# Potential impact and cost-effectiveness of Golden Rice

**To the editor**

A News & Views article by Michael Grusak in last year's April issue (*Nat. Biotechnol.* **23**, 429–430, 2005) highlighted the unresolved debate concerning the efficacy of Golden Rice in addressing the problem of vitamin A deficiency (VAD). He pointed out that an assessment of the potential impact of Golden Rice on this type of malnutrition requires the consideration of multiple variables, including the target individuals' life stages, the average amount of rice consumed daily by these individuals and the percentage of β-carotene that would be absorbed from rice. He further explains how early critics of the original Golden Rice technology had used simple estimates of these variables to suggest that unrealistic amounts of the transgenic rice would need to be consumed to satisfy the recommended dietary intakes of vitamin A equivalents (exclusively) through rice consumption. By replacing the daffodil phytoene synthase gene with the equivalent gene from maize, researchers have managed to increase the amount of β-carotene that accumulates in rice considerably[1]. However, a sound impact analysis of this new Golden Rice 2 variety, based on a solid methodological framework, is still outstanding.

Previous impact studies of Golden Rice either focused solely on effects of the rice on individual β-carotene intakes without considering the outcome on the health of those suffering from VAD[2] or considered health outcomes but used only highly aggregate intake data without taking into account important nutritional features like dietary heterogeneity[3]. Using a methodology developed for comprehensive *ex ante* evaluation, we present here a framework that substantially improves on these studies by combining health and nutrition details, as well as socioeconomic and policy factors, thus increasing the reliability of the results.

**Table 1 Disease burden of VAD in India and impact and cost effectiveness of Golden Rice 2**

| Scenario | Measure |
|---|---|
| *Current disease burden of VAD* | |
| Number of DALYs lost annually | 2,328,000 |
| Number of lives lost annually | 71,600 |
| *Potential impact of Golden Rice 2* | |
| Number of DALYs saved annually in low-impact scenario | 204,000 |
| Number of DALYs saved annually in high-impact scenario | 1,382,000 |
| Annual reduction in the DALYs burden in low-impact scenario | 8.8% |
| Annual reduction in the DALYs burden in high-impact scenario | 59.4% |
| Number of lives saved annually in low-impact scenario | 5,500 |
| Number of lives saved annually in high-impact scenario | 39,700 |
| *Cost-effectiveness of public health interventions* | |
| Cost per DALY saved through Golden Rice 2 in low-impact scenario | $19.4 |
| Cost per DALY saved through Golden Rice 2 in high-impact scenario | $3.1 |
| Cost per life saved through Golden Rice 2 in low-impact scenario | $358 |
| Cost per life saved through Golden Rice 2 in high-impact scenario | $54 |
| World Bank cost-effectiveness standard for DALYs saved[a] | $200 |
| World Health Organization standard for valuing DALYs[b] | $620–1,860 |
| Cost per DALY saved through supplementation[c] | $134–599 |

[a]The costs per DALY given in ref. 5 are expressed in 1990 US dollars; the equivalent in current terms rises above $200. [b]The WHO suggests that one DALY should be valued at the single-to-triple per capita income[6]; for India the gross national income per capita in 2004 was $620 (ref. 7). [c]DALY-costs for vitamin A supplementation in South Asia[8], converted into 2004 US dollars. For more details, see **Supplementary Discussion** online.

We apply our methodology in an empirical study of Golden Rice 2's impact in India (**Supplementary Discussion** online).

Adverse health outcomes of VAD include increased mortality, night blindness, corneal scars, blindness and measles among children, as well as night blindness among pregnant and lactating women. We calculated the disease burden associated with VAD-attributable fractions of these outcomes, building on a disability-adjusted life years (DALYs) approach. The combined annual mortality and morbidity burden is expressed in terms of the number of DALYs lost[4]. The present burden, calculated based on available health statistics, is the situation without Golden Rice 2.

Next, we derived present individual β-carotene intakes from nationally representative food consumption data and simulated the expected shift in the intake distribution through future consumption of Golden Rice 2. Higher β-carotene intakes will improve the vitamin A status of individuals, thus reducing the incidence of adverse health outcomes. We derived these new incidence rates to recalculate the expected remaining disease burden with Golden Rice 2. The difference in the disease burden with and without Golden Rice 2 is the impact of the technology expressed in terms of the number of DALYs saved. To allow for the uncertainty in *ex ante* analysis, we used different assumptions and constructed a high and a low impact scenario (**Supplementary Discussion** online).

According to our calculations, the current annual disease burden of VAD in India amounts to a loss of 2.3 million DALYs, of which 2.0 million are lost due to child mortality alone. In terms of incidence numbers, >70,000 Indian children under the age of six die each year due to VAD. In this context, widespread consumption of Golden Rice 2 with a high β-carotene content could reduce the burden of VAD by 59%, whereas under pessimistic assumptions the burden would be reduced by 9% (**Table 1**). In both scenarios, thousands of lives could be saved. As the severity of VAD is negatively correlated with income, the positive effects of Golden Rice 2 are most pronounced in the lowest income groups.

We also assessed Golden Rice 2's potential cost-effectiveness relative to alternative vitamin A interventions and appropriate benchmarks, with a view to informing policy decisions and international comparisons. Following the low-impact/high-impact scenario approach to determine the research, development and dissemination costs of Golden Rice 2 (**Supplementary Discussion** online), we find that even under pessimistic assumptions, the cost of saving one DALY is <$20. Compared with a cost of $134–599 of saving one DALY through vitamin A supplementation, which is a commonly practiced intervention, or compared with the World Bank's benchmark of $200, Golden Rice 2 promises to be very cost effective (**Table 1**). Sensitivity analyses have been carried out to identify critical factors of success and the robustness of the results.

In the future, preliminary results on β-carotene bioavailability will have to be verified, the Golden Rice trait needs to be incorporated into agronomically superior local varieties, biosafety and food safety tests have to be carried out and technology dissemination has to be promoted through public marketing campaigns.

Our findings suggest that related investments are worthwhile. These promising results notwithstanding, Golden Rice is no panacea in the fight against malnutrition. Given the magnitude and complexity of the problem, a multiplicity of approaches is needed.

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*Note: Supplementary information is available on the Nature Biotechnology website.*

*Alexander J. Stein[1], H.P.S. Sachdev[2] & Matin Qaim[1]*

*[1]University of Hohenheim, Department of Agricultural Economics & Social Sciences (490b), 70593 Stuttgart, Germany. [2]Sitaram Bhartia Institute of Science & Research, B-16 Qutab Institutional Area, New Delhi 110 016, India. e-mail: astein1@uni-hohenheim.de; qaim@uni-hohenheim.de*

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