Chapter 4

Impact on developing countries: implications for UK policy

Introduction

4.1 When deciding what to do, one major consideration, perhaps the overriding one, is to increase human well-being, or promote general welfare. Comparing the merits of different policies towards genetically modified (GM) crops is thus a question of discovering how many people are affected for the better or for the worse, and by how much. But 'how much' depends in turn on where people start off. Just as the loss of £50 is a disaster to a poor person and an inconvenience to a rich one, so small losses are disastrous to people already suffering low levels of well-being, and can amount to the difference between bare survival and death by starvation. At high levels of well-being, large losses seldom threaten survival or even health. This suggests that when choosing GM policies on the basis of their effect on human well-being, we should give more weight to the life-or-death concerns of the hungry, than to the less pressing concerns of the well fed. This principle in fact reflects a common idea of social justice: that we should distribute resources 'according to need'.

4.2 Although the principle of 'to each according to their needs' was adopted as a slogan by radicals in the nineteenth century, it is much less radical and much more generally accepted where the needs in question are the basic nutritional and health needs to which GM crops are relevant.[1] There is general support in wealthy countries for famine relief and prevention. Beyond that, developing and developed nations (and the global food system) can go far to ensure basic nutritional needs are met world-wide, and yet leave a huge surplus to pay for 'rights-related', incentive-based or other inequalities as might be seen, by some, as necessary or desirable for justice, economic growth or political order. These considerations suggest that there need be no competition between giving full attention to the food needs of the poor and adopting policies for the promotion of GM crops that ensure the safety of people in developed countries and profitability for companies. The burden of this chapter is that policies to achieve this are ethically indicated and feasible, yet such policies are not in place.

4.3 If we value the ethic of 'to each according to need' (or in the alternative, believe that the poorest possess a 'right to survive', given feasible efforts on their own part and a global capacity to feed them), then the introduction of GM crops on a large scale would be a moral imperative. This is because GM crops are expected to produce more food, or more employment income for those who need it most urgently. 'More food for the hungry', unlike 'tomatoes with longer shelf-life', is a strong ethical counterweight to set against the concerns of the opponents of GM crops.

4.4 However, ordinary notions of justice or fairness are challenged by the present distribution of research effort, GM seed marketing and field trials which are dominated by a small group of leading agrochemical and seed multinational companies. In contrast, the Green Revolution[2] was largely due to public-sector research. Most of the companies' effort goes into reducing costs in capital-intensive farming in developed countries. Research on staples mostly involves varieties used for animal food. Only a small proportion of effort goes into what is most needed in less developed countries: cheap, labour-intensive, robust and high-yielding staples for human food. Inevitably, the companies respond mostly to the demands of the market. So it is unlikely that this state of affairs will change in the near future unless like-minded governments step in and act on explicitly market-correcting moral principles – financing or stimulating an orientation of GM research towards the needs of the hungry.

1 It is accepted that some needs are 'socially constructed', see Douglas M and Ney S (1998) **Missing Persons: a critique of the social sciences**, University of California Press, California. But the level of calories and other nutrients required for functioning in particular circumstances can be determined (within probabilistic limits).

2 The Green Revolution is the popular term for the spread of high-yielding food staples in developing countries. This began with maize hybrids in the 1950s, but the main component was the semi-dwarf wheat and rice varieties, mainly in reliably watered parts of Asia and Central America, around 1962–85. See Lipton M and Longhurst R (1989) **New Seeds and Poor People**, London, Routledge.

The need for increased food supply

4.5 Just as the world could not feed itself today with the farming methods of the 1940s, so farmers can hardly expect to meet the increased global demand for food in 20 years time using today's crop varieties and agricultural technologies. Many of the current needs of the developing world, in particular, arise from a mixture of economic and social problems. However, new agricultural approaches and new crop varieties will also be needed if the doubling of agricultural output necessary for food security is to be achieved for a projected world population of eight billion or more in 2020. In 1961 the amount of cultivated land supporting food production was 0.44 hectares per person; today it is about 0.26 hectares.[3] Based on population projections, by 2050 it will be approximately 0.15 hectares per person. The rate of expansion of arable land is now below 0.2% per year and it continues to fall. The growth rate of food staple yields since the mid-1980s has, moreover, slowed to less than half the pace of the 1970s.

4.6 Projections by the Food and Agriculture Organisation (FAO) indicate that 680 million people, 12% of the developing world's population, could still be 'food insecure' in 2010, down from 840 million in 1990–92.[4] Food insecurity is expected to diminish in East Asia, South Asia and Latin America, but it could accelerate substantially in sub-Saharan Africa, West Asia and North Africa. Sub-Saharan Africa and South Asia, home to a projected 70% of the world's 'food insecure' people in 2010, are expected to remain the main locus of hunger in the developing world.

4.7 Since 1960, most people in the developing world have enjoyed huge increases in employment income and food access. This has been largely due to yield-enhancing progress in food farming and has brought big falls in under-nutrition. Yet the gaps (for example, most of Africa) and the unmet needs (of over 800 million underfed persons) remain vast. In addition, population growth is increasing these needs rapidly. Meanwhile, yield improvements are slowing, and with them the growth of employment and availability of cheap food staples needed to remedy world hunger. There are a number of fundamental reasons for the slowing of the Green Revolution (paragraphs 4.16–17). Conversely, renewed progress will require new routes to rapid yield enhancement, which will almost certainly involve developing new GM crop varieties. Other measures are also needed, but reliance on these *alone* is either not feasible, or environmentally unacceptable, or both (paragraphs 4.22–24).

4.8 As many respondents to the Working Party's consultation noted, better distribution might address some of today's problems of food shortages and deficiencies.[5] Indeed, if the world's supply of food had been equally distributed in 1994, it would have provided an adequate diet for 6.4 billion people, more than the actual world population. However, such observations are very bad arguments against seeking employment-intensive technological progress in food farming. Political difficulties of redistribution within, let alone among, countries are huge. Logistical problems and costs of food distribution also militate against sole reliance on redistributing income (i.e. demand for food) to meet present, let alone future, needs arising from increasing populations in less-developed countries. Hence we must stress the importance of any new options that will secure higher direct and indirect employment and cheap food in labour-surplus developing countries.

4.9 GM crops have the potential to assist in alleviating world hunger. Some progress, indeed, has been made (paragraph 4.29) but significant inroads require radical changes in the current focus and structure of research and development (R&D) for such crops. The current focus is on non-staple

3 Pimentel D (1989) in **Food and Natural Resources**, Pimental D and Hall C (eds) Academic Press, San Diego pp. 2–32.
4 FAO (1997) **Report of the World Food Summit November 1996**, Rome.
5 Response from the **British Medical Association** to the Working Party's Consultation, and others. Some respondents felt that more efficient redistribution of food would alleviate world hunger while others argued that steps to increase food production were needed in addition to improvements in distribution.

crops, consumer quality, herbicide tolerance and other requirements of labour-saving production by large farms in industrialised countries for developed markets. The nature of GM crop development means that most R&D is undertaken by a relatively small number of large companies.

4.10 What is required is a major increase in support for GM crop research and outreach, directed at employment-intensive production of food staples within developing countries.[6] Much of this should involve public-sector scientists in developing countries and the Consultative Group on International Agricultural Research (CGIAR)[7] institutions. However, given the increasing concentration of GM funding and expertise in a group of large companies, it will also be necessary to involve the private sector, much more than at present, in the enterprise of 'feeding the world'. There are currently insufficient incentives or institutions to realise this goal.[8]

4.11 The resulting spread of GM food staples will probably be, on balance, highly beneficial to consumers' health and the environment in developing countries. However, safety concerns dictate a parallel improvement in regulation, both of field trials and of the use of GM crops in the food chain. Not only for GM crops does such regulation in developing countries frequently fall far short of the minimum standards taken for granted in the developed world.[9]

4.12 In the context of the new 'focus on poverty' in the UK Aid White Paper[10] and the fall in global funding for appropriate agricultural science, the UK is ideally placed to take the lead in addressing this situation. If it is not tackled, the world will be hungrier and more disease-prone. It will also be more unstable, ecologically threatened and politically dangerous, for rich and poor alike.

Under-nutrition in the developing world

4.13 In 1990–92, 840 million people, one-fifth of the developing world, consumed so little food, relative to needs, that they suffered caloric under-nutrition.[11] About one-third of children less than five years old in developing countries were significantly underweight for their age, including most of the one in ten new-borns who would die before the age of five.[12] Severe anthropometric deficiency is associated with an increased risk of suffering from damaged human development as a result of more or longer illness, a shorter life-span, or reduced physical work capacity, mental functioning or immune response.[13]

6 Despite the undoubted importance of labour-intensive processing and other industrialisation, its costs per job are such that most of the poor will continue to depend, for income growth, mainly on extra farmwork. This alone, moreover, can generate nearby, safe and affordable basic foods.

7 The CGIAR system comprises sixteen international research institutions, with a principal mandate for increased, more robust and more sustainable agricultural production, especially of food staples in developing countries. Its annual budget in 1998 was US$345 million. Member institutions specialise in particular geographical areas, farm systems, problems (such as irrigation management) or particular crops. Some of the latter institutions, such as the International Rice Research Institute in the Philippines and the International Centre for Maize and Wheat Research in Mexico, have developed many of the successive key high-yielding and robust varieties that together brought about the 'Green Revolution'. There is some world-class GM research capacity in these institutions, but due to the high fixed and variable cost of GM research, the CGIAR institutions remain relatively minor contributors.

8 **Horticulture Research International** and several other respondents to the Working Party's Consultation considered this to be a very important issue.

9 **The Foresight Health and Life Sciences Council** and other respondents to the Consultation expressed fears that such shortfalls in regulation could lead to avoidable environmental and public health disasters. Concerns were also raised by **Ken Collins** (MEP for Strathclyde East) and others that lax regulation might lead to developing countries becoming testing grounds for GM crops.

10 Department For International Development (1998) **Eliminating World Poverty**, Cm 3789, The Stationery Office, London.

11 This rigorous definition of 'caloric under-nutrition' takes it to occur when dietary energy intake is less than 1.55 times the basal metabolic rate (BMR). BMR is the rate of energy breakdown by a warm, fasted (18 hour) person at complete rest. The caloric intake required to meet 1.55 BMR varies by country, partly because 'minimum calorie requirements take into account age and sex composition of the population' (FAO (1995) **Food Agriculture and Food Security** WFS 96/Tech/1, Rome). For example, 1.55BMR averages 1790 kcals/man/day in Asia but 2000 in Latin America.

12 United Nations (UN) (1997) **Human Development Report**, Oxford University Press, New York.

13 Payne P and Lipton M (1994) How Third World Rural Households Adapt to Dietary Energy Stress, **Food Policy Review** no. 2, International Food Policy Research Institute, Washington D.C. The association between mild to moderate

4.14 There have been very substantial recent gains in calorie consumption, causing corresponding falls in under-nutrition. The average calorie supplies per person in the developing world rose by 18% between 1969–71 and 1990–92, while the proportion of persons in developing countries with a daily calorie consumption below 1.55 BMR fell from 35% in 1970 to 20% in 1990. Such gains were absent only in sub-Saharan Africa. Small-scale surveys of children under five for 1976–95[14] confirm the big improvements, but also reveal serious gaps.[15]

4.15 Where under-nutrition is a problem, its levels and trends, and those in average dietary energy supply (DES), are linked to (and often caused by) levels and trends in national production of staple foods.[16] Such trends, in turn, have been improved mainly by yield-enhancing technical progress, through the Green Revolution. Yet cereals production growth slowed from 3% per year in the 1970s to 1.3% in 1983–93. It is projected to grow at 1.5% per year to 2020 'if investments in agricultural research and infrastructure do not fall below the already reduced levels of the 1980s'.[17]

The global slowdown in yield

4.16 This global slowdown in the growth of yields is only in part a response to attenuated farm subsidies in the developed world. It is observed in most of Asia, including India and China. It is especially worrying that yield growth has slowed right down in many of the previously most dynamic areas, such as parts of the Punjab. The underlying causes, such as groundwater exhaustion, micronutrient depletion and low-level pest build-up, have proved very hard to manage using conventional plant breeding. As will be shown, further reduction of under-nutrition among the world's poor depends mainly on growth in employment income from producing local food staples. This, in turn, depends increasingly on re-igniting growth in *yield potentials*, which has been very slow since the late 1960s.

4.17 The general fall in under-nutrition has exposed other problems. Some large groups (for example, girls in South Asia) and regions lag behind. A shift to monocultures, to intensive animal products, and in marginal lands from pasture (for animal grazing) to arable (growing crops), may threaten both the provision of staples for the poor and the environment. These major continuing problems could, in principle, be addressed through spreading growth in yields to areas such as Africa and most of the semi-arid world. But this continues to prove very difficult with the present range of methods. Ultimately, a sustainable increase in the field performance of food staples depends on higher and more robust yield potentials. GM crops offer one way to achieve this, while potentially also encouraging (i.e. making more economic) reduced use of water and agrochemicals.

4.18 Apart from under-nutrition, it could well prove feasible to greatly reduce malnutrition through the development of micronutrient-rich GM crops (such as the Vitamin A-enriched rice developed by the

anthropometric deficiency (especially stunting) and bad subsequent outcomes is, however, weak and probably not causal. Mild to moderate stunting is (a) a 'marker' of an economic and physical environment leading to troubles later, rather than a direct cause of such troubles; (b) often a sign of biological adaptation to an environment that imposes severe strain: a population that cannot acquire much food is under genetic pressure to adapt by selecting genes for low energy requirements (smallness).

14 FAO (1996) **Sixth World Food Survey**, FAO, Rome.

15 Sachdev H (1997) Nutritional Status of Children and Women in India: Recent Trends **Nutrition Foundation of India** 18, 3:1–5. In successive nation-wide surveys in sub-Saharan Africa, the proportion of under-fives underweight rose in ten countries and fell in three (substantially only in Zimbabwe). In the Near East and North Africa three countries showed improvements. In Latin America and the Caribbean, the favourable balance was 14 to three. In Asia, only Laos showed deterioration; ten countries showed improvements, which were especially big and steady in India and Pakistan. Regions such as Tibet and the 'Bimaru States' in India have remained little touched by the improvements, Drèze J and Sen A (eds) (1997) **Indian Development: Selected Regional Perspectives**, Clarendon, Oxford; Bhargava A and Osmani S (1997) 'Health and nutrition in emerging Asia', Background Paper for **Emerging Asia: Changes and Challenges**, Manila: ADB.

16 To see how a nation's DES per person reflected under-nutrition, see Lipton M (1998) **Food Consumption**, Background Paper, UNDP Human Development Report, OUP, New York.

17 Pinstrup-Andersen P and Pandya-Lorch R (1996), Food for all in 2020: can the world be fed without damaging the environment? **Environmental Conservation** 233:228.

Rockefeller Rice Biotechnology Programme). Vitamin A deficiency affects over 200 million people and over 14 million children have consequent eye damage. Iron deficiency affects some two billion (2100 million) people, impairing physical and mental work and increasing risks in pregnancy. Iodine deficiency affects some 1100–1500 million people, of whom over 600 million are goitrous.[18]

4.19 To evaluate the potential of GM crops for alleviating under-nutrition and malnutrition, it is essential to grasp the connection between more food and less hunger. This is not simply the 'balance between food requirements and food availability'. Hunger and famine happen mainly because, even where food is available, the poor cannot afford it. They depend largely on income from employment, including self-employment, to obtain cheap food staples; hunger happens when such employment, in wealth-creating and hence rewarded work, is too scarce to buy the requisite staple foods. It will remain overwhelmingly staples production that can provide such employment income at capital costs (per workplace) that poor countries can afford. So the fact that most hunger is due to lack of employment income *strengthens* the case for raising food productivity on small farms in developing countries.

The impact of the Green Revolution

4.20 The growth in yields achieved through the Green Revolution greatly reduced hunger in the 1970s and 1980s for two reasons. First, as new arable lands become scarcer, it provided much the most affordable route to productive employment at low capital cost. Secondly, it supported a combination of events of particular benefit for the poor: a steady downtrend in the price of food staples relative to manufactures, so that the poor in urban areas could afford more food with their wages. Yet in areas benefiting from the Green Revolution, food production increased faster than food prices fell[19] so that small surplus farmers there were also better off and had more incentives to employ the poor.

4.21 The need to revive the faltering momentum of yield increases in food staples in developing countries, and to extend it to arid lands and to Africa, is emphasised by three factors. First, although the rate of population growth in developing countries is falling, populations are still increasing rapidly.[20] Workforces, and hence the numbers of people needing employment income, are increasing faster still, even as fertility declines. Secondly, to produce an equal number of calories for human consumption, up to seven times as much grain is needed if this is consumed via animal products instead of being consumed directly. Yet global economic growth and increased prosperity increasingly swell demand for animal products. As these pressures lead to a shift of land and grains away from human food, towards animal feed, even higher grain yields are required if staples for human consumption are to be produced sustainably and affordably. Thirdly, paths to increased food output other than through higher yields from GM crops, while needed, will not be sufficient to revive world crop growth, or to achieve much nutritional improvement, without unacceptable side-effects.

Increasing yields: alternatives to GM crop varieties

4.22 What might such alternative paths be?

- *Area expansion*: this slowed to very low rates during 1960–98. Pushing crops further into marginal lands decreases returns and increases environmental hazards. One estimate suggests

18 Graham R and Welch R (1996) Breeding for staple crops with high micronutrient density. Agricultural strategies for micronutrients: **Working Paper No. 3**, **International Food Policy Research Institute**, Washington, D.C.

19 Food staples prices have been falling (relative to manufacturers' prices) by about 0.5% yearly for the past 35–40 years. But in Green Revolution areas of South and East Asia and Central America, total factor productivity in food farming has been rising by over 2% a year.

20 The world population is projected to rise in 1998–2050 from 749m to 1766m in Africa, from 504m to 809m in Latin America and the Caribbean, and from 3585m to 5268m in Asia. United Nations (1998) **Briefing Packet: 1998 Revision, World Population Estimates and Projections**, United Nations, Population Division, New York.

that, if world crop yields had not been tripled between 1960 and 1992, we would have ploughed 10–12 million square miles of additional uncultivated land for low-yield crops. To avoid this happening in the next 20 years, 'we must be able to triple the yields from the world's existing farmland again'.[21]

- *Irrigation*: like land expansion, this has contributed enormously to past food production growth but now faces sharply diminishing returns, increasing marginal costs and hazards. Irrigation covers approximately one-third of the cropped area in Asia, barely 5% in sub-Saharan Africa, and 16% globally. Irrigation increases land productivity over 2.5-fold on average, but both expansion and improvement of irrigation efficiency are limited by growing urban competition for water and by serious environmental problems.[22] Hence it is critical to know whether GM crops with 'increase[d] resistance to drought . . .[are] likely to be as valuable. . . for the lower-potential lands as for the high-potential'.[23] Drought resistance and salinity tolerance are not the current priorities of GM crop research or funding, but could become so.
- *Increased fertiliser and pesticide inputs*: especially in Africa, these can do much to enhance yields, but, like agrochemicals for pests, diseases and weeds, are expensive for poor farmers. Fertilisers and pesticides may also cause environmental and health problems, which are compounded by weak regulatory controls in developing countries. GM crops could raise the efficiency of fertilisers and can help to control pests and diseases with fewer chemicals.
- *Conventional plant breeding*: supported by agrochemicals and irrigation, this has been associated with huge falls in food poverty incidence since the mid-1960s, from 30–35% to below 10% in China and Latin America and from 55% to 32% in India.[24] These falls are, to a considerable extent, due to semi-dwarf rice and wheat and hybrid maize. Continually modified to meet evolving pests and new soil and water conditions, such varieties have spread to cover 70–80% of areas planted with these crops in developing countries. Conventional plant breeding still has much to offer, and still has high returns; but its increasingly 'defensive' orientation means that it has shown steadily decreasing yield impact since the dramatic spread of such semi-dwarfs as IR8 and IR20 rice and 7094 wheat in the 1960s. Conventional plant breeding aims to produce ever-improving crop varieties but faces continually evolving varieties of pests; and has to extend gains to ever more recalcitrant areas and crops. Without major increases in yield potential, such breeding will become increasingly defensive, at best maintaining results rather than improving on them.
- *Alternative approaches*: conventional plant breeding, and other means to food output enhancement, may benefit from alternative approaches. Integrated pest management, by manual and biological controls, together with tolerant or horizontally moderate-resistant[25] crop varieties and modest pesticide use, reduces chemical pollution. It also reduces the evolution of new virulent pests which can overcome pesticides and/or strongly resistant crop varieties. Inter-alley and relay cropping present promising alternatives to the monocultures typical of conventional research. Participatory research goes beyond 'farming systems analysis' to integrate farmers' priorities and experimentation. This includes the introduction of land-races and other populations of plants, such as beans in Rwanda, into conventional formal

21 Avery D (1997) **Saving the planet with pesticides, biotechnology and European farm reform**, Bawden Lecture, Brighton Conference, British Crop Protection Council.

22 Kendall HW, Beachy R, Eisner T, Gould F, Herdt R, Raven PH *et al*. (1997) **The Bioengineering of Crops, report of the World Bank Panel on Transgenic Crops**, World Bank and CGIAR, Washington D.C.

23 Conway G (1997) **The Doubly Green Revolution**, Penguin, London.

24 Lipton M and Ravallion M (1995) Poverty and Policy, in Behrman J and Srinivasan T (eds), **Handbook of Development Economics**, Vol. IIIB, North Holland, Amsterdam.

25 A moderate-resistant plant kills less than 100% of the pathogen that it is resistant to. If, for example, only 95% of the targeted pathogen is killed, the plant absorbs some damage but there is not such a strong selection pressure for the pest to evolve a new and virulent biotype.

research systems.[26] Such methods were central to smallholders' strategies in centuries of slow or zero growth of population and demand. But the very slow food output growth in those times shows that, in coming decades, such strategies cannot suffice to revive the faltering pace of staples yield, productivity and, above all, productive employment to the level required.

Field yields and incentives for farmers: why 'yield potential' matters

4.23 It is sometimes argued that, because farmers' yields in developing countries fall far short of 'yield potential', there is no urgency to increase it, by GM crops or other technical means. It is claimed that the need for more food can be more readily met by action from farmers or governments to raise field yields towards their full potential. GM crops, it is argued, are therefore not a priority for developing countries. We believe that this claim is misguided because the alternatives to raising yield potential via GM crops are either running out of steam or themselves rest on renewed success with GM crops.

4.24 'Yield potential' is the maximum attainable crop yield from a given soil-water regime under experimental conditions, with no limits to the addition or adjustment of inputs such as irrigation, fertilisers, farm labour and machinery, or of agronomic conditions, for example by staking individual plants. On a real farm, it hardly ever pays farmers to reach more than 20–40% of this yield potential.[27] Rises beyond that level involve extra costs that outstrip the declining value of the extra crop returns. If it is uneconomic for a farmer to expand yield above, say, 25% of potential in given conditions, and that percentage has been reached, then field yields can, in principle, be expanded towards the full yield potential by four sorts of actions:

- *Farmers* can, in principle, 'farm better' with the resources they have. However, researchers agree that most smallholders, even if illiterate, use scarce resources well, seeking profit and avoiding risk.
- *Service providers*, such as agronomists and extension workers, can increase the farmers' knowledge or provide innovations that are more responsive to local needs and conditions, so making it safer or more profitable for farmers to raise yields towards their potential. However, this approach alone, over large areas, has hardly ever raised yields by more than 0.5–0.7% per annum. Moreover, agronomic innovation, by farmers or service providers, is much more likely to be rapid when more attractive plant yields make it more profitable.
- *Policy makers* can improve farm incentives by investments such as irrigation extension, credit and transport. This should make it safer or more profitable to raise field yields towards the yield potential. Progress has been made along these lines, but often with diminishing returns or with strong resistance from urban interests. Such policy changes have more effect on farmers' responses, and hence on output, and are therefore politically more affordable if yield potentials and field yields are rising.
- *Breeders* can improve resistance to pests or moisture stress, enabling field yields to rise, even with a static yield potential. However, the great progress here since the mid-1960s increasingly involves 'running to stay in the same place'. Falling water-tables, new pest strains and micronutrient exhaustion, themselves the results of that progress, reduce potential gains. Improved plant varieties are the path to better responses to these constraints, as well as to higher yield potential. Such varietal improvement has been slowing down. Furthermore, if

26 McGuire SJ, Manicad G and Sperling LJ (1999) **Technical and Institutional Issues in Participatory Plant Breeding Done from the Perspective of Farmer Plant Breeding: A global analysis of issues and of current experience**, Systemwide Program for Participatory Research and Gender Analysis, CIAT, Colombia.

27 The best farmers in 'lead' areas, such as the Indian Punjab, obtain only 30–40% of yield potential for rice and wheat. In Malawi, good field yields of maize are usually below 10% of yield potential.

GM plants are not used, it is in many cases not clear where new basic resources are to be found to revive the flagging pace of improvement. For example, almost all the dwarfing of rice relies on a single gene; the huge genetic range of maize has not provided answers to the search for better tolerance of rainfall delays (paragraph 4.45); the non-GM search for a means to allow cereals to fix significantly more natural nitrogen has been disappointing; and so, to some extent, have F1 rice and wheat hybrids.

4.25 Hence, unless GM research is directed towards improving the yield potential of food staples, farmers' field yields in non-temperate areas will be sluggish. Since the major progress of the 1960s, it has become increasingly difficult and costly to raise field yields without a renewal of that rate of progress. Typically, the physical, price, service and policy environments make it profitable for farmers to attain only *x*% of yield potential – and *x* itself rises, if at all, only very slowly. However, if yield potential is increased, so is '*x*% of it'.[28]

The potential of GM crops to raise field yields

4.26 As a seed variety is adopted, learning takes place. Farmers gradually raise their field yields to the proportion of 'potential' that is most profitable (allowing for risk). Unless the plant, and hence the next new variety, shows increasing yield potentials, the growth of field yields must eventually slow down. GM crops may offer the best route both to higher yield potentials and resistance to stresses which have proved hardest to tackle by conventional plant breeding techniques alone. These recalcitrant problems include some biotic stresses such as viruses and fungi (in addition to birds, weeds and some insects, nematodes and bacteria); and abiotic stresses such as moisture and temperature stress (and in some conditions salt, iron and aluminium).

4.27 GM research should not, however, divert resources from conventional plant breeders where these efforts offer better promise of success. New conventionally bred varieties continue to seek improved crop robustness against pests and to increase yield potentials of food staples, for example through F1 rice and wheat hybrids, or biological nitrogen fixation. That these latter examples have proved disappointing is probably due in part to the greater concentration of GM crop research in developed countries. This indicates that the main risk at present is that without adequate GM inputs, conventional plant breeding will not greatly increase the growth of yield potentials in the main tropical food staples, so that field yields will be increasingly sluggish. This will seriously imperil employment, income and food access for the world's poorest people.

GM crop research on tropical staples

4.28 Despite the urgent need and the lack of adequate alternatives, well below 10% of the 25,000 GM crop field trials in 1997 were in developing countries.[29] Of the 27.8 million hectares of GM crops commercially grown in 1998, approximately 16% were grown in developing countries.[30] This is not surprising: 'total agricultural biotechnology research expenditure in the entire developing world may not exceed US$50 million annually' as compared to US$190 million for government-financed research[31] and well over ten times that sum in US private-sector research alone.

28 This is not to say that better yield potential alone, in the absence of improved policies, outreach or transport, is *sufficient* to transform, say, semi-arid African field yields – only that it may well prove *necessary*.

29 Kendall HW *et al*. **The Bioengineering of Crops**, p13.

30 James C (1998) **Global Review of Commercialised Transgenic Crops**, 1998, ISAAA Briefs No. 8, ISAAA, Ithaca, p4. Much recent growth is of herbicide-tolerant (and thus labour-displacing) soya on large Latin American farms for export as animal food to the US – a low priority for the poor.

31 Kendall HW *et al*. **The Bioengineering of Crops**, p14, 16.

4.29 Despite the small amount of GM research resources devoted to developing-country agriculture, there is ample evidence that GM crops could significantly improve nutrition in developing countries. For example, researchers in Mexico have inserted a gene which enables crop plants to secrete citric acid from their roots. This increases their tolerance to aluminium toxicity, which affects a significant proportion of arable land, and which often reduces yields by over 30% and sometimes by as much as 80%. In GM rice, inserting genes from two wild rice relatives into the best performing Chinese rice hybrids has raised yields by 20–40%. Research funded by the Rockefeller Foundation has produced a GM rice variety resistant to the tungro virus; very promising GM vitamin A-enriched rice varieties, and a tissue which is giving up to 25% higher yields in China.[32] Other GM crop examples relevant to developing countries include potato varieties bred in Peru with stable multigene resistance to late blight,[33] a wild wheat cross yielding 18 tonnes/ha[34] and virus-resistant sweet potatoes in Kenya, conservatively estimated to raise yields by 15%.[35,36]

4.30 As for the future, probable contributions to increased rice yields from biotechnology in Asia have been estimated at 10–25% over the next ten years.[37] Evenson[38] uses the best scientific and economic information to assess the probable impact of a ten-year halt in public-sector GM crop development on developing countries in 2020. Because cereal prices would rise by about 12%, mostly for want of the extra supply of GM rice, the numbers of undernourished children aged up to six years would increase by 1.2 million, more than half of them in sub-Saharan Africa. Of course, the impact would be larger if private GM research were also halted, and much larger (but positive) if it were more relevant to developing country staple production.

The implications of GM crops for developing country trade

4.31 The implications of GM crops and food products for trade are seldom considered.[39] The main developing country exports are tea, coffee, cocoa, cotton and sugar, while Africa and China are big cereals importers.[40] If GM crops (or substitutes), grown in developed countries, raised the supply of a beverage crop by 20%, a price fall of about 60% would be needed to clear the market.[41] Such a development would threaten to devastate low-income exporters of beverage crops such as Ghana and Sri Lanka (see paragraphs 3.63–67). Conversely, failure to achieve rapid cereal output increases in Africa or Asia would, in view of the pending growth of demand and population, mean explosive rises in food import needs and some rise in the price at which such imports would be available. We consider that such trade effects, while seldom quantified, are potentially very damaging. They justify a major effort by international agricultural research centres to offset the emphasis of commercial GM crop research on the consumption, crops and conditions of developed countries.

4.32 As GM crop research is organised at present, the following worst case scenario is all too likely:

- slow progress in those GM crops that enable poor countries to be self-sufficient in food;

32 Conway G, **The Doubly Green Revolution**.
33 Kleiner K (1998) Save our spuds, **New Scientist**, No. 2136:24.
34 C Holden (ed.) (1998) Wonder Wheat, **Science**, 280:527.
35 Kendall HW *et al*. **The Bioengineering of Crops**, p18.
36 Wambugu F (1998) **Benefits and risks of genetically modified crops: gathering important insights on research into the benefits and risks of genetically modified crops for man and his environment**, CERES Forum on Food Products from Plant Biotechnology II, 8–9 June 1998, Berlin.
37 Kendall HW *et al*. **The Bioengineering of Crops**, p17.
38 Evenson R (1998), Personal communication, Yale University.
39 Thus minor crop issues received the main emphasis: 'Bio-engineered sources of vanilla could compete against producers of vanilla beans in some developing countries'. Galvin T (1998) Agriculture trade implications, **Ceres**, p. 36.
40 Hardly any important, low-income cereal net exporters now remain.
41 The large price fall happens because consumers expand demand only slightly in response to each price cut.

- advances directed at crop quality or management rather than at drought tolerance or yield enhancement;
- emphasis on innovations that save labour-costs (for example, herbicide tolerance), rather than those which create productive employment;
- major yield-enhancing progress in developed countries to produce, or substitute for, GM crops now imported in conventional (non-GM) form from poor countries.

GM crops and the poor: getting the debate back on the rails

4.33 GM crops offer developing countries:

- *positive prospects*: for sustainably resuming and spreading the benefits of the Green Revolution and hence for rapid rises in the welfare of the food-poor;
- *positive dangers*: regulatory or political arrangements may lead to significantly lower food-safety and environmental standards than in industrialised countries. In addition, breeders may try to incorporate plant genetic resources in patent applications which are indigenous to developing countries;
- *negative risks*: GM crop technology may concentrate unduly on the crops and farm systems of industrialised countries, so that farm exports in developing countries may become uncompetitive, and there may be opportunity-costs of lost food production and employment. For example, research may be directed towards Roundup Ready yellow maize for poultry, rather than drought-tolerant white maize for people.

4.34 All three issues have implications for United Kingdom (UK) policy – nationally, and also in the United Nations (UN), the European Commission (EC), the World Bank and the CGIAR. So far, proponents of GM crops have made too much of the first issue (claiming that they will lead to big gains for the world's poor, even with the present structure of GM research). Opponents have overplayed the second issue (emphasising possible dangers, mainly in developed countries). The ensuing debate has neglected the third and most serious issue: the risk that the gains from GM crops will pass the poor by.

4.35 To correct the imbalance in the GM crop debate, we should recall the debate about the Green Revolution. Its early advocates stressed the mass benefits of higher food production. Critics stressed the proneness of the new varieties to drought and pests, and the increased risks for poorer, risk-averse farmers. The main problem proved to be different. Where the Green Revolution spread, mainly in irrigated Asian and Latin American rice and wheat monocultures, the potential dangers were largely avoided (partly because the breeders listened to critics) and the poor benefited. The main drawback of the Green Revolution was the exclusion of huge areas, notably in Africa, from the potential benefits.

4.36 This was due to inadequate or misdirected research into the farming systems (and crops) of semi-arid, ill-drained and inter-cropped areas.

> Africa, though relatively informed, is wanting, waiting and hoping that the biotechnology revolution will not pass them by, as the Green Revolution did, due to a lack of resources and unrealistic controversial arguments from the North based on imagined risks.[42]

42 Wambugu F, **Benefits and risks of genetically modified crops**.

4.37 This is something of an overstatement, as some of the risks are not 'imagined' and the developing countries largely lack a biosafety infrastructure. Nevertheless, Africans, facing continued expansion of population and workforce after forty years of static or worsening hunger, and slow technical progress in food production and hence employment, naturally stress 'risks' of GM plants less than well-fed Europeans do. The Director of the International Service for the Acquisition of Agri-biotech Applications (ISAAA) centre for technology transfer in Nairobi, herself a former researcher on GM crops, has provided a welcome corrective to the self-righteous.

4.38 In planning science policy for a second Green Revolution through GM crops, we believe that the main issue is not the danger to the developed world, which faces real but well-regulated environmental (and very small, if any, food safety) risks. It is the developing countries, with their far greater needs, prospects and risks, cash-starved science, and sometimes weak or corrupt regulation, which face greater dangers. These dangers may conceivably come from carelessly introduced GM plants or foods, but are more likely to be due to neglect. Since the mid-1980s, funds for developing-country agricultural research have stagnated, while those for private GM crop research in developed countries have rapidly expanded.

4.39 In the longer term, GM crops will probably transform farming in developed countries. However, unless something is done, this will be achieved largely to suit the needs of the food industry in supplying the market demands of adequately-fed people in developed countries, while passing the poor by. What can be done to encourage a more equitable outcome? In contrast to the situation with plant breeding for the Green Revolution in the 1960s, public-sector systems will not be able to carry out most of the work on their own. A very small and dwindling proportion of research money and GM expertise is in public-sector systems, both international (CGIAR) and national (Brazil, China, India, Mexico and South Africa), which are relevant for developing countries. Sole reliance on these public-sector systems will not be sufficient.

4.40 The costs of identifying and isolating a desired gene from an organism and transferring it to a target crop plant, in addition to field-testing and obtaining regulatory approval, will be extremely difficult to meet without the involvement of the private sector. However, the 'non-market' concerns of the poor and the hungry are likely to continue to be undervalued, unless the international public sector and the leading research institutions and scientists in developing countries retain some influence over GM research choices. One solution, although costly, might be for them (via the CGIAR) to set a research agenda and then to reward or finance private companies or researchers either for attaining specific monitored outcomes, or for research directed towards plants and activities that will mainly benefit the poor in developing countries.

4.41 Just as the CGIAR institutions attracted the scientific capacity that enabled the spread of the first Green Revolution, so the second, especially if it is to benefit those by-passed by the first, will require new incentives and new, or adapted, institutions for agricultural research. We conclude that developing countries and multilateral agencies need to devote much larger shares of effort to agricultural research that not only develops new GM crops, but derives criteria for such development from the stated requirements of small farmers in staples-based systems. These should take into account farmers from rainfed and intercropped areas, and the needs of poor countries for employment-intensive production and processing of cheap food staples.

4.42 **The Working Party recommends that the UK Government and EC, preferably working through the CGIAR,[43] invite those developing countries willing and able to commit genuinely additional resources, to enter a joint initiative. In view of the proven high**

43 There are two administrative bodies: the Technical Advisory Committee (TAC, located in Rome at the FAO) and the CGIAR (located at the World Bank in Washington DC), concerned with obtaining donor commitments, setting priorities on the basis of TAC recommendations, and obtaining consensual allocation of funding among CGIAR institutions.

returns to and impact on poverty of appropriate agricultural research, and the new salience of fundamental and applied GM research,[44] **there should be a funded and major expansion of research:**

(i) into higher, more stable and sustainable production of tropical and sub-tropical food staples;

(ii) seeking gains for poor farmworkers, food consumers and smallholders;

(iii) by mainly CGIAR institutes and developing-country national agricultural research systems (NARS), working with private sector researchers in the developing and developed world where desirable;

devising alongside *locally appropriate*:

(i) research planning;

(ii) regulatory/implementation mechanisms for environmental review of GM crop experiments (paragraph 4.62)**;**

(iii) food-safety clearance of GM releases to farmers.

The Working Party further recommends that the Department For International Development (DFID) and the Ministry of Agriculture, Fisheries and Food (MAFF) should jointly help UK researchers to contribute to developing this initiative. We endorse the recommendation by the House of Commons Environmental Audit Committee that a Minister from DFID be appointed to the Cabinet Ministerial Group on Biotechnology and Genetic Modification.[45]

Prospects for environmentally-friendly GM crop growth in poorer countries and the UK role

4.43 With appropriate emphasis and incentives in GM crop research, and with luck, GM crops could raise calorie or economic yields per hectare and per worker-hour by improving efficiency through:

(i) *conversion* of inputs of nutrients, water or sunlight into dry harvest;

(ii) *partition* of harvest between edible (or otherwise useful) and other dry matter;

(iii) *extraction* of soil nutrients and water (if sustainable).

The conventional Green Revolution approach to the first two points, through shorter-strawed, more fertiliser-responsive wheat and rice, has been less successful for other crops, intercropped systems, uplands, and marginal or uncertain rainfall areas. GM crops are believed to have the potential for particularly significant impact here[46] and to:

- improve bio-absorbable and acceptable micronutrients per calorie of food crops;
- stabilise yields in the face of pests and water stress, by improved resistance, tolerance, or crop timing for avoidance of pests and water stress. (This often also enhances conversion efficiency.)

44 In the NARSs, most research would be screening or adaptive. A few, however, have capacity at breeding and fundamental levels, for example India, China, Brazil, Mexico and Kenya.

45 House of Commons Environmental Audit Committee (1999) **GMOs and the Environment: Coordination of Government Policy**, Fifth Report, The Stationery Office, London.

46 Conway G, **The Doubly Green Revolution**.

4.44 Conventional plant breeding has usually been relatively successful when breeding for yield and for single-gene pest resistance. The latter, like pesticides, induces emergence of adapted and virulent pest strains (see paragraph 2.5). Pest tolerance (which allows plants to live with and survive pest attack), and multigene resistance, are more stable and better at reducing risks for remote, poor and small farmers and communities. Multigene resistance is harder to achieve, partly because it is associated with many genes, as is a plant's capacity to use water more efficiently and to avoid moisture stress. GM crop research, however, allows specific groups of genes to be integrated into the host plant genome, unlike conventional plant breeding.[47]

4.45 GM research into smallholder food staples will not be adequately addressed with the current balance of research incentives and institutions. For example, if white maize, Africa's main food crop, could be engineered to have prolonged latency,[48] this could make a major contribution to the fight against hunger. This unattained goal of conventional breeding is a key challenge to GM maize researchers. But the extent of gains for the poor will depend on the emphasis given to GM crop research that gives priority to employment-intensive methods and crops, especially cheap staples, not just to 'more output' or even 'more food'.

4.46 In planning for research strategies to realise the potential of GM crops for the world's poor, in the context of UK policy we must consider two objections. First, research into crops or farming systems, however targeted towards poor people's needs, is useless if prospects of success are also poor. To some extent, however, this is often a self-confirming argument. Yams are little researched because they are thought to be unpromising and therefore remain so. When the Rockefeller Foundation initiated GM rice research it was thought a recalcitrant crop; today it is a 'model' for other cereals.

4.47 Secondly, researchers need freedom to follow their intuition about which gene transfers are worth exploring and which farming systems can benefit. The best innovative research is seldom locked wholly into a policy-driven agenda. However, the direction of those intuitions may be affected not only by objective perceptions of what lines of work are the most promising but by peer-group incentives, promotion prospects, publication priorities of journals, and other aspects of the social setting. Policy makers seeking to transform GM crop research into an effective weapon against poverty must consult not only with researchers, but also with the poor. Often poor farmers' and workers' own perceptions of their needs and prospects need to be incorporated early on, if they are to gain the most benefit from the required substantial changes in the incentives and institutions that help fix scientific agendas.

4.48 The Working Party welcomes the aim of the March 1998 White Paper on overseas aid to underpin the agreed Organisation for Economic Co-operation and Development (OECD) effort, following the UN Copenhagen Summit on social policy and development, to construct 'aid partnerships' with developing countries to halve world poverty[49] by 2015. **To help to achieve this we recommend that alongside consultations with the developing countries concerned about their own agricultural research priorities, the UK Government should pre-commit a substantial amount of the rise in UK aid announced in July 1998 to additional spending on the R&D of GM food staples grown in developing countries.** A part of this sum should be for consultative work with those countries on the design of appropriate regulatory regimes (see paragraph 4.62). **We further recommend that this contribution should be used to leverage**

47 For example, GM potatoes in Peru have been planted with stable multigene (horizontal) resistance to late blight: (Kleiner K, Save our spuds). However, it is important to avoid the danger that early GM research, undertaken before the functions of all the genes in a plant are fully understood, may further shift the emphasis towards single-gene resistance. This underlines the importance of maintaining public-sector capacity and influence alongside commercial GM research. See Conway G, **The Doubly Green Revolution**.

48 The capacity to defer flowering if late rains mean that soil moisture is scarce.

49 Incidence of absolute poverty is defined as consumption per person worth less than US$1 per day at internationally standardised prices of 1985.

extra funds from other donors (including the EU) for developing-country NARS and for the CGIAR institutes. The funds should be focused on those developing countries eager to support the initiative with extra domestic financing for public-sector agricultural research.[50]

Regulation of GM crops in developing countries

4.49 The proposal above needs to be balanced with measures to help developing countries create an infrastructure to evaluate and regulate GM crop variety trials, initial distribution to farmers, and releases into the food chain. Structures for assessing environmental impact, food safety and socio-economic effects will be needed. This is partly because GM crops may carry additional risks. Most scientists agree that these dangers are not significantly different from those associated with conventional plant breeding, or indeed with natural outcrossing. However, 'Green' groups in some developing countries, like part of the UK public, are sceptical. Whether due to error, self-deception or incentives, regulators, and even the scientists who advise them, have sometimes been mistaken about health risks or risks to the environment.

4.50 Although approved GM crops are considered as safe by designated government advisory committees, if one or two high-profile accidents were plausibly linked to GM crops there would be a public outcry. Such accidents, which could discredit potentially valuable food innovations, are far more likely to occur in developing countries. In developed countries, public information is more readily available, there is more oversight and regulation and GM crop field trials and commercial releases are surrounded by well-developed infrastructures for assessing environmental and human biosafety.

4.51 GM plants raise issues of public concern, as discussed in Chapter 5. These are addressed in developed countries by infrastructures for regulation and overview. Developing countries also need to assess and to act on, actual or potential GM crop-linked environmental risks, especially from the unwanted spread to weeds of herbicide tolerance; from Bt-gene poisoning of untargeted insects; and from undesired food-chain or pathogen damage to life-forms.[51]

4.52 Without an effective and open-access regulatory infrastructure, there is a subtler danger. Commercial pressures may induce (or transfer from the North) GM crop introductions, decisions and outcomes that are manageable in developed countries, but that in most developing countries require:

- different regulatory measures, usually incentives rather than compulsion, because there are too many small seed distributors and far too many small farmers to supervise;
- special care (and methods) for communication to the public, given inadequacies of the 'open' civil society, and/or of public scientific literacy, education and media.

4.53 These problems are familiar in the UK, but need different solutions in many developing countries. Other issues, special to developing countries, include the need to:

- avoid 'biopiracy' (the unauthorised and/or uncompensated gathering, for commercial advantage, of developing-country and international biological resources) and yet retain incentives for properly compensated and beneficial exploitation;
- develop farmers' broad and equitable access to apomixis technology when this becomes available (see paragraphs 2.42, 3.39 and 4.72);

50 The African scenario of 1980–95, in which increasing aid funds for NARS were offset by declining national funding, must not be repeated.

51 Risks to human health from GM crops are probably much smaller than these potential environmental hazards. Such hazards might arise from insecticides and herbicides themselves – with or without GM crops. Indeed, GM crops embody more knowledge about what genes do, and so should be better at avoiding unwanted targets.

- consider and implement appropriate responses, both directly and via 'the international system', to the increasing concentration of GM crop research in a group of multinational companies (see paragraph 3.19).

4.54 The regulatory experiences, both good and bad, and global contacts throughout the European Union (EU), mean that the UK is well placed to assist developing countries. What environmental or biosafety concerns may require special regulatory or other solutions there? These need a strong scientific basis, public representation, monitored enforcement and open access. The appropriate means to achieve these ends will differ in, and between, developing countries.

4.55 The concern that plant pathogens will be induced to develop new and virulent strains has been focused largely on virus-resistant GM varieties (paragraph 6.31).[52] Rather than seeking to prevent the testing and release of such crops, it might well be more feasible to steer research towards forms of resistance that pose less risk. An example is countering the main virus of cassava (tobacco mosaic virus) through safe forms of coat protein-mediated resistance.[53] Strategies to avoid the emergence of new types of pathogens by selective cycling and deployment of particular types of crop have been developed with success in maize in the United States (US) against the build-up of virulent races of *H. maydis*. However, this approach is less feasible in most developing countries, where there are large numbers of very small farms, often with poor communications and controls.

4.56 Another risk is that herbicide-tolerant crops will hybridise with weed relatives. This has already happened in experimental plots between oilseed rape and the related wild radish (see paragraphs 6.22–26). The problem is also relevant for out-crossing food staples such as maize and sorghum, crops of major food interest to the poor. Even inbreeders such as rice outbreed occasionally, so that the problem could be important, especially for rice, where, as in some African uplands, it grows adjacent to wild rice and weed species in conditions where good weed control is costly and trying. The danger is not to the majority of poor smallholders who use no herbicides – for them, herbicide-tolerant weed varieties do not matter – but for the few smallholders, and the larger food producers, who do.[54] On family farms in many developing countries, weeds, especially wild rices and barnyard grasses, are probably the most serious single cause of crop loss, especially for upland farmers, and increase the need for deep ploughing which in turn leads to soil erosion.

4.57 Of the various traits under consideration in GM crops, it should be noted that herbicide tolerance may be associated with special socio-economic effects when utilised in varieties for use in developing country agricultures. For example, the use of herbicides replaces hand weeding. Notwithstanding the fact that some of the most striking applications of herbicide tolerance are in developing countries (such as the introduction of direct seeded rice in the Philippines), the same use of herbicide-tolerance varieties may work against poverty reduction programmes which require raising, not lowering, demand for labour. **We recommend that the CGIAR should carefully assess both socio-economic and agricultural needs before introducing crop varieties with novel traits into developing country agricultures and should co-ordinate careful assessment of the potential risks of hybridisation of GM crop plants with weed relatives.** The Working Party notes that the centres of diversity of the wild populations of some main modern agricultural crops lie in developing countries, for example wild potatoes in the Andes, wild wheats in the Middle East and wild rices in South East Asia. Although there is no indication of widespread transfer of genes from conventional cultivated varieties to close wild relatives, it may nevertheless be prudent to co-ordinate careful assessment of any potential risks of transfer in these regions.

52 Coghlan, A (1998) The devil we don't know, **New Scientist**, No. 2151:21.

53 Beachy R (1998) **Strategies that minimize real and perceived risks of pathogen derived resistance in transgenic plants**, CERES Forum on Food Products from Plant Biotechnology II, 8–9 June 1998, Berlin. Cassava is a main food staple produced and consumed by Africa's poor. Tobacco mosaic virus also affects other plants of interest to developing countries.

54 Recent work provides a route to reduce, but not eliminate, this risk: Gray A and Raybould A (1998) Reducing transgene escape routes, **Nature**, 392:653–4.

4.58 Other conceivable consequences of GM crops are even harder for developing countries to control in practice. One wonders how India, let alone Angola, could deal with the remote prospect that weed control through herbicide-tolerant varieties becomes so efficient that beneficent insects and birds, dependent on the weed seeds, are seriously harmed.

4.59 Several concerns have been voiced about the gene that expresses the Bt toxin (see paragraph 2.33). First, pest resistance may develop, limiting the use of directly applied Bt pesticides as well as the GM crop. Some leading US experts believe that 'Bt resistance management plans should be enforceable by the Environmental Protection Agency (EPA) and that Bt-engineered crops should be grown with ''large'' refuges of 25–50% of affected acreage'.[55] Secondly, untargeted organisms are threatened (paragraph 6.29).

4.60 The UK Advisory Committee on Novel Foods and Processes (ACNFP)[56] argues that the complaints cited in Greenpeace's report entitled *Genetic Engineering: Too Good to go Wrong*? 'indirectly highlight the strength of the existing European regulatory framework in being able to ensure that activities involving [GM crops] do not cause harm to human health or the environment in Europe'. Similar remarks probably apply to the US. However, it is unlikely that any developing country can afford to implement the sort of regulation of trials that is taken for granted in Britain. If field trials indicate some small risk and a GM crop is released on certain conditions, it is most unlikely that these could be enforced by developing counties for millions of smallholders, tiny retailers or semi-subsistence food consumers. Nor, in most cases, is there a 'civil society' of media and non-governmental organisations sufficiently active to induce effective regulation. India is ahead of most developing countries in such respects, yet every year many die by poisoning from unregulated liquor; until the mid-1970s many new cases of lathyrism arose from the 'prohibited' semi-staple lentil *Lathyrus sativus*;[57] and laws for the iodisation of salt remain unenforced.

4.61 The probable costs of the (mostly remote) environmental risks from GM crops to developing countries, even with no controls, do not approach the probable gains of GM crops concentrated on the local and labour-intensive production of food staples. Are lower safety standards justified because, by producing more and better food and more jobs for the undernourished, or by reducing agrochemical use, GM crops save many more lives than they cost and improve more lives than they worsen?

4.62 There are two objections to this argument. Ethically,innocent victims of GM crop side-effects will not often, in practice, be compensated out of the gains of others. Politically, frightened farmers and consumers will react to adverse side-effects by rejecting GM crops altogether, deferring any gains for many years. Consequently, it is important to ask how risks to environmental and human health can be minimised, given the limited regulatory capacity of many developing countries. The costs and risks can almost certainly be much reduced, and the risk of a backlash thus avoided, by ensuring appropriate public awareness, and by insisting on transparent arrangements for overview and enforcement. However, this will have to depend far more on incentives, and probably on co-operation with commercially employed scientists and companies, and less on command-and-control, than is feasible or necessary in the developed world. Nevertheless, we conclude that transfer of experience and know-how from advisory and regulatory bodies in developed countries to the developing world, with suitable adaptation to its socio-political as well as physical environments, is urgently needed. **The Working Party recommends that part of new UK aid funds recommended to be earmarked for GM in and for developing countries**

55 Fox J (1998) UCS says EPA Bts around the bush, **Nature Biotechnology**, 16:324.

56 See **ACNFP Consideration of Greenpeace Report on Genetic Modification**, May 1998, http://www.maff.gov.uk/food/novel/gpeace.htm

57 This crop is grown mainly in Bihar. It has long been known to induce lathyrism, but is a robust calorie source on very poor soils. It declined as wheat became high-yielding and cheaper (and as poverty fell somewhat) – not because of laws; any cheap staple, even if 'risky', is almost uncontrollable among the poor (indeed *Lathyrus sativus* has recently been *introduced* into Northern Ethiopia). The development of GM varieties which have lost the toxic effect, rather than prohibition, is a possible way ahead for developing countries.

(see paragraph 4.48) **should be used to help such countries in devising appropriate incentive and regulatory regimes against possible environmental and biosafety hazards**. While consultation with regulatory bodies in the US, EU and elsewhere is essential, developing countries have different (and varied) farming systems, food chains and environments, and so need different biosafety and environmental procedures. **We therefore recommend that this part of the new GM funding be guided by leading researchers via appropriate international bodies with strong developing-country representation such as the FAO, the International Food Policy Research Institute, and/or the Institute for the Support of National Agricultural Research.**

Developing countries' regulatory requirements: international aspects

(A) The Biosafety Protocol

4.63 Developing countries need appropriate GM crops to enhance their crop yields and food security. At the same time they need the ability to regulate the management of GM plants in their countries to protect their environments and their food safety just as developed countries do.

4.64 In many ways their dilemmas are more acute on this matter than those of the developed world. Their need for increased yields from crops that may be grown in inhospitable or deteriorating environments is more pressing. But at the same time some of the developing countries have particularly rich natural biodiversity which needs to be conserved. As and when GM crops suitable for their conditions are developed they are likely to be subject to very strong commercial and international pressures to grow these. But so far they have less well-developed regulatory structures and expertise to manage these introductions appropriately.

4.65 The Biosafety Protocol being considered by the parties to the Convention on Biological Diversity (CBD) is intended to provide a first line of defence in this area, principally for the benefit of developing countries. It enshrines the basic principles of requiring information to be given about imports of GM material, and informed agreement obtained in advance. So far, however, the negotiation of the Protocol has been blocked by the US acting with a few other countries which have already started extensive commercial planting of GM crops in their countries. **The Working Party considers the Protocol to be an essential safeguard to enable the desirable development of appropriate GM crops for developing countries to take place safely, and recommends the UK Government and its European partners redouble efforts to reopen the stalled negotiations on this subject and to bring them to a successful conclusion**.

(B) Controlling 'biopiracy' or stopping seed development?

4.66 The international infrastructure for seed movement has gaps and distortions that carry some risks[58] of harming developing countries by discouraging commercially fair bioprospecting, and by facilitating so-called 'biopiracy' instead. There are two distinct issues: legal field crop transfer and the unauthorised and uncompensated removal from developing to developed countries for experimental

58 Potatoes genetically modified with the Bt gene, legally introduced by Monsanto to Georgia, 'may have crossed into Russia and Azerbaijan' where priorities and risks may differ, and where tests have not been done, see Anon (1998) Environmentalists fear uncontrolled movements of GMOs, **Nature Biotechnology**, 16: 892. Gains from reduced risk of hunger may well outweigh the risk of collateral damage from the Bt gene. However, states, consumers and farmers want to be involved, and must feel in such cases that decisions are taken over their heads.

use with a view to commercial development. Neither approach necessarily involves GM crops. In addition, neither approach is necessarily confined to private companies. In a recent controversy, Australia's public-sector scientists claimed plant breeders' rights on CGIAR genetic resources, including chickpeas grown in India and Iran.[59] However, the increasing privatisation of GM crop research, in the context of the TRIPS agreement,[60] has increased the incidence, complexity and urgency of ownership issues.

4.67 It is widely agreed that obtaining crops from small farmers in developing countries, patenting genes of agronomic interest and attempting to restrict the use of such crops, is unethical. All inventors depend on predecessors; the special claim of small farmers is that they have almost always invested their own intellectual capital in selecting, developing and often informally researching their land-races or varieties. Fortunately, the principle of compensation has been explicitly recognised by Monsanto and some other companies. These companies have responded to requests from non-governmental organisations and others for the sharing of profits from such ventures, with funds to assist the farmers from whom the germplasm came. This seems to be the right approach but will be hard to enforce. Indian legislation restricting the export of biological samples[61] should make it less so but risks reducing the opportunities for international collaboration. However, any attempt to restrict subsequent use seems impossible to implement.

4.68 Patenting by individuals or agencies of varieties from an International Agricultural Research Centre (IARC) or NARS, especially F1 hybrids or other plants that do not reproduce true from retained seeds, raises a special problem. For a NARS, seed release and control is an important tool, not only for R&D, but also as an incentive and to ensure political salience. For the CGIAR system, open access has been a central principle exemplified by permitting the free exchange of plant material. Yet the NARS loses access (and conceivably even legal power to distribute) when there is a patent involving its resources. At least one IARC has felt obliged to include its own materials in patent applications, one reason being to protect the material from being patented by others. Even so, such patenting may threaten open access to the IARC material. ICARDA (International Centre for Agricultural Research in the Dry Areas) has admitted to signing agreements with Australian research institutes allowing them to claim rights over seeds developed by ICARDA 'as long as they gain approval from the countries of origin'. This has aroused wide opposition from developing countries and scientific organisations.[62]

4.69 Patents may be the best way for IARCs and NARSs to assert their intellectual property rights. A strong argument is that an IARC or NARS should raise as much funding as it can from a private organisation (or industrialised country public agency) that uses its seeds. Indeed, the CGIAR has just reversed its long-standing position on open access by allowing member institutes to file patents applications. Their capacity to continue to supply seeds to farmers in developing countries, as the seeds increasingly come to contain GM progeny, will partly depend on whether seed companies are much concerned about competing seeds in developing countries.

4.70 If, as seems the case, they are generally not, biopiracy may be transformed into bioprospecting through appropriate institutions. Existing national policies on medicinal plants are inadequate and do not promote local development of processes and technologies. This inadequacy also extends to food and fibre plants. The Indian Agricultural Research Institute has confirmed that Australian researchers seeking to work with seeds of its toxin-free variety of the pulse *Lathyrus sativus* (kesari

59 Anon (1998) Lest we starve, **New Scientist**, No. 2121:3; Anon (1988) Breeders' rights row leads to UN action, **GenEthics News**, 22:9.

60 The agreement for Trade Related Aspects of Intellectual Property Rights (TRIPS), which developing countries are under great pressure to ratify, has been modified by the World Trade Organisation (WTO) to exclude payment of fees for traditionally developed technical knowledge (including genetic materials) collected or otherwise obtained from indigenous communities.

61 Anon (1997) China and India move to control gene export, **GenEthics News**, 20:5.

62 Edwards R and Anderson I (1998) Seeds of wrath, **New Scientist**, No. 2121:14–15.

dal) must negotiate a deal.[63] However, Indian legislation, revoking open access to its gene banks, could be used to undermine this intelligent approach by 'nationalist' prevention of seed transfer, even if fairly recompensed. More probably, the law will be used to reinforce the 'deal' approach, which will encourage plant development by sharing its rewards in a more accurate proportion to intellectual inputs, corresponding precisely to the Monsanto–NGO (non-governmental organisation) approach to community-developed crops. Recent Chinese legislation is similarly double-edged: it could be used to ensure that bioprospectors pay for the materials and research (formal or indigenous) that they use, or to prevent access to and use of such research.

Intellectual property rights and the TRIPS agreement

4.71 The legal framework for regulating the ownership, access and exploitation of genetic resources has been substantially changed since the recent adoption of two international legal instruments: the 1992 CBD and the 1994 TRIPS agreement of the WTO.[64,65] The CBD is focused mainly on providing rules related to tangible property rights of access to, and exploitation of, genetic resources as phenotypes. The TRIPS agreement is concerned with mandatory standards for intellectual property rights, including those which cover genetic information.[66] These standards constitute the international law to be observed under the CBD (Article 16) whenever access to, and transfer of, patented or other intellectual property rights-protected technology is under consideration.[67]

4.72 The TRIPS agreement sets the minimum standards for certain existing rights. It has 'no requirement on applicants to involve or consult with local communities or governments about patenting a compound based on a natural product from that country [or] sharing the benefits or including the prior contributions of indigenous peoples'.[68] The CBD, on the other hand, requires host government consent and 'approval and involvement' of traditional communities. There have been attempts to amend patent law so that the CBD objectives would be better supported by taking into account the access legislation. For example, it has been suggested that provisions are included which require the patent applicant to disclose the country of origin of plant materials, any traditional knowledge in the application and whether explicit consent for use of the materials was obtained.[69] The European Parliament also tried to amend the EC proposal for a directive on the legal protection of biotechnological inventions[70] in 1997 in a similar way.

4.73 The proposed amendments were rejected, although EU Members States are required to give particular weight to the intentions of the CBD when enacting the necessary laws and regulations to comply with the Directive.[71] To 'help a common appreciation of the relationship between intellectual property rights and the relevant provisions of the TRIPS agreement and the CBD' it encourages the patent applicant to include information on geographical origin.[72] If patent laws need to be amended to better support the achievement of the CBD objectives for the benefit of all parties involved, it must be done within the framework of the WTO and the TRIPS agreement. The UK, occupying an intermediate position on GM crops between the liberal regulatory position of the US Government

63 Jayaraman K (1998) India seeks tighter controls on germplasm, **Nature**, 392:536.
64 As Annex IC to the Marrakesh Agreement establishing the World Trade Organisation.
65 Strauss, J (1998) Biodiversity and intellectual property, **AIPPI Yearbook 1998/1X**, p99.
66 Ibid. p. 102.
67 Ibid. p. 108.
68 Masood E (1998) Social equity versus private property: striking the right balance, **Nature**, 392:537.
69 Watal, cited in Strauss J, Biodiversity and intellectual property, p.99.
70 Official Journal of the European Commission (1988) **98/44/E Directive on the Legal Protection of Biotechnological Inventions of July 6, 1998**, 213/13, July 30 1988.
71 Strauss J, Biodiversity and intellectual property, p.99.
72 Recital 27 of the Directive states 'if an invention is based on biological material of plant or animal origin or if it uses such material, the patent application should, where appropriate, include information on the geographical origin of such material, if known'.

and the hostile view of some European governments and NGOs, is well placed to broker progress on this matter via the WTO and the CGIAR. **The Working Party recommends that the UK, in consultation with like-minded developing countries and other member states of the EU, propose that the WTO explore and report on the extent to which the international and national legal framework currently frustrates the objectives of the CBD on providing fair and equitable access to genetic resources and how this conflict might be addressed.** There is an overriding need to respect the property rights of developing country researchers, public agencies and indigenous communities regarding plant materials developed by them.

Apomixis or termination?

4.74 The role of appropriate national and international infrastructures in supporting the world's poor is well illustrated by the controversy over apomixis genes. It may soon be possible to develop plant varieties that can produce seeds without sexual fertilisation, by apomixis, resulting in offspring that are genetically identical to the mother plant (paragraphs 2.39, 3.39). This would revolutionise plant breeding by allowing any desired variety, including hybrids, to breed true, thus permitting plant breeders to more readily develop locally adapted and genetically diverse varieties. Moreover, resource-poor farmers would be able to replant the seed every year. Such a strategy is not possible with today's commercial hybrid varieties (paragraph 2.4). However, the current trend towards the consolidation of plant GM technology ownership into a relatively small number of companies may severely restrict access to affordable apomixis technology (at least for the duration of the patent rights). Moreover, agricultural products of the developing world cannot be sold in global markets if they infringe technologies patented in the developed world, denying resource-poor farmers access to the global marketplace.[73] (paragraph 3.54.)

4.75 Almost the opposite problem could be created by GURT (gene use restriction technology) ('Terminator') patented in the US by the Delta and Pine Land Company and the United States Department of Agriculture (USDA) (paragraphs 2.26–27, 3.38). This not only has the potential to compel annual seed purchase by users of varieties with GURT, but also to prevent the farm-to-farm spread of new varieties. The USDA's[74] Melvin Oliver sees this as 'a way of self-policing the unauthorised use of American technology'.[75] To others, GURT technology sounds like an assault on farmers' rights.[76] Indeed, the CGIAR, meeting in Washington DC in November 1998, agreed to ban the use of the technology because of its consequences for poor farmers, for genetic diversity, and for other plants denied cross-pollination.[77] This is despite the fact that the technology has not yet been demonstrated in practice and no decision has yet been taken on its development.[78] Yet GURT technology is only the latest in a long line of more or less efficient ways of compelling farmers to buy seeds from the companies that have developed them, which is thought perfectly reasonable for most researched products. The monopoly control, or non-release to poor farmers, of plants with apomixis could be similarly defended. It is right that seed developers should be able to obtain normal, market profit on their full investment, including R&D, and also some reward for risk-taking and for special scientific skill or business judgement. However, this right cannot apply without restraint to monopolies operating in non-contestable markets.

73 See **Bellagio Apomixis Declaration** at http://billie.harvard.edu/apomixis and paragraph 3.39.
74 Anon (1998) Company aims to block seed saving, **GenEthics News**, 22:1–2.
75 Edwards R (1998) End of the germ line, **New Scientist**, No. 2127:22.
76 Respondents to the Working Party's Consultation, such as the **Farm and Food Society** and others, considered that the use of GURT would be unethical because it would threaten the food security and independence of farmers in the developing world.
77 Anon (1998) Labs to terminate use of 'Terminator' gene, **Nature**, 396:11.
78 Waters S and Merritt C (1999) Personal communication, Monsanto (Europe SA) and Monsanto plc.

4.76 Despite the fact that most individual seed companies sell only a small proportion (below 3%) of all seeds in farm use, there is considerable and increasing market power over the supply of seeds for some crops, and for the best varieties for an increasing range of crops and conditions. Monsanto has recently acquired a significant stake in seed markets through acquiring Cargill, DeKalb Genetics, Plant Breeding International, and possibly Delta and Pine Land Co. (paragraphs 3.19, 3.38). Monsanto has so far used this power reasonably in many ways, appears to be more open than some large companies[79] and contains scientists of high ethical as well scientific quality. But this in no way guarantees future policies. Even if it did, there is a danger, especially if uncorrected by an adequately financed, open-access public research infrastructure and supervisory systems such as in the NARS and in the CGIAR, of exposing the feeding and farming of the world's poorest people to the R&D (and pricing) consequences of the business decisions of a few market-dominant multinational companies.

The need for public sector research

4.77 At present the agricultural research balances between private and public, research and regulation, and developed and developing world could well tie in more and more desirable plant types with patents on GM technology or other controls, perhaps including GURT technology – and to fail to develop or even to actively prevent development of apomixis genes. **This could be inefficient as well as inequitable. The UK should use its position in the World Bank, EU, CGIAR, WTO and other bodies to reverse this trend through improving the infrastructures and remedying the underfunding and biases of public-sector research in developing countries**.

4.78 There seems little doubt that the multinational companies will operate increasingly in developing countries, particularly in Asia and South America. There is every probability that these companies will wish to deploy the same sorts of intellectual property in developing country agriculture which have been successful in the North. While it is likely that farmers may benefit from these new technologies, it is most important that they retain the choice to grow either new improved, and probably more expensive, seed from the companies or grow the new improved seed from national breeding programmes or the CGIAR centres. We consider that it is vital, therefore, that these centres maintain proficiency in the latest technologies and continue to deploy the best technology available in the public sector. **We strongly recommend that the UK continue to support the CGIAR system to this end. At the same time we recommend that the CGIAR seeks to protect proactively its own technology through patenting and use it to access other protected technology on behalf of their clients, the developing world.**

Hidden risks of neglecting poor people's GM crops

4.79 The most serious of the 'positive dangers' for the developing world may arise from not developing the capacity to screen, breed and safety-test GM crops, and to manage their release and use. If no such capacities are developed, the best scientists in the developing countries, who are badly needed not only in genetic modification but also for the improvement of existing national conventional plant breeding, will continue to drain to commercial organisations in industrialised countries. The danger then is that yield increases and employment income from food staples will remain sluggish. Many

79 Even if much of this is primarily a public relations exercise, it still requires some real openness. For example, the website http://www.monsanto.co.uk has access to a searchable database containing a wide range of reports, articles and data, including those provided by opponents such as Greenpeace. See also Anon (1998) You, the jury, **New Scientist**, No. 2138:3.

respondents to the Consultation expressed concern that the narrowing of the commercial base could have the consequence of restricting availability of diverse crop varieties, particularly non-GM varieties.

4.80 Furthermore, attractive GM crops will spread and may cross, without effective controls, into ecologies quite different from those for which they were bred. Large-scale GM crop trials in China, a country with non-transparent regulatory procedures, are a cause for concern. The opposite situation may occur in other developing countries. By legislating restrictively but unenforceably, they may push GM crops into illegal channels where scientific and safety standards cannot operate.

4.81 If developing countries stimulate appropriate, regulated, open GM crop research and selective release, they can steer it towards activities that are safer, more employment-intensive and better directed towards availability, quality and stability of food for the poor. But such hopes would be thwarted, not just by a 'genetic Bhopal' (which is a negligible risk, not obviously much increased by GM crops), but even by a much smaller but well-publicised accident. That is much more likely without an appropriate regulatory regime. Hence the regulatory and research aspects of the recommendations set out in paragraphs 4.42,4.48, and 4.62 above are aspects of a single package.

Conclusions

4.82 So far, GM crops have had little effect, good or bad, on food-poor consumers in developing countries, or the farmers and farmworkers who mainly supply them. Millet, sorghum and yams, the main staples of Africa's food-poor, are largely untouched by GM technology although work on cassava has begun. Wheat is relatively unaffected and the impact on rice is only just beginning. Maize, the food-poor's main staple in Latin America and parts of Africa, is already being grown as genetically modified, but largely as feed crops grown by large commercial farmers in developed countries. So far, 'the market' has not directed major private-sector scientific resources towards breakthroughs in conventional Green Revolution type plant breeding, or into GM crops of main food staples (or tropical export crops)[80] for employment-intensive production in poor countries. Serious prospects for such shifts will require new market incentives, combining the work of private-sector scientists with that of national and international public-sector research institutions. To forgo such efforts would not protect the poor from the unregulated risks of genetic modification and other agricultural innovations, but would sacrifice the prospects of major GM crop-based advances in food and agricultural output and employment for the food-poor.

80 Cotton may prove an exception, but the gains seem likely to accrue mainly to developed-country producers, at the cost of developing-country competitiveness.