ENGINEERING NUTRITION

GM crops for global justice?

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Contents

Summary and recommendations

This report challenges the dominant view of the scientific establishment that the future of agriculture lies with genetic modification technologies. Europeans who reject genetically modified (GM) crops are being told that their worries are irrational and that they are denying the potential benefits of these crops to hungry people in poor countries. Whilst sweeping claims that GM crops will 'feed the world' are now made less frequently than they were in the 1990s, an influential set of scientists and development professionals maintains that specific GM crops could contribute to food security. Indeed, they argue that there is a *moral* case for greater public sector investment in GM research because, without it, there would be little incentive for scientists to develop 'pro-poor' GM technology. They criticise blanket policy responses to GM crops, such as the moratorium that the European Union (EU) put in place in 1999, arguing that the pros and cons of GM crops must be judged case by case.

We believe that, although there are some substantial differences between GM crops, a general moratorium on their use in the EU is not only prudent but an ethical requirement. Governments of wealthy countries certainly have a duty to invest more in building international food security and food justice, but research funding should not be earmarked for GM crop development. Instead, it should be directed at projects that involve small-scale farmers and other stakeholders, from the planning phase right through to implementation. We also identify reasons why technological 'solutions' to food insecurity are often favoured in science and policy at the expense of alternatives that are potentially both more effective and more just. Our report is not a field study intended to determine, once and for all, whether GM crops are good or bad for food security. It aims to be a constructive critique of assumptions taken for granted by many scientists, policy-makers and business people.

We begin with a brief overview of current arguments promoting GM crops for food security, in which we identify commonly held, but questionable, assumptions about: (1) the evaluation of new technologies by regulators; (2) the research process; and (3) the ownership of research and technology. The three main sections of the report analyse each of these areas in turn, drawing on the example of 'Golden Rice', a strain genetically altered to contain extra ß-carotene.

Regulation

Proponents of GM crops argue that EU regulations should be eased in the interests of food security in poor countries. They claim that the EU rules are based on a triple abuse of the precautionary principle that: requires the proponents of GM technology to prove 'zero risk', which is technically impossible; ignores the different risks and potential benefits of specific GM crops, by imposing a temporary ban on all GM crop approvals; and underplays the risks of *not* using GM crops. The proponents insist that GM crops should be assessed case by case.

In contrast, we argue that there are compelling practical reasons for a robust interpretation of the precautionary principle, which would justify a moratorium under specific circumstances. The precautionary principle deliberately shifts the burden of proof onto the proponents of a potentially harmful course of action. The standard of evidence that they must provide in order to prove safety depends on the social acceptability of the risks involved. If the acceptability of a risk common to different GM crops was low, yet the relevant field of risk assessment was characterised by high levels of uncertainty, then a moratorium would be the logical regulatory outcome.

We believe that a moratorium on GM crop approvals in the EU is an ethical requirement, though not simply for the reason just described. Risk acceptability is as important in precautionary regulation as the level of risk, yet the prevailing 'risk management' approach to regulation takes the acceptability of some potential harms for granted. For instance, regulation is currently not equipped to evaluate social or economic harms that might arise from a GM crop. Until publicly trusted mechanisms are put in place to make explicit these inevitable judgements about risk acceptability, it is essential to maintain a moratorium on approvals of GM crops because of the evident disagreement over the acceptability of their associated risks.

We recommend that:

- **The UK government and the European Commission research and develop mechanisms for evaluating the social acceptability of risks, that are widely trusted by members of the public including scientists.**
- **The UK government and the European Commission press for the concept of risk acceptability to be pivotal in international agreements that have a precautionary element.**
- **Until trusted mechanisms for evaluating risk acceptability are in place, governments place moratoria on highly controversial technologies such as GM crops.**

Research

The proponents of GM crops for food security are not just against a moratorium – they also recommend governments to invest greater resources in GM-related research. They argue that the potential benefits of GM crops will otherwise pass by the poorest people in society, unfairly benefiting the rich.

We agree that governments should invest more in projects to promote food security. However, in earmarking these additional resources for GM-related research, the proponents endorse a model of food insecurity that favours technological solutions and denies the people affected by new technology a genuine choice over its direction and use.

The criteria against which potential solutions to food insecurity are evaluated affect how the problem is understood. By taking cost-effectiveness for granted as the primary measure for comparing food security strategies, the GM proponents, and some of their critics, define food security in terms of a narrow range of quantifiable variables. Technologies designed to meet the specified criteria may therefore perform well on paper even though in practice, because food insecurity is highly complex, they may be less effective than multi-dimensional strategies based on already-available knowledge and tools.

Whilst proponents argue that farmers and consumers should be allowed to choose whether or not to use GM crops, and accept that end-users should participate in research, the limits that they place on stakeholder involvement deny these groups a genuine say. Early-stage research investment decisions taken in private, which depend on judgements about the interests and needs of different stakeholders, can lock subsequent decision-makers into the chosen course of action. If research sponsors are to meet their self-avowed responsibilities to enhance choice for end-users, it is crucial that the concerns of those stakeholders are built into research at the earliest possible stage.

We recommend that:

- **Policy approaches to alleviating hidden hunger and food insecurity involve the communities affected in defining the problem and in evaluating potential solutions.**
- **Food security strategies be assessed for their beneficial effect on the whole diet, taking into account the social dimensions of food insecurity.**
- **Food justice and food security at all levels be valued in policy as goals in themselves.**
- **The UK government and the European Commission invest greater resources in food security research that is driven by the demands of communities affected by food insecurity.**
- **Research be funded into effective means of incorporating non-specialists and stakeholders into high-level strategic science planning, ensuring that these means are also acceptable to the scientific community.**
- **A greater proportion of research funding is invested in cross-disciplinary programmes, in order to encourage broader approaches to addressing food security problems.**

Ownership

Private firms dominate agricultural research, particularly in biotechnology, where the private sector accounts for around 80% of spending world-wide. This skewed public-private ratio has affected the direction of research, and the kinds of technology made available. Even many proponents of GM technology are concerned by this private sector dominance, arguing that the result will be GM crops produced for the benefit of rich farmers and consumers who can afford to pay a premium, rather than for the poor and indebted people who are commonly food insecure.

In particular, these GM proponents are concerned that privately-owned patents on basic GM-related research tools will put GM crops beyond the means of poor farmers or even gridlock the research process entirely. Several high-profile initiatives are now under way that attempt to redress this situation by brokering partnerships between public sector researchers and private patent holders.

Patenting is a means of privatising knowledge that would otherwise be publicly available, on the assumption that this process will stimulate innovation and benefit the public in the long run. Over the past 20 years, patenting has been encouraged in the public sector to generate research revenue in an economic climate of retrenchment. We argue that the deal between inventors and society has been overdrawn in agriculture, and it should be renegotiated. Agricultural research should be exempt from patenting and similar forms of 'intellectual property' (IP) protection, nationally and internationally, wherever it is shown to limit the provision of public goods. The public sector should not be required to buy back from private owners a monopoly privilege granted in the public interest.

Effective food security promotion relies on genuine public goods that can be shared and copied freely. If GM crops cannot be developed without patenting or public-private partnerships (PPPs), then that is less a reason to endorse such institutions as an indictment of the pro-poor potential of GM technology.

We recommend that:

- **IP protection applied to plants or animals should not allow the holder to prevent users from re-using or developing their product.**
- **Non-exclusionary incentives for agricultural innovation, such as cash rewards or prizes, are introduced instead of IP.**
- **International IP rules be balanced by introducing comparable anti-trust and liability rules, and by enforcing other agreements on plant biodiversity and genetic resources.**
- **The rights of farmers to save, share and adapt seed, and to have affordable access to technology that promotes food security, overrule the privileges granted to inventors in national and international law.**
- **Because 'intellectual property rights' are actually intellectually-based monopoly privileges, they should be named and treated accordingly.**
- **Co-operation and community involvement should come before competitiveness as the catch-phrases for public sector research in the EU.**
- **The European Commission dedicate a portion of its research budget to fund Public Good Projects, which require that research is non-commercial and spins-off into non-profit entities rather than firms.**
- **PPPs are only pursued in exceptional circumstances, and are not viewed as necessary to food security.**
- **There is wider reform of the public sector research system, including additional state funding, to ensure that the provision of genuine public goods is its primary mission.**

1. Introduction

1.1 GM crops and food security

Europeans who reject genetically modified (GM) crops are being told that their worries are irrational and that they are denying the potential benefits of these crops to hungry people in poor countries. Whilst sweeping claims that GM crops will 'feed the world' are now made less frequently than they were in the 1990s, an influential set of scientists and development professionals maintains that specific GM crops could contribute to food security. Indeed, they argue that there is a *moral* case for greater public sector investment in GM research because, without it, there would be little incentive for scientists to develop 'pro-poor' GM technology. They criticise blanket policy responses to GM crops, such as the moratorium that the European Union (EU) put in place in 1999, arguing that the pros and cons of GM crops must be judged case by case.

This report challenges that dominant view of the scientific establishment. We believe that, although there are some substantial differences between GM crops, a general moratorium on their use in the EU is not only prudent but an ethical requirement. Governments of wealthy countries certainly have a duty to invest more in building international food security and food justice, but research funding should not be earmarked for GM crop development. Instead, it should be directed at projects that involve small-scale farmers and other stakeholders, from the planning phase right through to implementation. We also identify reasons why technological 'solutions' to food insecurity are often favoured in science and policy at the expense of alternatives that are potentially both more effective and more just.

1.2 Background

This report is intended to contribute to the ongoing debate in the United Kingdom (UK) over GM foods, of which GM crops are a subset. The close of the formal 'GM Nation?' debate that the UK government staged in June and July 2003 no more signalled the end of that wider discussion than its beginning had signalled the start. The Food Ethics Council has already produced one report examining the ethical issues that arise in GM food regulation, in the spirit of contributing to this wider public debate.[1] In that report we discussed whether GM foods respected three commonly-held ethical principles (Box 1.1). In a subsequent report on animal farming we have looked in more detail at GM animals, using a similar analytical framework.[2] In both of those reports we concluded that although GM foods were not intrinsically unacceptable, they were of questionable value to all but a very narrow subset of the groups they affected. We argued that they should only be developed with great caution.

We are revisiting the ethical arguments around GM crops and food security because they are becoming increasingly prominent in public discourse. Discussions have been less about policies in countries where food security is a major problem, as about the effects that decisions on GM crops by well-fed people in rich countries might have for the poorest farmers and communities in the world, through policy 'signalling', international trade, or flows of aid and new technology.[3]

Food security – defined by the United Nations Food and Agriculture Organisation (FAO) as freedom from hunger and fear of starvation – is currently denied to about 840 million

Box 1.1: The Ethical Matrix

The Food Ethics Council's previous report on GM foods was structured around the Ethical Matrix, a device for working through key issues raised in decision-making about GM technologies. The columns of the Matrix are defined by three principles that are widely used to justify decisions, namely 'wellbeing', 'autonomy' and 'justice'. **Wellbeing**, according to this approach, corresponds to issues prominent in utilitarian theory. Utilitarianism advocates the 'greatest good for the greatest number', and characteristically decides the 'right action' through a form of cost-benefit analysis. Costs and benefits are often difficult to define, in practice, and utilitarianism can be used to justify gross inequality so long as the majority are better off. The idea of **autonomy**, most associated with the work of Immanuel Kant, provides an alternative guide for decision-making. For Kant, ethics was about our duties to respect others as ends in themselves. One problem with this idea is that there is no rule for prioritising different duties. Finally, respect for **justice**, in the sense of fairness, is seen by some as the most important criterion for a good decision. However, it can be difficult to agree on what counts as fair: for instance, should goods be distributed according to need, ability or effort?

The rows of the Matrix consist of 'interest groups' that might be affected by the decision in question. In our previous reports, we have considered people in the agricultural/food industries, citizens in general (in rich and poor countries), and the ecosystem (meaning the living environment).[4] These interest groups are not assumed to be mutually exclusive, exhaustive or even to have homogeneous 'interests'.

At its simplest, the Matrix is a checklist of issues. However, it can also be used as a means of provoking structured discussion. The interest groups, the weighting of each cell and the appropriateness of the principles may be modified or challenged by those using it. At the least, using it ensures that more than the usual narrow range of concerns is aired.

	WELLBEING (Health and welfare)	AUTONOMY (Freedom/choice)	JUSTICE (Fairness)
People in the food industry	Satisfactory income and working conditions	Appropriate freedom of action	Fair trade laws and practices
Citizens	Food safety and quality of life	Democratic, informed choice	Availability of affordable food
The ecosystem	Conservation	Maintenance of biodiversity	Sustainability

undernourished people in the world.[5] Over 2 billion people also suffer from the 'hidden hunger' of micronutrient deficiencies, caused by a voluminous but invariant diet.[6] The FAO estimate that investment of US $24 billion per year – less than a tenth of the money that rich governments spend on agricultural subsidies – would be enough to halve the number of hungry people by 2015.[7] At the current rate, this target will not be met until around 2150.[8]

The injustice of food insecurity could hardly be more acute, and these shameful statistics have barely changed since we published our previous report on GM crops in 1999, despite international commitments to address them.[9] Arguably, food security now figures in rich country policy discourse as a justification for GM investment, rather than because of increased concern with food security *per se*. In the absence of clearly demonstrable, broad social benefits from the GM crops that are already in use (Figure 1.1), and in a climate of widespread public suspicion, proponents have pinned the case for GM crops on their 'pro-poor' potential. Hungry people have become trumps in a game of high stakes, where the main players sit in Washington and Brussels (Box 1.2). The first prize is access to the lucrative EU food market, currently closed to GM crops grown in the United States (US).

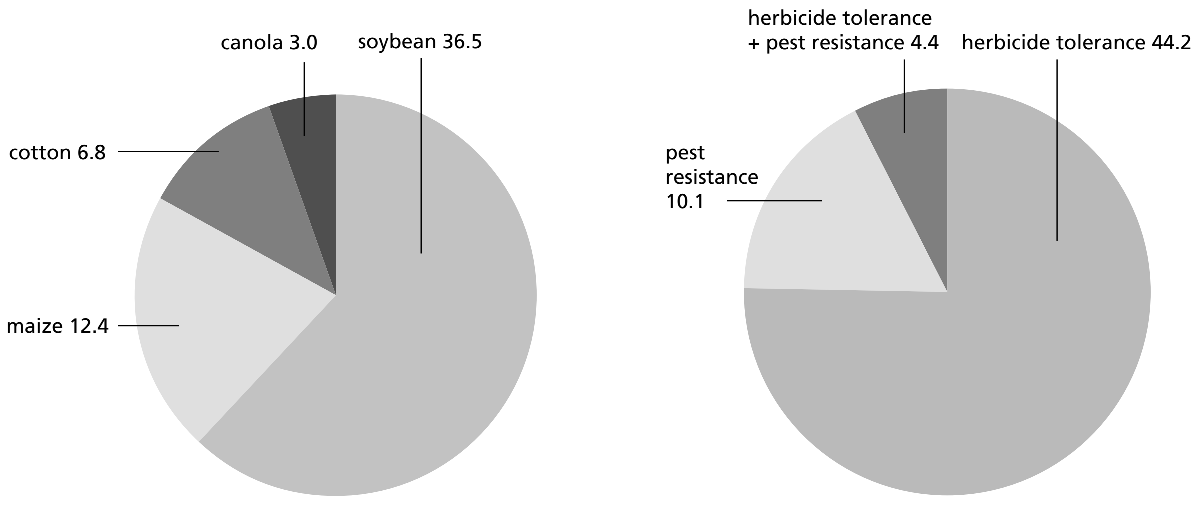
Of course, arguments about hunger and food security already figured at the time of our previous report. For example, the company Monsanto had run an advertising campaign announcing that "Worrying about starving future generations won't feed them. Food biotechnology will". What is different, now, is that the idea of GM crops being a 'magic bullet' is no longer regarded as credible, even by the biotechnology industry. Monsanto's UK Director of Corporate Affairs is recently reported to have said that "Nobody has ever claimed that GM is the answer to world hunger".[10] Instead, proponents now argue that GM crops have the *potential* to help increase food security, and only if the correct policies are pursued.

We describe this more subtle argument, and give examples, in subsequent sections of this report. In brief, it can be summarised thus. Most current GM crops serve the interests of large-scale farmers. However, a 'second generation' of GM crops has the potential to benefit some of the world's poorest people. For instance, scientists using GM techniques are researching how to make staple foods more nutritious, and how crops can be made to grow in drought-prone areas. It is claimed that two major barriers to realising this pro-poor potential of GM crops are overly restrictive regulation, particularly in the EU, and under-investment by governments. It is therefore recommended that all moratoria on GM crops cease, that public sector investment in GM research increases, and that governments pursue partnerships with firms in order to develop GM crops.

This view explicitly rejects broad generalisations of the benefits of using GM crops. It agrees with critics of the old claims that GM foods would 'feed the world', that no technology can in itself provide the answer to food insecurity – agricultural policy shifts, altered trade rules, peace and poverty alleviation are all also necessary. Some proponents also acknowledge that there is little evidence of pro-poor GM crops to date: fewer than 1% of the benefits from first generation GM crops are estimated to have accrued to tropical countries, where food insecurity is most prevalent, and there has been no major shift in the pattern of research investment for the second generation.[11]

Equally, however, this view that GM crops have pro-poor potential challenges arguments that GM crops in general will *not* contribute to food security. Several prominent development charities, such as Oxfam, Christian Aid and Action Aid, have published reports arguing that GM crops may exacerbate food insecurity, even if they increase the amount of food that is produced.[12] They argue that GM crops would not reach the poorest farmers, who therefore would be even less able

Figure 1.1: GM crops in 2002[13]



Global area of GM crops in 2002 by crop (million hectares)

Global area of GM crops in 2002 by trait (million hectares)

Box 1.2: Trading on hunger, 2003

January – US Trade Representative Robert Zoellick calls EU opposition to GM crops "Luddite" and "immoral", and says that there is wide agreement within the Bush administration to lodge a challenge against the EU ban with the World Trade Organisation (WTO)[14]

March – Iraq war puts US trade challenge on hold[15]

May – US government lodges challenge with WTO;[16] President Bush says that "European governments should join, not hinder, the great cause of ending hunger in Africa"[17] ; Egypt, which had been seen to give legitimacy to the challenge as a poor country partner, pulls out[18]

June – US government suspends free trade talks with Egypt in retaliation for Egypt pulling out of the GM crop challenge[19]; at the annual US biotechnology industry convention, President Bush pleas that "For the sake of a continent threatened by famine, I urge the European governments to end their opposition to biotechnology"[20]; in Sacramento (California) the United States Department of Agriculture takes part in a conference to showcase US agri-food technology to ministers from around the world[21]

August – the US government formally launches its trade challenge against the EU[22]

to obtain or retain food than they are now.[23] Even if GM crops might help in exceptional cases, these groups argue, their overall effect might therefore be to increase food insecurity. Proponents of GM crops argue that each crop is so different, and the contexts of their use are so varied, that it is impossible to make such general claims.

This focus on the specifics – specific countries, policies and crops – sounds quite reasonable. We certainly agree that it is impossible to sustain the old sweeping claim that GM crops will feed the world. However, we are also wary that focusing on the specifics may rule out concerns with GM crops arising from the practical circumstances under which they are produced and assessed by regulators. This report identifies some of these concerns and questions the assumptions that cause proponents to dismiss them. It is not a field study intended to determine, once and for all, whether GM crops are good or bad for food security. Our aim is look at the role that framing assumptions about ethics play in the case against the EU moratorium and in favour of more public investment in GM research.

1.3 The 'doubly green' theme

In this report, we treat the argument that GM crops have pro-poor potential as what can be called a 'policy theme'.[24] A policy theme is a set of linked facts, values and framing assumptions that appears to make 'good enough' sense of a problem that is too complex to be resolved by the evidence alone.[25] Successful themes allow experts, politicians and others taking part in decision-making to agree about what should be done when the evidence is uncertain or ambiguous. A good example is the theme of 'sustainable development'. It is associated with well-known events (notably the Rio Earth Summit), exemplars or clichés (such as 'think globally, act locally'), statements (such as the World Commission on Environment and Development (WCED) report of 1987) and proponents (such as Gro Harlem Bruntland, who chaired the WCED). Yet the popularity of the sustainable development concept relies partly on the fact that many different variants of it have coalesced around this central core, facilitating agreement between disparate groups of decision-makers.

Ian Scoones, of the Institute of Development Studies at Sussex University, has identified some of the main proponents of the policy theme the GM crops have pro-poor potential.[26] They include the Rockefeller Foundation, which has been a major sponsor of agricultural research in poor countries, and the Nuffield Council on Bioethics. We addressed some of the arguments made by Nuffield in our 1999 report. Scoones also mentions the Consultative Group on International Agricultural Research (CGIAR), which is a network of international research centres set up by the Rockefeller Foundation, amongst others, to co-ordinate public sector agricultural research. Other members of this 'discourse coalition' include the economist Michael Lipton (a coauthor of two Nuffield reports on GM crops), and the Royal Society, which represents the scientific establishment in the UK.[27] Mostly, their arguments are more cogent than the US trade rhetoric that has thrust the theme into the public eye.

The proponents of GM crops for food security argue that whilst the 'first generation' of GM crops has been of little benefit to the poorest people in the world, some 'second generation' technologies promise benefits that it would be immoral to deny to the poor (Table 1.1). In a report on GM crops published in 1999, Nuffield concluded that the "*moral imperative for making GM crops readily and economically available to developing countries who want them is compelling*".[28] They have reiterated and expanded this position in a more recent report about '*The use of genetically modified crops in developing countries*', published as a draft in June 2003. They approvingly cite Gordon Conway, who is President of the Rockefeller Foundation. Referring to the 'Green Revolution' of the 1960s and 1970s, during which new crop varieties increased food production in many poor countries, Conway has called for a 'doubly green revolution' in which GM crops would play an important part.[29] Conway agrees with critics who say that the original Green Revolution did not benefit the very poorest people and caused environmental damage.[30] But where many civil society organisations are concerned that GM crops have all the features necessary to repeat these faults, Conway argues that it will be possible to repeat the successes of the green revolution without making the same mistakes.[31]

However, Conway, Nuffield and other proponents of this theme insist that the 'doubly green revolution' will not happen if things remain as they are:

> "much current research on GM crops serves the interest of large-scale farmers in developed countries. There is also continuing concentration in the number of companies that control between them the provision of seeds, agrochemicals and important research technology. Consequently there is a serious risk that the needs of small scale farmers in developing countries will be neglected. *We therefore*

affirm the recommendation made in our 1999 report that genuinely additional resources be committed by governments, the European Commission and others, to fund a major expansion of public GM-related research into tropical and sub-tropical staple foods, suitable for the needs of small-scale farmers".[32]

According to this view there is no choice to be made *between* GM crops and the sustainable agricultural techniques favoured by many civil society groups: "it is mostly a situation of 'both/and'".[33] Whether a GM crop is appropriate is argued to depend on the particular circumstances, and cannot be determined categorically in advance: as far as possible, the end-users should be free to use GM crops as they please. This idea that the pros and cons of GM crops must be judged case by case – that there are no concerns common to all GM crops – is popular amongst scientists who are in favour of GM crops. It was an important, though contentious, recommendation of the GM Science Review Panel convened by the UK government to examine GM crops.[34]

Treating these arguments in favour of GM crops as a policy theme does not presume that they are false. As Scoones points out, the 'facts' are not enough to decide whether to favour this theme or the alternatives, which argue that GM crops are detrimental to food security and that investing in them is a waste of resources.[35] Rather, the theme concept emphasises the large part that framing assumptions play in decision-making about such complex issues as food security. However, that does not mean that the arguments one way or another are merely a matter of opinion. One criterion for judging whether a theme makes sense is to ask whether it takes seriously the base-line uncertainty that makes facts insufficient to determine policy – that is, the very uncertainty that makes themes normal features of the policy process.

A policy theme that takes account of the uncertainty and ambiguity built into complex decision-making must ensure: (1) that the framing assumptions built into decision-making are commensurate with the values of society at large; and (2), that there is a safe margin for scientific error. In this report, we argue that the 'doubly green' theme underestimates the normal degree of uncertainty in science and takes the framing assumptions of 'experts' for granted, even when they appear to be at odds with the values of society at large. Sociologist Brian Wynne has documented how committees of 'ethical experts', including Nuffield, often substitute for democratic

Table 1.1: Examples of first and second generation GM crop traits

This table only includes crops intended for human food use.[36]

		Traits aimed at farmers	Traits aimed at processors & retailers	Traits aimed directly at consumers
Generation 1	Commercialisation	Herbicide tolerance (oilseed rape, maize, soybeans) Pest resistance (rice, maize) Viral resistance (papaya, potato, squash) Increased yield (canola, chicory, maize)	Altered oil content (cotton) Increased shelf-life (tomato, strawberry)	Increased antioxidants (tomato)
Generation 2	Field studies	Herbicide tolerance (sugar, oilseed rape) Pest resistance (maize, potato) Fungal resistance (banana) Bacterial resistance (grapevine, rice) Viral resistance (wheat, oats, cabbage, tomato, melon, pepper, cassava, cucumber, potato, sweet potato, beet, sugar cane) Cold resistance (strawberry, maize, soybean, tobacco, tomato, potato) Increased yield (wheat)	Altered oil content (sunflower) Increased shelf-life (pepper, banana, pineapple, apple)	Increased flavour (pepper) Increased antioxidants (tomato, broccoli)
Generation 2	Greenhouse	Pest resistance (potato) Fungal resistance (potato, wheat, barley, tomato, strawberry) Pest resistance (potato)	Modified starch (potato)	Increased vitamin A (rice)
	Laboratory	Fungal resistance (sunflower, grapevine) General stress resistance (rice) Drought resistance (sugar beet) Salt resistance (rice, tomato) Metal tolerant (maize, soybean, cotton, field beans) Increased yield (rice) Flowering and sprouting control (potato) Nitrogen fixation (cereals)	Modified starch (wheat) Modified fermentation (barley) Altered oil content (soybean) Less bruising (potato) Altered sugar content (sugar beet, sugar cane) Reduced caffeine (tea, coffee)	Increased protein (potato, sweet potato, rice) Increased vitamin A (canola) Reduced allergens (soybean, wheat)

processes, on the assumption that the philosophers and scientists involved are more rational than 'lay' citizens.[37] This is the philosopher's equivalent of the old economist's joke, that 'if the model doesn't fit then reality is wrong'. A sound policy-process should ensure that people affected by an issue have a meaningful say in decision-making, and can draw on expertise as they see fit. The recommendations that we make in this report suggest ways of re-engaging 'non-experts' in the policy decisions that affect them, rather than attempting to speak in their stead.

We illustrate our argument with the case of 'Golden Rice' (Box 1.3), which is commonly treated as an example of a potentially pro-poor GM technology. This is a strain of rice genetically modified to contain increased levels of ß-carotene, a substance that our bodies can convert into vitamin A. It was developed non-commercially – part funded by the Rockefeller Foundation – in the hope that it would alleviate the serious problem of vitamin A deficiency in areas of Asia where rice dominates the diets of poor people. Golden Rice is well-known because it has become a two-faced totem in debates about GM crops and food security: for proponents, it typifies the promise of genetic engineering; for critics, its promises are a hoax. Other exemplars of the pros and cons of GM crops for poor countries have recently emerged, such as the 'protato' with added protein in India, pest resistant cotton in South Africa and virus resistant sweet potatoes in Kenya.[38] We focus on Golden Rice because, even on its own, it amply illustrates the major problems with the ethical arguments in favour of GM crops for food security.

A case study approach is appropriate because we are concerned to reopen the ethical questions prematurely closed by proponents of the 'doubly green' theme, and to suggest how they might better be answered, rather than to provide definitive answers to those questions ourselves. Specifically, we challenge three recommendations that are central to the theme that GM crops have pro-poor potential: (1) that the EU moratorium should cease because it is unjust; (2) that the public sector should invest more in GM research; and (3) that the public sector should pursue partnerships with the firms that produce GM crops. In contrast, we conclude that: a blanket moratorium on GM crops is prudent and ethically required (Section 2); the public sector should invest more in stakeholder-led agricultural research, rather than preferentially targeting GM (Section 3); and the emphasis should be on changing the terms of existing public-private partnerships, rather than creating new ones (Section 4).

Box 1.3: Golden Rice

The Golden Rice project was led by Ingo Potrykus, of the Swiss Federal Institute of Technology, and Peter Beyer, of the University of Freiburg. They agreed that it was theoretically possible to modify rice to contain ß-carotene in the endosperm, the part of the rice that people eat. ß-carotene is also called provitamin A because our bodies convert it into vitamin A. The researchers hoped that rice containing provitamin A would alleviate the very serious problem of vitamin A deficiency. The area of the world worst affected by vitamin A deficiency is Asia, where many people eat a diet consisting largely of rice.

After failing to interest the company Nestlé in funding the project, Potrykus and Beyer approached the Rockefeller Foundation.[39] The foundation was a likely sponsor because it had a long history of involvement in genetic engineering and agricultural research.[40] It agreed to back the project, which subsequently obtained additional funding from European Commission and the Swiss government.[41]

The genetic engineering of Golden Rice has been described as a "technical tour de force".[42] The concept was to introduce genetic material that would produce four new enzymes in the rice endosperm. These would act in series to convert a substance already present, called geranylgeranyl diphosphate, into ß-carotene. The polished rice grains were turned yellow by the ß-carotene they contained – initially estimated to provide the daily dose of pro-vitamin A needed to prevent deficiency in "the typical Asian rice diet (300g uncooked rice)" – and the prototype was soon dubbed 'Golden Rice'.[43]

The results became public knowledge in August 1999 and were published in *Science* journal the following year.[44] In January 2001 the prototype rice was transferred to the International Rice Research Institute (IRRI), so that work could begin on breeding the provitamin A trait into the rice varieties that farmers grow in areas with high levels of vitamin A deficiency.[45]

2. Regulation

2.1 Risk in regulation

Proponents argue that the rejection of GM crops by EU consumers, and the EU moratorium on their commercial use, are preventing poor farmers from reaping the potential benefits of the 'doubly green revolution'. This argument consists of two parts. On the one hand, the proponents claim that EU regulations are too restrictive. In particular, they regard the moratorium as invalid because it does not recognise the differences between GM crops. On the other hand, they allege that the EU moratorium is holding back the use of GM crops in low- and middle-income countries.

The second of these claims is simply conjecture. The degree of influence that GM crop regulation in the EU has on poor countries is not known. Certainly the regulation of crops that are not exported to the EU, which include the staple foods of many poor communities, would seem unlikely to be affected.[46] Nevertheless, if the first claim were correct and the EU regulations were shown to be unsound for other reasons, then there might be an ethical case to reform them, and other regulations like them, as the GM proponents advise.

The remit of EU regulators is to prevent unacceptable harms arising from new technology. This is based on the liberal principle that the state is only entitled to restrict individual freedom, including the freedom to sell or use technology, if the individual actions would harm others. Putting this principle into practice is complicated by the impossibility of predicting exactly what will cause harm, to whom. On the assumption that the science of 'risk assessment' offers a uniquely objective method for estimating future harms, regulation is often defined as risk management. Potential harms that cannot easily be quantified by scientists as risks, such as social and economic harms, are not seen as regulatory issues that might legitimately limit technology use. Proponents of the doubly green theme, who endorse this view of regulation, therefore only consider specific kinds of harm to count in regulation: potential harms to people include the risk that a GM crop might contain unexpected allergens or be toxic; potential harms to the environment include the risk that GM traits might transfer to weedy relatives or that the practices necessary to farm a GM crop successfully might damage wildlife.

Although some commentators doubt the capacity of regulators in low- and middle-income countries adequately to evaluate the risks arising from GM crops, that is not a concern for proponents of the 'doubly green' theme.[47] Indeed, some argue that a more serious danger is that the poor are being denied potentially useful GM crops because a shortage of risk management expertise is holding up the assessment process.[48] However, this theme is mostly concerned with the way that regulation in rich countries affects the use of GM crops in poor countries. The GM proponents are convinced that EU regulations, in particular, impose restrictions on the use of GM for 'political' reasons, and not because they pose genuine risks to people or the environment. For example Nuffield, attacking what they consider to be the worst case of regulatory overkill, "*take the view that there is not any evidence of actual or potential harm to justify a moratorium*" such as exists in the EU.[49] Their main bugbear is the way that EU regulators interpret the 'precautionary principle': "In a common, but controversial, interpretation of what is known as the *precautionary principle*, critics argue that GM crops should not be used anywhere unless there is a guarantee that no risk will arise...".[50] Nuffield suggest a "reasonable" alternative version of the principle, which "enjoins us to 'proceed with care', when we have no well-grounded reason to think that a hazard will arise and when there is a valuable goal to be achieved. By this interpretation, each release of a GM crop into the environment needs to be considered on a case by case basis".[51] They also argue that "[h]ighly restrictive interpretations invoke the fallacy that the option of 'doing nothing' is itself without risk... *risks arising from the option of inaction must also be considered*".[52] In their view, many low- and middle-income countries are not exploring the pro-poor potential of biotechnology because of "fears that a highly restrictive interpretation of the precautionary principle in Europe and Japan will close off export sales".[53]

2.2 The precautionary principle

The precautionary principle is now widely used in policy, at the national level and internationally. It features, for instance, in the United Nations Framework Convention on Climate Change and in the Convention on Biological Diversity.[54] It is also implicit in the WTO agreements under which the US government is challenging the EU rules on GM crops. Notably, Article 5(7) of the Agreement on Sanitary and Phytosanitary Measures (SPS) states that:

> "in cases where relevant scientific information is insufficient, a Member may provisionally adopt sanitary or phytosanitary measures on the basis of available pertinent information... In such circumstances, Members shall seek to obtain the additional information necessary for a more objective assessment of risk and review the sanitary and phytosanitary measure accordingly within a reasonable period of time".[55]

Despite this widespread use of the precautionary principle, it is often only loosely defined in policy. There are differences, notably between the EU and the US, in the interpretation of the principle by policy-makers and the importance that they attach to it. Whilst sceptics may attribute these differences to national interests in international trade, that would not preclude that some appeals to the principle are rational and ethically sound, and that others are not. Whilst the view that EU regulation is 'over-precautionary' purports to be in keeping with a more rational version of the principle, on closer inspection it appears to subvert two of the principle's basic precepts.

First, the precautionary principle deliberately shifts the burden of proof onto the party in favour of a potentially risky course of action. GM proponents appear to subscribe to the view that GM crops are innocent until proven guilty – in the absence of evidence of harm, they argue that we should proceed with a GM crop, albeit with care. This would be commensurate with the rules of evidence in many criminal courts, and also with the convention amongst scientists that a false negative (a 'Type II' error) is preferable to a false positive ('Type I').[56] But in some areas of the law and in some fields of science, different conventions apply – how the burden of proof is distributed in a particular context is a practical matter, not a hard and fast rule.[57] The precautionary principle holds that uncertainty should be handled *differently* in regulation than in the courts or learned journals, because regulators are charged with the weighty task of ensuring public safety, equipped with evidence that is highly uncertain (Box 2.1).[58] Nuffield's argument that the risks of 'doing nothing' should be given equal weight to the risks of GM crops "would in effect negate the central point of the [precautionary] principle, which is to create a presumption in favour of safety".[59]

If we accept that the precautionary principle requires that the burden of proof shifts more onto the proponents of a new technology, then what evidence must they provide in order for their technology to be deemed safe? One possibility, which the supporters of GM crops deride, is that they should demonstrate 'zero risk'. Strictly speaking, of course, this is impossible for any possible hazard occurrence:

> "However, the demand for 'zero risk' can often be interpreted as an expression of zero tolerance for any incremental *increase* in the already occurring background risk".[60]

Alternatively, they could be required to 'prove' safety to the 95% confidence level (that is, a 5% chance of being mistaken) that is the usual standard of proof in science. In practice, the levels of uncertainty characteristic of regulation would make it very difficult to demonstrate safety, or risk, to the 95% level. A final possibility is that burden of evidence should rest on the proponents of a technology, but the standard of evidence be relaxed below 95%. Thus, the second precept ignored by proponents of the 'doubly green' theme is that the appropriate threshold of evidence depends on depends on the context: factors include the type of risk, the likely benefits and beneficiaries of a technology, and the degree of choice that people have in taking a risk.[61] For instance, potentially catastrophic risks might call for a 'zero risk' approach, as defined above. Where the risks are largely confined to the stakeholders due to benefit from taking them, a more lenient balancing of risks, costs and benefits might be justified. Ultimately, then, the issue is again a practical one of ascertaining what counts as an 'acceptable risk' in a particular field of policy or technology.

2.3 Acceptable risks

When GM crop regulation incorporates both these precepts of the precautionary principle, one can envisage circumstances in which a moratorium would arise. Despite the differences between GM crops, they only need share one common feature that pushes the threshold of 'acceptable risk' above the level of proof that science can satisfy for a moratorium to apply. Each GM crop could be assessed case by case, as the proponents of the 'doubly green' theme insist is necessary, but the benefits of doing so would be questionable if it were known in advance that they would each be banned on the same grounds, because of the same area of outstanding scientific uncertainty. The moratorium would remain in place until the uncertainty was resolved or the acceptability of the risks was upgraded. This, ostensibly, is the logic of the EU moratorium on GM crops.

We believe that there should be a moratorium on GM crop approvals in the EU, and elsewhere, though not simply for the reason just described. The precautionary principle highlights the ethical requirement for a radical rethink of regulation, and a moratorium on GM crops should remain in place pending the completion of this process. Truly precautionary regulation must take the assessment of risk 'acceptability' as seriously as evaluating the level of the risk. The prevailing 'risk management' approach to regulation is not capable of achieving this.

Risk management takes the acceptability of some risks for granted. For instance, the potential social or economic harms that a GM crop might cause to a certain group of farmers simply do not figure as 'risks'. If they are to be addressed by government at all under the risk management model, which purports to leave technology evaluation to individual users as far as possible, then it is through policy interventions such as subsidies or tax breaks, rather than by regulating technology. The task of setting thresholds of evidence for the potential harms that qualify for consideration is left largely to expert regulators. However, both these judgements of risk acceptability are *evaluative*. Whilst the risk professionals who currently make them may be skilled at estimating the levels of certain kinds of risk, the values that they hold do not count for more than the values other citizens. Precautionary regulation needs trusted mechanisms explicitly to evaluate the social acceptability of risks, as well as the levels of risk. The liberal principle that the state should only constrain individual freedom in order to prevent harm is inoperable without

Box 2.1: Uncertainty in regulation[62]

Uncertainty is a normal feature of science. Even the most accurate scientific *models* only approximate actual situations, and the uncertainty this creates can only be reduced, never eliminated, by further work. The *data* fed into these models are often incomplete or may contain errors. Risk assessment in regulatory science is particularly uncertain because, amongst other factors:

- Regulation concerns real-world situations, which are very complex to model.
- The short time-frame of regulatory assessment means that it may not be possible to gather additional data.
- Assessments of risk (known uncertainty) also imply judgements about the likelihood of surprises (unknown unknowns), which are necessarily subjective.

Box 2.2: Golden Rice in the UK

In the UK, Golden Rice would be marketed as a 'functional food' by the company Syngenta.[63] Functional foods are commonly defined as foods that are attributed a health benefit beyond the traditional nutrients they contain. Golden Rice would not be sold as a source of vitamin A, but on the antioxidant properties of ß-carotene. Antioxidants are believed to lower the risk of cancer and other diseases of affluence.

The Advisory Committee on Novel Foods and Processes (ACNFP) advises the government on the safety of 'novel foods', including functional and GM foods. Using data provided by the food manufacturers, the ACNFP assesses whether the new food is likely to be toxic, carcinogenic, allergenic or otherwise harmful to consumers. The ACNFP can issue strong recommendations on labelling and consumer information but, unless it deems a product harmful, the government has little option but to issue a license. Functional foods are not prescribed in fixed quantities, like drugs, meaning that, once licensed, anyone can eat them in any possible quantity or combination. Yet, because the ACNFP is obliged to assess products consistently and case by case, it cannot address any cumulative or combinative effect that might arise form eating multiple novel foods.

The built-in assumption is that consumers are free agents in the market. However, given that scientists remain uncertain as to the effectiveness of ß-carotene in functional foods, it is questionable whether even the best conceivable labelling would allow consumers an informed choice. According to the nutritionist Marion Nestle:

"Although fruits and vegetables containing ß-carotene are demonstrably protective against disease[64], the results of clinical trials of ß-carotene supplements as a means to prevent cancer or cardiovascular disease have proved disappointing.[65] Some laboratory studies support the idea that ß-carotene produces biological effects that might protect against cancer[66], but others suggest that it might be co-carcinogenic[67]". [68]"

Furthermore, food manufacturers are partly responsible for confusing consumers about healthy eating, actually making them less informed. For instance, it is a long-standing platitude amongst the manufacturers of fatty, salty and sugary foods that there is no such thing as a bad food, only a bad diet. Whereas it is correct to say that there are only good diets rather than good foods, it is quite possible to identify foods that are *unhealthy* when they are consumed in the manner encouraged by advertising. Yet, at the same time, functional foods are marketed as 'improved', in and of themselves. Marion Nestle has recorded many examples in the US of the ways that food industry groups have subverted the public health recommendation for a balanced diet, which remains the bedrock of nutritional science.[69]

democratic institutions to decide what counts as harm and what to do when the risks are uncertain.

The second reason why precautionary regulation needs to be rethought, is that the case by case risk management that GM proponents consider essential to the freedom of GM producers is not always commensurable with the freedom or autonomy of other groups, with their wellbeing, or with the principle of social justice. For instance, treating GM crop manufacturers fairly would require that that their products are assessed consistently, one at a time. However, the possibility of cumulative risks means that this may compromise the safety of consumers. Box 2.2 discusses how UK regulators might face such difficulties in evaluating Golden Rice. Nuffield describe another potential conflict: farm to fork 'traceability' is crucial to giving consumers any choice in whether or not they eat GM foods under case by case regulation; however, if EU-style traceability rules were transferred to low-income countries, they would "strongly discriminate against small and poor farmers".[70] Whereas Nuffield see this as a reason for doing away with traceability regulation, we consider it to demonstrate a situation in which a general moratorium on GM crops would be appropriate. Until legitimate mechanisms for weighing values such as consumer choice, welfare and social justice are in place, then the fact that risk acceptability and social justice appear mutually exclusive if GM crops are licensed would be grounds for a blanket moratorium on the licensing of GM crops. Trusted mechanisms need to be established to weigh up these conflicting values, rather than assuming that the freedom and fair treatment of producers trumps all other considerations in regulation.

The precautionary principle is a guide to managing uncertain potential harms. Although the 'risk management' approach that dominates regulation sounds like the right tool for putting that principle into practice, it is far from adequate. Science, including risk assessment, has to be a central part of technology regulation, but an ethically sound regulatory process also requires trusted mechanisms to vet GM crops for other potential harms and to evaluate the acceptability of these wider 'risks'. No such mechanisms currently exist in the EU, and the SPS Agreement appears to discourage their implementation. Because the risks of GM crops are so plainly unacceptable to large portions of society, a moratorium should be maintained until trusted new mechanisms are in operation.

We recommend that:

- **The UK government and the European Commission research and develop mechanisms for evaluating the social acceptability of risks, that are widely trusted by members of the public including scientists.**
- **The UK government and the European Commission press for the concept of risk acceptability to be pivotal in international agreements that have a precautionary element.**
- **Until trusted mechanisms for evaluating risk acceptability are in place, governments place moratoria on highly controversial technologies such as GM crops.**

3. Research

3.1 Research values

Proponents of the 'doubly green' theme are not just against restrictions on GM crops – they encourage governments to produce more GM technology. Thus, Nuffield recommend that "*genuinely additional resources be committed by governments, the European Commission and others, to fund a major expansion of public GM-related research into tropical and sub-tropical staple foods, suitable for the needs of small-scale farmers*".[71] Their rationale is that the potential benefits of GM crops will otherwise pass by the poorest in society, unfairly benefiting the rich.

Whether a particular technology suits the needs of small-scale farmers is thought to depend on "a variety of factors":

> "such as the gene, or combination of genes being inserted, the target crop, and the agro-ecology and economy of the developing country. *We recommend focusing on the specific situation in particular countries and asking the question: How does the use of a GM crop compare to other alternatives*". [72]

Or, as Gordon Conway has more simply put it, "the best technology is the one that will safely get the job done in the simplest and least expensive way possible".[73]

The apparent simplicity of these formulae is deceptive. Section 2 has already shown that safety issues cannot satisfactorily be resolved by regulators without evaluating the social acceptability of risks. Now the question arises of how 'the job' that a GM crop is meant to do is decided during the research process, and whether the simplicity and expense are the main values against which GM technology should be compared with alternatives.

3.2 Cost-effectiveness

The 'job' that a GM crop is expected to do depends partly on the methods used to judge its potential to do the job against the alternatives. Even when there is broad agreement on the main features of a problem, different assumptions about the best way of comparing the possible solutions often imply different conceptions of what needs doing and how best to do it.

The problem of vitamin A deficiency, and the comparative merits of Golden Rice as a means of alleviating it, provides an example. Vitamin A deficiency became a top-priority public health problem in the 1980s. It had long-been recognised that insufficient dietary vitamin A caused night blindness,[74] but it only came to be considered as a major public health issue when scientists found new evidence for a link between low vitamin A and high childhood mortality, largely from infections.[75] The World Health Organisation (WHO) estimates that between 100 million and 140 million children are vitamin A deficient. Between 250,000 and 500,000 vitamin A deficient children become blind every year, of whom half die within a year of losing their sight.[76] Over 40% of the children affected are in South and Southeast Asia.[77] The 1990 World Summit for Children set a target of the "virtual elimination of vitamin A deficiency and its consequences" by 2000.[78] Three main approaches have been taken to alleviating vitamin A deficiency (Box 3.1).

Golden Rice is a test-case for a fourth strategy, known as biofortification. Biofortified crops have been bred, sometimes using genetic engineering, to include increased levels of micronutrients. The CGIAR institutes, notably the International Food Policy Research Institute (IFPRI), have been at the forefront of promoting biofortification, arguing that "new technologies and approaches are needed to help address the problem" of hidden hunger.[79] It offers a sustainable solution to hidden hunger, they say, because "Nutritionally improved varieties will continue to be grown and consumed year after year, even if government attention and international funding for micronutrient issues fades".[80] They insist that they intend biofortification not as an alternative but as a pragmatic addition to existing programmes, in the meantime, until diets become more diversified.[81]

Cost-effectiveness has been the key criterion by which people have compared the potential contribution of Golden Rice with supplementation, fortification and dietary diversification. The Golden Rice research team initially claimed that the provitamin A contained in "the typical Asian rice diet (300g of uncooked rice) alone would provide the necessary daily dose

Box 3.1: Alleviating vitamin A deficiency

The three main strategies for reducing vitamin A deficiency are supplementation, food fortification and dietary diversification.[82]

Supplementation

Vitamin A supplementation, by means of high-dose capsules twice a year, is considered by UNICEF to be "a safe, cost-effective, efficient strategy for ending vitamin A deficiency". The rate of supplementation has increased greatly since 1997: in 1996, only 11 countries had exceeded 70% supplementation to under-fives; by 1999, 43 had achieved that level. A key factor in this increase was the decision to combine vitamin A supplementation in many countries with National Immunization Days for polio.

Food fortification[83]

The World Health Organisation sees the fortification of foods such as sugar or wheat with vitamin A as "taking over where supplementation leaves off". Food fortification is widely used in Latin America.

Dietary diversification[84]

Since the cause of vitamin A deficiency is an invariant diet, often dominated by a single staple food such as rice, dietary diversification is considered to be the only permanent solution. Strategies for encouraging diversification include promoting home gardens, community fish ponds and livestock production. The key is not so much to make food sources of vitamin A more abundant, as to make them affordable to all. Although uncertainty remains over the bioavailability of vitamin-A from green vegetables, there is evidence that vegetable gardening schemes can significantly increase vitamin A status in the space of a year.

of vitamin A to prevent vitamin A deficiency".[85] Their paper in the journal *Science* claimed, by comparison, that supplementation and fortification schemes were problematic, "mainly due to the lack of infrastructure", so alternatives were "urgently required".[86] These efficiency estimates were challenged in October 2000 by Vandana Shiva, a prominent Indian critic of genetic engineering.[87] To meet the recommended daily allowance (RDA) of vitamin A, she argued, people would have to eat an impossible 2.3kg of rice per day. Greenpeace pursued this claim further, leading to a heated debate with Golden Rice scientist Ingo Potrykus, argued out in the press and over the internet.[88]

The cost-effectiveness of Golden Rice remains highly uncertain. It is not known whether its distinctive colour might lead to it attracting a price premium, rendering it unaffordable to those who most need it. Or even the opposite might happen, with the unusual colour discouraging people from eating it. Would the vitamin A content be affected by storage or cooking? How well would people's bodies convert the ß-carotene into vitamin A?[89] The effectiveness of approaches which favour dietary diversification, the preferred option of the critics like Shiva, is also uncertain.[90] Even green leafy vegetables, which are regarded as the most readily available non-animal source of vitamin A, are unaffordable to many people and may contain lower levels of pro-vitamin A than was once thought.[91] On each front, the evidence base is thin.

The Golden Rice team are worried that undue regulatory restrictions are delaying field trials of Golden Rice, thus preventing them from resolving these issues of outstanding uncertainty.[92] We are concerned that even if better evidence does become available, focusing on cost-effectiveness as the key criterion for deciding whether to continue investing in Golden Rice, construes the problem of vitamin A deficiency in such a way as to overvalue a technological solution. There are three aspects to the prejudice that arises from treating cost-effectiveness as the primary concern in technology evaluation.

First, the effectiveness of each solution is measured in terms of the amount of vitamin A that it delivers. Whilst the severity of vitamin A deficiency justifies a single nutrient approach such as supplementation as an emergency measure, the uncertainty surrounding the nutritional action of micronutrients means that such a one-dimensional approach is inappropriate over the 10 to 20 year time-scale of the Golden Rice project. The apparent 'precision' achieved by boosting nutrients in staple foods one at a time using genetic engineering is illusory, because so little is known about their uptake in malnourished people.[93] Dietary diversification makes greater allowance for this scientific uncertainty.

Second, focusing on the immediate nutritional effectiveness of the different approaches to vitamin A deficiency ignores the social value of food, which is also important to food security. Jules Pretty, at the University of Essex, has documented numerous instances in which community agricultural projects have drastically increased incomes and food security, as well as rehabilitating social life and the surrounding environment.[94] Seen from this perspective, single nutrient solutions such as Golden Rice are simplistic attempts to grapple with highly complex problems. Critics question whether the kinds of agroecological project described by Pretty can be reproduced more generally.[95] Whatever the answer, it is clear that evaluating such schemes only in terms of their cost-effectiveness at delivering a single micronutrient underestimates their potential contribution to food security. The communities affected by food security problems should be involved in determining precisely what needs to be done and in choosing between the alternatives.

Finally, governments often prefer incurring research and technology costs to investing in public health. Public health or development spending on problems such as vitamin A deficiency is thought of as a straight cost, rather than as an investment with obvious economic returns. By contrast, research spending is seen as pump-priming, so that spending on a technological solution to vitamin A deficiency is expected to have knock-on economic benefits. For instance, the European Commission contributed to the Golden Rice project under a programme that justifies biotechnology research spending on the grounds of boosting EU international economic competitiveness, not addressing hunger (see Section 4.2). This view is so prevalent that the FAO has been at pains to stress to governments that hunger and malnutrition are costly.[96] We are concerned at the primacy that this utilitarian concern with weighing up costs has achieved in contemporary understandings of the task of government. The human right to food, and the injustice that many policies in rich countries exacerbate hunger in poor countries, provide a strong ethical case for considerably increasing public health and international development spending irrespective of value-for-money.

We recommend that:

- **Policy approaches to alleviating hidden hunger and food insecurity involve the communities affected in defining the problem and in evaluating potential solutions.**
- **Food security strategies be assessed for their beneficial effect on the whole diet, taking into account the social dimensions of food insecurity.**
- **Food justice and food security at all levels be valued in policy as goals in themselves.**

3.3 The costs of late participation

There are compelling practical and ethical reasons for involving the people affected by food insecurity in designing and evaluating the potential solutions. Most obviously, a solution is more likely to succeed if it builds on the practical experience of the people who will be directly involved in implementing it, as well as on the knowledge of experts. The need for stakeholder participation in food security projects is now so widely recognised, including by proponents of the 'doubly green' theme, that we shall not retread that ground in this report.

However, in practice, there are more or less effective forms of participation. We are concerned that public participation is confined in the 'doubly green' theme to the later stages of research or to the marketplace, as consumer/farmer 'choice'. Insisting on case by case technology evaluation separates the

Box 3.2: Participation: pledge and practice

Rockefeller Foundation

The pledge: The Rockefeller Foundation put up the initial funding for Golden Rice. The Foundation aims "to enrich and sustain the lives and livelihoods of poor and excluded people throughout the world".[97]

The practice: Golden Rice was funded under the Rockefeller Foundation's IPRB, which grew out of an external review of Foundation activities that suggested crop biotechnology as a future area of activity.[98] After consulting with experts, it was decided to concentrate biotechnology funds on rice. Over 17 years, the Rockefeller Foundation invested an average of US $6.2 million per year in the programme.[99]

Within the IPRB, the Rockefeller Foundation conducted an elaborate cost-benefit comparison of the different avenues of rice research. It consisted of:

"(i) quantitatively estimating, for all possible challenges, the expected benefits to society from solving each; (ii) weighing the benefits by their contributions to environmental and equity goals; and then (iii) evaluating, for each challenge, the likely effectiveness of biotechnological as compared with conventional approaches".[100]

The possibilities were defined in consultation with "several groups of rice researchers with extensive knowledge of developing countries" and the potential for a biotechnology solution was scored by "knowledgeable scientists".[101] The "potential for a biotechnology solution" score compared biotechnology with non-biotech plant breeding, rather than with non-breeding based approaches.[102]

Provitamin A biofortification was included in the analysis but did not rate highly. However, it was argued that the potential benefits of alleviating vitamin A deficiency were very high.[103] When the Golden Rice lead researchers approached the Foundation for funding, an expert workshop was held to determine the project's chances of success. The experts were plant scientists, concerned with the technical feasibility of creating provitamin A rice, and did not focus on the socio-ecological implications of different approaches to alleviating vitamin A deficiency.[104] The issue was whether rice biotechnology offered a viable way of alleviating vitamin A deficiency, not whether new technology was the best way the Foundation could address the problem.

The Foundation also supports farmer-participatory research and agricultural development, but mainly at a local level, comparatively late in the process.

European Commission

The pledge: EU funding, which was also contributed to the Golden Rice project, is allocated by the European Commission. The Commission's strategy for biotechnology research stresses that "societal dialogue and scrutiny should accompany and guide the development of life sciences and biotechnology", that "life sciences and biotechnology should be developed in a responsible way in harmony with ethical values and societal goals", and that "informed choice should facilitate demand-driven applications".[105]

Regarding biotechnology for poor countries, it states that the technology is not a panacea and that it should only be developed "taking full account of both the environmental safety issues and the needs expressed by the populations concerned to reduce poverty and strengthen food security and nutritional quality".[106]

The practice: Applications for research funding are reviewed by experts in the relevant fields. The priorities for each five-year funding round, or 'Framework Programme', are set by the Commission in consultation with numerous expert advisory groups. The Commission's own strategic aims figure prominently.

The main stated aim of EU research funding is to foster international research links and exchanges of knowledge between member states. The stress is on big projects involving researchers from several countries. The EU funding for Golden Rice was allocated under the larger 'Carotene Plus' project, which mainly aimed to develop functional foods for EU consumers.[107]

Since the early 1990s, biotechnology has been considered a strategic priority in Brussels.[108] One of the key reasons given for this emphasis is that "Europe seems to be hesitating", and risks falling behind in the international race to profit from this field of science.[109] This theme of economic 'competitiveness' runs that deregulation stimulates technology investment, leading to economic growth, which in turn trickles down to satisfy social needs and promote a higher 'quality of life'. Many researchers argue that that the terms of this 'competition' are socially unjust, and that there is no evidence that it leads to higher quality of life.[110] Ingo Potrykus, who jointly led the Golden Rice research, has remarked that EU funding is responsible for "two very questionable consequences", by forcing public research into coalitions with industry: "Public research is oriented towards problems of interest to industry and public research is losing its independence".[111]

Syngenta

The pledge:The company Syngenta became directly involved in the Golden Rice project in May 2000, after the results of the Rockefeller- and EU-funded research had been made public. That month, Potrykus and his colleague Peter Beyer announced that they had passed exclusive commercial rights for Golden Rice to the company Zeneca, now part of Syngenta.[112] Syngenta say: "We believe in delivering better food for a better world through outstanding crop solutions, and we take pride in meeting our commitments to our stakeholders".[113]

The practice: Under the terms of the deal, the Golden Rice project was legally separated into two strands. The commercial strand was taken over by Syngenta, who hope to sell a premium product based on Golden Rice. However, Syngenta licensed non-commercial rights over Golden Rice back to Potrykus and Beyer. Under the guidance of a 'Humanitarian Board', Golden Rice would be developed for royalty-free distribution to farmers in low-income countries who earned less that US $10,000 from the rice.[114] IRRI and the national agricultural research centres breeding-out the trait are involved in the non-commercial strand.

The humanitarian strand of the Golden Rice project is clearly something of a one-off, albeit a model that the Rockefeller Foundation and others are keen to replicate through public-private partnerships. However, it is quite usual for companies to be licensed exclusively to develop research carried out using public sector funds. Commercial technology is increasingly bought in half-made. It is not developed from scratch by scientists in consultation with farmers. Licensing agreements are negotiated by different individuals and departments within the company, as well as between the company and the group offering the technology.

However, companies depend on knowing what consumers will buy. In the agri-food sector, this market research takes the form of consumer focus groups and direct contacts with farmers. What people will be persuaded to buy is not the same as what they feel they need, of course. But although there are also many other factors in commercial research decisions, firms have instrumental reasons for attempting to produce technology that approximately meets the perceived needs of consumers. The looser this approximation, the less open firms can be with their stakeholders and the more they have to spend on marketing. Recent experience shows that firms "dismiss consumer concerns at their peril" in the EU.[115]

public process of comparing ready-made solutions from the private process of designing and developing them. This leaves key early-stage judgements about the direction of research to be conducted behind closed doors. For instance, although three of the major organisations behind Golden Rice pledge to involve stakeholders, key strategic decisions are consistently performed in private, by bureaucrats and scientists (Box 3.2). When proponents of the 'doubly green' theme advise that additional resources should be spent on GM-related research, rather than suggesting that stakeholders should be involved in such decisions, they take this implied upper limit to participation for granted. This assumes that the degree of choice open to stakeholders is not affected by *when* they become involved.

However, it is important that stakeholders are involved early in the research process because spending at an that stage can lock subsequent decision-makers into pursuing the same course of action. In other words, unless stakeholders also participate in research planning and design, then their degree of subsequent 'choice' or involvement is compromised. At the worst, they will be offered products in ways that they cannot refuse: the technology on offer will be the best available way of meeting their perceived needs, by the time they are given any choice; but, had they been involved at an earlier stage in the process, they would have invested resources in an alternative.

The concept of 'sunk costs' helps to explain this lock-in effect. Rational economic decisions only take account of the future costs of pursuing a course of action, and pay no attention to irredeemable 'sunk' costs that have been already been incurred. By analogy, there is no point in sitting through a boring film just because you have already bought a ticket. Research spending is different from buying a film ticket, in as much as the past spending affects the future costs. Although the sunk costs are still irrelevant, strictly speaking, the more that you have invested in one research approach in the past, the cheaper it is likely to be in the future.

For instance, one recent cost-effectiveness comparison between Golden Rice, food fortification and supplementation found that, although Golden Rice would only make "significant contributions" to vitamin A intake where it was combined with the fortification of other foods, it was the cheapest strategy, costing US $4.24 per year for every million retinol activity equivalents (RAE) it would deliver in the period 2007-2016.[116] This figure was based on estimates of future research, breeding and promotional costs, and did not count the irredeemable US $2 million already been spent on developing Golden Rice – choosing not to develop Golden Rice would not recover that US $2 million to spend on other approaches.[117] The next cheapest option was wheat fortification, which worked out at US $6.93 per year per million RAE. Supplementation was much more expensive.

The authors noted that including the sunk costs of Golden Rice was a useful exercise, because it might "give an idea of whether it is worth pursuing other similar interventions in the future".[118] Including the past expenditure, the cost of Golden Rice rose to US $7.45 per year per million RAE. Golden rice becomes more expensive than wheat fortification, in other words, if we imagine performing the same calculation ten years previously. Back then, all other things being equal, it would have been more rational to have invested in wheat fortification than in Golden Rice research according to this model.

This example shows how research spending decisions made in private, before stakeholders are involved, can skew the field of play for public technology evaluation by stakeholders or their representatives. Unless research sponsors such as the Rockfeller Foundation, the European Commission and Syngenta involve stakeholders in early-stage research planning, they therefore fail to meet their responsibilities to allow end-users genuine input and choice. The future cost of alternative solutions to a problem like vitamin A deficiency should not be the only factor in deciding which to pursue. However, the importance ascribed to cost as a criterion for public decision-making (Section 3.2), and in the marketplace, means that past private spending decisions can be decisive.

Yet the Golden Rice example also reiterates the role that uncertainty and framing assumptions invariably play in decision-making. The Rockefeller Foundation sponsored Golden Rice even though, with hindsight, it may not have been the most cost-effective approach. One reason is that the same comparison was not attempted and, if it had been, it is quite possible that different data might have led to a different to a different prediction of the costs (Box 3.2). Another reason is that subjective judgements, based on the Foundation's wider aims and the experience of its expert consultants, also played a major part in the decision to sponsor Golden Rice. In other words, the investment decisions made in private are the first stage of an iterative process of technology evaluation, during which judgements are made about the interests and needs of different stakeholders – the decisions are not determined by the predicted cost and effectiveness of each alternative at achieving a predefined objective. It is therefore crucial that the values of potential end-users are built into research at the earliest possible stage. When it is too early to delineate clear stakeholder groups for a project, then a wider range of people should be involved in decision-making, not a narrower range.

We agree with proponents of the 'doubly green' theme that additional public resources should invested in food security projects and research. However, there is an ethical imperative to invest those extra resources in schemes that are driven by the demands of all stakeholders. Earmarking these resources for GM crop research subverts the responsibility of research sponsors to involve stakeholders and to enhance the choice available to them. A number of techniques already exist for involving stakeholders early on in the research process (Box 3.3). These should be more widely used, particularly in publicly-funded research, and complemented by experimentation with other genuinely participatory research tools. Building scientific excellence and funding 'curiosity-driven' research should still be priorities, but excellence and curiosity should be defined by a broader range of stakeholders than is currently the case.

We recommend that:

- **The UK government and the European Commission invest greater resources in food security research that is driven by the demands of communities affected by food insecurity.**
- **Research be funded into effective means of incorporating non-specialists and stakeholders into high-level strategic science planning, ensuring that these means are also acceptable to the scientific community.**
- **A greater proportion of research funding is invested in cross-disciplinary programmes, in order to encourage broader approaches to addressing food security problems.**[119]

Box 3.3: A toolbox for demand-led research and development

All too often, 'participation' and 'consultation' are little more than window-dressing for projects that are highly centralised, led by specialists in predefined fields and ignorant of the concerns and knowledge of stakeholders. It is important to give more power to the stakeholders in food security projects, not only because the project organisers have a moral responsibility to involve the people affected in planning and evaluating approaches to a problem, but also because the eventual outcome is more likely to be effective and acceptable to the people concerned. The following are three examples of tried and tested tools for giving 'non-expert' stakeholders more power in project design and research.

Prajateerpu[120]

Prajateerpu was the name given to a participatory appraisal of possible food and farming futures in the Indian state of Andhra Pradesh. The backdrop to *Prajateerpu* was a development plan for Andhra Pradesh, devised by state's governors, the World Bank and the management consultant firm McKinseys. The *Vision 2020* plan, as it was known, projected a future in which poverty was eradicated and GM crops were widely used. Many observers, reportedly including the UK Department for International Development, were concerned that rural people had not participated in this forecasting exercise and that, if implemented, *Vision 2020* might undermine rural livelihoods, agricultural biodiversity and food security.

Prajateerpu was organised by a range of organisations in India and the UK in the hope giving the rural poor a voice in planning the state's future. The process centred on a 'citizens' jury', in which the jurors were 19 farmers. They were given 4 days to cross-examine 13 witnesses, including officials of the state government, development specialists and representatives of the firms manufacturing GM crops. Their objective was not to give a 'yes' or 'no' verdict to GM crops, but to build their own scenario for Andhra Pradesh. Their own vision of sustainable and equitable agriculture contrasted starkly with the *Vision 2020* plan. As two of the facilitators write, the process was far from perfect, but it was still a great improvement on *Vision 2020*: "The verdict of the *Prajateerpu* jury demonstrated that even a comparatively top-down participation process can enable marginalised communities to critique dominant visions of their future, such as GM technology, and begin to develop their own alternatives".[121]

Multi-Criteria Mapping (MCM)[122]

The widely documented public antipathy towards GM crops in the UK stems in part from the distrust and disillusionment that many people feel towards existing institutions of technology governance. Conventional risk assessment can compound this feeling by reducing complex issues to a single answer – either a technology is safe or it is not. What are needed instead, argue the proponents of MCM, are risk appraisal tools that are: "flexible and broad in scope; able to acknowledge uncertainty; whilst being systematic, transparent, verifiable and accessible as well as practically feasible and efficient".[123]

The aim of MCM is to 'map out' the contours of a risk debate, highlighting the key areas of divergence and agreement. It focuses on comparing alternatives, rather than on assessing a single technology in isolation. The evaluation criteria and their relative weighting are chosen by the participants. By identifying optimistic and pessimistic scenarios, MCM attempts to capture the full extent of uncertainty, rather than stressing the most likely outcomes. Finally, sensitivity analysis can be used to explore the effects of altering key variables on the risk map MCM produces.

A study by Andy Stirling, from Sussex University, and Sue Mayer, from GeneWatch UK, used MCM to map the way that 12 leading protagonists saw the risks associated with GM oilseed rape in the UK.[124] The participants defined a total of 117 evaluation criteria, including environmental, agricultural, health and social issues. Across all of these criteria, participants scored organic farming methods relatively highly. Conventional intensive agriculture performed relatively poorly. GM options only performed best when the perspectives of certain government and industry participants were adopted. Critically, it was the framing assumptions of the different participants, more than the weighting of individual criteria, that had the greatest impact on the outcome: "An MCM approach may therefore assist in the crucial business of 'risk characterisation', prior to – and subsuming – the conduct of other risk assessment techniques".[125]

Constructive Technology Assessment (CTA)[126]

Technology assessment (TA) attempts to assess the likely impact of a technology that has already been designed. Its main purpose is to shape policy – what is the best way to benefit from a new technology or to mitigate its ill-effects? The process of regulation described in Section 2 of this report centres on a form of technology assessment. Yet TA, including participatory TA techniques, "has proven ineffective at predicting social responses or unexpected consequences associated with many technologies... Implicit in this approach to technology is the assumption that the creation or design of technology is an insular and self-generating activity; the public's role is in shaping, through policy and regulation, how that technology will be applied".[127]

By contrast, proponents of CTA hold that the design of technology is affected by the interests and values of the people involved. They also argue that the end-users or stakeholders may have valuable knowledge to contribute to the design and development of a technology. Therefore "CTA proposes bringing together all interested parties early in the design process... in CTA technology is assessed from many points of view throughout the entire process of design and redesign, and the interests of all parties can be incorporated in the design from the beginning".[128]

CTA was pioneered in the Netherlands. It emphasises the value of bringing together the investors, end-users and regulators at the earliest stage possible. The rationale for this is not so much to democratise technology production, although that can be its effect, as to avoid investing heavily in technologies that do not meet the needs or expectations of the people who might use them. Expressed in this way, CTA is simply good business and policy practice. However, it is a far cry from the way that GM crops have been developed to date.[129]

4. Ownership

4.1 Public goods and private profit

Despite their enthusiasm for GM crops, which have developed hand in hand with the privatisation of agricultural research, proponents of the 'doubly green' theme are ambivalent towards the private sector. On the one hand, they fear that the erosion of non-commercial agricultural research means that fewer resources are allocated to addressing the needs of poor farmers. On the other hand, they argue that unless public research institutions enter into partnerships with industry, then the poor will not benefit from GM technology at all. Golden Rice has been an exemplar of both their fears and their hopes for public-private partnerships (PPPs). The research team had intended Golden Rice to be developed for the public good, as a public good, using public goods (Box 4.1). It therefore came as a great disappointment to them when, on each count, the public good was appropriated for commercial gain.

First, it turned out that the knowledge used by the researchers was anything but a public good in practice. An initial review found that they had used around 70 patents. Patents are legal tools for making knowledge behave like private property by granting an exclusive monopoly, on the assumption that this stimulates invention for the greater good.[130]

Second, in order to escape from this apparent patent tangle, the Golden Rice team transferred exclusive commercial rights for Golden Rice itself to the firm Syngenta. "Hence by a stroke of a pen," a coalition of farmer groups lamented, Syngenta "was able to acquire exclusive commercial control over a technology that was developed with public funding and purportedly pursued for a humanitarian cause".[131] Golden Rice was no longer a public good.

Finally, even the ends of the Golden Rice project were appropriated by firms. Most notoriously, the Council for Biotechnology Information (CBI), an industry-funded publicity group, ran a North American television advertising campaign citing Golden Rice as an example of the way that "biotechnology is providing solutions that are improving lives today".[132] The advertisement omitted to mention that none of the biotechnology firms funding the campaign, not even Syngenta, had contributed significantly to Golden Rice.[133]

Proponents of the 'doubly green' theme condemned this final form of appropriation, as did critics of Golden Rice like Vandana Shiva. In an open letter to Greenpeace, Rockefeller Foundation president Gordon Conway said:

> "I agree with Dr Shiva that the public relations uses of Golden Rice have gone too far. The industry's advertisements and the media in general seem to forget that it is a research product that needs considerable further development before it will be available to farmers and consumers".[134]

For the proponents, however, the Golden Rice story is also proof that the appropriation of public goods by the private sector can work out well in the end. As a condition of the Syngenta deal, the firm agreed to allow lower-earning farmers in poor countries to use the product royalty-free. The proponents see PPPs such as this as the only realistic way of ensuring that the potential benefits of GM research reach the very poor. The Rockefeller Foundation is supporting two major initiatives to promote more PPPs in agriculture: the Public Sector Intellectual Property Resource for Agriculture (PIPRA) encourages universities to keep hold of rights to technologies they have developed, which can be used as bargaining chips in negotiations with industry;[135] the African Agricultural Technology Foundation (AATF) has recently been established in alliance with the four largest GM crop firms.[136]

Even if GM research pursued via PPPs was to produce some pro-poor technologies, we question whether those will be sufficient to off-set the 'anti-poor' effects of other GM crops that are developed commercially. Under the public-private relationship proposed in the 'doubly green' theme, pro-poor GM crops depend on being little more than 'loss leaders' for other products sold at a premium to rich farmers and consumers. Historically, the overall effect of premium agricultural technology has been to push small farmers off the land and consolidate the farming sector.[137] Whilst such consolidation may boost productivity, it is not in the interests of food security. We question whether a science that depends on privatising public goods to sell at premium prices can make a realistic promise to generate food security, which depends on public goods.

Box 4.1: Food security as a global public good

Public goods are both 'non-rival', meaning that consumption by one person does not detract from that of another, and 'non-excludable', meaning that it is difficult to prevent anyone from enjoying them. They provide benefits for many individuals and yet they are unlikely to be produced without collective action. Education is one example: its benefits are great and widespread; however, without collective action, education provision would fall short. At the 2002 Earth Summit it was agreed that creating 'global public goods' was a precondition of sustainable development.[138]

Food security – consistent and affordable access to sufficient safe and nutritious food for all – is considered by the United Nations Development Programme to be a global public good. This is different from the idea that individual people have a right to food, which is enshrined in Article 25 of the Universal Declaration on Human Rights.[139] For example, alleviating vitamin A deficiency is considered beneficial for society at large, not just the people directly affected. A bald expression of this social value is the Rockefeller Foundation's early prediction of economic benefits for Asia worth over US $100 million annually from an effective provitamin A rice.[140]

4.2 Patents

The ability to patent biological knowledge has been a key factor in the privatisation of agricultural research and in the development of genetic engineering. Proponents of the 'doubly green' theme, and even more so their critics, see the patent saga around Golden Rice as a cautionary tale. In creating Golden Rice, the research team used knowledge and genetic material that had been developed by other scientists before them. So long as they were just doing research, the knowledge and material were available for free.[141] As soon as the researchers began to develop Golden Rice into a product that farmers could use, however, those components ceased to behave like public goods: the knowledge was 'intellectual property' (IP), protected by privately owned patents; the genetic material had been lent under contract, via material transfer agreements, and was 'technical property' (TP) (Box 4.2).

The ensuing attempts to ensure that the original target group of poor farmers could still use Golden Rice have been the subject of great controversy (Box 4.3). However, both proponents and critics of the 'doubly green' theme are sceptical of the arguments made by firms such as Syngenta, that "patents are essential to encourage innovation and openness in scientific research [and there] is no case for treating biotechnology inventions differently to any other invention".[142] There are four main concerns about IP in this context.

First, the IP sceptics see the apparent patent tangle around Golden Rice as example of the 'tragedy of the anticommons'.[143] Instead of a public good being overexploited because nobody owns it (the so-called 'tragedy of the commons'), the concern is that research will be underexploited, or gridlocked, because the upstream scientific knowledge has too many different owners.[144] IP rules are a utilitarian compromise, granting temporary ownership *of* a public good (knowledge) *for* the public good, on grounds that the incentive this creates for making new knowledge outweighs the restrictions placed on its use.[145] In the 1980s it became possible to patent parts of living organisms in some countries, and it is now unusual to modify a plant genetically without using proprietary knowledge. Many public sector scientists are worried that the IP deal has thus been overdrawn. In a high-profile report on *Transgenic Plants and World Agriculture*, the UK Royal Society and other national academies of science recommend that "broad intellectual property claims, or claims on DNA sequences without a true invention being made, should not be granted because they stifle research and development".[146]

The second concern is that patenting is part of broader trend towards the privatisation of agricultural research that threatens to marginalise the needs of poor farmers who cannot pay for technology. Gordon Conway explains:

> "Until recently plant breeders have relied on the Plant Variety Protection (PVP) system to protect their rights. Under this system breeders gain protection for their varieties, but farmers can save the seed and other breeders can use the varieties to produce new varieties. In the US this has largely been replaced by a system of patents – applied to genes, pieces of the genome, technologies of gene transfer, and existing and new varieties. It is justified in terms of protecting intellectual property rights and stimulating innovation. For the developing countries, however, it is likely to move potentially beneficial innovations out of reach of the poor".[147]

Indeed, Conway understates the problem in as much as many low- and middle-income countries have had no IP protection for plants at all, not even PVP, and are only being required to put protection in place under new international rules.[148] The concentration of IP in the hands of the few giant firms that dominate the ag-biotech sector, achieved partly through company buy-outs, is widely seen to be contrary to the interests of poor farmers and to pose a serious threat to conventional breeding.[149]

A third shared concern is that poor countries are being bullied into abiding by patent rules that do not apply to them. As RAFI described (Box 4.3), most of the patents affecting Golden Rice did not actually apply in the countries where it would be grown.[150] They saw Golden Rice as a "Trojan trade rep", forcing US IP rules onto countries where they did not and should not apply. Efforts are under way to co-ordinate IP rules internationally through the Agreement on the Trade-Related Aspects of Intellectual Property (TRIPS). A previous Food Ethics Council report on IP discussed in some detail the ethical issues raised by TRIPS.[151] TRIPS, which is administered through the World Trade

Box 4.2: IP and TP

Intellectual property[152]

Intellectual property is the term used to refer to a range of legal devices that allow creators and inventors to prevent other people from using their work or invention without permission. It includes patents, which protect the knowledge behind technological innovations, copyrights, which protect creative works such as writing, music or pictures, geographical indications and trademarks, such as those associated with branded goods.

Patents are the form of IP that are most relevant to discussions of GM crops. Patents grant inventors a monopoly on non-obvious, novel and industrially applicable inventions. Since the 1980s, some countries have allowed patents on living organisms and other biological material. Genetic engineering has been associated with an explosion in the number of such patents, not only on the GM varieties such as Golden Rice, but also on the genetic sequences and techniques that are used to develop them.

The Agreement on the Trade-Related Aspects of Intellectual Property Rights (TRIPS), which is administered by the WTO, requires countries to put in place IP rules for plant varieties and micro-organisms, but allows plants and animals to be excluded from patentability if desired. In that case, however, other '*sui generis*' or type-specific forms of IP for plant varieties, such as Plant Breeders Rights must be adopted.

Technical property

Technical property refers to tangible material such as germplasm or actual plants, and material or information that is derived from it.[153] When scientists are genetically modifying a plant, they do not just use patented products or processes. They also often use samples of plant or other material that are owned by others. For instance, they may use material from a gene bank. Such exchanges are often covered by Material Transfer Agreements (MTAs). These are contracts that set out the terms of the exchange. They may require a royalty to be paid to the owner of the material if a commercial product is created from the material they provide. MTAs are often confidential to the parties involved.

Box 4.3: Who gets the gold?

It was IRRI who raised the possibility that IP and TP might hold back their efforts to develop Golden Rice as a public good. Prompted by IRRI's concern, the Rockefeller Foundation commissioned a group called the International Service for the Acquisition of Agri-biotech Applications (ISAAA) to conduct a 'freedom to operate' review.[154] ISAAA found at least 15 TP 'components' and around 70 patents. Altogether, a maximum of 44 of the patents were applicable in any one country. Outside of the US and the EU, in the main rice producing and importing countries, far fewer were applicable.

Between the extremes of either ignoring these IP and TP constraints or seeking licences for them all, ISAAA saw three options: more research could be done to invent around the patents, finding cheaper ways of doing the same job; the gene 'constructs' used in the research could be redesigned; or the patent holders could be persuaded to relinquish their claims.[155] It is not known what advice ISAAA initially gave the research team in April 2000. But the Rural Advancement Foundation International (RAFI), which watched these events closely, recounts what happened next:

"Despite their shock as to the number of potential intellectual property conflicts, the donors were stunned on May 16th when the two researchers independently signed a deal with AstraZeneca [now Syngenta]... In return for exclusive monopoly control of Golden Rice in the North and sales to larger farmers in the South, AstraZeneca agreed to make the technology freely available to the South's poor farmers. At the time, Beyer and Potrykus told the media that the dizzying muddle of conflicting intellectual property claims necessitated the deal".[156]

RAFI subsequently reviewed the patents listed by ISAAA and found that:

- 35 of the 60 countries suffering from the most serious levels of vitamin A deficiency recognised no patents related to Golden Rice.
- In the remaining 25 countries, only 12 patents were relevant.
- 7 of these patents were held by the four gene giants (then) AstraZeneca (1), Aventis (2), Monsanto (1) and DuPont (3, apparently identical), one was held by a small Israeli firm, and the rest were owned by public-sector institutions.
- Of the 12 countries with both high levels of vitamin A deficiency and high rice consumption, where Golden Rice might make a difference, 6 recognised no relevant patents.[157]

Little was known about the TP, because most of the agreements were confidential. However, RAFI concluded that the research team had been persuaded into the Syngenta deal by an exaggerated picture of the constraints on developing Golden Rice:

"Even though poor countries have every legal right to utilize a technology not patented within their territories – pressure from industry seems to have convinced public science – and its funders – that they had to negotiate access to all the patents in order to develop Golden Rice".[158]

"In RAFI's opinion, the Golden Rice deal was a rip-off of the public trust. Asian farmers get (unproven) GM rice and AstraZeneca gets the 'gold'".[159]

Organisation (WTO), institutes an IP regime that puts the interests of large firms and rich nations ahead of the global poor. However, it does not require all countries to allow plants to be patented.[160] At the time of the ISAAA review of Golden Rice, 76 WTO-member low- and middle-income countries had no IP protection for plant varieties at all.[161] IFPRI, a major proponent of biofortification, agrees with RAFI that the IP constraints on Golden Rice were exaggerated:

> "The well-publicized donations by major corporations of their intellectual property relevant to vitamin A rice left a strong impression that the exercise of large numbers of crucial patent rights was being relinquished in favor of the poor in developing countries. In fact, in some major rice-consuming countries, there are no valid relevant patents, and in most, there are very few".[162]

Finally, there is concern that existing forms of IP encourage the wrong kind of research. Proponents of the 'doubly green' theme fear that patents will make biotechnology too expensive for poor people to afford. But we would add a qualitative supplement to this quantitative worry. Patents turn knowledge into a commodity with *market* value; the broader *social* value of research and technology recedes into the background.

We are concerned that patents and other forms of IP are becoming primary means of attaching value to knowledge in public research institutions, as well as in firms. The rise of bio-patenting coincided with a period of funding cut-backs for public sector research in the US and in much of the EU. In this climate of retrenchment, public sector researchers have been encouraged to generate revenue by engaging in entrepreneurial activity, including patenting research. This may mean that they have produced more biotechnology, but it also means that they have produced fewer public goods. An in-depth study comparing several universities found that this profoundly affected the kind of research that got done. Research staff "began to see commercial application as inevitable, sometimes as intrinsic, to their inquiry".[163] However, public goods that can be shared and copied freely are crucial to ensuring food security in marginal areas. Not every GM crop will be 'anti-poor', but the IP forms sustaining biotechnology in general favour marketable technologies that add value off-farm, in the laboratory. This leads research in the opposite direction from the kinds of farmer-participatory field technologies that are now widely regarded as the route to pro-poor technology.[164]

We recommend that:

- **IP protection applied to plants or animals should not allow the owner to prevent users from re-using or developing their product.**
- **Non-exclusionary incentives for agricultural innovation, such as cash rewards or prizes, are introduced instead of IP.**
- **International IP rules be balanced by introducing comparable anti-trust and liability rules, and by enforcing other agreements on plant biodiversity and genetic resources.**
- **The rights of farmers to save, share and adapt seed, and to have affordable access to technology that promotes food security, overrule the privileges granted to inventors in national and international law.**
- **Because 'intellectual property rights' are actually intellectually-based monopoly privileges, they should be named and treated accordingly**.

4.3 Partnerships for the poor?

Rather than question the ethics of privatising public agricultural research through IP, the 'doubly green' theme proposes further links with firms, in the form of PPPs, as a means of mitigating the unwanted side-effects of privatisation. Because of heavy commercial investment since the late 1970s, partly stimulated by the patentability of biological knowledge, private firms are now the major players in biotechnology research and account for around 80% of spending.[165] Many governments have also preferentially promoted biotechnology research in the name of economic 'competitiveness', in the hope of pump-priming commercial activity. They have prioritised spending on 'appliable' research – 'basic' research with commercial potential – and cut back on non-commercial 'applied' projects that produce concrete public goods like seeds that might compete with business.[166] The same retrenchment that has seen universities and public agricultural research institutes embrace patenting has also led them to seek an increasing proportion of private funding, principally through collaborating with firms.

The UK government's stance is typical:

> "In the global knowledge economy in which we now live, jobs and prosperity depend on the application of new ideas and skills. This is a challenge for us all. British universities must build on their world-class expertise and embrace a new entrepreneurial role, bringing forward the businesses of the future".[167]

Box 3.2 described how the European Commision adopts a similar position. Proponents of the 'doubly green' theme are concerned that the policy focus on commerce means that poor farmers will miss out on the potential benefits of GM crops. What is needed, they argue, is for the public-private relationship to shift. The public sector should piggy-back on private research, to ensure that the "significant *potential* of modern biotechnology in developing countries to raise agricultural productivity in a more environmentally-friendly manner, enhance food security, and contribute to the alleviation of poverty" is realised.[168] Or, as the Royal Society puts it, "innovative and vigorous forms of public private collaboration are urgently needed if the benefits of GM technologies are to be brought to all the world's people".[169]

The tools for achieving this pro-poor potential, argue the proponents, are additional links between the public and private sectors, in the form of carefully tailored PPPs. The Golden Rice deal with Syngenta is often cited as a good example of a PPP resolving a situation where private patents threatened to jeopardise a project that was for the public good. The researchers argue that the deal has mutual benefits.[170] Syngenta obviously gained the commercial rights to an invention that it had not paid for, and the 'humanitarian' strand gained free access to knowledge derived from Syngenta's subsequent research on Golden Rice. The IP and TP problems now appear to be largely resolved, which the research team insist would not have been possible without Syngenta's assistance.

The Syngenta deal is an example of what is known as a 'market segmentation' approach. The dividing line between the 'humanitarian' licence and the commercial monopoly is determined in this case by geography and income. The technology is royalty-free to farmers in poor countries earning less that US $10,000 from Golden Rice. The Rockefeller Foundation hopes that the AATF (see Section 4.1) will encourage similar partnerships, and "will be a catalyst for the next agricultural revolution in Africa".[171] The US and UK governments, and the agri-food giants Syngenta, Dow, DuPont and Monsanto, have pledged their support for the scheme.[172] But despite this enthusiasm, even the proponents see problems with PPPs (Box 4.4).

In one sense, however, it is a mistake to treat PPPs as a new phenomenon. Even where the public and private sectors are not formally married, they have been cohabiting for years. We have already described how this 'common law' partnership is created by intellectual property, by industry funding of university research, by government funding of industry research and by many other processes. Proponents of the 'doubly green' theme agree with critics that this actually-existing partnership is not in the interests of poor people and leads to the underprovision of public goods. The litmus test for new public-private links is whether they tip this relationship towards the provision of more public goods. Building PPPs into the agricultural research infrastructure appears to do the opposite, institutionalising a framework in which public goods are only produced as 'loss leaders' for commercial products. They are strategic freebies from a public-private research complex that *needs* to turn a profit. Public goods that offer no marketing kick-backs will not be produced. If the public relations mileage associated with nominal-

Box 4.4: A stormy relationship: more or less sympathetic critiques of PPPs

Byerlee (World Bank) and Fischer (University of Queensland and IRRI):

"Although market segmentation is a conceptually appealing way for the public sector to gain access to proprietary technologies, there are major practical obstacles to be overcome".[173]

Tripp (Overseas Development Institute):

Market segmentation is a potentially effective strategy but it raises the broader question of whether the world should "be neatly divided into those areas for which markets are relevant and those that are not".[174]

Pingali (CIMMYT) and Traxler (Auburn University):

"Even if public-private partnerships could be developed, will the resulting technologies ever get to the poor? Given that the technologies that are on the shelf today (generated by conventional research methods) have not yet reached farmers' fields, there is no guarantee that the new biotechnologies will fare any better".[175]

Falcon (Stanford University) and Fowler (Agricultural University of Norway):

"Whether any partnerships with the private sector represent a viable direct option for national research programs in the very poorest countries remains to be seen. For this sub-set of developing nations, the chances appear to us to be depressingly slim."[176]

Wijeratna, Orton and Sexton (Action Aid):

"PPPs have not, so far, demonstrated their worth in terms of measurable benefits to poor communities. Private sector investment and PPPs need to operate within strong rules and regulations to ensure that control and benefits are more equitably distributed".[177]

ly ‘pro-poor’ products such as Golden Rice diminishes through time, then the hopes of producing even these will become increasingly slight.

The proponents of pro-poor biotechnology are probably right when they argue that, without PPPs, biotechnology will not be introduced on a significant scale into poor countries. However, we should not presume that those countries, and the poorest people within them, will be missing out if they have no access to biotechnology. GM crops are a supply-led technology driven by legal changes, in the form of bio-patenting, and by the technical innovations that have gone hand in hand with these new rules. Their main effect is to add *commercial* value to seeds in the laboratory, not in the fields of poor farmers.[178] There are many food security approaches that can be pursued in the absence of PPPs, untouched by corporate IP claims; the fact that GM crops cannot be, is less a reason to institute PPPs than an indictment of the pro-poor potential of genetic engineering. The unsubstantiated promise that genetic engineering will ‘improve’ crops has been treated as an excuse to short-cut stakeholder participation in striving for food security. Great changes are needed in the relationships between public and private institutions if the agricultural research system is to contribute more to alleviating hunger. The widespread enthusiasm for PPPs is a sign of just how little these relationships are changing right now.

We recommend that:

- **Co-operation and community involvement should come before competitiveness as the catch-phrases for public sector research in the EU.**
- **The European Commission dedicate a portion of its research budget to fund Public Good Projects, which require that research is non-commercial and spins-off into non-profit entities rather than firms.**
- **PPPs are only pursued in exceptional circumstances, and are not viewed as necessary to food security.**
- **There is wider reform of the public sector research system, including additional state funding, to ensure that the provision of genuine public goods is its primary mission.**

5. Conclusion

European governments are being advised by the scientific establishment that their precautionary stance on GM crops is unjust and that, instead of restricting the use of such crops, they should be investing more public resources in GM crop research. This report has explained why we think that advice is flawed and has made alternative recommendations concerning GM crop regulation and agricultural research. We have argued that a robust interpretation of the precautionary principle is ethically more sound than the weak version favoured by GM proponents, and should be complemented by upstream changes to the ways in which research is financed and directed.

We agree with the 'doubly green' theme that building food security at all levels should be a priority for rich country governments. However, the proponents of that theme presume that some of the key means of ensuring research and technology contribute to food security are off-limits. They rule out regulatory measures to protect vulnerable groups from technologies that might harm their food security economically, on the unquestioned assumption that it is more important to ensure freedom of action of technology manufacturers. They claim to support freedom of choice for the end-users of GM crops, but limit their involvement in defining the problem and evaluating solutions. Finally, they treat IP as if it were a right that society must accommodate, rather than a privilege that should be modified or withdrawn wherever it fails the public. We have attempted to show why these assumptions are questionable. However, our aim has not been to replace them with an alternative set of 'expert' value judgements. Rather, we have argued that new mechanisms are needed to ensure that agricultural regulation and research respect the values of their stakeholders, and benefit society at large.

In this report we have focused closely on the areas of technology regulation, research and ownership. However, they are only part of a much bigger picture. By concentrating on them, we do not wish to imply that new technology is the only or, even, the main factor affecting food security. In particular, reforms to EU and US agricultural and trade policies could have a far greater effect on international food security than any foreseeable technology. The argument that GM crops will contribute to food security does not only distract from these urgently needed policy changes. In some instances, it has been deployed to further precisely the kinds of unfair international trading relationships that contribute to food insecurity in the first place. International food security is being used as a political lever to promote the business interests of rich countries, rather than being valued as an end in itself.

The 'doubly green' theme promotes a food future in which commercial interests continue to drive agricultural research, and food security remains a 'loss leader'. In this scenario, it seems likely that the agri-food sector will become more like the pharmaceutical sector is today. Strong IMPs will mean that crop varieties, like drugs, will be developed with rich farmers and consumers foremost in mind, and will be beyond the means of the world's poor. Just as the large pharmaceutical firms obstruct generic drug manufacturers from copying their products in countries where they have no patent protection or market presence – for fear of cross-border smuggling or closing future markets – so will they obstruct local firms or the public sector from producing affordable or royalty-free versions of any useful crop technology, even when they are legally entitled to. Some research would be sponsored into non-commercial GM crops, as in orphan drug programmes, but this would be exceptional.

There are important differences between food and pharmaceuticals. Not least, the drugs sold to the rich do not obviously make the poor more sick. By contrast, if the GM crops sold to wealthy farmers make them economically more competitive, as the manufacturers claim, then poorer competitors who cannot afford the new crops may loose out, potentially jeopardising their food security. Another key difference is that regulatory standards for foods are generally weaker than for drugs, at the moment, despite the fact that foods are consumed in far larger quantities. You would not need to have held clinical trials to sell Golden Rice, nor would you need a prescription to eat it.

The comparison with the pharmaceutical sector illustrates some of the reasons why we believe that watering down GM crop regulation and spending more on GM crop research will lead away from food security. Not only may the poor get poorer in this scenario, but consumers in rich countries would also be worse off. The current laxity of food regulation, compared with drug regulation, combined with the incentive to differentiate foods in a market that has long been saturated, is leading to foods being marketed increasingly like drugs in rich countries. GM 'functional foods' such as Golden Rice will be sold at a premium for their alleged health benefits (Box 2.2). 'Nutrigenomics', by which diets are tailored to individual genetic 'requirements', presents further opportunities to sell foods at higher prices. The health benefits of these individualised diets are questioned by many nutritionists. Furthermore, it is clear that they cost more to consumers and erode the social value of food.

We believe that an alternative, ethical scenario is possible. By ethical, we mean driven by the values of the people who grow, exchange and eat food, and leading to a more just, secure and sustainable future. We believe that the recommendations we have made in the previous sections would point food regulation and agricultural research in this direction, because they focus on giving the people affected by technology a genuine say in its development.

In this second scenario, moratoria on GM crops would proliferate pending the development of mechanisms for evaluating risk acceptability. The biotechnology industry would move out of agriculture to concentrate on medical and industrial applications of genetic engineering, for which risk acceptability appears to be higher. Drug-like foods would be regulated like drugs, rather than like foods. IP protection for agricultural research would be wound back, and alternative incentives for invention implemented where necessary. Freely available public goods would become more important resources for agriculture, in poor and in rich countries. Food security projects would become increasingly community-driven and based on available technology. Agricultural and trade policies in the EU and the US would take account of all the people they affect, and not prioritise the interests of certain sectors of agriculture within the implementing countries.

Elements of both these trajectories are in evidence today. This report has concentrated on the first. The makings of the second scenario can be seen in successful community-driven food projects, in the opposition of poor country governments to the TRIPS Agreement, in the precautionary clauses that increasingly feature in international policy, and in the critical interest that consumers are showing in GM crops, not just in Europe but around the world. However, the two scenarios are mutually exclusive in the long-run. Unless policy-makers commit now to reforming risk regulation, agricultural research and agricultural policy, a just, secure and sustainable food system will remain nothing more than a promise.

Notes

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[3]Cabinet Office (2003) *Field work: weighing up the costs and benefits of GM crops*. Strategy Unit, London, July 11: 90-91.

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[9]FAO (2002) *Declaration of the World Food Summit: five years later.* Food and Agriculture Organisation, Rome, June 10-13.

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[22]Anon. (2003) US launches WTO case against EU over GM foods. *Just-Food*, August 8. www.just-food.com.

[23]The idea that food insecurity is caused by people being unable to sustain sufficient entitlement to food, and not by there being insufficient food to go around, has become widely accepted since Sen proposed it two decades ago: Sen, A. (1981) *Poverty and famines*. Oxford University Press, Oxford.

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[59]The Royal Society of Canada continues: "Even more importantly, a pure risk-cost-benefit approach is seen by some critics as anti-precautionary. This is because the usual methods by which it is carried out have a built-in bias in favour of technological benefits, which are immediate, highly predictable and quantifiable (otherwise the technology would have no market), and against the risk factors, which are discounted because they tend to be long term, less certain and less easily quantified". Royal Society of Canada Expert Panel on Food Biotechnology (2001: 200), see note 56.

[60]Royal Society of Canada Expert Panel on Food Biotechnology (2001: 210, original emhasis), see note 56.

[61]Commission of the European Communities (2000: 15-6), see note 54; Royal Society of Canada Expert Panel on Food Biotechnology (2001: 204-5), see note 56.

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[123]Stirling and Mayer (1999: 5), see note 62.

[124]Stirling and Mayer (1999), see note 62.

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[130]Food Ethics Council (2002) *TRIPS with everything? Intellectual property and the farming world*. Food Ethics Council, Southwell, Notts.

[131]BIOTHAI, CEDAC, DRCSC, GRAIN, MASIPAG, PAN-Indonesia, and UBINIG (2001) *Grains of delusion: Golden Rice seen from the ground.* www.grain.org/publications/delusion-en.cfm.

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[150]RAFI (2000) Golden rice and Trojan trade reps: a case study in the public sector's mismanagement of intellectual property. *RAFI Communique*.

[151]Food Ethics Council (2002), see note 130.

[152]For a fuller discussion of IP, see Food Ethics Council (2002), see note 130.

[153]Kryder, R. D., S. P. Kowalski, and A. F. Krattiger (2000) The intellectual and technical property components of pro-Vitamin A rice (GoldenRiceTM): a preliminary freedom-to-operate review. *ISAAA Briefs* 20.

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[156]RAFI (2000), see note 154. RAFI is now called ETC Group (the Action Group on Erosion, Technology and Concentration).

[157]RAFI (2000), see note 150

[158]RAFI (2000: 3), see note 154.

[159]RAFI (2000) On golden pawns. *Geno-types*:2..

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[168]Byerlee and Fischer (2001: 1, original emphasis), see note 165.

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[172]Conway (2003), see note 31. Gillis, J. (2003) To feed hungy Africans, firms plant seeds of science. *Washington Post*, March 11.

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[175]Pingali and Traxler (2002: 237), see note 11.

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[177]Wijeratna et al. (2003: 41), see note 12.

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Abbreviations

AATF	African Agricultural Technology Foundation
ACNFP	Advisory Committee on Novel Foods and Processes
CBI	Council for Biotechnology Information
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
CTA	Constructive Technology Assessment
DNA	Deoxyribonucleic Acid
ETC	Action Group on Erosion, Technology and Concentration
EU	European Union
FAO	Food and Agriculture Organisation
GM	Genetically Modified
IFPRI	International Food Policy Research Institute
IMP	Intellectually-based Monopoly Privilege
IP	Intellectual Property
IPRB	International Program on Rice Biotechnology
IRRI	International Rice Research Institute
ISAAA	International Service for the Acquisition of Agri-biotech Applications
MCM	Multi-Criteria Mapping
MTA	Material Transfer Agreement
PIPRA	Public Sector Intellectual Property Resource for Agriculture
PPP	Public-Private Partnership
PVP	Plant Variety Protection
RAE	Retinol Activity Equivalents
RAFI	Rural Advancement Foundation International (now called ETC)
RDA	Recommended Daily Allowance
SPS	Sanitary and Phytosanitary
TA	Technology Assessment
TP	Technical Property
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UNICEF	United Nations Children's Fund
UK	United Kingdom
US	United States
WCED	World Commission on Environment and Development
WHO	World Health Organisation
WTO	World Trade Organisation