



Impact of golden rice on vitamin A deficiency: A case study of India, Bangladesh and China

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Abstract

Genetically modified (GM) techniques in agriculture is a controversial topic in science and society at large. The impacts of GM crops on income, poverty and nutrition in developing countries continue to be a subject of public controversy. The first generation GM crops have been proved the potential in the field of agronomic trait. Millions of small-scale farmers, including those in India, China, and South Africa, have already switched over to bt-cotton. Farmers typically gain from lower pesticide costs, higher effective yields, and sizable income increases. According to insights from India, BT cotton creates jobs and lowers poverty. The second-generation GM crops, the likely impacts of beta-carotene rich Golden Rice are analyzed from an ex ante perspective. Vitamin A deficiency (VAD) is a major dietary issue that has a number of negative health effects. In poorer nations, VAD is regarded as a public health concern. Economic limitations, social restrictions, inadequate food intake, and poor absorption that results in the body's vitamin A stores being depleted have all been identified as potential contributors to India's high prevalence of VAD. Ex ante analysis for India indicates that Golden Rice could drastically lower health issues, averting up to 40,000 child fatalities annually. In conclusion, the high prevalence of VAD in India increases morbidity and mortality in young children, pregnant women, and babies. Golden Rice and other bio-fortified crops provide a long-term sustainable solution since, once deployed, they don't need ongoing, difficult logistical arrangements. Vitamin A insufficiency problems cannot be solved by golden rice. Therefore, it should be viewed as an addition to existing micronutrient therapies rather than their replacement.

Keywords: Golden rice, genetically modified crops, vitamin A, Cost, DALYs

Introduction

The most harmful micronutrient deficiencies in the world are the consequence of vitamin A, low zinc, dietary intake of iron and iodine. VAD is prevalent among the poor whose diets are based mainly on rice or other carbohydrate-rich, micronutrient-poor calorie sources. The majority of nutritional deficiencies are prevalent in low-income homes, whose diets are predominately made up of basic foods with little nutritional value. Programs for food and industrial fortification can reduce VAD, however they frequently do not reach the target people in rural areas. Rice is a foodstuff that is quite popular in India. Continuously declined the per capita consumption of rice in rural and urban areas due to continuous increasing the population. The situation in rice-eating communities is expected to improve if Golden Rice is consumed more widely. However, as this technology has not yet hit the market, actual results can only be speculated. Golden rice will likely start to be sold commercially in a few Asian nations in 2020.

The worldwide area under genetically modified (GM) crops grew from 1.7 million hectares in 1996 to 191.7 million hectares in 2018. Further, approximately 18 million farmers worldwide grow GM crops in 26 countries, including 20 developing countries, this makes GM crops the fastest adopted crop technology in recent times (ISAAA, 2018). Herbicide and insect resistance, along with additional features that are in the research pipeline, are two traits of GM crops that are predicted to be commercially available by the year 2018. A heated public discussion has accompanied the global introduction of GM crops. The proponents of GM technology recognised the enormous potential of the

technology and made the case that it increases agricultural output and reduces seasonal variations in food availability caused by biotic and abiotic pressures. This technology supports ensuring long-term food security, preserving biodiversity, and meeting the demand for agricultural products. Second generation GM crops are ones with a high amount of micronutrients; they may aid in reducing a particular nutritional deficiency among the underprivileged. Finally, proponents claim that GM technology would reduce the need of chemical pesticides in developing nations and will help to solve the environmental and health issues brought on by intensive agriculture systems. The World Health Organization also supported the claim and said that "GM foods currently available in international market have passed safety assessments and are not likely to present risks for human health. In addition, no effects on human health have been shown as a result of the consumption of such foods by the general population in the countries where they have been approved".

GM technology opponent has been given argument, this technology is harmful for environment and health. The doubts have been continuously raised by NGOs and some scientist, they consider this technology is inappropriate for smallholder farmers and disruptive for traditional cultivation system. Finally, opponents are arguing, in developing country like India, its feared the dominance of multinational companies in the field of genetic engineering and at global level intellectual property rights (IPRs) could lead to the exploitation of agriculture producers. In this view, opponents have been claimed GM technology is harmful for food security and development.

Golden rice is a variety of rice (*Oryza sativa*) produced through genetic engineering to biosynthesize beta-carotene, a precursor of vitamin A, in the edible parts of the rice. It is intended to produce a fortified food to be grown and consumed in areas with a shortage of dietary vitamin A. Vitamin A deficiency causes xerophthalmia, a range of eye conditions from night blindness to more severe clinical outcomes such as keratomalacia and corneal scars, and permanent blindness. Additionally, vitamin A deficiency also increases risk of mortality from measles and diarrhea in children.

Golden rice was first developed in the 1990s by Ingo Potrykus and Peter Beyer. The genes that code for beta-carotene production were taken from daffodils and introduced into rice. The resulting rice contains about 30 micrograms of beta-carotene per gram of rice, which is enough to provide about half of the recommended daily intake of vitamin A for adults.

Golden rice has been approved for commercial cultivation in the Philippines, and it is currently being grown in small trials. However, it has not yet been approved for commercial cultivation in other countries.

The development of Golden rice has been controversial. Some people have argued that it is a valuable tool to combat vitamin A deficiency, while others have expressed concerns about the safety of genetically modified food.

The debate over Golden rice is likely to continue, but it is clear that this technology has the potential to improve the health of millions of people around the world.

Here are some of the benefits of Golden Rice:

- It can help to prevent vitamin A deficiency, which is a serious public health problem that affects millions of people around the world.
- It is a sustainable way to improve nutrition, as it can be grown in the same way as regular rice.
- It is safe to eat, as it has been assessed by regulatory agencies in several countries.
- Here are some of the challenges of Golden Rice:
- It has not yet been approved for commercial cultivation in all countries.
- There is some public opposition to genetically modified food.
- The long-term effects of eating Golden rice are not yet fully known.

Overall, Golden rice is a promising technology that has the potential to improve the health of millions of people. However, there are still some challenges that need to be addressed before it can be widely adopted.

Impact of Bt-Cotton in India

The potential impact of Bt-cotton is a debated among researchers, policy makers, media and public. Bt cotton is a genetically modified (GM) crop that has been engineered to produce a protein that is toxic to certain insect pests. It was first introduced in India in 2002, and it has since become the most widely grown GM crop in the country India adopted its first commercial biotech crop in 2002 which is termed as bt- cotton. Bt technology hastened the adoption of cotton hybrids in India, from 45% to 96% in 2002-2017 respectively (ISAAA, 2021). A total of 7.5 million farmers in India cultivated 11.4 million hectares' insect resistant (IR) cotton in 2017, which is 93% of the total 12.24 million hectares of cotton grown in the country. In 2015, India

became world's top cotton producing country, attaining cotton production of 37.7 million bales in 2017, that is higher than 34.5 million bales in 2016. India produces more than a quarter of the world's cotton. Remarkably, the increased the area from 50,000 hectares of Bt cotton in 2002 to 11.4 million hectares in 2017 represents an extraordinary increase in 17 years (Chaudhary B. and Gaur, K. 2015). Over the succeeding twenty three years, 2007-2014 continued the growth of cotton mainly due to the introduction and fast adoption of dual gene Bt-cotton technology coupled with supply of better quality seeds by private sector and determined efforts by around 8 million cotton farmers in the country.

Vitamin A deficiency in South Asian countries

The majority of children affected by VAD continue to reside in South Asia. As with other inadequacies, there hasn't been much improvement in VAD reduction between 1991 and 2013. (Stevens *et al.*, 2015)^[8].

The prevalence of clinical and subclinical VAD is highest in India among South Asian nations, and 62% of preschoolers were found to have vitamin A deficiencies. This is especially found in South Asia and Sub-Saharan Africa where VAD was 44% and 48%, respectively, in children aged 6-59 months old (Stevens *et al.*, 2015)^[8]. Vitamin A deficiency (VAD) is a serious public health problem in South Asia. It is estimated that 44-50% of preschool children in the region are affected by severe VAD. This means that they have very low levels of vitamin A in their blood, which can lead to a number of health problems, including: Night blindness, Bitot's spots, Keratomalacia (inflammation of the cornea), Xerophthalmia (dryness of the eye), Blindness VAD can also increase the risk of death from measles and diarrhea.

There are a number of factors that contribute to the high prevalence of VAD in South Asia, including:

- **Poor diet:** Many children in the region do not eat enough foods that are rich in vitamin A, such as fruits, vegetables, and dairy products.
- **Malnutrition:** VAD is often associated with other forms of malnutrition, such as proteinenergy malnutrition.
- **Poverty:** Many families in South Asia cannot afford to buy enough food to meet their nutritional needs.
- **Lack of access to healthcare:** Many children in the region do not have access to regular healthcare, which means that they may not be diagnosed or treated for VAD.

There are a number of things that can be done to address the problem of VAD in South Asia, including:

- **Improving diet:** This can be done by increasing access to fruits, vegetables, and dairy products.
- **Fortifying foods:** This involves adding vitamin A to foods that are commonly eaten by children, such as wheat flour and cooking oil.
- **Supplementation:** This involves giving children vitamin A supplements.
- **Education:** This involves educating families about the importance of vitamin A and how to prevent VAD.

The World Health Organization (WHO) has set a target of reducing the prevalence of VAD by

50% by 2025. This is a challenging target, but it is achievable if all stakeholders work together. The usual prescribed procedure to alleviate VAD such as delivery of supplementary vitamin A capsule with serum retinol, food fortification, and dietary modification to include vitamin A-rich green and leafy vegetables, were not as successful in South Asia and Sub-Saharan Africa (ISAAA, 2017). Thus, a more effective method of alleviating VAD is needed, and Golden Rice could contribute immensely to this effort.

1. Undernourished Population in India

At world level two regions are more affected by scarcity of foods that is sub-Saharan Africa and South Asia. In south Asian countries, a major question for India concerns the agriculture sector's contribution to national food security. The Global Report on Food Crises 2017 shown that the UN Millennium Development Goals (UN-MDG) were not achieved that ended in 2015, and about 108 million people

in 48 countries affected by food crisis are still at risk or in severe acute food insecurity since 2016 (FAO, July 23, 2017). India, the second-most populated nation in the world, with the greatest proportion of farmers and people living in rural areas. A fourth of the world's population in India experienced food scarcity (OECD, 2014) [6]. Since only a food-based strategy can aid in eradicating malnutrition and undernutrition in a way that is both economically and socially sustainable, food and nutrition security are inextricably linked. Food security is based on food production because it is a major factor in determining the availability of food (Bhavani, 2013) [3]. Below table shows that the population of under-nutrition in India declined but slowly. In 2001 undernourished population is 18.4% of the total population. In 2005, it reached 21.5% of the total population but after this year decrease the undernourished population and it reached 16.3% in 2021.

Table 1: Prevalence of Undernourished Population in India

Year	No. of Undernourished Population (%)
2001	18.4
2002	20.1
2003	21.5
2004	22.1
2005	21.6
2006	19.6
2007	17.5
2008	16.6
2009	16.3
2010	15.9
2011	15.4
2012	14.9
2013	14.9
2014	14.8
2015	14.5
2016	13.9
2017	13.2
2018	13.3
2019	13.3
2020	14.6
2021	16.3

Source: <https://data.worldbank.org/indicator/SN.ITK.DEFC.ZS?locations=IN>

Potential Contribution of Golden Rice to Vitamin A Deficiency Alleviation

Golden Rice (GR), which has been genetically modified to produce β -carotene in the grain, has been proposed as a possible intervention to control vitamin A deficiency (VAD). A methodology for an extensive ex ante study of Golden Rice was established by Stein *et al.*, with an emphasis on socio-economic as well as nutritional and health implications. An empirical study in India employed this methodology. In order to determine the future effects of golden rice on VAD reduction and what the effects on cost which are employed in supplementation programmes, Stein *et al.* devised the technique. Ex ante analysis was used to conduct this empirical investigation in India. India is one of the target nations for Golden Rice because VAD is common there and average levels of rice consumption are relatively high. As a result, a more potent treatment for VAD is required, and Golden Rice could make a significant contribution.

Table 2: Burden of Vitamin A Deficiency in India and Potential Impact of Golden Rice

Burden of vitamin A deficiency	
Number of DALYs lost each year (thousands)	2328
Number of lives lost each year (thousands)	71.6
Potential impact of Golden Rice	
Number of DALYs saved each year (thousands)	1382
Reduction of the DALYs burden (%)	59.4
Number of lives saved each year (thousands)	39.7
Cost-effectiveness of Golden Rice and other	
Cost per DALY saved through Golden Rice (US\$)	3.1
World Bank cost-effectiveness standard for DALYs saved (US\$)	200
Cost per DALY saved through supplementation (US\$)	134
Cost per DALY saved through industrial fortification (US\$)	84

Source: Stein *et al.* 2008

Table 3: Future Impact of Golden rice in China

China	De Steur, 2012	
DALYS lost with VAD	Cost-effectiveness per DALY saved with GR	
1.9 million	US\$5 at optimistic circumstances	US\$18 at pessimistic circumstances

Table 4: Future Impact of Golden rice in Bangladesh

Bangladesh	Deb, 2016					
DALYS lost with VAD	1% Increase in GR coverage			5% Increase in GR coverage		
	DALYs saved with GR	C-E per DALY saved with GR	Monetary Benefits	DALYs saved	Monetary benefits (Total)	
25,065 under 5 year.	251	US\$1,285	US\$3 million	1,255	US\$25 million (CS)	US\$40 million (OS)

Legend: HIS = High Impact Scenario, LIS= Low Impact Scenario, C-E = Cost-effectiveness per DALY saved by GR intervention, CS = Conservative Scenario, OS = Optimistic Scenario

The most harmful micronutrient deficiencies in the world are the consequence of vitamin A, low zinc, dietary intake of iron and iodine. VAD is prevalent among the poor whose diets are based mainly on rice or other carbohydrate-rich, micronutrient-poor calorie sources. The majority of nutritional deficiencies are prevalent in low-income homes, whose diets are predominately made up of basic foods with little nutritional value. Programmes for food and industrial fortification can reduce VAD, although they frequently miss the target populations in rural regions (L.H. Allen 2003) [12]. Rice is a foodstuff that is quite popular in India. However, figure 2 demonstrates that due to continued population growth, both rural and urban areas' per capita consumption of rice has decreased. The situation in rice-eating communities is expected to improve if Golden Rice is consumed more widely. However, as this technology has not yet hit the market, actual results can only be speculated. Golden rice will likely start to be commercialised in a few Asian nations in 2020. A potential intervention to prevent vitamin A deficiency (VAD) has been suggested: Golden Rice (GR), which has been genetically altered to synthesise β -carotene in the grain (J.A. Paine, *et al.* 2005) [11]. A methodology for a thorough ex ante study of Golden Rice was established by Stein *et al.* in 2006 [1, 7], with an emphasis on socioeconomic and dietary consequences. An empirical study in India employed this methodology. In order to determine the future effects of golden rice on VAD reduction and what the effects on cost which are employed in supplementation programmes, Stein *et al.* devised the technique. Ex ante analysis was used to conduct this empirical investigation in India. India is one of the target nations for Golden Rice because VAD is common there and average levels of rice consumption are relatively high.

1. Impact on Nutrition and health

In 2006, Stein *et al.* had done a comprehensive ex ante analysis of GR through developed methodology to evaluate the future impact of GR on nutrition and socio-economic. Additionally, this approach was employed for an empirical investigation in India to determine the potential effects of golden rice on VAD (Stein *et al.* 2008). A lack of vitamin A in the diet is thought to affect 15% of pregnant women and 33% of children under the age of six. Additionally, 5.2 million preschool-aged children have clinical VAD. Among countries of sub-Saharan Africa and South East Asia, more than 40 per cent of pre-school age children are estimated to be vitamin A deficient. Stein *et al.* used a disability-adjusted life year (DALY) technique to determine the illness burden

related to the VAD-attributable portions of these outcomes. The number of DALYs lost is used to indicate the total annual burden of mortality and illness. The distribution of access to β -carotene from data on nationally representative food intake was installed as a next step, along with the likelihood of a change toward consumption of golden rice. Access to more β -carotene will improve people's vitamin A status, reducing the likelihood of adverse health outcomes. The necessary left burden with Golden Rice was recreated using these updated incidence rates, which were obtained. The required technology impact is the difference between the burden of disease with and without Golden Rice, expressed in terms of the number of DALYs saved.

Above table shows the DALY lost in each year is 2328 thousand in which 71.6 thousand lost their lives in each year. That creates burden which could be enhanced by using GR. Further, the study proves the potential impact of the GR. which would save 1382 thousand DALYs lives each year. It could reduce the burden of DALYs upto 59.4%. Due to such enhancement 39.7 thousand lives could easily be saved each year. GR could ameliorate the lives of people. this technology has potential to reduce VAD. But VAD could not be reduce alone with this technique.

Along conventional technique, it would be panacea for DALYs.

2. Cost-effectiveness

The above table shown the cost-effectiveness of GR in reduction of problems of VAD. However, there is need to be asked from an economic perspective at what cost certain effect is achieved. The expenditure of significant cost of GR is spent on improving, developing, testing, and disseminating the GM technology. By discounting the timing of costs and benefits, dividing expenditures by DALYs saved, and accounting for time, which is a popular way to assess how cost-effective health interventions are. Stein *et al.* performed this in their investigation of the golden rice in India. The cost per DALY saved by golden rice is estimated by them to be in the amount of 3 US\$, which is extremely low. According to a research, even under considerably more pessimistic assumptions, the cost would not exceed 20 US dollars for every DALY saved. These results need to be contrasted with relevant levels. When the cost of a health interruption is less than 200 US dollars, the World Bank classifies it as being very cost-effective. This serves as another evidence that Golden Rice might be very cost-effective. Nevertheless, how does Golden Rice stack up against conventional vitamin A interruption? In India

Scaling up industrial rampart vitamin A programmes or food supplements would cost between 84 and 134 US dollars per DALY saved. Golden rice would be different since GR could be produced by farmers themselves and its seeds would spread through regular and erratic distribution systems, despite the initial investment being much more. To persuade farmers to adopt GR, strategies must be developed.

Conclusion

The above discussion shown the potential positive impact of nutrition and cost-effectiveness of Golden rice but this technology is no potential in the fight against micronutrient deficiency. There is no capacity in GR and other intervention alone to eliminate VAD. But more severe and acute cases of VAD can be address by VA supplementation, and it can be useful in prevention in short run. its sustainability is less over longer period of time and also costly. The Industrial rampart is much effective in urban areas, whereas in rural areas poor people often can't access due to low consumption of processed, purchased foodstuffs. Malnutrition and VAD can be reduced through the poverty reduction and this will happen only in long run. Food crops breeding for higher micronutrient like GR, nutrition education, diversification of diet and many other foods based approaches are all interventions that have their own strengths and weaknesses.

The public sector should acquire and use the skills necessary to maintain beyond the purely scientific or proof-of-principle state of their work if India had demanded genetically modified Golden Rice. Driving a genetically modified plant through the procedures involved in regulatory approval and beyond requires a full set of highly specialised abilities that are currently uncommon in the public sector. For instance, greater specialisation is required in the fields of community participation, communication, social marketing, and nutritional extension and education, necessitating interdisciplinary collaborations as well as significant management skills (Beyer, P. 2010)^[2].

High-quality disaggregated data on status and trends as well as empirically supported evidence of effective policies and programmes that can produce cost-effective change at scale are required due to the region's need for a significant increase in public investments. In order to sustainably secure the nutrient needs of South Asia's expanding population, many more targeted interventions of information, services, and resources are required to meet the needs of the hardest-to-reach and most at-risk populations. However, these must be combined with nutrition-sensitive actions and food system approaches.

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