KLAUS M. LEISINGER*

The 'Political Economy' of Agricultural Biotechnology for the Developing World

INTRODUCTION

At the beginning of the new millennium, the 150-year-old conceptual skeleton of 'political economy' is rattling loudly in the closet. Early in his work Marx (1859) argued that there is a close and circular relationship between the social conditions of a nation and its conditions of production, the latter determining its level of economic development. In this context institutional structures and social values, as well as ways of thinking and attitudes of members of civil society, are very important. In the current discussion of agricultural biotechnology for developing countries this part of Marxian analysis is highly relevant, particularly for urban impoverished groups as well as resource-poor farmers and their families. This paper looks at the impact current politicized discussion in Europe is having on public research for the developing world and proposes a way of building a bridge over the troubled waters currently dividing proponents and opponents of agricultural biotechnology.

THE FUTURE OF FOOD SECURITY

The United Nations observed 12 October 1999 as the Day of Six Billion – the world's population had doubled since 1960. In some parts of the developing world, the population grew even faster; in sub-Saharan Africa, for example, it tripled. The number of people in Asia grew most in absolute terms, by nearly 2 billion. Most population experts expect that world population will grow by another 50 per cent, which means at least 3 billion more people by 2050. Table 1 shows that almost all this growth will occur in less developed regions (UN, 1999; Population Reference Bureau, 2000).

In the developing world today, an estimated 800 million people already do not have enough to eat. Countless children die from nutritional deficiencies or grow up with reduced physical or intellectual abilities, and will later suffer from lower productivity (FAO, 1999a; Smith and Haddad, 2000). In addition to the absolute increase in the number of people to be fed, structural changes will

*Klaus M. Leisinger, Novartis Foundation for Sustainable Development and University of Basle (Switzerland).

TABLE 1 *Current and projected population, by region, 2000–2050 (millions)*

Region	Population		
	2000	2025	2050
World	6 070	7 909	9 243
More developed	1 184	1 232	1 222
Less developed	4 886	6 677	8 021
of which in			
Africa	800	1 258	1 804
Asia	3 566	4 707	5 379
Latin America	520	712	838

Source: Population Reference Bureau, Washington, DC, personal communication, May 2000.

have an impact on the quantities needed. Urbanization will soar, for example. The global urban population is expected to nearly double from 2.6 billion people in 1995 to 5.1 billion in 2030. By then, 57 per cent of the population of developing countries will live in cities (UN, 1998). A high rate of urbanization will not only confront inhabitants with social, environmental and probably political problems of unprecedented magnitude, but will also have notable consequences for food security.

Whatever the hopes for urban gardens and nearby farms, people living in cities are unable to feed themselves through subsistence food production in the same way as rural dwellers. This necessitates a significant increase in marketed food supplies. Since the eating patterns of urban populations differ substantially from those of rural folk, different food will have to be produced. The amounts of high-value, transportable and storable grain (such as rice and wheat), animal protein (both meat and milk) and vegetables are higher in urban diets, while the proportion of traditional foodstuffs in the diet decreases. This means that there will be a diversion of cereals from food to animal feed.

If incomes continue to rise for urban professional groups as they have in the past ten years, the number of people who move up the food chain and eat more livestock products will continue to grow rapidly. This again means that grain demand will probably grow even faster. For political, cultural, economic and logistical reasons, this increased demand should be met as little as possible by imports from North America, Europe or Australia, so there is a need to increase production in developing countries.

If increased production is done in a sustainable way and with increased productivity, additional benefits will be achieved in poverty alleviation and improved livelihoods. Nearly three-quarters of the poor live in rural areas. As long as the number of rural poor is high, and indeed rising as in sub-Saharan Africa, food security as a general political goal cannot be achieved. Higher productivity for those who depend on agriculture and on common property resources is a precondition for poverty alleviation. For the quality of life of poor people in cities, who depend on the market for nearly 90 per cent of their food supply, a low and stable price for food is the most important variable (McCalla, 2000).

Higher productivity is also of ecological value. If average annual per hectare productivity increases by just 1 per cent, the world will have to bring more than 300 million hectares of new land into agriculture by 2050 to meet expected demand. But a productivity increase of 1.5 per cent could double output without using any additional cropland (Goklany, 1999). To increase local output through larger production volumes or higher productivity will be very difficult, however. A world of 9 billion by 2050 will meet significant constraints.

Water scarcity

Water, the source of all life, is going to become increasingly scarce. More than a quarter of the world, and a third of the population in developing countries, lives in regions that will experience severe scarcity (IWMI, 1999). The deforestation of the planet continues unabated, reducing the capacity of soils and vegetation to absorb and store water (FAO, 1999b). Water demand continues to rise much faster than supply, and the distributional battles between industry and urban households and agricultural irrigation are not likely to be won by agriculture. Today the irrigated sector accounts for close to 60 per cent of the food grown in all developing countries. The Consultative Group for International Agricultural Research estimates that, taking into account constraints on rainfed agriculture, the irrigated sector will have to meet 80 per cent of increased food demand in developing countries, which will be home to 2 billion more people in 2025 (CGIAR, 2000a). If, however, the availability of irrigation water stagnates or (what is more likely) decreases, average yields are likely to fall. Water supply for agriculture has already started to decrease in India, for example, as a result of overpumping in highly productive agricultural areas, and in China because of reallocation for industrial purposes or higher urban demand (Postel, 1999).

Pressure on land

There is growing concern that the developing world is facing a decline in long-term soil productivity. Wide areas of land are already heavily degraded, and this process, including salinization and waterlogging of irrigated land, has adverse effects on rural food consumption, on agricultural markets and hence on rural incomes (Scherr, 1999). Low and declining soil fertility is a serious problem in Africa, where about 86 per cent of the countries show losses of nutrients greater than 30 kilograms of fertilizer (NPC) per hectare per year (Pinstrup-Andersen *et al.*, 1999).

In 1960, the world still had 0.44 hectares of arable land per person; today the figure is about 0.22 hectares, and by 2050 it is expected to drop to 0.15

hectares (WRI, 1998). Since the reserves of unused arable land are dwindling, the expansion of cultivated areas will contribute a mere 20 per cent to the increase of food production (mainly cereals) (Pinstrup-Andersen *et al.*, 1999). Thus higher food quantities to meet the needs of a growing world population will have to come from higher yields, which is more easily said than done.

Reduction in the rates of increase in basic grain yields

There is considerable debate about the outlook for agricultural productivity. The Green Revolution increases in yields of cereals from conventional breeding have reached a plateau and are beginning to decline. Even the gap between yields obtained on experimental stations (maximum potential) and those obtained by the best farmers in the best production regions is narrowing (Pingali and Heisey, 1996). The question for agriculturists has therefore been, and remains, how to attain and sustain higher yields.

Scientific agriculture is one of the most important answers, not only to achieve desired production goals, but also to improve resistance to both biotic and abiotic stress. Reducing total costs of production by reducing chemical inputs through genetic research has implications both for production and for the environment. Moreover, research to reduce high post-harvest losses of crops can result in significant increases in the amount of usable agricultural production. This research ought to be publicly financed in order to reach those who do not have the purchasing power to buy research results on market terms.

Unforeseeable changes in climate

Although difficult to predict, climatic change might create additional problems for countries whose economies are heavily dependent on agriculture. Climate change is expected to have dramatically adverse effects on food security in the low and middle latitude areas of low-income countries. In addition, the warming of the Earth is expected to bring extreme climate events, such as Hurricane Mitch (Brown, 1999; Worldwatch, annual).

FOOD SECURITY AND GOOD GOVERNANCE

Summing up, population growth, urbanization and rising incomes will increase food demand, which will necessitate increases in food production. As water and land for agricultural use become increasingly scarce, more food will have to be produced through higher yields per unit of water and land. But, to avoid any misinterpretation, let me stress that more food production is not the only issue that matters for the welfare of poor people; what they need is more food security.

The Food and Agriculture Organization of the United Nations (FAO, 1996) defines food security as a situation in which all people at all times have access to safe and nutritious food to maintain a healthy and productive life. Food security has at least three characteristics: first, producing or importing safe, nutritious food in sufficient quantities; second, giving economic and physical access to rich and poor, male and female, old and young, on a continuous basis. The third characteristic has to do with the use and preparation of available food. This depends on the knowledge, skills and care of mothers as well as the health of those who eat. Since parasitic and other diseases substantially hamper metabolism and assimilation, health conditions figure significantly in the food security equation.

Shortfalls in food security can and do result from various interlinked adverse conditions in a country's socioeconomic and political system (Sen, 1981). Most of what is politically right or wrong for food security is known; also known are the emerging issues and the unfinished business (Pinstrup-Andersen, 2000). In the end, the only reliable pathway to food security is sustainable human development.

We know what needs to be done. The 'wheel' of sustainable development does not have to be reinvented. 'Good governance', with transparency of political decision making, accountability for politicians and state employees, institutional pluralism and the rule of law, is the most important prerequisite. Lack of sufficient allocations in national development planning in the socioeconomic areas of health, education and food security are often the result of denial of civil and political rights, such as the right of democratic elections, free speech and information dissemination. Authoritarian governments that deny freedom of speech and the right to vote do not provide adequate information on the causes of famine and lack of food security, or on the low levels of literacy and health.

The best of present thinking indicates that a human-centred and market-friendly approach with an emphasis on good governance is the most effective way to break the vicious circle of continuing poverty, environmental deterioration and acute institutional deficiencies. There may be a need for adaptations to different sociopolitical and national circumstances, but, in comparison to the available knowledge with regard to the political, economic, social and ecological essentials of sustainable development, adaptation is a relatively minor issue. Good governance alone, however, will not be sufficient for food security; something has to happen on the supply side as well.

More local food production, not more imports

In order to supply enough food to the growing populations of Asia, Africa and Latin America without increasing dependence on international markets or food aid, more food has to be produced where people live. This will be predominantly in the tropical and subtropical, low-yielding farming systems (McCalla, 2000). Imports may be appropriate to bridge short-term gaps or in cases of emergency, but, for most developing countries, imports cannot substitute for local production. The argument that global food production is sufficient and that food security problems can be solved by redistribution is inadequate, for a number of reasons.

First and foremost, agriculture in developing countries is far more than just a producer of food. In most cases it still provides 60–80 per cent of all gainful employment. Agriculture is a source of income not only for rural farm workers but also for those employed in related trades and small industries, be they landless labourers, small traders or those working in cottage industries. Whatever productivity increase can be achieved, the income effects will be even higher. A dynamic agriculture is not only the best remedy against rural poverty: the sustained growth of industry and services has rarely been possible without the basis of growth fuelled by a flourishing agriculture.

Second, appropriate agriculture always means sustaining ecological intactness and caring about the environment. Third, as the word implies, agri-'culture' is a constituent of the many-faceted cultural patrimony of developing countries. And last but not least, the idea of feeding the African or Asian poor with surplus grains from the United States, Europe, Australia or Argentina implies the heroic assumption that immense logistical problems could be solved in a sustainable way.

BIOTECHNOLOGY AND GENETIC ENGINEERING

While good governance and appropriate rural and agricultural development endeavours remain necessary conditions, they are far from sufficient. There is a need for technologies that raise agricultural productivity and hence rural welfare. Considering the continuing absolute population growth, threats of water scarcity and the shrinking of arable land, and bearing in mind that the yield increases from conventional breeding for at least some crops are moving in the wrong direction, whatever has to happen on the production side will have to happen with new varieties. Hence something has to happen on the technology side. Biotechnology and genetic engineering – used wisely within a pluralistic technological portfolio – can play a crucial role in the development of the modern varieties that will be needed.

The term 'biotechnology' describes the integrated application of biochemistry, microbiology and process technology with the objective of turning to technical use the potential of microorganisms and cell and tissue cultures (including parts thereof). The key components of modern biotechnology include the following:

- genomics – the molecular characterization of all species;
- bioinformatics – the assembly of data from genomic analysis into accessible forms ('genetic fingerprinting');
- tissue culture;
- transformation – the introduction of single genes conferring potentially useful traits into plants, livestock, fish and tree species;
- molecular breeding – increased efficiency of selection for desirable traits in breeding programmes using molecular marker-assisted selection; and
- diagnostics – the use of molecular characterization to provide more accurate and quicker identification of pathogens.

In addition, there is hope for new health technologies such as vaccine technology, which uses modern immunology to develop recombinant DNA vaccines for improving control of lethal diseases. In view of the vastly increased capacity to accumulate knowledge that is made possible by molecular techniques, the goal of a 'knowledge-driven' agriculture, in particular plant breeding, is now entirely realistic.

Technologies such as molecular breeding or diagnostics are relatively non-controversial. This is not the case, however, with genetic engineering: the precise modification of hereditary genetic material in living organisms by the addition, removal or exchange of one or more genes, resulting in altered genetic information being passed on to descendants. One of the key differences between conventional breeding and genetic engineering is that with the latter it becomes possible to overcome natural cross-breeding barriers – in other words, to insert genes from one species into another unrelated species to produce 'transgenic varieties'.

This part of biotechnology has triggered enormous controversy in some European countries, raising similar concerns all over the world. In Germany, the United Kingdom or Switzerland, the broader public perceives genetic engineering as structurally different from other new technologies. Public opinion regarding the use of biotechnology in agriculture is predominantly sceptical or negative (Environmental Monitor, 1998).

In order to assess the value of biotechnology and genetic engineering for a growing population in the developing world, we must look at what has been achieved so far and what is likely to be achieved, consider the risks, and then weigh risks and benefits in a fair way.

Expectations and objectives of agricultural biotechnology

The main objectives of biotechnological research and development for food security are basically similar to those of conventional breeding: (a) to secure the given yield potential, (b) to increase the yield potential, and (c) to raise productivity. Efforts to achieve this include research for varietal qualities such as resistance to or tolerance of plant diseases (fungi, bacteria, viruses) and animal pests (insects, mites, nematodes) as well as to stress factors such as climatic variation or aridity, poor soil quality and crop rotation practices. Ideally, crop varieties that result from such research endeavours should lead to the cultivation of plants that fall into the category of 'sustainable agriculture': that is, they should not abet erosion or leaching of the soil. To complete the packet of desired characteristics, seed of improved varieties should be affordable to resource-poor farmers and have better product quality traits (more protein, minerals or vitamins).

Conventional crop-breeding programmes will remain important for the foreseeable future. They have a competitive disadvantage, however, in that they have to proceed in small steps toward single targets and are thus time-consuming; in addition, conventional breeding is more limited in scope as it cannot overcome natural cross-breeding barriers. If, in contrast, selection systems are developed that can be implemented in the test tube – through characterization of genetic markers for certain properties, for example – then research can be carried out with much greater efficiency. With the help of biotechnology, it seems likely that apomixis (asexual type of reproduction) for hybrids will be achieved, providing a potential breakthrough for small and big farmers alike. In the long term, plants may also be developed that can produce cheap, edible vaccines for humans from locally grown crops (Staubl, 2000; McGloughlin, 1999).

Case studies show that over the past few years biotechnology, with a lesser contribution from genetic engineering, has helped make progress towards food security, whether through resistance to fungal and viral diseases in major food crops or through improved plant properties (Potrykus, 1996; Krattiger and Rosemarin, 1994). The implementation of these research results is theoretically scale-neutral, though it is worth noting that the small farmer does not have to learn a sophisticated new agricultural system, since he or she has only to plant the new seeds embodying the research results. But research and science are only able to solve problems that are allowed to be solved by political leaders and the social setting. What is needed to put the theory into practice is well known by anyone who looks for the answer.

Hopes continue to be high. A World Bank panel predicts, for example, that efforts to improve rice yields in Asia through biotechnology will result in a production increase of 10–20 per cent over the next ten years (Kendall *et al.*, 1997). A German poll of scientists found that they expect that genetically engineered drought and salt tolerance will be achieved by 2012 and nitrogen fixation by 2017 – within the next generation, and before world population reaches 9 billion (ISI, 1998).

Achievements so far

First of all, by using non-renewable resources more efficiently, germ plasm enhancement has in most instances the same effects on preserving natural resources and improving the environment as germ plasm enhancement through conventional methods. To quote an example used by Norman Borlaug, in 1999 India produced about 220 million tonnes of grain, with an average yield of 2.2 tonnes per hectare. In 1961–3, the yield figure stood at 0.95 tonnes per hectare. If India had continued using the agrarian technology of the 1960s – that is, if the yield per hectare had not more than doubled – India would need more than twice the amount of arable land to produce today's food quantity. That land is simply not available; creating some of it would have involved conversions at high ecological cost.

Much has been achieved during the past ten years (Persley and Lantin, 2000; Hohn and Leisinger, 1999). Genome mapping and biotechnology research offer powerful tools for crop improvement, for example, in China, where transgenic varieties are now routinely produced in crops such as rice, corn, wheat, cotton, tomato, potato, soybean and rapeseed. The objectives of this research and development are crops that are disease-resistant, tolerate abiotic stress and have improved product quality and increased yield potential (Zhang, 2000). According to Gordon Conway, president of the Rockefeller Foundation, China is doing 'spectacularly well' with *Bt* cotton, increasing yields and reducing the number of pesticides sprayings from about 12 to three per season (Conway, 2000).

Achievements in India include tissue culture regeneration, stress biology and market-assisted breeding, as well as new types of biofertilizer and biopesticide formulations. Research to develop genetically improved (transgenic) plants for brassicas, mung bean, cotton and potato is well advanced (Sharma, 2000). Programmes adapted to local needs and priorities are under way in the Philippines, Thailand, Brazil, Costa Rica, Mexico, Egypt, Iran, Jordan, Kenya, South Africa and Zimbabwe (Wambugu, 1999). Of particular interest for Africa are the research results on the transgenic sweet potato resistant to feathery mottle virus in Kenya and on South African types which contain up to five times the normal protein levels. Early laboratory results of research for nematode resistance in potatoes of indigenous Bolivian small farmers give rise to great hopes for a resource-poor population.

In many countries tissue culture has produced plants that increase yields by providing farmers with healthier planting material. In addition, marker-assisted selection and DNA fingerprinting allow a faster and more focused development of improved genotypes for important agricultural species. Moreover, as FAO points out, these technologies make available new research methods 'which can assist in the conservation and characterization of biodiversity. The new techniques will enable scientists to recognize and target quantitative trait loci and thus increase the efficiency of breeding for some traditionally intractable agronomic problems such as drought resistance and improved root systems' (FAO, 2000).

Among the many achievements one is of particular value. It has become possible to genetically modify rice so that it contains increased levels of vitamin A. It will soon be possible to achieve a similar result with regard to iron. This could be of immense benefit to about 250 million poor, malnourished people who are forced to subsist on rice. The consequences of this restricted diet are well known: 180 million people are vitamin A-deficient. Each year 2 million of them die, hundreds of thousands of children turn blind, and millions of women suffer from anaemia, one of the main killers of women of child-bearing age (WHO, 1999; UN, 2000).

Another achievement could turn out to be a major breakthrough. Researchers from Washington State University were able to transfer a maize gene into rice. The new strain of genetically modified rice, unveiled in late March 2000 in the Philippines at an international conference, boosts yields by a massive 35 per cent. As an added benefit, the genetically modified (GM) rice, which has been tested in China, South Korea and Chile, extracts as much as 30 per cent more carbon dioxide from the atmosphere than controls, offering a way of curbing climate change.

Since I will later deplore the fact that some of the louder critics seem to see risks, only to overemphasize them and fail to put them into context, I want to put these benefits in perspective. Agricultural biotechnology is no *deus ex machina*. No technology is of intrinsic value. Humanity has always used and will continue to use technologies as a means to an end – to facilitate living or to achieve other desirable goals. In their decision processes, societies and individuals have always weighed benefits and risks to arrive at a benefit–risk assessment they can tolerate. Advocating the use of biotechnology and genetic engineering to help improve food security in developing countries is not meant to support these technologies for their own sake or out of context. Using them is desirable only if and where, on a case-by-case basis, they have a comparative advantage in solving constraints related to agricultural objectives: that is, if they prove superior to other technologies with regard to cost-effectiveness.

Potential risks

Of course there are potential dangers associated with this technology, since every action has implicit and explicit risks. No technology in and of itself is good or bad, safe or unsafe, although some are inherently riskier than others, such as live vaccines versus new crop varieties. What makes a technology safe or unsafe is the way it is applied and the outcome of that application. The quantification of perceived risk can be described as a function of four interrelated variables (Daniell, 2000):

(1) the scale of the potential harm, adjusted by
(2) the likelihood of that harm occurring net of
(3) the ability of an effective response to be put in place, adjusted by
(4) the likelihood of that response mechanism being deployed effectively.

To a significant extent in today's debate in Europe, risk analysis is not done that way: risks are too often isolated from benefits and blown out of proportion, immensely small probabilities are not revealed in public discussion, and available effective responses are ignored or denied. Countless websites and publications tell horror stories about the perceived risks of biotechnology;[1] few discuss the weight and management of risks in a scientific manner (Rifkin, 1999).

For a variety of good reasons, perceived risks must be divided into those that are technology-transcending and those that are inherent to a technology (Leisinger, 1999). Fairness of discussion would also demand division of risks into hypothetical and speculative. Hypothetical risks are ones scientists know can occur, and they know how they occur, in the given technological or biological context. Speculative risks are those related to potential (hitherto) unknown interactions, with risk assessments commonly being brought forward in a dramatic scenario of assumptions that can neither be scientifically proven nor refuted. As there is scientific consensus that 'the same physical and biological laws govern the response of organisms modified by modern molecular and cellular methods and those produced by classical methods' (US National Research Council (1989)), and as 'no conceptual distinction exists', the introduction of speculative risks into the debate on transgenic crops is a deliberate attempt to stir up controversy.

Technology-inherent risks

As far as technology-inherent risks (such as allergic reactions or the unwanted flow of genes into wild species or landraces) are concerned, the best of present judgment indicates that genetically modified organisms (GMOs) pose no substantial unmanageable long-term health hazards for humans or animals (Cohen, 1999; Qaim and Virchow, 1999). Many unsubstantiated claims continue to circulate, but let the record show the following:

- The sensational report that potatoes transformed with a lectin protein could end up as being poisonous to human health has been rejected by the vast majority of reviewing scientists either because the methodology was flawed or on the grounds that the data do not support the conclusions.
- The old L-Tryptophane scare story (EMS syndrome due to the use of a genetically altered Bacillus amyloliquefaciens) has been proved wrong.
- Even the much-quoted Monarch butterfly laboratory study has been put into empirical perspective. Follow-up studies at Iowa State University and the University of Guelph have indicated that harm to Monarchs under field conditions are minimal. According to Mark K. Sears, chair of the Department of Environmental Biology at the University of Guelph, reports that *Bt* maize kills monarch butterflies are overly alarmist. After a six-month study of how pollen from GM maize affects butterfly larvae under field conditions, the preliminary findings indicate that 90 per cent of pollen fell within 5 metres of the cornfield. Pollen counts on milkweed leaves were lower than those demonstrated to be toxic to neonates, hence posing little risk to larvae (Sears *et al.*, 2000). In addition, there is increasing evidence that the time overlap of the pollen flight and the vulnerable development of the larvae is very small.
- The risk of allergy to genetically modified foods seems to be controllable and therefore minimal.
- In 1999, nearly 100 million acres around the world were planted with transgenic crops. No serious issues – forget about uncontrollable risks – came up.

To date, most empirical evidence supports the conclusion of the US National Academy of Sciences (1987): the safety assessment of a recombinant DNA-modified organism should be based on the nature of the organism and the environment into which it will be introduced, not on the method by which it was modified. The same view is contained in the declaration signed by more than 1500 scientists worldwide (including several Nobel laureates) in support of agricultural biotechnology.[2] If and where unresolved questions arise concerning risks of genetically modified food, science-based evaluations should be used on a case-by-case approach to answer them.

Technology-transcending risks

As far as social and political risks are concerned, today's criticism of genetic engineering and biotechnology is structurally similar to discussions about the Green Revolution in the 1970s. The improved plant varieties that appeared in the 1950s and 1960s were developed through systematic selection and crossing (hybridization), with the objective of increasing production and averting famines, particularly in Asia. Despite undisputed success in achieving significantly higher food production and an overall positive employment effect, there was (and still is) substantial criticism of the Green Revolution as being responsible for growing disparities in poor societies and for the loss of biological diversity. These developments, however, were not a consequence of the technology itself but of its use in a particular social setting. Risks of such type are neither caused by nor able to prevent the technology as such. Consequently, the successful management of such risks depends on an appropriate national framework for socially and ecologically sustainable agriculture.

The Green Revolution has certainly created some environmental problems, but it has reduced others, for example by allowing farmers to concentrate production on the best cropland and hence preventing the destruction of vulnerable biotopes or protected areas. As far as social problems are concerned, the overall effects are also good for small farmers. Owing to a social setting that was described by Gunnar Myrdal in 1968, the rich got richer. But the poor also got less poor (Hazell and Ramasamy, 1991).

A new category: risks of not acting proactively

Normally not part of technological risk assessments are the social, economic and political risks of not using genetic engineering for developing country agriculture. In view of expected population and natural resource developments over the next 50 years, an approach that tends to overemphasize present perceptions and underestimate the vulnerabilities of future generations presents a great risk to humankind and those future generations.

In this context there is an accountability issue. Who stands accountable for the anti-GMO activism that results in denying poorer nations access to a technology that could help them produce more and better food? Who stands accountable for scientific results not available in 10–15 years owing to political resistance today – results that might make the difference between food shortages and normal supply in resource-poor countries? There is no 'polluter pays principle' for pressure groups that poison today's discussions and are proud to go on record that they, as self-appointed attorneys for poor people in the South, can prevent agricultural biotechnology for the developing world.

The dominance of private sector research

If society approves of better access to improved technologies by food-insecure countries in the South, then public research has to be supported. Today, two-thirds to four-fifths of R&D in agricultural biotechnology is carried out in the private sector. On the one hand, this is desirable, as the public sector should cease supporting activities wherever the private sector can do things better or more cost-effectively. On the other hand, this dominance is a cause for concern to some who favour and most who oppose agricultural biotechnology (Lappé and Bailey, 1998).

Because the life sciences corporations must compete to appear attractive to the international financial community, their research priorities are determined by the financial returns on investment, and hence the needs of those who wield purchasing power in the relevant markets. To put this another way, it is not very likely that these corporations will be willing to fund research for drought tolerance, tolerance to soil and mineral toxicity, or other characteristics of relevance to the typical resource-poor farmer family in poor countries. Even if they were to make progress in these areas, the costs of developing useful products would be high and hence the products would remain out of reach for those who need them most. Part of the explanation for this is intellectual property rights: the knowledge and technologies, including DNA sequences, research tools and output traits are now largely proprietary. This, according to the CGIAR, has partly impeded secondary innovation and led to conflicting proprietary claims and high transaction costs (CGIAR, 2000b).

For private industry, a focus on profitable markets is necessary for survival. Some people may regret this reality, but then they should look for alternatives. The alternative to private sector research is public research. There the emphasis can be given to plant species that are most relevant to poverty reduction and income generation of specific ecological regions, and research can focus on losses caused by biotic and abiotic factors and on stabilizing yields on poor soils. The fruits of public research can be passed on to small farmers at cost or, via subsidized channels, even free of charge. As in the past, the CGIAR, with its focus on the needs of developing countries, will have to play a conspicuous role in such efforts in close cooperation with the different national agricultural research systems. The record shows how much has been achieved in the past 30 years through CGIAR and local partners (CGIAR, 1998; Anderson and Dalrymple, 1999; Shah and Strong, 1999).

Public agricultural research systems, however, depend heavily on public funding, which depends on political goodwill. That, in turn, depends to a large extent on judgments made by civil society about the objectives of the research. If these are seen as contributing to solutions, it will be feasible to raise funds. If they are seen to be adding to the problems, it will become impossible, especially in the long run. In order to make cutting-edge biotechnology available to small farmers, more public research has to be financed and more public–private partnerships (as when the private sector provides access to cutting-edge technology and gives permission to use it for the benefit of resource-poor farmers) need to be established. Successful cooperation for the poor will do a lot to improve the perception of a complex technology. The Insect Resistant Maize for Africa Project, which involves the Kenya Agricultural Research Institute, the International Maize and Wheat Improvement Centre (CIMMYT) and the Novartis Foundation for Sustainable Development, could serve as a pilot for more projects with different constituencies. But a politicized discussion in some northern countries about biotechnology is likely to prevent wider use of these options.

The tenor of the current public debate

Over the past several years we have witnessed an intense and highly controversial discussion of biotechnology and, especially, genetic engineering. Protests against food containing GMOs cross all social barriers, and opponents range from members of the English royal family to Indian trade union leaders. The degree of polarization is very high, as are the passions. While technological innovations are always associated with some anxiety and fears (remember the early story of the railway, penicillin and vaccination), the degree of scaremongering and the heat of the current discussion cannot be explained in terms of natural science, or at least not in these terms alone.

Genetic engineering is not very different from other types of activities that are carried out with the objective of creating organisms with desirable characteristics. Conventional plant breeding also involves gene transfer. Genetic engineering differs from conventional breeding inasmuch as it allows that to be done more easily across taxonomic boundaries, but this difference in technology cannot account for the difference in public perception. Clearly, there are more complex elements at work here. Analysing the current debate, it seems that highly sophisticated anti-biotech activists are easily able to mislead a scientifically uneducated public about issues of high scientific complexity.

'Hate sites'

One of the most important constraints on the social acceptance of biotechnology and genetic engineering is an unusually negative social marketing. There are biotech-related websites that read like 'hate sites'. Far away from any scientific evidence and often in contrast to the truth, biotechnology is associated with the worst disasters of modern history.

On several websites, risks of field trials with GMOs are compared with the impact of a nuclear disaster such as Chernobyl. This is not only far from a scientific risk assessment, it ridicules and derides innocent victims of Chernobyl. Food containing GMOs is referred to as 'Frankenfood' and food from genetically modified crops is labelled 'contaminated'. Opponents even criticize food aid to drought-stricken countries in sub-Saharan Africa as a conspiracy between the US government and the World Food Programme, 'dumping unsafe, American genetically modified crops into the one remaining unquestioning market-emergency: aid for the world's starving' (Walsh, 2000). This is an enormously cynical view to dump on the backs of starving people. Several websites use sophisticated Machiavellism instead of reason: on the one hand, they warn about unknown risks in the context of the environmental impact of a release of GMOs, and they ask for more studies; on the other hand, they call for vandalism and destruction of trials that have been set up to answer unresolved questions. Where more research is needed to create more data for the assessment of the likelihood and seriousness of risks, such research ought not to be prevented. Obviously, those who oppose the research have no interest in the results – at least in terms of the traditional concept of rationality that is based on plausibility and comprehensibility. Still worse, masters of political social marketing blow up risks with an extremely low likelihood through worst-case scenarios (for example, 'genetically altered food could trigger rare but deadly allergies').

Regulation as a political process

As a result of the negative tenor of the discussion, even politically neutral regulators want to be on the safe side. Thus food from genetically modified crops is 'held to standards that are irrational, far beyond those that any other product can or should meet, and that prevent their competing successfully' (Miller, 2000). Instead of applying the scientific consensus for a risk analysis – that the risk-based characteristics of a new product should be the focus of attention, regardless of the production techniques used – the method by which a product was created becomes the bone of contention.

The current work of a task force of the Codex Alimentarius is 'en route to codifying various procedures and requirements more appropriate to potentially dangerous prescription drugs or pesticides than to GM tomatoes, potatoes and strawberries. They include long-term monitoring for adverse health effects and batteries of tests for genetic stability, toxins, allergenicity, and so on' (ibid.). In industrial countries, food production has a low profit margin, and in developing countries regulatory absorptive capacity is low, so such over-regulation is likely to achieve the political goal of preventing GM food from reaching markets. Regulation of this degree violates a fundamental principle of regulation: that the degree of scrutiny should be commensurate with the risk.

Labelling should also be commensurate with the issues at stake. Would it serve the purpose of warning consumers of food risks if all organically produced food were labelled 'May contain bacteria and aflatoxin'? Would the consumer be wiser or better off if all meat from the European Community carried the label, 'May contain BSE'? And if not, what difference in substance makes the labelling of GM food mandatory? It is a fact that not all regulators are politically neutral, and it is my perception that at the moment there is no political downside to being against biotechnology and genetic engineering. While those promoting the technology are kept busy producing assessment after assessment, those opposing it get away with their self-made image of saving the world from disaster. The outcomes of publicly funded symposia may be manipulated by organizers inviting predominantly opponents while rejecting offers of lecturers with positive case studies on GM crops. The results of such conferences can then be used as 'evidence' by politicians and regulators who had made their mind up against the technology long before, but needed 'events' to go public with their negative preoccupations. In other words, tell me on what political grounds you want to decide and I tell you which institute or 'expert' should be given the job to write the report you need as 'scientific evidence' for your decision. Is it any surprise that the public has developed a considerable amount of distrust of 'experts'?[3]

Whereas, in a perfect world, regulation should rest on independent and unbiased expert knowledge, the real world has different parameters. In most states there is a close relationship between regulators and politicians. While scientists can assess the structure and extent of a risk, the decision on what exactly represents an 'acceptable' risk is a purely political one. As politicians decide on the key personnel of regulatory authorities, it should be no surprise that this has consequences for the direction of decisions. This political judgment is today different – in my view, biased in a negative way – in Europe than in the rest of the world. While this bias will not make a difference to the food security of Germany, Switzerland, the United Kingdom or the United States, it may affect rèsource-poor farmers in the developing world significantly and in a negative way.

Consequences for public agricultural research funding

As noted earlier, public agricultural research is of great importance for a sustained growth of food production in the developing world. But despite the known facts about population growth and environmental pressures, funding for this research for developing countries has declined. For example, the CGIAR – despite high praise for its work, which sparked an agricultural revolution in Asia and Latin America, with dramatic increases in food production and reduced food costs – has experienced a significant downturn in funding over the past few years. In most developing countries, where drastic reductions in public support for agricultural research have taken place, there are no compensating increases in private sector support. Unfortunately, the outlook for a substantial increase in funding is bleak.

Over the past ten years, most of the world went through dramatic changes in terms of geostrategic interests, political concepts, understanding of 'good governance', the role and understanding of technology, and other determinants of life. Partly as a result of this, the concept of the state's role in sustainable development and development assistance changed. Different ideas about what the state is best able to do led to critical choices about what to do and what not to do, and this had practical consequences. In addition, the value of macroeconomic stability and fiscal discipline for economic development is today better understood, which has led to consistent efforts to close budget deficits.

During this time, donor countries' official development assistance (ODA) dropped significantly, reversing a long-term trend, while private flows rose appreciably (albeit concentrating mostly on a limited number of emerging countries). This necessitated cuts within ODA budgets. In one area, mainly owing to a negative public perception of agricultural research in the context of the Green Revolution and genetic engineering, politicians obviously did not have to be afraid of incurring the wrath of the electorate, and that was support for research in favour of resource-poor farmers. Very personal convictions of individual critics and pressure groups about right and wrong, along with very different living conditions and natural resource bases, form the basis of protests that will have a harmful effect on people in sub-Saharan Africa and Asia. The fact that farmers in developing countries who are short of resources are thereby deprived of options for the future is either not apparent or not considered important.

Reviving dialogue and consensus-driven action

To a certain extent, pluralism of opinion is normal in modern societies, which are immensely pluralistic in their values, interests and beliefs. And the knowledge and experience that inform these societies also show an extremely diverse range of content and form. Modern, open societies are thus much more sophisticated social organizations than closed authoritarian societies – at a price that is worth paying. The assessment of new technologies occurs within this pluralistic structure; simple answers and undisputed processes for consensus are therefore not at hand.

The strength of the negative overtones that currently dominate the debate about agricultural biotechnology and affect the views of the public and, as a consequence, of many politicians does not give cause for optimism. Fair discussion on the Internet and elsewhere remains the exception to the rule.[4] My concern is that, in the next two to three years, little can be done to turn around the public perception. Recent public opinion polls indicate substantial scepticism about scientists working for the chemical industry and about regulatory authorities. Environmental pressure groups arguing against GMOs are seen in a much more favourable light. According to one recent poll, 63 per cent of British citizens tend to oppose or strongly oppose GM crop testing in their local area, being at least somewhat afraid of a potential negative impact.

It seems that things will have to get worse in order for them to get better. More visible consequences of the low productivity of resource-poor agriculture will have to occur. Issues like increasing poverty-driven migration, political upheavals, humanitarian disasters in these contexts and environmental destruction will be needed to bring the message home to the broader public: research that can raise the productivity and hence the income and the quality of life in poor countries is in the enlightened self-interest of all. It is preferable from a human dignity point of view and also more cost-effective than the political management of poverty-driven mass migration.

Thus, while doing whatever can be done technically, legally, in the media, and otherwise to improve the situation in the short term, we must focus on the medium and longer term. The current impasse is only to a small degree due to lack of information. It is much more a matter of attitudinal rejection. There is already a wealth of information on all important aspects of agricultural biotechnology, and there is excellent advice for all parties on how to deal with this information.[5] But more information alone is not the answer. Rather, those of us who are convinced of the potential benefits of biotechnology and genetic engineering must engage in spreading the 'gospel' through dialogue and cooperation.

To turn the situation around, we need a number of changes. First and foremost, research in agricultural biotechnology must come up with results that are more tangible and more easily understood by a wider public. Empirical social science suggests that lay people strongly believe that some scientific developments are beneficial and others are not. Their opinions are mainly coloured by whether people will benefit from the development and whether the application will be safe to use. While characteristics such as insect or herbicide resistance might warm the hearts of some researchers or farmers, most consumers will neither understand nor appreciate the blessings of this technology. Those must be brought home to a wider public by success stories such as the vitamin A rice or 'iron-rice' or by other improvements of the nutritional profile that are easier understood – and by putting potential risks into perspective. If they perceive the technology as beneficial, people are prepared to overlook benefit–risk trade-off objections. If the expected benefits are of questionable value (such as extended shelf life for tomatoes in countries with ample refrigeration facilities), there may be little justification for accepting any appreciable amount of risk. But if the expected benefits are clearly enormous (such as vitamin-A-enriched rice), it may make sense to accept a limited degree of risk.

Advantages for the consumer (better nutritional value, reduction of toxins) as well as advantages for farmers (less costly inputs) and the environment (fewer chemicals) must be empirically substantiated and properly explained. It should be possible to explain to a broader public the benefits of insect-resistant cotton – achieved by genetic modification with *Bt* – that cuts the use of cotton insecticides by nearly 40 per cent.[6]

DIALOGUE AND COOPERATION: FROM RITUALISTIC FIGHTS TO ISSUE-ORIENTED DISCOURSE

In addition to positive case studies for the improvement of human quality of life, consistent and coherent dialogue as well as practical cooperation are necessary to bring about a change in public perception of agricultural biotechnology. Dialogues are able to improve mutual understanding by providing and exchanging information, learning about other people's concerns and reducing prejudice. In addition, cooperation between different members of civil society can build up and strengthen mutual trust.

As people do not trust what they do not understand, communication becomes crucial. What cannot be communicated cannot be done. Experience from other social or political conflicts suggests that the vast majority of those involved in discussions want to be taken seriously and hence given competent and reliable information (European Federation of Biotechnology, 2000). Most people look to minimize possible risks through fair controls and want to participate in the decision process about values and objectives. This is possible, but quick results are unlikely. The fight for public acceptance will be a lengthy uphill battle and will have to involve many different constituencies.

Dialogue

All institutions, whether business enterprises, research centres, government agencies or non-governmental organizations, tend to be self-referring: that is, every organization has a more or less self-contained system of values and interests that it takes for the full version of reality. If people proceed on the assumption that their convictions are the sole correct ones, their ideas the best, their proposals the most telling, then – like all narcissists – they court danger: unable to size up chances and risks dispassionately, they commit errors that could have been avoided.

Dialogues, as search processes for better solutions, are not easy. In a perfect world, all parties can listen, evaluate, learn and, if necessary, change their opinion. The fact that people get into arguments over their positions only shows that they are concerned about the same things. A plurality of opinions and a competition of ideas are the expression of a dynamic intellectual climate. A plurality of interests in a society gives rise not only to conflicts but to significant opportunities as well. Why not make the most of this pluralistic situation when it comes to working out a path to consent on a politically sensitive issue such as agricultural biotechnology? To be sustainable, solutions to problems must reflect more than the narrow horizon of a single party. They also need to include other varieties of experience and interests. In view of the urgency and complexity of the many problems besetting our time, including the need to achieve world food security, a narrow-minded approach to problem analysis and solutions is just as hazardous as thinking in simplistic 'left/right' terms.

Dialogue does not do away with conflicts, of course, but it does help to resolve them constructively. The four prerequisites of dealing rationally with conflicts posited by Ralf Dahrendorf are central here (Dahrendorf, 1981).

(1) Conflicts must be looked upon as right and meaningful, for they can inaugurate or speed up significant social change.
(2) Intervention in conflicts must be limited to agreeing ground rules on the forms it should take.
(3) Conflicts must be organized and channelled, for example in political parties, trade unions, employers' associations, and so on.
(4) There must be agreement on the 'rules of the game' governing how a conflict is resolved.

Yet, even with these stipulations, dialogue is an open-ended process. The course dialogues take cannot be planned beforehand, and their outcomes are comprehensible only to a limited extent.

Dialogue participants

The question of who should be represented in a dialogue is difficult to answer. On the one hand, the full spectrum of opinion should be represented. On the other hand, at least in my experience, there is little sense in including fundamentalist advocates of particular interests. Organizations that explicitly state a preferred strategy of confrontation choose not to be involved in genuine dialogue. They seem to be so bent on confirming the 'truth' of their opinions about the way the world works and so preoccupied with the public splash this makes that they would feel themselves completely invalidated by any kind of compromise.

So-called 'issue champions' often seem unable to permit themselves the luxury of objectivity. They have moulded themselves to the opinion profile that works for their public, and the slightest compromise could mean a loss of face or lead to an identity crisis. So the role assignment that defines their persona takes on the function of a hypothesis corroborated by every act that does not conclusively refute it. Ideological reasoning adopts a given thesis as the unquestionable truth – also known as dogma.

Very often, even qualified experts, depending on whether they are on the supporting or the opposing side of a controversial issue, will evaluate one and the same set of facts quite differently. 'Schools of thought' tend to exert on their adherents a certain pressure to conform. Diverging opinions, being institutionally unacceptable or upsetting, are brushed aside. Yet many of the positions on technical and political issues espoused 10–15 years ago by outsider minority groups enjoy broad acceptance today.

In order to reach a consensus, both sides must be willing to join in learning together and in this way, perhaps, to arrive at a new, shared platform of certainty. This calls not only for scientific understanding but also for methodical efforts to keep dialogues between different participants with different interests and values results-oriented. One path to this state of affairs, already mapped out in antiquity, is still useful today. First, find out what everyone can agree on. Second, discuss the remaining areas of disagreement in a spirit of aiming to reconcile them. Third, ascertain the consensus reached at this point in the discussion. Fourth, identify the areas of disagreement still remaining. (These usually have to do with different priorities in considering pros and cons or differing expectations where decisions attended with uncertainty are concerned.) Finally, strive for a fair compromise.

By fair compromise I do not mean the arithmetical mean between two standpoints. If that were the definition of a fair compromise, all the participants would simply demand twice as much as what they actually hope to get. A fair compromise consists of a reasonable joint framework of action elicited through forthright argumentation and based on the participants' elementary interest in coexisting in concord.

Essential ingredients of productive dialogue

The ingredients of a constructive and productive dialogue are known: bring together all relevant factual knowledge; clarify the value questions that divide the participants; honour the right of self-determination of individuals and groups as indispensable in a democratic society. For a discussion to lead to better understanding and more consensus, it can be neither a playground for politics nor a stage for boosting NGO portfolios or making exaggerated promises by life sciences corporations or research institutes. All must lower the rhetoric and deal honestly with the issues. More subtlety must allow more differentiation. All opportunities for dialogue must be used and include as many people of good will as possible. New coalitions must be formed to find constructive ways out of the impasse. The interests of the participants should be made explicit, along with the responsibilities, rights and duties.

Criticism and opposing views, whether based on science or emotions, have to be taken seriously. Euphemistic or horror language has to be avoided. Once mutual understanding and respect for each other's intellectual integrity has been established, open issues can be solved in a scientific manner rather than discrediting the personalities voicing the opposing view.

Credible dialogue will never focus on benefits only. As all human actions (or non-actions) have risks, these too must be part of the communication. If risks can be anticipated, they must be named and discussed proactively; there is nothing more destructive for the credibility of science or industry than pretending that there are no risks, only to be forced later by circumstances to admit their existence. Such behaviour is also incompatible with high professional competence and integrity.

Dominance-free communication

When masters and underlings talk to or about one another, the conversational tone is not the same as between those who are free and equal. Dominance-free communication denotes an ideal situation in which the rulers do not try to impose their claims to the truth on the ruled, but in which all participants have the same chance to speak their piece. In this model situation, the interlocutors must not deceive themselves or others as to their intentions, and there is no place for privileges in the sense of 'rules of order' binding on one side only.

A further part of dominance-free communication is the timely imparting of information, ensuring that everyone is equally informed. Whatever information is available and needed for the dialogue must be made freely available before discussions start. Tactically produced knowledge deficits are neither helpful nor necessary. Publications such as the one by Feldman *et al.* (2000) are a good start, especially for information disseminators such as science journalists, political advisors and public servants of national and international institutions. The information provided must be honest, complete, comprehensive and factually accurate. Unsupported claims or accusations are a waste of time and counterproductive to reaching informed consent. Appropriate information emanating from a joint venture of different constituencies could help an interested lay public to digest conflicting or controversial information and deal with the pressure of activist groups.

To expect that science will provide final proof at any time and in any event as a condition of taking action would be to paralyse our very ability to act. To put the 'precautionary principle' into perspective, every act, not excluding an act rooted in scientific theory, is 'tainted with provisionality'. But perhaps that is not our real problem, for no matter how narrow the margin of uncertainty in scientific pronouncements may become, people will bet on it when theory appears inadmissible and unbearable in practice.

Relinquishing animosities and 'searchlights'

Time and again we can see how people take up a hostile stance the moment their opinions encounter opposition. From that point on the mind is no longer open to impulses or ideas emanating from other directions; it only takes in the arguments that come from a 'friendly' quarter and therefore jibe with its own set convictions. Under such circumstances, it is not the facts that determine whether an argument is accepted or rejected but rather two mirror-image hypotheses: the 'presumed friend hypothesis', which lets people place their trust in what they have direct knowledge of and are able to understand; and the 'presumed enemy hypothesis', with the help of which everything that is unfamiliar or incomprehensible is seen as a potential enemy that must be foiled. Who turns out to be friend and who an enemy depends, of course, on personal experience and interests and on socially conditioned preconceptions.

With his 'searchlight' theory of science, Karl Popper drew attention to the fact that lay people are not alone in being susceptible to prejudices. Every scientific description of facts is also selective and dependent on hypotheses. The situation, said Popper, can best be described by comparison with a searchlight. What the searchlight makes visible will depend on its position, our way of directing it, and its intensity, colour and so on. It will, of course, also depend very largely on the things illuminated by it. Similarly, a scientific description will depend largely on our point of view and our interests, which as a rule are connected with the theory or hypothesis we wish to test. It will also depend on the facts described. No theory is final, and every theory helps us to select and order facts (Popper, 1980). As we all have our intuitions and assumptions, preconceived opinions, fiercely held beliefs and other searchlights, and as we all have tendencies to avert loss and a preference for the status quo, we all should do our best to be aware that it is not only our opponents who have limits. So do we.

The practical limits to dialogue

In practice, a dialogue cannot go on being prolonged until every last potentially or actually involved party is convinced. So it is necessary to agree on guidelines governing the technical aspects (beginning, end, breaks, sufficient familiarity with the subject) and the content (a demarcation of what is to be discussed). And there must be rules defining what constitutes a majority. Less than absolute majorities have to suffice for a decision, otherwise action will be stymied. The right of the majority does not rest on the erroneous assumption that it is always right. Nor does it rest on the assumption that one group has a natural authority over the other just because it is more numerous. Rather it rests on the absence of something like a higher authorization.

And there is another obstacle. Years of experience in stakeholder dialogue show that those who are normally delegated by companies or regulatory authorities to take part are not usually those who are able to implement what has been achieved as a compromise through consensus. Although the top management of companies and regulatory authorities – at least among the enlightened institutions – have no problem delegating representatives to such talks, the persons doing the delegating do not go through the all-important learning processes that the delegates experience. This gives rise to divergent perceptions and realities of the task ahead.

In the end, it is the benefit–risk analyses that should convince not only the scientists and experts but also a broader public. Democracy, not oligarchy, also has to work here. This also means that scientists will have to learn to explain their work in a manner that is understandable at least by an interested lay public. Myths have their own life and will only slowly fade away through continual communication and a consistent and coherent 'walk-as-you-talk' attitude by all parties involved in agricultural biotechnology.

Cooperation

Dialogues will not suffice. There must also be 'dialogue through cooperation'. Common research can lead to positive case studies of societal learning for different constituencies, including scientific committees, science journalists and other interested stakeholders. When people join together to work on a concrete project to achieve goals that are judged to be important to everyone, prejudices eventually disappear and labels that have been acquired lose their importance. The cooperation in the laboratories and fields allows differentiation between justifiable hopes and worries and unjustifiable ones. The opportunities, mechanisms and limits of such cooperation are made clear in the Tlaxcala Statement on Public/Private Sector Alliances in Agricultural Research initiated by CIMMYT.[7]

Different stakeholders can contribute diverse knowledge, on an equal footing and without any differences in social class, for the benefit of all. Controversies are dealt with on a case-by-case basis and as a side effect of the concrete work at hand. The process of moving from ignorance through arrogance and then to tolerance of different views of the world cannot be delegated. It has to be lived. It is a unique opportunity to discover parallel perceptions of reality, to cope with them and to combine them to form a larger whole. The ability to engage in constructive teamwork will separate the chaff from the wheat: anyone who is not capable of breaking free from the kind of friend/enemy thinking anchored in dogma and of working towards coalition, who prefers demarcation to teamwork for political reasons, will have to put up with the slur of being a fundamentalist.

Those who have broader shoulders must exercise visible solidarity in a consistent way. First and foremost, in view of today's limitations, capacity and institution building for biotechnology must be supported and funded by development assistance resources. Only if there is a national absorptive capacity to understand the technology and deal with it safely can the benefits of technology transfer be maximized and its risks minimized. This support can range from consulting for state-of-the-art bio-safety regulation, best practices of capacity building, and clearing house advice to genetic material and laboratory equipment. Support from the private sector can also make a major contribution to putting constructive partnerships into practice in developing countries.

CONCLUSIONS

Public acceptance of agricultural biotechnology is at a critical juncture. The next two to three years will be decisive for its long-term viability. The discussion today in Europe is a predominantly political one, and has, in the old Marxian sense, a direct influence on society and the economy. In addition, it does harm to the public acceptance of technologies outside Europe and to the support for public research for resource-poor farmers.

The political economy of agricultural biotechnology could well turn into a missed opportunity to provide the developing world with effective means to facilitate food security for a growing population with shrinking natural resources. Given the complexity of socioeconomic, political and ecological problems behind deficits in food security, agricultural biotechnology cannot be a silver bullet or a miracle cure for all problems in all countries. A successful battle for food security in the developing world requires battles on many different fronts: economy, social policy, gender policy, ecology, water and soil management, agronomy, breeding programmes, agricultural extension, farm management, pest management, and others. New technologies, however, are part and parcel of a successful package. If agricultural biotechnology is used wisely in conjunction with conventional breeding, improved agricultural methods and better agricultural policies, it can become a powerful tool in the fight for higher productivity in the small farmer's field.

More than 100 years ago, it took the scientific world a whole generation to understand the significance of Gregor Mendel's findings. I hope that it will take much less time to grasp the importance of genetic engineering for a world that will have to feed nearly 9 billion inhabitants in 2050.

NOTES

[1]For the horror stories, see <*biotech_activists@iatp.org*>; for a scientific discussion of risks, see <*www.agbioworld.com*> or <*www.cropgene.com*> and <*kamman@sgi.unibe.ch*>. Another (<*www.gene.ch/pmhp/gs/media.htm*>) is a guide to media exploitation.

[2]The scientific declaration (found in <*www.agbioworld.com*>) states: 'No food products, whether produced with recombinant DNA techniques or with more traditional methods, are totally without risk. The risks posed by foods are a function of the biological characteristics of those foods and the specific genes that have been used, not of the processes employed in their development.'

[3]There is some evidence of obvious conflicts of interest. For an interesting example relating to the U.S. National Academy of Sciences, refer to Henry Miller, Senior Research Fellow at Stanford University's Hoover Institution on 'Nescience, not Science, from the Academy' (at <*miller@hoover.standforf.edu*>).

[4]More balance is to be found in the excellent work by C.S. Prakash of the Centre for Plant Biotechnology Research at Tuskegee University, Alabama (<*prakash@tusk.edu*>), and Klaus Ammann, director of the Botanical Garden of the University of Berne, Switzerland (<*kammann@sgi.unibe.ch*>) as well as of all those who contribute to <*AgBioView@listbot.com*>.

[5]For the basic information, see Nuffield Council on Bioethics (1999) and Dag Hammarskjöld Foundation (2000). For how to deal with the information, see <*www.ificinfo.org/resource/guidelines.htm*>.

[6]Described by Traxler *et al.* (2000). Such a substantial reduction has not been achieved in all years and in all areas where *Bt* technology is applied, as shown by the Economic Research

Service (1999). The easily understandable reasons for this are explained in Gianessi and Carpenter (1999).

[7]See <*www.cimmyt.cgiar.org*>.

REFERENCES

Anderson, J.R. and Dalrymple, D.G. (1999), *The World Bank, The Grant Program and the CGIAR: A Retrospective Review*, Washington, DC: World Bank Operations Evaluation Department.

Brown, L.R. (1999), *State of the World 1999*, New York: W.W. Norton.

CGIAR (1998), *The Impact of Knowledge* (Annual Report 1998), Washington, DC: CGIAR.

CGIAR (2000b), *Synergies in Science: Intercenter Collaboration to Eradicate Hunger and Poverty*, Washington, DC: CGIAR.

Cohen, J.J. (ed.) (1999), *Managing Agricultural Biotechnology – Addressing Research Programme Needs and Policy Implications*, London: CAB International.

Consultative Group on International Agricultural Research (CGIAR) (2000a), *A Food Secure World For All: Towards a New Vision and Strategy for the CGIAR in 2010*, Rome: CGIAR.

Conway, G. (2000), 'The Voice of Reason in the Global Food Fight', interview by David Stipp, *Fortune*, 21 February.

Dag Hammarskjöld Foundation (2000), *Seeding Solutions: Policy Options for Genetic Resources – Crucible II Report: People, Plants and Patents Revisited*, Stockholm: Hammarskjöld Foundation.

Dahrendorf, R. (1981), *Gesellschaft und Freiheit*, Munich: Piper.

Daniell, M.H. (2000), *World of Risks: Next Generation Strategy for a Volatile Era*, Singapore: John Wiley.

Economic Research Service (1999), *Genetically Engineered Crops for Pest Management*, Washington, DC: U.S. Department of Agriculture.

Environmental Monitor (1998), *Global Public Opinion on the Environment: 1998 International Report*, Washington, DC: Environmental Monitor.

European Federation of Biotechnology (2000), *Task Force on Public Perceptions of Biotechnology: Biotechnology for Non-specialists. A handbook of information sources*, Delft and London: European Federation of Biotechnology.

Feldman, M.P., Morris, M.P. and Hoisington, D. (2000), 'Genetically Modified Organisms: Why All The Controversies?', *Choices, The AAEA Magazine of Food, Farm, and Resource Issues*, first quarter, 8–12.

Food and Agriculture Organization (1996), *Food Security Assessment*, Document WFS 96/Tech/7, Rome: FAO.

Food and Agriculture Organization (1999a), *The State of Food Insecurity in the World 1999*, Rome: FAO.

Food and Agriculture Organization (1999b), *The State of the World's Forests 1999*, Rome: FAO.

Food and Agriculture Organization (2000), *Statement on Biotechnology*, Rome: FAO.

Gianessi, L.P. and Carpenter, J.E. (1999), *Agricultural Biotechnology: Insect Control Benefits*, Washington, DC: National Center for Food and Agricultural Policy.

Goklany, I.M. (1999), 'Meeting Global Food Needs: The Environmental Trade-offs between Increasing Land Conversion and Land Productivity', *Technology*, **6**, 107–30.

Hazell, P.B. and Ramasamy, C. (1991), *The Green Revolution Reconsidered*, Baltimore: Johns Hopkins University Press.

Hohn, T. and Leisinger, K.M. (eds) (1999), *Biotechnology of Food Crops in Developing Countries*, New York: Springer.

International Water Management Institute (1999), *Water Scarcity in the Twenty-First Century*, Colombo, Sri Lanka: IWMI.

ISI/Fraunhofer Institut für Systemtechnik und Innovationsforschung (1998), *Studie zur Globalen Entwicklung von Wissenschaft und Technik*, Karlruhe: ISI.

Kendall, H.W. *et al.* (1997), *Bioengineering of Crops: Report of the World Bank Panel on Transgenic Crops*, Washington, DC: World Bank.

Krattiger, A.F. and Rosemarin, A. (eds) (1994), *Biosafety for Sustainable Agriculture*, Stockholm: Stockholm Environment Institute.

Lappé, M. and Bailey, B. (1998), *Against the Grain: Biotechnology and the Corporate Takeover of Your Food*, London: Earthscan.

Leisinger, K.M. (1999), 'Disentangling Risk Issues', in G.J. Persley (ed.), *2020 Vision Focus 2*, Washington, DC: IFPRI.

McCalla, A.F. (2000), *Agriculture in the 21st Century* (Economics Programme, Fourth Distinguished Economist Lecture), El Batan: CIMMYT.

McGloughlin, M. (1999), 'Ten Reasons Why Biotechnology Will Be Important to the Developing World', in University of Missouri (ed.), *The Economics of Biotechnology in Developing Countries* (at <*www.agbioforum.org*>).

Marx, K. (1859), 'Zur Kritik der Politischen Ökonomie', Preface to K. Marx and F. Engels, *Werke*, Bd. 13, 1985 edn, Berlin: Dietz Verlag.

Miller, H. (2000), 'Anti-Biotech Sentiment Has Its Own Risks', *Financial Times*, 22 March.

Myrdal, G. (1968), *Asian Drama*, 3 vols, Harmondsworth, UK: Methuen.

National Academy of Sciences (1987), *Introduction of Recombinant DNA-Engineered Organisms into the Environment: Key Issues*, Washington, DC: National Academy Press.

National Research Council (1989), *Field Testing Genetically Modified Organisms – Framework for Decision*, Washington, DC: National Academy Press.

Nuffield Council on Bioethics (1999), *Genetically Modified Crops: The Ethical and Social Issues*, London: Nuffield Council.

Persley, G.J. and Lantin, M.M. (eds) (2000), *Agricultural Biotechnology and the Poor*, Washington, DC: CGIAR/National Academy of Science.

Pingali, P. and Heisey, P. (1996), 'Cereal Crop Productivity in Developing Countries: Past Trends and Future Prospects', Conference Proceedings: Global Agricultural Science Policy for the Twenty-First Century, Melbourne, Australia.

Pinstrup-Andersen, P. (2000), 'Food Policy Research for Developing Countries: Emerging Issues and Unfinished Business', *Food Policy*, **25**, 125–41.

Pinstrup-Andersen, P., Pandya-Lorch, R. and Rosegrant, M.W. (1999), *World Food Prospects: Critical Issues for the Early Twenty-First Century*, Washington, DC: IFPRI.

Popper, K. (1980), *Die offene Gesellschaft und ihre Feinde*, Tübingen: Francke.

Population Reference Bureau (2000), *World Population Data Sheet 2000*, Washington, DC: Population Reference Bureau (or at <*www.prb.org*>).

Postel, S. (1999), *Pillar of Sand: Can the Irrigation Miracle Last?*, New York: W.W. Norton.

Potrykus, I. (ed.) (1996), *New Horizons in Swiss Plant Biotechnology – from the Laboratory to the Field*, Proceedings of a Symposium organized at the ETH Zurich on the occasion of the 125th anniversary of the Department of Agronomy and Food Sciences.

Qaim, M. and Virchow, D. (1999), *Macht die Grüne Gentechnik die Welt satt? Herausforderungen für Forschung, Politik und Gesellschaft*, Bonn: Friedrich-Ebert-Stiftung.

Rifkin, J. (1999), *The Biotech Century: Harnessing the Gene and Remaking the World*, New York: Penguin Putnam.

Sears, M.K., Stanlex-Horn, D.E. and Mattila, H.R. (2000), *Preliminary Report on the Ecological Impact of* Bt *Corn Pollen on the Monarch Butterfly in Ontario*, Guelph: University of Guelph.

Sen, A. (1981), *Poverty and Famine: An Essay on Entitlements and Deprivation*, New York: Oxford University Press.

Scherr, S.J. (1999), *Soil Degradation: A Threat to Developing-Country Food Security by 2020?*, Washington, DC: IFPRI.

Shah, M. and Strong, M. (1999), *Food in the 21st Century: From Science to Sustainable Agriculture, Highlights of the System Review 1998/99*, Washington, DC: CGIAR.

Sharma, M. (2000), 'India: Biotechnology Research and Development', in G.J. Persley and M.M. Lantin (eds), *Agricultural Biotechnology and the Poor*, Washington, DC: CGIAR/National Academy of Science.

Smith, L.C. and Haddad, L. (2000), *Overcoming Child Malnutrition in Developing Countries. Past Achievements and Future Choices*, Washington, DC: IFPRI.

Staubl, J.M. (2000), 'High-Yield Production of a Human Therapeutic Protein in Tobacco Chloroplasts', *Nature Biotechnology*, **March**, 333–8.

Traxler, G., Falk-Zepeda, J.B. and Sain, G. (2000), 'Genes, Germplasm and Developing Country

Access to Genetically Modified Crop Varieties', contribution to ICABR conference, The Shape of the Coming Agricultural Biotechnology Transformation, Rome.
UN Sub-Committee on Nutrition (2000), *The 4th Report on The World Nutrition Situation*, New York: United Nations.
United Nations Population Division (1998), *World Urbanization Prospects: The 1996 Revision*, New York: United Nations.
United Nations Population Fund (1999), *The State of World Population 1999*, New York: Oxford University Press.
Walsh, D. (2000), 'America Finds Ready Market for GM Food – The Hungry', *The Independent*, 30 March.
Wambugu, F. (1999), 'Why Africa Needs Agricultural Biotech', *Nature*, **400**, 15–16.
World Health Organization (1999), *Nutrition for Health and Development: Progress and Prospects on the Eve of the 21st Century*, Geneva: WHO.
World Resources Institute (annual), *World Resources 1998–99*, New York: Oxford University Press.
Worldwatch Institute (annual), *Vital Signs*, New York: W.W. Norton.
Zhang, Q. (2000), 'China: Agricultural Biotechnology Opportunities to Meet the Challenges of Food Production', in G.J. Persley and M.M. Lantin (eds), *Agricultural Biotechnology and the Poor*, Washington, DC: CGIAR/National Academy of Science.