Review

Lessons from the 'Humanitarian Golden Rice' project: regulation prevents development of public good genetically engineered crop products

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Compared to a non-Genetically Engineered (GE) variety, the deployment of Golden Rice has suffered from a delay of at least ten years. The cause of this delay is exclusively GE-regulation. Considering the potential impact of Golden Rice on the reduction in vitamin A-malnutrition, this delay is responsible for an unjustifiable loss of millions of lives, mostly children and women. GE-regulation is also responsible for the fact that no public institution can deliver a public good GE-product and that thus we have a *de facto* monopoly in favour of a few potent industries. Considering the forgone benefits from prevented public good GE-products, GE-regulation is responsible for hundreds of millions of lives, all of them, of course, in developing countries. As there is no scientific justification for present GE-regulation, and as it has, so far, not prevented any harm, our society has the urgent responsibility to reconsider present regulation, which is based on an extreme interpretation of the precautionary principle, and change it to science-based regulation on the basis of traits instead of technology. GE-technology has an unprecedented safety record and is far more precise and predictable than any other 'traditional' and unregulated breeding technology. Not to change GE-regulation to a scientific basis is considered by the author 'a crime against humanity'.

Contents

Background: the Humanitarian Golden Rice project

The following analysis is based on ten years of day-to-day experience with the public good project 'Humanitarian Golden Rice' [1]. This project from the public sector follows the successful proof-of-concept work [2–6] in which GE-technology was used to engineer the biochemical pathway for the synthesis of pro-vitamin A into the starch-storing tissue of the rice seed, the endosperm, which is consumed in the form of 'polished rice'. Polished 'Golden Rice' thus contains substantial amounts of pro-vitamin A (which the body converts into vitamin A). This concept of 'bio-fortification' [7] (defined as using the potential of genetics to improve the micro-nutrient content of food) was applied to save eyesight and lives of the numerous vitamin A-deficient children dependent on rice as their basic diet [1]. As polished rice does not contain pro-vitamin A, rice-dependent poor populations, which cannot afford

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a diversified diet, suffer from vitamin A-malnutrition. 'Yellow rice' (yellow indicating pro-vitamin A) was, therefore, on the wish-list of rice breeders since the early 1980s, but could not be attained via traditional breeding because of the lack of natural variability in this trait [1]. This trait became an option only with the advent of 'genetic engineering' [8] and is still beyond the reach of traditional breeding. Subsequent to the early proof-of-concept work by the teams of my collaborator Peter Beyer and my own, which produced the first Golden Rice in 1999, research by the private sector [9] and traditional breeding by the public sector (e.g., Cuu Long Delta Rice Research Institute, Vietnam and International Rice Research Institute, The Philippines amongst other institutions) [1] has led to substantial increases in the accumulation of pro-vitamin A in polished Golden Rice, such that the routine and standard daily diet of Golden Rice instead of white rice could prevent vitamin A-malnutrition [1].

Figure 1 illustrates, with the typical example of Bangladesh, how different dietary components contribute to vitamin A and pro-vitamin A to the daily diet. Rice-dependent poor societies typically receive between 40% and 80% of their food calories from rice and the remaining calories from fruit and vegetables (providing pro-vitamin A), and fish and poultry (providing vitamin A) [1]. Figure 1a shows that neither women nor children reach the 50% line of the recommended daily allowance, the minimum required to be protected from malnutrition [1]. Figure 1b indicates how a shift to Golden Rice would raise the vitamin A-level across this critical line. The concept of Golden Rice represents, therefore, a sustained intervention for a reduction in vitamin A-deficiency.

The concept of using the potential of genetics and GE-technology in a public sector project to fight a severe public health problem affecting poor societies was welcomed with much enthusiasm by the scientific community, the private sector, the media and the public, and Golden Rice has been featured in numerous international print media, including the cover of the Asian and US (but not the European) editions of TIME Magazine [10]. However, it also provoked heavy opposition by anti-GE-advocates, largely as the project undermined this opposition's views that GE-technology was only for industrialised farmers in industrialised countries for multinational profit. Rather, Golden Rice is to be free of any charge to growers and consumers in poor developing countries, to address one of the great public health travesties of our time – vitamin A-deficiency. Expectations were high and it was generally expected that Golden Rice would be in the fields 'soon' [11]. On the Basis of the experience with traditional variety development with such a clear and single locus trait, experienced rice breeders were predicting that eight backcross generations (three years at IRRI for example, or even less if marker-assisted breeding were to be applied) would be sufficient to develop and register Golden Rice varieties [12]. The International Rice Research Institute, Philippines (IRRI), and other public rice research institutions in developing countries were keen to progress variety development and registration [1]. According to these expectations Golden Rice should have reached the farmers' fields in Asia by 2002. It is now 2009 and it will take at least until 2012 before Golden Rice can be handed over to the farmers in the first Asian countries.

Hurdles preventing the use of GE-technology for public good projects

What then were the hurdles which, in comparison to a comparable non-GE-variety, delayed the deployment of Golden Rice for more than ten years? How can we understand a ten-year delay for a case with so much public support and such high expectations of social benefits? And what can we learn from this experience for the numerous other public good projects in the pipeline around the world?

It turned out that, under the enthusiasm of the scientific breakthrough, neither the scientists involved, nor the scientific community, nor the media, nor the public were aware of the specific requirements associated with development of a GE-crop variety. There were numerous problems which came as a surprise to the 'naïve' public sector scientists, who followed the idealistic concept of using their scientific breakthrough to fight vitamin A-malnutrition. In retrospect, however, it turned out that one single problem was responsible for nearly all of the delay. This outstanding problem was (and still is) the political dimension of GE and particularly its effect on GE-regulation. The rules and regulations established worldwide for the handling and use of 'transgenic plants' (genetically engineered plants, GEs) and the expectations of the regulatory authorities are so demanding that even with best support it takes ten years to prepare for and assemble all the data required for a regulatory dossier, not to mention the exorbitant costs involved. In the following I will briefly describe the various

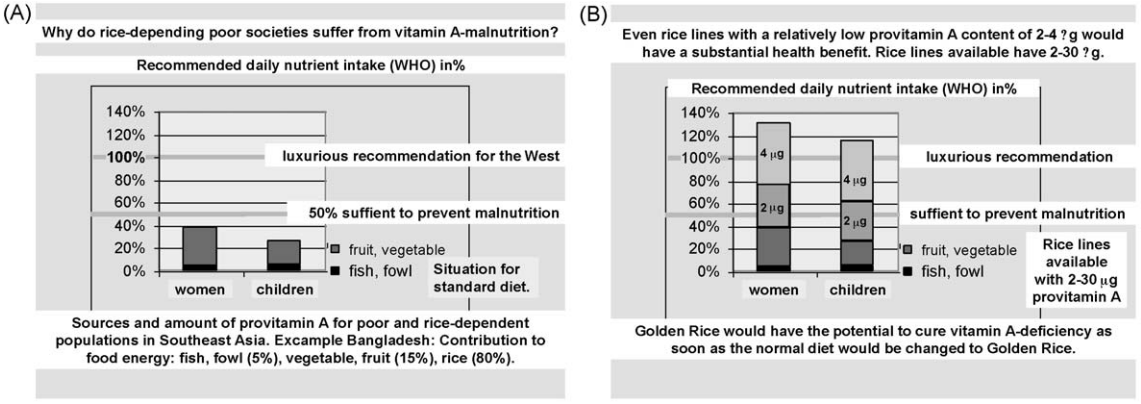

FIGURE 1

Contribution of vitamin A from the routine diet in rice-dependent poor populations without and with Golden Rice with the example of Bangladesh.

hurdles and their contribution to the 'unexpected' delay of more than ten years.

Intellectual property (IP) rights were the first and apparently 'insurmountable' hurdle we were faced with. As long as working for proof-of-concept, scientists can effectively ignore IP rights. Patents do not play a role. Scientists are free to exploit the public knowledge provided by patented inventions. We had no idea, which patents we were using for our task. The best scientific breakthrough, however, cannot rescue a single child from vitamin A-malnutrition, if a product is not developed on its basis. From this moment on, however, patents count. As we intended that Golden Rice would be handed over to the farmers free of charge, we had to organise free licences for the IP involved. It turned out that the number of patents was dramatically high [13,14]. Free licences, as it turned out, for 70 patents belonging to 32 patent holders appeared, not only to us, like the end of our idea. Under the specific circumstances of our 'humanitarian' project [1] however, the support within a 'public–private partnership' [1], and the experience and engagement of our partner from the private sector, Dr. Adrian Dubock, it was possible to solve this supposedly 'insurmountable' problem within less than half a year and in such a way that it did not delay the project for even a day [15]. Another important early contribution from Dr Dubock to the humanitarian project's long-term viability was the concept of the Humanitarian Golden Rice Board & licensee Golden Rice Network [1].

Lack of financial support from the public domain was the next hurdle. It turned out that within the public domain there was no funding beyond proof-of-concept. Financial support for 'product development' is probably beyond the philosophy of any academic institution. Academic institutions are set up to finance basic or strategic research for 'scientific novelty'. Product development is considered a task for the private sector. As a result of that situation, we were caught in an institutional 'dead end road': our concept was to use the results from our proof-of-concept work for a public good project on the reduction of vitamin A-deficiency, and this required developing a 'product'. There is no question that the responsibility for public good projects are within the public sector. But the public sector does not support – and has no expertise in – product development, and expects the private sector to take care of product development. This concept works for cases where the private sector has an interest and can expect a financial return for the investment required to develop a product on the basis of a public sector result. Humanitarian projects do not offer a chance for such a return. Therefore, the private sector cannot afford to develop such a public good product. So, again this looked like the end of our concept of a 'Humanitarian Golden Rice'.

The only way out was to find some mutual interest which could encourage the private sector to support the humanitarian project. As we had patented our invention, we could accept a proposal by the private sector (Zeneca, now Syngenta) to grant them the rights for *commercial* exploitation of our invention in return for rights to additional necessary technology from Syngenta and defined support for clearly and precisely defined *humanitarian* exploitation. This concept worked out [1]. The rights for our invention were transferred to Zeneca/Syngenta. We licensed back, together with other necessary technology and defined support, the rights for 'humanitarian use', and agreed a 'sublicense agreement' to be used as the basis for collaboration with numerous partner institutions on the basis of a 'sub-sub-license agreement'. We benefited from this 'public–private partnership' through substantial in-kind support and solution of the patent problems, and received very valuable donations for the humanitarian project from work done by Syngenta while working towards the development of a commercial Golden Rice product. Much to our regret, the company stopped the commercial project because the chance for a financial return at the level of the investment was too low. We learned the hard way what it means to develop a product and what it means to manage such a task effectively.

Nothing from these activities was holding back the development of a Golden Rice product. Financial support was received from philanthropic and other visionary organisations such as The Rockefeller Foundation, USAID, and the Syngenta Foundation under Mr Andrew Bennett. But no support was available from any public European or any UN institution. Thanks to the existence of altruistic organisations, although it was not easy to find financial support, it was possible, and lack of financial support was not a factor blocking the development of our product.

There were further disturbing factors such as the negative political climate around GE-technology [16], anti-GE-activists [17], the negative attitude of developmental aid organisations to GE crops [18], which all had strong negative effects on possible governmental support and especially on putative support from UN-organisations, even those having a specific mandate to reduce vitamin A-malnutrition, who did not reply to written invitations to engage in some way. But all this did not slow down Golden Rice development.

How GE-regulation delays GE-variety deployment by ten years

The only and dramatic bottleneck was, and is, *GE-regulation*. As there was no experience in the public domain with deregulation of a GMO-product, we followed advice from the private sector with appropriate expertise. Regulation affects a GE-product long before the collection of data for a regulatory dossier starts, and much longer before a complete dossier can be handed in to national authorities for the actual process of deregulation. The actual process of regulatory clearance, once a dossier is in line with the regulatory requirements, can be relatively fast. Which are then the practical GE-stumbling blocks which interfere with the development of a product long before regulatory authorities work on the regulatory clearance?

(1) **Deletion of selectable marker (two years)**: GE-technology requires use of selectable marker genes, which allow the selection, from amongst millions of cells, of a few which have integrated the novel genes of interest. Regulatory authorities prefer, under public scrutiny, that antibiotic selectable marker genes be deleted. This is technically possible, but takes a lot of time and effort. This has to be done despite the fact that there is a wealth of scientific literature documenting that the antibiotic marker genes in use have no effect on consumer and environmental safety [19].

(2) **Screening for streamlined integration (two years)**: Regulatory authorities do not accept complicated integration patterns of the 'transgenes'. The argument is that this can have unexpected and unforeseeable consequences. As inte-

gration of genes is a random event, the only way to achieve clean integration is to repeat the experiment so often until such an event has been found. This requires endless repetitions of the same experiment. Use of *Agrobacterium*-mediated transformation is helpful, but does not guarantee clean integration. This request is maintained for GE crops despite the fact that any 'traditional' standard breeding process leads to uncontrolled integration as well, especially if prior mutagenesis by radiation or chemical means is involved, yet such random mutagenesis goes unregulated if no new genes have been introduced from other organisms.

(3) **Screening for regulatory clean events (two years)**: 'Regulatory clean' events are DNA integration events which combine all the features which make them unproblematic for regulatory authorities, in all molecular genetic aspects. The gene cassette for one transgene is integrated in an ideal and perfect manner when there is: (a) one copy only, (b) no alterations of the construct, (c) no read-through on both sides possible, (d) no disturbance of existing reading frames, (e) no activation or inactivation of neighbouring genes or expression signals, (f) no activation of possible mobile elements, (g) stable expression at the predicted level and under the predicted conditions. Such 'ideal' events are rarities. To find them requires not only hundred-fold repetitions of the same experiment with regulatory clean constructs and technology, but also sequencing for all candidate events not only of the construct but also of the adjacent host DNA, which by itself is not as problematic as the discovery of such an event amongst thousands. We were in the fortunate situation that Syngenta was screening for them with an enormous effort during their, later abandoned, 'commercial' Golden Rice phase and was donating the material to the humanitarian project under the terms of the original licence. All final Golden Rice varieties are based on such 'regulatory clean' events.

(4) **Trans-boundary movement of seeds (two years)**: Golden Rice is, of course, an international breeding exercise. Rice breeders within the Golden Rice network [1] in the different countries, using traditional and marker-assisted breeding, develop agronomically improved, locally optimised Golden Rice varieties on the basis of the most popular varieties in their countries. This requires free exchange of breeding seed material between countries. The conditions set up by the Cartagena protocol [20] make exchange of transgenic seed so complicated that it took more then two years to transfer, for example breeding seed from The Philippines to Vietnam; and one year from USA to India, during which time 30 politically loaded questions were asked in the Indian Parliament. These Cartagena conditions are enforced, despite common sense suggesting that it is extremely difficult to construct a hypothetical risk from seed transfer between two breeding stations in different countries, especially for Golden Rice.[1]

(5) **Obligatory sequence from growth chamber to greenhouse to screen-house to field (two years)**: Permission for work in the field is given, if at all, only after intensive testing and data collection in (a) a contained growth chamber, (b) followed by the same in a contained glasshouse, and (c) followed by the same in a contained screen-house. This means that tests can begin on small plots only after 18 months, according to the regulatory requirement. Whether permission is given, however, also has a political component. We waited until late 2008 for the first permission for the first small-scale field plot in a developing country. Fortunately, we carried out initial field tests in Louisiana, USA, in 2004, where granting of the permission did not even require half a year. Variety development, however, means 'breeding'; breeding depends upon large numbers of offspring; large numbers are possible only in the field. Breeding also requires response to the natural environment to explore response to the natural stress conditions. Neither the necessary numbers nor the environmental conditions can be achieved under artificial conditions. This most severe impediment of normal, efficient breeding is the automatic consequence of regulation. It does not matter that nobody has ever come up with a hypothetical scenario arguing for any hypothetical environmental risk from Golden Rice. Every GE case has to follow all rules and regulations, independently of whether there is any putative risk or not. Again, we lost far more than two years to ideology-based regulation!

(6) **Requirement for one-event selection (two years)**: Preparing a regulatory dossier for a single transgenic event is so demanding and expensive that it is totally impossible to deregulate several independent transgenic events. This forces any GE-product developer to base all variety development on a single transgenic event. To be able to select the single event and then invest all resources in it requires collection of numerous data from many events. To collect these data without extended work in the field is impossible. Event selection can come only after permission for field experiments (see above for the problems!). Different varieties developed from a single transgenic event can be deregulated on the basis of the same regulatory dossier, if they are derived by traditional breeding. Therefore, all Golden Rice varieties are derived from one single transgenic event more than half a decade ago and all subsequent steps are the result of traditional plant breeding in the different partner institutions in the different countries. We definitely would prefer to have varieties based on different events, but the conditions for deregulation leave no choice, despite the whole basis of the applicable rules being a one-time transitory necessity to overcome the limitations of conventional breeding all those years and seed generations before.

(7) **Requirements for the regulatory dossier (four years)**: I will not describe all the hundreds of expensive studies in molecular genetics, biochemistry, nutrition, protein identity, -digestibility, -immunogenicity, gene expression, anti-nutrients, and agronomy required, at publication level quality, for the final regulatory dossier. These requirements keep an entire team of specialists busy for at least four years. Part of the studies can already be done during the course of develop-

[1] Incidentally, free movement of cereal seed between different countries seed breeding systems was absolutely at the heart of the success of the green revolution of the 1960s and 1970s in introducing new genes to countries, increasing biodiversity, and increasing food productivity and reducing malnutrition.

ment, but an essential part has to be done with the final variety to be released. This also means that ten years of expensive experimentation has to be performed with no guarantee that at the end everything will be in accordance with the regulatory requirements. Not to be in line with the regulatory requirements, however, does not need to constitute a realistic risk. It just means no permission for release.

(8) **Deregulation procedure (one year)**: Once a complete regulatory dossier, especially one based on a regulatory clean event, has been assembled, the actual procedure for regulatory clearance has a fair chance of taking less than a year. Therefore, it is neither the regulatory authorities, nor the final regulatory process, which has to be blamed for delaying registration of GE varieties. It is the rules and regulations themselves for the use of transgenic plants and, of course, the political attitude enforcing its 'extreme precautionary application'.

The putative impact of Golden Rice

The definite impact of Golden Rice will be monitored in epidemiological studies following release to the farmers and consumption by vitamin A-deficient and rice-dependent populations. Because of regulation this will not be possible before 2013. Socio-economic studies, however, allow one to get an educated estimate already now, by performing state-of-the-art *ex ante* studies. Because solid data about human bioconversion and bio-availability of pro-vitamin A from Golden Rice have been generated [21,22], the predictions can be relatively precise. There has also been a series of economic *ex ante* studies with Golden Rice in different countries. In the following paragraph I refer to the detailed study on the putative impact of Golden Rice in India, published by the team of Professor Matin Qaim, Göttingen [23].

The annual burden of vitamin A-deficiency in India is characterised by the loss of 71,600 lives or 2,328,000 'DALYs'. (A DALY is a technical term used by economists to quantify, and allow comparison between the impacts of interventions and refers to a standardised disability-adjusted life year.) The potential annual impact of Golden Rice is presented in two scenarios, one 'pessimistic' and the other 'optimistic'. Three years after this publication, we know that the optimistic scenario is a realistic one. According to these scenarios, Golden Rice could save up to 40,000 lives per year, or in DALYs, up to 1,382,000 healthy life years annually. The lives saved would represent 95% of those rice-dependent poor in danger of losing eyesight and life. As only half of the Indian poor depend upon rice and the other half upon wheat, Golden Rice could not save more than half of the 71,600. (For the others 'Golden Wheat' might be an option.)

The World Bank's benchmark cost of saving one 'disability-adjusted life year', valued at $620–$1860 by the Bank, is $200. The actual costs for the, so far most effective, traditional intervention – the free distribution of vitamin A-capsules – is between $134 and $559. Golden Rice is expected to do the same thing for only $3. And this $3 cost would include all the money spent in ten years of proof-of-concept work, plus all the money spent on product development, deregulation, variety registration and social marketing. These unprecedented low costs are the consequence of the fact that there are no recurrent costs, once a variety has been released. This is the major reason why this intervention based on 'biofortification' is highly sustainable as well as cheap.

Once cleared for adoption by the national authorities, seeds of agronomically optimised and locally adapted Golden Rice varieties will be provided to the farmers by public seed distribution units or by licensed seed multiplications units, free of charge for the trait and within the framework of the humanitarian project. The farmer will be free to grow, harvest, sell, consume and store Golden rice without restrictions, including to use part of the harvest for the next sowing and to pass seeds on to neighbours. The rice farmers will continue to use their traditional farming practices and will not require any additional input in the form of agrochemicals or fertiliser. The costs of production will be the same as for any other variety of rice The yield of Golden Rice varieties is at least as good as other popular non-GE varieties and there is no off-taste which would discourage consumers from eating Golden Rice. The only difference is the yellow colour. Initial but in depth social marketing research has shown that households have no problem with the colour when they understand it is associated with good nutrition.

Lessons learned from the Humanitarian Golden Rice project

From ten years work with the development of the first public sector GE-product we can derive a series of lessons which apply to any further public sector GE project. These lessons are probably new to most colleagues in academia as well as to the public sector in general. As they have, however, far-reaching consequences for all those projects in the public domain, financed with the vision of contributing to the solution of altruistic problems (much of basic science in plant molecular biology and biotechnology is financed with this argument in mind), those financing and working on such problems should at least be aware of what stands between a pleasing, academic, proof-of-concept result and the practical impact it claims to achieve.

A. Negative attitudes to GE crops:
   1. The European negative attitude to GE has a very strong negative effect on governments in developing countries.
   2. The negative attitude is prevalent within several NGO's, a small part of the public, much of the media, many development aid organisations and most European governments.
   3. This effect is exacerbated by the financial support of the EU to NGO groups paid to lobby the EU against GE crops
   4. This effect is exacerbated by the financial support by European NGOs to NGOs in developing countries.

B. Regulatory process:
   1. Justification for present regulation is based on the notion that the technology leads to 'unpredictable and uncontrolled modifications of the genome'.
   2. This argument ignores the fact that all traditional breeding has been and is doing exactly the same (e.g., [24–28]).
   3. In the entire history of GMO-technology development and application there is not a single documented case of harm, which could be used to argue for maintenance of the present regulatory situation [29].
   4. There is no scientific justification for present regulation.

C. The financial and time cost implications of excessive regulation:
   1. The costs for the development of a GE-variety are currently so immense, due to politics, not science, that it is difficult to identify a product which offers a fair chance for financial return of the investment for non-industrial crops.
   2. In addition, GE-regulation delays delivery of GE-based products for about ten years, compared to non-GE varieties and carries a huge financial penalty.
   3. Time and costs for delivery of a GE-product to the market are, therefore, so immense that neither public institutions, nor any small- or medium-sized enterprise, can afford the investment in funds and/or personnel.

D. Impact on food security of unscientific regulation:
   1. Food security for developing countries, however, requires, besides the best of traditional agriculture, also the best of novel technologies. GE-regulation excludes a very potent and promising technology.
   2. There is, in addition to Golden Rice, excellent progress within the Bill & Melinda Gates Foundation funded biofortification projects within *Grand Challenges in Global Health No. 9* [30] with regard to high-iron-, high zinc-, high protein-rice, and exactly the same in cassava, banana, and sorghum, which have the potential to save further millions of lives per year.
   3. All these projects suffer from the same consequences of regulation as described for Golden Rice, increasing the number of lives lost to the tens of millions per year. And there are *drought-*, *salt-*, *flooding-*, *virus-*, *bacterial- fungal-*, *insect-*, *nematode-resistance* projects too, not only with the major crops, but also with staple crops important for food security in developing countries, and there is improved exploitation of natural resources which could all substantially contribute to food security [31], if only GE-regulation did not prevent public good GE-product development.
   4. Numerous other public projects for, for example, improved food security, including many from developing country laboratories and with orphan crops, have – under these conditions – no chance to make it to the market place.
   5. GE-potential is, therefore, blocked for public good projects. The often-raised complaint (especially by the GE-opposition) that GE-technology has been only exploited for industrial projects, has its only cause in the GE-regulatory system, and politicisation of this useful technology.

E. The social cost of over regulation:
   1. According to the *ex ante* study mentioned above [21] Golden Rice could save in India alone ca. 40,000 lives per year. The social costs as the consequence of GE-regulation, calculated only for the case of Golden Rice, India and the delay of deployment of ten years, would add up to a loss of about 400,000 lives.
   2. However, there are further countries with vitamin A-deficiency problems and poor, rice-dependent poor populations, such as The Philippines, Bangladesh, India, Vietnam, Indonesia, and China for which Golden Rice is under development [1]. Delay of deployment raises the social costs of regulation to a loss of lives far beyond one million.
   3. A conservative estimate of the social costs of all those blocked public good projects indicated above, and considering just the ten years of delay, amounts to astronomic losses of hundreds of millions of lives.
   4. And this is not everything with regard to social costs, because the great majority of the public good projects will not just be delayed; they will never make it to the market place, thus adding further loss in lives.
   5. In addition to the unacceptable and astronomic social costs, there are also enormous economic losses which cannot be recovered because the loss of lives and healthy life years (DALYs) are irreversible.
   6. A World Bank study [32] calculates the annual economic loss of GDP due to lack of adoption of 'Golden Rice technology' to be ca. $15.6 billion in Asia alone, with utmost $300m of exports to Europe at risk.

F. The role and limitations of the public sector:
   1. The public sector, not the private one, is responsible for public good, altruistic and humanitarian projects.
   2. The public sector has competence for proof-of-concept work, but is totally incompetent and unwilling to deliver public good GE-products from its own successful research.
   3. The public sector, therefore, depends upon partnership with the private sector for the exploitation of its achievements in science and technology.
   4. In contrast to the private sector, academic personnel survive on publications. All the work necessary for product development and deregulation does not offer the slightest chance of publication.
   5. New ways of recognising merit need to be developed to address this shortcoming, which impedes academic involvement in pro-poor product development.

G. The role of the private sector and those with broad based commercial experience in the private sector:
   1. The consequence of the above is a *de facto* monopoly for GE-products among a few financially potent companies and for industrial crops.
   2. There is goodwill in, and from those individuals with experience of, the private sector to support development of public good products with expertise and intellectual property, as long as this does not interfere with commercial interests.

H. The role of public–private partnerships:
   1. Public–private partnerships function only, if there is a strong mutual interest also for the private partner and if the public partner can be considered reliable.
   2. Public–private partnerships require clear definition of, and the related contractual basis for, those mutual interests and reliable management structures on the public side, to minimise liability risks for the private sector and to ensure that the public sector gets what it needs consistently from the private sector, despite changing personnel and business situations.

I. The moral imperative:
   1. The damage to lives and welfare from GE-regulation is enormous, and affects the poor, and not the rich Western societies, which are responsible for the establishment and maintenance of these regulations.

2. The West ignores a moral imperative to make these technologies available to the poor, including its application to orphan crops [33,36] and therefore carries responsibility for the consequences.

Considering the above and the additional fact that there is a scientific consensus that transgenic plants pose NO novel risk as compared to non-transgenic plants derived from traditional plant breeding [34], it is difficult to understand that our society continues with the practice of extreme precautionary regulation, exclusively of those plants which have been produced with the most precise and predictable technique of genetic modification and which have the safest track record compared to any other technology [35].

Are those opposing the technology and those politically responsible for existing regulation willing to take responsibility for the economic losses? Or, far more importantly, are they ready to take responsibility for the astronomic social costs?

What else is necessary to open the eyes of those, who carry political responsibility, to understand that not changing GE-regulation from extreme precautionary to science-based regulation, guided by considerations of the risks and benefits of the trait instead of regulating a technology on ideological terms, constitutes a 'crime against humanity' [28]?

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