

Biotechnology and food security*

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Agriculture in developing countries will be confronted with three major challenges in the decades to come: (a) to increase the availability of nutritious food to an increasing population; (b) to use natural ecosystems more efficiently and (c) to make a contribution to economic development. It is not conceivable that agriculture can deliver the expected outputs without modern technologies such as genetic engineering and biotechnology.

WHILE the world has been changing over the last years both politically and economically in unexpected and remarkable ways, food security remains an unfulfilled dream for currently more than 800 million people, about 10% less than in 1970. What seems to be a small improvement, should not go unappreciated, however, as about 1.5 billion people were added to the population of the developing countries since then. There has been progress on a global scale – but not for all (Table 1).

There are good chances for continuing progress in the years to come – but, again, not for all and much more difficult to achieve: during the next 30 years, the increase in numbers of human beings will be in the same dimension as the total world population in 1950, i.e. about 2.4 billion people. In the same period of time the globe's ecological carrying capacity is expected to shrink. The combination of these two trends will keep food security 200 years after Malthus on the agenda for human development.

World population continues to increase

Never before in human history has our planet been so densely populated as today: about 6 billion people now live on earth and, even though birth rates are decreasing in most countries, 70 to 80 million will be added to our numbers in 1999, 98% of them in developing countries¹. Those of us born before 1950 are the first generation in human history to witness a doubling of world population.

While some of the developing countries are steadily moving towards lower birth and death rates, others – mainly those with high levels of poverty and limited social and economic progress for women – are experiencing constant birth rates at a high level. In aggregate, the population of the developing countries – 80% of the

global total – continues to increase at record levels in absolute terms: with an increase of over 50 million per year, Asia has the highest absolute growth; with 2.6% population growth per year, Africa has the steepest rate.

Because nearly 40% of the people living in developing countries are younger than 15 years, i.e. still not in what the demographers call reproductive age, the high absolute population growth will continue into the next century despite declining birth rates. The present international consensus is that in the next thirty years the world population will swell to over 8 billions – and there might be one billion more until population growth reaches replacement levels.

Already the fact that a significantly higher number of human beings will have to be provided with food in adequate quantity and quality poses a number of political, economic, social, ecological and technological problems. Two salient features of population growth will make it particularly difficult to achieve future successes on the food security front:

The world is becoming more urbanized

The world, in particular the developing world, is in the midst of an unprecedented urban transition. Within the next decade, more than half of the world's population, an estimated 3.3 billion, will be living in urban areas². As recently as 1975, just over one-third of the world's population lived in urban areas; by 2025, only 50 years later, it will be almost two-thirds (Table 2).

The megacities of the future are increasingly to be found in developing countries, and will confront them with social and environmental problems of unprecedented magnitude³. This has notable consequences for food security: urban populations are not able to feed themselves by subsistence food production, and their eating patterns differ from those of rural folk. The amount of high-value, transportable, and storable grain (such as rice and wheat), animal protein, and vegetables in their diets is higher, with a corresponding decrease in the proportion of traditional foodstuffs.

As incomes rise for some urban professional groups – this is expected to be the case, particularly in the indus-

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Table 1. Estimates and projections of the incidence of chronic undernutrition in developing countries

Region	Year	Total population (millions)	Undernourished % of population (millions)	
Sub-Saharan Africa	1969-71	268	36	103
	1990-92	500	43	215
	2010	874	30	264
Near East/North Africa	1969-71	178	27	48
	1990-92	317	12	37
	2010	513	10	53
East Asia	1969-71	1,147	41	475
	1990-92	1,665	16	268
	2010	2,070	6	123
South Asia	1969-71	711	33	238
	1990-92	1,138	22	255
	2010	1,617	12	200
Latin America	1969-71	279	19	53
	1990-92	443	15	64
	2010	593	7	40
Total	1969-71	2,583	35	917
	1990-92	4,064	21	839
	2010	5,668	12	680

Source: FAO, Food, Agriculture and Food Security: World Food Summit Technical Background Documents, 1996, vol. 1, p. 9.

Table 2. Total population growth and urban population growth 1950-2025 (in millions)

Year	Total population		Urban population	
	World	Developing countries	World	Developing countries
1950	2,516	1,683	783 (31%)	295 (18%)
1970	3,697	2,648	1,353 (37%)	676 (26%)
1990	5,295	4,084	2,274 (43%)	1,435 (35%)
1999	6,008	4,828	2,824	1,979
2025	8,082	6,842	5,011	3,968

Source: UN: World Population Prospects, The 1992 Revision, p. 284ff; for the year 2025: Population Reference Bureau 1996; for Urban Population: UN: World Urbanization Prospects, The 1994 Revision, pp. 86f; UN Population Division October 1998.

trializing Asian countries – people move up the food chain, i.e. consume more livestock products, the production of which either requires more grain or absorbs arable land.

Already today's 400 million or so subsistence farmers cannot feed the urban population of 1.5 billion; the 800 million subsistence farmers of the year 2025 will not possibly be able to feed 4 billion city-dwellers. This means that future food production will come from a dualistic agriculture. The subsistence sector will continue to support those living in the backward areas, while modern agriculture and intensified production will have to supply the urban dwellers.

While cities grow and a part of the urban population enjoys increased incomes, overall the world is becoming

more polarized and poorer as the lower-income classes grow faster than the total population.

The world is growing poorer

Poverty reduction has been the top priority of development endeavours over many years. Yet, despite the fact that significant progress has been made in improving living standards in almost all developing countries, more than 1.3 billion people in the developing world still struggle to survive on less than a dollar a day: they live in absolute poverty⁴. Every year nearly 8 million children die from diseases linked to dirty water and air pollution, 50 million children are mentally or physically damaged because of inadequate nutrition, and 130 million children – 80% of them girls – are denied the chance to go to school. The shocking fact is that a child born in Sub-Saharan Africa is still more likely to be malnourished than to go to primary school and is as likely to die before the age of five as to enter secondary school⁵.

Up to now, poverty has been mainly a rural phenomenon, attributable in part to a vicious circle: a lot of today's degradation of agricultural resources is poverty-related⁶ – and degraded environmental resources contribute to the perpetuation of poverty. Yet, although poverty will continue to characterize the rural landscape, projections show that the number of urban poor will overtake the number in rural areas by early next century⁷.

Relative poverty has also increased. Over the past 15 years the world has seen spectacular economic advances for some countries – and unprecedented decline for others. The gap in per capita income between the industrial and the developing world tripled from \$5,700 in 1960 to \$15,400 in 1993 (ref. 8).

Disparities have grown within societies as well. To repeat: today the world is more polarized than ever before in human history. The poorest 20% of the world's people saw their share of global income decline from 2.4% to 1.4% in the past 30 years, while the share of the richest 20% rose from 70% to 85%. That doubled the ratio of the shares of the richest and the poorest – from 30:1 to 61:1.

While absolute poverty has direct negative implications for human development, increasing economic disparities against a background of widespread poverty put the social fabric at risk. As Robert D. Kaplan has demonstrated convincingly, a disintegrating social fabric will have grave consequences not only for the environment, political stability, and the safeguarding of regional and national tranquillity but also for food security⁹.

And there is another mega-issue.

The world's agricultural environment is deteriorating

A last but certainly not least trend threatening sustainable agricultural development and hence food security has to do with the widespread effects of human activities on the environment: on the global level, major key indicators show that the physical condition of the earth is deteriorating, i.e. the earth is getting warmer (the 10 warmest years in the last 130 have all been in the 1980s and 1990s; of those 10, the three warmest were in the 1990s, with 1998 the record year to date)¹⁰. The deforestation¹¹ of the planet continues unabated, reducing the capacity of soils and vegetation to absorb and store water.

Soil erosion by water and wind due to inappropriate agricultural techniques as well as overuse of scarce resources¹², particularly overuse of water resources¹³, make every effort to improve food security an even more difficult task. The scale of land degradation is estimated to be very high: the global land assessment of degradation (Glasod) estimates that of the 3.2 billion hectares which are under pasture, 21% are degraded, while of the nearly 1.5 billion hectares in cropland, 38% are degraded to various degrees¹⁴. Water and wind erosion are the principal causes of degradation. Various sources suggest that 5 to 10 million hectares of land are being lost annually to severe degradation. The degradation of cropland appears to be most extensive in Africa, affecting 65% of the cropland area, compared with 51% in Latin America and 38% in Asia¹⁵. Declining yields or increasing input requirements will be the consequence.

The Sahelian Zone in Sub-Saharan Africa continues to be among the ecologically most endangered regions of the world¹⁶ – with dire consequences for self-reliance. A number of populous countries suffer particularly high losses. Each year Indonesia, for example, loses 20,000 hectares of cropland on Java alone, which is enough to supply rice to 378,000 people¹⁷. China, the most populous country in the world, continues to be under heavy land pressure, with at least uncertain consequences for national food self-sufficiency.

It is against the background of continuing population growth, accelerated urbanization, increasing poverty, increased pressure on the social fabric and the environment that the question of whether food security can be achieved in the next generation must be posed.

In search of food security

The concept of 'food security'

The Food and Agriculture Organization of the United Nations (FAO) defines 'food security' as a state of affairs where all people at all times have access to safe and nutritious food to maintain a healthy and active life¹⁸. This means that in order to enjoy food security, there must be on the one hand a provision of safe, nutritious, and quantitatively and qualitatively adequate food and, on the other, rich and poor, male and female, old and young must have access to it.

Food security thus has three dimensions¹⁹:

- (i) Availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports;
- (ii) Access by households and individuals to appropriate foods for a nutritious diet; and
- (iii) Optimal uptake of nourishment thanks to a sustaining diet, clean water and adequate sanitation, together with health care.

The multi-dimensionality of this concept allows an overview of both global and national food security – or insecurity – at the household level among low-income groups and among individual household members who, because of intra-family obstacles, suffer from inequitable distribution. As parasitic and other diseases substantially hamper the metabolism and assimilation of sustenance taken, individual state of health also figures significantly in the food security equation.

Because shortfalls in food security can and do result from various interlinked adverse conditions in a country's socio-economic system, the only pathway to eventual food security is sustainable human development. This means breaking the vicious circle of continuing poverty, environmental deterioration, and acute institu-

tional deficiencies. To aim for a commensurate food production volume within the framework of such a development strategy, adapted to specific local circumstances, is a must.

Against the background of the interdependence of continuing population growth, accelerated urbanization, increased pressure on the social fabric and the environment, the fight for food security will have to be a fight on many fronts. The technological front is only one, and genetic engineering and biotechnology is one within several technical options – it is, however, in my perspective a very important one: most experts agree today, that the task of meeting world food needs to 2010 by the use of existing technology may prove difficult, not only because of the historically unprecedented increments to world population that seem inevitable during this period but also because problems of resource degradation and mismanagement are emerging. Such problems call into question the sustainability of the key technological paradigms on which much of the expansion of food production since 1960 has depended²⁰.

In order to pass a judgment on whether genetic engineering and biotechnology promise to be the new technological paradigm in the fight for food security or not, we must take a look at the technologies' perceived benefits and risks.

The contribution of genetic engineering and biotechnology

In Berlin around 1750, the priest and statistician Johann Peter Süßmilch calculated that the earth could feed at least 10 billion people. About 50 years later, another cleric – the Englishman Thomas Robert Malthus – prophesied dark times ahead: since the growth of the population was clearly more rapid than that of food, hunger and mass poverty were inevitable. The basic difference in the assumptions of the two was the weight they assigned to the role of technological progress – progress such as genetic engineering and biotechnology today.

In order to pass a judgment on whether genetic engineering and biotechnology promise to be the new technological paradigm in the fight for food security or not, we must take a look at the technologies' perceived benefits and risks.

The benefits of genetic engineering in the fight for food security: (i) *The expectations.* The spectrum of potential benefits from the application of genetic engineering and biotechnology to food crops in developing countries ranges from diagnostic aids, for example in plant diseases, through to gene mapping, where the genetic characteristics of plants are visibly cartographed, enabling speedier identification of interesting genetic material for

every kind of plant usable in agriculture²¹. The main objective of research and development for food security is to find improved seed varieties, that enable reliable high yields at the same or lower tillage costs through 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, crop rotation practices, and others. Equally important objectives are the transfer of genes with nitrogen-fixing capacity on to grains, and the improvement of food quality by overcoming vitamin or mineral deficiencies (e.g. in rice).

The realization of these objectives will bring tremendous benefits – benefits that can easily be demonstrated using rice (the staple food for 2.4 billion people) and cassava (the staple food for 500 million people)²² as examples:

Rice. Fungal diseases destroy 50 million metric tons of rice per year; varieties resistant to fungi could be developed through the genetic transfer of proteins with antifungal properties.

Insects cause 26 million tons loss of rice per year; the genetic transfer of proteins with insecticidal properties would mean an environmentally friendly insect control.

Viral diseases devastate 10 million tons of rice per year; transgenes derived from the *Tungro virus* genome allow the plant to develop defense systems.

Bacterial diseases cause comparable losses – transgenes with antibacterial properties are the basis for inbuilt resistance.

Vitamin A deficiency is the cause of health problems for more than 100 million children – transgenes will provide provitamin A with the rice diet.

Iron-deficiency in the diet is a health problem for more than one billion women and children – transgenes will supply sufficient iron in the diet.

Cassava. The African Mosaic Virus causes immense damages in cassava; transgenes interfering with the life cycle of the virus could lead to virus-resistant varieties.

Cassava contains toxic cyanogenic glycosides; the integration of transgenes could inhibit their synthesis.

Cassava roots efficiently store starch but do not contain protein; the transfer of genes for storage proteins would substantially improve their nutritional quality.

Cassava roots have a basic capacity for provitamin A synthesis, transfer of appropriate genes could lead to regulated accumulation.

An equally important goal of research is the transfer of genes with nitrogen-fixing capacity on to grain. Ideally, seed varieties which result from such research en-

deavours should lead to the cultivation of plants which fit into the concept of 'sustainable' agriculture, i.e. they should not abet erosion or leaching of the soil. To complete the packet of desiderata, a variety should afford dependable or even high yields at low production costs.

The big edge that recombinant genetics has over conventional breeding is that the desired properties can be systematically sought, identified, extracted ('snipped') from a plant or almost any other organism, and within a relatively short time transferred ('spliced') to another plant. The result is the same as that achieved with conventional methods, but without the costly and time-consuming cross-breeding they involve.

In addition, gene technology has the capability to provide growers with a greater diversity of hardy plant varieties by transposing properties from one species to another – a further advantage it has over conventional methods. The prospects are good. The World Bank expects that efforts to improve the rice yields in Asia through biotechnology will result in a production increase of 10 to 20% over the next ten years²³.

The progress will come from improved hybrid rice systems in China and in other Asian countries from rice varieties transformed with genes for resistance to pests and diseases. These transformed rice varieties will raise average yields by preventing crop damage. Further contributions for better food security through biotechnology are expected in maize, cassava and smallholder banana.

(ii) *The achievements.* Over the past four decades, yield increases in the major foodgrains throughout the world have been substantial. Yield levels of maize, rice and wheat nearly doubled over the period from 1960 to 1994. These yield increases are attributable largely to improved varieties, irrigation, fertilizers, and a range of improved crop- and resource-management technologies. Much of this has been part of the Green Revolution. In addition to producing more food, the Green Revolution has expanded farm and non-farm output, employment and wages, thus contributing to food security also by reducing poverty²⁴. Higher productivity has also reduced the conversion of forests, grasslands and swamplands for cultivation of food crops, thus contributing to the preservation of biodiversity.

Development of short-duration varieties has contributed to higher food production and improved the returns to costly resources used by poor farmers, while crop- and resource-management technologies have improved environmental and resource sustainability. Cultivation of less-favourable lands made possible by new plant varieties (for example, drought-tolerant crop varieties) has also contributed to higher food production.

Rapid productivity gains have, in general, decreased food costs and improved food security, particularly for vulnerable sections of the society. The urban poor have been important beneficiaries of this downward trend.

While landowning households often benefit most from the direct income effects of agricultural growth, landless and small food-deficit farmers often benefit most from the indirect effects such as the generation of off-farm employment. Indirect employment effects that help the poorest households are further facilitated by infrastructural development.

Conventional seed-breeding programmes will remain important also in the future. They, however, have a competitive disadvantage in that they have to proceed in small steps towards single targets and are thus time-consuming. If, in contrast, selection systems are developed for the test tube – through characterization of genetic markers for certain properties, for example – then research can be carried out with a notably greater efficiency. Case studies show that over the past years biotechnology and – so far only to a lesser extent – genetic engineering have made possible marked concrete advances in the direction of higher food security, be it through resistance to fungal and viral diseases in major food crops or through improved plant properties²⁵. The development of new plant protection techniques with the aid of genetic engineering and biotechnology (primarily transposing selected traits of *Bacillus thuringiensis* into crops) has already led to noteworthy progress with respect to the environment and lessened dependence on chemical weapons²⁶.

Especially where arable land is getting to be scarce and the use of fertilizers and plant protection agents is nearing the ecologically tolerable limit, genetic engineering and biotechnology, by providing novel products and mechanisms of action, can indeed bring farmers closer to solving some of the present agricultural problems²⁷ – problems either not solvable with traditional technologies or else only with a far greater expenditure of time²⁸. Many of the above mentioned expected results (rice and cassava) are within reach.

No one can add to the area of arable land available on earth. But with the aid of new plants 'made to measure' using gene technology and with biotechnological methods it is possible to wrest more food from the land we have with less energy input (fertilizers) and less problematic plant protection. For farmers both large and small this is of sizable importance²⁹. Based on the empirical evidence already compiled by the International Labour Organization (ILO) on the effects of biotechnological and gene-technological interventions in Third World agriculture, the ILO drew the conclusion that the positive impact could prove more far-reaching than that resulting from the application of present-day mechanical and chemical technologies³⁰.

The risks of genetic engineering in the fight for food security. Every action or non-action has implicit and explicit benefits and risks. There is a wealth of scientific and popular discussion concerning the risks of genetic

engineering and biotechnology³¹. To a great extent, today's criticism of genetic engineering and biotechnology can be compared to the discussion about the 'Green Revolution' in the seventies³². The improved seeds of the Green Revolution of the 1950s and 1960s were developed through systematic selection and crossing (hybridization) with the objective of increasing the production volume and avert famines, particularly in Asia³³. Despite undisputed success in achieving a significantly higher volume of food production and the overall positive employment effect³⁴, there was (and sometimes still is) vociferous criticism making the Green Revolution responsible for growing disparities in poor societies and for the loss of biological diversity³⁵.

The current public debate on the 'gene revolution' often suffers – like that centered on the Green Revolution – from a failure to differentiate between the risks *inherent* in a technology and those that *transcend* it. This differentiation is of utmost importance in any attempt to reason out the matter.

(i) *Technology-inherent risks*: Since the early 1970s, recombinant DNA technology – the ability to transfer genetic material through biochemical means – has enabled scientists to genetically modify plants, animals and micro-organisms rapidly. Modern biotechnology can also introduce a greater diversity of genes into organisms – including genes from unrelated species – than traditional methods of breeding and selection. Organisms genetically modified in this way are referred to as living modified organisms derived from modern biotechnology. Although modern biotechnology has demonstrated its utility, there are concerns about the potential risks posed by living modified organisms. Today, most countries with biotechnological industries have sophisticated legislation in place intended to ensure the safe transfer, handling, use and disposal of those organisms and their products. The World Bank and other institutions recommend ways and means for a proper risk assessment as well as risk management in order to assure a maximum of *biosafety*³⁶.

There is a wealth of scientific literature on the deliberate release of living modified organisms into either new environments or into areas where it could prove particularly harmful. Until today, not one severe biosafety risk has materialized. There is a broad consensus amongst scientists that serious concerns about the release of living modified organisms are unwarranted³⁷. This judgment supports the early principle of the US National Academy of Science that 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 modified³⁸.

As a social scientist, I am not competent to pass more than a layperson's judgment on matters of biosafety. I

therefore refer the readers to specialized literature³⁹. There is, however, one demand to be made: risks that are not allowed to be taken in industrial countries with their stringent regulatory framework should not be exported to developing countries. If genetically engineered organisms and biotechnological procedures are used in developing countries, state of the art quality management must be applied, taking into consideration the specific conditions of the countries concerned⁴⁰. But even then leftover risks will remain. Risks – calculable risks – must be taken, otherwise technological progress becomes impossible.

(ii) *Technology-transcending risks*: They are of an altogether different nature and emanate from the application of a technology in certain political and social circumstances. In developing countries these risks spring from both the course the global economy is taking and country-specific political and social configurations. The most critical fears in this connection have to do with three socio-political and ecological concerns:

- Aggravation of the prosperity gap between North and South, e.g. through possible substitution of tropical agricultural exports with genetically engineered products, as well as the exploitation of indigenous genetic resources of the South without appropriate compensation by the North.
- Growing disparities in the distribution of income and wealth within poor societies because the privileged classes (by dint of better education or stronger financial position) profit earlier and more from the introduction of powerful technologies than do the socially disadvantaged. This problem accompanies every innovation, of course, but the high potency of genetic engineering and biotechnology stirs fears that the negative effects on development may prove specially severe.
- Loss of biodiversity, as farmers will increasingly use the small number of more productive genetically engineered varieties instead of the many thousands of traditional local varieties they have previously used.

In light of the growing disparities within specific poor societies and between industrialized and developing countries⁴¹, the dwindling competitiveness of a great many poor countries and the ongoing loss of biological diversity⁴², very serious heed must be paid to these concerns.

Aggravation of the prosperity gap between North and South. What is usually discussed under this heading is an international trade issue of a very general nature, i.e. economic risks for (some!⁴³) developing countries due to a loss of export opportunities. With genetic engineering and biotechnology it will become possible to pro-

duce in the laboratory or in temperate zones, agricultural goods that have hitherto been grown exclusively in the tropics. This prospect gives rise to concerns that the resultant competitive edge could drive a number of tropical products off the market. The example commonly used to shed light on this issue is the production of vanilla aroma in the laboratory using biotechnological techniques, with existence-threatening effects on several tens of thousands of vanilla-producing small farmers in poor African countries.

Similar but even more far-reaching consequences could materialize in connection with cocoa. Genetically improved cocoa varieties could not only result in higher yields and a concomitant drop in prices. They could also lead to the dislodging of smallholder production in the poor West African countries by plantation-scale farming in the newly industrialized economies of Asia. A comparable outcome might happen with vegetable oils.

Furthermore, countries like Cuba or Mauritius, which depend on sugarcane for a decisive share of their export earnings, could find themselves extremely hard-pressed should industrial manufacture of the low-calorie protein sweetener thaumatin or similar substances come broadly to supplant sugarcane⁴⁴. The story of thaumatin is one that fits very much into the context discussed here. Some 10 years ago, Nigerian researchers at the University of Ife identified the sweetener thaumatin in the berries of *Thaumatococcus danielli*, which is common in the forests of that part of Nigeria. At that time, no industry was interested in using the fruit as a sweetener. With the advent of biotechnological possibilities, the gene for thaumatin – which is a protein weight-for-weight some 1,600 times sweeter than sugar – has been cloned and is now being used for the industrial production of sweetener in the confectionery industry. Patents on the process have been registered, but the people from whose lands the gene was obtained never received any compensation.

Where food crops are concerned, this category of risks is not of importance, as the farmers who grow food crops are not in danger of being threatened by genetically engineered substitutes for their crops⁴⁵. Nevertheless the risk of aggravation of the prosperity gap between North and South must be addressed because of its tremendous importance. From a *holistic political perspective* it cannot make sense to uncouple the North from the agricultural raw materials of the South, for this would plunge a large part of humanity into dire misery. It is incompatible with sustainable development and hence a peaceful future for all the inhabitants of our planet if life goes on getting better for a relatively small segment of the world's already affluent population, while for billions of others their already skimpy living standard stagnates or even shrivels.

In the perspective of economic rationality, however, it has to be expected that superior goods will conquer the

market. Copper can serve as an example. Its price is determined by the metal's electrical conductivity. Once electric current can be conducted cheaper and better by glass or carbon fiber, for instance, copper will in due course no longer be used for this purpose – with corresponding consequences for demand and thus price. The substitution will take place even though crumbling prices may lead in countries like Zambia or Chile to mass unemployment, with all the human distress it brings.

The same market 'logic' tells us to expect that if 'lab vanilla' or 'lab sugar' should prove cheaper or exhibit some other edge – healthier than the real thing, for example – over products previously imported from the South, then substitution will follow. Ultimately this process cannot be forestalled, not even by sizable government intervention, which is not desirable anyway.

The solution to the product substitution problem must therefore lie in a concerted international endeavour to diversify the production structure in vulnerable countries and not in counter-market intervention. Here, better governance⁴⁶ and more appropriate long-term structural planning from the governments of the countries in danger as well as a bigger allocation of funds from the international development establishment to the support of diversification efforts are urgently required.

In the context of the aggravation of the prosperity gap between North and South there is one further important issue that has to be examined: who shall compensate whom for the use of genetic material from developing countries and how much shall the compensation amount to?

There is widespread fear that private enterprises and research institutes could gain control of the genes of plants native to the developing world free of charge, as it were, and use them for developing and producing superior varieties that would then be sold back to developing countries at high prices. Suppose a private seeds company discovered a property in an Ethiopian barley strain making it resistant to certain plant diseases and genetically transferred this property to a wheat variety that would afterwards be commercialized in Ethiopia. Obviously, the farmers of Ethiopia, male and female, have contributed something by selecting and preserving this variety over a long period of time. It is also obvious that without the research and development work of the seeds company the 'something' would not have been turned to use outside Ethiopia or in food grains other than the native barley. So, both parties, the farmers of Ethiopia and the seeds company, have contributed to the new wheat variety, and therefore both have some kind of an intellectual property right and thus a right to compensation.

The basic question of whether remuneration is due has been clearly and positively answered by Article 19 of the Rio Convention on Biological Diversity (UNCED

1992) and the virtually unanimous consensus of the agencies engaged in development. While the general political decision in favour of compensation has been taken, the technical details of how it should be handled in specific nations are still unclear. What especially needs unequivocal regulation is who should compensate whom for what, and how much this compensation should be.

As a rough first approach, I would recommend that the issue be dealt with in terms of a license agreement and the price left to the mechanism of supply and demand. Those who benefit should pay the license fee to those who over centuries through their hard agricultural work helped to preserve the varieties in question. The unimproved genetic wealth of the world's Vavilov centers should be considered as common heritage of humankind⁴⁷.

It should not be difficult to find a simple and effective way to establish fair compensation. The INBio-Merck contract has pilot character, other mechanisms could deal with the matter by looking at the issue in the way of a licensing agreement, whereby those who use the genetic material from a traditional agricultural society pay a license fee into a fund for the support of the national agricultural research of the gene-exporting country.

Risks rooted in growing disparities in the distribution of income and wealth in poor societies. The use of genetically modified seeds adapted to the specific conditions of difficult biotopes can no doubt provide most desirable driving forces to national agricultural development as well as tremendous benefits to all farmers who use them. In a socially and politically deficient setting, it can hardly bring about improvements in the condition of those who are not able to use the new varieties. Where land ownership and tenancy systems, access to extension services, credit and marketing channels as well as to new technologies are governed by a socio-political power structure that favours only a small minority, technological progress cannot possibly be neutral in impact.

The answer to the question of who benefits and how much from the advent of new technologies and to what extent economic and social progress can be achieved virtually depends on the social and political configuration in place. Disease-resistant cassava, millet richer in protein or vitamin A enriched rice tolerant to stress can contribute to prosperity and thus enhance food security on a broad scale only if the new varieties and other social advances come within the reach of the broad mass of the population, male and female. Whether this is possible and within what time depends on the political will to create the necessary national development framework. As poor farmers tend to be risk-minimizing and not output-maximizing, even under the best social circumstances, early adopters stand to gain earlier.

Today's review on the effects of the Green Revolution shows that in countries where small farmers were supported by agricultural extension services, where they had access to land, inputs and credit – in other words, where the agricultural development framework assisted the endeavours of the small farmers – they were able to benefit much more and earlier. Even where the Green Revolution made the rich richer, because they could use the new technologies earlier, on better land, with better inputs and less expensive credits, the poor also benefited over time becoming less poor as agricultural modernization proceeded. This may not be the best of all social results one could imagine, but in a world where more than 1.3 billion people live in absolute poverty such achievements should not go unappreciated.

Like the Green Revolution, genetically engineered crop varieties are a land-saving technology and, as such, can be of particular importance to those who have little or only marginal land. Whether the potential benefits become economic and social reality for the small farmers is not a question of the technology as such but of the social quality of the development policy. The respective criticism should therefore address the deficient social setting and the lack of good governance and not be levelled against a technology which can be of use to all farmers: if land and tenure reforms are implemented, if there is support for the small farmers and other elements of a development-friendly environment, the benefits of a new technology – also of genetic engineering and biotechnology – is scale-neutral. Where 90% of the land belongs to 3% of the population and where the agricultural extension and credit services are only available to the big landholders, the introduction of a new technology will deepen the gap between incomes. The economic and social impact of genetic engineering and biotechnology can only be as good as the socio-political soil in which the resulting new varieties are planted – solutions therefore have to be looked for in the good governance domain.

Reduced use of biodiversity. The extent of biological impoverishment all over the globe has been a source of great concern for many years. More recently, in the context of genetic engineering and biotechnology, the term 'biodiversity' has gained an even wider currency and has tended to become increasingly confusing.

Evidently a certain level of biological diversity is necessary to provide the material basis of human life: at one level to maintain the biosphere as a functioning system and, at another, to provide the basic materials for agriculture and other utilitarian needs⁴⁸. The most important direct use of other species is food. Although a relatively large number of plant species, perhaps a few thousand, have been used as food, and a greater number are believed to be edible, only a small percentage of these are nutritionally significant on a global level. It is

clear that successful cultivation of agricultural crops on a large scale requires a number of other organisms (chiefly soil micro-organisms and, in a few cases, pollinators) but these probably amount to a statistically insignificant percentage of global biological diversity. But highly productive agricultural systems require the virtual *absence* of some elements of biological diversity (pest species) from given sites.

Given the immense reduction of biological diversity due to the destruction of tropical forests, the conversion of native land to agriculture, the replacement of wildlands with monocultures, over-fishing and other activities to feed a growing world population, the loss of biodiversity due to the use of modern crop varieties is not of significance for overall global diversity. The genetic erosion in the crop varieties used is of concern in so far as it has implications for food supply and the sustainability of locally adapted agricultural practices. Genetic resources may not only influence the productivity of local agricultural systems but also, when incorporated in breeding programmes, provide the foundation of traits (disease resistance, nutritional value, hardiness, etc.) of global importance in intensive systems and which will assume even greater importance in the context of future climate change.

Erosion of diversity in crop gene pools is difficult to demonstrate quantitatively, but tends to be indirectly assessed in terms of the increasing proportion of world cropland planted to high yielding, but genetically uniform, varieties. The availability of improved varieties in the field has direct consequences for the diversity of varieties used for food production: farmers who gain access to varieties that produce higher yields because they are resistant or tolerant against plant diseases and animal pests as well as to stress factors such as poor soil quality will not continue to cultivate inferior varieties. If traditional varieties are not preferable in taste or attractive for cultural reasons, it will simply not be in the farmer's interest to continue to use them. Precisely because farmers find new varieties advantageous, the number of food crop varieties has diminished throughout the world over the last 100 years; farmers discontinue cultivating traditional varieties because modern varieties are more remunerative⁴⁹.

To fight against genetic engineering and biotechnology because they make available superior varieties to the small farmer in developing countries would be the wrong way to join battle against the continuing loss of biodiversity. The availability of high yielding, resistant and tolerant varieties allowed for a substantial increase in hectare productivity: in 1991–93, India produced on average 196 million tons of grain a year, with an average yield of 1.98 tons per hectare. In 1961–63, the yield figure stood at 0.95 tons per hectare. If India would still be using the varieties of the sixties, 208 million hectares

of arable land would be needed – 116 million more hectares than were available in 1961–63. If the yield per hectare had not doubled, achieving the results recorded in 1991–93 would have required doubling the land under cultivation – a sheer impossibility without causing an ecological disaster by destroying the last remaining forests and converting them to cropland.

To slow down the continuing loss of biodiversity, the main battlefield must be the preservation of tropical forests, mangroves and other wetlands, rivers, lakes and coral reefs. The fact that – from a farmer's economic production point of view – inferior varieties are replaced by superior varieties does not at all have to result in an actual *loss* of biodiversity. Varieties that are under substitution pressure can be preserved through *in vivo* and *in vitro* strategies and hence be saved from extinction⁵⁰. If this were not done, a highly regrettable loss of biodiversity is likely to occur. As this would be the result of a lack of political will for appropriate conservation strategies, the loss of biodiversity associated with the introduction of improved varieties must be considered to be a technology-transcending risk. Improved governance and international support are necessary to limit this risk. Actually or potentially useful resources should not be lost simply because we do not know or appreciate them at present.

The benefit-risk-evaluation: (i) *Value judgments determine the weight of arguments.* There are few technological issues which have caused as much debate as genetic engineering and biotechnology. Assessing the contribution that genetic engineering can make towards fighting hunger in developing countries is not simply an academic task, where facts and figures are collected and rationally evaluated – the evaluation of the results is subject to a great variety of interests and value judgments of a multitude of stockholders. On the basis of the identical information available, some authors consider agricultural biotechnologies to be amongst the most powerful and economically promising means⁵¹, while others perceive them as a threat⁵² to development in poor countries. Once again one will have to live with the theory of constructivism which postulates, that there is no such thing like the reality, but, as the result of differing value-judgments, world views and personal experiences, differing subjectively perceived realities: individual observers regard what they are able to see or would like to see from their viewpoints as uniquely real and assess their perceptions according to their preconceived ideas and basic assumptions⁵³.

Differing realities and hence pluralism of opinion is by no means unique to genetic engineering and biotechnology, they can be observed in the context of all major social events – things, however, are more complicated, as most people confronted with the issue are not special-

ists in molecular biology or gene technology and hence have to believe what others say or the media discuss. Wild stories about the creation of monsters, scientists who lack morals and professional responsibility in order to 'play god' are more likely to be taken up by media than stories about slow but steady progress with regard to pest tolerance of rice.

As we live in a world with very heterogeneous social systems, with a multitude of value judgments and interests, we must live with deviating evaluations: on the one hand, there are obvious agricultural benefits from the use of genetic engineering and biotechnology in the development of new varieties. They result in a significant potential to increase production and productivity, preserve the environment, and improve food safety and quality.

On the other hand there are a number of economic, social and ecological risks. These risks, however, are not a consequence of the technology *per se* but of its use in a particular social setting – they are predominantly of a technology-transcending nature. Risks of such a nature are neither caused nor can they be prevented by the technology as such. In this respect, progress with genetic engineering and biotechnology is no different from any other form of technological and societal progress, which, as the German theologian Helmut Gollwitzer once said, is '...nothing other than the unremitting struggle to secure its positive aspects, learning to live with the dangers that come with it and surmounting the impairments it causes'⁵⁴. Exactly what constitutes the 'positive aspects', 'dangers' and 'impairments' in a given case is the cause of dispute. The valence of a certain effect of technological progress is very much a function of individual value judgments. Depending on how someone judges the worth of a good gained or lost through the march of technology, either the gain or the loss will bulk larger. The result of this can be utterly irrational: The large majority of people in the industrialized countries is willing to accept a technology that is contributing to global warming, kills about 50,000 persons per year and maims another 500,000 in the US alone, and is adding nothing vital to our lifestyles except the added convenience of personalized fast travel – the technology in question is the automobile. On the other hand, the release of genetically modified organisms into nature is often perceived to be too risky to be acceptable⁵⁵.

(ii) *The quality of governance determines the degree of food security.* One thing is sure: where there is war, civil strife and irresponsible, despotic political regimes there will be hunger. Food insecurity is one of the most terrible manifestations of human deprivation and is inextricably linked to every other facet of the development predicament⁵⁶. Poverty is one of the major causes of food insecurity and sustainable progress in poverty al-

leviation is critical to improved access to food⁵⁷. Poverty is linked not only to poor national economic performance but also to a political structure that renders the poor people powerless. So policy matters of a general nature, and in particular good governance⁵⁸, are of over-riding importance for food security.

The main precondition for food security is a constructive political leadership that is responsive and responsible to the people and uses peaceful means in dealing with both internal conflicts and other governments. Secondly, progress for food security requires a proper macro-economic framework. The elements which have been most important for success on the poverty front are known today⁵⁹: It is obvious that any and all efforts to reduce population growth in an ethically acceptable way constitute a critical pillar of future food security⁶⁰.

Technological innovation is no panacea to all problems of sustainable development – it is just one stone in a large and complex socio-economic mosaic. Whether the economic blessing becomes a social curse depends on the political and the broad social ramifications. A technology can only be as good as the warp and woof of a society permits. Social and ecological risks materialize because a gap opens between human scientific technical prowess and human willingness to shoulder moral and political responsibility. The risks lie in the political, economic and social milieu in which technology is applied. If and when poor small farmers have access to land, to agricultural extension services, to marketing opportunities, to working equipment and to fair terms of credit, then higher-yielding seeds adapted to the biotope and resistant to pests can be developed with the use of genetic engineering and biotechnology and bring noteworthy advantages and more food to the mass of small farmers.

(iii) *Technological progress can help in the fight for food security.* If the political setting is development-friendly, if small farmers have access to land, extension services, agricultural inputs and credit, technological improvements such as new varieties – as a result of conventional breeding or genetic engineering – can contribute substantially towards food production, rural employment and hence income development: if more can be grown on the available land, if less water and less fertilizer is needed for higher yields, if there is tolerance against major pests, fungi and adverse cropping conditions and if the nutritional quality can be increased through modified plants, small and large farmers alike will benefit. If there is more pre- and post-harvest work to be done, further stimuli for rural development will be the consequence.

The objective of genetic engineering in the context of food security is not to invent freakish hybrids but rather to sustain or increase yields of important cultivated plants, by imparting to them resistance to insect pests or

disease agents or by increasing their ability to withstand competitive pressures (or to eliminate such pressures) from, e.g. weeds. It is obvious that the realization of these possibilities is expected to be of substantial advantage to the farmers and hence to the rural communities as a whole⁶¹. If genetic engineering and biotechnology were oriented to a greater extent on the needs of the poor people in the developing countries, particularly on those of smallholders, they could become indispensable to the whole development effort.

The creation of an enabling environment for genetic engineering and biotechnology in developing countries and more publicly financed research North and South is summoned to make a bigger contribution to finding expedient solutions. The emphasis is on *public* research, because the fruits of public research can be passed on to small farmers at cost or, via government channels, even free of charge. This cannot be done with the results of research sponsored by private enterprise. When the research priorities are determined by the financial return on investment, the needs of those who have the purchasing power are likely to have high priority, whereas the needs of the poor small farmers (if and where they are different) are likely to receive a low priority. For this reason public research must be strengthened. The Consultative Group on International Agricultural Research (CGIAR) with its focus on the needs of the developing countries could play a conspicuous role in such an effort. In a number of countries, agricultural biotechnology seminars are already under way to assess research priorities and turn them into feasible programmes⁶².

More work is to be done in this respect. And there must be more intensive cooperation between the private and the public sector. Were the private sector to become more receptive to the needs of the international development effort and the international research community, funds already in short supply and valuable time could be saved. The special knowledge and know-how and the different experience – and patented intellectual property as well – that are at the disposal of the private sector but are used only selectively for lucrative markets in the industrial countries could be passed on via donated transfers or very favourable licensing terms to public research institutes in developing countries. This can be done, as a concrete example shows: Novartis has made available a gene of *Bacillus thuringiensis* to the International Rice Research Institute (IRRI). Cooperation with the private sector and other 'coalitions against famine' could be an important unconventional way to make progress faster and less expensive.

Conclusions

The developing countries are faced with the formidable task of doubling their food output over the next 25

years, and this – in contrast to how it has so often been done in the industrial countries – in ways sparing of the environment and resources. Population pressure has already begun to affect the environment in large parts of the developing world. Because of intensive land use and widespread biomass shortage, cultivated soils are being depleted of essential nutrients and organic matter. Fisheries, livestock and forestry resources are also under increasing strain. Unless countries with high population growth achieve a sustained social transformation that results in a substantially lower birth rate and unless they start regenerating their resource base, they will continue to move towards a major social and ecological disaster. In order to secure positive economic and social development possibilities in the South and the North, what is needed first and foremost are social and political reforms⁶³.

Because deficits in food security stem from the combined effects of factors such as poverty, low levels of food production, and diminishing environmental quality, the best way to deal with the challenge lies in strategies that tackle all problems comprehensively, i.e. transforming local agriculture into a sector that generates employment and income for the rural people, stimulates the nonfarm sector and the overall economy, and increases food supply. As there are no technical solutions to social and political problems, new agricultural technologies can only contribute one stone to a complex mosaic. But without yield-increasing innovations world food security will not be attainable.

The next 25 years will be decisive in many respects, environmentally, demographically and with regard to economic development. There is still time – and there is the knowledge as well as financial resources – to reverse the social and ecological trends that threaten food security in the developing world. Sustainable development and sustainable food security cannot be achieved without better governance and a new dimension of solidarity between the 'rich' and the 'poor' of this world – but also not without new technologies such as genetic engineering and biotechnology.

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