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The use of genetically modified crops in developing countries

a follow-up Discussion Paper

NUFFIELD COUNCIL ON BIOETHICS

Nuffield Council on Bioethics

Professor Bob Hepple QC FBA (Chairman)

Professor Catherine Peckham CBE (Deputy Chairman)

Professor Tom Baldwin
Professor Sir Kenneth Calman KCB FRSE
The Rt Reverend Richard Harries DD FKC FRSL
Professor Andrew Grubb
Professor Peter Lipton
Baroness Perry of Southwark*
Professor Martin Raff FRS
Mr Nick Ross
Professor Herbert Sewell
Professor Peter Smith CBE
Professor Dame Marilyn Strathern DBE FBA
Professor Albert Weale FBA
Dr Alan Williamson FRSE

* *(co-opted member of the Council for the period of chairing the Working Party on the ethics of research involving animals)*

Secretariat

Dr Sandy Thomas (Director)
Ms Tor Lezemore (until August 2003)
Mr Harald Schmidt
Mrs Julia Fox
Ms Natalie Bartle (until July 2003)
Ms Caroline Rogers (from August 2003)
Ms Nicola Perrin
Ms Elaine Talaat-Abdalla
Ms Maria Gonzalez-Nogal (until September 2003)

The terms of reference are as follows:

1 to identify and define ethical questions raised by recent advances in biological and medical research in order to respond to, and to anticipate, public concern;

2 to make arrangements for examining and reporting on such questions with a view to promoting public understanding and discussion; this may lead, where needed, to the formulation of new guidelines by the appropriate regulatory or other body;

3 in the light of the outcome of its work, to publish reports; and to make representations, as the Council may judge appropriate.

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Foreword

In its 1999 Report ***Genetically modified crops: ethical and social issues*** the Council concluded that there is a moral imperative to make GM crops readily and economically available to people in developing countries who want them. The Council conducts regular follow-ups of all its publications. There was a particular need to do so in the case of the Report on GM crops because of the many developments in science and policy which have taken place over the past four years. We undertook this task in time to contribute to the national debate on the use of GM crops which was sponsored by the UK Government in 2003. We published a draft Discussion Paper in June 2003 and invited comments from interested individuals, organisations and the wider public in developed and developing countries. Eighty-three responses were received. The valuable points they made are reflected in this final version of the Paper.

I have been struck by the extent to which the public debate on GM crops continues to be highly polarised in a partisan way. Instead of a sober estimate of the risks and benefits of GM crops on a case by case basis, there is a view that any attempt to even consider their potential is unconscionable. This cannot be right. All forms of agriculture affect human health and the environment, including organic agriculture. GM technology needs to be considered not in the abstract, but by means of comparing its short and long term impact with the impacts of alternative technologies. In this Discussion Paper we provide examples with current and potential benefits to resource-poor farmers and communities. There may well be situations in which such benefits are outweighed by associated risks of GM technology. Intelligent public policy will seek to discriminate between the cases and find ways of developing regulation so as to help those in most need.

This is particularly important in developing countries, where issues of food security and agricultural development press hard. All too often, the situation of agricultural communities threatens to become worse, not better. The status quo is not an option unless we are prepared to see increased suffering and destitution. A precautionary approach may mean going ahead with novel technologies rather than stalling, as is conventionally assumed when the approach is applied to agricultural practice in wealthy societies. It cannot be responsible to render a technology unavailable to those whose needs are urgent. Nor can it be responsible to be partisan in a debate where empirical evidence should be decisive in settling the question.

I hope that the Paper will help to clarify these complex issues and encourage constructive discussion. I also hope that the conclusions and recommendations will provide guidance for policy makers and others who have to make difficult judgments about the use of GM crops.

Finally, on behalf of the Council I should like to express our appreciation to the members of the Working Group: Professor Derek Burke, Professor Mike Gale, Professor Michael Lipton and Professor Albert Weale, who devoted enormous amounts of their time to this review, to those listed in the Acknowledgments who assisted their work, and to the individuals and organisations who commented on the draft Discussion Paper. As always, we are much indebted to the Council's Secretariat: Dr Sandy Thomas, Ms Tor Lezemore, Mr Harald Schmidt, Ms Julia Fox, Ms Elaine Talaat-Abdalla, Ms Nicola Perrin, Ms Natalie Bartle, Ms Caroline Rogers and Ms Maria Gonzalez-Nogal for their dedication and efficiency in producing this Paper.



Professor Bob Hepple QC FBA
Chairman

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Members of Working Group

Dr Sandy Thomas (Chair)

Director, Nuffield Council on Bioethics

Professor Derek Burke CBE

Former Vice Chancellor of the University of East Anglia and Former Chairman of the Advisory Committee for Novel Foods and Processes

Professor Mike Gale FRS

Emeritus Professor, The John Innes Centre, Norwich

Professor Michael Lipton CMG

Poverty Research Unit, University of Sussex

Professor Albert Weale FBA

Professor of Government, University of Essex
Member of the Nuffield Council on Bioethics

Terms of reference

1 To examine recent, current and prospective developments in the use of genetically modified crops in developing countries, in particular:

   i) to review recent progress of research in the use of genetically modified crops in developing countries
   ii) to identify current and possible applications of genetically modified crops that would be of particular benefit to developing countries;

2 to re-examine and assess arguments set forth for and against the use of GM genetically modified crops in developing countries;

3 to assess the consequences of a moratorium on the use of genetically modified crops in developing countries;

4 to produce a short publication.

Summary and recommendations

Introduction

In May 1999, the Nuffield Council on Bioethics published a Report on **Genetically modified crops: the ethical and social issues**. One conclusion of the Report was that genetically modified (GM) crops had considerable potential to improve food security and the effectiveness of the agricultural sector in developing countries.

Since then, a highly polarised debate on the risks and benefits associated with the use of GM crops has continued and intensified. This debate has focused predominantly on the needs of European countries, with little attention paid to the impact of research on GM crops for agriculture in the developing world. However, the total acreage planted with GM crops in developing countries has more than doubled since 1999 and research has continued.

In October 2002 the Council decided that the implications of these developments deserved further examination. In order to contribute to the continuing debate in the UK and elsewhere, we have reviewed relevant recent evidence. Our objective has been to reassess the potential contribution that GM crops could make towards improving the effectiveness of agriculture in developing countries.

Background

Between 1970-90 the Green Revolution brought about greatly improved crop yields in many, but by no means all, parts of the developing world. Poverty and hunger fell dramatically. However, Africa and parts of Asia saw little gain, and the initial rate of improvement of the Green Revolution was not sustained between 1985-90. The best areas had already been saturated with semi-dwarf wheat and rice. Further yield increases were held back by water shortages, soil problems, and the emergence of new types of pest and disease. Population growth had slowed down sharply (in Asia since the mid 1970s, and in Africa since the mid-1980s). In contrast, the rapid and widespread growth in the numbers of people of working age was sustained (paragraphs 2.7-2.8). These trends look set to continue.

Food insecurity prevails, even in developing countries with food surpluses. One proposed solution, the redistribution of surpluses among and within countries poses serious practical and political challenges. Food aid programmes and efforts towards land reform have achieved much and should continue. However, improving the productivity of small farms is by far the best means of achieving a substantial reduction of food insecurity and poverty. Many people are poor, and therefore hungry, because they can neither produce enough food on their small farms, nor obtain enough employment by working on those of others. Enhancement of yields on small farms tends to increase the demand and hence rewards for poor labourers (paragraphs 2.4, 2.9-2.11).

Main findings

We have explored the potential of GM crops to improve agriculture in developing countries by means of eight case studies. These concern the use of GM cotton, rice, sweet potato, banana and soybean, and the production of biopharmaceuticals. Most GM crops have been developed by companies to suit the needs of large-scale farmers in developed countries. With the exception of GM cotton, soybean and maize, only a limited number of commercially available GM crops are currently suitable for conditions in developing countries. However, of the approximately six million farmers who grew GM crops legally in 2002, more than three-quarters were resource-poor, small-scale cotton farmers in developing countries, mainly in China and South Africa (paragraph 3.21).

Our main conclusion is that possible costs, benefits and risks associated with particular GM crops can be assessed only on a case by case basis. Any such assessment needs to take into account a variety of factors, such as the gene, or combination of genes, being inserted, and the nature of the target crop. Local agricultural practices, agro-ecological conditions and trade policies of the developing country in which GM crops might be grown are also important. **We therefore recommend that in considering whether GM crops should be used or not, it is essential to focus on the specific situation in a particular country, asking the question: 'How does the use of a GM crop compare to other alternatives?' All possible paths of action must be compared, including inaction, in respect of improving, in a cost-effective and environmentally sustainable way, human health, nutrition, and the ability to afford an adequate diet** (paragraph 4.49).

The improvement of agriculture and food security depends on several factors. These include stable political environments, appropriate infrastructures, fair international and national agricultural policies, access to land and water, and improved crop varieties which are suited to local conditions. In focusing on current and potential uses of GM crops we therefore consider only part, albeit an important one, of a large and complex picture. However, we are clear that **in particular cases, GM crops can contribute to substantial progress in improving agriculture, in parallel to the (usually slow) changes at the socio-political level. GM crops have demonstrated the potential to reduce environmental degradation and to address specific health, ecological and agricultural problems which have proved less responsive to the standard tools of plant breeding and organic or conventional agricultural practices. Thus, we affirm the conclusion of our 1999 Report that there is an ethical obligation to explore these potential benefits responsibly, in order to contribute to the reduction of poverty, and to improve food security and profitable agriculture in developing countries** (paragraph 4.48).

Specific conclusions and recommendations

The precautionary approach

It has sometimes been suggested that GM crops should not be used because there may be a very low probability of the occurrence of an unpredictable adverse effect on the environment or on human health. This case is frequently argued in terms of the so called *precautionary principle*. The argument is that, irrespective of possible benefits, a new technology should never be introduced unless there is a guarantee that no risk will arise. If this line of thought is pursued to its logical outcome, there should be a delay (i.e. a moratorium) in the use of the technology until a complete assurance of absence of risk is available. However, no one can ever guarantee an absolute absence of risk arising from the use of any new technology. In our view, such a principle would lead to an inappropriate embargo on the introduction of all new technology. We have come firmly to the view that the only sensible interpretation of the precautionary principle is comparative, i.e. to select the course of action (or of inaction) with least overall risk. We use the term *precautionary approach* to indicate that it is not a single inflexible rule, as often portrayed, but a way of applying a set of interacting criteria to a given situation. We make the following observations in offering this interpretation.

- An excessively conservative interpretation of the precautionary approach, demanding evidence of the absence of all risk before allowing the pursuit of a new technology is fundamentally at odds with any practical strategy of investigating new technologies. In fact, **such interpretations are essentially impractical**. There are countless cases which show that if it were essential to demonstrate complete absence of all risk before the introduction of a new technology, then technical achievements such as vaccination, aeroplanes or mobile phones, which have become accepted by almost everybody, would never have entered regular use.

- **It is easier to forgo possible benefits in the light of assumed hazards, if the status quo is already largely satisfactory**. Thus, for developed countries, the benefits offered by GM crops may, so far, be relatively modest. However, in developing countries the degree of poverty and the often unsatisfactory state of health and agricultural sustainability is the baseline, and the **feasibility of alternative ways to improve their situation must be the comparator**.
- **To hold to the most conservative interpretation of the precautionary approach invokes the fallacy of thinking that the option of doing nothing is itself without risk**. Yet, food security and environmental conditions are actually deteriorating in many developing countries. Restrictive interpretations of the precautionary approach that imply a general prohibition on the use of GM technology therefore require very strong justification.

In some cases the use of a GM crop variety may well pose fewer risks than the agricultural system already in operation. **We therefore conclude that an adequate interpretation of the precautionary approach would require comparison of the risks of the status quo with those posed by other possible paths of action**. Such assessments must be based on sound scientific data (paragraphs 4.35-4.42).

The use and governance of GM crops in developing countries

It is important that any country should have in place appropriate mechanisms to determine whether it is desirable to introduce any new crop, GM or non-GM, into the environment, and to monitor its impact. Many already do. Systems that enable the views of farmers and relevant stakeholders to be taken into account by policy makers are also required.

Availability of choice

When a decision is made to introduce new varieties of crops, whether GM or non-GM, problems might arise because the new seed might be more costly. Problems can also arise in cases where one single monopolistic seed supplier controls the provision of seed. It is therefore desirable that as far as possible farmers have a genuine choice. **To provide a genuine choice it is important that support for the public sector be sustained, so that suitable seeds (whether GM or non-GM), which can be retained by farmers with minimal yield losses, are available. Policies also need to be in place to keep the private supply of seeds reasonably competitive** (paragraph 4.19).

Decision making processes about the use and regulation of GM crops

Local communities must be included as far as possible in processes of decision making. The dissemination of balanced information, and the education and training of those involved is essential. In particular, farmers need to be informed about the technological potential and management requirements of GM crops. Expectations are sometimes inappropriately high, and knowledge about specialised farm management practices may be absent. **We recommend that companies marketing GM crops in developing countries share, with governments, the costs of:**

- **locally appropriate schemes to elicit the preferences of small-scale farmers regarding traits selected by plant breeders;**
- **their participation, where appropriate, in plant breeding; and**
- **subsequent mechanisms to improve dissemination of balanced information, education and training about the use of GM crops** (paragraph 5.33).

Regulation of GM crops in developing countries

There is considerable evidence of illegal planting of GM crops in a number of developing countries including Brazil, India and Mexico. In view of the alleged risks posed by the use of GM crops, many argue that stringent systems of governance should be implemented, which could then be

deregulated. We do not share this view: such regulations are unlikely to stop illegal planting. In addition, amendments to regulations in the light of new research findings are often delayed by unrelated political and administrative disputes. It is therefore important that all developing countries which are currently involved in the implementation of the *Cartagena Protocol on Biosafety* consider carefully how to interpret the provisions which concern the precautionary approach, to allow for appropriate regulation before the need arises. **Any highly restrictive interpretation of the precautionary approach is likely to ignore the possibility that in some cases, the use of a GM crop variety may pose fewer risks than are implied by current practices or by plausible non-GM alternatives. In applying the precautionary approach, risks implied by the option of inaction (or by alternative actions) must also be considered** (paragraph 5.10).

The most appropriate approach would normally be a centralised and evidence-based safety assessment at the national or regional level. Environmental and health risks should be assessed on a case by case basis. Wherever possible, such assessments should consider information which is available from international sources, particularly with respect to data about food safety, which are more transferable than environmental risk assessments (paragraph 5.34).

In most developing countries, it will be a major financial and logistical challenge to provide the capacity and resources to undertake such evaluations. The proliferation of diverse regulations, resulting in every new GM crop being assessed for possible risks to human health and the environment in each developing country will cause problems. **We therefore recommend that particular attention should be given to measures that will enable the sharing of methodologies and results. An example is environmental risk assessments for countries which have similar ecological environments. It should also be considered whether harmonised regional policies can be established, for example, by the Southern African Development Community (SADC) and the Common Market for Eastern and Southern Africa (COMESA). We welcome the recent initiative by SADC to produce guidelines on food safety assessment and management of GM crops. Developing countries should be encouraged where possible to implement standardised procedures for the assessment of environmental and health risks. Established international guidelines such as the *Cartagena Protocol on Biosafety* and the guidelines of the Codex Commission should be considered. Care must be taken to avoid an overly restrictive interpretation of the precautionary approach** (paragraph 5.27)**. In this context we welcome and endorse initiatives to promote the strengthening of capacity in relevant regulatory and scientific expertise, which have recently been launched jointly by the United Nations Environment Programme and the Global Environment Facility (UNEP/GEF), and the Food and Agriculture Organization (FAO)** (paragraphs 5.24-5.25). However, since duplication of effort can be counter-productive, and since administrative resources in developing countries are scarce, it is essential that international development efforts are coordinated.

Current and future research

For a variety of reasons, many of the crops such as rice, wheat, white maize, millet, sorghum, yams, cocoyams and others, which provide food and employment income for the poor in developing countries, have been ignored by the private sector. Much of the current privately funded research on GM crops serves the interest of large-scale farmers in developed countries. Consequently there is a serious risk that the needs of small-scale farmers in developing countries will be neglected. It appears that research on these crops will have to be supported primarily by the public sector.

We therefore affirm the recommendation made in our 1999 Report that genuinely additional resources be committed by the UK Department for International Development (DFID), the European Commission, national governments 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 in developing countries. In determining which traits and crops should be developed, funding bodies should be proactive in consulting with national and regional bodies in developing countries to identify relevant priorities (paragraphs 6.16-6.17).

There is not enough evidence of actual or potential harm to justify a blanket moratorium on either research, field trials, or the controlled release of GM crops into the environment at this stage. **We recommend that research on the use of GM crops in developing countries be sustained, governed by a reasonable application of the precautionary approach. Accumulating evidence from new scientific developments must be used to inform discussions about the current or future use of GM crops. The views of farmers and other relevant stakeholders must also be taken into account** (paragraph 4.50).

Liability

It has been suggested by some that the use of GM crops by farmers in developing countries might be exploited by the multinational seed industry in such a way that seed of questionable quality were provided. We are not aware of any such instances. However, it is clear that the same standards of liability need to apply to both developing countries and developed countries. **Where there is clear evidence of damage attributable to the seed producer, compensation will need to be provided, regardless of whether the seed is GM or non-GM** (paragraph 5.36). We note that in previous instances of crop failures in developed countries, compensation has been negotiated successfully.

We recommend that possible scenarios, which include the principle of compensation, be considered by policymakers and the seed industry. Agreed standards should be published widely, taking into account in particular the situation of small-scale farmers in developing countries. Illiteracy and lack of adequate infrastructure for effective communication can present additional obstacles that need to be considered. Wherever possible, agreements should be established, to facilitate compensation of small-scale farmers who, in the event of loss or damage, are unlikely to be able to afford appropriate legal action (paragraphs 5.36 and 5.45-5.46).

The impact of European regulations on GM crops

The freedom of choice of farmers in developing countries is being severely challenged by the agricultural policy of the European Union (EU). Developing countries might well be reluctant to approve GM crop varieties because of fears of jeopardising their current and future export markets. They may also not be able to provide the necessary infrastructure to enable compliance with EU requirements for traceability and labelling (paragraphs 5.20-5.21).

One strategy which developing countries might choose could be to adopt GM crops for domestic use only. However, problems could arise if separation of GM crops and non-GM crops for export cannot be readily achieved. For example, small amounts of GM produce might become mixed with non-GM produce during storage. If current attitudes among EU policy makers and consumers prevail, countries which depend on exports to the European market might then be at considerable disadvantage (paragraphs 5.43-5.48).

A number of recent authoritative reviews have concluded that, based on current evidence, neither GM crops, nor food produced from GM crops, pose a significant risk to humans who consume them. However, complications could arise where risks for human health or the environment are exaggerated by the scepticism of some commentators from developed countries. Policy makers in developing countries would then be faced with very difficult choices. If a national policy that allowed the responsible domestic use of GM crops were adopted, it might well be perceived as promoting unsafe foods, and could lead to the loss of EU export markets. It is therefore important that policy makers in developing countries seek a range of advice about these issues.

There is a considerable imbalance between the hypothetical benefits afforded by the EU policy for its own citizens, and the probable and substantial benefits that could be afforded to developing countries. Current provisions of the revised *Directive 2001/18/EC*, *Regulation 1830/2003/EC on Traceability and Labelling* and of *Regulation 1829/2003/EC on Food and Feed* have not given sufficient consideration to the effects that these policies are likely to have on developing countries. **We recommend that the European Commission (EC), the UK Department for International Development (DFID) and appropriate non-governmental organisations which monitor the agricultural policies of developing countries examine the consequences of EU regulatory policies for the use of GM crops in developing countries. We recommend that the European Commission establish a procedure to report on the impact of its regulations accordingly** (paragraph 5.50).

The case of food aid

During the course of our investigation, we have repeatedly observed the extent to which complex issues are over-simplified. In a highly charged political atmosphere, the impact of public statements by influential bodies needs to be carefully considered, including the way in which those statements may be misinterpreted. In our view, there is a pressing obligation on all those who seek to be influential in policymaking to weigh carefully all the current and relevant evidence, and to consider the characteristics of specific uses of GM technology by comparison with other feasible systems. This obligation to base statements on an impartial consideration of the evidence applies as much to campaigning organisations as it does to any other public or professional body. We are sceptical about claims from individuals or organisations who found their arguments on political convictions rather than scientific evidence.

The issues raised by food aid are complex. We recognise that long-term reliance on food aid, whether provided in the form of GM or non-GM cereals, is highly undesirable. Clearly, assistance to developing countries should, where possible, be directed towards self sufficiency in food production. This is a complex task and GM crops could play a substantial role in improving agriculture. However, the question remains as to how developed countries can comply with their ethical obligations when emergencies arise. With regard to donations of GM crops as food aid, **we note that the preferences of developing countries dependent on emergency food aid must be taken seriously. A genuine choice between GM and non-GM food should be offered, where this is possible. It will therefore be necessary to provide full information about whether or not donated food is derived wholly or in part from GM crops** (paragraph 5.41).

Where developing countries prefer to receive non-GM food, the World Food Programme and other aid organisations should consider purchasing it. This is subject to its availability at reasonable financial and logistical costs. Where only donations of GM varieties are available and developing countries object to their import solely on the basis of environmental risks, we recommend that it be provided in milled form (paragraph 5.42). This is because seeds from food aid donations are likely to be planted in developing countries, and it would be unacceptable to introduce a GM crop into any country against its will by this means.

Micronutrient-enriched GM crops

The development of GM crops which can provide increased levels of crucially important micronutrients has been the focus of much public discussion. Strong claims with regard to the potential of Golden Rice have been made by both proponents and opponents, sometimes in the absence of validated empirical evidence. We conclude that Golden Rice could make a valuable contribution where rice is the principal staple crop and other means of obtaining sufficient levels of vitamin A are more difficult to provide. This is often the case in developing countries where extreme poverty is widespread. But full assessment of the effectiveness of Golden Rice is a

complex process which is not yet complete. It depends critically on the bioavailability of ß-carotene, on which there are widely different claims and assumptions. It is thus premature to proclaim that the approach will fail. The need being addressed is an urgent one. **It is therefore essential that reliable empirical data from nutritional and bioavailability studies be obtained as a priority. At the same time, in endorsing continuing research on crops such as Golden Rice, we emphasise that evaluation of its cost-effectiveness, risk, and practicality in comparison to other means of addressing micronutrient deficiency is vital** (paragraph 4.25).

Gene flow and biodiversity

The possibility that genes from GM crops could be transferred by pollen to other cultivars or wild relatives has caused concern. Gene flow may require special attention where GM crops are used in developing countries. Whether or not it is acceptable depends primarily on its consequences. The introduction of GM crops in developing countries which are centres of diversity of specific crops may in some cases be problematic. **We recommend that in the case of sensitive areas such as centres of diversity, introgression of genetic material from GM crops in related species should be monitored. However, we are not persuaded that the possibility of gene flow should be sufficient to rule out the planting of GM crops in such areas, provided that regulatory requirements are met. Specific risks need to be assessed in particular contexts, and possibilities of safeguarding biodiversity must be considered carefully. The establishment and maintenance of comprehensive seed banks to conserve genetic resources of crop plants and their relatives is of crucial importance** (paragraph 4.34).

Intellectual property rights (IPRs)

In 1999 we noted that the agrochemical and seed industry was tightly consolidated around a small number of multinational companies. There has been continuing concentration in the number of companies that control between them the provision of seeds and important research technologies. There are concerns that growth of patents in both the private and public sectors could have an inhibiting effect on publicly funded research. The challenge for the public sector, especially where research is directed at agriculture in developing countries, is how to access GM technologies without infringing IPRs. New initiatives which recognise the potential of these constraints to inhibit research into crops relevant to developing countries are therefore very timely. However, we also note that the recent example of Golden Rice shows that patented technologies need not necessarily be a barrier.

Control of and access to genetic modification technologies

Access to plant genetic resources is critically important for the development of GM crops which are suited to the needs of developing countries. Usually, access to such resources is governed by Material Transfer Agreements (MTAs). The perception that the recent proliferation of MTAs is not necessarily in the public interest is widespread.

We welcome the decision by the UK Government to ratify the *International Treaty on Plant Genetic Resources for Food and Agriculture.* Access to resources falling under the Treaty is of crucial importance in the development of crops suited to developing countries. We recommend that in the negotiations regarding the standard Material Transfer Agreement (MTA), the UK Government aims for provisions that exempt users in developing countries from payments, where commercial applications arise from material covered by the MTA. Where exemptions are not appropriate, differentiation of payments should take into account the level of development of the country in question (paragraph 5.15).

Under patent law in the UK, it appears that a plant breeder does not have the clear right to use a patented GM plant variety for breeding purposes. To avoid possible litigation, he can either refrain

from using the variety or apply for a licence from the patent owner. Such requests may be refused or granted on less than favourable terms and the provision of compulsory licensing is often not straightforward. As we noted in our 1999 Report, this potential locking up of genetic variation would be contrary to the spirit and intent of plant variety rights (PVRs). We consider that there is a strong case for the principle of the breeders' research exemption, established for PVRs, to be applied to patented varieties. **We reaffirm our recommendation from that Report that the World Intellectual Property Organization (WIPO), the European Commission (EC), the Union for the Protection of the New Varieties of Plants (UPOV), the Consultative Group on International Agricultural Research (CGIAR) and the International Plant Genetic Resources Institute (IPGRI) together closely monitor the impact of patents on the availability of germplasm to plant breeders** (paragraph 6.11 and paragraph 3.61 of the 1999 Report).

Chapter 1

Introduction



Introduction

Background

1.1 In May 1999, the Nuffield Council on Bioethics published a Report on **Genetically modified crops: the ethical and social issues**.[1] When work began in 1997, issues raised by the use of genetically modified (GM) crops had received relatively little public attention. By the time the Report was published, GM plants and animals had been likened in the media to Frankenstein's monsters. It was claimed that reckless academic and commercial scientists were endangering the natural world. This view gained wide support and GM crops were frequently referred to as 'Frankenfoods'. In his foreword the Chairman of the Working Party, Professor Alan Ryan, wrote:

> *'As Reports of previous Working Parties have had occasion to observe, heat and light are not the same thing. We have been struck by the extent to which hard-to-allay fears are aroused by almost any discussion of genetic science, not only in this context, but also in the contexts of cloning and the genetic components of physical and mental illness.'*

1.2 In June 1999, the Environment Ministers of the European Union (EU) declared a *de facto* moratorium on the use of GM crops which had not yet received regulatory approval. Since then, the controversy about their use has persisted and intensified. In many parts of Europe, experimental field trials on GM crops have been sabotaged. In the UK, some farmers, fearing repercussions, withdrew from these experiments. Supermarkets and restaurants have labelled produce as 'GM-free' to allay the concerns of consumers. Others, however, unconvinced about the alleged risks of GM crops, view these developments with dismay.

1.3 Most people believe that evidence-based, rational assessment of risks and benefits should take the place of scaremongering and highly polarised debates. As one way of contributing to a more balanced and open discussion, the UK Government announced in 2002 a public debate on possible uses of genetic modification. This comprised three strands: a series of public meetings and discussions;[2] an economic analysis of the costs and benefits of using GM crops;[3] and a review of the science underlying the genetic modification of plants.[4] The Council decided to complement these various initiatives by producing a Discussion Paper to follow up its 1999 Report. This Paper focuses in particular on the role of GM crops in developing countries (see Box 1.1). There were two main reasons for this decision.

1.4 First, the Council was concerned that disproportionate attention was being paid to the implications of the use of GM crops in developed countries, at the expense of consideration of poorer countries. This narrow focus ignores the possibility that decisions made about the use of GM crops in developed countries may also have considerable consequences for those in developing countries. Furthermore, some developing countries have already adopted the technology. Since 1999, the total area planted with GM crops in developing countries has

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1 The Executive Summary of that Report is at Appendix 1.

2 GM Nation? The Public Debate. Available: http://www.gmpublicdebate.org.uk/index.html. Accessed on: 10 Oct 2003. A report summarising the discussions was published in September 2003, *GM Nation? The findings of the public debate.* Available: http://www.gmpublicdebate.org.uk/ut_09/ut_9_6.htm#summary. Accessed on: 8 Oct 2003.

3 GM Crops - Strategy Unit Study. Available: http://www.number10.gov.uk/output/Page3673.asp. Accessed on: 10 Oct 2003. The final report of the Strategy Unit was published in July 2003, *Field Work: weighing up the costs and benefits of GM crops.* Available: http://www.number-10.gov.uk/su/gm/index.htm. Accessed on: 10 Oct 2003.

4 GM Science Review. Available: http://www.gmsciencedebate.org.uk. Accessed on: 8 Oct 2003. *The Science Review's First Report – An open review of the science relevant to GM crops and food based on interests and concerns of the public.* Available: http://www.gmsciencedebate.org.uk/report/default.htm. Accessed on: 10 Oct 2003.

more than doubled, from 7.2 to 16.0 million hectares.[5] The implications of this development deserve further examination.

1.5 Secondly, the 1999 Report concluded that on the basis of the evidence available, there was a moral imperative for making GM crops readily and economically available to those in developing countries who wanted them.[6] We intended to ask whether the arguments for this conclusion were still valid today. To answer these questions, the Council decided to re-examine the current and possible future role of GM crops in developing countries. This requires a careful analysis of the benefits and risks associated with their use. Below we briefly outline what these are commonly held to be.

Box 1.1: **What do we mean by 'developing countries'?**

A useful way of distinguishing between countries at different levels of development is to compare their relative income. This is often expressed as the gross national product (GNP) per person. By *developing countries* we mean those countries with a GNP in 2001 of less than US$9,205 per capita.* However, a country's economic development, the well-being of its population, and its capacity to benefit from decisions and policies made in the developed world depend on much more than average GNP. Other influential factors include:

- the purchasing-power of a country's currency;
- the composition and efficacy of its spending, especially on basic health and education;
- its income distribution; and
- its climatic and other risks.†

* World Bank (2003) *World Development Report 2003* (Washington, DC: Oxford University Press and World Bank), pp. 233–5.

† A succession of annual United Nations Human Development (UNHD) reports has endeavoured to allow for such matters. In practice, indicators of mean GNP which are adjusted to take into account the variable purchasing power of one US$ in different countries (purchasing-power parity, PPP) provide a rough guide to levels and trends of welfare, and are closely correlated with human development indicators such as life expectancy and access to education, see World Bank (2003) *World Development Report 2003* (Washington, DC: Oxford University Press and World Bank), pp. 2347.

Benefits and risks associated with the use of GM crops in developing countries

1.6 Generalised judgements about possible benefits and risks of 'GM crops' to 'developing countries' as such, are of limited use. When assessing the benefits and risks of introducing a specific GM crop, the socio-economic and agricultural context of individual countries needs to be considered. Relevant factors include:

- the prevalence of specific climatic conditions;
- the presence of wild relatives of the crop;
- the availability of water for irrigation;
- the level of infrastructure in place;
- the extent to which commercial fertilisers or pesticides are used;
- the proportion of farm produce which is sold;

5 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

6 See *paragraphs* 4.1–4.82 of the 1999 Report.

- the relative proportion of crop production directed to domestic and/or export markets;
- access to export markets;
- the effects of competition from subsidised agricultural products from developed countries; and
- the nature of national regulation for biotechnology.

It is therefore much more helpful to focus on particular countries, or, where possible, on sufficiently similar types of countries, to assess the impact of a specific GM crop on the environment, agriculture and the economy.

Possible benefits

1.7 GM crops (see Box 1.2) might offer advantages where other forms of plant breeding, agricultural practice or farm land management are not suitable to address particular problems prevalent in developing countries. Genetic modification can provide improved resistance to disease and pests. It may enable the production of more nutritious staple crops which provide essential micronutrients, often lacking in the diets of poor people. GM crops that are better suited to cope with stresses such as drought or salty soils, common to many developing countries, are also being developed.[7]

Box 1.2: **Genetically modified crops**

Genetic modification allows selected individual genes to be transferred from one organism into another, including genes from unrelated species. The technology can be used to promote a desirable crop character or to suppress an undesirable trait (see paragraphs 3.4-3.17).

1.8 Furthermore, proponents note that GM crops might prove to be an important tool in accelerating the increase of crop yields, especially of staple crops.[8] This might be particularly relevant for small-scale, resource-poor farmers in developing countries. Seventy per cent of the world's poor live in rural areas and about two-thirds of these rely primarily on agriculture for their livelihoods.[9] Increased yields through improved seeds normally lead to higher demands for labour in agriculture. This usually implies growth in employment income among the malnourished, and would have a positive effect on their ability to afford sufficient food. Such developments would be valuable. It has become clearer that both the reduction of poverty and growth in crop yields have slowed in most of the developing world since the 1980s. Moreover, poverty has persisted and crop yields have remained low in most of Africa, the poorest continent of the world.[10] In this Paper, we examine which kinds of GM crops have been grown in particular developing countries, and assess whether there have been, or are likely to be, significant improvements for farmers who grow them. However, any deliberation about the benefits of a technology also needs to address likely risks.

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7 Thomson J (2002) *Genes for Africa: Genetically Modified Crops in the Developing World* (Cape Town: University of Cape Town Press); Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century*. Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf. Accessed on: 10 Oct 2003.

8 The term staple crops refers to crops which are mainly used for household consumption. By non-staple crops we mean crops which are grown predominantly for sale.

9 World Bank (2003) *World Development Report 2003* (Washington, DC: Oxford University Press and World Bank).

10 Between 1987 and 1998 the percentage of people living on less than US$1 a day in sub-Saharan Africa remained unchanged at 46%. See World Bank (2001) *World Development Report 2000/2001: Attacking Poverty* (Washington, DC: World Bank and Oxford University Press); Huang J, Pray C and Rozelle S (2002) Enhancing the crops to feed the poor, *Nature* **418**: 678–84.

Possible risks

1.9 Some commentators take the view that possible risks of GM crops for human health have not yet been sufficiently examined. 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 (for a discussion of this approach see paragraphs 4.35-4.42).[11]

1.10 There is also concern about the impact of GM crops on the environment. Critics point to the risk of potentially irreversible effects on *biodiversity*, which can be understood as the variety of plants, animals and other organisms that exists in nature. Genetic material from GM crops could be transferred to other plants and organisms, which might lead to unpredictable transformations. Critics therefore argue that unless there is certainty about the absence of such risks, neither field trials, nor commercial planting should take place. The centres of diversity of modern crops such as cotton or maize are primarily in developing countries. There are those who fear that cultivated crops and their wild relatives, which still grow in these regions, might be irreversibly altered by the transfer of genetic material from GM crops.[12]

1.11 There are also concerns about how and by whom GM crops are developed and marketed. The substantial benefits which accrued in developing countries from the Green Revolution (see Box 1.3) were largely the result of research undertaken in the public sector. But most research on GM crops is being undertaken by a relatively small number of private companies, although there is also significant work in the public sector. Many of those who object to the use of GM crops fear that research will be directed primarily towards the demands of commercial users in developed countries.[13] It could be that only large-scale industrial farmers and the agro-chemical industry will benefit, while the needs of small-scale, resource-poor farmers in developing countries will be neglected.

Box 1.3: **The Green Revolution**

The Green Revolution is the popular term for the development and spread of high-yielding staple foods in developing countries. It began with maize hybrids in the 1950s. However, the main component was the introduction of semi-dwarf wheat and rice varieties, mainly to parts of Asia and Central America with well-functioning systems of irrigation, between 1962 and 1985.* The Green Revolution was brought about almost exclusively through research undertaken by institutions in the public sector. Apart from systematically spreading crop varieties that would flourish in a wide range of environments, it also involved increased use of fertilisers, pesticides and mechanised agriculture.

* Lipton M and Longhurst R (1989) *New Seeds and Poor People* (London: Routledge).

11 British Medical Association (1999) *The Impact of Genetic Modification on Agriculture, Food and Health: An Interim Statement* (London: BMA); Oxfam (1999) *Genetically Modified Crops, World Trade and Food Security* (Oxford: Oxfam).

12 Food and Agriculture Organization (FAO) Electronic Forum on Biotechnology in Food and Agriculture (2002) Background Document to Conference 7, 31 May – 6 July 2002 *Gene flow from GM to non-GM populations in the crop, forestry, animal and fishery sectors* (FAO UN). Available: http://www.fao.org/biotech/C7doc.htm. Accessed on: 10 Oct 2003.

13 Action Aid (2003) *GM Crops - Going Against the Grain* (London: Action Aid); Five Year Freeze (2002) *Feeding or Fooling the World?* (London: Five Year Freeze).

1.12 Doubts have also been expressed about the technical and financial capacity of some developing countries to develop and apply regulation to ensure the safe use of GM crops.[14] Some take the view that encouraging developing countries to adopt GM crops demonstrates a lack of sensitivity to their vulnerable position. Many of these countries have an urgent need to address issues of food security and may be tempted to adopt in haste a technology that could pose severe risks.[15] Furthermore, there is concern that a focus on GM-related applications may detract from efforts to explore other ways of enhancing agriculture, such as fostering more relevant national and international policies, improving systems of seed production and distribution, and promoting better development of markets and improved agricultural practices.[16] We consider these and other arguments in the chapters that follow.

Structure and methodological approach

1.13 In this Discussion Paper, we review recent scientific, regulatory and policy-related developments in the use of GM crops in developing countries. We assess the potential of the technology to improve the effectiveness of agriculture under the often difficult conditions which prevail in these countries. Chapter 2 begins with an outline of the economic and demographic observations which guided our deliberations in the 1999 Report and contrasts them with recent evidence. In Chapter 3 we explain the basic technical and conceptual principles behind the genetic modification of plants. We also present eight case studies which illustrate some of the evidence that has been gathered over the past three years on the current and potential use of GM crops in developing countries. This is followed by a discussion of socio-economic and ethical arguments about their use (Chapter 4). We then consider issues raised by developments in governance, national and international regulation and trade (Chapter 5). Chapter 6 examines issues relating to the control of and access to GM technologies.

1.14 The Paper does not aim to provide an exhaustive account of how food security could be improved and poverty reduced in developing countries. By focusing on the role of GM crops we consider only a part, albeit an important one, of a large and complex picture. We are aware of the many factors that affect agricultural productivity in developing countries. For example, the Food and Agriculture Organization (FAO) of the United Nations (UN) has listed war and other forms of armed conflict as the exclusive cause of food emergencies in 10-15 developing countries during the last three years.[17] Furthermore, many developing countries have to cope with worsening economic conditions for local agriculture. These result from the failure of national agricultural policies and the absence of private organisations that could fill the void of state services. There are also instances of poor governance and corruption. In addition, land reform is urgently needed in many developing countries.

1.15 At the international level, problems arise from the fact that developing countries are constrained in their participation in global agricultural markets. Subsidies and import restrictions are commonly provided by developed countries to support their own farmers.

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14 See, for example, the discussion in the Archives of Debate of Conference 9 of the FAO Electronic Forum on Biotechnology in Food and Agriculture 28 April – 25 May 2003, *Regulating GMOs in developing and transition countries.* Available: http://www.fao.org/biotech/logs/c9logs.htm. Accessed on: 10 Oct 2003.

15 Independent Science Panel (2003) *The Case for a GM-Free Sustainable World* (London: ISP).

16 Action Aid (2003) *GM Crops – Going Against the Grain* (London: Action Aid); Food Ethics Council (2003) *Engineering Nutrition: GM crops for global justice?* (Brighton: Food Ethics Council); Oxfam (1999) *Genetically Modified Crops, World Trade and Food Security* (Oxford: Oxfam).

17 FAO (2003) *Foodcrops and Shortages: Global Information and Early Warning System on Food and Agriculture.* Available: http://www.fao.org/giews/english/fs/fstoc.htm. Accessed on: 10 Oct 2003.

According to the International Food Policy Research Institute (IFPRI), in 2001, member states of the Organisation for Economic Co-operation and Development (OECD) provided US$311 billion to subsidise their domestic agricultural production.[18] This results in the frequent glutting of markets, leading to lower prices, which in turn reduce incentives for poor farmers from developing countries to produce for the world market. Even incentives to produce for the domestic market are harmed by subsidised imports from developed countries. Examples of such practices are well known in relation to cotton, sugar and rice, with the main distortions due, respectively, to the USA, the EU and Japan.[19] IFPRI estimates that in 2001, the agricultural policies of wealthy countries cost developing countries US$24 billion in lost agricultural income. The elimination of protectionism and subsidies provided to farmers in developed countries could triple the net agricultural trade of developing countries.[20]

1.16 We emphasise that such problems urgently need to be addressed, taking into account the vulnerable situation of farmers in developing countries and their even poorer employees. But whatever progress is made in resolving these issues, other substantial problems remain, such as difficult climatic conditions and increasingly scarce and unreliable access to water. In this context, GM crops could have a role to play. Restricting our examination to the specific question of what kind of technical contribution GM crops can make to improving agricultural practice does not mean that we are indifferent to, or complacent about, the prevailing geo-political context in the majority of developing countries.[21]

1.17 We take a sceptical view about broad, often sweeping, generalisations of either the benefits or the risks associated with the use of GM crops in developing countries. As will be clear throughout this Discussion Paper, there are considerable differences in the ways in which:

(a) socio-economic conditions, agricultural practices and national regulations bear upon decisions over GM crops in different developing countries;

(b) the impacts of international and regional trade policies affect different developing countries; and

(c) traits of particular GM crops pose risks and benefits to human health and to the environment.

1.18 The interplay of these factors makes generalisations about the use of GM crops in the developing world almost impossible. For example, small-scale, resource-poor farmers in rural Africa will usually benefit from increased yields resulting from the use of GM sweet potatoes that are resistant to particular pests (see paragraphs 3.51-3.52). However, it may also be the case that using GM crops could be to the detriment of agricultural workers, for example, if the use of herbicide resistant GM crops leads to a considerable reduction in the demand for labour for weeding on farms (see paragraph 3.61).

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18 Diao X, Diaz-Bonilla E and Robinson S (2003) *How Much Does It Hurt? The Impact of Agricultural Trade Policies on Developing Countries* (Washington, DC: IFPRI).

19 OECD Joint Working Party on Agriculture and Trade (2002) *The Medium-Term Impacts of Trade Liberalisation in OECD Countries on the Food Security of Non-Member Economies.* Available: http://www.olis.oecd.org/olis/2001doc.nsf/LinkTo/com-agr-td-wp(2001)74-final. Accessed on: 10 Oct 2003; Diao X, Diaz-Bonilla E and Robinson S (2003) *How Much Does It Hurt? The Impact of Agricultural Trade Policies on Developing Countries* (Washington, DC: IFPRI); Oxfam (2002) *Cultivating Poverty: The Impact of US Cotton Subsidies on Africa* (Oxfam International).

20 Diao X, Diaz-Bonilla E and Robinson S (2003) *How Much Does It Hurt? The Impact of Agricultural Trade Policies on Developing Countries* (Washington, DC: IFPRI).

21 For a discussion of issues arising in context of global food and trade policy, see Chapter 5.

1.19 We also note that discussions about the benefits and risks of GM crops are as much about politics and economics as they are about technological issues. Thus, whether or not the use of a GM crop will be beneficial will depend on many factors. Even if the technology is effective and there is no scientific evidence of risks for human health or the environment, political constraints such as restrictive trade policies of some markets, may lead to the conclusion that it is better not to use a specific GM crop in a particular context.

1.20 We therefore take the view that it is important to focus on the specific situations in particular countries and to ask the question: 'How does the use of a GM crop compare to other alternatives?' All possible paths of action must be compared, including inaction, in respect of improving, in a cost-effective and environmentally sustainable way, human health, nutrition, and the ability to afford an adequate diet. This approach might lead to the conclusion that there may be other safer, more efficient or more economic options. It could also mean that GM crops might have attractive benefits in particular cases.

Chapter 2

The socio-economic context: the role of agriculture in developing countries



The socio-economic context: the role of agriculture in developing countries

2.1 In this section, we briefly review the economic and demographic evidence which guided our deliberations in the 1999 Report on the use of GM crops in developing countries. We considered possibilities for the improvement of agricultural practice, food security and reduction of poverty. We contrast the findings of the 1999 Report with recent evidence about the growth of populations, particularly the proportion of those of working age, in developing countries. We then discuss the relationship between the availability of food and the demand for labour, which leads to conclusions about the role of agriculture in reducing poverty. We also consider the impact of specific climatic and ecological conditions.

The framework of the 1999 Report

2.2 In the 1999 Report, we approached the question of whether GM crops can offer benefits for poor people in developing countries through the following argument. In developed countries, food production has kept ahead of growth in population during the past 60 years. This was also the case in much of Asia and Latin America, even where the area of available farmland could not be increased. Across these latter regions, a yield-enhancing Green Revolution (see Box 1.3) created considerable employment and greatly improved life for small-scale farmers and landless labourers. It also brought less expensive and more reliable staple foods to poor consumers. In consequence, crop yields of small-scale farmers and incomes for those in rural employment rose, and poverty and hunger fell dramatically in many countries between 1970-90.

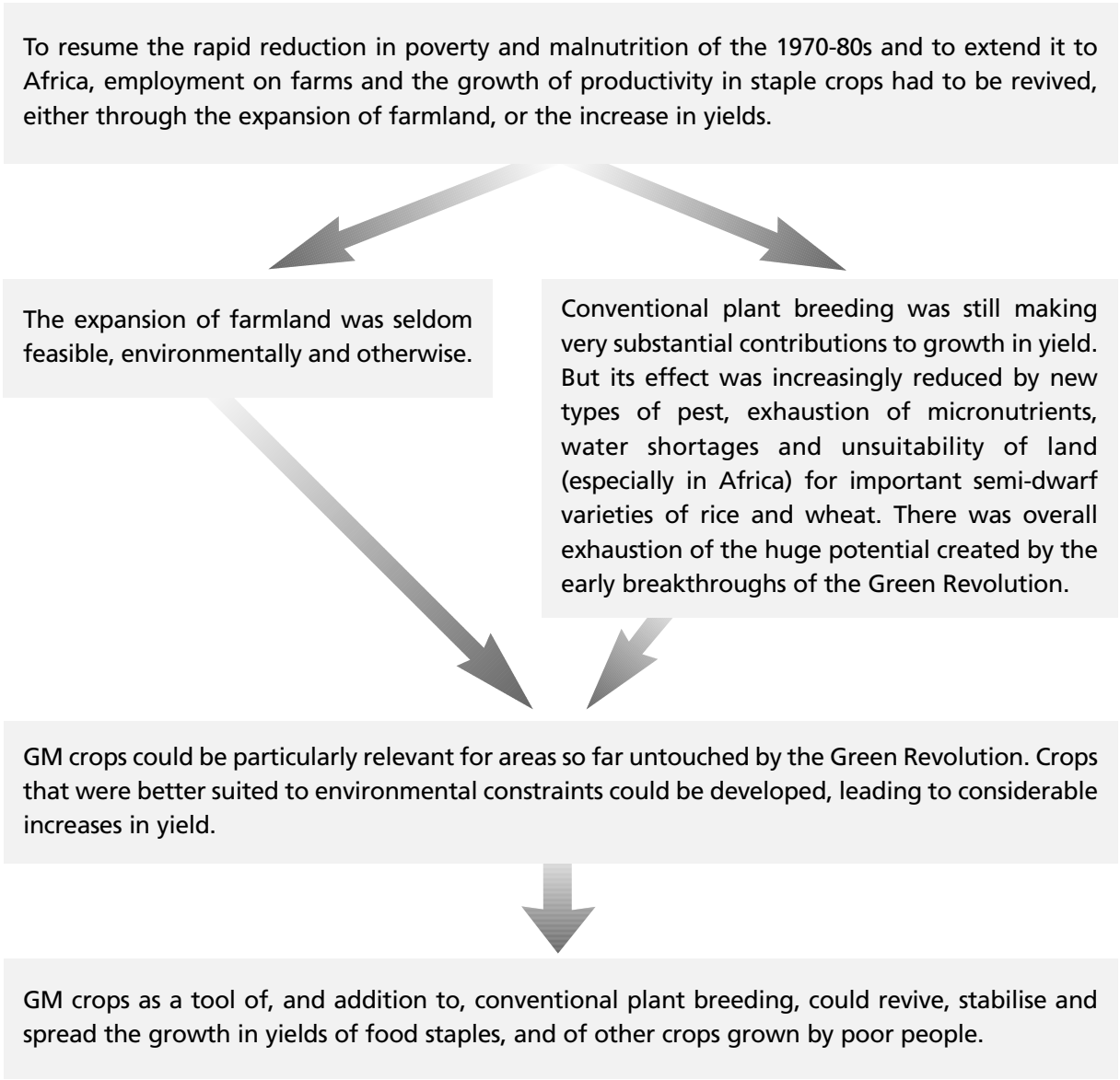
2.3 However, Africa and some parts of Asia saw little gain and agricultural production grew no faster than population. In the 1990s, the improvement in yields and the rate of decline of global poverty were far less than in the previous two decades. Yield expansion had been curtailed by water shortages, soil erosion and new types of pests and diseases. In addition, the initial rate of improvement of the Green Revolution was not sustained between 1985-90. Semi-dwarf rice and wheat varieties had already been introduced to the best-suited lands, leaving less dynamic crops for use elsewhere. These trends looked set to continue, as did a rise in the population, and more significantly, in the number of persons of working age.

2.4 Even in countries with aggregate surpluses of food, people remained unable to afford enough to eat, unless they were able to increase their incomes from employment. India frequently has 60 million tons of staple foods, over a third of its annual consumption and production, in public grain stores. Yet, access is limited. Despite slow and steady improvements over the last few decades, over half of all children under five years old are stunted, an even higher proportion than in Africa.[1] But this does not mean that extra food production is irrelevant to India's undernourished. Most of them are poor, and therefore hungry, because they can neither produce enough food on their small farms, nor obtain sufficient employment by working on those of others. Enhancement of yields on small farms, which tends to increase the demand and hence rewards for poor labourers, addresses this problem. It does so much more affordably than alternative and less employment-creating routes to economic growth. This approach also increases the availability of food for poor people by reducing and stabilising the price of basic foodstuffs locally, which is of particular importance since food accounts for 60-80% of total expenditure by low-income groups.

[1] United Nations Administrative Committee on Coordination Sub-Committee on Nutrition (ACC/SCN) in collaboration with IFPRI (2000) *Fourth Report on The World Nutrition Situation: Nutrition Throughout the Life Cycle* (Geneva: ACC/SCN with IFPRI).

2.5 Employment can be provided most readily in industry or agriculture. However, it is normally much more expensive to create jobs in modern, especially urban, industries. This is due to high costs of related capital such as equipment, machinery and factory buildings. Investments in private and social infrastructure, such as policing, healthcare and urban roads are also required. The provision of employment in agriculture, on the other hand, can be achieved at lower costs. Furthermore, growth in rural non-farm jobs, which was the source of much reduction in rural poverty after the initial Green Revolution in China and elsewhere, depended mainly on demand from nearby small-scale farmers and their employees.

2.6 The above evidence and argument led us to the following conclusions in our 1999 Report, which have been reinforced by evidence accumulating from 1999-2003:



Growth in populations and demand for labour

2.7 Although growth in population has progressed somewhat more slowly than anticipated, the current global population of 6.3 billion people is expected to increase to 8.1 billion by 2030.[2] Growth in population in Asia and Africa in 2030 is expected to be 1.33 and 1.76 times its present level, respectively. Groups in those regions most subject to poverty and under-nutrition are expected to increase the most rapidly. Hence, requirements for food are likely to rise substantially.[3]

2.8 More important is the even faster growth predicted for the numbers of people of working age (15-59) in Asia and Africa. For example, in 2030, Africa's population will have expanded by 1.76 times the level in 2000. However, the working-age population will be 1.97 times larger while the non-working-age population will only be 1.52 times as large.[4] This higher ratio of workers can be advantageous if it is complemented by improved working opportunities. These are most affordable where agriculture raises yields and demand for labour, but they are a burden if it does not. Unless the rise in working age population is at least matched by rising numbers of jobs, employment or wage rates will fall. Poor people will then have even more difficulty in affording enough food.

Food security and the role of agriculture

2.9 Improvement in the diet of poor people depends on growth not only in the supply of food and nutrients, but also in demand for their labour.[5] Yet it has become even clearer since our 1999 Report that the extent of undernourishment is substantial, and that the previous decline in undernourishment has stalled. According to the FAO, 815 million people worldwide were undernourished in 1997-1999, of whom 777 million were living in developing countries. One third of the population of sub-Saharan Africa is undernourished.[6]

2.10 Seventy per cent of the world's poor live in rural areas and depend mainly upon agriculture for their livelihood. Despite increasing urbanisation, over half will remain there in 2035.[7] The role of agriculture in reducing poverty is therefore crucial. Its rapid growth can lower and stabilise the cost of food to poor consumers living in rural and urban environments.[8] Where, as in the Green Revolution, small-scale agriculture has been a major

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2 Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2003) *World Population Prospects: The 2002 Revision* (New York: UN).

3 A major increase in production of food grain per head will further be required, as increasing urbanisation, growth of populations and rise in incomes will lead to a higher demand for meat and dairy products. Between now and 2020 the demand is expected to double in developing countries, see Delgado C *et al*. (1999) 2020 Vision for Food, Agriculture and the Environment Discussion Paper 28 *Livestock to 2020: The Next Food Revolution* (Washington, DC: IFPRI). This expansion means that the demand for cereals used for animal feed will increase substantially, as approximately three to seven times as much cereal is needed to provide the same amount of calories as for people who consume animals as food.

4 Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2003) *World Population Prospects: The 2002 Revision* (New York: UN). In some African countries the HIV/AIDS virus considerably impacts this trend, for example in Kenya, see paragraph 3.61.

5 FAO Electronic Forum on Biotechnology in Food and Agriculture (2000) Background Document to Conference 1, 20 March – 26 May 2000 *How appropriate are currently available biotechnologies in the crop sector for food production and agriculture in developing countries* (FAO UN). Available: http://www.fao.org/biotech/C1doc.htm. Accessed on: 10 Oct 2003; Department for International Development (DFID) (2002) *Better Livelihoods for Poor People: The Role of Agriculture* (London: DFID).

6 FAO (2002) *The State of Food and Agriculture 2002* (Rome: FAO).

7 Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2003) *World Population Prospects: The 2002 Revision* (New York: UN).

8 The recent report on rural poverty produced by the International Fund for Agricultural Development (IFAD) provides some evidence about the role of agriculture, enhancement of yield within agriculture and GM plants as possible sources of greater or more stable yields in providing food and labour income to poor people. See IFAD (2001) *Rural Poverty Report 2001 – The Challenge of Ending Rural Poverty* (Rome: IFAD).

beneficiary, it has been associated with an unprecedented reduction of poverty.[9] Rapid agricultural growth, achieved on smallholdings using labour intensive methods, remains the best hope for poor people to enhance their prospects to achieve sufficient availability of food, and sufficient access to work or land to afford it. But this will happen only if farming is more lucrative. In view of the fact that expansion of the current agricultural area is uneconomic in most parts of the world, this can be achieved only by the enhancement of yields (see also Appendix 2).

2.11 Land reforms and fairer agricultural policies in the developed world can help in several ways. First, more equitable distribution of land and access to it could enable more people to benefit from agriculture. Secondly, trade barriers to agricultural imports from poor countries could be lowered, which would increase markets for developing countries. Thirdly, reducing subsidies to farmers in developed countries would reduce the glutting of world markets for agricultural products, which depresses prices and consequently the attractiveness of agricultural production in developing countries. However, history suggests that these situations will improve only slowly. Moreover, even changes in global trading rules will do little to help the many very poor farmers in developing countries, especially those in Africa, who are in substantial food deficit. Many of those with significant land operate with such poor quality seeds, and such recalcitrant soil-water environments, that their land and labour productivity are too low for them to feed themselves adequately. While conventional plant breeding has achieved some improvements for parts of Africa, especially for maize, similar advances are lacking with respect to the most important crops of the very poor, such as millet, sorghum, yams and cocoyams.[10] We conclude that resuming and spreading rapid sustainable growth of farm yields, especially for food crops in developing countries, still remains crucial to achieving better income and food security for the world's poor.

Climatic and ecological challenges for agriculture in developing countries

2.12 Physical conditions for agriculture appear to be becoming increasingly difficult. Despite distinguished dissenters, the majority of agro-climatologists (as represented in the UN International Commission on Climate Change) believe that extreme weather conditions are becoming more frequent, especially in and near the inter-tropical convergence zone.[11] Even in normal years, water shortages are worsening in tropical areas, probably due to higher air temperatures, and therefore higher rates of evaporation and plant transpiration. Both trends are expected to accelerate. Even if the majority view on 'global warming' may be too pessimistic, the demand for water from expanding urban populations and industries adds to the problem. Work subsequent to our 1999 Report confirms an even sharper increase in the proportion of people and countries facing water shortages than anticipated.[12] In almost all of Asia, and most of Africa, expansion into marginal lands is unprofitable and increases environmental hazards. Moreover, the

9 This has been evident in the case of China in 1975-96, India in 1975-90 and Indonesia in 1970-95.

10 This is because conventional plant breeding is limited in part by the characteristics of plant genomes that are adapted to robustness at the expense of yield.

11 The inter-tropical convergence zone (ICTZ) is a region that encircles the earth, near the equator, where the trade winds of the Northern and Southern hemispheres come together, resulting in an almost perpetual series of thunderstorms. Examples of countries affected by the ICTZ include Zaire, Kenya and the People's Democratic Republic of the Congo.

12 Cosgrove WJ and Rijsberman FR (2000) *World Water Vision* (London: World Water Council).

quality of soil is in many places poor or actually decreasing, due to erosion, salination, loss of micronutrients and accumulation of heavy metals.[13] Agricultural progress therefore has to depend on increased yields.

2.13 To safeguard the environment from degradation, it is increasingly important to achieve higher agricultural production by more productive and more conservative use of water and land already devoted to farming.[14] GM technology may well have a significant contribution to make towards such progress by producing plants that are more resistant to moisture stress or highly salty soils. However, commercial companies are unlikely to be interested in producing such varieties, primarily because it would be difficult to enforce property rights and to secure profitable markets for improved seeds. We note with concern that research on GM crops which provide employment, income and food for poor people in developing countries, especially rice, wheat, millet, sorghum, cassava, yams and white maize has been neglected. New research will have to be supported, and also provided primarily by the public sector (see Chapter 6). In the next chapter, we outline the potential of contemporary plant breeding and examine recent developments relating to GM crops which could be of use to developing countries.

13 FAO Statistics on TERRASTAT database. Available: http://www.fao.org/ag/agl/agll/terrastat/. Accessed on: 29 Oct 2003; FAO (2000) *World Soil Resources Report: Land Resource Potential and Constraints at Regional and Country Levels* (Rome: FAO UN); Kendall H *et al*. (1997) *The Bioengineering of Crops: Report of the World Bank Panel on Transgenic Crops* (Washington, DC: World Bank). We consider in paragraphs 4.28-4.34 the possible effects of existing or likely GM crops on the environment, in developing countries and more widely.

14 Conway G (1997) *The Doubly Green Revolution: Food for All in the 21st Century* (London: Penguin).

Chapter 3

Current and potential uses of GM crops in developing countries



Current and potential uses of GM crops in developing countries

3.1 In the following section we provide a brief introduction to the concept of genetic modification in the context of contemporary plant breeding.[1] We then describe the traits which researchers are hoping to achieve by means of genetic modification and give an overview of the types of GM crops that are currently grown in commercial agriculture worldwide. Finally, we present eight case studies, which describe in more detail current and potential uses of GM crops in commercial and subsistence agriculture in developing countries.

Research on GM crops in the context of conventional plant breeding

3.2 Following the rediscovery of Mendel's Laws in 1900, selective plant breeding has made dramatic progress. Together with new agricultural methods, the application of this knowledge has contributed to a doubling of global food production over the past 50 years. In parallel, plant breeders have assimilated a variety of new technologies which have been used in both developed and developing countries. Many of these are aided by applications of biotechnology. Examples include:

- *double haploids*, where pure breeding lines can be made in a single step;
- *mutation breeding*, where new variations can be generated by irradiation or by chemical treatments;
- *F1 hybrids*, where farmers can benefit from the expression of *hybrid vigour* (plants grow faster, have higher yields and are more resistant to environmental stresses as a result of selecting parental varieties with specific genetic differences); and
- *tissue culture*, a process which has been particularly beneficial to tens of thousands of small-scale farmers in developing countries (it allows whole, often virus free, plants to grow from a single cell in an artificial medium).[2]

3.3 *Marker-aided selection* (MAS) enables plant breeders to select a piece of DNA that is associated with a particular trait, thereby avoiding time-consuming and expensive tests to select the ideal parent or offspring. MAS can significantly speed up the plant breeding process and a new variety can be produced in approximately four to six generations, rather than in ten. MAS is particularly useful for breeding crops with resistance to moisture-stress for environments with an irregular supply of water. To achieve this characteristic, a variety of different traits would have to be selected and MAS allows plants that express these different traits to be rapidly identified. The technique is also useful in research which aims to interbreed maize varieties that are already resistant to moisture-stress with African varieties of the crop, which are otherwise well adapted.[3]

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1 Further information can be found in Chapter 2 of the 1999 Report.

2 Successful applications of this technique include, for example, the production of improved and disease-free banana seedlings which have been made available to small-scale farmers in Kenya, see Wambugu FM and Kiome RM (2001) *The Benefits of Biotechnology for Small-Scale Banana Producers in Kenya* International Service for the Acquisition of Agri-biotech Applications (ISAAA) Brief No. 22 (Ithaca, NY: ISAAA). Another major application of tissue culture is the *embryo rescue* technique which allowed researchers to cross the particularly high-yielding Asian rice *Oryza sativa* with an African rice variety that was exceptionally competitive with weeds, resistant to moisture-stress and disease resistant, see Jones MP (1999) Basic breeding strategies for high yield rice varieties at WARDA, *Jpn J Crop Sci* **67**: 133–6.

3 Ribaut J-M *et al*. (2002) Use of molecular markers in plant breeding: drought tolerance improvement in tropical maize, in *Quantitative Genetics, Genomics and Plant Breeding*, Kang MS, Editor (Wallingford, UK: CABI Publishing), pp85–99.

Genetic modification

3.4 Genetic modification allows selected individual genes discovered in one organism to be inserted directly into another. This can be a related or unrelated species. Since the way particular genes function is similar in most organisms, genes or part of genes from one organism can generally be transferred to any other organism. The transferred gene is called the *transgene*. Genetic modification can be used to promote a desirable crop character or to suppress an undesirable trait. The technology is also sometimes called gene technology, recombinant DNA technology or genetic engineering. Practical and functional methods have now been developed to modify most of our major crops.

3.5 Regulatory provisions require that the actual transfer of genes into the selected organism must always take place in a laboratory under carefully controlled conditions. GM plants will later be grown in a special glasshouse, and then in fields under regulated conditions, before being grown commercially. Once transferred, transgenes behave like other genes and can be managed further in a conventional cross breeding programme.

3.6 However, the technology has given rise to several concerns. Some perceive the act of genetic modification as more 'unnatural' than processes applied in conventional plant breeding (see paragraphs 3.7-3.17).[4] Critics also fear that genes introduced into GM plants grown in fields, whether for experimental or commercial purposes, might 'escape' into wild relatives of the plant, or to other organisms. There is concern that such events may be irreversible and uncontrollable.[5] There are also questions about the effect of GM crops on human health (see paragraphs 4.43-4.47).[6]

Naturalness

3.7 Some people think intuitively that it cannot be right to change the 'essence' of natural objects like plants. Arguments about naturalness are complex, and raise many difficult issues. We addressed some of these in our 1999 Report, where we examined concerns which were based on commonly held views, or on philosophical, cultural or theological grounds (see paragraphs 1.32-1.40 of the 1999 Report). However, we wish to reconsider two areas in more detail. The first concerns the question of the relationship between conventional plant breeding and plant breeding that uses genetic modification: can it be said that the use of genetic modification is 'unnatural'? The second concerns the question of what it means to transfer genes between species: are such procedures unacceptable because they violate natural boundaries?

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4 For a more abstract discussion of the issue of naturalness, see Alan Holland's submission to the New Zealand Royal Commission on Genetic Modification. Available: http://www.gmcommission.govt.nz/pronto_pdf/save_animals_from_exploitation_safe/(WB%20IP%200085-Al%20Holland).pdf. Accessed on: 14 Oct 2003. See also Food Standards Agency (2002) *Public Attitudes to GM: Debrief notes on qualitative research* (London: FSA). Available: http://www.foodstandards.gov.uk/multimedia/pdfs/gmfocusgroupreport.pdf. Accessed on: 14 Oct 2003.

5 FAO Electronic Forum on Biotechnology in Food and Agriculture (2002) Background Document to Conference 7, 31 May – 6 July 2002. *Gene flow from GM to non-GM populations in the crop, forestry, animal and fishery sectors* (FAO UN). Available: http://www.fao.org/biotech/C7doc.htm. Accessed on: 14 Oct 2003; Independent Science Panel (2003) *The Case for a GM-Free Sustainable World* (London: ISP). See also paragraphs 4.28-4.42.

6 British Medical Association (1999) *The Impact of Genetic Modification on Agriculture, Food and Health: An Interim Statement* (London: BMA).

Conventional plant breeding and plant breeding using genetic modification

3.8 Conventional plant breeding is often understood as the selection of particular individuals from a great variety of naturally occurring types of plants. This activity tends to be seen as natural. Many would also view the systematic interbreeding of naturally occurring types of plants in the same vein. However, plant breeders also create plants which would not be achievable by judicious interbreeding, using techniques such as wide-crossing. This has led to completely new varieties such as Triticale (a hybrid between wheat and rye). Another technique, mutation breeding, involves the exposure of plants and seeds to radiation or chemical substances. These procedures have been, and still are being used to produce many important staple crops around the world (see paragraph 4.44).[7] Thus, it is important to note that the deliberate alteration of plants as they occur in nature has been practised and accepted for several decades. In this context, genetic modification can be seen as a new means to achieve the same end; it is certainly used in that way. It differs from conventional plant breeding in that it can allow for much faster and more precise ways of producing improved crops. For this reason, we concluded in our 1999 Report that it was not helpful to classify a crop that has been arrived at by means of conventional plant breeding as 'natural', and to classify a crop with the same genetic complement as 'unnatural' if it has been produced through genetic modification.

3.9 However, there is some concern that the technique of genetic modification poses risks that differ from those implied by other forms of plant breeding. It may be the case that the intended effect of conferring a particular trait by insertion of specific gene sequences brings with it unintended effects, for example, disruptions in existing genes in the modified material.[8] However, unintended effects are not specific to the use of genetic modification. They are often encountered in conventional breeding, particularly in the case of mutation breeding.[9]

3.10 Other concerns relate to the fact that some forms of genetic modification involve foreign genetic material. Often, viral sequences are used to facilitate the expression of a specific gene sequence in a modified organism (this function is also known as 'switching on' the gene). For example, a short sequence of the genetic material of the cauliflower mosaic plant virus is often used for this purpose.[10] Some people regard this step as crossing a threshold which should not be breached. In their view, an organism has been created which has not previously existed in nature. We now consider the transfer of genes between species in more detail.

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7 For example, radiation in the form of gamma rays was used to alter the genes of a successful rice variety known as Calrose 76. The radiation reduced the height of the plants which resulted in increased yields of grain. The same technique was also used to develop 'Golden Barley', the main variety grown in Scotland until the 1980s. Chemical substances such as sodium azide and ethyl methane sulphonate are still being used, particularly in developing countries, to alter plant genes.

8 See FAO and World Health Organization (2000) *Safety Aspects of Genetically Modified Foods of Plant Origin*, Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology 29 May – 2 June 2000 (Geneva: WHO), Section 4.3 for a more extensive discussion of this issue. See also Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health – an update* (London: Royal Society), p6.

9 The Royal Society notes two examples: celery and potatoes, see Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health – an update* (London: Royal Society), p6.

10 Such sequences are used as 'promoters', see Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health – an update* (London: Royal Society), p8; Independent Science Panel (2003) *The Case for a GM-Free Sustainable World* (London: ISP). We discuss health issues raised by these and other techniques in paragraphs 4.43-4.47.

The transfer of genes between species

3.11 Genetic modification enables researchers to insert genes from unrelated species into crop plants. This is the case with *Bt* crops (see paragraphs 3.28-3.38) where bacterial gene sequences have been transferred into many crop species. Transgenic varieties of rice are also being produced using genes from bacteria, daffodils and *Arabidopsis* (paragraphs 3.42-3.50). For many people, such possibilities raise the ethical question of whether it is acceptable to mix the genes of different species in this way. The notion underlying this often intuitive response is that there is a meaningful order in nature that needs to be respected (see paragraph 1.43 of the 1999 Report).

3.12 There are several aspects to this view. First, it can entail a claim about the status of species and their role in nature. The diversity of wild species of plants can be seen as a reflection of the process of natural selection and other evolutionary mechanisms. These are frequently interpreted as intrinsically valuable and 'off-limits'. Genetic modification is sometimes viewed critically because it is thought to interfere with these processes. The possibility that GM crops might interbreed with wild relatives is also seen by some as changing natural selection (see paragraphs 4.28-4.42). However, the same objection can be made with respect to many other forms of plant breeding. In fact, crop varieties which are used in agriculture already frequently interbreed with their wild relatives. Given that the systematic cultivation of plants had begun by 6,000 BC, humans have been influencing natural selection for a long time.[11]

3.13 Secondly, the claim that the natural world order should be respected can also be understood as a reluctance to transgress boundaries between species. On this view it could be argued that they are established by nature ensuring a specific balance between different living organisms. However, it does not follow that because something exists in nature, it should exist, or that it is good in and of itself.[12] Furthermore, even within nature, boundaries between species are not irreversibly fixed. There is, for example, increasing evidence that throughout evolution, gene transfer has occurred between lower and higher organisms, including humans.[13] *Horizontal gene transfer*, as this phenomenon is called, appears to occur naturally.

3.14 It is therefore difficult to maintain that nature as such should never be altered. However, a third line of argument may be to say that the order of nature needs to be respected because biological and ecological systems are relatively robust and predictable, and pose few risks for humans. However, interferences may result in irreversible adverse consequences for biological systems, which in turn might eventually endanger the natural world and our relationship to it. While it may be the case that horizontal gene transfer has occurred in nature, this has happened over a very long timescale. But with genetic modification, the transfer of genes between species introduces a sudden change. If GM crops are released into the environment, biological and ecological systems might not be sufficiently adapted to integrate the plants, possibly resulting in unforeseeable and potentially irreversible changes in biodiversity. It could be argued that 'nature knows best' how to integrate genetic changes, and that it would be irresponsible to interfere with this highly complex system that evolves slowly over time.

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11 Of course it does not follow that all the ways in which humans have influenced natural selection are unproblematic, see Chapter 3, footnote 14. It does mean however that attention should be given primarily to the consequences rather than to the act of interfering with nature.

12 There is a substantial philosophical discussion on the question of how to derive values from facts. Seminal contributions have been made by David Hume in *A Treatise of Human Nature* (1739-40) and G.E. Moore's *Principia Ethica* (1903).

13 Syvanen M (2002) Recent emergence of the modern genetic code: a proposal, *Trends Genet* **18**: 245–8; Capy P, Anxolabehere D and Langin T (1994) The strange phylogenies of transposable elements: are horizontal transfers the only explanation?, *Trends Genet* **10**: 7–12.

3.15 Some conclude from this line of argument that all forms of genetic modification which introduce foreign DNA into another organism should be rejected, regardless of the possible benefits. Others conclude that changes in nature should only be undertaken if there can be absolute certainty that no risks are implied. However, while the latter position seems to differ from the former, it needs to be noted that the requirement of absolute certainty is unattainable (see paragraphs 4.35-4.42). Neither do we apply such criteria consistently in other cases where human intervention affects biological and ecological systems.[14]

3.16 A third conclusion is to challenge the assumption that 'nature knows best' with its corollary that altering nature requires proof of the exclusion of all conceivable risks. Proponents of this position would argue that it is more important to assess and balance risks in individual cases. In some instances, it may be clear that risks outweigh benefits. In others, it may be the case that the risks are not severe and that a step by step approach can allow for a responsible use of new technologies (see paragraphs 4.35-4.42).

3.17 For now, we conclude that the arguments about 'naturalness' are insufficient to rule out the responsible exploration of the potential of genetic modification. All forms of plant breeding have directly and indirectly changed biodiversity. It is undesirable to forgo likely benefits because of the possibility of hypothetical adverse events. This is particularly pertinent to the use of GM crops in developing countries. GM crops may prove to be effective tools for addressing specific agricultural problems, while any associated risks for human health and the environment might be contained. To examine this question further, we now consider possible benefits and risks that may arise as a result of the use of GM crops in developing countries. The issue of how best to make decisions about the use of GM crops in conditions of uncertainty is considered in more detail in paragraphs 4.35-4.42.

GM crops relevant to developing countries

3.18 Most commonly, the improvement of plants aims to increase the yield or quality of crops. Yield is influenced by many factors including pests, diseases, soil conditions, or abiotic stresses[15] which stem from unfavourable climatic conditions. Significant improvements can often be achieved by means of irrigation, the application of insecticides or pesticides and the addition of fertiliser. However, most of these interventions are expensive, particularly for small-scale farmers in developing countries.[16] The use of genetic modification provides plant breeders with new opportunities to produce crops that are protected from environmental stresses and attacks from pathogens and insects. The following list gives examples of traits that researchers aim to develop by means of genetic modification. Some of these are still in early stages of development, while others have been achieved more recently in the laboratory setting. A few are in field trials, or can already be found in crops used by farmers.

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14 For example, we may question whether the rhododendron, which originated in Spain and Portugal, should ever have been introduced into the UK; it has been highly invasive and adversely affected the environment, but it seems that this did not prevent its cultivation. Similar effects have resulted from the introduction of other garden plants such as Japanese knotweed (*Fallopia japonica*) which has resulted in a significant loss of biodiversity in some areas of the UK, particularly along waterways. See Royal Horticultural Society (2002) *Invasive Non-Native Species* (Surrey, UK: The Science Departments, The Royal Horticultural Society's Garden). Available: http://www.rhs.org.uk/research/c_and_e_nonnative.pdf. Accessed on: 14 Oct 2003. These examples illustrate the inconsistency in decision making about risks to the natural environment. We take the view that a thorough assessment of the likely benefits and risks is required in all cases.

15 Stresses upon a crop may be either biotic or abiotic. Biotic stresses refer to the influence or impact which other living organisms have on a crop. Abiotic stresses usually refer to physical and chemical components of a crop's environment.

16 For example, the price of urea, a commonly used fertiliser, is US$400 per metric tonne in Western Kenya, US$770 in Malawi and only US$90 in Europe. See Sanchez PA (2002) Soil fertility and hunger in Africa, *Science* **295**: 2019–20. See also Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century*. Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf, p8. Accessed on: 10 Oct 2003.

In some cases the traits can be arrived at by conventional breeding, while others are achievable only by genetic modification (see also Appendix 3).

- **Herbicide tolerance** A transgene confers tolerance to a specific herbicide. This trait allows farmers to apply a herbicide which acts on a wide range of weeds while not affecting the modified crop. Herbicide tolerance is currently the most commonly used GM trait worldwide, for example in soybean, maize, cotton and oil seed rape (see case study 7). Herbicide tolerant crops are mainly grown in developed countries with the primary aim of reducing applications of herbicides. The trait has also been achieved using other methods, particularly mutation breeding and gene transfer from wild relatives.
- **Insect/pest resistance** A transgene produces toxins to specific insects that feed on the crop. Such genes have been widely used and are already leading to substantial reductions in the use of pesticides and insecticides. Insect-resistant cotton, maize and potato varieties are being grown in both developed and developing countries (see case study 1 on *Bt* cotton).
- **Bacterial, fungal and viral resistance** Here a transgene makes crops resistant to biotic stresses such as plant pathogens which often reduce yields substantially. Examples of crops in which these traits are being introduced include coffee, bananas, cassava, potato, sweet potato, beans, wheat, papaya, squash and melon (see case Studies 5 and 6 on sweet potatoes and bananas). In some cases the transgenes used are genes which occur naturally in the same species.
- **Abiotic stress resistance** The ability of some plants to survive in harsh climatic or soil conditions is sometimes associated with specific groups of genes. These genes can be isolated and introduced into crops. Such applications promise to be particularly valuable for developing countries, where abiotic stresses such as drought, heat, frost and acidic or salty soils are common. Research on crops such as cotton, coffee, rice, wheat, potato, *Brassica*, tomato and barley varieties is currently in different stages of completion (see case study 2 on rice that is resistant to moisture-stress).
- **Micronutrient enrichment** In aiming to prevent malnutrition, transgenes could play a vital role in the provision of vitamins or minerals. GM crops could help to provide people with essential micronutrients through consumption of their main staple crop. Research in this area is currently being undertaken in rice, cassava, millet and potato (see case study 4 on Golden Rice).

3.19 Another application of genetic modification includes the controversial gene use restriction technology (GURT), also known as 'terminator technology', which leads to seed sterility (see paragraph 4.18 of this Discussion Paper and paragraphs 2.26 and 4.75 of the 1999 Report).[17] Other applications which are either in advanced stages of development or already used in agricultural practice include improved shelf-life of fruit and vegetables, and the use of plants for the production of biopharmaceuticals, such as vaccines (see case study 8).[18] There is also a range of traits which are still in relatively early stages of development, but which are nonetheless promising and potentially important. This includes research to enable the transfer of genes conferring *apomixis*, which is the capacity to produce seeds in the absence

[17] Companies developing this technology emphasise that its purpose is to allow the control of gene flow, whereas critics claim that the purpose is the control of seed markets, by making the saving of harvested seed for re-sowing in the next season unfeasible.

[18] Agriculture and Environment Biotechnology Commission (AEBC) (2002) *Looking Ahead - An AEBC Horizon Scan* (London: Department of Trade and Industry); GeneWatch (2003) Briefing No. 21 *Genetic Modification: The Need for Special Regulation* (Derbyshire, UK: GeneWatch).

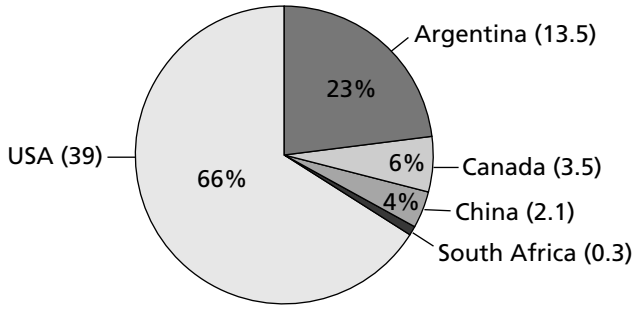
of normal sexual reproduction, to crops.[19] This application could enable outstanding traits to be perpetuated over generations without farmers needing to buy new seed (see paragraphs 2.23, 2.39 and 3.39 of our 1999 Report). Other research aims to produce GM crops that can be used for the production of bioplastics or biofuels, as substitutes for fossil fuels and their products. It may also be possible to develop nitrogen-fixing cereals; gluten-producing sorghum for bread-making in Africa (currently dependent on imported wheat); and crops with such high tolerance to salinity that salty marsh water can be used for irrigation.[20]

3.20 We provide in the next section a brief survey on the kinds of GM crops that were grown worldwide in 2002. This is followed by eight case studies which illustrate current and potential benefits and risks associated with the use of GM crops in developing countries.

Global commercial use of GM crops

3.21 Three-quarters of GM crops which are grown worldwide are cultivated in developed countries, predominantly on large-scale industrial farms in the US, Argentina and Canada. Traits which have been successfully introduced by means of genetic modification relate primarily to the needs of these farmers. However, of the approximately six million farmers who grew GM crops legally in 2002 worldwide, more than three-quarters were resource-poor, small-scale cotton farmers in developing countries, mainly in China and South Africa.[21] While the number of farmers using GM crops is the highest in developing countries, they only account for 27% of the total area. The five countries which grew 99% of the global GM crop are shown in Figure 3.1.

Figure 3.1: **Global area of legally planted GM crops in 2002 by country (million hectares)**



James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

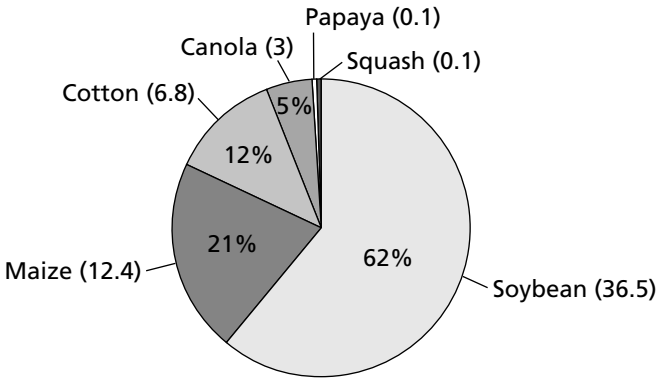
19 For a review see Chaudhury AM *et al.* (2001) Control of early seed development, *Annu Rev Cell Dev Biol* **17**: 677–99.

20 See, for example, Mazur B, Krebbers E and Tingey S (1999) Gene discovery and product development for grain quality traits, *Science* **285**: 372–5; AEBC (2002) *Looking Ahead - An AEBC Horizon Scan* (London: Department of Trade and Industry); Fitzgerald P (2003) Salt-Tolerant GM Wheat, *Ground Cover* **44** (Grains Research & Development Corporation). Available: http://www.grdc.com.au/growers/gc/gc44/gene_scene.htm. Accessed on: 14 Oct 2003; James C (1999) *Global Review of Commercialized Transgenic Crops:* 1999 ISAAA Brief No. 12 (Ithaca, NY: ISAAA).

21 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA). This figure excludes those farmers who grew GM crops illegally, for which there is anecdotal evidence in Brazil, Pakistan and India during 2002.

3.22 Between 1999-2002, the principal GM crops grown have been non-staple crops, grown by commercial farmers in developed countries. The most commonly used traits were herbicide tolerance (75%) and pest resistance (15%). Varieties carrying two or more transgenes which conferred both pest resistance and herbicide tolerance accounted for 8% of all crops. Herbicide tolerant soybean was the most widely grown GM crop in 2002 (see Figure 3.2).

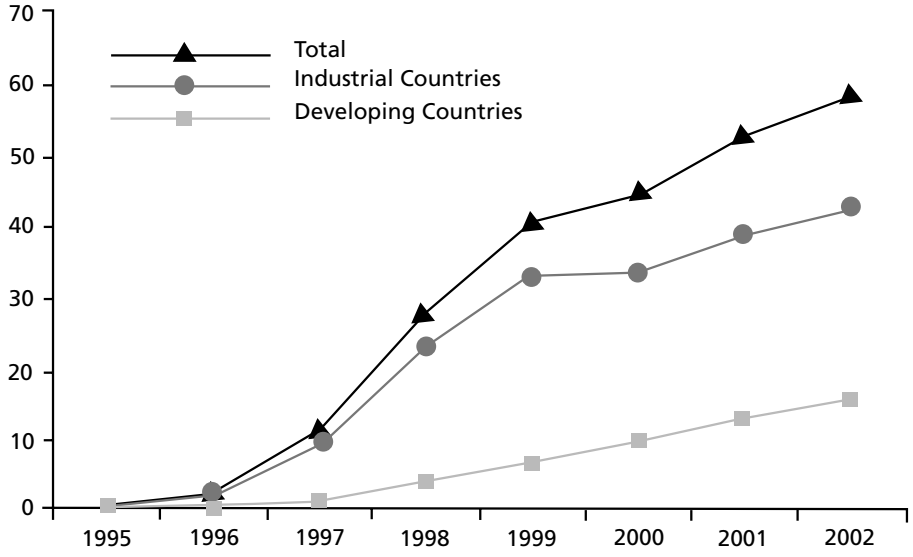
Figure 3.2: **Global area of legally planted GM crops in 2002 by crop (million hectares)**



James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

3.23 In 2002, nearly one-quarter of the total area of GM crops worldwide was grown in Argentina. Soybean and maize for export as animal feed were planted predominantly on large-scale farms. Since our 1999 Report was published, the area of GM crops in developing countries has doubled. The growth in cultivation of GM non-staple crops in developing countries is expected to continue over the coming years (see Figure 3.3).

Figure 3.3: **Global area of legally planted GM crops, 1996-2002 (million hectares)**



James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA)

3.24 In China, GM varieties were grown on 51%, or two million hectares, of the land used for growing cotton. In India, GM cotton received regulatory approval in April 2002 and 45,000 hectares were subsequently planted. Indonesia has also recently introduced GM crops, which means that the three most populous countries in Asia have adopted the technology.[22]

3.25 While the rapidly increasing spread of GM crops is noteworthy, most GM food and feed crops, such as soybean or rice, have not yet been approved for commercial planting in Africa, Asia, or the Middle East. The exceptions are South Africa and the Philippines, where GM maize has been approved, and Argentina, where GM maize and soybean are grown. One of the main reasons for this pattern is that regulators in developing countries often opt for a highly conservative precautionary approach when deciding about the use of a new GM crop. Unresolved concerns about the safety of GM crops for human consumption and for the environment (see paragraphs 4.28-4.47), together with possible restrictions arising from international trade policies (see paragraphs 5.43-5.50) have been influential in this respect.

Current and possible uses of GM crops in developing countries

3.26 As we have said, concern has been expressed about the speed with which GM crops have been, or are intended to be, introduced in some developing countries (see paragraphs 1.10-1.13).[23] With regard to food crops, critics point out that despite increasing populations, over the past 35 years, growth in global food production has outstripped growth in population by 16%. They argue that current global food production is sufficient to provide food for the world's population, if only inequalities in access to food were eliminated.[24] GM crops are frequently perceived as a 'technological fix', proposed by those who fail to address the underlying causes of hunger and poverty, which really require economic, political and social change.

3.27 We are aware of these and further general objections and address them in more detail in Chapter 4. Here, we consider what kind of GM crops could offer benefits to farmers in developing countries, and what the likely risks might be. We also aim to assess the claim that GM technology may only benefit agrochemical companies and large-scale commercial farmers in developed countries, and may be of no use or even harmful for small-scale, resource-poor farmers in developing countries.[25] We first consider in more detail the use of GM cotton in China and Africa. We then discuss five examples of research where genetic modification is used to improve traits of rice, sweet potatoes and bananas. These crops are important to many people in developing countries, but have been largely neglected by plant breeders elsewhere. We also examine issues arising from the use of GM soybean in South America and the implications of modifying crops for the production of biopharmaceuticals.

22 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

23 Oxfam (1999) *Genetically Modified Crops, World Trade and Food Security* (Oxford: Oxfam); Five Year Freeze (2002) *Feeding or Fooling the World?* (London: Five Year Freeze).

24 Five Year Freeze (2002) *Feeding or Fooling the World?* (London: Five Year Freeze).

25 See, for example the study on possible benefits and disadvantages of GM coffee in Hawaii, Action Aid (2001) *Robbing Coffee's Cradle - GM coffee and its threat to poor farmers* (London: Action Aid).

Case study 1: Non-food crops – Bt cotton in China and South Africa

3.28 Cotton attracts a variety of serious pests which farmers seek to control by the use of chemicals. One example of these pesticides is based on the naturally-occurring soil bacterium *Bacillus thuringiensis (Bt)*. There are a number of strains of *Bt*, each of which produces a slightly different protein. All cause a toxic reaction in the guts of certain insects or pests when they digest the protein. While such a reaction does not occur in humans, it strongly affects cotton bollworm, maize borers or potato beetles, which devastate many crops worldwide. The toxic effect of *Bt*-derived compounds has been widely used by conventional and organic farmers for several decades.[26] Usually, farmers apply the toxin by spraying the crops. However, this method of application is relatively imprecise and repeated sprayings over an extended period of time are required to control pests effectively.

3.29 The attraction of using the *Bt* toxin is that it is generally not harmful to beneficial insects that are closely related to pest species. These insects, which would otherwise have been killed by the application of conventional chemical pesticides, are left unaffected due to the selectivity of *Bt*. To preserve this useful quality, and to control pests more effectively, researchers have produced genetically modified crop varieties which can express the relevant proteins that are toxic to selected insect pests. While the protein is usually produced throughout the crop, more recent developments also allow it to be expressed in specific parts of the plants, such as the roots.[27]

3.30 The major advantage of *Bt* crops is the reduction in the levels of pesticides used by farmers. This can have considerable ecological benefits, as excessive use of pesticides can be harmful to the environment. There are also potential economic benefits: in 2001, 20% of pesticides applied globally were used on cotton, at a total cost of US$1.7 billion.[28] Significant reductions can also have health-related benefits for farm workers who apply pesticides or insecticides, or who work in fields in which these have been applied (see also paragraph 3.55). Whether or not the use of *Bt* crops leads to overall savings for farmers will depend on a variety of factors, such as the price of seed, licensing agreements with the producer of the seed, costs of insecticides and global cotton prices.

3.31 In China, researchers at the public sector Chinese Academy of Agricultural Sciences (CAAS), in cooperation with regional academies, have successfully developed several *Bt* cotton varieties for domestic use. These varieties have initially been sold by the national seed network. However, due to a reform of the national seed law in 2000, private seed companies now operate in many provinces, enabling farmers to choose from a wider variety of GM and non-GM seed.[29] By 2002, half the cotton grown in China was in the form of *Bt* varieties. Reports have highlighted three main advantages:

- The average application of pesticides fell by as much as 50 kilograms per hectare, a reduction of between 60-80% in comparison to 2001.[30] This implied considerable

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26 James C (2002) *Global Review of Commercialized Transgenic Crops: 2001, Feature Bt cotton* ISAAA Brief No. 26 (Ithaca, NY: ISAAA).

27 Kota M *et al.* (1999) The Next Generation of *Bt* Plants? Auburn University. Available: http://www.ag.auburn.edu/aaes/communications/highlights/spring99/btplants.html. Accessed on: 14 Oct 2003.

28 James C (2002) *Global Review of Commercialized Transgenic Crops: 2001, Feature Bt cotton* ISAAA Brief No. 26 (Ithaca, NY: ISAAA).

29 Huang *et al.* (2002) *Bt* cotton benefits, costs, and impacts in China, *AgBioForum* **5**: 153–66; James C (2001) *Global Review of Commercialized Transgenic Crops: 2001* ISAAA Brief No. 24 (Ithaca, NY: ISAAA).

30 Huang J *et al*. (2002) Plant biotechnology in China, *Science* **295**: 674–6.

financial savings for approximately 3.5 million farmers who managed small farms of an average size of between 0.5-2 hectares (see Table 3.1).[31]

- Yields of *Bt* cotton were estimated to have increased by 10% in 2001, in comparison to farmers who grew non-*Bt* cotton.[32]
- As in many other developing countries, pesticides in China are often applied in the absence of protective clothing. The use of *Bt* cotton seems to have led to reductions of instances in which farmers suffered toxic effects related to exposure to pesticides. Such events were reported to be reduced by 60%, compared with farmers who grew non-*Bt* cotton.[33]

Table 3.1: **Average costs and returns (US$) per hectare for farmers surveyed in China, 2001**

Cost	*Bt*	Non-*Bt*
Output revenue	1277	1154
Non-labour costs		
Seed	78	18
Pesticides	78	186
Chemical fertiliser	162	211
Organic fertiliser	44	53
Other costs	82	65
Labour	557	846
Total costs	1000	1379
Net revenue	277	-225

Source: Pray CE *et al*. (2002) Five years of *Bt* cotton in China - the benefits continue, *Plant J* **31**: 423–30.

3.32 Similar improvements in yield were achieved in the Makhathini Flats area of KwaZulu-Natal, South Africa, where a well developed extension system is in place.[34] The private company VUNISA Cotton is the sole supplier of seed, agrochemicals and support services. Through its extension officers, it offers several GM as well as non-GM varieties. VUNISA also provides

31 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA). There is evidence that many Chinese farmers growing non-*Bt* cotton apply excessive amounts of pesticides, see Shankar B and Thirtle C (2003) Pesticide Productivity and Transgenic Cotton Technology: The South African Smallholder Case, Working Paper, Dept. of Agricultural & Food Economics, University of Reading. It would therefore be wrong to attribute the total reduction to the use of *Bt* cotton alone. Some reduction could also have been achieved by means of promoting a better understanding of the appropriate amounts of pesticides for use in cotton. This highlights the importance of training and provision of information about pesticide use for both *Bt* and non-*Bt* crops.

32 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA); Pray CE *et al.* (2002) Five years of *Bt* cotton in China - the benefits continue, *Plant J* **31**: 423–30.

33 Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century.* Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf. Accessed on: 10 Oct 2003; Pray CE *et al*. (2002) Five years of *Bt* cotton in China – the benefits continue, *Plant J* **31**: 423–30; Huang *et al.* (2002) *Bt* cotton benefits, costs, and impacts in China, *AgBioForum* **5**: 153–66.

34 Thirtle C, Piesse J and Jenkins L (2003) Can GM-technologies help the poor? The Impact of *Bt* Cotton in Makhathini Flats, KwaZulu-Natal, *World Dev* **31**: 717–32.

credit for farmers and buys their harvest, competing with the company NSK. Farmers are members of farming associations, which hold regular meetings to provide support and to discuss mutual concerns.[35] In 1999/2000, 12% of 1376 cotton farmers who mostly managed small farms of an average size of 1.7 hectares adopted *Bt* cotton. This rose to 60% the following year. Ninety five per cent are expected to have grown *Bt* cotton in 2001/2002. Due to increased yields, and reduced costs of pesticides and labour, farmers were able to augment their gross margin by 11% in the first season, and 77% in the second, compared to farmers growing non-*Bt* cotton. These increases were achieved despite the fact that the *Bt* cotton seeds were twice the cost of conventional seeds.[36] The use of *Bt* cotton is also said to have led to savings of approximately 1,500 litres of water per farm.[37]

3.33 Despite these benefits, the use of *Bt* cotton carries a number of risks. Concern has been expressed with regard to a perceived undue influence of multinational agrochemical and seed companies. Companies can decide to levy 'technology fees' from users of newly developed GM crops such as *Bt* cotton. Such fees may be acceptable to large-scale farmers in developed countries, but they could exclude small-scale farmers in developing countries from using GM crops.[38] There are fears that some farmers might try to avoid these costs by reusing seed saved from previous seasons, or by purchasing seeds illegally, both options usually resulting in significantly reduced yields. Such incidents have recently been reported in India.[39] Thus, corporate control of seed markets and ownership of technologies are important issues. For example, the company Monsanto has made 90% of the patent applications for genes relating to the improvement of cotton.[40] In the case of agrochemicals, 10 companies control approximately 85% of the global market.[41] We consider issues relating to intellectual property rights in more detail in Chapter 6.

3.34 Reductions in the use of pesticides arising from the cultivation of *Bt* cotton might lead to less employment for farm workers. However, recent data from the Makhathini Flats have shown that, overall, this can be compensated for by increased demand for farm workers during the harvest, because of increased yields.[42] While this issue of labour is not relevant for small-scale farmers who do not employ labourers, it may require consideration in the case of larger farms. Problems could arise if farm workers are not able to obtain employment on other farms during the growing period of the crop.

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35 Thirtle C, Piesse J and Jenkins L (2003) Can GM-technologies help the poor? The Impact of *Bt* Cotton in Makhathini Flats, KwaZulu-Natal, *World Dev* **31**: 717–32.

36 Ismael Y, Bennett R and Morse S (2002) Benefits of *Bt* cotton use by smallholder farmers in South Africa, *AgBioForum* **5**: 1–5. The disproportionate increase in the second season is a result of exceptionally heavy rainfalls. The rain washed off the pesticides applied to non-*Bt* cotton, which allowed for less effective control of the bollworm. *Bt* cotton, on the other hand, was not affected in the same way.

37 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

38 However, as the example of China showed, higher prices for seed can be offset by overall savings in other areas (see Table 3.1).

39 India approved the growing of *Bt* cotton in April 2002. However there are reports that illegal plantings of *Bt* cotton has already taken place over the past three years. Unlicensed seeds have been produced by crossing Monsanto's varieties with other previously used conventional varieties. In Gujarat about one half of the *Bt* cotton seeds sold are estimated to be illegal 'pirate' seeds, which are considerably less expensive than commercial seeds. Several thousand acres had been sown illegally with second and third generation seeds, which had very low yields. Jayaraman KS (2002) Poor crop management plagues *Bt* cotton experiment in India, *Nat Biotechnol* **20**: 1069. While some favour this practice as a democratisation of plant breeding, others point to losses in quality. Monsanto is concerned that its technology is being used without payment of royalties and the company is said to have lodged an official complaint to the Indian Government, requesting an end to the illegal use of its cotton variety. Ghosh P (2003) India's GM seed piracy. http://news.bbc.co.uk/1/hi/sci/tech/2998150.stm. Accessed on: 14 Oct 2003.

40 GeneWatch (2001) Briefing No. 13 *Genetic Engineering: A Review of Developments in 2000* (Derbyshire, UK: GeneWatch).

41 AEBC (2002) *Looking Ahead - An AEBC Horizon Scan* (London: Department of Trade and Industry).

42 Shankar B and Thirtle C (2003) Pesticide Productivity and Transgenic Cotton Technology: The South African Smallholder Case, Working Paper, Dept. of Agricultural & Food Economics, University of Reading.

3.35 It is uncertain whether the concept behind *Bt* crops will prove to be robust over the medium to long term. It is known that pests may eventually acquire resistance to toxins.[43] However, the cotton bollworm has been monitored for *Bt* resistance in China since 1997, and resistant mutants have not yet been reported.[44] Nonetheless, resistance is likely to develop if the first generation of plants remains in cultivation for long enough. The use of *refuges* is one way of addressing this issue. To slow down the emergence of resistance, many regulatory schemes require that sufficient acreage of non-*Bt* crops are grown close to the *Bt* crops, to allow refuges for insects which can mate with potentially *Bt*-resistant insects. There is disagreement about the theoretical and practical effectiveness of refuges. Their success depends on factors such as size, spatial proximity relative to GM crops, the inheritance patterns of the trait that confers resistance to the toxin in pests, and the synchronous emergence of resistant and non-resistant pests.[45] The efficacy of refuges is well documented for *Bt* cotton farms in Australia, where regulatory requirements have been successfully implemented.[46] However, while the monitoring of refuges seems feasible for large-scale commercial farms, it may be much more difficult to achieve for numerous small-scale farms in developing countries.[47] Other approaches to avoid resistance might be to use two or more *Bt* genes,[48] or to carry out research into new insecticidal genes that could eventually take the place of *Bt*.[49] However, at present *Bt* varieties have remained resistant to pest infestation for considerably longer than had initially been anticipated.

3.36 In evaluating the risks and benefits of *Bt* crops it is not sufficient to examine effects solely on the target species. Effective control of, for example, the cotton bollworm may lead to an increase in the numbers of other pests unaffected by *Bt*. These pests may then require control, which in turn might lead to increased use of pesticides. Such changes in the

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43 We note that this is a problem that is not unique to GM crops. It is equally applicable to conventionally applied pesticides.

44 Wu K (2002) *Agricultural and biological factors impacting on the long term effectiveness of Bt Cotton*, Conference on Resistance Management for Bt crops in China: Economic and Biological Considerations, 28 April 2002, North Carolina State University, Raleigh.

45 Liu Y-B, Tabashnik BE, Dennehy TJ, Patin AL and Bartlett AC (1999) Development time and resistance to *Bt* crops, *Nature* **400**: 519; Gould F (1998) Sustainability of transgenic insecticidal cultivars: Integrating Pest Genetics and Ecology, *Annu Rev Entomol* **43**: 701–26; Tabashnik BE (1994) Delaying Insect Adaptation to Transgenic Plants: Seed mixtures and refugia reconsidered, *Proc R Soc Lond B Bio* **255**: 7–12.

46 Peacock J (2003) Presentation at conference *Towards Sustainable Agriculture for Developing Countries: options from life sciences and biotechnologies,* 30-31 Jan 2003, Brussels. For a critical account on the effectiveness of refuges see Liu Y-B, Tabashnik BE, Dennehy TJ, Patin AL and Bartlett AC (1999) Development time and resistance to *Bt* crops, *Nature* **400**: 519.

47 It has also been reported that poor crop management frequently occurred in India when *Bt* varieties were planted legally. Farmers were said to have failed to provide refuges of non-*Bt* cotton. It has been suggested that the crops were introduced too hastily and that farmers had not been made aware that more intense irrigation would be required. Farmers had also paid four times the price of traditional varieties for *Bt* crops Qaim M (2002) *Bt* Cotton in India: Field-Trial Results and Economic Projections, Dept of Agriculture and Resource Economics, University of California. However, there is also anecdotal evidence that professionally managed *Bt* cotton has led to reductions of 70% in the amount of pesticides used in and yield gains of up to 80% comparison to conventionally planted cotton. These developments suggest that is too soon to draw conclusions as to whether the use of *Bt* cotton in India is likely to be beneficial. Jayaraman KS (2002) Poor crop management plagues *Bt* cotton experiment in India, *Nat Biotechnol* **20**: 1069.

48 Peacock J (2003) presentation at conference *Towards Sustainable Agriculture for Developing Countries: options from life sciences and biotechnologies,* 30-31 Jan 2003, Brussels; Gould F (1998) Sustainability of transgenic insecticidal cultivars: Integrating Pest Genetics and Ecology, *Annu Rev Entomol* **43**: 701–26.

49 Bowen D *et al*. (1998) Insecticidal toxins from the bacterium *Photorhabdus luminescens, Science* **280**: 2129–32.

spectrum of pests have recently been reported in the US, South Africa and China, and require close monitoring.[50]

3.37 Additional problems might arise from the possibility of gene flow from *Bt* crops to wild relatives.[51] Some fear that the introduced *Bt* gene may 'escape' from the modified plant and change the genetic composition of other plants. It is argued that this may be particularly relevant in the case of countries such as India, which is a centre of diversity for cotton. Centres of diversity often contain landraces, other cultivated crop varieties, as well as wild relatives, and possible outcrossing of *Bt* crops could irreversibly affect the local gene pool.[52] While some argue that these and related issues simply require stringent monitoring and assessment in field trials, others doubt whether such risks should be taken. We consider questions relating to the management of gene flow in paragraphs 4.28-4.34.

3.38 Further concerns have been expressed with respect to the possibility that the use of *Bt* crops may lead to a decrease in biodiversity. For example, in 1999, researchers undertaking laboratory studies claimed that the pollen of *Bt* maize negatively affected non-target species, such as monarch butterflies. When these insects were fed milkweed leaves dusted with large amounts of *Bt* pollen, increased larval mortality, slower development and smaller sizes of monarch butterflies were recorded.[53] However, subsequent studies have shown that the risk of acute toxicity to monarch butterflies in the wild is negligible.[54] Evidence from *Bt* cotton field trials in KwaZulu-Natal even seems to suggest that the use of *Bt* can contribute to enhanced biodiversity, as increased numbers and varieties of insects and insectivorous birds were recorded in *Bt* fields.[55]

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50 Bacheler JS (2003) Managing insects on cotton, in 2003 *North Carolina Cotton Production Guide* (North Carolina State University), Chptr 11. Available: http://ipm.ncsu.edu/Production_Guides/Cotton/chptr11.pdf. Accessed on: 20 Oct 2003; Joubert GD *et al*. (2001) *South African Experience with Bt Cotton,* International Cotton Advisory Committee Technical Seminar of the 60th Plenary Meeting 16-21 Sept 2001 (Victoria Falls, Zimbabwe). Available: http://www.icac.org/icac/cotton_info/tis/biotech/documents/techsem/SAexperience_tis01.pdf. Accessed on: 20 Oct 2003; Glover D (2003) *Bt Cotton: Benefits for Poor Farmers?* Genetically Modified Crops in Developing Countries Briefing Series Briefing 9 (Brighton, UK: Institute of Development Studies). Available: http://www.ids.ac.uk/ids/env/PDFs/Briefing9.pdf. Accessed on: 20 Oct 2003; Wu K, Peng Y and Jia S (2003) What we have learnt on impacts of *Bt* cotton on non-target organisms in China, *AgBiotechNet* **112**.

51 The transfer of genes via pollen to or from a cultivated crop to other crop plants, wild relatives, other plant species or other organisms.

52 Nester E *et al*. (2002) 100 years of *Bacillus thuringiensis:* a critical scientific assessment, at *100 Years of Bacillus thuringiensis, a Paradigm for Producing Transgenic Organisms: A Critical Scientific Assessment,* 16-18 Nov 2002 (Ithaca, NY: American Academy of Microbiology Colloquium); Shiva V (2002) speech at the Soil Association's International Sir Albert Howard Memorial Lecture 27 March 2002. Available at: http://www.soilassociation.org/web/sa/saweb.nsf/librarytitles/vandanashiva.html. Accessed on: 20 Oct 2003.

53 Losey JE, Rayor LS and Carter ME (1999) Transgenic pollen harms monarch larvae, *Nature* **399**: 214.

54 Sears MK *et al*. (2001) Impact of *Bt* corn pollen on monarch butterfly populations: a risk assessment, *Proc Natl Acad Sci USA* **98**: 11937–42; Hellmich RL *et al*. (2001) Monarch larvae sensitivity to *Bacillus thuringiensis* – purified proteins and pollen, *Proc Natl Acad Sci USA* **98**: 11925–30; Pleasants JM *et al.* (2001) Corn pollen deposition on milkweeds in and near cornfields, *Proc Natl Acad Sci USA* **98**: 11919–24; Stanley-Horn DE *et al*. (2001) Assessing the impact of Cry1Ab– expressing corn pollen on monarch butterfly larvae in field studies, *Proc Natl Acad Sci USA* **98**: 11931–6; Oberhauser KS *et al*. (2001) Temporal and spatial overlap between monarch larvae and corn pollen, *Proc Natl Acad Sci USA* **98**: 11913–8; Zangerl AR *et al*. (2001) Effects of exposure to event 176 *Bacillus thuringiensis* corn pollen on monarch and black swallowtail caterpillars under field conditions, *Proc Natl Acad Sci USA* **98**: 11908–12; Committee on Environmental Impacts Associated with Commercialisation of Transgenic Plants (2002) *Environmental Effects of Transgenic Plants: The Scope and Adequacy of Regulation* (Washington, DC: National Academy Press).

55 Thomson J (2002) *Genes for Africa: Genetically Modified Crops in the Developing World* (Cape Town: University of Cape Town Press), p169; Head G, Freeman B, Moar W, Ruberson J and Turnipseed S (2001) Natural enemy abundance in commercial Bollguard® and conventional cotton fields, Proceedings of the *Beltwide Cotton Conferences*, Anaheim, California, National Cotton Council, Memphis, Tennessee.

Examples of improved traits in staple crops

3.39 Cotton is a non-food crop that is grown predominantly for international trade. We now consider examples of food crops that are relevant to both subsistence and commercial farming. In many tropical areas of developing countries, two or three crops a year can be harvested. Temperatures and daylength are often more favourable to the growth of crops than conditions in temperate developed countries and best-case yields are therefore, often higher in the tropics than in highly productive areas of temperate zones.[56] However, the average yield of almost all crops grown in tropical regions is significantly lower than in developed countries. This is so because poor farmers and government departments in developing countries are generally not well placed to deal with problems such as poor quality seed, salty or otherwise recalcitrant soil, environmental stresses such as drought and heat, pests and diseases, lack of fertilisers, short-term management of farm land, and inadequate control of water.

3.40 Often, substantial improvements can be achieved cost-effectively in one or more of these areas by means of better irrigation, integrated pest management, or agricultural extension services. However, these approaches have limitations. Furthermore, with regard to improved seeds, there are a number of cases where conventional, non-GM approaches have achieved little progress. For example, sorghum and maize in Africa have shown scant improvement in yield. Maize hybrids, which are high-yielding with adequate water and nutrient conditions, have proved very vulnerable to even short delays in the rains during flowering. Hence, it may be worth exploring the potential contribution of GM crops for raising 'yield potential' (that is, the maximum attainable crop yield from a given soil-water regime), and yield stability of crops (see paragraphs 4.20-4.27 of the 1999 Report).

3.41 We now discuss several examples of research on food crops relevant to the developing world which may contribute to increasing yield in terms of quantity and quality. The first three concern research on genetically improved traits in rice, a staple food for over three billion people, in other words, half the world's population.[57]

Case study 2: Abiotic stress resistant rice

3.42 In 2002, researchers at Cornell University successfully tested under greenhouse conditions a variety of GM rice that maintained yields under abiotic stresses such as cold, drought and salty soil. Such research is crucial since one third of the 1.5 billion hectares of the world's arable land is affected by drought.[58] The researchers transferred a set of genes which control the expression of a sugar called trehalose into a variety of *Indica* rice, which represents 80% of rice grown worldwide. Trehalose occurs naturally in many so-called 'resurrection' plants, which can survive prolonged droughts in desert conditions. Under extreme stress, these plants appear dead; however, the sugar helps stabilise biological molecules and protects tissue damage during dehydration. It is estimated that the modified variety has the potential to increase yields under poor conditions by as much as 20%, although field trials will not take place for several years.[59] The researchers plan to seek

56 For example, best-case yields for wheat have been obtained in Amritsar and Ludhiana in the Indian Punjab, and in Sonora and Sinaloa, Mexico; similarly ideal conditions prevail for rice in parts of Taiwan.

57 Lantin R. Compendium on Post-Harvest Operations. FAO. Available: http://www.fao.org/inpho/compend/text/ch10.htm. Accessed on: 20 Oct 2003.

58 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA), p19.

59 Garg AK *et al.* (2002) Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses, *Proc Natl Acad Sci USA* **99**: 15898–903.

patent protection for the modification and will ensure public availability of the modified crop, particularly for farmers in developing countries. They also hope to introduce the trait in other crops, such as maize, wheat or millet.[60]

Case study 3: Increasing yield in rice by dwarfing

3.43 Another method of increasing crop yields is by the production of dwarf varieties. Shorter plants can make more nutrients available for grain production. The introduction of semi-dwarfing genes into wheat was one of the primary technical achievements of the Green Revolution in the 1960s and 1970s, contributing to the doubling of wheat yields worldwide. The development of the dwarf rice variety IR-8 in 1963 was equally important.[61] However, the genes used to reduce height in the two crops were very different. In both cases the farmer could use the improved strength of straw to gain yield because he was able to apply more fertiliser (where he could afford to do so). The wheat variety also had the advantage of increasing yield directly through a greater number of grains in the ear.

3.44 In 1999, a team at the John Innes Centre (JIC) isolated a gene from a common weed (*Arabidopsis thaliana*) which codes for the same type of dwarfism found in the semi-dwarf wheat varieties used in the Green Revolution. When the gene was introduced into rice, dwarf plants were obtained.[62]

3.45 Together with their Indian collaborator, researchers at the JIC have introduced the *Arabidopsis* gene into basmati rice to produce the first dwarf variety. Basmati is commonly grown on the Indian subcontinent, but the plants are usually tall, have weak stems and are highly susceptible to damage by wind and rain. These features frequently lead to considerable yield losses. Previous attempts to reduce the height of the basmati variety while retaining its desirable qualities using conventional breeding methods have resulted in the loss of the very characteristics for which it is valued. Field trials will eventually reveal whether the dwarfed basmati rice varieties have higher yields, as is the case with semi-dwarf wheat varieties. An important feature of this application of genetic modification is that it contributes both to the improvement of traits and the conservation of biodiversity. The single gene can be inserted with minimal disturbance to the rest of the genetic complement and a multitude of locally well-adapted varieties can simultaneously be conserved and improved.[63]

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60 At the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico, trials on moisture-stress resistant wheat plants are currently taking place in experimental greenhouses. See Pellegrineschi A (2003) Drought-resistant GM crops: a promising future, *SciDev.Net* 30 Jan 2003. Available: http://www.scidev.net/dossiers/index.cfm?fuseaction=dossierReadItem&type=3&itemid=5&language=1&dossier=6. Accessed on: 20 Oct 2003. Other crops resistant to abiotic stress, which are currently at the stage of field trials include frost tolerant potatoes in Bolivia, cold tolerant tomatoes in China, salt tolerant wheat in Egypt, moisture-stress resistant *Brassica* in India, and salt and moisture-stress resistant rice in Thailand. See FAO Electronic Forum on Biotechnology in Food and Agriculture (2002) Background Document to the Conference 8, 13 Nov - 11 Dec 2002 *What should be the role and focus of biotechnology in the agricultural research agendas of developing countries?* (FAO UN). Available: http://www.fao.org/biotech/C8doc.htm. Accessed on: 20 Oct 2003.

61 Dalrymple D (1976) *Development and Spread of High Yielding Wheat and Rice in the Less Developed Nations* US Dept of Agriculture, Foreign Development Division, Economic Research Service: Foreign Economic Agricultural Report No. 95, p120.

62 Peng J *et al.* (1999) 'Green revolution' genes encode mutant gibberellin response modulators, *Nature* **400**: 256–61.

63 Peng J *et al.* (1999) 'Green revolution' genes encode mutant gibberellin response modulators, *Nature* **400**: 256–61.

Case study 4: Improved micronutrients in rice

3.46 There are several research projects which aim to produce enhanced levels of ß-carotene in food crops.[64] ß-carotene is an important micronutrient which is converted to vitamin A in the body. In rice, ß-carotene is present in the leaves, but not in the rice endosperm (the edible part). However, ß-carotene can be produced in the endosperm of the grain by means of genetic modification. This development was achieved by Professor Ingo Potrykus and Dr Peter Beyer at the Swiss Federal Institute of Technology in 2000. They transferred one bacterial gene and two daffodil genes into a variety of rice to develop a ß-carotene enriched strain which they called *Golden Rice*.[65] The primary aim of the researchers was to help prevent vitamin A deficiency (VAD) which is a common phenomenon in developing countries. In 1995, clinical VAD affected some 14 million children under five, of whom some three million suffered xerophthalmia, the primary cause of childhood blindness. 250 million children had sub-clinical deficiency, greatly increasing their risk of contracting ordinary infectious diseases such as measles. In many developing countries such diseases contribute significantly to high mortality rates.[66] At least one third of the sufferers are found among poor people in Asia who rely on rice as their staple crop and for whom alternative sources of vitamin A are usually unaffordable.

3.47 There have been reports that the development of Golden Rice was significantly complicated by issues relating to intellectual property rights (IPRs), see Chapter 6. However, these issues were resolved after a public-private partnership with the company Syngenta was established, which provided assistance in the negotiation of access to protected materials and processes. The terms of the partnership are such that the company retains the rights for the commercialisation of Golden Rice, but allows seed to be made available free of charge to farmers and traders whose profit is below US$10,000 per year. Research on Golden Rice is currently being undertaken at 14 public research institutes which form the Golden Rice Network. This is an international research cooperative, bringing together researchers from India, China, Indonesia, Vietnam, Bangladesh, the Philippines and South Africa.

3.48 A successful laboratory strain of Golden Rice has been available since 2000. However, field trials, required before the crop can be made available to farmers, have been delayed. In particular, gaining regulatory approval for trials in the countries participating in the Golden Rice Network has proved to be onerous. Influenced by European debates about the risks associated with the use of GM crops, regulatory agencies in developing countries have been hesitant to grant licences for field trials.

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64 Research is currently being undertaken in India, where researchers aim to produce mustard seeds containing ß-carotene. The seeds are used for the production of oil and preliminary findings suggest that fairly high levels of ß-carotene can be provided. The project is a joint enterprise between the Tata Energy Research Institute (TERI) and Monsanto, with support of the US Agency for International Development (US AID). Monsanto (2002) *Growing Partnerships for Food and Health* (St. Louis: Monsanto). Researchers at the International Crops Research Institute for Semi Arid Tropics (ICRISAT) have produced a variety of millet that contains high levels of ß-carotene, similar to those found in Golden Rice. However, unlike Golden Rice, the Golden Millet strain was produced by conventional breeding techniques. Genetic marker techniques will be used to transfer the trait to other millet varieties. See Jayaraman K (2002) Natural 'golden millet' rivals 'golden rice', *SciDev.Net* 25 June 2002. Available: http://www.scidev.net/News/index.cfm?fuseaction=readnews&itemid=182&language=1. Accessed on: 20 Oct 2003. Further research relating to micronutrient enriched crops involves potatoes. Researchers at the Jawaharlal Nehru University in New Delhi are currently working on the 'Protato'. Adding the *AmA1* gene to conventional potatoes produced three times more protein, including significant amounts of the essential amino acids lysine and methionine. Deficiencies of these nutrients in the diets of children are common. Lack of lysine, for example, affects brain development. See Coghlan A (2003) 'Protato' to feed India's poor, *New Scientist* **177** (2376): 7.

65 In part, the name is derived from the fact that the rice is more yellow in colour than conventional rice. Golden Rice technology was developed with funding from the Rockefeller Foundation (1991-2002), the Swiss Federal Institute of Technology (1993-1996), the European Union under a European Biotech Programme (1996-2000) and the Swiss Federal Office for Education and Science (1996-2000).

66 ACC/SCN in collaboration with IFPRI (2000) *Fourth Report on the World Nutrition Situation: Nutrition throughout the Life Cycle* (Geneva: ACC/SCN with IFPRI); Personal communication, Professor Potrykus, 21 March 2003.

3.49 Proponents of Golden Rice point out that the delays are a particularly undesirable consequence of the EU regulatory framework. They emphasise that the genome of Golden Rice, like any other GM crop, is modified in a much more precise way than is the case for non-GM varieties, where unpredictable and major rearrangements of parental genomes occur frequently. They argue that the regulatory requirements for Golden Rice are therefore unreasonably high. Under the current regulatory regime, the first approved varieties of Golden Rice are not expected to be released before 2007/8.[67] Proponents of the technology, frustrated by these setbacks, point out that Golden Rice could shortly be tested in field trials in many developing countries, if the regulatory procedures were not so burdensome.[68]

3.50 Opponents, on the other hand, have questioned whether the amount of ß-carotene in Golden Rice would actually be sufficient to make a significant contribution to improved vitamin uptake.[69] In addition, the bio-availability of ß-carotene from Golden Rice is unknown, and it is therefore not yet clear to what extent the human body can make use of ß-carotene in this form. Some point out that an adequate intake of fat is needed to make use of the vitamin. Others claim that the yellow colour of the rice may not be compatible with cultural preferences, and that Golden Rice will be rejected accordingly.[70] We consider these questions in more detail in paragraphs 4.21-4.26.

Case study 5: Improved resistance to viruses in sweet potato

3.51 In Kenya, as in many other African developing countries, sweet potato is an important subsistence crop grown typically by small-scale farmers. About 40% of the harvest is usually kept for household consumption. Sweet potatoes can adapt to a wide range of environmental conditions and grow in both fertile and marginal areas. It is the second most important subsistence crop after maize. However, yields are low. The usual African yield of six tons per hectare is less than half of the global average.[71] Viruses and weevils frequently reduce yields by as much as 80%.[72] Effective controls for these pathogens are not available, and the crop has generally been neglected in international agricultural research.[73]

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67 Personal communication, Professor Potrykus, 21 March 2003; Potrykus I (2000) *The Golden Rice Tale*. Available: http://www.mindfully.org/GE/Golden-Rice-Ingo-Potrykus.htm. Accessed on: 20 Oct 2003.

68 Zimmerman and Qaim discuss the usefulness of introducing Golden Rice in the Philippines and estimate that every year of delaying its introduction results in between 1,500 – 9,000 cases of child blindness, see Zimmermann R and Qaim M (2002) *Projecting the Benefits of Golden Rice in the Philippines* Discussion Paper on Development Policy No. 51 (Bonn: Centre for Development Research ZEF). There is also the possibility of producing micronutrient-enriched plants with enhanced levels of iron, vitamin E or protein. Experiments to produce these traits independently and simultaneously in rice have already been completed successfully. However, it has been reported that regulatory authorities might be hesitant to give approval for field trials of crops which involved multiple transgenic events. If that were the case, it would seem unlikely that such crops will be available to people in developed or developing countries in the near future. Personal communication, Professor Potrykus, 21 March 2003; Potrykus I (2000) *The Golden Rice Tale.* Available: http://www.mindfully.org/GE/Golden-Rice-Ingo-Potrykus.htm. Accessed on: 20 Oct 2003.

69 Greenpeace (2001) *Vitamin A: Natural Sources vs 'Golden Rice'*. Available: http://archive.greenpeace.org/~geneng/reports/food/VitaAvs.PDF. Accessed on: 20 Oct 2003.

70 Five Year Freeze (2002) *Feeding or Fooling the World?* (London: Five Year Freeze); Koechlin F (2000) *The 'Golden Rice' – a Big Illusion?* (Third World Network). Available: http://www.twnside.org.sg/title/rice.htm. Accessed on: 20 Oct 2003.

71 Qaim M (1999) *The Economic Effects of Genetically Modified Orphan Commodities: Projections for Sweet Potato in Kenya* ISAAA Brief No. 13 (Ithaca, NY: ISAAA).

72 Monsanto (2003) *Our commitments: Technology Cooperation*. Available: http://www.monsanto.com/monsanto/layout/our_pledge/techcoop.asp. Accessed on: 20 Oct 2003.

73 However, there is a major research programme at the International Potato Centre (CIP), one of the centres of the Consultative Group on International Agricultural Research (CGIAR). CIP's aim is to reduce poverty and achieve food security on a sustained basis in developing countries through scientific research and related activities on potato, sweet potato and other root and tuber crops. The research programme comprises 13 projects, several of which involve the use of genetic modification. They include the improvement of sweet potato varieties, virus control, and improving post-harvest quality and nutrition. See CIP Projects. Available: http://www.cipotato.org/projects/ projects.htm. Accessed on: 20 Oct 2003.

3.52 Since 1991 the Kenya Agricultural Research Institute (KARI), in cooperation with Monsanto and universities in the US, has developed GM sweet potato strains that are resistant to the feathery mottle virus. Royalty-free licensing agreements have been signed that allow KARI and research institutes in other African countries to use the technology in the future. The crops are currently being tested in field trials and it is expected that yields will increase by approximately 18-25%. Where farmers sell part of their harvest, it has been predicted that the increased income will be between 28-39%.[74] However, some commentators caution against overly optimistic prognoses for the success of the GM sweet potato. They point out that there are three main viruses, and that resistance to the feathery mottle virus would not ensure protection against the other types.[75]

Case study 6: Improved resistance to diseases in bananas

3.53 Bananas make important contributions to food security in many developing countries. Leaves and fibres are used for a multitude of household and industrial purposes. Bananas also provide income to the farming community through local and international trade. World production of bananas is estimated to be approximately 70 million tons per year, of which around 85% are grown for local consumption by tropical, small-scale farmers.[76] Approximately half a billion people in Asia and Africa depend directly on farming of bananas. In Uganda, the crop is cultivated on one third of the arable land, and per capita consumption is 50 times higher than in the UK.[77]

3.54 Like all plants, bananas attract a range of different and highly adapted pests. However, in bananas these can have a particularly harmful effect. Unlike most plants, bananas only reproduce asexually, because the cultivated form is a sterile triploid. The different varieties grown around the world today have been cultivated from shoots of a small number of naturally occurring mutants. These have been derived from an even smaller number of man-made triploid varieties, some produced over a hundred years ago. Each 'variety' is therefore a clone, and the crop species is characterised by a very low level of genetic diversity. There is little hope that conventional plant breeding will produce crops that are resistant to bacterial or viral infections.[78] However, GM technology offers possibilities of increasing resistance to pests and diseases. It may also help to increase the diversity of banana varieties, which in turn could contribute to slowing down the impact of pests.

3.55 Common infestations of bananas include nematodes, viruses, and fungal diseases. The most harmful fungal disease is black Sigatoka which can reduce fruit yields by as much as 50-70%. It can cut the productive lifetime of a plant from approximately 30 to two or three years. Usually, up to 40 sprayings of fungicide are applied annually to afford protection from the fungus. These sprayings represent up to a quarter of the production costs, are environmentally problematic, and a cause of considerable ill health of farm workers. According to a 1999 study by the National University of Costa Rica, one fifth of the male workers on banana farms in Costa Rica are sterile. It has also been reported that female

74 Qaim M (1999) *The Economic Effects of Genetically Modified Orphan Commodities: Projections for Sweet Potato in Kenya* ISAAA Brief No. 13 (Ithaca, NY: ISAAA); Pew Initiative on Food and Biotechnology (2001) *Harvest on the Horizon: Future Uses of Biotechnology* (Washington, DC: Pew Initiative on Food and Biotechnology).

75 Odame H, Kameri-Mbote P and Wafula D (2002) Innovation and policy process: case of transgenic sweet potato in Kenya, in *Econ Polit Weekly,* **XXXVII** No 27.

76 FAO (2002) FAOSTAT. Available: http://apps.fao.org/. Accessed on: 20 May 2003.

77 Pearce F (2003) Going bananas, *New Scientist* **177** (2378): 26–9.

78 Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century.* Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf, p19. Accessed on: 10 Oct 2003.

workers have a 50% increased chance of developing leukaemia and of passing on birth defects to their children.[79]

3.56 One of the goals of a public, global biotechnology consortium led by the International Network for the Improvement of Banana and Plantain (INIBAP) is to sequence the genome of inedible wild bananas from South East Asia, as these are resistant to black Sigatoka.[80] It is hoped that the project will help identify genes which confer resistance. Once identified, the gene(s) could be introduced in leading varieties of edible bananas.[81] Other research is being undertaken to produce bananas that are resistant to nematodes,[82] or to viral diseases such as the banana bunchy top virus or banana bract mosaic virus.[83] There are also other forms of biotechnology-aided plant breeding, such as tissue culture, which have already resulted in improved, disease free crops.[84]

Case study 7: Herbicide resistant soybean

3.57 The genetic trait which confers tolerance to a specific broad spectrum herbicide can allow farmers to control a wide range of weeds while not affecting the modified crop.[85] Herbicide tolerant crops are grown mainly in developed countries. However, more recently, they have also been used in some developing countries. In Argentina, more than 90% of the local soybean harvest in 2002 was produced from GM varieties, making it the world's second largest producer of GM soybeans.[86] The multinational company Nidera provides the majority of commercially traded soybean seeds (70%). The remaining fraction is sold by six other companies, including Monsanto which first developed GM soybeans resistant to the herbicide glyphosate, marketed as Roundup Ready soybeans (RR). It is noteworthy that the RR technology is not patented in Argentina, and that national legislation allows farmers to use farm saved seed, which accounts for 30% of all soybeans planted.[87]

3.58 Proponents of this type of GM crop highlight the fact that its use can lead to more efficient agriculture as the need for herbicides, machinery and labour is significantly reduced. Seeds can be drilled directly into unploughed soil which helps to prevent soil erosion (the so called

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79 Smith J (2002) The truth about the banana trade, *The Ecologist* 22 March 2002. We note that one of the most dangerous chemicals, dibromochloropropane has now been banned. Rates of other types of cancers have been shown to be increased amongst Costa Rican banana plantation workers as compared with the national incidence rate, see Wesseling C, Antich D, Hogstedt C, Rodriguez AC and Ahlbom A (1999) Geographical differences of cancer incidence in Costa Rica in relation to environmental and occupational pesticide exposure, *Int J Epidemiol* **28**: 365–74

80 INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI).

81 Pearce F (2003) Going bananas, *New Scientist* **177** (2378): 26–9. AstraZeneca is also developing cultivars with resistance to black Sigatoka, see Biotechnology Industry Organization Agricultural Biotech Products on the Market. Available: http://www.bio.org/food&ag/approvedag98.html. Accessed on: 20 Oct 2003.

82 Researchers at the Catholic University of Leuven are developing banana cultivars with resistance to nematodes and to fungal diseases, which can lead to an average 20% loss in banana plantations. KU Leuven Laboratory of Tropical Crop Improvement. Available: http://www.agr.kuleuven.ac.be/dtp/tro/home.htm. Accessed on: 22 Oct 2003.

83 Research at the Catholic University of Leuven and at Queensland University of Technology in Australia has focused on developing bananas which are resistant to these viruses, which are among the major viral diseases relevant for bananas worldwide. KU Leuven Laboratory of Tropical Crop Improvement. Available: http://www.agr.kuleuven.ac.be/dtp/tro/home.htm. Accessed on: 22 Oct 2003; Demegen (2001) International Plant Biotech Groups Collaborate. Available: http://www.demegen.com/prs/pr011213.htm. Accessed on: 22 Oct 2003.

84 Wambugu FM and Kiome RM (2001) *The Benefits of Biotechnology for Small-Scale Banana Producers in Kenya* ISAAA Brief No. 22 (Ithaca, NY: ISAAA).

85 As noted above, paragraph 3.8, this trait has also been achieved through the use of other methods, such as mutation breeding and gene transfer from wild relatives.

86 Qaim M and Traxler G (forthcoming) Roundup Ready Soybeans in Argentina: Farm Level and Aggregate Welfare Effects, *Agricultural Economics.*

87 Qaim M and Traxler G (forthcoming) Roundup Ready Soybeans in Argentina: Farm Level and Aggregate Welfare Effects, *Agricultural Economics.*

no till practice). Conventional soybeans require regular application of a variety of herbicides, whereas RR soybeans require fewer applications of only one type of herbicide.

3.59 However, the use of RR soybeans in Argentina has raised several issues. Many critics are concerned about the dramatic increase in the use of the herbicide glyphosate.[88] Since the release of RR soybeans, glyphosate sales have increased eleven-fold, amounting to 82.35 million litres in 2001. In part, this is a result of the expiry of Monsanto's patent on the compound: in 2001, 22 companies were able to provide generic versions of the product at competitive prices.[89] The 'no till' practice has also contributed to increased use. However, proponents point out that glyphosate has no residual activity and is rapidly decomposed by soil microorganisms.[90] The increased use of glyphosate also significantly reduced applications of more hazardous herbicides in higher toxicity classes in Argentina.[91]

3.60 Others are concerned about the rapid growth in production of soybeans. In 1995, almost six million hectares of soybeans were harvested, predominantly for export; by 2001, the figure had risen to 10 million hectares.[92] Several commentators claim that the use of RR soybeans is disadvantageous for smaller farms, and leads to deforestation, rural unemployment and food insecurity.[93] The highly complex interplay of technological factors as well as societal, political and regulatory processes means that it is difficult to evaluate these various claims. With regard to the impact on farmers managing smaller farms (less than 100 hectares), recent research shows that they realised greater cost savings and an approximately 5% gain in gross margins than farmers operating larger farms.[94]

3.61 The mean costs in hired labour and custom operation per hectare for RR soybeans and for conventional soybeans were found to be very similar.[95] Because Argentine production of soybeans is fully mechanised, the use of herbicide does not displace hand-weeding labourers. Savings result from fewer tillage operations and more efficient harvesting. Whether herbicide resistant crops will be an appropriate addition to agricultural practice in specific developing countries will depend on the type of agriculture practised as well as on the type of crop. As one respondent to our Consultation observed:

> 'Herbicide tolerance as a trait is harmful, not helpful in our situation …the socio-economic interest of the poor rural community lies in manual weeding which provides wages to agricultural labour, which are usually the land-less farmers. Weeding is mostly done by women, providing them with a direct, and often only, income source. Also,

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88 Joensen L and Ho M-W (2003) Argentina's GM woes (Institute of Science in Society). http://www.i-sis.org/AGMW.php. Accessed on: 22 Oct 2003.

89 Qaim M and Traxler G (forthcoming) Roundup Ready Soybeans in Argentina: Farm Level and Aggregate Welfare Effects, *Agricultural Economics.*

90 Glyphosate is classified as "Unlikely to present acute hazard in normal use" in *The WHO Recommended Classification of Pesticides by Hazard 2000-2002* (WHO).

91 Qaim M and Traxler G (forthcoming) Roundup Ready Soybeans in Argentina: Farm Level and Aggregate Welfare Effects, *Agricultural Economics.*

92 CIARA (2002) Datos Estadísticos, Cámara de la Industria Aceitera de la República Argentina, Buenos Aires.

93 Greenpeace (2002) *Record Harvest – Record Hunger Starving in GE Argentina* (Berlin: Greenpeace); Eduardo Rulli de Jorge (2003) Biotechnology and the origins of the Argentine catastrophe, *Ecopartal* 11 Sept 2002; Backwell B and Stefanoni P (2003) Soya solidarity or food apartheid: The business of hunger in Argentina, *Le Monde Diplomatique* Feb 2003.

94 Savings resulted from reduced use of pesticides and lower seed prices, as saved or uncertified seed is more commonly used by farmers managing smaller farms. See Qaim M and Traxler G (forthcoming) Roundup Ready Soybeans in Argentina: Farm Level and Aggregate Welfare Effects, *Agricultural Economics.*

95 The mean cost of hired labour and custom operation per hectare for RR soybeans was US$43.22, compared to US$46.82 for conventional soybeans. See Qaim M and Traxler G (forthcoming) Roundup Ready Soybeans in Argentina: Farm Level and Aggregate Welfare Effects, *Agricultural Economics*.

> some of the plants that are collected as weeds are consumed by the rural household. Many of these are leafy greens like amaranth … a rich source of vitamins and minerals, or serve as fodder for the livestock that is maintained as an additional source of income. These weeds are also medicinal plants which are accessed by rural communities for health and veterinary care.'
> *Suman Sahai, New Delhi, India, Gene Campaign*

As we have said, raising demand for labour is the very essence of reducing poverty. Agricultural innovation should therefore aim to raise labour productivity. However, in poor countries with rapidly growing workforces and severe land and water shortages, productivity of land and water need to rise, so that employment and labour demand can increase. Therefore herbicide resistance which encourages farmers to displace labour is seldom a main priority for GM research in poor countries. But there may be very specific circumstances where less labour intensive crops can be of benefit to small-scale farmers in developing countries, as has been pointed out by the following respondents to our Consultation:

> 'the use of genetically modified crops that reduce labour could significantly address specific social and economic crisis facing rural communities as a result of the AIDS pandemic… In Kenya, for example, the losses in agricultural production from AIDS at household level range from 10-50%. Shortage of farm labourers means that children are increasingly involved in agriculture, impacting their education and quality of life.'
> *International Service for the Acquisition of Agri-biotech Applications (ISAAA) AfriCenter and the African Biotechnology Stakeholder Forum (ABSF)*

Thus, the use of herbicide resistant crops will always have to be considered carefully on a case by case basis, taking into account the specific situation of the developing country concerned.

Case study 8: Biopharmaceuticals

3.62 An application of genetic modification that differs considerably from the previous examples is the possibility of producing biopharmaceuticals, such as vaccines, in crops. Two distinct procedures can be identified. One option is to modify plants so that they produce substances which can be extracted from the harvested plant and then processed into refined compounds. The other option is to modify plants in such a way that they produce vaccines which can be administered by eating the crop. This is achieved by changing the genetic structure of the crop to produce DNA fragments from a specific pathogen. These fragments code for proteins which provoke an immune response in the human body. The advantages of edible vaccines are manifold: injected vaccines are expensive, require trained medical staff for their administration, and usually require constant cooling during transport and storage, which creates difficulties in many developing countries. The use of needles also brings with it the risks of spreading infections.

3.63 Development of GM crops which can produce biopharmaceuticals is at a very early stage. Scientists at Cornell University are currently working on tomatoes modified to be used as a vaccine against the Norwalk virus, which causes severe diarrhoea. Studies on mice have already shown an increased immune response. In another study, bananas have been genetically modified to produce a vaccine against hepatitis, although it has not yet been

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[96] AEBC (2002) *Looking Ahead - An AEBC Horizon Scan* (London: Department of Trade and Industry).

[97] Wong K (2001) Souped-Up Spuds Show Promise for Edible Vaccines, *Scientific American*. Available: http://www.sciam.com/article.cfm?chanID=sa003&articleID=00019658-ED97-1C5E-B882809EC588ED9F. Accessed on: 20 May 2003.

possible to produce robust levels of antigens in the fruit.[96] There have also been experiments with GM potatoes aiming to develop a vaccine against rotavirus and against the bacterium *E. coli* which causes diarrhoea. Feeding studies involving mice have shown valid responses.[97]

3.64 However, a number of questions remain to be addressed. One of these is how the appropriate dose could be controlled. Another concerns the effect of such crops on insects and other animals which might feed on it. For example, it has been reported that avidin, which has been produced commercially in GM maize for use in research and diagnostics, is toxic for certain insects.[98] There are also environmental issues relating to gene flow from GM crops to non-GM crops. Furthermore, it has been reported that left-over grains from GM maize, modified to express biopharmaceutical compounds, have inadvertently germinated amidst soybeans grown on the same field in the season following the trial.[99] It is clear that this use of GM crops will require the provision of special agronomic facilities that restrict, for example, the spread of seed and pollen. Furthermore, appropriate regulatory oversight would need to be in place to ensure that the required standards are met.

Summary of case studies

3.65 We briefly summarize the possible benefits and risks which have been illustrated by the eight case studies. Current evidence suggests the following advantages of specific GM crops:

- The use of *Bt* cotton has resulted in more efficient and selective pest control, reduced applications of pesticides, reduction of environmental degradation, increased health benefits for farm workers and increased profits for farmers (case study 1).
- Improved resistance to environmental stresses such as cold, moisture-stress and high salt levels in the soil can be achieved in GM rice (case study 2).
- The yield in rice can be increased more efficiently by means of 'dwarfing', (case study 3), while maintaining the benefits of locally well adapted varieties.
- There is potential for the production of micronutrient-enriched rice which could make a significant contribution to prevent health problems such as VAD (case study 4).
- Case study 5 showed that the use of GM virus-resistant sweet potatoes could prevent dramatic and frequent reductions in yield of one of the major food crops of many poor people in Africa.
- Case study 6 on GM bananas illustrated the possibility of achieving protection against serious fungal diseases and reduction in pesticide use, with direct financial and health-related benefits for farmers and farm workers. Since bananas produce sterile pollen and only reproduce asexually, genetic modification could also help to produce a more diverse range of varieties, which would allow for additional protection against pests.
- Case study 7 demonstrated the possibility of reducing the use of environmentally damaging herbicides by the introduction of glyphosate resistant GM soybeans. In the absence of royalty fees being levied, farmers were able to increase their profit margins as a consequence of reduced costs for seeds and herbicides.
- Although somewhat more distant in terms of practical application, GM crops may also offer inexpensive and far-reaching provision of vaccines against diseases such as severe diarrhoea and possibly hepatitis (case study 8).

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98 GeneWatch (2003) Briefing No. 21 *Genetic Modification: The Need for Special Regulation* (Derbyshire, UK: GeneWatch). Avidin is an avian egg white protein, useful due to its high affinity to biotin. The avidin-biotin reaction has now become a tool in molecular biology, with numerous applications.

99 Cohen P (2002) Stray genes spark anger, *New Scientist* **176** (2370): 7.

3.66 We also noted the following possible risks associated with these benefits:

- The occurrence of gene flow, and the potential impact on other plants and organisms needs to be considered in the case of all GM crops which have been discussed, with the exception of bananas (case study 6). Transgenes inserted into crops for the production of biopharmaceuticals (case study 8) will require special consideration. The possibility of gene flow will also need to be considered carefully where a GM crop is planted in an area which serves as a site for *in situ* conservation of plant cultivars.
- Case studies 1 and 7 showed that the effects of genetic modification on insects and animals that may feed on the GM crop need to be evaluated. This aspect may be of particular relevance where crops have been modified to contain substances which wild relatives of the respective crops would not normally contain.
- There were also questions related to the setting of priorities: should developments such as Golden Rice (case study 4) or the production of biopharmaceuticals (case study 8) be pursued, if there could be other ways to achieve the same end? Would investments in these crops distract attention and resources from other approaches?
- Agrochemical companies and others who own IPRs for technologies necessary for the development of GM crops can have considerable influence over the availability of GM crops, as was clear from the case study on Golden Rice (case study 4), *Bt* cotton (case study 1), and on RR soybean (case study 7).
- The case study on *Bt* cotton (case study 1) showed that a multitude of factors determine whether or not the use of such GM crops is preferable to conventional crops. Some relevant factors are: the incidence of pests; the impact of pest control on other pests that might require additional applications of pesticides; the effective management of refuges; resistance of pests to toxins; and the size of any technology fee.
- Case study 7 on RR soybeans illustrated that particular care needs to be given to GM crops which have the potential of reducing labour. This can have negative consequences for those developing countries which have populations of working age unaffected by, for example, HIV/AIDS, and which practise non-mechanised agriculture.

3.67 We next consider arguments in relation to these potential risks and benefits, and possible ways to balance them.

Chapter 4

Questions relating to the use of GM crops in developing countries



Questions relating to the use of GM crops in developing countries

In view of the amount of food available worldwide, are GM crops really necessary?

4.1 Some argue that GM food crops are unnecessary because enough food is already produced globally. Instead, they recommend that greater effort should be given to achieving a more equitable distribution of food.[1] It is true that the world's current population could obtain more than enough calories and most other essential nutrients from the global production of staple crops. 3,600 calories per person per day are available.[2] However there are two critical objections to this argument.

- Most cattle and poultry consume maize or soybean. The conversion of fodder into meat and milk requires three to six times the amount of these crops than would be needed if people ate them directly. Therefore, the provision of 3,600 calories (or even only the recommended 2,000-2,500 calories), daily for each person from existing production of staple crops would require the consumption of meat, dairy products, eggs and poultry to be abandoned.
- The land on which to grow staple crops, and cash to buy them, would need to be distributed equally to all in the world, entailing considerable logistical and political challenges.

4.2 Progress towards such ends has been, and will probably remain, slow, as we pointed out in our 1999 Report (paragraph 4.8 of that Report). Moreover, the growing demand for meat, milk and eggs has meant that a rapidly rising proportion of the world's staple crops are used for their production. This rise is set to continue.[3] As for redistribution, political difficulties within, let alone between, countries would be considerable. In addition, there are onerous logistical problems to be taken into account. Costs for local and international distribution of food are high, and it may not always be possible to consider cultural preferences for certain types of food. All in all, while striving for a fairer distribution of land, food and purchasing power, we take the view that it would be unethical to rely entirely on these means to address food security. Given the limits of redistribution, we consider that there is a duty to explore the possible contributions which GM crops can make in relation to reducing world hunger, malnutrition, unemployment and poverty. We consider it unacceptable to reject such exploration on the basis that there are theoretical possibilities of achieving the intended ends by other means.

4.3 Providing farmers with, for example, pest-resistant crops is a more appropriate solution than the alternative of leaving them to rely on food donations supplied by the World Food Programme (WFP) or other organisations, if their harvest is destroyed by pests or viruses. The production of food is not just a necessity of life, but an integral part of social and cultural practice. A substantial part of people's livelihood in developing countries depends on agriculture. We conclude that the potential of GM crops to benefit small-scale farmers whose

1 Five Year Freeze (2002) *Feeding or Fooling the World?* (London: Five Year Freeze).

2 Prof Mazoyer in FAO Electronic Forum on Biotechnology in Food and Agriculture (2000) Background Document to Conference 5, 1 Nov – 17 Dec 2000 *Can agricultural biotechnology help to reduce hunger and increase food security in developing countries?* (FAO UN). Available: http://www.fao.org/biotech/C5doc.htm. Accessed on: 21 Oct 2003.

3 Delgado C *et al*. (1999) 2020 Vision for Food, Agriculture and the Environment Discussion Paper 28 *Livestock to 2020: The Next Food Revolution* (Washington, DC: IFPRI). A further increase in the use of staple crops for animal feed can be expected because animal feed derived from meat has been abandoned due to risks associated with BSE.

crops are seriously affected by droughts, pests or viruses should be explored as far as possible. We have noted promising approaches in the case of rice (see case study 2), GM sweet potato (see case study 5) and banana (see case study 6). If such crops can be made freely available in developing countries, they could contribute to preserving the independence and livelihood of farmers, and avoid reliance on redistribution or food aid.

Are alternative forms of agriculture, such as organic farming, better suited to improve agricultural practice in developing countries?

4.4 Farmers in many developing countries currently practise a form of organic farming. They are unable to afford artificial fertilisers, insecticides and pesticides. Some people in developed countries view this situation with approval and think that it is a particularly 'natural' and desirable form of agriculture. Often, they are unaware of the intensive inputs which are supplied by organic farmers in developed countries. But organic farmers in developing countries are usually not able to provide the continuous enrichment of the soil with fertiliser. On closer inspection 'organic farming' in developing countries takes on a different meaning. Most crop yields are too low to provide leftover material to replenish the land. Livestock produce poor quality manure which is mostly burned as fuel. Moreover, cattle are absent from large parts of Africa. Organic manures are little used as fertilisers, and exhaustion of soil nutrients is therefore widespread, leading to rapid soil degradation. Infestations of pests can seldom be countered effectively.[4]

4.5 As a consequence of these difficult conditions, crop yields are low. For example, yields of maize, rice and sweet potato are on average approximately half of those in developed countries.[5] In most of Africa, yields of staple crops are lower still. In addition, we have noted the devastating effect of fungal pathogens, viruses and weevils (see case studies 5 and 6). It is unlikely that organic farming alone can cope with these challenges and provide the basis for sustainable agriculture.

4.6 This view does not imply that other important strategies in agricultural research and practice should be neglected. For example, integrated pest management can be a useful way to combat *Striga*, a weed that attacks maize. Research has shown that planting maize together with the legume *Desmodium uncinatum* can help to control *Striga*. Biological control has also been an effective means of combating the cassava mealy bug. The introduction of a South American wasp, a natural enemy, has helped to reduce the impact of the pest.[6] Thus, many factors can contribute to improving agriculture. The development of better adapted crops is as important as the development of alternatives to inorganic fertilisers and pesticides, or the improvement of soil and water management.

4.7 As Gordon Conway, President of the Rockefeller Foundation, has recently observed, the question of whether agriculture should be improved by biotechnological approaches, rather than by more effective use of resources and alternative methods, is hardly ever a question of 'either/or'. It is mostly a situation of 'both/and': 'the best technology is the one that will safely get the job

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4 Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century.* Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf. Accessed on: 10 Oct 2003.

5 FAO (2002) FAOSTAT. Available: http://apps.fao.org/. Accessed on: 20 May 2003; Qaim M (1999) *The Economic Effects of Genetically Modified Orphan Commodities: Projections for Sweet Potato in Kenya* ISAAA Brief No. 13 (Ithaca, NY: ISAAA).

6 Herren HR (1995) Cassava and Cowpea in Africa, in *Biotechnology and Integrated Pest Management*, Persley GJ, Editor (Wallingford, UK: CABI Publishing); Khan ZR *et al.* (2002) Control of witchweed *Striga hermonthica* by intercropping with *Desmodium spp.*, and the mechanism defined as allelopathic, *J Chem Ecol* **28**: 1871–85. However, we note that, just as with the introduction of any new crop variety, whether GM or non-GM, all such measures have to be carefully considered with regard to their impact on biodiversity (see paragraphs 4.28-4.34). In all cases, a reasonable application of the precautionary approach needs to take place.

done in the simplest and least expensive way possible'.[7] Thus, while in some cases, organic farming has the potential to improve agricultural practices of small-scale, resource-poor farmers, it seems highly unlikely that it can address all of the serious problems which they face.[8] For example, growing rice in semi-arid areas (see case study 2), protecting crops from viral or fungal diseases (see case studies 5 and 6) or producing crops with higher levels of micronutrients (case study 4) may require other solutions. In these cases, the use of GM crops may be the more promising approach. We therefore take the view that sustainable agriculture can be achieved most effectively when the relevant approaches and practices are combined, as appropriate.

Will GM crops be of benefit only to large-scale farmers? Is the use of GM crops of advantage in the context of international trade?

4.8 We concluded in our 1999 Report that agriculture has a crucial role in reducing poverty and enhancing local food supply in developing countries. We noted that GM crops could have substantial potential to contribute to improving agriculture (see paragraphs 4.4-4.12 of the 1999 Report). In re-examining the arguments, we find our views confirmed in light of subsequent developments (see paragraphs 2.1-2.13).[9]

4.9 Poverty has many causes (see paragraphs 1.12-1.16). Poor efficiency of agriculture is one of them. It is also clear that the efficiency of agriculture has considerable impact on the standard of living of people involved in work on small-scale farms in developing countries. This is most notable in Africa, where the majority of the population live and work on small farms in rural areas (see paragraphs 2.10-2.11). Moreover, it is particularly true with respect to improving the situation of women, who make up the majority of the world's resource-poor farmers. While it is estimated that worldwide, women produce more than 50% of all the food crops, this percentage is considerably higher in many developing countries.[10] For example, it has been estimated that 80% of the food grown in sub-Saharan Africa, and 50-60% in Asia, is grown by women. In many instances, the improvements which can be achieved through GM crops may reduce much of the effort required in subsistence agriculture.[11]

4.10 With respect to crops grown primarily for commercial reasons, as in the case of *Bt* cotton in China and South Africa (see case study 1), we conclude that the case for the use of GM crops remains compelling. Beneficiaries of the crop have been predominantly small-scale farmers who manage farms of between one and two hectares. We have noted the significant financial gains (see Table 3.1) and benefits for the health of farm workers, and for the environment, resulting from considerable reductions in the amount of pesticides applied to GM varieties (paragraphs 3.30-3.31, see also case study 6 on GM bananas, and case study 7 on GM soybean).

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7 Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century.* Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf. Accessed on: 10 Oct 2003.

8 With regard to alternative ways of improving agricultural practice, Pretty *et al*. found one or more of the following four mechanisms to show significant effect: intensification of a single component of a farm system, addition of a new productive element to a farm system, better use of water and land, improvements in per hectare yields of staples through introduction of new regenerative elements into farm systems, and new locally appropriate crop varieties and animal breeds. See Pretty JN, Morison JIL and Hine RE (2003) Reducing food poverty by increasing agricultural sustainability in developing countries, *Agr Ecosyst Environ* **95**: 217–34.

9 Similarly, a recent report by DFID points out that agriculture is critical for the reduction of poverty in developing countries as it contributes to economic growth, provides a crucial basis for livelihood strategies of poor people and locally available staple foods for the poor, and enables a sustainable management of resources. DFID (2002) *Better Livelihoods for Poor People: The Role of Agriculture* (London: DFID).

10 DFID (2002) *Better Livelihoods for Poor People: The Role of Agriculture* (London: DFID).

11 FAO UN (1997) *The State of the World's Plant Genetic Resources for Food and Agriculture* (Rome: FAO UN),Background documentation prepared for the *International Technical Conference on Plant Genetic Resources*, Leipzig, Germany, 17 - 23 June 1996.

4.11 We also observed in our 1999 Report that it was important to consider the implications of GM crops for international trade (paragraphs 1.21, 4.31-4.32 of that Report). The main agricultural exports from developing countries are tea, coffee, cocoa, cotton and sugar. In the cases of cotton and sugar, products from developing countries will have to compete with those produced in developed countries. The use of *Bt* cotton and other GM crops is likely to become more widespread in developed countries. Any lowering of production costs for GM cotton growers is likely to lead to an increase in the global supply of cotton and probably, in the short term, to lower cotton prices. Those farmers who use non-GM varieties would face sharply reduced net income per unit of output. There is also the possibility of losing markets. It is therefore of crucial importance that developing countries have the opportunity to use high-yielding crops to allow their exports to compete on the world markets. Failure to develop the capacity to use GM crops safely may result in increasing the gap between the wealthy and the poor even further.[12]

4.12 However, some respondents to our Consultation have also suggested that it may be in the interest of developing countries to deliberately opt for a GM-free agriculture. Focusing on food crops, one respondent from the UK observed:

> 'There is little doubt that the European position – not only of government regulators, but perhaps more significantly of consumers too – will have an impact on the global trade in agricultural products. This creates a significant market for non-GM products (not necessarily organic). This market for key products with high export value – supermarket-supplied vegetables, soya beans, maize etc. may be highly advantageous for developing countries to capitalise upon.'
> *Anonymous*

4.13 The implications of decisions made by European policy makers and consumers are complex and are considered in more detail below (see paragraphs 5.16-5.21 and 5.37-5.50). In principle, it may be possible for developing countries to derive benefits from specialisation in non-GM agricultural exports. However, the conditions which have to be met for this to be feasible are manifold and demanding. The non-GM crops involved will need to command durable premium prices sufficient to cover the higher production costs, on their local, regional or global markets. 'Contamination' of non-GM material with GM material would have to be excluded. This would require strict monitoring of sowing, growing and transportation of harvested crops. Separation would need to be ensured in facilities for processing and storing produce. Potential spread of genetic material from GM crops grown in neighbouring countries would also have to be considered. Finally, there would be need to ensure that the probable steady rise in the excess production costs of non-GM varieties will not place those countries growing them at a competitive disadvantage. Possible health effects, for example arising from higher pesticide use on non-*Bt* crops would also have to be take into account (see case studies 1, 6 and 7).

4.14 Where countries decide to grow both GM and non-GM crops, the possibility of benefiting from exports of the latter will depend to a significant degree on the costs for the segregation during cultivation, harvesting and processing. Furthermore, the interplay between policy makers and farmers needs to be considered. While governments of developing countries may decide to adopt a non-GM policy, farmers may wish nevertheless to grow GM crops, if they promise higher yields or lower costs per unit. Hence, and this observation is particularly true for the scenario of a GM-free national agriculture, thought would need to be given to the ethical case, as well as the practical feasibility, of controlling and preventing illegal planting and selling of GM crops by impoverished smallholders.

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12 However, the uptake of GM crops in developing countries is, for a variety of reasons, not likely to be straightforward. In particular, the lack of appropriate systems for the administration and monitoring of the use of GM crops, and the restrictive policy currently adopted by the EU are likely constraints. These and other issues relating to international trade and policy will be considered in more detail in Chapter 5.

4.15 Lastly, GM crops may offer solutions to very specific climatic conditions prevalent in developing countries and allow for more effective control of pests and fungal infections (see case studies 1, 2, 5 and 6). Policy makers who favour the scenario of a GM-free national agriculture would need to consider whether the possible benefits offered by exporting non-GM crops are sufficient to justify forgoing the potential advantages of some GM crops, particularly for small-scale farmers who do not benefit from exports to developed countries.

Can GM crops be introduced in such a way that local customs and practices are respected?

4.16 It is sometimes argued that the introduction of GM crops into developing countries will transform agricultural practices without respecting local traditions. It is alleged that so-called 'informal seed systems' may break down, which could make it impossible for farmers to keep, or exchange harvested grain as seed for the next season.[13] In the 1990s, more than 80% of crops sown in developing countries were sown from farm-saved seeds.[14]

4.17 While it is clearly important to respect such traditions, we question whether, in contemporary agricultural practice, informal seed systems are significantly challenged. Neither GM crops nor conventional plant breeding more generally prevent farmers from retaining and re-sowing their own seed varieties or landraces if they prefer to do so. If new GM or conventionally bred seeds are preferred by farmers, that is entirely their own concern, provided the crops are safe for human consumption and the environment. Moreover, the retention of seed by farmers is more important for some crops and some countries, than others. Farmers are often aware that, for open-pollinated crops such as maize, saved seed produces lower yields than F1 hybrids (see paragraph 3.3). Many farmers in Zambia, Kenya and South Africa have therefore been buying hybrid seed from local or multinational companies for some years.[15] For self-pollinated crops such as rice and wheat, hybrids are unavailable. However, there is nothing to prevent farmers from retaining seed from the harvest for several years with only minor reductions in yield, as they have been doing for decades with leading varieties developed during the Green Revolution.[16]

4.18 Seed re-use can be prevented by technologies such as GURT which effectively sterilises saved seed (see paragraph 3.19). Such technologies continue to be patented and may be problematic, as we observed in our 1999 Report (see paragraphs 2.26 and 4.75 of that Report).[17] Nonetheless,

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13 Action Aid (1999) *AstraZeneca and its Genetic Research: Feeding the World or Fuelling Hunger?* (London: Action Aid); Christian Aid (1999) *Selling Suicide: Farming, False Promises and Genetic Engineering in Developing Countries* (London: Christian Aid); The Corner House (1998) *Briefing 10 - Food? Health? Hope? Genetic Engineering and World Hunger* (Sturminster Newton, UK: The Corner House).

14 Jaffee S and Srivastava J (1992) *Seed System Development: The Appropriate Roles of the Private and Public Sectors* World Bank Discussion Paper 167 (Washington, DC: World Bank); Srivastava JP and Jaffee S (1993) *Best Practices for Moving Seed Technology: New Approaches to Doing Business* World Bank Technical Paper 213 (Washington, DC: World Bank); Tripp R (2001) *Seed Provision and Agricultural Development: The Institutions of Rural Change* (Oxford: James Currey Publishers).

15 Thomson J (2002) *Genes for Africa: Genetically Modified Crops in the Developing World* (Cape Town: University of Cape Town Press); Ismael Y, Bennett R and Morse S (2002) Benefits of *Bt* cotton use by smallholder farmers in South Africa, *AgBioForum* **5**: 1–5; deVries J and Toenniessen G (2001) *Securing the Harvest: Biotechnology, Breeding and Seed Systems for African Crops* (New York: CABI Publishing).

16 Although there is some loss of yield if farmers apply this practice to the still infrequent F1 hybrids of such crops; we note however, that farmers are not compelled to adopt these varieties.

17 It has been reported that, despite its pledge in 1999 not to commercialise GURT, Monsanto has recently reconsidered its position. See Collins HB and Krueger RW (2003) *Potential Impact of GURTs on Smallholder Farmers, Indigenous & Local Communities and Farmers Rights: The Benefits of GURTs* Paper made available to the CBD's Ad Hoc Technical Expert Group on the Impact of GURTs on Smallholder Farmers, Indigenous People and Local Communities, 19 – 21 Feb 2003. The paper is presented as the official position paper of the International Seed Federation.

this development need not prevent farmers from continuing to save seed from non-terminated varieties.[18]

4.19 However, where farmers choose to buy seed, problems of affordability might arise if new varieties of crops, whether GM or not, are more costly than previously used seed. The prevalence of single monopolistic seed suppliers can further complicate access to inexpensive seed. It is therefore desirable that, as far as possible, farmers have a genuine choice. **To provide a genuine choice it is important that funding for research in the public sector be sustained, so that suitable seeds (whether GM or non-GM), which can be retained by farmers with minimal yield losses, are available. Policies also need to be in place to keep the private supply of seeds reasonably competitive**.

4.20 Some applications of GM crops might have detrimental effects on traditional farming practices, as has been suggested in the case of coffee.[19] However, we are not persuaded by the argument that the use of GM crops, as such, tends to disseminate Western farm practices which will displace the use of locally-adapted crops. As we have noted, researchers are using genetic modification to improve traditional crops such as rice (see case studies 2, 3 and 4) sweet potatoes (see case study 5) and bananas (see case study 6). These crops are frequently grown by small-scale farmers. They are important for subsistence farming and also for local trade. Much of this research is, moreover, being undertaken by researchers from developing countries.

Can GM crops make a relevant contribution to solving health problems in developing countries?

4.21 The development of Golden Rice (see case study 4) has been a focus of much public discussion. Strong claims have been made by both proponents as well as opponents, in some cases in the absence of validated empirical evidence. Some see Golden Rice as a prime example of an ineffective 'technological fix' and a waste of public and private funds. They argue that access to food should be achieved through reforms in political, economic and social policies rather than through the introduction of biotechnology-based solutions. Others claim that provision of a greater variety of food is the best solution to improving health.[20]

4.22 Most of the proponents of Golden Rice do not see the crop as a long-term substitute for a properly balanced diet. However green leafy vegetables, which are often cited as an appropriate alternative for the provision of vitamin A, are seldom inexpensive nor available year-round to people in developing countries. In addition, if and when they are available and affordable, several servings are required to provide a desirable level of vitamin A.[21] Therefore proponents argue that there is every reason to examine the potential of Golden Rice, and that even small increases in the level of vitamin A could be beneficial.

4.23 An important question is whether the increased levels of micronutrients available from Golden Rice are sufficient to achieve the benefits that are claimed. Assessments depend on a number of factors, including: (a) the estimated ideal amount of vitamin A to be ingested, usually expressed as recommended daily allowance (RDA); (b) the levels of ß-carotene produced by Golden Rice; and (c) the ratio at which ß-carotene is converted into vitamin A

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18 We also note that in developed countries, the use of GURT has been suggested as an effective way of preventing the spread of pollen from GM crops to neighbouring organic or conventional crops, a cause of great concern to many farmers.

19 Action Aid (2001) *Robbing Coffee's Cradle - GM coffee and its threat to poor farmers* (London: Action Aid).

20 Five Year Freeze (2002) *Feeding or Fooling the World?* (London: Five Year Freeze) p20–6; Ho M-W *'Golden Rice' - An Exercise in How Not to Do Science* (ISIS). Available: http://www.i-sis.org.uk/rice.php. Accessed on: 21 Oct 2003.

21 Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century.* Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf. Accessed on: 10 Oct 2003.

when digested. Regarding RDAs, the environmental group Greenpeace assumes that 400 micrograms of vitamin A per day are adequate for a child of between one and three years. Professor Potrykus and Dr Beyer report that provision of 300 micrograms of vitamin A is an acceptable level. RDAs for adults are estimated to be 50-100% higher.[22]

4.24 How much Golden Rice would a child have to eat so that VAD related diseases such as blindness and increased risk of mortality would be prevented? Assuming that the sole source of vitamin A would be Golden Rice, Greenpeace estimates an amount of approximately three kilograms of uncooked rice, equalling 7 kilograms of cooked rice.[23] The developers of Golden Rice take the view that approximately 200 grams of uncooked rice, or even less, could be sufficient. For the most part this difference can be explained as follows:

- Greenpeace bases its calculation on the assumption that 100 grams of Golden Rice yield 160 micrograms of ß-carotene. This level has been confirmed as robust in the first successful strains of Golden Rice. Greenpeace further estimates that ß-carotene from Golden Rice is converted into vitamin A in the same way as from leafy greens. Accordingly, a conversion rate of 12:1 is assumed. One hundred grams of rice would therefore provide 13 micrograms of vitamin A. To meet the daily requirement of 400 micrograms of vitamin A, approximately three kilograms (13 micrograms x 30) need to be consumed.[24]

- The developers of Golden Rice consider that the provision of 30-40% of the RDA is sufficient to prevent increased mortality and blindness in children. With regard to conversion rates they draw on data from the Indian Council of Medical Research and assume a rate of 4:1. One hundred grams of Golden Rice would therefore produce 40 micrograms of vitamin A. To attain the minimum daily requirement of 90-120 micrograms of vitamin A, 225-300 grams would have to be eaten. However, these estimates are based on the first generation of Golden Rice. Research is continuing and the production of significantly increased levels of ß-carotene in comparison to the first generation now seems feasible. For example, a threefold increase yielding 480 micrograms of ß-carotene would be equivalent to 120 micrograms of vitamin A per 100 grams of Golden Rice. This would already be sufficient to cover the daily requirement to prevent VAD-related ill health.[25]

4.25 Questions about the efficacy and efficiency of Golden Rice clearly depend upon further scientific research. It is particularly important to identify standard conversion rates for the production of vitamin A from ß-carotene in man. We understand that experiments to assess the levels of vitamin A uptake more precisely are being planned, to be led by the United States Department of Agriculture (USDA) Laboratory for Human Nutrition, Boston. These are expected to be completed by the end of 2005. We conclude that it is premature to proclaim that the approach will fail. The need being addressed is an urgent one. **It is therefore essential that reliable empirical data from nutritional and bioavailability studies be obtained as a priority. At the same time, in endorsing continuing research on crops such as Golden Rice, we**

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22 Greenpeace (2001) *Vitamin A: Natural Sources vs 'Golden Rice'*. Available: http://archive.greenpeace.org/~geneng/reports/food/VitaAvs.PDF. Accessed on: 20 Oct 2003; Beyer P and Potrykus I How Much Vitamin A Rice Must One Eat? AgBioWorld.org. Available: http://www.agbioworld.org/biotech_info/topics/goldenrice/how_much.html. Accessed on: 21 Oct 2003.

23 Greenpeace (2001) *Vitamin A: Natural Sources vs 'Golden Rice'*. Available: http://archive.greenpeace.org/~geneng/reports/food/VitaAvs.PDF. Accessed on: 20 Oct 2003.

24 Greenpeace (2001) *Vitamin A: Natural Sources vs 'Golden Rice'*. Available: http://archive.greenpeace.org/~geneng/reports/food/VitaAvs.PDF. Accessed on: 20 Oct 2003.

25 Beyer P and Potrykus I How Much Vitamin A Rice Must One Eat? AgBioWorld.org. Available: http://www.agbioworld.org/biotech_info/topics/goldenrice/how_much.html. Accessed on: 21 Oct 2003, see also Bouis H (2003) at the conference *Biotechnology and the Poor,* 7 Nov 2003, Cornell University, US.

emphasise that evaluation of its cost-effectiveness, risk and practicality in comparison to other means of addressing micronutrient deficiency is vital.[26]

4.26 The example of Golden Rice raises the question of the appropriateness of regulatory requirements. Regulatory provisions should always be proportionate to the risks implied. Unnecessarily stringent regulations that hinder the development of crops which can substantially improve malnutrition should be avoided (see paragraph 4.41). Costs for regulatory approval are considerable and there is a risk that only large multinational agrochemical companies will be able to cover them. These companies have so far tailored their research programmes predominantly to the needs of farmers in developed countries. Research on crops and traits relevant to the needs of small-scale farmers in developing countries has been mainly undertaken in the public sector. However, the high costs of gaining regulatory approval may deter publicly funded institutions from pursuing such research.

Will GM technology be controlled in ways that are compatible with self governance and economic security?

4.27 Case studies 2 and 5 (on drought resistant rice and virus resistant sweet potato) have shown that there is some evidence of increasing awareness to ensure the public availability of new varieties: in particular issues relating to access of poor farmers to beneficial varieties of seed should be considered early in the development phase. Case study 7 showed that some farmers were able to benefit from the absence of IPRs relating to GM soybean in Argentina. They were also able to take advantage of the increased competition between providers of agrochemicals. The latter provided considerably less costly generic versions of the herbicide glyphosate, which have entered the market since the expiry of Monsanto's patent on the compound. However, there have also been reports of difficulties with IPRs in the case of Golden Rice (see case study 4). We note that the increasing concentration of seed companies and their control over germplasm have raised concerns and consider these issues in Chapter 6.

Is the introduction of GM crops in developing countries consistent with a precautionary approach to biodiversity and human health?

Gene flow and biodiversity

4.28 The possibility that genes from GM crops may be transferred by pollen to other cultivars or wild relatives of the same kind of crop has caused concern. This phenomenon, termed *gene flow,* occurs frequently in nature where many plant species cross with related species to produce new kinds of plants.[27] Gene flow is in part responsible for the wide variety of plants which have evolved over many thousands of years. It may, however, be undesirable where it leads to the transfer of specific unwanted traits, or to the permanent and irreversible transformation of a species or variety. While the possibility for gene flow exists for both non-GM and GM crops, some fear that gene flow from GM crops could endanger biodiversity in a new way. In particular, this could occur where a GM crop has been modified to include a gene from another type of organism (see case study 1 on *Bt* cotton, and case study 8 on the production of biopharmaceuticals).

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26 Such comparisons would need to consider, for example, estimations of the cost of averting death by means of vitamin A supplements. One study considered data from the WHO and the United Nations Population Division and estimated the average cost per death averted at US$64 in 1999. Supplementation was carried out as an addition to vaccination programmes. However such approaches are hampered by logistical problems. For example, supplements distributed with a vaccine programme only help those who are able to reach the facility where the vaccination is carried out. See Ching P, Birmingham M, Goodman T, Sutter R and Loevinsohn B (2000) Childhood mortality impact and costs of integrating vitamin A supplementation into immunization campaigns, *Am J Public Health* **90**: 1526–9.

27 Ellstrand NC, Prentice HC and Hancock J (1999) Gene flow and introgression from domesticated plants into their wild relatives, *Annu Rev Ecol Syst* **30**: 539–63.

4.29 In the UK there are no indigenous close relatives of crops such as maize or wheat, reducing the chances of negative consequences of gene flow. However, the situation is different in other countries. For example, in Mexico, gene flow between modern cultivated maize varieties and ancient landraces or wild relatives is likely to occur. Mexico is home to many different kinds of maize, and is a centre of diversity for the crop. The different varieties are used as raw material to improve the quality of maize varieties by farmers and plant breeders around the world. It is feared that the introduction of genetic material from GM maize varieties may have a negative impact.

4.30 Considerable interest was therefore aroused when researchers at the University of California at Berkeley published findings in 2001 which claimed that genes from GM maize had crossed into native Mexican maize landraces and become permanently established in their genetic material (an event known as 'introgression'). The researchers further claimed that the transgenes were unstable and 'seemed to have become re-assorted and introduced into different genomic backgrounds'.[28] There are fears that these events could lead to unpredictable alterations in native maize. For example, a truncated promoter sequence might activate other genes. Some groups engaged in the monitoring of GM crops interpreted this as an instance of 'genetic pollution'[29] claiming that the 'well had been poisoned'.[30]

4.31 While it was unclear how the GM maize might have been introduced in Mexico, where a ban on GM crops has been in place since 1999, subsequent debate about the scientific validity of the research led the journal *Nature* to disavow the published paper.[31] The question of whether or not gene flow from GM maize had actually occurred was not disputed by any of the critics of the original paper and was subsequently supported by independent research.[32] Debate centred around methodological issues concerning the study design and data analysis, which were used to support the claim that the alleged introgression was a significant threat to biodiversity.[33]

4.32 The possibility of gene flow from GM crops may indeed require special attention. However, we need to be clear about the precise characteristics of gene flow. First, the fact that a crop has been genetically modified to express a particular trait does not automatically mean that this trait confers a selective advantage in the wild. A specific trait may be present for a

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28 Quist D and Chapela I (2001) Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico, *Nature* **414**: 541–3.

29 ETC Group (2002) Genetic Pollution in Mexico's Center of Maize Diversity, in *Backgrounder* (Food First Institute for Food and Development Policy) Spring 2002.

30 GRAIN (2003) Poisoning the well: the genetic pollution of maize, in *Seedling* 20 Jan 2003.

31 (2002) Editorial note, *Nature* **416**: 600.

32 In 2001, scientists of the Mexican National Institute of Ecology (INE) and the National Biodiversity Council (CONABIO) took randomised samples from 22 locations in Oaxaca and Puebla. The samples were split into two groups and analysed at the National Autonomous University of Mexico and the Centre for Investigation and Advanced Studies (CINVESTAV). Findings suggested that approximately 12% of the analysed plants contained transgenic promoters. In some areas, it was reported that up to 35% of the grain contained foreign sequences, see Mann CC (2002) Has GM corn 'invaded' Mexico?, *Science* **295**: 1617–9. It is assumed that gene flow occurred as a consequence of illegal planting of GM maize amidst conventional maize varieties, see Advisory Committee on Releases to the Environment (ACRE) (2002) Report on an article concerning gene flow from genetically modified maize to native landraces in Mexico. Available: http://www.defra.gov.uk/environment/acre/advice/advice14.htm. Accessed on: 21 Oct 2003. See also AgBioWorld.org: Mexican Maize Resource Library. http://www.agbioworld.org/biotech_info/articles/mexmaizeresource.html. Accessed on: 21 Oct 2003.

33 Two communications criticising the original findings of Quist and Chapela appeared in *Nature*, see Metz M and Fütterer J (2002) Suspect evidence of transgenic contamination, *Nature* **416**: 600–1; Kaplinsky N *et al*. (2002) Maize transgene results in Mexico are artefacts, *Nature* **416**: 601; together with a reply by Quist and Chapela on page 602 of the same volume. It was later alleged that the criticisms by Metz & Fütterer and Kaplinski *et al*. were lacking objectivity since the researchers received funding from the company Syngenta. The letter appeared in a later volume of *Nature*, see Worthy K, Strohman RC and Billings PR (2002) *Nature* **417**: 897; the same volume (pages 897–898) also includes a response by the accused researchers, addressing the allegation.

generation or two in wild plants, and then disappear, because other plants are more suited to the specific environment.[34] Nonetheless, in some instances, selective advantage has been reported, for example, in GM insect-resistant rape seed.[35] Possible risks would therefore depend largely on the particular crop and trait.

4.33 Secondly, research is being undertaken to prevent pollen-mediated transmission of transgenes by ensuring that transgenic DNA is not incorporated in the pollen.[36] Such research would be crucial in the case of GM crops used for the production of biopharmaceuticals (see case study 8). Thirdly, although pollen can travel over considerable distances, pollination, and therefore the successful transfer of genetic material, does not always occur.[37] Fourthly, appropriate separation distances can be established between fields containing GM and non-GM crops. Research to examine these and other issues is underway in the UK and other countries.[38] Where results of such research are not transferable to developing countries, additional research should be undertaken as necessary, to assess the impact of gene flow, particularly in centres of diversity. Finally, we note that many GM crops are male sterile varieties, which means that pollination cannot occur, although pollen may spread widely.[39] While these points make it clear that the risks of gene flow need to be assessed on a case by case basis, we recall that gene flow occurs widely throughout nature. Whether or not it is acceptable depends primarily on its consequences. Research to assess such risks is essential.

4.34 The question to be asked must therefore be: what kinds of risks are posed by the transfer of specific genetic material? Are these risks substantial? A necessary condition for answering these questions depends upon whether gene flow has occurred at a measurable level. We note that these two sets of issues are often confused. We accept that the introduction of GM crops in developing countries which are centres of diversity of specific crops may in some cases be problematic. **We recommend that in the case of sensitive areas such as centres of diversity, introgression of genetic material from GM crops in related species should be monitored. However, we are not persuaded that the possibility of gene flow should be sufficient to rule out the planting of GM crops in such areas, provided that regulatory requirements are met. Specific risks need to be assessed in particular contexts, and possibilities of safeguarding biodiversity must be considered carefully. The establishment and maintenance of comprehensive seed banks to conserve genetic resources of crop plants and their relatives is of crucial importance**.

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34 Brookes M (1998) Running wild, *New Scientist* **160** (2158): 38–41; Masood E (1999) UK gets the green light on modified crops, *Nature* **397**: 286.

35 Stewart C *et al*. (1997) Increased fitness of transgenic insecticidal rapeseed under insect selection pressure, *Mol Ecol* **6**: 773–9.

36 Daniell H *et al*. (1998) Containment of herbicide resistance through genetic engineering of the chloroplast genome, *Nat Biotechnol* **16**: 345–8; Gray A and Raybould A (1998) Reducing transgene escape routes, *Nature* **392**: 653–4.

37 ACRE (2000) *Gene Flow From Genetically Modified Crops* Unpublished Report (London: ACRE Secretariat, Department of the Environment, Transport and the Regions; Young J *et al*. (1999) *The Risks Associated with the Introduction of GM Forage Grasses and Forage Legumes* Report for MAFF (RG0219) Research Project (Aberystwyth: Institute of Grassland & Environmental Research).

38 Department for Environment Food and Rural Affairs (DEFRA) Farm Scale Evaluations. Available: http://www.defra.gov.uk/environment/gm/fse/index.htm. Accessed on: 21 Oct 2003.

39 Pretty J (2001) The rapid emergence of genetic modification in world agriculture: contested risks and benefits, *Environ Conserv* **28**: 248–62.

Box 4.1: **The precautionary approach**

The precautionary approach is invoked in order to address the absence of reliable scientific data, as stated in Principle 15 of the *Rio Declaration on Environment and Development:*

> 'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'*

The non-binding Declaration was agreed by 178 governments in Rio de Janeiro in 1992.

Similarly, Annex III of the *Cartagena Protocol on Biosafety* (see paragraphs 5.7-5.10) states that:

> 'lack of scientific knowledge or scientific consensus should not necessarily be interpreted as indicating a particular level of risk, an absence of risk, or an acceptable risk'.

* Rio Declaration on Environment and Development (1992) *The United Nations Conference on Environment and Development*, Rio de Janeiro, 3 - 14 June 1992. Available: http://habitat.igc.org/agenda21/rio-dec.htm. Accessed on: 21 Oct 2003.

The precautionary approach

4.35 Most people agree that an assessment of the environmental safety of GM crops should focus primarily on the severity of the consequences of gene flow. However, some also take the view that GM crops should not be developed at all because there may be a very low probability that some unpredictable and serious adverse consequences may ensue. This case is frequently argued in terms of the so called *precautionary approach* (see Box 4.1). The argument is that, irrespective of possible benefits, a new technology should never be introduced unless there is a guarantee that no risk will arise.

4.36 An alternative interpretation of the approach with regard to the use of GM crops is that it 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 new release of a GM crop into the environment needs to be considered on a case by case basis. Each application would require an iterative approach, beginning with the contained use of GM crops, followed by several smaller field trials, and then possibly by larger trials and a provisional and time limited commercial release.

4.37 How might we decide between alternative interpretations of the precautionary approach? We offer the following observations. First, an excessively conservative interpretation, demanding evidence of the absence of all risk before allowing the pursuit of a new technology is fundamentally at odds with any practical strategy of investigating new technologies. Pursued to its logical outcome, a conservative interpretation would require a delay (i.e. a moratorium) in the use of a new technology until a complete assurance of absence of risk is available. However, no one can ever guarantee an absolute absence of risk arising from the use of any new technology. In our view, such an approach would lead to an inappropriate embargo on the introduction of all new technology. There are countless recent cases which indicate that it would make impossible technologies which are now accepted by most people in developed countries, such as the wide deployment of vaccination programmes or the use of mobile phones or aeroplanes. We have come firmly to the view that the only sensible interpretation of the precautionary approach is comparative, i.e. to select the course of action (or of inaction) with least overall risk.

4.38 Secondly, it is easier to forgo possible benefits in the light of assumed hazards, if the existing status quo is already largely satisfactory. Thus, for developed countries, the benefits offered by GM crops may, so far, be relatively modest. However, in developing countries the degree of poverty and the often unsatisfactory state of health and agricultural sustainability is the baseline and the feasibility of alternative ways to improve their situation must be the comparator.

4.39 The precautionary approach is thus relevant to the effectiveness of conventional and 'organic' agriculture in developing countries. As we have noted (paragraphs 2.13-2.14), expansion into marginal lands is usually a source of increased average cost, reduced returns, and increased environmental hazards. Nonetheless, for want of other options, the expansion into marginal lands is widely practised throughout much of Africa. This leaves an unmistakable and undesirable *farming footprint* characterised by exhausted or overgrazed soils, and degraded forests and other areas of wildlife. Much of the current agricultural practice in the farming of cotton, bananas and soybeans requires the application of large amounts of pesticides and fungicides, with adverse consequences for the environment, and the health of farm workers (case studies 1, 6 and 7). Thus, questions about the use of GM crops need to be posed in the light of a realistic comparator system:

- How does the use of a GM crop compare to other alternatives?
- What are the risks of the non-GM approach, that would constitute the option of 'doing nothing'?
- In what respect are the risks posed by the introduction of a GM crop greater or less than those of the alternative system?
- Does the comparator system involve a higher level of benefits than the alternative system?

It seems likely that GM crops could have an active role to play in the safeguarding of the environment, if they can grow under more demanding conditions imposed by water shortages, or poor soils.[40] The precautionary approach should also be invoked in cases of biological control, where, for example, wasps, are deliberately imported from another continent to act as the natural enemy of a domestic pest (see paragraph 4.6). While these solutions can make valuable contributions to improving agriculture in developing countries, the alleged *naturalness* of the approach should not distract from careful analysis of possible impacts on the environment. Here, too, the potential for the irreversible alteration of eco-systems needs to be considered.[41]

4.40 Thirdly, to hold to the most conservative interpretation of the precautionary approach invokes the fallacy of thinking that the option of doing nothing is itself without risk. Yet, as we said in our 1999 Report (Chapter 4, see also paragraphs 2.9-2.13 above), food security and environmental conditions are actually deteriorating in many developing countries. This is not to say that we should be imprudent in the assessment of risks. It is to say, however, that restrictive interpretations of the precautionary approach, that imply a general prohibition on the use of GM technology, require very strong justification.

4.41 **We therefore conclude that an adequate interpretation of the precautionary approach would require comparison of the risks of the status quo with those posed by possible paths of action**. We use the term *precautionary approach* to indicate that it is

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[40] We have also pointed out that, in specific instances, GM crops can have the potential for improving biodiversity (paragraph 3.38) as increased numbers and varieties of spiders, beetles and other insects that are important food for a number of birds have been reported for *Bt* crops.

[41] See also Chapter 3, footnote 14.

not a single inflexible rule, as often implied when commentators refer to the 'precautionary *principle*', but a way of applying a set of interacting criteria to a given situation. Such assessments must be based on sound scientific data. This is consistent with a cautious attitude in the sense that rules and procedures need to be put in place to safeguard against any untoward effects and to mitigate their incidence should they occur. However, it recognises that there can be dangers in inaction, or alternative courses of action, as well as in the adoption of a particular innovation, dangers that are of particular importance when people are vulnerable and hungry. Thus, provided that technological expectations are met, it could well be argued that the use of Golden Rice can be justified by a reasonable application of the precautionary approach, if alternative approaches are less cost-effective and unable to achieve the aim of preventing VAD (see paragraphs 4.21-4.26).

4.42 It is also worth noting that the precautionary approach needs to be applied in ways that ensure broader policy aims are met. A useful contribution in this respect is the *Communication from the European Commission on the Precautionary Principle*, which recommends that measures based on the precautionary approach should be, among other things:

- proportional to the chosen level of protection;
- non-discriminatory in their application;
- consistent with similar measures already taken;
- based on an examination of the potential benefits and costs of action or lack of action (including, where appropriate and feasible, an economic cost/benefit analysis);
- subject to review, in the light of new scientific data; and
- capable of assigning responsibility for producing the scientific evidence necessary for a more comprehensive risk assessment.[42]

Food safety

4.43 Given the previous arguments, a reasonable interpretation of the precautionary approach should also be applied when assessing the safety of GM crops that are intended for human consumption. In this context, we welcome the use of the concept of 'substantial equivalence' as an essential part of safety assessments of GM crops. This concept, which has been endorsed by the World Health Organization (WHO) and the FAO/WHO Codex Alimentarius Commission, involves comparing the GM crop in question to its closest conventional counterpart.[43] The purpose of the procedure is to identify similarities and differences between a GM crop and a comparator which has a history of safe use. Although previous interpretations of the concept viewed 'substantial equivalence' as an endpoint in safety assessment,[44] the current interpretation favours the concept as a framework for a comparative approach.[45] The comparison does not aim to establish absolute safety, which is impossible to attain for any type of food. Rather, it should be seen as the first step in

42 *European Commission (2000) Communication from the Commission on the Precautionary Principle* COM(2000) 1, Summary p6. See also Section 6.3 of this Communication.

43 FAO and WHO (2000) *Safety Aspects of Genetically Modified Foods of Plant Origin* Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, WHO, Geneva, Switzerland, 29 May - 2 June 2000 (Geneva: WHO), paragraph 4.4.

44 See OECD (1993) *Safety Evaluations of Foods Derived by Modern Biotechnology: Concepts and Principles* (Paris: OECD).

45 GM Science Review (2003) First Report (London), p45; FAO and WHO (2000) *Safety Aspects of Genetically Modified Foods of Plant Origin* Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, WHO, Geneva, Switzerland, 29 May - 2 June 2000 (Geneva: WHO), paragraph 4.4.

Box 4.2: **Safety issues relating to GM crops**

Following identification of the differences between a GM crop and its nearest conventional counterpart, it may be important to consider the following aspects:

- process of genetic modification;
- safety of new proteins;
- occurrence and implications of unintended effects;
- gene transfer to gut microflora;
- allergenicity of new proteins;
- role of the new food in the diet; and
- influence of food processing.

identifying whether it is safe for human consumption. Although the approach is not infallible, it is useful for identifying intended or unintended differences which might require further safety assessments (see Box 4.2).[46]

4.44 The concept of substantial equivalence has been applied successfully to crops produced by other forms of contemporary plant breeding, such as mutation breeding (see paragraph 3.8). With regard to assessing risks that are specific to GM crops, we have already seen that the technique often involves the introduction of genetic material from other species. Risks may also arise from the use of gene sequences from some plant viruses to facilitate the expression of an inserted gene (see paragraph 3.10).

4.45 Fears have been expressed that viral promoters could produce new viruses that would affect humans. However, only a small part of a plant virus is used (usually the 35S promoter from the cauliflower mosaic virus). Additionally, viruses usually infect only a very narrowly defined range of species. It is therefore unlikely that viruses that are adapted to infect Brassicas would infect humans.[47] Another concern is that plant viruses may produce new viruses in humans by recombination with remnants of viral DNA sequences which exist in human DNA. However, research has shown that there are significant natural barriers to such a process.[48] Indeed humans have eaten virally infected plants for millennia and there is no evidence that new viruses have been created as a consequence.[49]

4.46 There are also questions about whether foreign genetic material that has been introduced into a GM crop will be absorbed by the body. When humans eat plants or animals, they also eat DNA. This also applies to GM crops. However, the fact that such crops have been

46 The European Network on Safety Assessment of Genetically Modified Food Crops (ENTRANSFOOD) incorporates a major cluster of EC-sponsored research projects and is set to publish a forthcoming report. The coordinator, H Kuiper concluded in a recent paper, "When evaluating a new or GM crops variety, comparison with available data on the nearest comparator, as well as with similar varietites on the market, should form the initial part of the assessment procedure". See Kok EJ and Kuiper HA (2003) Comparitive safety assessment for biotech crops, *Trends Biotechnol* **21**: 439.

47 Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health - an update* (London: Royal Society), p8.

48 Worobey M and Holmes E (1999) Evolutionary aspects of recombination in RNA viruses, *J Gen Virol* **80**: 2535–44; Aaziz R and Tepfer M (1999) Recombination in RNA viruses and in virus-resistant transgenic plants, *J Gen Virol* **80**: 1339–46.

49 Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health - an update* (London: Royal Society), p9. This Report also discusses other implications of the use of viral DNA in plants, relating to the use of the CaMV 35S promoter, which functions in a wide variety of species, and the possibility that viral DNA may activate so called transposable elements which are already present in the human genome. However, the Report concludes that risks to human health associated with the use of specific viral DNA sequences in GM crops are negligible.

genetically altered does not necessarily equate with the creation of new health risks. According to a recent FAO/WHO document, the amount of DNA which is ingested varies widely, but it is estimated to be in the region of 0.1 to 1.0 grams per day. Novel DNA from a GM crop would represent less than 1/250,000 of the total amount consumed.[50] The probability of gene transfer is extremely low. In fact, it would require that all of the following events occur:

- the relevant gene(s) in the plant DNA would have to be released, probably as linear fragments;
- the gene(s) would have to survive harvesting, preparation and cooking, and also nucleases in the plant;
- the gene(s) would have to compete for uptake with other dietary DNA;
- the recipient bacteria or mammalian cells would have to be able to take up the DNA and the gene(s) would have to survive enzymatic digestion;
- the gene(s) would have to be inserted into the person's DNA by very rare recombination events.[51]

Thus, the DNA of the modified crop will normally be processed and broken down by the digestive system in the exactly the same way as that of conventionally bred, or otherwise modified crops.[52]

4.47 Finally, a number of recent authoritative reviews have concluded that there are no proven health damages arising from the consumption of GM crop products on the market as yet.[53] However, long-term risks for most conventional foods have never been analysed. This is not because all naturally occurring, or conventionally bred foods are safe; indeed, the use of some conventional varieties of crops can have grave health consequences. For example, most varieties of *Lathyrus sativus*, a lentil formerly grown widely in North India and now spreading in Ethiopia, are known to cause the crippling disease of lathyrism. Traditional varieties of cassava in Nigeria also have dangerously high levels of hydrocyanic acid. Research on GM crops could create safer varieties of these and other crops which could replace harmful traditional varieties by reducing the levels of undesirable substances including mycotoxins, alkaloids and glucosinolates.[54] In our judgement, there is no empirical or theoretical evidence that GM crops pose greater hazards to health than plants resulting from conventional plant breeding. However, we welcome the fact that concerns about GM have focused attention on issues of safety with regard to new crops and varieties.

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50 FAO and WHO (2000) *Safety Aspects of Genetically Modified Foods of Plant Origin* Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, WHO, Geneva, Switzerland, 29 May - 2 June 2000 (Geneva: WHO), p11.

51 FAO and WHO (2000) *Safety Aspects of Genetically Modified Foods of Plant Origin* Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, WHO, Geneva, Switzerland, 29 May - 2 June 2000 (Geneva: WHO), p11.

52 FAO and WHO (2000) *Safety Aspects of Genetically Modified Foods of Plant Origin* Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, WHO, Geneva, Switzerland, 29 May - 2 June 2000 (Geneva: WHO); Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health - an update* (London: Royal Society).

53 GM Science Review (2003) First Report (London); ENTRANSFOOD Forthcoming report; International Council for Science (ICSU) (2003) *New Genetics, Food and Agriculture: Scientific Discoveries – Societal Dilemmas* (France: ICSU).

54 Mycotoxins, for example, are toxic chemical products formed by certain fungal species that readily colonise crops in the field or after harvest; they pose a potential threat to human and animal health through the ingestion of food products prepared from these commodities. Chronic levels are considered to be a major cause of infant mortality, inefficient nutrient uptake in humans and farm animals, liver and other cancers in adults, and may strongly contribute to the lower life expectancy in tropical and sub-tropical developing countries. See Biosafety Information Network and Advisory Service (BINAS) http://binas.unido.org/binas/. Accessed on: 10 Nov 2003.

Summary of Chapters 2-4

4.48 In the short time between the publication of our 1999 Report and 2003, there has been a substantial increase in evidence, relating to the use of GM crops in developing countries (see also Appendix 3). However, the debate about the safety of GM crops remains characterised by highly polarised views. Proponents often claim that all forms of GM crops will benefit developing countries, while opponents frequently argue that any applications of GM crops are unsuitable for use to farmers in developing countries. The examples in Chapter 3 amply demonstrate the potential advantages offered by some GM crops. The discussion in Chapter 4 shows that possible costs, benefits and risks resulting from the introduction of a specific GM crop in a particular developing country depend on a variety of factors and can only be assessed on a case by case basis (see also paragraph 4.36).[55] **We conclude that the potential benefits of contemporary plant breeding, including those arising from the use of genetic modification of crops, have been empirically demonstrated in some instances, and have considerable potential in others, to improve agricultural practice and the livelihood of poor people in developing countries while reducing environmental degradation. There is an ethical obligation to explore these benefits responsibly, in order to improve food security, profitable agriculture and the protection of the environment in developing countries** (see also paragraphs 1.20-1.31 of the 1999 Report).

4.49 **In assessing whether GM crops should be used or not, it is essential to focus on the specific situation in the particular countries, asking the question: 'How does the use of a GM crop compare to other alternatives?' All possible paths of action must be compared, including inaction, in respect of improving, in a cost-effective and environmentally sustainable way, human health, nutrition, and the ability to afford an adequate diet.**

4.50 **We do not take the view that there is currently enough evidence of actual or potential harm to justify a blanket moratorium on either research, field trials, or the controlled release of GM crops into the environment. We recommend that research on the use of GM crops in developing countries be sustained, governed by a reasonable application of the precautionary approach. Risks arising from the adoption of GM crops need to be compared with risks of other possible courses of action, and of the status quo. Accumulating evidence from new scientific developments must be used to inform discussions about the current or future use of GM crops. The views of farmers and other relevant stakeholders must also be taken into account** (see also paragraphs 5.33-5.34). Research and use of GM crops needs to be governed by appropriate regulation. We consider the current regulatory context, relevant recent developments in the area, and ethical issues arising from these, in the next chapter.

55 This approach may provoke the objection that most of the GM food crops which are promising for developing countries have not yet been planted in field trials, and that a robust assessment of their usefulness and the associated risks is therefore currently unavailable. However, this objection also applies to promising new developments in conventional plant breeding. With regard to both cases we take the view that it is too early to dismiss ongoing research in its entirety.

Chapter 5

Governance



Governance

5.1 Decisions regarding the development, planting and regulation of GM crops take place at many levels and are influenced by international regimes and national policies. They are also made by sub-national authorities, local communities and, ultimately, individual farmers and households. We have stressed that we cannot generalise about developing countries (see Box 1.1 and paragraphs 1.17-1.20). However, all such countries face the challenge of ensuring that policies towards GM crops make sense in the context of their own development needs, and also that they cohere with the complex system of international governance that is developing for GM crops.

5.2 In this chapter we:

- outline the system of governance that applies to GM crops, including issues of national administrative and technical capacity;
- identify emerging ethical and regulatory issues within this system, particularly relating to the level of authority at which decisions should be made; and
- highlight ethical and regulatory problems arising from the interdependence created through international trade.

Governance: international regulation

5.3 There are five main elements of international regulation relating to research into, and the trade and use of, GM crops:

- Agreements by the World Trade Organization (WTO) which aim to control barriers to international trade. It is within this framework that the US and a number of other states have most recently challenged the EU on the authorisation of GM crops.[1]
- The *Codex Alimentarius*, a set of international codes of practice, guidelines and recommendations pertaining to food safety. The WTO currently relies upon the *Codex* in making its adjudications.
- The *Cartagena Protocol on Biosafety* under the *Convention on Biological Diversity* (CBD), a multilateral agreement covering the movement across national boundaries of living modified organisms (LMOs) that might have an adverse effect on biological diversity.
- The *International Treaty on Plant Genetic Resources for Food and Agriculture* by the UN FAO, a multilateral agreement relating to any genetic material of plant origin of value for food and agriculture (not yet entered into force).
- Directives and Regulations by the EU and its regional policies on agriculture, environment and genetically modified organisms (GMOs).

The World Trade Organization

5.4 The primary purpose of the WTO is to facilitate international free trade. It aims to achieve this by establishing trade rules, serving as a forum for trade negotiations and assisting in the settlement of disputes. There are two principal agreements that relate to GM crops. They concern the negotiation of free trade (the *Technical Barriers to Trade Agreement*, TBT), and the protection of public health and welfare standards in member states of the WTO (the *Sanitary and Phytosanitary Agreement,* SPS, see Box 5.1).

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[1] de Jonquieres G, Alden E and Buck T (2003) Sowing discord: after Iraq, the US and Europe head for a showdown over genetically modified crops, *Financial Times* 14 May 2003, p21.

Box 5.1: **WTO agreements relating to the use of GM crops**

***Sanitary and Phytosanitary Agreement* (SPS)**

- The SPS allows members of the WTO to temporarily block trade in the interest of protecting public health. However, such decisions must be based on scientific principles, internationally established guidelines and risk assessment procedures.
- When there is insufficient scientific evidence to determine the likely risk arising from the import of particular goods, members of the WTO may adopt measures on the basis of available information. Additional information which can support the initial decision must be submitted within a reasonable period of time.
- The SPS does not permit members to discriminate between different exporting countries where the same or similar conditions prevail, unless there is sufficient scientific justification for doing so.

***Technical Barriers to Trade Agreement* (TBT)**

The TBT obliges members of the WTO to ensure that their national regulations do not unnecessarily restrict international trade. Three components make up the agreement.

- First, members are encouraged to accept 'standard equivalence' which means that the standards of other countries are mutually recognised through explicit contracts.
- Secondly, the TBT promotes the use of internationally established standards.
- Thirdly, the TBT requires members of the WTO to inform each other of relevant changes in policy. This means that members must establish centres that compile all available information on product standards and trade regulations. These centres must answer questions raised by other countries and consult with trading partners as requested, to discuss the relevant requirements for trade.

The Codex Alimentarius

5.5 The *Codex Alimentarius* was established by the Codex Alimentarius Commission, a subsidiary body of the FAO and the WHO. The Commission is the principal international body on food standards and represents more than 95% of the world's population. The primary aim of the *Codex* is 'to guide and promote the elaboration and establishment of definitions and requirements for foods to assist in their harmonisation and in doing so to facilitate international trade.'[2] The *Codex* consists of a collection of food standards, guidelines and other recommendations (see Box 5.2).[3] It also includes a Code of Ethics which aims to encourage food traders to adopt voluntarily ethical practices to protect human health and to ensure fair practices in food trade.

5.6 A conference organised jointly by the WHO and the FAO in 1999 addressed the question of how developing countries could participate more actively in the work of the Codex Commission. Delegates identified the need to make greater efforts to learn about and

2 FAO (1999) Understanding the *Codex Alimentarius*: Codex and the international food trade. Available: http://www.fao.org./docrep/w9114e/W9114e06.htm. Accessed on: 17 May 2003.

3 The *Codex Alimentarius* standards, guidelines and other recommendations cover a wide range of issues and currently comprise 204 Food Standards, 43 Codes of Practice, 197 evaluated Pesticides, 2516 Limits for Pesticide Residues, 25 Guideline Levels for Contaminants, 1300 evaluated Food Additives, 54 evaluated Veterinary Drugs and 289 Limits for Veterinary Drug Residues. See FAO (1999) *Food Quality, Safety and International Trade: Codex Alimentarius and the SPS and TBT Agreements* Agricultural Trade Fact Sheet. Available: http://www.fao.org/DOCREP/003/X6730E/X6730E05.HTM. Accessed on: 17 May 2003.

Box 5.2: **Standards of the Codex Commission relating to the use of GM crops**

- The standards set out by the *Codex* have been used widely as the benchmark in international trade disputes. They are explicitly referred to and adopted in the SPS agreement of the WTO, and the TBT agreement implicitly refers to them.
- Issues relating to the use of GM crops have recently been considered by the Codex Commission. At its meeting on 30 June – 7 July 2003 the Commission agreed three standards relating to GM crops:
  - *Principles for the Risk Analysis of Foods derived from Modern Biotechnology;*
  - *Guidelines for the Conduct of Food Safety Assessment of Foods derived from Recombinant-DNA Plants;* and
  - *Annex on the Assessment of Possible Allergenicity to the Guidelines for the Conduct of Food Safety Assessment of Foods derived from Recombinant-DNA Plants.**
- The principles include a science-based, pre-market risk assessment, performed on a case by case basis, and also an evaluation of both direct effects (from the inserted gene) and unintended effects (that may arise as a consequence of insertion of the new gene). Risk management should be based on the risk assessment and be proportionate to the risks identified. Effective post-market monitoring may in some cases require mechanisms of traceability and labelling to allow the withdrawal of products that pose risks to human health.

* Adopted at the Twenty-sixth Session held in Rome, 30 June – 7 July 2003. Report available: www.codexalimentarius.net/session_26.stm. Accessed on: 12 Nov 2003.

respond to concerns of consumers in these countries. Subsequently, National Codex Alimentarius Committees have been established with financial assistance from the FAO in most developing countries. These National Committees involve representatives of relevant government ministries, industry and consumer initiatives; each National Committee sends delegates to international Codex meetings.[4]

The Cartagena Protocol on Biosafety

5.7 At the time of publication of our 1999 Report, an international treaty which addressed possible risks posed by the introduction of GM crops was not in force. Negotiations on a protocol to the *Convention on Biological Diversity* (CBD), which focused on such matters, had been blocked by the US and a few other countries. However, agreement was reached in 2000 and the *Cartagena Protocol on Biosafety* was adopted by the parties of the CBD. It entered into force in September 2003. The Protocol was signed by 103 countries and has, to date, been ratified by 66 member states.[5] Although the US participated in the negotiations of the Protocol, it is not a member of the CBD and hence the Protocol is not applicable to US trade relating to LMOs. The EU ratified the Protocol on 27 August 2002, when *The Regulation of the European Parliament and of the*

4 FAO (1999) *Food Quality, Safety and International Trade: Codex Alimentarius and the SPS and TBT Agreements* Agricultural Trade Fact Sheet. Available: http://www.fao.org/DOCREP/003/X6730E/X6730E05.HTM. Accessed on: 17 May 2003.

5 *Convention on Biological Diversity. Cartagena Protocol on Biosafety.* Available: http://www.biodiv.org/biosafety/. Accessed on: 2 June 2003.

Council on the Transboundary Movement of Genetically Modified Organisms implemented the provisions of the Protocol into Community Law. The Protocol is an important regulatory device which relates directly to the trade and use of GM crops.

5.8 Article One lists the objectives as follows:

> 'to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.'

The Protocol contains procedural rather than substantive measures, relating to the provision of information and the carrying out of tests to assess the safety of LMOs such as GM crops. Some of the main procedures introduced by the Protocol are described in Box 5.3.

Box 5.3: **Main procedures of the *Cartagena Protocol on Biosafety***

- **Advanced informed agreement procedure (AIA):** before exporting LMOs which are intended for release in the environment, the recipient country must be notified. The notification must include a detailed description of the LMO, including reference to existing risk assessment reports. Only upon consent of the recipient country may the export take place (Articles 7-10).
- **Risk assessment:** parties to the Protocol decide whether or not to accept LMOs primarily on the basis of scientific risk assessment procedures. Parties may decide to apply a precautionary approach and refuse the import of LMOs if the available scientific evidence is considered insufficient. Parties may also take into account socio-economic implications likely to result from the import of LMOs (Article 15). Article 15 enables a potential recipient to require the exporter to carry out a risk assessment. It may also charge the exporting country the full cost of the regulatory approval.
- **Capacity-building and involvement of the public:** Article 22 expects the parties to the Protocol to cooperate in the development and/or strengthening of human resources and institutional capacities. Article 23 requires the involvement of the public in the decision making process.
- **Biosafety Clearing House:** in order to assist parties of the Protocol in its implementation and in order to facilitate the exchange of scientific, technical, environmental and legal information on, and experience with, LMOs, the Protocol established the Biosafety Clearing House as a central source of reference (Article 20).
- **LMOs intended for direct use as food or feed:** parties in developing countries can declare through the Biosafety Clearing House that they wish to take a decision based on risk assessment information before agreeing to accept an import (Article 11).

5.9 The Protocol differs significantly from the WTO's SPS in terms of provisions for risk assessment. Under the SPS, import restrictions can only be established on a temporary or provisional basis. The Protocol, on the other hand, endorses a more open-ended approach, drawing on the precautionary approach (see paragraphs 4.35-4.42). We welcome the development and implementation of the Protocol as an important and essential device in the regulation of the transboundary movement of LMOs, such as GM crops. However, with regard to the implementation of the Protocol, we caution against overly narrow application of the precautionary approach (see paragraphs 4.37-4.41). Due to international controversies about the use of GM crops, and due to lack of facilities for safety assessment, policy makers in developing countries are under substantial pressure to opt for a conservative interpretation of this approach. However, there is a real risk that highly restrictive legislation could considerably delay research, development and use of potentially beneficial GM crops in developing countries.

5.10 It could be argued that in view of the alleged risks posed by GM crops, developing countries should first implement rigid regulation which could then be deregulated as appropriate. However, significant difficulties can be encountered in the deregulation of previously established regulations, as revisions can be delayed considerably by unrelated political and administrative disputes. It is therefore important that all developing countries which are currently involved in the implementation of the *Cartagena Protocol* consider carefully how to interpret the provisions of the precautionary approach, to allow for appropriate regulation before the need arises. **We draw attention to our view that a highly restrictive interpretation of the precautionary approach is likely to ignore the possibility that, in some cases, the use of a GM crop variety may pose fewer risks than are implied by current practices or by plausible non-GM alternatives. In applying the precautionary approach, risks implied by the option of inaction (or by alternative actions) must also be considered.**

The International Treaty on Plant Genetic Resources for Food and Agriculture

5.11 The *International Treaty on Plant Genetic Resources for Food and Agriculture* (henceforth: the Treaty) was unanimously adopted by members of the FAO's Conference of November 2001.[6] The objectives of the Treaty are the conservation and sustainable use of plant genetic resources, and the fair and equitable sharing of benefits derived from their use, so as to promote sustainable agriculture and food security. 'Plant genetic resources' are defined as 'any genetic material of plant origin of actual or potential value for food and agriculture'.

5.12 The exchange of plant genetic resources is indispensable for research and development of improved crops. Over recent decades, it has become increasingly common for the exchange of resources used for academic or commercial research to be covered by material transfer agreements (MTAs, see paragraphs 3.47 and 6.3-6.4). The new Treaty will establish a multilateral system for access and benefit-sharing for 33 important crops that are under the management and control of the Contracting Parties and in the public domain (Article 11.1 and Annex 1).

5.13 To facilitate access to these plant genetic resources, a standard MTA will be established, setting out the terms and conditions under which the resources can be used, for instance, 'solely for the purpose of utilisation and conservation for research, breeding and training for food and agriculture' (not, for example, for pharmaceutical use). The MTA will also require the sharing of benefits relating to information, technology, strengthening of

6 See Commission on Genetic Resources for Food and Agriculture *The International Treaty on Plant Genetic Resources for Food and Agriculture.* Available: http://www.fao.org/ag/cgrfa/itpgr.htm. Accessed on: 18 May 2003.

expertise and monetary benefits, arising from the use of the resources covered by the Treaty (Section 12.4 and 13.2.d). Article 13.2.d(ii) requires that a recipient who commercialises a product that involves material accessed through the multilateral system, shall pay 'an equitable share of the benefits arising from the commercialisation of that product' into a fund established by the Treaty unless access to the commercialised product is not restricted (for instance, by a patent), in which case payment is merely encouraged.

5.14 Article 13.2.d(ii) also provides that the Treaty's Governing Body, which consists of those countries which have ratified the Treaty, shall determine at its first meeting the level, form and manner of the payment, in line with commercial practice. The Governing Body may decide to establish different levels of payment for various categories of recipients who commercialise such products. It may also choose to exempt from such payments small-scale farmers in developing countries and in countries with economies in transition. Levels of payment are to be reviewed from time to time, as well as provisions which concern the question of whether benefit-sharing should also be mandatory where access to the product is not restricted. The Treaty has been signed by 78 members and non-members of the FAO. At the time of publication, fourteen countries have ratified the Treaty. It is due to enter into force 90 days after ratification by 40 governments.

5.15 **We welcome the recent decision by the UK Government to ratify the *International Treaty on Plant Genetic Resources for Food and Agriculture*. Access to resources falling under the Treaty is of crucial importance in the development of crops suited to developing countries. We recommend that in the negotiations regarding the standard Material Transfer Agreement (MTA), the UK Government aims for provisions that exempt users in developing countries from payments, where commercial applications arise from material covered by the MTA. Where exemptions are not appropriate, differentiation of payments should take into account the level of development of the country in question.**

The European Union

Directive 2001/18/EC and *Directive 90/220/EEC on the deliberate release into the environment of genetically modified organisms (GMOs)*

5.16 The current EU legislation on GMOs is regarded as the strictest in the world. *Directive 90/220/EEC* relating to experimental releases and marketing of GMOs was entered into force in 1990. Eighteen applications, relating to varieties of GM soybean, maize and oilseed rape have received authorisation. However, shortly after implementation of the Directive, member states of the EU decided that it should be amended in the light of considerable advances in genetic modification in the 1990s. In the ensuing debate, five member states invoked the so-called safeguard clause of *Directive 90/220/EEC* in 1998. The clause allowed member states to temporarily ban a genetically modified product on its territory if there was substantial evidence that it implied risks to human health or to the environment.[7] This resulted in a stalling of evaluations of further applications, and a declaration of a *de facto* moratorium at an EU Environment Ministers Council meeting in June 1999. While some viewed this as a reasonable application of the precautionary approach (see paragraphs 4.35-

7 Article 16, the so-called safeguard clause, stated 'Where a Member State has justifiable reasons to consider that a product which has been properly notified and has received written consent under this Directive constitutes a risk to human health or the environment, it may provisionally restrict or prohibit the use and/or sale of that product on its territory. It shall immediately inform the Commission and the other Member States of such action and give reasons for its decision.' (Council *Directive 90/220/EEC* Article 16.)

4.42), others perceived it to be primarily a barrier to trade, violating the WTO agreements. It has been claimed that the moratorium cost the US US$250-300 million a year in lost exports.[8]

5.17 After substantial revisions, *Directive 90/220/EEC* was replaced by *Directive 2001/18/EC* in October 2001. It introduced the following measures to ensure that the regulation of GMOs would meet the demands of EU regulators and consumers:

- principles for environmental risk assessment (see Box 5.4);
- mandatory post-market monitoring requirements, including any long-term effects arising from the interaction with other GMOs and the environment;
- mandatory information for the public;
- a requirement for member states to ensure labelling and traceability at all stages of marketing (see paragraphs 5.20-5.21); and
- commercial approvals for the release of GMOs to be limited to a maximum of ten years.

5.18 *Directive 2001/18/EC* requires a step by step approval process for GMOs. The procedure is as follows: a company wishing to market a GMO must first submit an application to the relevant national authority of the EU member state where the product is to be marketed. This application must contain a full environmental risk assessment. The assessment needs to take into account direct or indirect effects on human health and the environment which may arise from the deliberate release or marketing of the GMO(s). The assessment must also consider whether these effects might be manifested immediately, cumulatively or on a long-term basis.[9] Box 5.4 shows the methodology of the risk assessment process. If the national authority is satisfied with the application, the authority informs the other EU member states through the European Commission (EC). If, within a specified time limit, no objections from other states are received, approval is granted and the product can be placed on the market throughout the EU.

Box 5.4: **Risk assessment methodology in *Directive 2001/18/EC***

- Identification of any characteristics of the GMO(s) which may cause adverse effects.
- Evaluation of the potential consequences of each adverse effect.
- Evaluation of the likelihood of the occurrence of each identified potential adverse effect.
- Estimation of the risk posed by each identified characteristic of the GMO(s).
- Application of management strategies for risks from the deliberate release or marketing of GMO(s).
- Determination of the overall risk of the GMO(s).

8 Mitchell P (2003) Europe angers US with strict GM labelling, *Nat Biotechnol* **21**: 6.

9 Council *Directive 2001/18/EC* Annex II.

5.19 As noted above, *Directive 2001/18/EC* introduces basic provisions for a traceability system for GMOs. However, the Directive contains neither a definition of traceability, nor a complete approach for its implementation. These issues, and more detailed regulation concerning the labelling of GMOs and products derived from GMOs are addressed in two more recent regulations.

Regulation 1830/2003/EC on Traceability and Labelling

5.20 *Regulation 1830/2003/EC concerning traceability and labelling of genetically modified organisms and traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC* was formally adopted by the Council of Ministers in July 2003. It has the objective of controlling and verifying labelling claims; facilitating the monitoring of potential effects of GMOs on the environment; and enabling the withdrawal of products that contain or consist of GMOs that might prove to pose unforeseen risks to human health or the environment. The Regulation requires the labelling of all foods produced from GMOs. However, in November 2002, the European Council agreed that food and feed do not have to be labelled if the amount of genetically modified material is below a threshold of 0.9%, and if its presence could be shown to be unintentional and technically unavoidable. The threshold for the presence of GMOs which have not yet received approval in the EU was set at 0.5%. Although the primary criterion for labelling is detectibility, processed foodstuffs such as highly refined oils derived from GM crops, which do not contain genetic material of the original GM crop, still have to be labelled as 'GM' according to the new Regulation.[10]

5.21 With regard to traceability, the Regulation requires that GMOs must be traceable throughout the entire production and distribution process. Thus, a company selling GM seed must inform any purchaser that the seed has been genetically modified, supplying specified information on the identity of the individual GMO(s). The company is required to keep a register of all recipients of the seed concerned for five years. Similarly, farmers who buy GM seed must transmit relevant information to those who buy their harvest, and keep a register of recipients. In the case of food and feed produced from GM crops, the process is repeated throughout the production and distribution chain.

Regulation 1829/2003/EC on GM Food and Feed

5.22 A second Regulation which was formally adopted by the Council of Ministers in July 2003, is *Regulation 1829/2003/EC on genetically modified food and feed*.[11] The new component which the Food and Feed Regulation introduces is a centralised authorisation procedure for GMOs used as food or animal feed. This means that those wishing to market GM crop in the EU need not request separate authorisations for the use of the crop as food or feed. A crop is either authorised for both uses, or for neither.[12] The use of GMOs in animal feed did not previously require a specific authorisation procedure. The Regulation will thus have an impact on imported GM crops, which are predominantly used as feed for animals. In view

10 However, food produced with the help of a GM enzyme, such as bakery products that involve amylase, do not need to be labelled.

11 The Regulation replaces the authorisation for GM foods and food ingredients, which was previously covered by the *Novel Food Regulation (EC) 258/97.*

12 One of the reasons for this approach is to prevent controversies such as those caused by the Bt maize variety StarLink™. StarLink™, produced by the company Aventis, received regulatory approval from the US Environmental Protection Agency (EPA) to be used as animal feed only. However, in 2000, traces of StarLink™ were found in taco shells which were sold in supermarkets in the US.

of the current stance of EU consumers, the Regulation is likely to give a considerable advantage to those producers who offer non-GM crops. The labelling requirements for GM crops which are used as feed follow the *Traceability and Labelling Regulation*, outlined above. However, the *Food and Feed Regulation* exempts products such as milk and meat, obtained from animals fed on GM crops, from mandatory labelling.

Regulatory and ethical issues

National administrative and technical capacity of regulating the use of GM crops in developing countries

5.23 We have noted that a number of the international agreements require the regulation of GM crops by administrative and technical measures at the national level. However, costs for provision of the relevant authorities which could undertake and verify risk assessment procedures are considerable, as is evident from the comprehensive European regulatory framework. It is not yet clear how different developing countries will respond to the requirement of establishing such regulations. We are likely to see considerable variation between developing countries. A recent document produced by the UK Prime Minister's Strategy Unit on the implications for developing countries of GM crops suggests that there is some pattern in this variability.[13] Across eleven countries it assesses the capacity to undertake biotechnology assessments as ranging from advanced, in countries such as China, India and Brazil, to weak or non-existent in Kenya, Zambia and Mozambique.[14] However, even this classification may be too general to be useful. The capacity of national agricultural research systems also varies widely. Weaknesses at the national level are often accompanied by weaknesses at the local level, particularly in agricultural extension systems.

5.24 At present, most developing countries do not have appropriate legal and administrative systems in place to regulate biotechnology-related activities as required by the *Cartagena Protocol*.[15] However, initiatives such as the joint project by the United Nations Environment Programme and the Global Environment Facility (UNEP/GEF) on the *Development of National Biosafety Frameworks* (2002-2004) have recently been initiated. The aims of the project are to prepare parties of the *Cartagena Protocol* for entry into force of the treaty; to assist countries which are eligible under GEF to prepare frameworks for national biosafety; and to facilitate regional cooperation between countries.[16] The project brings together more than 100 countries and has close working relations with other relevant organisations.[17] It has received support from the UK Department for International Development (DFID), which seeks to devise guidelines for participation by the public in decision making processes for biosafety frameworks, and also from the EC. The EC recently

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13 The UK Strategy Unit has published a working paper considering the potential economic impact of the commercialisation of GM crops in the UK on developing countries, see Strategy Unit (2003) *Developing Country Background Working Paper: Potential UK impact on developing countries*. Available: http://www.number-10.gov.uk/su/gm/developing.pdf. Accessed on: 30 Oct 2003.

14 Strategy Unit (2003) *Developing Country Background Working Paper: Potential UK impact on developing countries*, p35. Available: http://www.number-10.gov.uk/su/gm/developing.pdf. Accessed on: 30 Oct 2003.

15 United Nations Environment Programme (UNEP) – Global Environment Facility (GEF) *Project on the Development of National Biosafety Frameworks* Business Plan for 2002-2004 (Geneva, Switzerland: UNEP); Kinderlerer J (2002) Regulation on Biotechnology: needs and burdens for developing countries. Available: http://www.unep.ch/biosafety/BTregulationJK.pdf. Accessed on: 23 March 2003.

16 UNEP – GEF *Project on the Development of National Biosafety Frameworks* Business Plan for 2002-2004 (Geneva, Switzerland: UNEP), paragraph 1.2.

17 Such as the Bureau of the Intergovernmental Committee on the *Cartagena Protocol on Biosafety* (ICCP), the Secretariat of the CBD, the World Bank, the United Nations Development Programme (UNDP) and the International Centre for Genetic Engineering and Biotechnology (ICGEB).

offered to fund an initiative to help develop guidelines for establishing risk assessment and management systems for participating countries.[18]

5.25 It is of particular importance that developing countries improve their capacity to independently review and assess the use of GM crops in specific situations. As one respondent to our Consultation observed:

> 'There is a very urgent requirement to empower developing countries to make their own risk/benefit assessments and decisions to implement technologies, based on their local needs. Otherwise they will remain the victims of others' agendas. Key elements are capacity building in biosafety assessment and intellectual property management…'
> *Dr Ray Mathias, John Innes Centre, UK*

We share this view and emphasise that those involved in the use and regulation of GM crops in developing countries need to decide on suitable devices and procedures to govern the use of GM crops themselves. **Since means for the development of the required expertise are limited in most developing countries, we welcome and endorse the UNEP/GEF undertaking of promoting the building of capacity in relevant expertise.**

5.26 Similar projects have recently been announced by the FAO, to the same ends.[19] Whilst the commitment of any international organisation to the improvement of administrative capacity in developing countries is to be welcomed, duplication of effort among international organisations can be counter-productive. Administrative resources are scarce in developing countries and it is important to ensure that international development efforts are coordinated.

5.27 It is clear that regulation needs to be established primarily at the national level. However, diverse regulations, requiring that every new GM crop is assessed for possible risks to human health and the environment in each country, can cause problems. For most developing countries, it will be a major financial and logistical challenge to provide the capacity and resources to undertake such evaluations. The absence of appropriate testing facilities could delay the granting of approval for much needed improved crops. **We therefore recommend that particular attention should be given to measures that will enable the sharing of methodologies and results. An example is environmental risk assessments for countries which have similar ecological environments. It should also be considered whether harmonised regional policies can be established, for example by the Southern African Development Community (SADC) and the Common Market for Eastern and Southern Africa (COMESA).[20] In this context, we welcome the recent initiative by SADC to produce**

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18 UNEP - GEF Project on the *Development of National Biosafety Frameworks* Business Plan for 2002-2004 (Geneva, Switzerland: UNEP), paragraph A4.3.

19 Fresco L (2003) "Which Road Do We Take?" Harnessing Genetic Resources and Making Use of Life Sciences, a New Contract for Sustainable Agriculture, in *EU Discussion Forum Towards Sustainable Agriculture for Developing Countries: Options from Life Sciences and Biotechnologies* FAO, Brussels, 30-31 Jan 2003.

20 COMESA is a regional grouping of 20 countries of Eastern and Southern Africa with a population exceeding 380 million. It was established in 1994 to replace the Preferential Trade Area for Eastern and Southern Africa (PTA) which had been in existence since 1981. COMESA aims to function 'as an organisation of free independent sovereign states which have agreed to co-operate in developing their natural and human resources for the good of all their people.' SADC comprises 14 Southern African nations and has the general aims of achieving development and economic growth, alleviating poverty, enhancing the standard and quality of life of the people of Southern Africa and supporting the socially disadvantaged through regional integration.

guidelines on food safety assessment and management of GM crops.[21] **We also recommend that developing countries should implement as far as possible standardised procedures for the assessment of environmental and health risks. Established international guidelines such as the *Cartagena Protocol on Biosafety*** (see paragraphs 5.7-5.10) **and the guidelines of the Codex Commission** (see paragraphs 5.5-5.6) **should be considered. Care must be taken to avoid an overly restrictive interpretation of the precautionary approach** (see paragraphs 4.37-4.41 and 5.10).

5.28 The transfer of experience from advisory and regulatory bodies in developed countries to the developing world is urgently needed (see paragraphs 4.49-4.62 of our 1999 Report). Poor compliance of farmers with technical specifications, illegal planting of *Bt* cotton in India[22] and the smuggling of GM soybean seeds from Argentina to Brazil are already raising concerns.[23] By ensuring appropriate public awareness, and by insisting on transparent arrangements for overview and enforcement, costs and any risks associated with GM crops can be minimised (see paragraphs 5.30-5.36).

5.29 What kind of regulatory systems are appropriate for the enforcement of biosafety regulations in developing countries? It is again difficult to generalise. For example, in China and Ghana, very different conditions prevail with regard to the capacity for policy enforcement, the number of farmers, and the type of agriculture. In particular, the very large number of small-scale farmers in developing countries poses great challenges for enforcement.[24] It seems unlikely that regulation can be achieved successfully by a compulsory 'command-and-control' approach. Such measures may be successful in developed countries, where licensing and monitoring is frequently a standard component of agricultural policy. However, in many developing countries it will be more likely that the intended effect of a particular policy will be achieved by incentives and well developed extension systems. An assessment of appropriate regulatory systems at the national level is beyond the scope of this Discussion Paper.

Local autonomy and choice

5.30 We now consider who, within a complex system of governance, should have the responsibility for deciding whether or not to use GM crops. In particular, the question arises whether it would be right to prevent farming communities in developing countries from adopting GM crops if they thought it was to their advantage. In this context, some might see an argument for the application of the principle of subsidiarity. The principle of subsidiarity says that, within a system of governance, decisions should be taken at the

21 Njoroge J (2002) Southern African nations to probe GM safety, *SciDev.Net*. Available: http://www.scidev.net/News/index.cfm?fuseaction=readnews&itemid=273&language=1. Accessed on: 2 June 2003; SADC (2003) Launching of the SADC Advisory Committee on Biotechnology and Biosafety. Available: http://www.sadc.int/index.php?lang=english&path=newscenter/mediareleases/&page=mr35_16042003. Accessed on: 20 May 2003.

22 Jayaraman KS (2002) Poor crop management plagues *Bt* cotton experiment in India, *Nat Biotechnol* **20**: 1069, see Chapter 3, footnote 14.

23 Bonalume Neto R (1999) Smugglers aim to circumvent GM court ban in Brazil, *Nature* **402**: 344–5.

24 It is estimated that there are about 817 million small-scale farmers in developing countries, see FAO (1988) *The Impact of Development Strategies on the Rural Poor: Second Analysis of Country Experiences in the Implementation of the WCARRD Programme of Action* (Rome: FAO).

lowest possible level, provided that goals such as safety and environmental protection are secured. Why might this principle be thought to apply?

5.31 First, in many cases the beneficiaries of GM crops may be poor communities in developing countries for whom improved agriculture is crucial. If members of such communities believe that a particular technology can be an important means of improving their livelihoods, then it may be argued that it would be wrong to prevent them from pursuing that option. Secondly, there is evidence of illegal plantings of GM crops in some developing countries, most notably of soybean in Brazil and cotton in India. This indicates that irrespective of decisions made at the national level, promising technologies will be taken up regardless. It might therefore be better to allow communities to adopt the technology within a framework of regulation, despite its inevitable inadequacies, than to have them try it outside such a framework. Thirdly, there is evidence that it is institutions at the level of the local community, rather than the state, in which members of poor farming communities have most confidence.[25] Small-scale farmers are some of the most vulnerable people in the world. If they are enabled to make their own decisions within their own communities, then they can exercise some influence over their own future.

5.32 In principle, we sympathise with this approach, but we also anticipate problems. First, would local communities be given real or merely nominal control, if the decision to grow GM crops were left to them? In view of the increasing concentration of biotechnology, seed and agrochemical companies, many decisions are taken by powerful corporations. It seems unlikely that local communities would be given an equal role in negotiations. We therefore see a real risk of exploitation if the principle of subsidiarity were rigidly applied. Secondly, important issues are raised in the context of international trade. It could be the case that a particular community decides to grow GM crops, but in doing so affects the ability of others in the country to export crops of the same kind to external markets that have a restrictive policy towards GM crops. Thirdly, we have noted that the administrative and technical capacity of developing countries to monitor and regulate health and environmental effects, even at the national level, is often very limited. It seems unlikely that local communities would be able to undertake individual environmental and health risk assessments.

5.33 Nevertheless, local communities should be included as far as possible in decision making processes, for example by means of consultations with stakeholders. In this context, formal and non-formal programmes that promote the dissemination of balanced information, communication, education and training of those involved are essential. In particular, farmers need to be informed about the technological potential and management requirements of GM crops. Expectations are sometimes inappropriately high, and knowledge about specialised farm management practices may be absent. **We recommend that companies marketing GM crops in developing countries share, with governments, the costs of:**

- **locally appropriate schemes to elicit small-scale farmers' preferences regarding traits sought by GM-based breeding;**
- **their participation, where appropriate, in plant breeding; and**
- **subsequent mechanisms to improve dissemination of balanced information, education and training about the use of GM crops.**

25 Pimbert M and Wakeford T (2002) Prajateerpu: Food and Farming Futures for Andhra Pradesh: A Citizens' Jury / Scenario Workshop, *Economic and Political Weekly* [India] **37**: 2778–87 (Review of Science Studies), 6-12 July 2002.

5.34 Such measures can help to ensure that the views of farmers and other stakeholders are considered in the decision making processes about the possible use of GM crops. **We conclude that the most appropriate approach would normally be a centralised and evidence-based safety assessment at the national or regional level. Environmental and health risks should be assessed on a case by case basis. Wherever possible, such assessments should consider information which is available from international sources, particularly with respect to data about food safety assessments, which are more transferable than environmental risk assessments.**

5.35 While such arrangements could enable an appropriate means of balancing benefits and risks of GM crops, we need to consider one additional element that is crucial for an efficient and effective regulatory framework. This is the provision of a system of remediation in the case of crop failures. As one respondent to our Consultation observed:

> 'Regulations must include provisions for correcting mistakes. Multinational companies cannot be allowed to use small-scale farmers as guinea-pigs to try out whether new crop varieties are really successful. When the cotton balls fell off prematurely in the US,[26] farmers were able to get compensation. Would the same be true of crop failures in developing countries?'
> *Tracey McCowen, MBE, Canada*

5.36 **We agree that the same standards of liability need to apply in both developing countries and developed countries. Where there is clear evidence of damage attributable to the seed producer, compensation will need to be provided, regardless of whether the seed is GM or non-GM.** We note that in previous instances of crop failures in developed countries compensation has been negotiated successfully. **We recommend that possible scenarios, which include the principle of compensation, be considered by policymakers and the seed industry. Agreed standards should be published widely, taking into account in particular the situation of small-scale farmers in developing countries. Illiteracy and lack of adequate infrastructure for effective communication can present additional obstacles that need to be considered. Wherever possible, agreements should be established, to facilitate compensation of small-scale farmers who, in the event of loss or damage, are unlikely to be able to afford appropriate legal action.**

Interdependence: the case of food aid

5.37 The nature of international economic interdependence means that the freedom of developing countries to choose technologies that they judge to be to their own advantage is influenced by decisions of policy makers and consumers in developed countries. For example, the agricultural policies of the US and the EU have been of particular significance in the case of food aid to three East African countries in 2002 (see Box 5.5).

26 This refers to problems encountered by some cotton farmers in a specific area of the Missisippi Delta in the US, see Memphis Commercial Appeal (1997) Mississippi Investigates Monsanto's Cotton, 18 Aug 1997. Available at: http//newgomemphis.com/newgo/core/archives.htm. Accessed on: 10 Nov 2003.

Box 5.5: **Food Aid**

In the summer of 2002, several African governments rejected donations of food aid from the US through the World Food Programme (WFP). Zimbabwe, Mozambique and Zambia faced dramatic food shortages which threatened more than ten million people with starvation.* Their governments decided to refuse maize donations from the US on the grounds that the cereal was genetically modified.

In the autumn of 2002, Zimbabwe and Mozambique agreed to accept milled GM maize but the Zambian government remained unconvinced and rejected 63,000 tons of maize from the US, despite the threat of more than two million Zambians facing starvation.† The decision was based on an appeal to the precautionary approach (see paragraphs 4.35-4.42) as well as on advice from a team of Zambian scientists who undertook a fact-finding mission to the US, Europe and South Africa.

First, it was argued that circulation of GM maize in Zambia might lead to its uncontrolled spread, if kernels were used for planting rather than for consumption. There were fears that the unauthorised planting of GM maize could have unpredictable consequences in terms of gene flow and in particular, that pollen could eventually spread to fields on which non-GM maize might be grown for export. Given the *de facto* moratorium in the EU and its reluctance to accept imports of GM foods, there were concerns that a major future export market might be lost.‡

Secondly, although the governments of Zimbabwe and Mozambique had eventually decided to accept milled food aid, the Zambian government was sceptical about whether GM food was safe to eat. While acknowledging that GM maize may be safe for consumption by the US population where the crop forms a relatively small proportion of the diet, it was noted that maize accounted for as much as 90% of the typical Zambian diet. It was also feared that the high prevalence of HIV/AIDS in Zambia could bias the transferability of studies on food safety undertaken in developed countries. Thus, it was argued that GM maize might be unsafe for consumption by Zambians.

In response to the controversy, agricultural ministers of 20 African countries decided at a meeting of the COMESA in the autumn of 2002 to establish a regional policy on the trade and use of GMOs. A similar agreement was reached between delegates of the SADC who decided to establish an Advisory Committee on GMOs 'to develop guidelines to assist member states guard against potential risks in food safety, contamination of genetic resources, ethical issues, trade related issues and consumer concerns'.∫

In view of the number of people faced with starvation in Zambia, international critics took issue with the decision to refuse food that was considered safe by US regulatory authorities and was consumed by the US population on a regular basis.** Others expressed support for the Zambian position and referred to the notification procedure enshrined in the *Cartagena Protocol*, arguing for respect for the decision to reject GM food aid.†† Various donor countries agreed with the Norwegian Minister for International Development who, in February 2003, offered to finance GM-free donations where a recipient country made the explicit demand, and urged that all international donors should respect the principle of freedom of choice of recipient countries, which should be 'real and not illusive'.‡‡

* World Food Programme (2002) WFP launches massive regional appeal as starvation threatens millions. 26 Sept 2002. Available: http://www.wfp.org. Accessed on: 23 March 2003.

continued >>

† Mitchell P (2003) Europe angers US with strict GM labelling, *Nat Biotechnol* **21**: 6.

‡ Zambia exported 254 metric tonnes of maize to the UK in 1999, and 88 metric tonnes in 2000. See FAO (2000) FAOSTAT. Available: http://apps.fao.org/. Accessed on: 20 May 2003.

∫ GENET (2002) COMESA to have regional GM policy. Available: http://www.gene.ch/genet/2002/Nov/msg00065.html. Accessed on: 2 June 2003.

** The same stance was taken by India in January 2003, when it rejected a large shipment of GM maize and soybean. See Luce E (2003) India rejects gene-modified food aid, *Financial Times*, 3 Jan 2003.

†† As noted, the US is not party to the CBD and hence neither to the *Cartagena Protocol*. In addition, the Protocol has not yet entered into force.

‡‡ Johnson HF (2003) Globalisation, Food and Freedom. *International Conference on GM Food*, Oslo, 5 Feb 2003. Available: http://odin.dep.no/ud/norsk/aktuelt/taler/statsraad_b/032171-090111/index-dok000-b-n-a.html. Accessed on: 20 May 2003.

5.38 The issues raised by food aid are complex. For example, it is noteworthy that the US donates food aid in kind, whereas the three other major donors worldwide, the WFP, the EU and the UK, donate in cash. The latter group argues that financial assistance allows for the quickest and most effective form of aid, which also supports local economies of countries close to the recipient country. The US, on the other hand, has provided aid to southern African countries entirely in the form of shipments of US maize. Indeed, the US Agency for International Development (USAID) emphasises on its website that in buying cereals from US farmers rather than from the world market or markets in developing countries, it actively seeks to subsidise US farmers and the US economy.[27] Furthermore, the US did not offer to provide milled maize, once it had become apparent that several African countries would prefer the donation in that form. This has led some to allege that USAID is seeking to play a role in a US-led marketing campaign designed to introduce GM food in developing countries.[28] There have also been reports that donations through the WFP have previously included GMOs, and that the recipient countries had not been informed accordingly.[29]

5.39 While these events are quoted as evidence that food aid is being used to promote the marketing of GM crops, there are also reports that pressure has been put on developing countries from the opposite end of the spectrum. For example, it has been alleged that African leaders were advised by EU officials not to accept GM maize, as this would jeopardise current and future trade relations. However, this claim has been refuted vehemently by, amongst others, EU Development Commissioner Poul Nielsen.[30] With regard to discussions organised in Zambia, proponents of the use of GM crops reported that major workshops had been organised by national, regional and international consumer organisations. These had been attended by Zambian government officials, but apparently failed to provide balanced panels of speakers. It has also been alleged that inaccurate

27 'The principal beneficiary of America's foreign assistance programs has always been the US. Close to 80% of the USAID contracts and grants go directly to American firms. Foreign assistance programs have helped create major markets for agricultural goods, created new markets for American industrial exports and meant hundreds of thousands of jobs for Americans.' USAID (2002) Direct economic benefits of US assistance by State. USAID. Available: http://www.usaid.gov/procurement_bus_opp/states/. Accessed on: 30 Sept 2002.

28 Greenpeace (2002) USAID and GM Food Aid. Available: http://www.greenpeace.org.uk/MultimediaFiles/Live/FullReport/5243.pdf. Accessed on: 18 May 2003; Friends of the Earth International (2003) *Playing with Hunger: The Reality Behind the Shipment of GMOs as Food Aid* (Amsterdam: Friends of the Earth International).

29 Pearce F (2002) UN is slipping modified food into aid, *New Scientist* **175** (2361): 5; Friends of the Earth International (2003) *Playing with Hunger: The Reality Behind the Shipment of GMOs as Food Aid* (Amsterdam: Friends of the Earth International).

30 Verbal statement at the conference *Towards Sustainable Agriculture for Developing Countries: Options from Life Sciences and Biotechnologies*, 30-31 Jan 2003, Brussels.

evidence had been presented which supported claims that GM crops posed dangers to human health and the environment.[31]

5.40 However, a number of recent authoritative reviews have concluded that, on current evidence neither GM crops, nor food produced from GM crops, pose a significant risk to humans who consume them.[32] During the course of our investigation, we have been repeatedly impressed by the extent to which complex issues are over-simplified in public and policy debates. In a highly charged political atmosphere, the impact of public statements by influential bodies needs to be carefully considered, including the way in which those statements may be misinterpreted. In our view, there is a pressing obligation on all those who seek to be influential in the making of policy to weigh carefully all the current and relevant evidence and to consider the characteristics of specific uses of GM technology by comparison with other feasible systems. This obligation to base statements on an impartial consideration of the evidence applies as much to campaigning organisations as it does to any other public or professional body. We have therefore come to a sceptical view of claims from individuals or organisations who found their arguments on political convictions rather than scientific evidence.

5.41 We recognise that long-term reliance on food aid, whether provided in the form of GM or non-GM cereals, is highly undesirable. Clearly, assistance to developing countries should, where possible, be directed towards self sufficiency in food production. This is a complex task and GM crops could play a substantial role in improving agriculture. However, the question remains as to how developed countries can comply with their ethical obligations when emergencies arise. With regard to donations of GM crops as food aid **we note that the preferences of developing countries dependent on emergency food aid must be taken seriously. A genuine choice between GM and non-GM food should be offered, where this is possible. It will therefore be necessary to provide full information about whether or not donated food is derived wholly or in part from GM crops.**

5.42 **Where developing countries prefer to receive non-GM food, the World Food Programme and other aid organisations should consider purchasing it. This is subject to its availability at reasonable financial and logistical costs. Where only donations of GM varieties are available and developing countries object to their import solely on the basis of environmental risks, we recommend that it be provided in milled form.** This is because seeds from food aid donations are likely to be planted in developing countries, and it would be unacceptable to introduce a GM crop into any country in this way against its will. We further note that although milling increases the costs of providing food aid, it does allow for the fortification of the milled produce with micronutrients.

Interdependence: the impact of European and international trade policy

5.43 The issues associated with the provision of food aid derived from GM crops clearly illustrate the powerful influence that external factors can have on decision making regarding the use of GM crops in developing countries. As we have observed, the attitudes of consumers in Europe and the US and the provision of direct and indirect agricultural subsidies by

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31 Institute of Science in Society (2002) African Consumer Leaders Support Zambia. http://www.i-sis.org.uk/ACLSZ.php. Accessed on: 31 Oct 2003. Consumers International organised a three day conference 18-21 Nov 2002 in Lusaka, Zambia. Delegates agreed the *Lusaka Declaration* which concluded that GM technology was not suitable to address problems of food security. See http://www.consumersinternational.org/search/newssearch.asp?newsID=175&regionid=135&langid=1. Accessed on: 31 Oct 2003.

32 GM Science Review (2003) First Report (London); The European Network on Safety Assessment of Genetically Modified Food Crops (ENTRANSFOOD) Forthcoming report; International Council for Science (ICSU) (2003) *New Genetics, Food and Agriculture: Scientific Discoveries – Societal Dilemmas* (France: ICSU); Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health – an update* (London: Royal Society).

developed countries have been significant. However, the impact of EU regulatory policy for the management of GM crops and GM food may have an even greater impact.

5.44 In the case of GM food crops intended for export, decisions made by developing countries about the choice of crops are likely to be influenced by the selection of crops approved by European regulations. The revised *Directive 2001/18/EC* in conjunction with *Regulations 1830/2003/EC* and *1829/2003/EC* on *Traceability and Labelling* and on *Food and Feed* determine the types of GMOs that may be imported into the EU. Furthermore, if the current perception of the majority of European consumers that such imported materials are 'contaminated' prevails, it is very likely that GM food and feed, and products derived from GM crops, will be less competitive on European markets.

5.45 There are also issues with regard to ensuring the traceability requirements specified in the EU regulations. As we have said, most developing countries may find it difficult and costly to put in place adequate institutions and systems to assure required standards of monitoring. EU regulations may also have a significant financial impact when a developing country decides to use GM crops for domestic use only. As the thresholds for labelling are very low (0.9% for an approved GMO, and 0.5% for an unapproved GMO), care would have to be taken to prevent mixing of grain and flour from GM crops intended for domestic use with non-GM grain and flour intended for export. Ensuring adequate separation of the two is likely to be costly. It would be highly undesirable for developing countries to choose not to use higher yielding GM crop varieties for domestic use because of concerns about 'contamination' of non-GM crops for export.

5.46 Within any country, regulations similar to those in the EU would tend to discriminate strongly against poor small-scale farmers, for two reasons. First, the grades and standards of verification for, say, 1,000 hectares of a crop is more costly if those hectares are divided between 1,000 farmers, than if they comprise one very large (and almost certainly labour-displacing) farm.[33] Secondly, where the food supply chain comprises a great number of small-scale farmers connected through many small-scale retailers, the verification of GM content and processing methods will be much more expensive than for a few large farmers linked mainly to supermarkets or multinational exporters. Where traceability is required, the effect will be especially harmful to poor farmers. Under the newly approved EU regulations, the determination of the level and type of genetically modified DNA in the end-product will not suffice. Instead, verification will be required for all stages of the production and processing, throughout the whole food chain, from producer to final user.

5.47 Just as overly stringent regulation which focuses almost exclusively on the possible risks of GM crops discriminates against poor countries, so it also discriminates against smaller and poorer producers and retailers. Many small-scale farmers in developing countries grow crops for export such as sugar, coffee, tea, rubber and cotton. Small-scale farms are run by much poorer people, and employ considerably more workers per hectare than large plantation-based farms. It is therefore especially important that developed and developing countries avoid measures that discriminate against these small-scale growers.

5.48 Unless European consumers become far less sceptical towards GM crops, few developing countries will wish to grow them. We have observed that a rapid spread of GM crops has already occurred in several parts of the world (paragraph 3.21). However, scarcely any GM food and feed crops have been approved for commercial planting in the developing countries of Asia, Africa or the Middle East. This situation appears to derive in part from

33 Reardon T *et al*. (2001) Global change in agrifood grades and standards: agribusiness strategic responses in developing countries, *International Food and Agribusiness Management Review* **2**(3).

fears that a highly restrictive interpretation of the precautionary approach in Europe and Japan will close off export sales.

5.49 The freedom of choice that farmers in developing countries can exercise is severely restricted by the agricultural policy of the EU. This policy has been developed primarily to protect European consumers and the environment from potential dangers. But after almost a decade of use of GM crops, there is no robust scientific evidence that their consumption has adverse effects on human health.[34] There have been reports of gene flow from GM crops to other cultivars or wild relatives. However, as we have said (see paragraphs 4.28-4.34) this phenomenon is not specific to GM crops. It also occurs frequently in the case of organic and conventionally bred crops, and from improved crops, which have been changed in their genetic structure by exposure to radiation or chemical substances. In our view, the possibility of gene flow as such cannot justify the prohibition of the planting of a crop; only specific adverse consequences which result from it should provide the basis for such a decision (see paragraphs 4.28-4.34).

5.50 There is thus a considerable imbalance between the hypothetical benefits afforded by the EU policy for its own citizens, and the probable and substantial benefits that could be afforded to developing countries (see also paragraphs 4.1-4.2 of the 1999 Report). We conclude that the current provisions of the revised *Directive 2001/18/EC*, *Regulation 1830/2003/EC on Traceability and Labelling* and *Regulation 1829/2003/EC on Food and Feed* have not taken sufficiently into account the negative effect that these policy instruments are likely to have on those working in the agricultural sector in developing countries. It seems unlikely that the current and proposed European regulations will be substantially revised in the near future to prevent the raising of artificial trade barriers for GM products from developing countries. **However, we recommend that the European Union (EU), the UK Department for International Development (DFID) and appropriate non-governmental organisations which monitor the agricultural policy of developing countries examine the consequences of EU regulatory policies for the use of GM crops in developing countries. We recommend that the European Commission (EC) establish a procedure to report on the impact of its regulations accordingly.**

34 FAO and WHO (2002) *Safety Aspects of Genetically Modified Foods of Plant Origin* Report of a Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology, WHO, Geneva, Switzerland, 29 May – 2 June 2000 (Geneva: WHO); Royal Society (2002) *Genetically Modified Plants for Food Use and Human Health – an update* (London: Royal Society).



Chapter 6

Control of and access to genetic modification technologies

Control of and access to genetic modification technologies

6.1 Over the past 15 years, the expansion of the interests of the private sector in agriculture, particularly in the areas of GM crops and seed production, has resulted in much of the technology and germplasm being under commercial control. Universities in developed countries, encouraged by governments, have also increasingly sought patents to protect their inventions in this area.[1] As a consequence, many discoveries and important technologies in plant biotechnology are no longer treated as *public goods*.[2] Rather, they tend to be patented and licensed, often exclusively, to private companies working on major crops such as maize, soybean and cotton. The development of GM crops relevant to agriculture in the developing world will also require the negotiation of intellectual property rights (IPRs).

6.2 In making our recommendations in the 1999 Report, we recognised the potential of IPRs to constrain the development and commercial growing of crops important in developing countries. In particular we recommended that owners of patented technology should be encouraged to license their technology non-exclusively, that patent offices should avoid the granting of overly broad patents, and that the impact of patents on access to germplasm should be monitored (see paragraphs 3.47, 3.56 and 3.61 of the 1999 Report). In this chapter, we consider whether recent developments in IPRs demonstrate that the concerns underlying these recommendations were well-founded. We give particular attention to three aspects of IPRs which are crucial to the development of GM crops: use of Material Transfer Agreements (MTAs), licensing of patented technology, and access to germplasm.

Material Transfer Agreements

6.3 MTAs are widely used as a means of transferring tangible property, such as isolated DNA sequences and plasmids, between research laboratories. An MTA is a binding private contract between the provider of the technology and the recipient. In essence, it limits the right of the recipient to work with the materials except under terms agreed by both parties. Commercial use usually requires a licence agreement. An MTA can be a powerful tool for controlling novel technologies in plant biotechnology, and access to germplasm. For example, an MTA can be used by the provider to exercise a right of refusal to negotiate a non-exclusive licence with the recipient for patents incorporating materials or data provided under the MTA. In the case of GM crops, MTAs may also impose *reach through* rights to products developed by the recipient. The development of the majority of new crop varieties will often involve MTAs.

6.4 The perception that the recent proliferation of MTAs is not necessarily in the public interest is widespread. Researchers in the public sector often view the use of MTAs in research as burdensome in that they tend to make unwelcome demands on their time and resources. The fact that many research materials can no longer be shared freely but must be the subject of a private contract, irrespective of their potential value, is a trend which runs counter to the ethos of scientific research in the public sector. Nor is the use of MTAs confined to transfers between researchers in the public and private sectors. Researchers in the public sector now routinely exchange materials using MTAs. Despite these concerns, there are as yet few

[1] In the US, the Bayh-Dole Act (1998) gave universities and other public research institutions the rights to patent inventions funded by government research grants. Similar legislation is being applied in a number of industrialised countries.

[2] Toenniessen G and Herdt R (2001) Intellectual property rights and food security. Available: http://www.genomics.cornell.edu/gmo/toenniessenpaper.html. Accessed on: 18 May 2003.

documented examples where MTAs have had a negative impact on the development and application of research. We note however that in the case of Golden Rice, difficulties over access to an MTA owned by a private company delayed progress in development by about twelve months.[3]

Licensing of patented GM technologies

6.5 Five major industrial groups of large agricultural biotechnology companies control between them most of the technology which is needed to undertake commercial research in the area of GM crops.[4] They have achieved this position by licensing, strategic mergers and acquisitions. Several of these companies have used their proprietary technologies effectively to develop new varieties of major crops that enhance farm productivity and reduce agricultural impacts on the environment, both in the US and elsewhere.[5] However, work on crops of less commercial interest has progressed slowly, highlighting the need for greater involvement of the public sector in these cases of market failure. The power and advantage that these companies may choose to exercise in respect of licensing patent rights has attracted much negative comment. We concluded in our 1999 Report that the development of GM crops relevant to the developing world would depend in part upon availability of low cost licences or the waiving of fees for patented technologies. As with MTAs, the development of Golden Rice (case study 4) is illustrative in this respect. It shows that while patented technologies may delay the development of new crops, they are not necessarily a barrier.

6.6 Golden Rice is intended for use by farmers and traders whose profit is below US$10,000 per year. These farmers are predominantly subsistence farmers. In view of their vulnerable position it is desirable that seed can be supplied at low or no cost and without restrictions. Once research was complete it appeared that commercialisation would require licences covering 70 patents belonging to 32 different owners.[6] In the event only six licences were required and licence fees were waived. This example suggests that requests for waivers of licence fees to allow the use of patented technologies for the development of crops suitable for subsistence farmers may be received sympathetically in future. However, a more systematic mechanism may be needed if large numbers of patents are involved, and if seed is to be made available to farmers at the low prices that they can afford.

6.7 The shift towards exclusive control of agricultural technologies by the private sector has been aided by organisations in the public sector.[7] Universities, especially those in the US, have licensed many of their innovations, including important technologies in plant biotechnology, exclusively to companies. Consequently, three quarters of new agricultural biotechnology products, including those funded by the public sector, are controlled by the private sector. This trend of increasing investment in universities by industry is becoming much more

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3 Personal communication, Professor Potrykus, 21 March 2003.

4 Syngenta, Bayer CropScience, Monsanto, DuPont and Dow AgroSciences. ETC group (2002) Ag Biotech Countdown: vital statistics and GM crops. Available: http://www.etcgroup.org/documents/biotech_countdown_2002.pdf. Accessed on: 2 June 2003.

5 Huang J *et al*. (2002) Plant biotechnology in China, *Science* **295**: 674–6; Phipps RH and Park JR (2002) Environmental benefits of genetically modified crops: Global and European perspectives on their ability to reduce pesticide use, *J Anim Feed Sci* **11**: 1–18.

6 Potrykus I (2001) Golden rice and beyond, *Plant Physiol* **125**: 1157–61.

7 Conway G (2003) Biotechnology and the War on Poverty, in *Biotechnology and Sustainable Development: Voices of the South and North*, Serageldin I and Persley GJ, Editors (CAB).

common in the life sciences. It has led to concerns that the current levels of academic-industry collaboration are resulting in university research being increasingly influenced by corporate interests.[8]

6.8 The growth of IPRs has been attributed to the intense competition and low profit margins which exist in the seed industry. These conditions, it has been suggested, encourage companies to accumulate intellectual property to render technologies inaccessible to competitors despite the fact that they may have low market potential. The increasing number and complexity of IPRs which need to be licensed tends to limit their availability to researchers from the public sector. Indeed some take the view that only large companies currently have the capacity to assemble the complex mix of IPRs necessary to enable the efficient development of new technologies and products.[9]

Germplasm

6.9 Germplasm in the form of seeds is the starting point for a plant breeding programme. Some germplasm is publicly available in national and international collections. The 16 International Agricultural Research Centres (IARCs) of the CGIAR (Consultative Group on International Agricultural Research, see Box 6.1) hold over 500,000 accessions of landraces and improved varieties of the world's major crops. These *ex situ* collections are held in trust on behalf of the international community by the IARCs. Companies engaged in plant breeding also hold large collections of germplasm, which they use for breeding and improvement of the crop varieties in which they specialise. They may seek access to national collections and to those of the CGIAR, to improve their own elite strains of germplasm that have resulted from their breeding programmes. The *International Treaty on Plant Genetic Resources for Food and Agriculture* will require a standardised MTA to be used by institutions holding these collections (see paragraphs 6.3-6.4). We welcome this Treaty which, once ratified, will regulate the fair exchange of germplasm for 33 important crops (see paragraphs 5.11-5.15).

6.10 Plant breeders have used plant variety rights (PVR) to protect new crop varieties. These rights are a form of intellectual property and allow the breeder some protection for his new variety. The plant breeders' exemption allows breeders to use varieties protected by PVRs for the purpose of developing new varieties. Genetic modification has provided the breeder with new tools to create novel varieties and stronger rights in the form of patents have been granted to protect them. The collections of germplasm held by the IARCs cannot be patented 'in the form received'. However, once a modification has been introduced, they may then be eligible for patenting. Patent protection for plants or seeds is frequently obtained by securing a broad patent which claims rights over the gene or gene carrier (vector), and may cover a number of varieties or even crops incorporating the gene. In effect, this may have the same outcome as patenting the whole plant because the patent extends to 'all material … in which the product is incorporated'.[10] The holder of a patented variety may be able to prevent others from using it for breeding purposes.

8 For a discussion of how the increasing trend to acquire IPRs may also affect the direction of academic research see Royal Society (2003) *Keeping Science Open: the effects of intellectual property policy on the conduct of science* (London: Royal Society).

9 Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century.* Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf. Accessed on: 10 Oct 2003.

10 *Directive 98/44/EC* Article 9

6.11 Under patent law in the UK, it appears that a plant breeder does not have the clear right to use a patented GM plant variety for breeding purposes. To avoid possible litigation, he can either refrain from using the variety or apply for a licence from the patent owner. Such requests may be refused or granted on less than favourable terms.[11] Nor does the provision of compulsory licensing necessarily offer a further option. UK regulations require the existence of a significantly improved variety to justify a compulsory licence. Such a variety must have been tested in the field and would require prior use of the patented variety. As we noted in our 1999 Report, this potential locking up of genetic variation would be contrary to the spirit and intent of plant variety rights. We consider that there is a strong case for the principle of the breeders' research exemption established for PVRs to be applied to patented varieties. **We reaffirm our recommendation from that Report that the World Intellectual Property Organization (WIPO), the European Commission (EC), the Union for the Protection of the New Varieties of Plants (UPOV), the Consultative Group on International Agricultural Research (CGIAR) and the International Plant Genetic Resources Institute (IPGRI) together closely monitor the impact of patents on the availability of germplasm to plant breeders (paragraph 3.61 of the 1999 Report).**

Box 6.1: **Consultative Group on International Agricultural Research (CGIAR)**

The CGIAR, created in 1971, is an association of public and private members supporting research in a system of 16 centres that are active in more than 100 countries. The CGIAR aims to contribute to food security and the reduction of poverty in developing countries through research, strengthening of local expertise, and support for policy through environmentally sound practices. The CGIAR's research agenda has five main priorities: increasing agricultural productivity, protecting the environment, conserving biodiversity, improving policies which influence the spread of new technologies, as well as the management and use of natural resources, and strengthening networks for national research. The CGIAR holds one of the world's largest *ex situ* collections of plant genetic resources in trust for the global community. It contains over 500,000 accessions of more than 3,000 crop, forage, and agroforestry species. The germplasm within the collections is made available without restriction to researchers around the world, on the understanding that no intellectual property protection is to be applied to the material as such.

Conclusion

6.12 We observed in the 1999 Report that the agrochemical and seed industries were tightly consolidated around a small number of multinational companies. We noted that further consolidation might not be in the public interest and we recommended that the relevant competition authorities keep the sector under close review. Since then, AstraZeneca and Novartis have merged to form Syngenta and Aventis CropScience has merged with Bayer to form Bayer CropScience. With regard to markets in developing countries, Monsanto has, for example, increased its share of the Brazilian maize market from zero to 60% in just two years. Only one Brazilian company remains, which has a 5% share of the market.[12] In anticipation of such developments, we emphasised in our 1999 Report that farmers in developing countries should retain the capacity to choose between growing either new

11 Submission of the British Society of Plant Breeders (BSPB) to the Intellectual Property Advisory Committee (IPAC) concerning Research Exemptions under Patent Law, 17 Oct 2003.

12 Commission on Intellectual Property Rights (2002) *Integrating Intellectual Property Rights and Development Policy* (London: CIPR).

improved seed from the companies or improved seed from national breeding programmes or the CGIAR centres.

6.13 It has been argued that the growth of patent claims in both the public and private sectors could have an inhibiting effect on research. The challenge for the public sector, especially where research is directed at agriculture in developing countries, is how to access GM technologies without infringing IPRs. In addition, they must decide on the way in which their own technologies will be made available.

6.14 New initiatives which recognise the potential of these constraints to inhibit research into crops relevant to developing countries are therefore particularly welcome. Several US universities are now finding that the exclusive licensing of their technologies has deprived them of access to their own inventions. The Public Intellectual Property Resource for Agriculture (PIPRA) is a recent initiative which aims to promote licensing strategies in US universities that encourage retention of rights to their own technologies.[13] These rights can be exercised for non-profit purposes or for the development of crops especially suited to the needs of developing countries.

6.15 The recent establishment of the African Agricultural Technology Foundation (AATF) also seeks to address IP issues in agriculture, relevant to the needs of developing countries.[14] Together with similar activities organised by the ISAAA, the AATF will create partnerships with existing organisations. It will transfer materials and knowledge associated with advanced agricultural technologies that are privately owned by companies and other research institutions, on a royalty-free basis.[15] The AATF will focus on improvements that can be achieved by genetic modification of crops relevant to small-scale African farmers. These include cowpeas, chickpeas, cassava, sweet potatoes, bananas and maize. It has secured support from four of the leading multinational agrochemical companies which have agreed to share patent rights, seed varieties and expertise with African researchers.[16] The AATF also intends to negotiate with other companies for support as well as for licences to important patents.[17]

6.16 As we have noted, the majority of successful applications of GM crops have been developed by industry for commercial agriculture in developed countries (see paragraphs 3.21-3.25 and 3.27). In contrast, most research on GM crops that may have potential for developing countries continues to be undertaken by publicly-funded organisations. A major concern which we expressed in our 1999 Report was the neglect of a serious issue: the risk that gains from GM crops will not be brought to bear on the needs of poor people in developing countries. We also concluded that GM crop technology was unduly concentrated on the crops and farm systems of industrialised countries. The role of the CGIAR in research on GM crops is strategically important. But funding for the CGIAR has fallen in real terms since 1990. Although it spends about US$360 million per year, less than 10% is directed to research on the genetic modification of crops. **We therefore affirm the recommendation made in our 1999 Report that genuinely additional resources be committed by**

13 See http://www.pipra.org/.

14 See http://www.aftechfound.org/index.php.

15 Conway G (2003) *From the Green Revolution to the Biotechnology Revolution: Food for Poor People in the 21st Century.* Speech at the Woodrow Wilson International Center for Scholars Director's Forum. 12 March 2003. Available: http://www.rockfound.org/documents/566/Conway.pdf. Accessed on: 10 Oct 2003; see also: ISAAA The Papaya Biotechnology Network of Southeast Asia, http://www.isaaa.org/Projects/SEAsia/transfer.htm. Accessed on: 31 Oct 2003.

16 Monsanto, DuPont, Syngenta and Dow AgroSciences.

17 Gillis J (2003) To feed hungry Africans, firms plant seeds of science, *Washington Post* 11 March 2003.

governments, the European Commission and others, to fund a major expansion of GM-related research into tropical and sub-tropical staple foods.

6.17 Furthermore, as one respondent to our Consultation observed:

> 'The priorities for the development of GM crops seem to be set by institution and/or organisations outside of Africa that may not necessarily address on-farm constraints of major importance. And currently very few countries outside of South Africa have the capacity to develop GM crops. Africa at least needs to develop an inventory of intractable constraints of major food and commercial crops that need urgent attention. Regional bodies such as FARA, CORAF, ASARECA and SADC/FANR[18] might best draw up a list of such constraints and seek funding to develop the capacity necessary for the evaluation of GM crops in Africa.'
> *Dr Kanayo F Nwanze, Director General, WARDA - The Africa Rice Centre*

We endorse this suggestion and recommend that those sponsoring research, in determining which traits in which crops should be developed, be proactive in consulting with national and regional bodies in developing countries to determine priorities for research.

18 FARA – Forum for Agricultural Research in Africa, CORAF – West and Central African Council for Agricultural Research and Development, ASARECA – Association for Strengthening Agricultural Research in Eastern and Central Africa, SADC – South African Development Community and FANR – Food, Agriculture and Natural Resources Development Unit in Harare, Zimbabwe.

Appendices



Appendix 1: Executive Summary of the 1999 Report

The introduction of genetically modified (GM) crops has become highly controversial in the UK and some other parts of the world. The principal objections concern possible harm to human health, damage to the environment and unease about the 'unnatural' status of the technology. The Working Party has therefore examined the ethical issues which are raised by the development and application of GM plant technology in world agriculture and food security. Its perspective on GM crops has been guided by consideration of three main ethical principles: the principle of general human welfare, the maintenance of people's rights and the principle of justice. Some of these considerations, such as the need to ensure food security for present and future generations, safety for consumers and care of the environment have been straightforward and broadly utilitarian. Others, stemming from the concern that GM crops are 'unnatural', have been more complex.

The Working Party accepts that some genetic modifications are truly novel but concludes that there is no clear dividing line which could prescribe what types of genetic modification are unacceptable because they are considered by some to be 'unnatural'. It takes the view that the genetic modification of plants does not differ to such an extent from conventional breeding that it is in itself morally objectionable. GM technology does, however, have the potential to lead to significant changes in farming practices in food production and in the environment. **The Working Party concludes that it is now necessary to maintain and develop further a powerful public policy framework to guide and regulate the way GM technology is applied in the UK. It recommends that an over-arching, independent biotechnology advisory committee is established to consider within a broad remit, the scientific and ethical issues together with the public values associated with GM crops.**

Recommendations about the needs for improved risk assessment methods, post-release monitoring and the evaluation of cumulative and indirect environmental impacts are made. **The Working Party does not believe that there is enough evidence of actual or potential harm to justify a moratorium on either GM crop research, field trials or limited release into the environment at this stage**. Public concern about the introduction of GM crops has led to calls for bans on GM food and moratoria on plantings. **The Working Party concludes that all the GM food so far on the market in this country is safe for human consumption**. A genuine choice of non-GM foods should remain available, with foods which contain identifiable GM material being appropriately labelled. The Working Party urges the Government and the scientific community to share their responsibilities in disseminating reliable information about the underlying science and to respond to public concerns.

The application of genetic modification to crops has the potential to bring about significant benefits, such as improved nutrition, enhanced pest resistance, increased yields and new products such as vaccines. **The moral imperative for making GM crops readily and economically available to developing countries who want them is compelling. The Working Party recommends a major increase in financial support for GM crop research directed at the employment-intensive production of staple foods together with the implementation of international safeguards**.

Appendix 2: The importance of labour intensive agriculture

In parts of rural Africa, the incomes of small-scale farmers and farm workers are constrained by lack of labour. This can be a result of mortality due to HIV/AIDS, or because many young people have abandoned farming. However, even in these areas, higher demand for labour pushes up wages, which improves the well-being of poor people. In addition, few areas remain in Africa, or even Latin America, where farm land can be expanded without:

- significantly lower returns than are obtained on existing land, or
- intensification of fragile lands (for example, converting grazing to maize in parts of Southern Africa; shortening fallows in shifting cultivation in parts of West Africa).

The development of sustainable methods of enhancing yields on farmed land which increase the demand for labour therefore remains a crucial priority. Income from agriculture is the best way to enable the poor in rural areas of developing countries to afford food. Agricultural research should therefore seek outcomes that are labour-intensive.

If farmers are to be encouraged to employ more labour, and workers to supply it, farm labour-productivity (i.e. the output per unit of labour) also has to rise. With land and water in increasingly short supply, how can both conditions be met? When new crop varieties are assessed in the field, it is important to examine their effect on raising:

i) labour productivity (sufficient to offset any fall in output prices and rise in input costs), and also

ii) land and water productivity (i.e. output per hectare and per litre), normally at a faster rate.

Total employment on farms can then continue to rise despite constraints of land and water, and rising labour productivity.

Modern plant breeding in the Green Revolution generally met both conditions (i) and (ii). The same can be expected in many cases where genetic modification is introduced, provided there is a careful choice of crop, trait and user. However, care is needed. For example, if land is scarce, the introduction of GM or other varieties with herbicide tolerance might merely lead to the replacement of farm labour by herbicides without raising yield. This would reduce the demand for labour, and hence the wages and/or employment.

Appendix 3: Examples of GM crops with relevance to developing countries

The following table gives examples of GM crops which are either currently used in developing countries or are the subject of ongoing research. The table does not provide an exhaustive list of all applications or research projects. Rather, it aims to give an overview of the kinds of projects which are being undertaken and it aims to detail the stage of research or use.

Stage of Research

L Laboratory studies

G Greenhouse studies

N Not specified

F Field studies

C Commercialised

Crop	Country	Improved trait	Comments	Stage
Banana	Egypt[1]	Viral resistance	– Resistance to banana bunchy top virus and banana-cucumber mosaic virus – Research undertaken by the Agricultural Genetic Engineering Research Institute (AGERI), Egypt	L
	Uganda, South Africa, Belgium and France[2]	Pest resistance (e.g. nematodes and weevils) Fungal resistance	– Aims to enhance the resistance of the local East African Highland bananas to the wide range of pests and diseases currently affecting the crop – Project undertaken by the International Network for the Improvement of Banana and Plantain (INIBAP) – Project began in 2001 with an expected duration of 5 years – See case study 6	L

1 AGERI Production of Transgenic Banana Plants Resistant to Banana Bunchy Top Virus (BBTV) and/or Banana-Cucumber Mosaic *Cucumovirus* (Banana-CMV). Available: http://www.ageri.sci.eg/topic6/banana.htm. Accessed on: 9 Jan 2003.

2 INIBAP (2001) Novel approaches to the improvement of banana production in Eastern Africa the application of biotechnological methodologies. Available: http://www.inibap.org/presentation/biotechnology_eng.htm. Accessed on: 17 Jan 2003.

continued >>

Crop	Country	Improved trait	Comments	Stage
Banana	US[3]	Biopharma-ceutical	– Vaccine for hepatitis – Research undertaken at Cornell University, US – See case study 8	L
	Australia[4]	Fungal resistance	– Resistance to black Sigatoka – Project undertaken by the Queensland University of Technology and the companies Demegen and Farmacule BioIndustries – See case study 6	L/F[5]
Barley[6]	Egypt	Abiotic stresses	– Development of varieties tolerant to salt, drought and heat shock – Partnership between AGERI and the International Centre for Agricultural Research in the Dry Areas (ICARDA)	L
Cassava[7]	Various developed and developing countries	Pest and disease resistance Enhanced protein and nutrient levels	– Project undertaken by the Global Partnership for Cassava Genetic Improvement, a partnership of institutions including the FAO and the Swiss Federal Institute of Technology	N[8]
Coffee[9]	Hawaii, Brazil and Central America	Controlled ripening Caffeine-free	– Research by the company Integrated Coffee Technologies, Hawaii	L

3 Demegen (2001) International plant biotech groups collaborate. Available: http://www.demegen.com/prs/pr011213.htm. Accessed on: 20 May 2003.

4 Demegen (2001) International plant group collaborate. Available: http://www.demegen.com/prs/pr011213.htm. Accessed on: 29 May 2003.

5 AEBC (2002) *Looking Ahead - An AEBC Horizon Scan* (London: Department of Trade and Industry), p50.

6 ICARDA (2001) *ICARDA Annual Report 2001*. Available: http://www.icarda.cgiar.org/Publications/AnnualReport/2001/cooperat/nile.htm. Accessed on: 20 May 2003; AGERI Development of Transgenic Barley with Improved Tolerance to Abiotic Stresses. Available: http://www.ageri.sci.eg/topic6/barley.htm. Accessed on: 9 Jan 2003.

7 FAO (2002) Partnership formed to improve cassava, staple food of 600 million people, News Release 5 Nov 2002. Available: http://www.fao.org/english/newsroom/news/2002/10541-en.html. Accessed on: 9 Jan 2003.

8 The Global Partnership for Cassava Genetic Improvement was launched on 5 Nov 2002. The Partnership next aims to raise funds for specific research projects.

9 Action Aid (2001) *Robbing Coffee's Cradle - GM coffee and its threat to poor farmers* (London: Action Aid).

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Crop	Country	Improved trait	Comments	Stage
Cotton	Egypt[10]	Abiotic Stresses Biotic stresses	– Development of varieties which have tolerance to salt, heat and drought as well as pests – Project undertaken by AGERI and the Cotton Research Institute	L
	Columbia[11]	Pest resistance (*Bt*)	– Commercialised planting expected in 2003	F
	India[12]	Pest resistance (*Bt*)	– Approval to grow *Bt* cotton developed by the company Monsanto granted in March 2002	C
	South Africa[13]	Pest resistance (*Bt*)	– See case study 1	C
	Indonesia[14]	Pest resistance (*Bt*)	– 2,700 farmers grow *Bt* cotton in South Sulawesi	C
	China[15]	Pest resistance (*Bt*)	– Both locally developed varieties and varieties by the company Monsanto are grown – *Bt* cotton is grown on over 50% of the cotton farming area in China – See case study 1	C
Faba bean[16]	Egypt	Viral resistance	– Resistance to the faba bean necrotic yellows virus	L
Maize	Egypt[17]	Pest resistance (*Bt*)	– Resistance to maize stem borers – Project being undertaken by AGERI and the company Pioneer	L

10 Momtaz OA (2002) Current Status and Prospects of Transgenic Egyptian Cotton. Available: http://www.icac.org/icac/Meetings/Plenary/61cairo/documents/tis/momtaz.pdf. Accessed on: 9 Jan 2003.

11 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

12 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

13 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

14 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

15 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

16 AGERI Development of Improved Strategies for the Control of Faba Bean Necrotic Yellows Virus (FBNYV) in Food Legume Crops of West Asia and North Africa. Available: http://www.ageri.sci.eg/topic6/fbnyv.htm. Accessed on: 9 Jan 2003.

17 Agricultural Biotechnology Support Project (2002) *Biotechnology Research and Policy Activities of ABSP in Egypt: 1991-2002.* Available: http://www.iia.msu.edu/absp/egypt-absp.pdf. Accessed on: 29 May 2003.

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Crop	Country	Improved trait	Comments	Stage
Maize	Philippines[18]	Pest resistance (*Bt*)	– Fields trials to evaluate the resistance of *Bt* maize to the Asiatic corn borer began in 2000 – Multi-site trials began in 2001	F
	Honduras[19]	Pest resistance (*Bt*)	– Commercialisation expected in 2003	F
	Argentina[20]	Pest resistance (*Bt*)	– Four varieties are grown commercially[21]	C
	South Africa[22]	Pest resistance (*Bt*)	– Varieties produced by the companies Monsanto and Pioneer	C
	Bulgaria[23]	Herbicide tolerance	– Less than 100,000 hectares were grown in 2002	C
Melon[24]	Egypt	Viral resistance	– Resistant to the zucchini yellow mosaic virus	G
Papaya[25]	Malaysia, Thailand, Philippines, Brazil, China and Mexico	Viral resistance	– Resistance to the papaya ringspot virus – Project undertaken by the Papaya Biotechnology Network of Southeast Asia with support from the company Monsanto and the ISAAA – Project aims to benefit small-scale farmers in southeast Asia	L, F

18 ISAAA Introduction and Field Testing of Insect Resistant Corn in the Philippines, Current Asian project portfolio. Available: www.isaaa.org. Accessed on: 9 Jan 2003.

19 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

20 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

21 Agbios Essential Biosafety. Available: http://www.essentialbiosafety.info/dbase.php. Accessed on: 20 May 2003.

22 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

23 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

24 Agricultural Biotechnology Support Project (2002) *Biotechnology Research and Policy Activities of ABSP in Egypt: 1991-2002*. Available: http://www.iia.msu.edu/absp/egypt-absp.pdf. Accessed on: 29 May 2003.

25 Chiang C-H *et al*. (2001) Comparative reactions of recombinant papaya ringspot viruses with chimeric coat protein (CP) genes and wild-type viruses on CP-transgenic papaya, J *Gen Virol* **82**: 2827–36; Monsanto (2001) Monsanto Welcomes UN Report on Biotech's Benefits for Developing World, News Release July 9 2001. Available: http://www.monsanto.com/monsanto/layout/media/01/07-09-01.asp. Accessed on: 16 Jan 2003; Flasinski S *et al*. (2001) Value of Engineered Virus Resistance in Crop Plants and Technology Cooperation with Developing Countries, The International Consortium on Agricultural Biotechnology Research (non-technical abstract). Available: http://www.economia.uniroma2.it/conferenze/icabr01/nontechabsrtact2001/Falsinski.htm. Accessed on: 15 Jan 2003.

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Crop	Country	Improved trait	Comments	Stage
Potato	Mexico[26]	Viral resistance	– Cooperative project between the Centre for Advanced Studies (CINVESTAV), the ISAAA and the Rockefeller Foundation – The company Monsanto provided funding in earlier stages of research	F
	Egypt[27]	Pest resistance	– Resistance to potato tuber moth – Project undertaken by AGERI (Egypt), Michigan State University (US), Central Research Institute for Food Crops (Indonesia), Vegetable and Ornamental Plant Institute (South Africa), and International Potato Center (Peru) – Four years of field trials have been completed	F
	US[28]	Biopharma-ceutical	– Development of vaccine against rotavirus and *E. coli*, prevalent in many developing countries – Project being undertaken at Loma Linda University	L
	India[29]	Protein enhanced	– Varieties are in the final stage of testing	L
Rice	US and India[30]	Dwarfing	– Gene from *Arabidopsis* transferred into Basmati Rice – See case study 3	L

26 Monsanto (2001) Monsanto Welcomes U.N. Report on Biotech's Benefits for Developing World. News Release July 9 2001. Available: http://www.monsanto.com/monsanto/layout/media/01/07-09-01.asp. Accessed on: 16 Jan 2003.

27 Agricultural Biotechnology Support Project (2002) *Biotechnology Research and Policy Activities of ABSP in Egypt: 1991-2002.* Available: http://www.iia.msu.edu/absp/egypt-absp.pdf. Accessed on: 29 May 2003.

28 Wong K (2001) Souped-Up Spuds Show Promise for Edible Vaccines, Scientific American. Available: http://www.sciam.com/article.cfm?chanID=sa003&articleID=00019658-ED97-1C5E-B882809EC588ED9F. Accessed on: 20 May 2003.

29 Coghlan A (2003) 'Protato' to feed India's poor, *New Scientist* **177** (2376): 7.

30 Peng J *et al*. (1999) 'Green revolution' genes encode mutant gibberellin response modulators, *Nature* **400**: 256–61.

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Crop	Country	Improved trait	Comments	Stage
Rice	Philippines[31]	Micronutrient enrichment	– Vitamin A (ß-carotene and other carotenoids) – Project undertaken by the Golden Rice Network (India, China, Indonesia, Vietnam, Bangladesh, the Philippines and South Africa). Collaborators include the International Rice Research Institute (IRRI), the Rockefeller Foundation and the company Syngenta – See case study 4	L
	India[32]	Pest resistance (*Bt*)	– Research undertaken at the International Centre for Genetic Engineering and Biotechnology, New Delhi	L
	US and South Korea[33]	Abiotic stresses	– Salt, drought and cold tolerance – Research undertaken by Cornell University and researchers in South Korea with funding from the Rockefeller Foundation – Technology to be placed in public domain to benefit farmers from developing countries – See case study 2	L

31 Pearce F (2001) Protests take the shine off golden rice, *New Scientist* **169** (2284): 15; IRRI (2001) Greenpeace Visits IRRI News Release. Available: http://www.irri.org/vis/line2001.htm. Accessed on: 14 Jan 2003; Syngenta (2000) 'Golden Rice' Collaboration Brings Health Benefits Nearer. Available: http://www.syngenta.com/en/media/zeneca.asp. Accessed on: 15 Jan 2003; Rockefeller Foundation (2001) International Rice Research Institute Begins Testing 'Golden Rice'. Available: http://www.rockfound.org. Accessed on: 15 Jan 2003.

32 Bhatangar RK (2000) ICGEB Activity Report. Available: http://www.icgeb.org/RESEARCH/ND/Bhatnagar.htm. Accessed on: 9 Jan 2003.

33 Coghlan A (2002) Sweet genes help rice in a drought, *New Scientist* **176** (2371): 10; Garg AK *et al.* (2002) Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses, *Proc Natl Acad Sci USA* **99**: 15898–903; (2002) GM rice can tough it out, BBC News Online, 26 Nov 2002. Available: http://news.bbc.co.uk/1/hi/sci/tech/2512195.stm. Accessed on: 15 Jan 2003.

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Crop	Country	Improved trait	Comments	Stage
Rice	Philippines[34]	Micronutrient enrichment	– Increased iron and zinc content – Research undertaken by the Institute of Human Nutrition, at the University of the Philippines, in cooperation with IRRI – Trials involving humans are about to commence to establish whether the micronutrients are bioavailable	F
	US and Philippines[35]	Bacterial resistance	– Resistance to bacterial leaf blight – Gene patented by the University of California, Davis. The technology has been made available to developing countries free of charge. – Field trials conducted in the Philippines by IRRI	F
Soybean[36]	Argentina Uruguay South Africa Mexico Romania	Herbicide tolerance	– The majority of herbicide tolerant soybeans grown worldwide are Monsanto varieties	C
Squash[37]	Egypt	Viral resistance	– Egyptian cultivar transformed using a construct with the zucchini yellow mosaic virus coat protein gene – Collaboration between AGERI, Cornell University and Michigan State University – Preliminary field trials in 1999 and 2000	F

34 Future Harvest (1999) New rices may improve human health: iron and zinc enriched rice undergoing trial in convent; Vitamin A-Enhanced and iron-enriched rice varieties to be tested. Available: http://www.futureharvest.org/news/rice.bckgrnd.shtml. Accessed on: 17 Jan 2003.

35 GRAIN (2000) BB rice: IRRI's first transgenic field test. Available: http://www.grain.org/publications/bbrice-en.cfm. Accessed on: 9 May 2003.

36 James C (2002) *Preview, Global Status of Commercialized Transgenic Crops: 2002* ISAAA Brief No. 27 (Ithaca, NY: ISAAA).

37 Agricultural Biotechnology Support Project (2002) Biotechnology Research and Policy Activities of ABSP in Egypt: 1991-2002. Available: http://www.iia.msu.edu/absp/egypt-absp.pdf. Accessed on: 29 May 2003.

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Crop	Country	Improved trait	Comments	Stage
Sweet potato	Vietnam[38]	Pest resistance (*Bt*)	– Resistance to the sweet potato weevil – Research undertaken by the Institute of Biotechnology in Hanoi, Vietnam – *Bt* strains were donated free of charge by the company Novartis	L
	Kenya	Viral resistant	– Resistance to Sweet Potato feathery mottle virus – Research undertaken by the Kenya Agricultural Research Institute (KARI), ISAAA and Monsanto – See case study 5	F
Wheat[40]	Egypt	Abiotic stresses	– Development of varieties with tolerance to salt and drought – Collaborative research undertaken by AGERI and Ohio State University	L

38 Syngenta (2000) Novartis Agribusiness: New agricultural technologies for developing countries. Available: http://www.syngenta.com/en/media/article.asp?article_id=63. Accessed on: 15 Jan 2003.

39 Monsanto (2001) Monsanto Welcomes U.N. Report on Biotech's Benefits for Developing World. Available: http://www.monsanto.com/monsanto/layout/media/01/07-09-01.asp. Accessed on: 16 Jan 2003.

40 Agricultural Biotechnology Support Project (2002) *Biotechnology Research and Policy Activities of ABSP in Egypt: 1991-2002.* Available: http://www.iia.msu.edu/absp/egypt-absp.pdf. Accessed on: 29 May 2003.

Appendix 4: Methods of Working

In October 2002, the Council decided to follow up its 1999 Report ***Genetically modified crops: ethical and social issues.*** Three former members of the Working Party that produced this Report, and one member of the Council were convened to form a small Working Group. The Group met eight times between December 2002 and August 2003. A first draft of the draft Discussion Paper was sent to nine peer reviewers. As part of its work, the Working Group held four fact-finding sessions with experts in a number of fields. The Working Group also held a consultation with the public. This took the form of inviting comments on a draft version of the Discussion Paper. Details about the consultation exercise are at Appendix 5.

Ms Kate Miller prepared a background research paper for the Working Group while working as an intern at the Nuffield Council on Bioethics from the 7 – 24 January 2003.

Fact-finding meetings

The Working Group is very grateful to the following individuals for providing valuable insights into issues relating to the use of genetically modified crops in developing countries.[1]

21 March 2003, London

Mr Alex Wijeratna
Food Rights Campaign Coordinator, ActionAid, UK

Dr Richard Tapper
Advisor, UK Food Group, ITDG (Intermediate Technology Development Group)

Professor Ingo Potrykus
Professor Emeritus, Institute of Plant Science, ETH Zuerich

15 April 2003, London

Professor Julian Kinderlerer
Professor of Law, University of Sheffield, UK

17 April 2003, London

Dr Andrew Bennett
Executive Director, Syngenta Foundation for Sustainable Agriculture, Basel

9 May 2003, London

Professor Gordon Conway
President, The Rockefeller Foundation, USA

1 Institutional affiliations at the time of the meeting are listed.

Peer reviewers
The Working Group is also very grateful for the following individuals for providing very helpful comments on an earlier draft of this Discussion Paper:[2]

Dr Andrew Cockburn
Director of Scientific Affairs, Europe and Africa, Monsanto UK Ltd

Dr Joseph DeVries
Associate Director of Food and Security, The Rockefeller Foundation, Kenya

Dr Geoffrey Hawtin
Director General, International Plant Genetics Resource Institute, Rome

Dr Luis R. Herrera Estrella
Director, Plant Biotechnology Unit Centro de Investigacion y Estudios, Mexico

Mr Antonio Hill
Policy Advisor, Environment and Sustainable Livelihoods, Oxfam, Colombia

Professor John O'Neill
Institute for Environment, Philosophy and Public Policy, Lancaster University, UK

Professor Robert Paarlberg
Professor of Political Science, Wellesley College, USA

Professor Jules Pretty
Director of the Centre for Environment and Society, University of Essex, UK

Dr Ana Sittenfeld
Associate Professor, Centro de Investigación en Biología Celular y Molecular (CIBCM), Universidad de Costa Rica

2 Institutional affiliations at the time of the meeting are listed.

Appendix 5

Responses to the invitation to comment

On 10 June 2003, the Council published a draft version of this Paper for comment. Information about the launch was circulated widely to individuals and organisations with an interest in this area, as well as to Internet-based news groups. During the two month period of consultation, 5,833 copies of the document were downloaded from the Council's website. In addition, The Science and Development Network (SciDevNet) drew attention to the paper on its website, inviting comments which were passed on to the Council. In total, the Council received 83 responses from more than 20 countries (see Figures 1 and 2). Those who responded are listed in Table 1 and the Council and its Working Group wish to thank them for their valuable comments.

Figure 1: **Breakdown of responses: developed and developing countries**

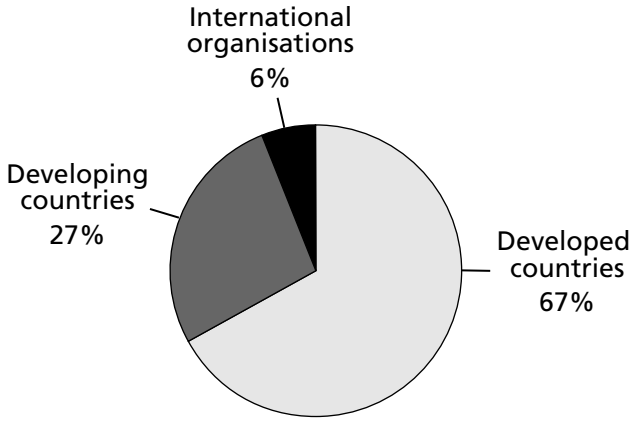
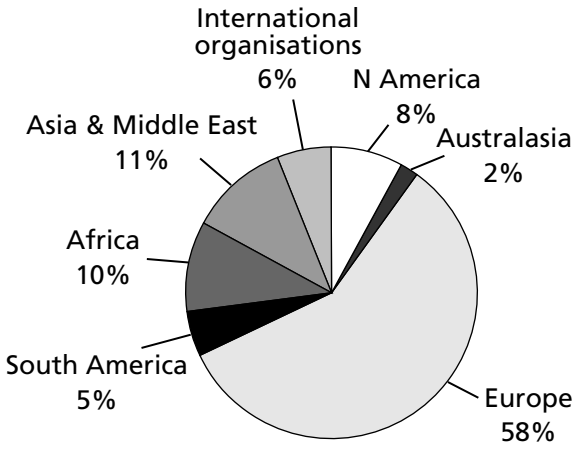


Figure 2: **Breakdown of responses by continent**



Respondents

Comments received from organisations

ActionAid, UK
ADAS Consulting Ltd.
Agriculture Biotechnology Council, UK
The Biosciences Federation
British Society of Animal Science
CropLife International
EuropaBio, Plant Biotechnology Unit
Farmers Federation, India
Food Ethics Council, UK
Friends of the Earth: Real Food and Farming Campaign, UK
Gene Campaign, New Delhi, India
GeneWatch UK
Hylobates Consulting Srl, Italy
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India
Institute of Food Science & Technology Trust Fund, Technical & Legislative Committee
Institute of Horticulture, UK
ISAAA AfriCenter and the African Biotechnology Stakeholders Forum (ABSF), Kenya
John Innes Centre, UK
Munlochy GM Vigil, UK
National Council of Women, UK
The Scientific Alliance, UK
The Royal Society, UK
Task Group on Public Perceptions of Biotechnology of the European Federation of Biotechnology
WARDA – The Africa Rice Centre

Comments received from individuals

Krishna Amirthalingam: Center for Rural Reconstruction through Social Action (CRESA), India
Jay Aronson: Program on Science, Tech. & Society, Harvard Univ., Kennedy School of Government, USA
Amit Basole: Graduate Student, Dept. of Neurobiology, Duke University Medical Center, USA
Mauricio Bellon: International Maize and Wheat Improvement Center (CIMMYT), Mexico
Andrew Bennet: Syngenta Foundation for Sustainable Agriculture
Judy Brander: Consumer 'representative' and scientist, UK
Mark Cantley: Council of Europe
Charles Clift: IPR unit, Department for International Development, UK (Head of Secretariat for CIPR)
Joel Cohen: Program for Biosafety Systems at the International Service for National Agricultural Research (ISNAR), The Netherlands
Nguyen Cong: Agricultural Genetics Institute, Vietnam
Zephaniah Dhlamini: Food and Agriculture Organisation of the United Nations, Research and Technology Development Service (SDRR)
Abednego M. Dlamini: Head of Animal Prod. and Health Department, University of Swaziland
Dr Margarita Escaler: International Service for the Acquisition of Agri-biotech Applications (ISAAA), UK
Professor Gerhard Flachowsky and Dr Egbert Strobel, Institut für Tierernährung der FAL, Germany
Koshy George: The Resource Persons Group (TrG), India
Paul Goettlich, USA
Hector Gomez Vazquez: Independent scientific journalist, Mexico
Jonathan Gressel, Weizmann Institute of Science, Israel
Michael Hughes
Professor Roger Hull: John Innes Centre, UK

Lee Ann Jackson: Centre for International Economic Studies, Adelaide University, Australia
Nick James, UK
Professor J Gwynfryn Jones, UK
Christopher King, UK
Rudolf Kirst: independent human rights researcher, UK
Dr Ulrich E Loening: Fellow and member of Board of Directors, Centre for Human Ecology, Edinburgh, UK
Linda Martin, UK
Wali-ul-Maroof Matin, Bangladesh
Tracey McCowen, Canada
Aloyce Simon Menda: Journalists' Union For Science & Technology Advancement In Africa (JUSTA), Tanzania
Alejandro Mendez, Argentina
Dr P L Mitchell: Dept. of Animal and Plant Sciences, The University of Sheffield, UK and
Dr J E Sheehy: International Rice Research Institute, Crop, Soil and Water Sciences Division, Philippines
Mehdi Naderi-Manesh: Associate Professor, Tarbiat modarres University, Iran
Nagib Nassar: Professor of genetics and plant breeding, Universidade de Brasilia
Dr Olusanya Olutogun: Department of Animal Science, University of Ibadan, Nigeria
Baroness O'Neill: Principal of Newnham College, Cambridge and Chairman of Trustees, Nuffield Foundation
Helena Paul
David Petch
Professor T V Price: Head of Dept. of Agriculture, The University of Vudal, Papua New Guinea
Professor Dr Ingo Potrykus: Professor Emeritus, Switzerland
J David Reece: Egenis, ESRC Centre for Genomics in Society, University of Exeter, UK
Carolyn Rogers, UK
Stephan le Roux: Student at the University of South Africa
Professor Alan Ryan: Chair, former Nuffield Council on Bioethics Working Party on GM crops, UK
Cordelia Salter-Nour, Ghana
Jørgen Schlundt: Director, Food Safety Department, World Health Organization, Switzerland
Jennifer Schmidt: Schmidt Farms, Inc., USA
Ian Scoones, Dominic Glover, James Keely, Peter Newell and Farhana Yamin: Environment Group, Institute of Development Studies, University of Sussex, UK
Rory Short, Zambia
Andrew Simms: Policy Director, New Economics Foundation, UK
Walter Simon
Nigel Simpson, UK
Tony Somera, USA
Geoffrey Stapleton
Jan van der Steen: retired agronomist, Portugal
Robert Tripp: Overseas Development Institute, UK
Robert Wager: Malaspina University College, Canada
Max Withers
Martin F Yriart, Spain

Glossary

Abiotic stress: Environmental stresses which can reduce the productivity of a crop. These include weather conditions such as excessive or untimely frosts, and extended droughts and adverse soil conditions such as high levels of salt or aluminium.

Agrochemical: A chemical, such as a fertiliser, a *herbicide* or an insecticide, that improves the productivity of crops.

Amino acids: Molecules which, when linked together, form *proteins*.

Biodiversity: The number and variety of plants, animals and other organisms that exist in nature.

Biopharmaceuticals: Compounds which are used for the development of medicines, that are produced by living organisms rather than by chemical synthesis.

Biotic stress: Stress resulting from attack by organisms capable of causing disease.

Bt: The bacterium *Bacillus thuringiensis* which produces *proteins* that are toxic to some insects.

Carrier: *DNA* of undefined sequence which is used to 'carry' genes which are inserted into cells. A *plasmid* is a type of carrier.

Cell: The smallest component of a living organism that is able to grow and reproduce independently.

Centre of diversity: A centre of diversity would often contain a variety of *cultivars* and their wild relatives. Such areas often harbour a wide range of natural genetic variation for a particular crop.

Chromosomes: The thread-like structures in *cells* that carry *DNA*, on which genetic information is arranged.

Crossing: Cross breeding different varieties of a crop species or, occasionally, varieties of closely related species.

Cultivar: A genetically defined plant variety which has been selected to be adapted for agricultural use.

Developed countries: Those countries with an average *per capita gross national income* in 2001 of more than US$9,205 at official exchange rates (see Box 1.1).

Developing countries: Those countries with an average *per capita gross national income* in 2001 of less than US$9,205 at official exchange rates (see Box 1.1).

Disease resistance: The capacity of a plant, usually determined by one or a few *genes*, to suppress or retard the activities of a disease-causing organism.

DNA: The biochemical substance from which the genetic material of cells is made. DNA has a thread-like structure. The DNA in a plant or animal cell is in several long lengths called *chromosomes*, each of which contains many *genes*.

Double haploid: A crop variety in which each member of a pair of *chromosomes* is identical. This can also be achieved by several generations of inbreeding although the resultant line never has identical copies of every gene. With double haploid techniques, a pure line is achieved in one generation.

Dwarfed crops: Crop varieties that are bred to be relatively short. Dwarfed cereals are higher yielding and will accept more fertiliser before they collapse in the field.

F1 hybrid crop: The initial *hybrid* generation resulting from a cross between two parents. F1 hybrids are favoured by farmers because they display *hybrid vigour.* They are favoured by industry because *hybrid vigour* is suppressed in subsequent generations. This means that farmers need to purchase new seed every year, rather than use saved seed.

Farming footprint: The impact that agricultural practice leaves behind on the natural ecology of an environment.

Food security: According to the FAO, a state in which all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for a healthy life.

Gene: A linear fragment of *DNA* which contains the information needed to make *proteins*.

Gene flow: The transfer of *genes* via pollen to or from a cultivated crop to other crop plants, wild relatives, other plant species or other organisms.

Genetic modification: A technology which allows selected individual *genes* to be transferred from one organism into another, including *genes* from unrelated species. The technology can be used to promote a desirable crop characteristic or to suppress an undesirable trait.

Gene use restriction technology (GURT): A technology which genetically compromises the fertility or the performance of a *cultivar* so that harvested grains cannot germinate without agrochemical treatment. The technology is intended to prevent undesired *gene flow* and/or to protect the market of the seed producer.

Genome: The entire complement of *DNA* (*genes* plus non-coding sequences) present in each *cell* of an organism.

Germplasm: Tissue from which new plants can be grown, for example seeds, pollen or leaves. Even a few *cells* may be sufficient to culture into a new plant.

Golden Rice: A type of *genetically modified* rice, which contains increased amounts of ß-carotene (a precursor of vitamin A). It was achieved by *genetically modifying* rice with two *genes* from daffodils and one from a bacterium.

Green Revolution: The Green Revolution is the popular term for the development and spread of high-yielding staple foods in developing countries from the 1950s (see also Box 1.3).

Gross national income: The dollar value of all goods and services produced by a nation's economy, including goods and services produced abroad.

Herbicide: A substance that kills plants and is used to control weeds. Herbicides vary in their specificity. Some kill a broad spectrum of plant species, while others kill only specific species or groups of species.

Herbicide tolerance: This allows a plant to tolerate a *herbicide* that would otherwise kill it. This can be achieved by means of either *genetic modification* or conventional plant breeding.

Hybrid: See *F1 hybrids*.

Hybrid vigour: The extent to which a *hybrid* crop performs better relative to the parents with respect to specific traits, particularly yield.

Informal seed system: Seed production and exchange activities by farmers and grassroots organisations. The informal seed system is a semi-structured system which primarily deals with small quantities of farm-saved seed, farmer to farmer exchange and informal markets.

In situ/ex situ: Generally used in the context of conservation of *germplasm*. *In situ* describes the conserving of *germplasm* in its natural environment. This can include conservation by continued farming of crop varieties. *Ex situ* refers to conserving *germplasm* in long term storage such as seed banks and by growing it, for example, in botanical gardens.

Intellectual property: An intangible form of personal property. Copyrights, patents, and trademarks are examples of intellectual property. Intellectual property rights enable owners to select who may access and use their property, to protect it from unauthorised use and to recover income.

Introgression: The incorporation of genetic material from one species into another. The term was originally coined in connection with the directed transfer of useful *genes* from wild relatives to crop plant species. Recently the term *'transgene* introgression' has been used in connection with the inadvertent transfer of genetic material from transgenic crops to wild relatives. In each case introgression requires the production of a fertile *hybrid* between a crop plant and a wild relative with subsequent backcrossing either to the crop plant species or the wild species.

Landrace: A crop *cultivar* that has been genetically improved and maintained by traditional methods of selection rather than modern breeding practices.

Lathyrism: A disease resulting from poisoning by a substance found in certain legumes of the genus *Lathyrus* and characterised by severe symptoms including spastic paralysis.

Marker-aided selection: The use of *DNA* markers to select a particular trait. Selection of a *DNA* sequence near the *gene* on a *chromosome* avoids time-consuming and expensive tests to select the ideal parent or offspring.

Material Transfer Agreement (MTA): A widely used means to govern the property rights in relation to the exchange of materials used in plant breeding research such as isolated *DNA* sequences and *plasmids*. An MTA is a binding private contract between the provider of the material and the recipient. In essence, it allows the recipient the right to work with the materials under terms agreed by both parties.

Micronutrient enrichment: The production of crops with increased levels of essential micronutrients. This process aims to address the problem of micronutrient malnutrition which occurs primarily as the result of diets poor in vitamins and minerals.

Moisture stress: A condition of abiotic physiological stress in a plant caused by lack of water.

Mutation breeding: The induction of novel and useful variation by the exposure of plants or seeds to radiation or chemical mutagens. Mutants can be used directly as new *cultivars* or used as parents in conventional breeding programmes.

Mutations: The modification of a *DNA* sequence that can lead to a change in *gene* function. Mutations can be harmful, beneficial or, as is most often the case, have no effect at all.

Open-pollination: Pollination by wind, insects or other natural mechanisms. See also *self-pollination*.

Plasmid: A type of small *DNA* molecule that can be used to deliver a *DNA* sequence or *gene* into a *cell.*

Precautionary principle/precautionary approach: A rule that permits governments to impose restrictions on otherwise legitimate commercial activities, if there is a perceived risk of damage to the environment or to human health. Its interpretation is disputed (see Box 4.1).

Promoter: A short *DNA* sequence that regulates the expression of a *gene*. Each *gene* has its own promoter, to which specialised *proteins* bind in order to activate it.

Proteins: Biological molecules that are essential for all life processes and are encoded by an organism's *genome*. A protein consists of chains of *amino acid* subunits and its function depends on its three-dimensional structure, which is determined by its *amino acid* sequence.

Purchasing power parity (PPP): A method of measuring the relative purchasing power of different countries' currencies over the same types of goods and services. Because goods and services may cost more in one country than in another, PPP aims to make more accurate comparisons of standards of living across countries. However, since not all items can be matched exactly across countries and time, the estimates are not always robust.

Refuges: Areas of crops which are susceptible to weeds or, more usually, insects, and thus provide a safe haven for them. These are maintained near fields of *herbicide tolerant* or insect resistant crops with the aim of providing a supply of insects and weeds that remain susceptible to the respective toxin. The strategy is designed to greatly decrease the odds that a resistant insect can emerge from the *herbicide tolerant* or insect resistant field and choose another resistant insect as a mate. By preventing the pairing of *genes* conferring resistance, these refuges help ensure that susceptibility is passed on to offspring.

Resistance: The ability to withstand *abiotic* or *biotic* stress, or a toxic substance. Resistance, relative to susceptibility, is genetically determined. Forms of biotic resistance are pest resistance, insect resistance, bacterial resistance and fungal resistance.

Rotavirus: A virus which causes acute gastroenteritis. Symptoms include vomiting and diarrhoea.

Self-pollination: Plants that pollinate their own flowers. See also *open-pollination*.

Subsidiarity: According to the principle of subsidiarity, within a system of governance, decisions should be taken at the lowest possible level, provided that goals such as safety and environmental protection are secured.

Subsistence farmers: Farmers who mostly grow food for themselves and their dependents, with any surplus typically being sold locally.

Substantial equivalence: A concept that allows a novel food to be compared with a similar existing food.

Tissue culture: The growth of *cells*, tissues or organs in a nutrient medium under sterile conditions.

Traceability: The ability to trace and follow a food or feed through all stages of production, processing and distribution.

Transformation: The process by which foreign *DNA* is transferred and incorporated into a living *cell*.

Transgene: An isolated *gene* sequence used to transform an organism. The transgene may have been derived from a different species than that of the recipient.

Triploid: An organism, or a *cell* type, with a chromosomal complement of three times the haploid number of *chromosomes*. A haploid *cell* (for example a pollen *cell*) contains a single set of *chromosomes*. An example of a triploid species is the cultivated banana.

Wide-crossing: The process of undertaking a cross where one parent is from outside the immediate (primary) genepool of the other. The term usually refers to artificially induced hybridisations between cultivated crop species and wild relatives.

Glossary of abbreviations and acronyms

AATF	African Agricultural Technology Foundation
ABSF	African Biotechnology Stakeholder Forum
ACC/SCN	United Nations Administrative Committee on Coordination, Sub-Committee on Nutrition
AEBC	Agriculture and Environment Biotechnology Commission
AGERI	Agricultural Genetic Engineering Research Institute
AIA	*Cartegena Protocol*'s advanced informed agreement procedure
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
BMA	British Medical Association
Bt	*Bacillus thuringiensis*
CAAS	Chinese Academy of Agricultural Sciences
CBD	*Convention on Biological Diversity*
CGIAR	Consultative Group on International Agricultural Research
CIP	International Potato Centre
COMESA	Common Market for Southern and Eastern Africa
CORAF	West and Central African Council for Agricultural Research and Development
DEFRA	UK Department for Environment, Food & Rural Affairs
DFID	UK Department for International Development
DNA	Deoxyribonucleic acid
DTI	UK Department of Trade and Industry
EC	European Commission
EU	European Union
FANR	Food, Agriculture and Natural Resources Development Unit in Harare, Zimbabwe.
FAO	UN Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
GEF	Global Environment Facility
GM	Genetically modified
GMO	Genetically modified organism
GNP	Gross national product
GURT	Gene use restriction technology
IARC	International Agricultural Research Centres
ICCP	Intergovernmental Committee on the *Cartagena Protocol on Biosafety*
ICGEB	International Centre for Genetic Engineering and Biotechnology
ICRISAT	International Crops Research Institute for Semi Arid Tropics
ICSU	International Council for Science
ICTZ	Inter-tropical convergence zone
IFAD	International Fund for Agricultural Development
INIBAP	International Network for the Improvement of Banana and Plantain
IPGRI	International Plant Genetic Resources Institute
IPR	Intellectual property rights
IRRI	International Rice Research Institute
ISAAA	International Service for the Acquisition of Agri-biotech Applications
JIC	John Innes Centre
KARI	Kenya Agricultural Research Institute
LMO	Living modified organism
MTA	Material Transfer Agreement
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development

PAHO	Pan American Health Organization
PPP	Purchasing-power parity
PIPRA	Public Intellectual Property Resource for Agriculture
PVR	Plant Variety Rights
RDA	Recommended daily allowance
SADC	South African Development Community
SPS	WTO's *Sanitary and Phytosanitary Agreement*
TBT	WTO's *Technical Barriers to Trade Agreement*
TERI	Tata Energy Research Institute
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UPOV	International Union for the Protection of New Varieties of Plants
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VAD	Vitamin A deficiency
WFP	World Food Programme
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

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