occurs not only in the countryside, but also in urban centres where the population has no opportunity to grow their own Golden Rice: for these locations, an ongoing Government-managed supply system will probably be beneficial. In some countries, there is a well-established midday meal service in schools. Mandatory inclusion, and supply of Golden Rice as part

of the midday meal would do a lot to combat vitamin A deficiency in the most vulnerable group to vitamin A deficiency: children. Where such a service does not currently exist, perhaps it could be created and Golden Rice routinely served. Alternatively, perhaps each child could be provided with a bag of polished Golden Rice to take home for preparation and consumption, on a regular basis, and receive instruction on the expected benefits in school to share with parents.

Again, local experience and commitment will determine the most appropriate way forward. And again, measurement of progress from the first beginning, for example, of the different delivery systems for the nutritional message will allow refinement and improvement in processes to make them more and more effective in the later targeted adoption areas. The same measurement systems will also allow determination of when external support can be reduced without adverse impact, so that available resources can be focussed elsewhere.

#### d. Measurement of effectiveness

It is well established that a source of vitamin A is beneficial to health, with no side effects. The human body converts the coloured beta-carotene in Golden Rice to vitamin A. Beta-carotene surplus to the bodies requirement is excreted without conversion to vitamin A.

Mothers have sufficient vitamin A when the circulating vitamin in their blood protects the mothers sight and ensures a robust immune response to infections. When mother's vitamin A status is sufficient, it is expected that this will benefit any developing foetus through the placental blood supply, and any breastfed child through the mother's milk.

It is important to measure the effectiveness of Golden Rice adoption. Initially, this will need to be by proxy measurements. Dietary records are useful. Dietary recall 24 h after consumption is a validated method for nutritional record keeping. General health records of a population are also useful contributory data to understanding.

Measurement of the impact of Golden Rice consumption on vitamin A status of large groups of people requires sophisticated science involving randomized controlled trials ('RCTs') and is carefully controlled by national, and international, regulations. Such research is carefully planned, and costly, and is for specialised and independent clinical researchers to take the lead on. It is to be encouraged.

Measuring epidemiological impacts of new vitamin A deficiency interventions, that is—in this case—measuring changes in health outcomes as a result of Golden Rice consumption, also requires careful experimental design and experimental conduct. Such research also involves

RCTs, within established rules for conducting such research. It also requires more time than vitamin A status research, to understand and measure population health effects. Again, such appropriately qualified independent research is to be encouraged.

All results should be published in appropriate formats, in reputable peer-reviewed scientific journals, not least so that each country's results can benefit from experience in other countries.

### Conclusions

Initially, the justification for promoting adoption of Golden Rice as an additional intervention for vitamin A deficiency will be based on studies which have clearly demonstrated that a universal source of vitamin A can prevent 23–34% of global under five years' child mortality, and up to 50% mortality prevention in the case of measles. It has also been known for a long time that vitamin A deficiency is the most important cause of irreversible childhood blindness. And most people who die of vitamin A deficiency do not become blind first. The payback from Golden Rice adoption, that is its regular consumption by populations, will be more advantageous than almost any other use of the money.

Sophisticated science has already confirmed that the beta-carotene in Golden Rice is very efficiently converted to circulating vitamin A in both adults and children: "Golden Rice may be as useful as a source of vitamin A

as preformed vitamin A from vitamin A capsules, or eggs and milk".

Green vegetables are an important source of beta-carotene. But the conversion of beta-carotene in green leaves to vitamin A is very inefficient. So vitamin A deficiency is common even in populations where green vegetables are easily available and consumed.

Additionally, lack of dietary variety, especially the lack of sufficient animal products in the diets of many who depend on rice, is responsible for vitamin A deficiency.

Golden Rice has a huge, low cost and sustainable potential to help combat vitamin A deficiency, and reduce preventable blindness and death in populations where rice is the staple food, and without changing the culture.

Over to you, dear reader, to turn Golden Rice's potential into reality.

#### Competing interests

Not applicable.

#### Ethics approval and consent to participate

Not applicable.

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