Available online at www.sciencedirect.com
ScienceDirect
Agricultural Sciences in China
2006, 5(12): 885-894
December 2006

Exploration of the Biopolitics of GMOs: Using Golden Rice as an Analytical Model

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Abstract

Several disputes exist around Genetically Modified Organisms (GMOs). This article uses the concept of biopolitics to refer to all the GMO-related political issues and the mechanisms that are used to handle them. As a world famous genetically modified crop developed for the welfare of humanity by public institutions, Golden Rice has on one hand won glories, whereas on the other met with criticisms. It could be used as an analytical model to illustrate the biopolitics of GMOs. On the basis of an overview of its technological background, this article first introduces the participants and the debated issues of the Golden Rice project and then the disputes between the supporters and opponents and consequently analyzes the biopolitics of the Golden Rice. In conclusion, this article justifies the biopolitics of the GMOs and its doctrine.

Key words: Golden Rice, biopolitics, GMOs, NGOs, Greenpeace

INTRODUCTION

Ever since its invention in the early 1970s, although playing a leading role in modern biotechnology, the recombinant DNA technique has been a source of worries and triggered debates and disputes among the scientists and the public. The debates cover all issues relevant to the living modified organisms or genetically modified organisms (GMOs) and the biological products derived from them, such as transgenic food. The issues include not only the technique itself but also its safety and other social and ethical implications, and its effect on agriculture, international trade, and even international relationship among different countries. Regarding its significance for the society, this complex phenomenon necessitates a general description and an explanation. This article has attempted to use the concept of "biopolitics" to define and illustrate all the aspects that modern biotechnology, especially GMOs, has had to deal with, including the relevant technical, political, ethical, and social issues and the corresponding mechanism. The concept of biopolitics has been invented for decades and consequently involves various meanings at multiple levels (Editorial 2005). However, this article will concentrate mainly on its positive political aspects. Specially, this article has used the world famous genetically modified (GM) Golden Rice as an analytical model.

In addition to the Introduction, Part Ⅰ introduces the technical background of the Golden Rice; Part Ⅱ and Ⅲ describe, respectively, the participants and the debated issues of the biopolitics of the Golden Rice. Part Ⅳ and Ⅴ present critiques of the Golden Rice by Greenpeace and the counter-critiques of Greenpeace by the inventors, respectively. On the basis of the Part Ⅰ to Part Ⅴ, Part Ⅵ provides an overview of the biopolitics of the Golden Rice by referring to the several hotly debated issues. In the concluding remarks, Part Ⅶ justifies the biopolitics of the GMOs and its

This paper is translated from its Chinese version in *Scientia Agricultura Sinica.*
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doctrine. The author of this article declares that the terms “biopolitics” and “politics” that are used in this article are neutral concepts without any good or bad appraisal.

TECHNICAL BACKGROUND OF THE GOLDEN RICE

The story of the Golden Rice sounds like a fairy tale in the biotech era, which is yet to complete its long march toward its goal of serving the needs of humanity-saving from blindness millions of children in the developing countries, where rice is the major staple food. The edible part of the rice seed, the endosperm, lacks several important nutrients including provitamin A, which is *in vivo* metabolized to form vitamin A (VA). As a well-known GM crop, Golden Rice was invented primarily by public institutions to help solve vitamin A deficiency (VAD), which leads to blindness and other serious illness in or even death of children. It is reported that annually there might be an average of 250 000 children becoming blind because of VAD (Ye *et al*. 2000). For this reason, VAD remains a major health problem on the agenda of international fora such as the WHO and the UNICEF.

VA plays a central role in alleviating VAD, and VA capsules are distributed by national and international humanitarian programs for poor children in developing countries. However, it is argued that these distributions generally require infrastructure and personnel, which may not be readily available and therefore children in urgent need of VA may not get it. An alternative is to enrich rice or other foods with provitamin A, but this will increase the cost and push up the price. From the perspective of plant biology, it would be a good idea to cultivate new varieties of rice that would produce and store in the endosperm β-carotene or other kinds of provitamin A. Because varieties of rice with this property are yet to be found, cultivators can do this only by transforming the planted rice, *Oryza sativa*, using transgenic methods, and this is exactly what the inventors of the Golden Rice have done (Ye *et al*. 2000; Paine *et al*. 2005).

In general, cultivation of GM crops requires the transfer of only a single gene or two genes; however, the Golden Rice requires transfer of three or four corresponding genes working together for the formation and storage of β-carotene in endosperm, making it much more difficult than that of other GM crops. This is called “pathway engineering” (Potrykus 2000). The four genes, deriving from *Narcissus pseudonarcissus* and *Erwinia uredovora*, respectively, are those responsible for enzymes including the phytoene synthase, phytoene desaturase, æ-carotene desaturase, and lycopene β-cyclase. The genes work in tandem and synthesize carotenoid in the endosperm. When the outer coat and aleurone layer are removed, the pigments present in the rice lend it a shallow golden yellow color and therefore it is called “golden” rice (Potrykus 2000). Using similar procedures to insert three “iron genes”, scientists from the same laboratories developed iron-rich rice that could help fight iron deficiency prevalent in developing countries (Lucca *et al*. 2002).

It has been published in the *Science* that the content of carotenoid in the Golden Rice is 1.6 μg per gram of endosperm (Ye *et al*. 2000) and has been assessed to be far less than one’s daily requirement of VA. Five years from then, scientists in Syngenta have successfully developed the second generation of Golden Rice, in which the content of carotenoid is 37 μg per gram of endosperm, which is 23 times higher than that of the first generation and has been regarded as adequate to meet the daily requirement (Paine *et al*. 2005). Presently, experiments on bioavailability, substantial equivalence, toxicology, and allergenicity of the Golden Rice are being carried out.

The Golden Rice program, the main objective of which is to serve the poor suffering VAD, has been supported mainly by the Rockefeller Foundation for a rather long duration, together with supports from other institutions such as the Swiss Federal Institute of Technology (ETH) and the 4th/5th Framework of EU funding. To settle the issues of intellectual property rights (IPR) and facilitate its transfer to the targeted developing countries, the principal inventors signed an agreement with Syngenta, who in response to the IPR issues promised to license without charge the Golden Rice to farmers in the developing countries subject to the condition that a farmer’s annual income from the Golden Rice is less than ten thousand US dollars. Potrykus describes the Golden Rice project and such similar projects as

"successful projects that were developed in public institutions using public funding that address an urgent need, are not solvable with traditional techniques, are being made available free of charge and limitations to the poor, and have no deleterious effects on the environment or human health" (Potrykus 2001).

During its research and development, Golden Rice has given rise to several disputes regarding its technological, social, ethical, economical, trade, and political aspects. It could thus be a rather good model to describe and illustrate the biopolitics of the GMOs in the contemporary times.

PARTICIPANTS OF THE BIOPOLITICS OF GOLDEN RICE

Since its commencement in the early 1990s, the Golden Rice project has been through a tough but splendid journey that continues till today. Participants at the national, regional, and international levels are involved in its biopolitics; these participants play important roles in the project and it is their actions, reactions, and interactions that make the biopolitics of the Golden Rice a rather complicated game. The participants mainly include the following.

(a) Public research institutions: such as the ETH, University of Freiburg in Germany, and the Golden Rice Network. The Golden Rice Network was formed by the International Rice Research Institute (IRRI) and various other public research institutions from the Asian countries including the Philippines, India, China, Vietnam, Bangladesh, and Indonesia, with IRRI as the leader. The Network's main responsibility is to support and enhance R&D of the Golden Rice in the developing countries of Asia (Golden Rice Humanitarian Board 2005).

(b) The principal inventor and promoter, Professor Potrykus. Although Professor Potrykus is a retired scientist belonging to the ETH, this article acknowledges his contribution to highlight his irreplaceable role. He has been leading the R&D efforts of the Golden Rice even after his retirement from the ETH despite criticism and the threats to his personal safety from the opposition. It is noteworthy that his views and actions do not necessarily reflect those of his university, and this may be important for the R&D. Another key inventor is Peter Beyer from the University of Freiburg.

(c) Public foundations, mainly the Rockefeller Foundation. This foundation plays a key role in the R&D of Golden Rice and its potential transfer to developing countries, which cannot be replaceable by governments or business corporations.

(d) Business entities, such as the Syngenta and Monsanto. Syngenta is actually a partner in the Golden Rice project and is a member of the Golden Rice Humanitarian Board. It has been responsible for the IPR issues of the first-generation Golden Rice. More importantly, it succeeded in developing the second generation of Golden Rice and claimed to have donated it to the Golden Rice Humanitarian Board so that it could be transferred to developing countries. Monsanto, among others, had licensed relevant patents to the Golden Rice project, without charges.

(e) Golden Rice Humanitarian Board ("Board"). The Board was formed to facilitate the goal of the Golden Rice to serve humanity, including transfer of the Golden Rice to developing countries. It has a broad membership consisting of the principal inventors, relevant public institutions, the Rockefeller Foundation, Syngenta, and related branches of the governments. Consequently, its views reflect the shared knowledge and recognition among its members.

(f) Nongovernmental organizations (NGOs), mainly the Greenpeace. In dealing with the issues of IPR, the RAFI (now ETC), the ISAAA, and several other NGOs were involved. Besides, several NGOs from the targeted Southeastern Asian developing countries have also been involved in the biopolitics of the Golden Rice.

In addition, media such as the *Time Magazine*, many radio and TV stations, and information networks have actively participated in the biopolitics of Golden Rice. Although the media may have its own emphases and views, its active presentation of the news and relevant comments has kept the public informed of the latest developments in the project. Furthermore, farmers and consumers from the targeted developing countries are believed to be the direct beneficiaries of the Golden Rice. However, till date, they have not used the rice, neither have they been involved directly in the biopolitics. Because the rice is yet to be commercialized, the role of the government as a regulator has not yet

fully materialized.

ISSUES CONSTITUTING THE BIOPOLITICS OF GOLDEN RICE

The Golden Rice project involves various interwoven elements and issues that have made up the biopolitics of the Golden Rice. The issues involved include at least the following.

(a) Social issues, including the prevalent VAD and the related diseases and poverty. These are the main reasons that prompted inventors to carry out the research and the foundations to support the project. Malnutrition, diseases, and poverty are deep rooted in the society and are closely linked to the inequitable distribution of social resources.

(b) Technical issues, including the breakthrough in the transgenic technology that makes the "pathway engineering" possible. From the first to the second generation, the content of carotenoid in the endosperm has improved over 23 times (Paine *et al*. 2005).

(c) Legal issues, including the IPRs and biosafety (including food safety). Because the R&D of the Golden Rice has not yet been concluded and its commercialization has not yet been materialized, other legal issues are yet to come. The Golden Rice project has been caught in a rather complicated IPR controversy, but not yet to an extent that transfer of the Golden Rice to targeted developing countries is impossible (Kryder *et al*. 2000; RAFI 2000; Liu 2006).

(d) Biosafety issue. Experiments on the biosafety of the Golden Rice are still being carried out and these are unlikely to conclude in the immediate future, but biosafety is already one of the hotly debated issues that the Golden Rice has had to confront. This situation is similar to those faced by other GMOs: the more the indeterminateness, the more the debates.

(e) International trade issue. Trading of GMOs has been one sensitive issue discussed in international fora. Although the Golden Rice is yet to be commercialized, it has already triggered off international trade disputes. For example, Thailand is an important exporter of rice with also a strong domestic consumer market and is interested in cultivating the Golden Rice. But the Thai government has been warned by the European importers that if Thailand plant transgenic rice, they would no longer import its rice. This no doubt influenced the Thai government's decision not to participate in the Golden Rice project or the Golden Rice Network. Potrykus criticized this as "neocolonialism" (Köppel and Canonica 2001).

(f) Issues of globalization and antiglobalization. Since the 1990s, the acceleration of globalization has accentuated many social problems, such as the disappearance of local traditions and the decrease in cultural diversities. This trend is placing the developing countries in a more disadvantageous position and thus faces opposition to globalization. This constitutes a barrier to the Golden Rice project. For example, some NGOs from certain Asian developing countries expressed their opposition to the Golden Rice project and this may be due partially to their abhorrence to globalization. Participation of Syngenta as a transnational giant might have intensified their opposition.

(g) Historical issue. The unfortunate detrimental effects of the Green Revolution, including the diminishing of crop diversity, have already been a historical burden, which has affected the evaluation and acceptability of the Golden Rice. When compared with other commercialized GMOs on the market, Golden Rice is thought being more in line with the humanitarian goal (Nash 2000), but it has to bear this historical burden.

(h) Biopolitical issues. All the issues listed above could finally be transformed into biopolitical issues, constituting the common issues of all the aspects the project has been facing. Accordingly, this may increase the complexity of the biopolitics of the Golden Rice.

In short, the multiple games played by various participants render the biopolitics of the Golden Rice more complicated. Based on their attitudes toward the Golden Rice project, the participants could be classified basically into two groups: the supportive group that acknowledges, supports, and actively participates in the project, including mainly Potrykus, ETH, IRRI, the Rockefeller Foundation, Syngenta, and the Golden Rice Humanitarian Board and the oppositional group that objects to the project, including mainly the Greenpeace and other NGOs. The supportive group could be represented by Potrykus and the opposition group by the Greenpeace. But this does not mean that all the participants of the same group do necessarily share the same

views regarding every issue. For example, with regard to IPR, Syngenta would probably hold a perspective that is different from those of others. However, these differences in perspective on certain aspects do not hinder their cooperation in promoting the Golden Rice project.

CRITICISMS OF THE GOLDEN RICE BY GREENPEACE

In the present biotech era, NGOs exert significant political influences in certain areas such as environmental protection and GM food; therefore, the biopolitical forum of the GMOs would be incomplete without NGOs. This is also true in the case of the Golden Rice, which has met with strong opposition from Greenpeace: from the R&D to the transfer of the Golden Rice, and from Europe to Asia, where the Golden Rice project goes, there comes criticism from the Greenpeace. The criticism of Golden Rice by Greenpeace could be ascribed to five main aspects.

First, the Greenpeace comments that the Golden Rice project is not necessary to alleviate VAD and that it is a technical failure. It says that as a serious social issue such as VAD can hardly be resolved by a crop, especially a GM crop. Instead, it emphasizes the importance of diversified nutrition and certain other means, such as VA distribution, food fortification, and "home gardening". It argues that these methods have been proved to be effective; but the Golden Rice project tries to simplify the issue and misdirect the public's attention, and this would probably make things worse (Greenpeace 2005a,b,c,d).

Second, the Greenpeace says the Golden Rice project would not solve the problem of VAD: for the first generation, the content of carotenoid in the Golden Rice was 1.6 μg per gram of endosperm and in terms of bioavailability, this has been assessed to be far less than one's daily requirement of VA and one would have to consume 12 times the quantity of the normal meals; for the second generation, although the carotenoid content was much more higher than before, other aspects are yet to be tested, for example, the bioavailability and stability after cooking (Greenpeace 2005a, d).

Third, it is not necessary to adopt a transgenic approach to develop the Golden Rice because newly found traditional landraces contain not only carotenoid but also iron, high-quality protein, and lipids that help in the adsorption of carotenoid (Greenpeace 2005b). The article it cited says that the content of carotenoid in certain upland cultivar is almost the same level as that in the Golden Rice (Frei and Becker 2005).

Fourth, the biosafety could not be warranted. Greenpeace holds that it is known that the cultivated rice could outcross with its wild and weedy relatives and thus the Golden Rice could possibly lead to genetic contamination of wild rice; this is not reversible and thus endangers biodiversity and brings with it economic and environmental problems; furthermore, the transferred genes from daffodil and bacteria may cause allergic reactions (Greenpeace 2005a, b).

Finally, R&D of the Golden Rice does not serve the needs of humanity. Greenpeace says that Syngenta conducts R&D and professedly declares that farmers from the developing countries could use the Golden Rice for free but in reality it has filed patent applications in more than 100 countries; this shows that Syngenta's real purpose is to ensure its monopoly on crop breeding and gain supports from the European countries (Greenpeace 2005b, e). Regarding Potrykus' comments that GMOs should be treated on par with other plants, that the precautionary principle is not a necessity, and that there is no need to carry out environmental and health assessments for the Golden Rice, Greenpeace says that it is clear that the genetic engineering industry is using the Golden Rice and the poverty-stricken population that is greatly suffering from malnutrition as propaganda tools (Greenpeace 2005c). Greenpeace complains that "…if you queried their claims, or had concerns about possible genetic contamination of a global staple food, you were an environmental extremist who cared more about trees than children" (Greenpeace 2005a).

Besides, several NGOs from some of the targeted Asian developing countries that may benefit from the Golden Rice project also expressed their dissatisfaction with the project. Invoking lessons learned from the Green Revolution, they say that poverty is the root cause and Golden Rice would not solve the problem, but may make things worse by leading to problems such as genetic erosion and increase in the disequilibrium of

nutrition. They commented that the best method to get rid of VAD is to make use of the diverse, cheap food available. Similar to the comments of Greenpeace, they also deem that Golden Rice is only one kind of marketing maneuver that would limit poor farmers' right to selection. Their predicament would never be solved by it or by other GMOs. They alleged that any attempt to exploit hunger and malnutrition by GMOs should be strongly opposed (BIOTHAI *etc*. 2001).

V. POTRYKUS' COUNTER-CRITICISMS OF GREENPEACE

Potrykus, together with the Board, fought back and discredited the criticisms by Greenpeace. First, Potrykus argues that the Golden Rice is definitely a beneficial method for elimination of VAD. With regard to the other approaches listed by the Greenpeace for solving the problem of VAD, he points out that it is difficult to say whether all the methods can be effective. For example, the VA capsule distribution to school children requires infrastructure and financial support, and it cannot be guaranteed that VA will reach everyone who needs it, such as those children who are too poor to go to school (Potrykus 2001). Instead, the Board believes that the Golden Rice is indeed a solution to VAD but admits that the rice alone would not be an adequate answer to the malnutrition because it has many political, economic, and cultural involvements. Miracles would not occur by the application of a single agricultural technology. Instead, it is only one of the several options that developing countries could choose from and it could complement other approaches such as VA distribution and food fortification (Golden Rice Humanitarian Board 2005).

Second, Potrykus justifies that there would be no problem with biosafety of the Golden Rice. Regarding Greenpeace's comment that Golden Rice's pollen could travel with wind and pollinate other rice varieties, Potrykus argues that rice's pollen can fly only few centimeters. It is true that the possibility of cross-fertilization between the Golden Rice and other rice varieties could not be excluded theoretically. However, because all green plants could synthesize carotenoid and thus the Golden Rice has neither ecological advantage nor risk, and VA and its gene are constituents of human food, the genes transferred into the Golden Rice are therefore safe for both environment and humans. Furthermore, he justifies that GMOs have been used for more than 20 years and yet there are no evidences indicating that they are harmful. This safety standard maintained for GMOs is so high that so far no other technologies could possibly meet (Köppel and Canonica 2001).

Regarding elimination of the risks by adopting the precautionary principle, he comments that genetic engineering has been strictly following the precautionary principle since its beginning and this is rare among other technologies. However, he emphasizes that no single biological system could be free from all risks, including the biofarming system that was applauded so much; therefore, it would be unfair to expect the GMOs to be fully free from risks. As to the Golden Rice which "can make a contribution to preventing that every year 500 000 children go blind and millions of mothers die in childbed", on one hand, it is "the predictable blindness and deaths of hundreds or thousands of humans in the Third World", but on the other, it is "[A] possibly still unidentified, indefinable and hypothetical risk", he asked, "What weighs heavier?" (Köppel and Canonica 2001).

Third, he commended the Golden Rice as a challenge to GMOs' opponents because it has met every requirement the critics proposed to attack genetic engineering and thus invalidate all of the arguments against the transgenic technology so far. The Golden Rice has *inter alia* the following properties, as compared with other GMOs: it is not developed by or for the industry and the biotech industry does not benefit from it; it fulfills an urgent need by complementing existing approaches and it was impossible to develop the trait by traditional breeding methods; it avoids the side effects of the Green Revolution and presents a cost-free as well as sustainable solution, requiring no other resources; it does not create advantages for rich landowners but instead benefits the poverty-stricken and the disadvantaged; it is given free of charge to farmers in the developing countries, it can be grown every year without additional inputs, including seed, and does not create any new dependencies; it reduces neither agricultural nor natural biodiversity and therefore presents no conceptual negative effect on the environment and conceivable risk to consumer health (Potrykus 2001).

Fourth, regarding the political objective of Greenpeace and the moral obligations of the scientists, Potrykus raises the question whether scientists should ignore the aspersions cast by the opponents proclaiming that the Golden Rice would cause hair loss and impotence, and he concludes that this would be a "wrong strategy". He comments that the specious arguments of the Greenpeace would probably lead to unwarranted opposition in developing countries, which in turn would lead to millions of avoidable blindness and VAD deaths among children. Therefore, scientists have the moral obligations to inform the public what a dangerous and immoral game Greenpeace has been playing. He doubts the motive of the opponents who always ask the scientists to be responsible for their acts while they themselves evade theirs, given the harm they may cause to the disadvantaged and poor. He says that "hindering a person's access to life- or sight-saving food is criminal", and "[T]o do this to millions of children is so criminal that it should not be tolerated by any society" (Potrykus 2001).

Potrykus comments that although Golden Rice has so many merits, the opponents insist on preventing its distribution to the malnourished, poor farmers. This indicates that they care neither for the environment and consumers nor for the alleviation of hunger and malnutrition. Instead, the Greenpeace has just one goal, that is, "to organize media-effective actions for fund raising"; the Greenpeace has criticized the Golden Rice as strongly as it did the GM insect-resistant Bt cotton, and this indicates that the organization does not care about certain issues but is demonizing the entire biotechnology, the Golden Rice will hence "hopefully may help to unmask the true and shameful face of Greenpeace". Obviously, he added, GMOs could help increase the standard of living and quality of life of people in the developing countries and that is not sufficient if scientists carry out research alone, they should also be propagandists of the new technologies (Potrykus 2001; Köppel and Canonica 2001).

REVIEW OF THE BIOPOLITICAL ISSUES OF GOLDEN RICE

On the basis of the above introduction to the participants and debates regarding the biopolitics of the Golden Rice, this article now attempts to review the biopolitics of the Golden Rice by referring to the several main issues.

First, is genetic engineering the only way to develop the Golden Rice and is the Golden Rice a molecular biological masterpiece or a technical failure? These questions involve only the technical aspects of the Golden Rice and should be indisputable, but actually there are disputes about the technical issues. It the article on Golden Rice published in the *Science* in 2000, it was stated that because no rice cultivars producing β-carotene in the endosperm were found, recombinant DNA techniques rather than conventional breeding technologies are required (Ye *et al*. 2000). It is a biological fact that although rice produces β-carotene, it exists only in parts such as leaf, stem, and seed hull and not in the endosperm; therefore, when the hull and bran are removed, the rice consumed everyday does not have β-carotene.

However, an article published by Greenpeace in 2005 states that traditional rice varieties yielding β-carotene have been discovered (Greenpeace 2005b). This seems to imply that the discovered rice varieties could express β-carotene in the endosperm, but the article it cited introduces the Philippine upland rice varieties in which high levels of β-carotene are found only in the bran fraction and the traditional processing practice of the brown rice, where the bran is retained (Frei and Becker 2005). This evidence apparently does not contradict the article on Golden Rice of 2000. Because the industrial processing of rice includes removal of the bran after the removal of the hull in order to prevent deterioration, the traditional processing practice of retaining bran could not be industrialized. Therefore, the cited literature not only supported the diverse rice planting and traditional processing practice but also helped justify the R&D of the Golden Rice.

Correspondingly, although it has been proved that the transgenic approach is the only choice for the R&D of the Golden Rice (Ye *et al*. 2000; Potrykus 2001), the Golden Rice has been proved to be a masterpiece of genetic engineering, and Potrykus was given the "Leadership in Science Public Service Award" by the American Society of Plant Biologists (Palevitz 2001), the Greenpeace still calls it a technical failure (Greenpeace

2005b). This departs from an objective view.

Second, is the Golden Rice one of the useful approaches to overcome VAD? Research carried out indicates that when compared with other methods such as food fortification and VA distribution, Golden Rice has the advantage of lower cost and does not require corresponding infrastructure; thus, if it had a good taste and was acceptable culturally to the targeted developing countries, it could be one attractive method to overcome VAD (Dawe *et al*. 2002). However, before the Golden Rice could be accepted as a real means to overcome the problem of VAD, the following issues have to be dealt with: (1) biosafety; (2) biostability, i.e., if the Golden Rice would be more unstable than other GM crops because of the pathway engineering, wherein Golden rice requires transfer of three or four genes, whereas other GM crops require the transfer of only a single gene or two genes; (3) biosensitivity, i.e., when compared with the normal rice, Golden Rice could express carotenoid in the endosperm, whether this would make it more susceptible to attack by pests? (4) bioavailability, i.e., how much β-carotene the Golden Rice has and how much VA it corresponds to? (5) food safety, regarding toxicity and allergens; (6) cultural acceptability; and (7) social and economic implications (Potrykus 2001; Conko 2001; Dawe *et al*. 2002; Nielsen and Anderson 2001). Therefore, the question whether the Golden Rice could be a useful approach to overcome VAD is yet to be answered, and it is premature to arrive at a positive or negative conclusion. But this does not hinder the supporters and opponents from commenting on the relevant possibilities using the data available.

Third, what is the role played by Greenpeace? This article holds that some of the criticisms by Greenpeace are reasonable, such as its emphasis on complementing of the multiple approaches including diverse nutrition and its queries on the bioavailability and biosafety. Actually, some of the queries have been accepted by the Golden Rice project. However, some of its comments were not based on scientific evidences. For example, in commenting on whether the Golden Rice project is necessary and will be able to help overcome VAD, the Greenpeace shows its prejudice when it states that the Golden Rice was a technical failure even before evidences could be collected (Greenpeace 2005b). This is not a scientific attitude; instead, it may be just one means to control or affect the biopolitics of the Golden Rice.

It is observed that many queries on the Golden Rice by Greenpeace have been in accordance with its basic stand of being against transgenic biotechnology. In its websites, the Greenpeace expresses clearly that it would "[S]ay no to genetic engineering". It lists basically two points: One is that genetic engineering may cause damage to biodiversity and integrity of the environment, and the other is the uncertainty of the technology regarding human health (Greenpeace). This article holds that Greenpeace has now been accepted as an important political organization in the field of biotechnology, and as an NGO, it has definite purposes for its active participation in the biopolitics of the Golden Rice and other GMOs.

There may be several reasons for the oppositions by the NGOs from the Asian developing countries to the Golden Rice and other GMOs, such as dissatisfaction caused by the unfortunate negative effects of the Green Revolution, apprehensions about environmental safety, food safety, and biodiversity, a growing sense of anger due to the loss of the genetic resources or "bio-piracy", antipathy toward the scientific and business influences of the Western world that act as promoters of globalization and globalization itself, as said above, and appreciation of propaganda by the Greenpeace or other international NGOs.

Fourth, whether Potrykus' counter-criticisms of the Greenpeace are reasonable? This article holds that most of his comments regarding Greenpeace are reasonable because they are based on factual evidences such as the justification of the biosafety of GMOs; however, some of his judgments are yet to be backed by sound scientific evidences. For example, in commenting on the Golden Rice, Potrykus stated without solid scientific proofs that it would avoid the unfortunate negative side effects of the Green Revolution, that it does not create advantages for rich landowners, that it will reduce neither agricultural nor natural biodiversity and there is no conceptual negative effect on the environment, that the biotech industry does not benefit from it, and that there is no conceivable risk to consumer health (Potrykus 2001). Furthermore, he even questions the precautionary principle and criticizes it as "regulatory

obstacles based on undue paranoia" (Cantrell 2004). This is farther than scientific rationality could reach because it should be known that the precautionary principle has been a fundamental principle laid down for handling biosafety issues by the Cartagena Protocol on Biosafety. Although the Golden Rice has a bright future, it needs to conform to both domestic laws and international treaties.

Finally, is the biosafety issue a technical issue or a political one? Just as many other GMOs, the Golden Rice's biosafety issue has not yet a definite answer and probably not for a long time. Although biosafety could be considered a technical issue, the fact that there would probably be no exact answer in the near future would transform this issue very easily into a political one. Both groups do agree that biosafety and biodiversity should be protected, but each of them has different explanations for the same set of evidences: the supporters hold that it should be deemed safe if there are no evidences to show that the GMOs are unsafe and thus GMOs should be permitted; whereas the opponents hold that GMOs should be deemed unsafe if there are no evidences indicating their safety and thus GMOs should be prohibited. Actually these are two kinds of epistemologies regarding the biosafety issue of the GMOs and are correspondingly relevant to the different understandings and policies of different countries and areas in the world. With publications of the biosafety experiments of the Golden Rice, it could be expected that the relevant disputes might probably mitigate or their emphases may change, but the disputes themselves will never disappear.

CONCLUDING REMARKS: JUSTIFICATION OF THE BIOPOLITICS OF GMOS AND ITS DOCTRINE

Using the world famous GM crop Golden Rice as an analytical model, this article illustrates that there are many issues existing around the GMOs that could turn into political debates, consequently building up a forum that could be described or labeled biopolitics of the GMOs. Along with the ongoing biopolitical disputes among the participants, the Golden Rice has been developed from the first generation to the second generation and complementary experiments on biosafety and bioavailability have been conducted. By considering the reasonable elements from the views raised by the opposition, the promoters of the Golden Rice have been modifying their views and strategies to safeguard the fulfillment of the project. This might justify the biopolitics of the Golden Rice. For GMOs in general, it is the potential risks of genetic engineering and involvement of many social aspects that justify the rationale of the biopolitics of the GMOs. However, it should be added that in reality each of the GM crops has a more complex biopolitics than that of Golden Rice, which has been simplified here by this article, with the aim of illustrating the concept of biopolitics and its various aspects.

Accordingly, the biopolitics of the GMOs should be directed by a "diverse" doctrine with multiple implications. First, there should be a diverse and equal participation. Biopolitics of the GMOs always has participants with diverse views. Every party, including the NGOs, should be treated equally so as to ensure respect of the value of public participation in the modern society. Administrators of GMOs should remain scientific, objective, and independent in their legislation, administration, and judicial activities in order not to be influenced by certain groups such as the NGOs.

Second, a "diverse" policy should be adopted to support both the traditional and transgenic breeding as also to support preservation and conservation of wild crop varieties. The coexistence of transgenic, nontransgenic, and wild varieties should definitely be brought under scientific management to avoid possible genetic contamination. This diverse policy aims to protect biodiversity and the corresponding cultural diversity.

Third, a differentiated policy may be adopted in management of the GMOs. This means that, in order to maximize the social good of the GMOs and to warrant biosafety, polices should not necessarily remain the same for various GM crops, such as transgenic cotton, corn, and rice. Elements such as a crop status, biosafety, and its practical and potential effect on economy, trade, and standard of living and quality of life of people must be taken into consideration.

Fourth, all the policies and activities regarding management of the GMOs and their biopolitical disputes should be dealt with within the legal frameworks. Nei-

ther domestic laws nor international treaties should be violated. The applicable international treaties may include, among others, the Convention on Biological Diversity, the Cartagena Protocol on Biosafey, the Agreement on Trade Related Aspects of Intellectual Property Rights, and the Agreement on the Application of Sanitary and Phytosanitary Measures.

In concluding, a checked balance should be maintained carefully by the biopolitics of GMOs to ensure sustainable development of the modern biotechnology.

Acknowlegements

This research is supported by National Social Science Fund of China (04CFX004).

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(Edited by ZHANG Yi-min)