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Food, Agriculture, and the Environment Discussion Paper 2

Sociopolitical Effects of New Biotechnologies in Developing Countries

Klaus M. Leisinger

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

2020 VISION

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Foreword

This is the second paper in the Food, Agriculture, and the Environment Discussion Paper series, a product of IFPRI's 2020 Vision initiative, which seeks to develop an international consensus on how to meet future world food needs while reducing poverty and protecting the environment. In this paper, Klaus M. Leisinger of the Ciba-Geigy Foundation for Cooperation with Developing Countries examines the role that recombinant genetics and biotechnology can play in future food security.

Acknowledging that use of such technologies is controversial, Leisinger contends that to bring about the broad social and political transformation needed to overcome hunger and malnutrition, people must be willing to consider economic and technical innovations. Only two roads now exist for increasing agricultural output—expansion of land under cultivation and intensification of cultivation. As expansion possibilities dwindle, long-term increases in yields are the only viable answer. New seed varieties will play a key role in making high yields possible.

Just as the Green Revolution has been criticized on the grounds that only part of the rural population benefited from it, objections to genetically engineered seeds rest on ecological and sociopolitical grounds. Leisinger examines these concerns from the viewpoint of both the developing economies and the effects on poor farmers in developing countries and looks at solutions for making the new biotechnologies socially acceptable. Given the dimensions of the food security problems facing the world by 2020, a frank discussion of the possibilities and problems of genetically altered seed and other biotechnologies is crucial. This paper adds to that dialogue.

Per Pinstrup-Andersen
Director General

The sociopolitical ramifications of new biotechnologies in developing countries are extremely complex. Not only do they vary from country to country and from sector to sector of each country's economy, they also vary for different segments of a country's population. Generalizations therefore have scant pertinence. To circumscribe the subject more concretely, the discussion here will be limited to agriculture, with the main emphasis falling on adequate food production. This aspect is particularly timely because over the next quarter century grave problems of food security will affect hundreds of millions of people. Yet to date this prospect has not aroused much concern.

Food Security in Developing Countries

Growth rates in food production over the past three decades could give the impression that there is no cause to be concerned about an assured supply. Between 1960 and 1990 increases in food output in the developing countries consistently outstripped population growth. The aggregate picture is misleading, however, for when regional statistics are lumped together in a sum total, important—and alarming—details go unseen.

- In 26 of the 40 low-income countries listed by the World Bank and in 26 of the 50 reporting countries in the middle and higher income category, per capita food output declined between 1979 and 1991 (Table 1) (World Bank 1993, Table 4). In most African countries south of the Sahara and in the Middle East the degree of self- sufficiency in grains, the most important staples of these regions, decreased (FAO 1993, A17).
- Annual growth rates in yields per hectare of rice and wheat fell in some of the most productive areas of cultivation in Asia, mainly those where intensive agriculture has been practiced for many years. In the opinion of the Food and Agricultural Organization of the United Nations (FAO), this trend will continue well into the twenty-first century

Table 1—Food security in developing countries

Country	Average Annual Growth Rate: Population 1991-2000	Average Annual Growth Rate: Food Production Per Capita, 1979-91	Degree of Self-Sufficiency 1971	Degree of Self-Sufficiency 1990	Food Aid in Form of Grain 1979/80	Food Aid in Form of Grain 1990/91
	(percent)	(1979-81 = 100)	(percent)		(1,000 metric tons)	
Low-income countries						
Bangladesh	1.9	–0.6	97	87	1,480	1,356
Ethiopia	2.7	–1.4	99	87	111	894
Malawi	3.1	–2.7	101	94	5	181
Mozambique	2.9	–3.1	89	54	151	454
Niger	3.5	–3.4	108	93	9	79
Middle-income countries						
Dominican Republic	1.6	–2.6	64	35	120	6
Jordan	4.0	–1.2	48	9	72	481
Philippines	1.9	–1.9	94	83	95	81
Syria	3.4	–2.9	76	69	74	30

Sources: World Bank 1993; FAO 1993.

(FAO 1993). FAO anticipates that by 2010 many developing countries that were hitherto net exporters will have become net importers of agricultural products, despite continuing shortages of foreign exchange.

In a time when the world's population grows by about 250,000 people every day, the natural resources required to feed them decrease day by day. At present, about 3,000 square meters of forest and 1,000 tons of topsoil are lost every second, numerous species of flora and fauna are being wiped out, and year after year arable land shrinks by 20,000 hectares.[1] Erosion alone has so far made a billion hectares of soil unusable for agriculture (FAO 1993, 16).

Funding for international cooperation in agricultural development amounts to less in per capita real terms today than only a few years ago. Problems regarding available land, irrigation possibilities, and ecological margins that in the past could be solved with fertilizers and plant protection, and with commensurate financial outlays if conditions were relatively favorable, will in future have to be tackled under far less favorable conditions. This outlook imparts urgency to the questions of whether agricultural yields can be achieved in adverse environments with new technologies and how high they can be expected to go.

This much is certain: food security in the developing countries must not depend on surpluses from the industrialized countries or, worse, food aid. This does not make sense for a number of political, economic, and ecological reasons. The affected countries themselves must strive for food security. They must give thought to the future nutritional needs of their people and to ways and means of meeting those needs locally.

Magnitude of Nutrition Problems

According to FAO figures, nutrition in the developing countries as a whole has improved appreciably over the past 30 years. The supply of food increased from 1,950 calories per capita in the early 1960s to 2,475 calories in the early 1990s, even though population almost doubled during the same period (FAO 1993). But these lump figures conceal the fact that several regions failed notably to progress, and in some countries, poverty and with it hunger increased dramatically. Sub-Saharan Africa in particular lagged distinctly behind other developing regions. There the per capita calorie supply has declined since the early 1970s (FAO 1993, 38).

Again according to FAO (1992), the number of chronically undernourished people has also declined from 941 million in 1969-71 to 781 million in 1988-90. Yet, as these figures indicate, for multitudes of people in the developing world, a dependable food supply is already an unfulfilled dream. Where improvements have come about, they have scarcely reached the lower strata of society.

Future Food Requirements

The Population Reference Bureau projects an increase in world population from about 5.6 billion in 1994 to more than 7 billion in 2010 and almost 8.4 billion in 2025 (PRB 1994). The picture in the developing world is presented in Table 2. Of the 90 million or so children added to the earth's population each year, over 95 percent are born in the developing countries. Asia's current population growth of 58 million annually is the world's largest; Africa's yearly growth rate of 2.9 percent is the steepest.

How to provide all these additional people with a qualitatively and quantitatively adequate diet is one of the biggest challenges facing the international community. Only in rare cases is hunger a matter of an actual shortfall of food; as a rule it is a consequence of dire poverty. Production increases alone can never be the solution to nutrition problems, and measures to reduce poverty must be an integral part of every effort to combat hunger.

This said, there is no doubt that expanded production of foodstuffs is also imperative to preclude shortages. If the goal is to surmount chronic undernourishment—under a favorable scenario FAO predicts that 637 million people will still be suffering from it in 2010—or if it is to vanquish the "hidden" hunger that at present afflicts hundreds of millions of malnourished people, then by 2010, food output will have to more than double. And by the year 2050, a further 50 percent increase in demand is likely.[2]

Since the early successes of the Green Revolution (1966-82) in expanding crop yields, it has not been possible to even remotely approach increases of the order recorded then. Estimates of the food production increases that will be required are opti-

[1]On the population problem, see Leisinger and Schmitt 1994; on the environment problem, see World Resources Institute 1994 and Von Weizsäcker 1992.

[2]This figure is estimated by the Action Group on Food Security (Blake 1994).

Table 2—Population by developing regions in 1994 and projections for 2010 and 2025

Region	Population, Mid-1994	Projected Population 2010	2025
	(millions)	(millions)	
Africa	700	1,078	1,538
Latin America and the Caribbean	470	584	679
Asia, excluding Japan	3,257	4,123	4,981
Total	4,427	5,785	7,198

Source: Population Reference Bureau 1994.

mistic on two counts: they fail to consider, first, that when a developing country becomes more prosperous, its people eat more meat, and more meat in the diet means that some of the foodstuffs produced are consumed by livestock. Second, the estimates fail to consider that high past increases were achieved in part through intensive fertilization, exploitation of fossil aquifers, cultivation of land endangered by erosion, and other methods that do not meet the sustainability imperative and are therefore out of the question in future.

The Action Group on Food Security, a group of high-caliber American experts,[3] foresees the demand for grain in the developing countries by 2020 as amounting to more than three times the current U.S. harvest, which was around 310 million tons in 1990, or about one-fifth of the world total (Blake 1994, 3). Greater demand for wheat and rice will be especially pronounced, for wheat because ongoing urbanization is changing dietary habits to foods prepared from it; for rice because Asia has to cope with the largest population growth. The developing countries, especially those in Asia, produce and consume more than 95 percent of the global rice output. The demand for rice in these countries is expected to rise from about 350 million tons today to double that amount by 2025 (Blake 1994), or more than two-and-a-half times what China (by far the world's leading rice producer) grew in 1990.

In addition to higher demand for wheat, rice, and other cereal grains, substantial increases in the demand for all other foodstuffs are anticipated, most notably potatoes, cassava, and pulses. These constitute about 40 percent of the food consumed in the developing countries.

Building Blocks for Increasing Food Security in Developing Countries

General Considerations

Because hunger and undernourishment are first and foremost a consequence of flawed or inadequate social and economic development, they will require broad social and political transformation to overcome them lastingly. To this end people must first be mobilized to amend static traditional modes of thinking and behaving; adoption of economic and technical innovations must follow. Since food shortages in the Third World stem from the interplay of poverty, inequity, low yields, and declining environmental quality, the most promising strategies will be those that address all four problems simultaneously. This approach can be described as the comprehensive and sustained improvement of economic capability and of the conditions shaping rural society: in other words, advancement of those who live on and off the land in rural areas, with particular attention to the female population. In view of the obvious connection between high population growth and diminishing food security it would also be desirable to augment rural development strategies with components known to lead to lower birth rates (Leisinger and Schmitt 1994).

In principle, there are two roads toward maintaining agricultural output in general and food production in particular at levels that can satisfy demand: either expand land under cultivation or intensify cultivation (increase productivity per unit).

[3]The Action Group on Food Security is made up of Robert O. Blake, David E. Bell, Jessica Tuchman Mathews, Robert McNamara, M. Peter McPherson, and Montague Yudelman.

Although unevenly distributed, considerable reserves still exist in the developing countries for expanding agricultural land. These reserves are found mainly in Latin America and Sub-Saharan Africa (FAO 1993). The Asian countries, especially the most densely populated, have only slight expansion possibilities.

In part because of rapidly deteriorating environmental quality and the dwindling availability of water resources, efforts to intensify cultivation are much more critical now than 20 years ago. Although it is very difficult to quantify the direct influence of soil erosion, salinization, or loss of humus on food production, there can be no doubt that henceforth long-term increases through intensified cultivation will be viable only if they do not impair the environment.

Both roads—expansion and intensification—show clear benefits and risks. On the risk side, expansion of land under cultivation often proves costly, for example, when it entails building artificial irrigation systems or exploiting mountainous terrain. It is often ecologically risky as well, as, for example, when forests (especially tropical rain forests) are cleared, or marginal soil suitable for extensive livestock farming but not for intensive cultivation is put under tillage. A further potential risk lies in the overuse of farmland obtained by burn-off. In such cases, irreversible damage—in the extreme, desertification—may come about through erosion and soil impoverishment (Leisinger and Schmitt 1992).

When cultivation is intensified with the aid of fertilizers, new seed varieties, controlled irrigation, integrated plant protection, mechanization, and intercropping, the benefits of short-term yield increases also have to be set against the costs and ecological risks. Excessive use of fertilizers and plant protection agents (such as pesticides and fungicides) and overintensive mechanization are not only costly (as is known from experiences in many industrial countries), they have unwanted effects on the environment, too.

On balance, the potential for increasing yields through intensification and modernization, carried out in conformity with the ecosystem, outweighs the alternative of expanding acreage. Grain harvests per hectare in the Third World are only one-half as high as in Europe; in Sub-Saharan Africa they are only one-fifth as high (FAO 1990)—and similar differences are found in other food crops. Stepping up tillage intensity and securing crop yields depend on a variety of input factors that have to be used selectively and with different emphases from case to case: labor, advice and training, irrigation, fertilizer, seed, plant protection, and mechanization. Seed varieties, whether bred in the conventional way or by recombinant genetics, are thus an essential ingredient, although no more important in relation to the total package than, say, the oil in a large gear unit that is in turn part of a larger engine.

Still, any discussion of the sociopolitical effects of biotechnology in the developing countries must necessarily include a closer look at the role that seeds play.

The Role of Seeds in Developing Countries' Agriculture

The challenges to food production posed by a rapidly growing world population and increasingly scarce natural resources are immense. This explains why such great hopes are placed in new seed varieties that purport to make consistent high yields possible. In recent years these hopes have risen even higher, thanks to the promise of biotechnology and gene technology. At the time of the Green Revolution, seeds played a key role in relation to the other components: fertilizer, irrigation, plant protection and selective mechanization.[4] In the 1950s and 1960s, against a backdrop of high population growth and attendant fears of unimaginable famines (especially in Asia), scientists associated with international (public) agricultural research centers developed seed varieties incorporating properties not contained in the traditional varieties of the respective growing regions. They were distinguished by

- short vegetation periods, making possible more frequent harvesting;
- a pronounced capacity to transmute high fertilizer inputs into high crop yields (rather than into stem and leaf growth); and
- relative insusceptibility to fluctuations in daylight.

Unwanted and unexpected side effects of the new varieties and the experience gained with their use resulted as time went on in significant changes in the concept and substance of the Green Revolution. In particular, by setting—and largely attaining—two additional research objectives, ecological shortcomings were reduced and "smallholder friendli-

[4]The role of new varieties in the Green Revolution is extensively discussed in Leisinger 1984, 357-381, and Leisinger 1987.

ness" was improved: resistance to or tolerance of plant diseases and animal pests, and tolerance to irregular irrigation, poor soils, and other stress factors.

By and large, it is undisputed that under otherwise unchanged conditions Asia could not have escaped widespread famine without the new seed varieties. Although increased yields were the original and central research goal, and this was achieved, the sociopolitical impact of the Green Revolution was and still is highly controversial. At the heart of the unease lies the charge that its benefits have been distributed inequitably. At least in the initial phase of implementation of the Green Revolution, only a small segment of farmers (and even fewer women) profited from the higher yields. Deplorable as this is, it was hardly surprising in societies run along feudal and patriarchal lines.

Today, genetically engineered seeds are in their turn evoking objections, chiefly on ecological and sociopolitical grounds and mostly from the same critical circles that argued against the Green Revolution.

The Role of Recombinant Genetics and Biotechnology in Food Security in Developing Countries

The relevant research goals of genetic engineering and biotechnology[5] focus on the development of plant varieties that provide reliable high yields at the same or lower tillage costs by breeding in qualities such as resistance to or tolerance of plant diseases (fungi, bacteria, and viruses), animal pests (insects, mites, and nematodes) and stress factors (climatic variation or aridity, for example). An equally important goal is the transfer of genes with nitrogen-fixing capacity to grain. The realization of these aims could bring tremendous benefits.

Potential Benefits

The spectrum of anticipated benefits from the application of recombinant genetics and biotechnology in agriculture ranges from diagnostic aids, for detecting plant diseases, for example, 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 agriculture or forestry (OECD 1990). Properties such as adaptability to specific local climatic conditions, soil quality, and crop rotation practices are sought and transferred. Moreover, cultivation of such plants fits into the concept of sustainable agriculture, that is, they should not abet erosion or leaching of the soil. To complete the packet of desiderata, a variety should also afford dependable or even high yields at low production costs.

Conventional seed-breeding programs have to proceed step-by-small-step toward a single target, and they consume a lot of time. 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 perceptibly greater efficiency. For farmers both large and small, this is potentially important.[6]

The development of new plant protection techniques with the aid of gene technology and biotechnology (primarily with *Bacillus thuringiensis* as vector) has already led to noteworthy progress regarding the environment and lessened dependence on chemical weapons (Commandeur and Komen 1993). Other efforts aimed at using the new technologies in animal husbandry and pisciculture are currently in progress (Walgate 1990, Bijan 1992).

In China especially,[7] where arable land is becoming scarce and the use of fertilizers and plant protection agents is nearing the ecologically toler-

[5]In this paper *gene* (recombinant DNA) *technology* means "the calculated modification of hereditary genetic material in living organisms by the addition, removal, or exchange of one or more genes, resulting in the passing on of this altered genetic information to descendants" (Dohmen 1988, 5). *Biotechnology* is "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 as well as parts thereof" (Dellweg 1987, 1). Biotechnology therefore deals with the utilization of biological processes in technical operations and industrial production. Gene technology is a means to an end, inasmuch as it allows the properties of microorganisms to be modified in such a way that a desired effect is brought about through biological processes. *Three different generations* of biotechnology can be distinguished. In the first, bacteria or yeast, for example, were used in making cheese or beer. In the second, microorganisms were used to produce antibiotics, and molecular biology was further developed. In the third generation, finally, it has become possible to alter the genetic material of an individual cell directly. The combination of all three generations confers great potential power on biotechnology.

[6]See, for example, Bunders 1990 and Miflin 1992, 153-163.

[7]See, for example, Chen and Gu 1993.

able limit, marked advances in food security have been made with the help of the new technologies (Neue Zürcher Zeitung 1993). In contrast to just a few years ago, the talk today is of a breakthrough in the field (Wirtschaftswoche 1994). An international conference of experts convened by the World Bank, United Nations Development Programme (UNDP), and FAO concluded that a solution to the problem of securing world food supplies while preserving the environment is today well-nigh inconceivable without recombinant genetics and biotechnology (CGIAR 1992; Moffat 1992).

A steadily accruing number of case studies give evidence that the two technologies, by providing new products and ways of proceeding, can indeed bring the research community closer to solving agricultural, medical, and other problems—problems either not solvable with traditional technologies or only with a far greater expenditure of time (Langenbach 1992; Walker and Gingold 1992).

Potential Risks

Yet, in spite of the widely uncontested favorable potential of genetic engineering and biotechnology, the climate in the industrial countries remains skeptical, even to the point of rejection.[8] Possible risks must always be taken seriously, of course, and it is in everyone's ultimate interest to make sure that a risk-benefit assessment based on a broad—but informed—social consensus has been undertaken before decisions are made.

The current public debate on the new technologies often suffers, however, from a lack of specialized knowledge as well as from a failure to differentiate between the risks *inherent* in a technology and those that *transcend* it.

Technology-inherent risks arise when a technical action plan is designed to improve an existing situation, but then during the research or implementation phase unforeseeable problems and unwanted side effects crop up—undesirable mutations, for instance. Risks of this sort must be distinguished from those hazards that transcend technology, those that emanate from its mode of application in certain circumstances. Such risks might materialize when proposed and technologically feasible improvements founder on social, economic, or cultural obstacles. But to "throw the baby out with the bath" on account of technology-transcending risks—that is, to flatly demonize a technology instead of giving thought to how external conditions can be altered for the better—is, short-sighted in view of the dimensions of the problems to be dealt with in the developing countries.

Because sociopolitical effects clearly lie in the sphere of technology-transcending risks, only that aspect will be considered here.[9]

Technology-Transcending Risks

To repeat, technology-transcending risks are not caused by a technology as such and therefore cannot be prevented by changing the technology. In the developing countries these risks spring from both the course the global economy is taking and country-specific configurations. The most critical fears in this context have to do with sociopolitical concerns. These include

- *Aggravation of the prosperity gap* between North and South through possible substitution of tropical agricultural exports with genetically engineered products and exploitation of indigenous genetic resources without appropriate compensation.
- *Increased inequalities in the distribution of income and wealth* 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 especially severe.

In light of the magnitude of poverty-related problems throughout most of the developing world and the dwindling competitiveness of many poor countries (World Bank 1994), serious heed must be paid to these concerns.

Economic Risks for Developing Countries Contingent on International Trade Relations. With the new technologies it will become possible to produce in the laboratory or in temperate zones

[8]For critical views of gene technology and biotechnology in relation to the Third World, see Altner et al. 1990; Studier 1991; Walgate 1990; Hobbelink 1991; and Fowler and Mooney 1990.
[9]For a discussion of technology-inherent risks, see Leisinger 1991.

goods that have hitherto been grown exclusively in the tropics. This prospect gives rise to concerns that the resultant competitive edge could drive tropical products off the market. For example, the production of vanilla flavoring in the laboratory using biotechnological techniques could threaten the existence of 70,000 small farmers in Madagascar alone (Wambui 1989).

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 displacement of smallholder production in poor West African countries by plantation-scale farming in the newly industrialized economies of Asia (Zweifel 1990, 22-25). A similar outcome might occur 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 broadly supplant sugarcane (Sasson 1988, 269-276; Jacobson, Jamison, and Rothman 1986; Hobbelink 1989).

From a more holistic political perspective, it does not make sense to uncouple the North from the agricultural raw materials of the South. It would plunge a large part of humanity into dire misery (Junne 1992). It is incompatible with a peaceful future if life goes on getting better for a relatively small segment of the world's already affluent population, while the already skimpy living standard of billions of others stagnates or shrivels.

From the perspective of economic rationality, however, superior goods can be expected to conquer the market. Copper serves 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 price. The substitution will take place even though crumbling copper prices may lead in countries like Zambia or Chile to mass unemployment, with all the human distress it brings.

According to the same market "logic," if "lab vanilla" or "lab sugar" should prove cheaper or healthier than the real thing or exhibit some other edge 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 endeavor to *diversify* the production structure in vulnerable countries and not in countermarket intervention. Here a bigger allocation of funds from the international development establishment to the support of diversification efforts is urgently required. A comprehensive risk-benefit analysis of the substitution of agricultural export commodities from the tropics would also have to examine alternative uses of the land left fallow. It could be used to increase local food production, or perhaps for an ecologically favorable use such as afforestation.

Another matter attracting critical attention turns on who shall have power of disposition over the genetic resources of the Third World. The critics fear that multinational firms or even government research institutes could gain control of the genes of plants native to the Third World free of charge, as it were, and use them for developing and producing superior varieties that would then be sold back to the Third World at high prices. Suppose a multinational seeds company discovered a property in an Ethiopian barley strain that makes it resistant to certain plant diseases. Suppose the company genetically transferred this property to a wheat variety that would afterwards be commercialized in Ethiopia. Obviously, Ethiopian agriculture contributed something, but without the research and development work of the seeds firm the "something" would not have been useful outside Ethiopia or in foodgrains other than the native barley.

A step in the direction of satisfying both sides' claims to compensation would be to work out binding national and international regulations. These urgently needed regulations should be designed to keep open access to the genetic riches of the Third World and at the same time to enable the people who have helped to build this wealth through decades of indigenous selection to profit equitably from the commercial returns on gene exports. The 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. It would not only be unjust and unfair to withhold compensation but also not in the enlightened self-interest of the business or research communities to help themselves to the valuable resources of impoverished people without extending them a quid pro quo.

Although a political decision in favor of compensation has been made, the technical details of how it should be handled are still unclear. What especially needs unequivocal regulation is who should compensate whom and how to ensure that remuneration—accruing, for example, from license payments by business firms—does not end up in the pockets of those who, because they are politically influential, have ready access to the pot, while those who the remuneration is meant to help end up empty-handed.

The difficulty of finding a judicious means of compensation should not serve as an excuse for delaying tactics by the beneficiaries of the genetic resources of the developing countries. One could imagine, for instance, that money designated for compensation might be funneled into development cooperation.

What happens if genetically altered, patentable seed gains such a dominant position of superiority over traditional seed in major Third World crops that, dictated by overall considerations of what will foster development best, its broad-scale use has to be recommended? Should this happen, publicly endowed research in the seeds sector should be increased but, to save time, socially compatible ways and means of transferring technology must be sought.

Risks Rooted in Social Inequalities. Living on the land largely continues to mean being poor, underemployed, and uneducated (in the sense of lacking formal schooling) (Glewwe 1990). So economic and social development, at least as measured by a reduction in the incidence of rock-bottom poverty, cannot take place on a broad and lasting basis without adequate rural and agricultural development.

The widespread misunderstanding persists that development is equivalent to "industrialization." As a consequence, too low a priority is placed on promoting rural and agricultural development, and therefore such development is underfunded.[10] Neglect of extension services for poor farmers, insufficient provision of working implements, and a skewed price policy for agricultural products are the most devastating outcomes of this attitude. At the same time ecological impediments to development are gaining steadily in significance (Leisinger and Schmitt 1992). These deficits all act as hindrances to sustained and socially balanced rural development.

From country to country various other factors further complicate the picture. Wherever unjust social and political power structures determine the distribution of wealth and income and access to the means of production, and so deprive people of the possibility of feeding themselves, hunger is the logical result (Drèze and Sen 1993).

The use of genetically modified seeds adapted to the specific conditions of difficult biotopes can no doubt provide real incentive to agricultural development. But in a socially and politically defective setting, it can hardly bring about improvements in the conditions of the poor. Where land ownership and tenancy systems and access to extension services, credit, marketing channels, and new technologies are governed by a sociopolitical power structure that favors only a small minority, technological progress cannot possibly be neutral in impact. The answers to the questions of who profits and how much from the advent of new technologies and to what extent hunger can be overcome depend decisively on the social and political systems in place (Drèze and Sen 1993). Disease-resistant cassava, protein-enriched millet, or stress-tolerant rice can contribute to greater food security and prosperity only if these and comparable social advances come within the reach of the broad mass of the population, male and female.

In short, the developmental impact of recombinant genetics and biotechnology is only as good as the sociopolitical soil in which they are planted. Any technical advance, progress in genetics included, can only benefit those who understand the technology and are able to apply it. Every restriction on access, whether lack of schooling or feudal power structures, can aggravate income discrepancies—pronouncedly so when the technology is very potent. Unless social reforms are introduced and reinforced with supportive measures that also enable the middle and lower strata of society to gain their share step by step, technological innovations actually work against the development goal of breaking down inequalities.

Different Countries, Different Effects

As a collective term, "developing countries" is no longer appropriate in discussions of the social and economic effects of the sophisticated new technologies. It is too sweeping: it takes in countries so different economically, socially, and culturally, and in their capacity to absorb the fruits of research and technology, that generalizations are defied.

[10]With few exceptions (Singapore, for example), industrialization is very difficult, if not impossible, without a self-sufficient, value-creating domestic agricultural economy (see Egger 1993).

This is why recent studies differentiate more carefully, categorizing the developing countries on the basis of their research capacity and their institutional arrangements for stimulating biotechnological development. Further criteria include the share of agriculture in overall exports, whether a country is a net exporter or importer of agricultural products, and how agriculture is structured (the relative importance of large-scale farming versus smallholders) (Commandeur and von Roozendaal 1993, 49-52).

In their analysis of the effects on agriculture of biotechnology in the developing countries, Commandeur and von Roozendaal (1993, 7) come to the following conclusions:

- Countries that are net agricultural exporters but have weak technological potential will not be in a position to avail themselves of biotechnology. Because these countries depend chiefly on exports of their products they will be affected more negatively than other countries.

- Countries that have weak technological potential but are net importers of food could profit short-term from lower prices on the world market. In the long term, however, the trend toward use of biotechnology could adversely affect domestic food production.

- Countries with strong technological potential and high food imports could benefit most from biotechnology, since it could help them orient their economies toward self-sufficiency.

- Countries with strong technological potential and high food exports could benefit from biotechnology by using it to diversify their exports.

- A country's vulnerability to the new technologies is greatest where a low technological potential coincides with net exports of potentially substitutable agricultural products. This constellation exists in most of the countries of Sub-Saharan Africa and the Caribbean.

Yet the final postulate also needs to be qualified. Today the sort of economic, social, and environmental policies best suited to prepare the way for a higher quality of life for a country's population are known (Nohlen and Nuscheler 1993). It is becoming increasingly clear that governance is of paramount importance here. According to the World Bank (1992), governance, the art of political leadership, denotes the manner in which governments and their agencies exercise power in conducting state affairs and in dealing with the economic, social, and ecological resources entrusted to them. Human and humane development presupposes a multitude of national and international actions. Technological innovation is just one stone in a large and complex mosaic. When small farmers have access to land, to marketing opportunities, to working equipment, and to fair terms of credit, then the technological component can engender positive sociopolitical effects and thus serve to enhance the quality of life of the rural population.

Any assessment of the circumstances shaping development and technology policies necessarily rests on individual and collective value judgments and on narrower or broader definitions. The social sciences have never been and never will be "disinterested" (Myrdal 1968, 32)—and the same can be said for technology sciences. In societies with a plurality of interests and viewpoints, divergent opinions are normal and should be treated as such (Watzlawick 1991).

Moreover, when benefits and risks are weighed, the emphases placed always depend on the level of affluence of those doing the weighing. To people in a poor country, the benefits of gene technology may appear greater than they do to people in a rich country, who merely stand to gain more prosperity from it. But in Sub-Saharan Africa, especially in the Sahel Zone, for example, genetically improved seed varieties can mean the difference between a reasonable standard of living and chronic starvation.

Preconditions for Making the New Biotechnologies Socially Compatible

Social Reforms

There are no technical solutions to political and social problems. Therefore, the modernization of agriculture in the Third World, whether by means of biotechnology or otherwise, will prove socially most consonant if provision is made from the outset to ensure that all strata of society have reasonable chances of benefiting. In most of the developing countries, social reforms such as land reform or special support programs for small farmers (male and female) are therefore an indispensable part of the drive to modernize. Where modernization moves ahead too quickly and without adequate social preparation, and where the institutional framework is not aligned with progress, increased yields cannot be apportioned in a sensible way.

The same applies to the use of the new biotechnologies: the principle of modernization has to go hand in hand with the principle of social balance. Given the salient importance of recombinant genetics and biotechnology for agricultural productivity and food security in the developing countries, however, it is even more important that they be made accessible.

Two mutually complementary possibilities can ease the way: more publicly endowed research in the interest of the developing countries and increased cooperation with the private sector.

Public Research

Basic research aside, at present private industry accounts for most of the research being done in the field of genetic technology. Whatever results from such research is thus patentable for commercial purposes, and consequently often too high-priced for the poor countries. While one could envision special agreements being worked out for life-saving medicines—an AIDS vaccine, for example—or for seed varieties vital to survival, it would be unrealistic to expect private enterprise to forgo market-oriented pricing of the fruits of its research for charitable reasons. A clear-eyed scrutiny of numerous companies' research objectives leads one to conclude that, with a view to optimizing the funds ventured in research, they are concentrating on problem solutions that can be marketed primarily in the rich industrial nations, because only these countries have the buying power needed to bring the aimed-for return on investment.

That is the why more public research is called for, especially in the developing countries. The results forthcoming from this research can be made available at cost-oriented prices, subsidized, or even gratis (Von Wijk, Cohen, and Komen 1993). In this connection, the research institutes of the Consultative Group on International Agricultural Research (CGIAR) are attempting to increase the productivity of diverse tropical systems of cultivation on a sustained basis and without impairing the environment. Although a number of countries do have impressive national programs in biotechnology research, a great deal more still needs to be invested.

If the gap between North and South is not to widen endlessly and the needs of the poor people in the poor countries are not to be simply forgotten, then public research geared to the specific problems of these people must be built up in the Third World and supported by international funding. Without a substantial reinforcement of international agricultural research, more and more developing countries with rapidly growing populations could face serious food shortfalls in the next 10 years (Blake 1994).

Tragically, the present trend points precisely in this direction. A spreading swath of budget cuts in most of the industrial countries frequently affects national and international contributions to public research, including the CGIAR program. Over the past two years support for CGIAR's core program decreased by 21 percent in real terms (Blake 1994, 10). With a reduction of 31 percent in five years, the falloff for the Group's four original research centers—the International Rice Research Institute (IRRI), Centro International de Majoramiento de Maiz y Trigo (CIMMYT), International Institute of Tropical Agriculture (IITA), and Centro Internacional de Agricultura Tropical (CIAT)—was even more drastic. The result: research centers on whose success or failure the food security of entire continents could hinge are having to curtail programs and let staff go.

Expanded research does not signify only expanded scientific research. To an ever greater extent, it also means research in development policy and sociology aimed at improving the social parameters for technology transfers, thus paring the social transaction costs.

Finally, more community participation is essential to establishing research priorities. Research policy is still too much a matter of offers from "on high" rather than the result of an empirical analysis of what is needed "down below." Systematic use of the instrument of participatory needs assessment would likely lead to a redirection of research priorities toward other food crops, such as yams, manioc or cassava, and millet. It might also add to knowledge of what properties are most desirable in traditionally cultivated crops.

Increased Collaboration with the Private Sector

Humane advancement of the present generation and future generations depends on finding solutions to the problems discussed in this paper. In most cases this will necessitate trying new approaches and forming new, broader coalitions. Traditional institutional barriers must be surmounted.

Many development projects and programs suffer from problems that could be better solved or even avoided by applying the knowledge available in private enterprise. Many development organizations are hobbled by hazy guidelines, overlapping areas of responsibility, a compulsory outflow of funds, and a tendency to reinvent the wheel, as it were. These are all drags on effective performance and an optimum cost-benefit relationship. A growing body of evidence indicates that the management quality and efficiency of humanitarian institutions depend to a considerable degree on methods and practices that bear a close resemblance to those common in business and industry (Drucker 1990). Managerial and operational techniques that have proved their worth in private enterprise, including operational guidelines, job descriptions, personnel performance appraisals, and financial control systems, could contribute to more rational operations and efficiency and hence to greater effectiveness in the realm of development cooperation.

But the private sector should also feed the summons to teamwork. 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. Moreover, the efficiency of international collaboration and of agricultural research would be boosted. The private sector has special knowledge and experience, as well as patented intellectual property at its disposal. These assets, often used only selectively for lucrative markets in the industrial countries, could be passed on via donated transfers or favorable licensing terms to public research institutes in developing countries. For example, Ciba has made a gene of *Bacillus thuringiensis* available to the International Rice Research Institute.

Outlook: From Knowledge to Wisdom

Since the beginning of the 1990s per capita income has risen slowly or even declined in most western industrial countries. Nevertheless, the prosperity gap between the industrial countries and the majority of Eastern European and developing countries has grown wider (Stiftung Entwicklung und Frieden 1993). The richest 20 percent of the world's population gets 82.7 percent of the world's total income—and the poorest 20 percent gets a mere 1.4 percent (UNDP 1992).

Many signs indicate that this sharpening of social contrasts, together with the ongoing destruction of the environment, represents an acute danger to a peaceful future. If the poor majority of the people on earth have no prospect of incomes that enable them to satisfy their basic needs, armed civil conflicts incited by deprivation will increase in frequency as well as violent international confrontations actuated by the scramble for scarce resources. This sequel will lead to greater habitat destruction, poverty, and worldwide migrations. Peace and prosperity for just a few cannot be maintained so long as the great mass of humanity continues to live with violence and misery.

No simple cause-and-effect nexus underlies the complex problems presented by the challenge of development. Rather, because the problems issue from extremely intricate interdependencies in systems, generally applicable approaches to resolving them do not exist (Drèze and Sen 1993). But certain key components can be discussed, and these will be of prime importance. First, a greater measure of common endeavor among all the members of society, and, second, governance, as defined earlier. These can be singled out as the most important prerequisites for success in fostering development (Hösle and Leisinger 1995).

The immense problems burdening people in the impoverished regions of the planet did not come about overnight, nor are there any short-term solutions—certainly not from the North alone and with technical means alone. The socially compatible employment of recombinant genetics and biotechnology can help to improve the quality of life of the poor in developing countries, provided an environment conducive to development is present. In many respects the conclusions set forth by the Club of Rome in its last report apply to this discussion:

"Living as we do at the onset of the first global revolution, on a small planet which we seem hell-bent to destroy, beset with conflicts, in an ideological and political vacuum, faced with problems of global dimensions which the fading nation states are impotent to solve, with immense scientific and technological possibilities for the improvement of the human condition, rich in knowledge but poor in wisdom, we search for the keys to survival and sustainability (Club of Rome 1992, 129)."

Sustainable development cannot be achieved without a new dimension of solidarity with the impoverished masses in the Third World, but also, not without new technologies such as genetic engineering and biotechnology.

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