www.elsevier.com/locate/worlddev

World Development Vol. 36, No. 1, pp. 144–158, 2008

0305-750X/$ - see front matter

doi:10.1016/j.worlddev.2007.02.013

Genetic Engineering for the Poor: Golden Rice and Public Health in India

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Summary. — Vitamin A deficiency (VAD) affects millions of people, causing serious health problems. Golden Rice (GR), which has been genetically engineered to produce β-carotene, is being proposed as a remedy. While this new technology has aroused controversial debates, its actual impact remains unclear. We develop a methodology for *ex ante* evaluation, taking into account health and nutrition details, as well as socioeconomic and policy factors. The framework is used for empirical analyses in India. Given broad public support, GR could more than halve the disease burden of VAD. Juxtaposing health benefits and overall costs suggests that GR could be very cost-effective.

Key words — vitamin A deficiency, biofortification, Golden Rice, disability-adjusted life years, cost-effectiveness, India

1. INTRODUCTION

Vitamin A deficiency (VAD) is a considerable public health problem in many developing countries: it affects 140 million pre-school children and 7 million pregnant women worldwide. Of these, up to 3 million children die every year (UN SCN, 2004). Apart from increasing child mortality, VAD can lead to visual problems, including blindness, and it increases the incidence of measles (Sommer & West, 1996). This affects public health, economic productivity, and individual well-being. Income growth alone is not expected to reduce micronutrient malnutrition in the short to medium term (Haddad, Alderman, Appleton, Song, & Yohannes, 2003). Pharmaceutical supplementation and food fortification with vitamin A (VA) are commonly practiced, but these programs also have their shortcomings: for example, those children that tend to be most at risk of VAD are least likely to receive VA supplements (Adamson, 2004), and extending program coverage is becoming increasingly difficult. Golden Rice (GR), which has been genetically engineered to produce β-carotene, a precursor of VA, has been proposed as another intervention to control VAD (Ye *et al.*, 2000). However, the usefulness of GR is questioned by some, and the technology has become one of the centerpieces in the public

* We are grateful to G. Barry, A. Dubock, J. Mayer, S.R. Rao, A.K. Singh, and U. Kapil for providing cost figures and expert inputs for essential assumptions. The financial support of the German Research Foundation (DFG) and the Golden Rice Humanitarian Board is gratefully acknowledged. Final revision accepted: February 1, 2007.

controversy over genetically engineered crops. Because GR is still at the stage of research and development (R&D) its actual effectiveness remains unknown (Grusak, 2005; Nuffield, 2003). So far, a sound and in-depth scientific analysis of the potential impact has been missing. While partial impact studies show the technology's potential for deficient populations (Dawe, Robertson, & Unnevehr, 2002; Zimmermann & Qaim, 2004), the public debate is dominated by biased assessments of anti-biotechnology groups that are not peer-reviewed and only published on activist websites (Greenpeace, 2005; Shiva, 2000). Most of the conclusions thus derived do not withstand thorough scientific scrutiny, as will be discussed later in this article where appropriate. This is not to say that issues of public interest should be dealt with only at a scientific level, but a profound and objective analysis could still contribute to a rationalization of the debate and help policy makers in their decisions.

We develop a methodology for comprehensive *ex ante* evaluation, which substantially improves upon the previous, more partial impact studies. Dawe *et al*. (2002) focused on the potential effects of GR on β-carotene intakes, but without considering actual health impacts. Zimmermann and Qaim (2004) considered health aspects, but only at a highly aggregate level and without taking into account important nutritional features like dietary heterogeneity across different regions and social groups or the role of reference intakes in dietary assessments. We use a truly interdisciplinary approach, integrating epidemiological and nutrition details, as well as socioeconomic and policy factors. In particular, we determine the current public disease burden of VAD in a country with an important rice-eating population, and simulate to what extent this burden could be reduced through GR. The simulations build on new insights of the technology's efficacy (Paine *et al*., 2005). Finally, we assess the cost-effectiveness of GR more comprehensively than the previous work and compare the results with the cost-effectiveness of alternative VA interventions and other public health programs.

The empirical analysis is carried out for India, where GR lines are currently adjusted to local conditions and are likely to be released in 4–6 years. Of the 140 million pre-school children suffering from VAD world-wide, more than 35 million live in India (UN SCN, 2004). Coverage levels of the existing national VA supplementation program are low (Planning Commission, 2002). Since rice is widely consumed in the country, introducing GR may reduce the prevalence of VAD and free scarce resources in the health sector.

2. METHODOLOGY

Although the extent of VAD in a country is generally captured by prevalence rates, merely counting the number of people below a certain threshold for VA sufficiency fails to take account of the problem's depth. Disability-adjusted life years (DALYs) provide a means to measure the total disease burden in one single index. This is done by weighting different health conditions (including premature death) according to their severity and adding up their duration. [1] DALYs were first used in the "World Development Report 1993" (World Bank, 1993) and subsequently elaborated and popularized in "The Global Burden of Disease" report (Murray & Lopez, 1996). In a study on the potential health benefits of GR in the Philippines, DALYs were introduced in an analysis of the benefits of an agricultural technology (Zimmermann & Qaim, 2004). Incorporating more detailed nutrition aspects, we further developed and refined the approach to determine the burden of VAD. Moreover, we improved the methodology to assess the impact of an increased intake of VA on this disease burden through future consumption of GR or other biofortified crops. [2] The present study on the impacts of GR in India is the first empirical application of this methodology. In the following, we provide a more detailed description of the analytical approach and the data used.

VAD itself does not impose a burden on populations that suffer from it; it is the related health outcomes that matter. Proven adverse health outcomes of VAD are night blindness, corneal scars, blindness, measles, and increased mortality among children, and night blindness among pregnant and lactating women. [3] Within the DALY formula (Eqn. (1)) disability weights make different health outcomes comparable: a disability weight of zero corresponds to perfect health, and a weight of one corresponds to a health state equal to death. The other important component of the DALY formula is the inclusion of a time dimension: the full duration of a health outcome is counted in years (or fractions thereof) at the onset of the condition. The duration of permanent diseases is determined by using the average remaining