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The Impact of Modern Biotechnology on Developing Countries: Some Emerging Issues

by

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ABSTRACT

The main impact of biotechnology on agricultural production will not be realized for years to come. However, there are already concerns that biotechnology may widen the gap not only between rich and poor nations, but also between the rich and poor countries in the Third World. In this paper we examine the development of biotechnology as it relates to the changing institutional structure of research, to technology transfer to Third World, and to trade between developed and developing countries. We suggest steps that can be taken to lesson the potentially negative distributional impact of biotechnology.

The conclusions and recommendations are summarized as follows. The change in the interpretation of the U. S. patent law makes it possible for firms and research institutions, whether public or private, to capture a major share of the profits from investment in biotechnology research. The private sector is already playing a major role in the development of new biotechnologies. There is concern that a division of labor is emerging between public and private sector. with the former concentrating on basic research and the latter on technology development. This in turn could limit Third World access to biotechnologies particularly for those crops and problem areas where there was little potential for private profit. Greater support must be found for public sector research conducted in advanced-country laboratories on problems that are important to the Third World. At the same time, it will be necessary to strengthen public-sector applied research capacity in developing countries in order to facilitate biotechnology transfer.

Many developing countries are afraid that advances in biotechnology will result in a loss of their export markets. Biotechnology enhances the capacity of industrial countries to create substitutes for their imports. The protectionist policies of the developed countries create further incentives for scientists to search for substitutes. In the current GATT negotiations, efforts are being made to encourage trade liberalization in agriculture. If this were coupled with strengthened applied research and technology transfer capacity in the developing countries, the potentially negative distributional impact of biotechnology could be greatly reduced.

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INTRODUCTION

Productivity growth in both agriculture and industry in the post-World War II period was dependent in large measure on advances in the petrochemical and transportation industries. With the maturing of these industries, the potentials for further growth in productivity from these sources have diminished. Furthermore, the rapid rise in energy consumption and heavy dependency on fossil fuels has led to growing concerns about resource depletion and the pollution of the environment. Biotechnology and microelectronics (or information technology) are the new "core technologies" which offer prospects for further productivity growth, saving raw materials, reducing energy consumption, and lessening pollution problems (Van Tulder and Junne, 1988). Over time, these two technologies are becoming increasingly interlinked. Biotechnology is knowledge-intensive and advances in biotechnology require considerable scientific manpower and investment. The challenge for the developing countries is to generate the capacity to utilize this knowledge and adapt biotechnologies to suit local conditions.

This paper examines some of the emerging issues There are a number of questions to be considered: (1) Will the introduction of biotechnology result in a continued rapid growth in agricultural productivity? (2) To what degree will

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the development of the new technology be based on public as opposed to private investments, and what are the implications? (3) How will technology transfer take place between and among developed and developing countries? and finally, (4) What will be the impact of these technologies on trade between developed and developing countries? The main impact of biotechnology will not be realized for years to come. Any speculation about future impacts must be judged with a good deal of caution. Despite the popularity of terms such as green revolution, and biorevolution, technological change is evolutionary, and assessing the socioeconomic impact of technological change should be a continuous process.

BIOTECHNOLOGY AND PRODUCTIVITY

Prior to the turn of the century, sustained growth rates in agricultural production seldom exceeded one percent (Hayami and Ruttan, 1985). With the advent of industrialization, potentials for growth in agricultural output shifted upward to the range of 1.5 to 2.5 percent.

Following World War II, advances in medicine, health care, and nutrition greatly reduced mortality, leading to a population explosion in the developing world. Population growth rates of two to three percent have become normal. The annual increase in food demand in developing countries now ranges from two to four percent.

This unprecedented growth in demand has been met over the past several decades by opening up new land for cultivation, by expanding irrigated area, and by increasing yield per hectare of the major cereal grain crops. Improvements in yield per hectare of the order of two to three percent annually were made possible through rapid increases in the use of purchased inputs, particularly manufactured chemical fertilizers. Despite the rapid spread of green revolution technology, not all of the developing world achieved these growth rates. Some countries, particularly several in Africa, have become increasingly more dependent on food imports, and agricultural production per capita has even declined in some.

The situation that the world now faces with respect to sustained growth in agricultural production is aptly described by Ruttan (1987) who notes that we are approaching the end of a remarkable transition in agriculture, and that by the end of this century agricultural output will have to expand almost entirely from more intensive cultivation in areas already being used for agricultural production. In the developing countries, the degree to which this growth will come from expanded use of existing technologies or application of new biotechnologies is not at all clear.

Ruttan (1986) argues that developing-country gains in crop and animal productivity over the next several decades will continue to come from conventional breeding, from more effective management of water resources, and from higher levels of plant nutrients. Herdt (1988) indicates that developing country farmers, at least in Mexico and the Philippines, are "using up" the profitable unexploited yield potential created by research on wheat and rice as fast or faster than that potential is being created. Unexploited potential is falling. Jain (1986) has examined the record of wheat, rice, barley, and sorghum yields during this century and noted that the harvest index has risen from 20-30 to 50 percent. That is to say, yield gains have been made almost exclusively by redistributing the dry matter between the vegetative and reproductive parts of the plant. A yield plateau now appears to have been reached. Evidence based on long-term experiments conducted by the International Rice Research Institute supports this argument. Since the release of the first of the high-yielding varieties, IR8, there has been no yield increase (in fact a slight decline) in uniform trials conducted at four locations in the Philippines (De Datta, Gomez, and Descalsota, 1988). Evans (1987), on the other hand, envisages many possible avenues for greater yield potential in wheat. He refers, however, to as yet to be developed achievements such as enhanced photosynthesis, modified timing of the reproductive cycle, and growth regulation. These yield gains are expected to be achieved largely through biotechnology research.

There are at least four ways in which biotechnology is likely to impact significantly on agriculture:

(1) through the substitution of one crop for another, or alternatively a synthetic for an agricultural commodity.

(2) through the adaption of existing crops to different environments.

(3) through the shift in marketed surplus (the proportion of agricultural output in excess of that needed for home consumption) to farmers, to regions, and to nations with high productivity or with protectionist policies.

(4) through the substitution of renewable (agricultural) for non-renewable (fossil fuel) energy sources.

The emphasis in this paper is on the first three changes. All of the above four shifts in agricultural production have been underway to a greater or lesser extent even before the advent of biotechnology. However, the growing dependence on science-based agriculture and associated advances in biotechnology and information technology are likely to speed up the process.

The list of areas of biotechnology research is long, and includes pest and pathogen resistance, quality enhancement, manipulation of growth regulators, improved tolerance to stresses (including temperature, moisture, and soil conditions such as salinity), enhancement of photosynthetic activity, achievement of nitrogen fixation in non-leguminous crops. Thus, there is the prospect of lowering production costs, reducing dependency on energy from non-renewable resources, increasing productivity of agriculture in hitherto disadvantaged environments, and mitigating environmental and pollution problems. Major advances in almost any of these areas would seem to offer significant benefits for Third World countries. All of this sounds too good to be true, and indeed there is a major gap between the potential and the reality.

The reality as stated by Herdt (1988), is that biotechnology applications must be specifically designed for target organisms, and may require intensive research to perfect the many separate techniques required by a process. Furthermore, technology once perfected must be adapted to local conditions. This has been a major obstacle in traditional technology dissemination. However, biotechnology could facilitate this process. For example, tissue culture is already being widely used, even in developing countries, to speed up the process of screening large numbers of cultivars for desired agronomic traits.

Agricultural applications of biotechnology will be more rapid in those crops where cloning is possible, where genetically manipulated organisms or enzymes can be used to produce or displace agricultural products, and in animal applications, where there has been considerably more research to date, some of it a spillover from research in human health. Progress will be slower in the major cereal and feed grains, which are of vital importance to the Third World. This is because in these monocots much work needs to be done in gene mapping and perfection of recombinant DNA techniques before important genes can be identified and transferred.

In summary, biotechnology will vastly expand the range of choices in research and offers the prospect for advances in a wide range of areas which would be of benefit to society. However, with limited research budgets, choices must be made. Which line of research to pursue, which gene to transfer involves both technical and socio-economic considerations. The establishment of research priorities will determine in the long run who benefits. In the next two sections we examine the changing institutional structure of research in developed countries, and the impact this is likely to have on research priorities and the availability of new knowledge and technologies to developing country farmers.

PUBLIC AND PRIVATE SECTOR RESEARCH

The emergence of biotechnology has been accompanied by a change in the institutional structure of agricultural research in the developed countries. We now appear to be in the midst of a change in the division of labor between public and private sector research (Buttel, 1986). This could have a major impact on the kinds of technologies that are developed and the way in which benefits are shared.

Historically, agriculture has relied on public investment in both basic and applied research because the private sector could not capture the benefits from biological technologies such as improved seeds and cultural practices. The highly successful public sector research system that existed in the United States for almost a century is described by Ruttan (1982). Beginning in the 1970s, advances in the biological sciences have led to a major change in laws governing intellectual property rights and in the institutional structure of research in both the public and private sector.

In the public sector, as a result of advances in molecular and cell biology, an important new family of basic science disciplines has become an integral part of agricultural research. It is increasingly difficult to argue that basic research is "neutral" or unbiased and that most scientific discoveries are serendipitous, obviating the need to set priorities for basic science research. However, even in basic science the priorities of developed and developing countries differ, with, for example, the developed countries giving higher priority to health and environmental quality, and the developing countries giving higher priority to production and distribution of food. However, present capabilities for basic research in biotechnologies are concentrated in a few developed countries (i.e., the United States, Japan, Australia and several European Countries).

Turning now to the private sector, a distinguishing feature of many of the new biotechnologies is that the processes and or products are often patentable. The US was signatory to the 1961 International Convention for the Protection of New Varieties of Plants. This led to the US Plant Variety Protection Act of 1970. The 1980 decision of the US Supreme Court in Diamond vs Chakrabarty established the legality of obtaining patents for novel life forms. This has greatly stimulated private investment in agricultural research. Over the past decade private sector investment in biotechnology has grown sharply. However, there have been many financial casualties, especially among venture capital companies. The private sector increasingly recognizes that its own progress in biotechnological development depends on the rate of progress in publicly supported basic research.

In biological research, an alliance is emerging between public sector basic science and private sector technology development. Many researchers represented by these areas do not belong to the traditional agricultural research establishment. However, these new participants in agricultural R and D should be viewed as a complement to, rather than a substitute for existing publicly supported agricultural research. In fact, advances in basic biological research will increase the demand for technology generated by both public and private sector.

Growth in developing country agriculture will become increasingly dependent on access to scientific and technical knowledge and skills from developed countries. Thus the advances in biological sciences and changes in the institutional structure of research that have occurred in developed countries raise important questions for developing countries. Will for example, advances in basic science in the developed countries make it easy for developing countries to undertake applied biotechnology research? How these countries will obtain access to new biotechnologies suitable to their own conditions is the subject of the next section.

TECHNOLOGY TRANSFER AND EQUITY

Because of the biological basis of agriculture, technologies tend to be specific to particular locations. Technology transfer takes on the form of scientific information, knowledge, and techniques (Office of Technology Assessment, 1986). The United States, as a leader in most aspects of agricultural technology, occupies a central role in technology transfer through direct trade, scientific research and training, and agricultural development programs. The pace of technology transfer has increased over the past two to three decades, and the expanding role of the private sector has created a higher degree of competition for technology leadership among developed countries. This is reflected in the US concern about intellectual property rights which has become a point of contention in the General Agreement on Trade and Tariffs (GATT) negotiations. The rational for such policies is clear. A handful of developed countries have a strong lead in biotechnology research. It is generally believed that the use of patents and other legal devices to restrict the flow of technology and information will enhance the competitive position of these countries in world markets.

The strengthening of intellectual property rights will effect different countries differently (Evenson, 1989). Those developing countries with the capacity for local adaptive research want foreign firms to provide inventions at low cost, but because they receive nothing in return for protecting the rights of foreign firms, there is a wide-spread tendency to acquire technology through non-compliance with legal controls or "pirating". The poor countries can gain no advantage from pirating since they need assistance at all levels of technology transfer. If developing countries are to abide by international laws governing intellectual property rights, they must see a clear economic advantage in compliance.

As a whole, the developing countries at present have no capacity to deal with intellectual property rights, and neither the International Agricultural Research Centers (IARCs) nor the National Agricultural Research Centers (NARCs) have given this matter much attention. It is difficult to judge the effectiveness of efforts by developed countries to restrict the flow of new knowledge and new technology. Furthermore, such efforts could be counterproductive if they dampen the growth of agriculture in the Third World. There is clear evidence that developing countries increase their demand for agricultural imports from the developed countries as incomes rise (de Janvry and Sadoulet, 1988 and Congress of the United States, 1989).

The International Agricultural Research Centers (IARCs) were created with financial and technical support from the developed countries to help develop and disseminate Green Revolution technology largely because earlier efforts at direct technology transfer had failed. On one aspect of this experience there is little debate: the Green Revolution was spatially uneven in its applicability and diffusion (Buttel and Barker, 1985). The vast bulk of crop area devoted to modern varieties has been accounted for by two crops: rice and wheat. Furthermore, the IARC impact was greatest in those countries with geo-climatic conditions similar to those of the IARC host location (Evenson, 1986). The improvement of National Agricultural Research Centers (NARCs) has been highly uneven. There is evidence that countries with strong national research programs are more likely to adopt modern technology, because they have greater capacity to transfer and adapt technologies to suit their local conditions. Despite all the controversy generated by the tendency of the Green Revolution to serve "narrow" private ends, it is important to remember that it was conceived and implemented within an institutional structure composed mainly of public and quasi-public organizations (Buttel, Kenney, and Kloppenburg, 1985).

The potential for new biotechnologies has already drawn interest from IARCs, which have established a number of research links with institutions in the developed countries (Plucknett and Cohen, 1989). Several developing countries have set up national institutes or programs in biotechnology, and many rudimentary techniques such as tissue culture are now being widely applied. In 1975 the United Nations Educational, Scientific, and Cultural Organization (UNESCO) along with the United Nations Environment Programme (UNEP), convened a meeting of many of the world's foremost microbiologists to establish a world-wide network of Microbiological Resource Centers (MIRCENs) (DaSilva et al. 1987). The objective of this organization is to make every facet of microbiological knowledge (including microbial gene pools) available to the Third World. The United Nations Industrial Development Organization (UNIDO) is establishing an International Center for Genetic Engineering and Biotechnology with a research center in India and another in Europe.

Many people anticipate that, in the area of the major food crops, the IARCs will play the same central role in biotechnology transfer that they did earlier in the Green Revolution. This, however, will require the development of close institutional links between the IARCs, NARCs and developed country institutes which will enable the developed country laboratories to address the critical needs of developing countries. Aside from the rice biotechnology program being funded by the Rockefeller Foundation (Toenniessen and Herdt, 1988), there is relatively little research being done to develop the knowledge and tools of biotechnology for crops such as cassava and millets important mainly to the developing countries.

Others argue that the IARCs lack the scientific capacity and will simply be bypassed with the private sector playing a dominant role, perhaps even in the area of cereal grains. Buttel, Kenney, and Kloppenburg (1985) suggest, for example, that the hybridization of rice and wheat may make it possible for the private sector to control markets for new cultivars in the developing countries. Alternatively, the IARCs and NARCs, who are finding it increasingly difficult to obtain adequate public financial support for research, might accept money from the private sector to support applied biotechnology research, as is done now to a limited degree with some agricultural chemicals. This would tend to blur the lines between public and private sector research, as is happening in the developed countries. Whatever the outcome, there is no question that the private sector will play a major role in biotechnology transfer to developing countries.

World agriculture has become accustomed not only to heavy public investment in the development of new agricultural technology (particularly varietal improvement and improved agronomic and management practices), but also to a high degree of public control over extension processes and institutions which have dispensed this technology free to farmers (Longworth, 1987). There is a concern that the private sector will capture the benefits that otherwise would be captured by farmers and consumers. There is also the concern that the private sector research agenda will be too narrowly focused on the well-to-do farmers with the capacity to purchase inputs. Transnational petrochemical and pharmaceutical companies have acquired all of the major American and European seed companies with the single exception of Pioneer Hybrid, and one fear is that biotechnologies will be developed by these companies to enhance the sale of their chemical products (Buttel, Kenney, and Kloppenburg, 1985). However, although there are many studies of returns to public investment in agricultural research, there are no careful studies available for the agricultural input, processing, and marketing industries that measure the social benefits of private sector research investments.

The tendency for the public sector to under invest in agricultural research has been well documented (Norton and Davis, 1981, and Ruttan, 1982). The problem is more acute today in the developing countries. Faced with mounting national debts and severe budget constraints, many countries have found it increasingly difficult to maintain the level of investment in agricultural research precisely at a time when research budgets should be increasing. Developed countries are also experiencing difficulty finding political support for funding developing country research initiatives, given the increased competition for export markets created in large measure by surpluses generated as a result of their own protectionist policies.

The private sector will invest in research only in those areas where it sees the opportunity for a profit. In biotechnology there is still a great deal of risk and uncertainty. For example, after more than a decade of investment of more than $100 million in biotechnology-engineered vaccines for animal viruses, the private sector has virtually withdrawn from this area, finding conventional technologies more profitable. The challenge to the public sector is to identify those areas of research where private incentives remain too difficult to institutionalize or where private sector technology is likely to be too costly to be widely adopted by all but the well-to-do farmers. That is to say, the public sector should ask the question, what important technological goals should be pursued because they will not be undertaken by the private sector? In the area of biotechnology designed to benefit the Third World, these goals are many and varied. They include agendas for a wide range of research to improve the performance of crops such as cassava, sorghum, millets, grain legumes (especially pigeon peas and cow peas), and plantain that are important to the developing countries.

In summary, biotechnologies appear to offer a wide range of potential benefits to the developing countries. However, because these technologies are knowledge-intensive and location specific, a considerable amount of investment will be needed to facilitate technology transfer to the developing countries. Although the private sector will play an increasingly important role, much of this investment must be made by the public sector if benefits are to be widely distributed across societies. Although in absolute terms the benefits of biotechnology will extend broadly, it seems almost inevitable that the gap in technological progress will widen not only between the developed and developing countries, but also between the more advanced and the less advanced countries in the Third World.

In the next section of this paper this problem is illustrated with specific reference to changing patterns of world trade.

TRADE BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

The rapid growth in world agricultural trade in the 1970s has been followed by a slowdown in economic growth and world trade in the 1980s. Agricultural commodity prices fell and protectionism increased as countries sought to insulate their producers from declining world prices. A recent editorial in the Economist describes the situation as follows:

> In the rich and mainly industrial countries farmers are paid too much, so they produce too much. In the poor and mainly agricultural countries farmers are paid too little, so they produce too little. Europeans trample Cognac grapes into industrial alcohol; Americans fill Rocky Mountain caverns with butter; Japanese pay eight to ten times the world price for their bowl of rice. Meanwhile many millions of Asians and Africans live in rural poverty and go hungry to bed. Do not despair. The mistakes are so large that these country policies will soon collapse. Properly staged and handled, the collapse will leave the world better off (Economist, Nov. 15, 1986, p. 13).

The author of this editorial is more sanguine about the prospects for trade liberalization than would seem to be warranted by the slow progress toward major reforms in the current GATT negotiations. The high subsidy levels have been maintained in almost all developed countries on the basis of political rather than economic rational. These protectionist policies lead to distortions in research investments and technology development which may lead to a further slow down in trade.

With a few exceptions, development in Third World countries must be led by the growth in domestic demand (Mellor, 1988). Nevertheless, trade is extremely important in the development process. As incomes rise, it is often difficult for countries to keep pace in production of basic food requirements such as cereals and oils as well as other necessities to promote industrial development. Exports are needed to pay for essential imports. Agricultural exports account for a major share of export earnings in developing countries.

Table 1 shows the percent share of export markets for developed, developing, and eastern bloc countries by major product groups. Developing countries, which lie largely in the tropics, have long been associated with the export of raw materials and often exports are concentrated in one or two major commodities such as sugar, coconuts, coffee, tea, or rubber. By contrast, the temperate-zone developed countries have been exporting dairy and meat products, food grains and feed grains.

Commodity substitution historically has been an important source of productivity growth, but the gain in one commodity comes at the expense of another. Direct substitution of one crop for another can occur as a crop gains wider adaptability to environmental conditions. For example, improved and more drought tolerant maize is substituting for sorghum and millets in some of the drier portions of Africa. Another more important form of substitution occurs as a result of the change in end-product utilization. For example, the substitution of vegetable fats (margarine) for animal fats (butter) that was accelerated by the shortage of butter during World War II. More recently liquid maize sweetener has replaced approximately 50 percent of the sugar consumed in the United States

Table 1. Trade in Farm Products.

Product group	Percent Export Share (1986)		
	Developed countries	Developing areas	Eastern bloc
Dairy products	95.2	1.7	2.9
Beverages excluding tropical	87.9	5.2	6.9
Pulp	87.7	7.1	5.2
Hides and skins	86.2	6.9	5.7
Cereals and cereal preparations	82.5	12.1	5.7
Meat and meat preparation	78.2	11.4	10.3
Tobacco and tobacco products	70.2	21.3	8.5
Crude materials	68.5	22.5	9.0
Wood	65.3	21.9	14.1
Fruits and vegetables	61.5	30.7	7.2
Oilseeds, fats, oils, oilcakes, etc.	61.4	32.4	6.4
Fish and fish preparation	57.7	35.8	6.5
Natural fibres	48.7	30.9	20.4
Sugar	23.3	71.3	4.0
Tropical beverages	9.4	88.7	1.9
Natural rubber	2.6	96.3	1.5

Note: Figures have been rounded.

Source: Gatt.

and accounts for close to 15 percent of the world sweetener market. Biotechnology facilitates the focus on the use of end-products such as starches, proteins, cooking oils, or sweeteners. Biotechnology can drastically change the comparative advantage of particular crops in the production of these end products.

Social science research has been initiated at the University of Amsterdam to examine the impact of product substitution through biotechnology (van den Doel and Junne, 1986). As a part of this study, researchers are analyzing four areas which are likely to have major impact on Third World exports:

- the impact of the substitution of sugar exports by other sweeteners.
- the impact of increased palm oil production in some developing countries on the production of competing crops elsewhere.
- the eventual impact of the Common Agricultural Policy in Europe on soybean production in the developing countries which may be effected by competition from feed grain improved by added amino acids.
- the potential impact of the industrial production of flavors and plant substances on the exports of developing countries.

Attempting to forecast the impact of biotechnology in a given area is difficult because it is necessary to speculate on what the technical change will do to the production relationships. Scientists are often poor judges of whether their technology will be adopted by producers, and what impact this will have on society. Thus, joint research between social and biological scientists may be useful in establishing research priorities and assessing the impact of technological change.

In the first two areas listed above, sugar and palm oil, changes have already occurred which allow us to examine the general nature of the impacts that can occur, not only as a consequence of the technology itself, but also as a consequence of the expanding role of the private sector, and as a consequence of inappropriate policies in both developed and the developing countries.

Enzymatic digestion of maize starch to obtain high-fructose corn syrup (HFCS) was first introduced into commercial production in Japan in 1967 and spread to the US in 1972. As noted earlier, in little more than a decade this industrial process had become a serious threat to natural sugar. The technology has spread most rapidly in the developed countries - Europe, Japan, and the United States - where high price supports have been maintained to protect domestic sugar beet industries. Sugar exports from the developing countries fell sharply. Particularly hard hit were those former colonies who had preferential trade agreements with developed countries. The Philippines is a notable example. Under the Laurel Langley agreement, which expired in 1974, the Philippines had a preferential tariff and a US import quota for over 1 Mt of raw sugar. Raw sugar exports averaged 1.36 Mt between 1970 and 1974. Sugar was the second largest export earner. By 1986 sugar exports had fallen to a little over 0.2 Mt!

What is the potential for future sugar exports? A recent study projects that if all restrictions on sugar and maize sweetener were removed, sugar production would rise modestly but by the year 2008 maize sweetener would be expected to account for 36 percent of the world market (Landwell Mills, 1987). World sugar prices would be about 17 USc/lb compared to the 1987 world market price of 7 c/lb and the US loan rate of 18 c/lb. This assumes, of course, that there is no technological change in either crop. However, a new biotechnology process patented under the name of SUCROTECH is now being commercially marketed. Ironically, this new approach to making ethanol also has the potential to produce fructose from sugarcane cheaply enough to undercut HFCS and regain the world sweetener market for cane growers (Longworth, 1987). However, it seems highly unlikely that cane growers will regain their lost export markets.

The major deficit regions for oils and fats are Asia, the Middle East, Africa, Latin America, and USSR. Soybean and oil palm have become the two most important sources of vegetable oils and fats in the 1970s, with oil palm having overtaken copra (coconut) during the 1970s (van den Doel and Junne, 1986). However, from 1983 to 1987 rapeseed production and oil consumption had the fastest rate of growth 9.9% per annum for rapeseed, 8.5% per annum for palm, and 2.8% per annum for soybean (Scowcroft, 1989). The rapid growth in oil palm and rapeseed reflects significant technological advances in both crops.

Over 80 percent of world oil palm exports come from just one country, Malaysia. In cooperation with Unilever, the Malaysian oil palm industry has been able to develop high yielding palms. In 1982, Malaysia achieved a record yield of 4.1 t/ha of crude palm oil plus 0.35 t/ha of palmkernel oil and 0.47 t/ha of meal per hectare. This compares with record US soybean yields of 0.4 t/ha of oil and 1.7 t/ha of meal and EEC rape yields of 1.06 t/ha of oil and 1.45 t/ha of meal also in the same year (Mielke, 1984).

The first application of biotechnology to oil palm has been in the micro-propogation of clonal palms from selected elite individuals (Jones, 1989). Tissue culture propagation of oil palm has been researched for two decades. This technique offers potential for increasing yields by 30 percent. However, commercial application has been delayed by the occurrence of flowering abnormalities in some of the first clones.

Despite the lack of success to date with cloning, Malaysia has been able to dominate the export market, and this has had a significant effect on other developing countries. Palm oil exports from West Africa, once a leading exporter to Europe, declined still further. Hart (1982, p. 57) comments that West Africa has come in the past 150 years from the position of monopoly supplier of palm oil to that of an over-committed competitor in one of the most open and unreliable sectors of world trade. The Philippines, with its heavy emphasis on coconuts, also suffered adversely from the expansion of palm oil production and depressed world oil prices.

What does the future hold for palm oil exports? Successful commercialization of cloning would be a major boost. However, much will depend on technical advances in competing crops such as rapeseed. Rapeseed is a significant source of vegetable oil in many of the deficit areas of the world. Biotechnology has led to the development of canola in Canada, a superior quality rapeseed with low erucic acid in the oil (Scowcroft, 1989). Canola is rapidly becoming the international standard rapeseed for trading purposes. The prospects for improving rapeseed yields through biotechnology are very promising.

The area of sweeteners and vegetable oils represent but two examples of how improvements in either the quality or yield of a crop can have significant impact on world export markets. The advent of biotechnology will enhance the competitive advantage of developed countries with the research and marketing capacity to strengthen their share of world markets, and of developing countries able to gain access to these new technologies through multinational firms. The protectionist policies of developed countries will provide greater incentives for researchers to create lower-cost substitutes for developing country imports. The developing countries will in turn invent technologies which will enable them to reduce imports. The multinational firms will look for competitive advantage wherever it can be found, and their plantation style of agricultural production may result in pockets of prosperity, often at the expense of incomes in other regions of the Third World.

CONCLUSIONS

Biotechnology offers the potential for lowering production costs, increasing the productivity of agriculture in hitherto disadvantaged environments, reducing dependency on energy from non-renewable resources, and mitigating environmental and pollution problems. Major advances in any of these areas would seem to hold significant benefits for Third World countries. But there are major obstacles to the realization of these potentials. There is a growing concern that with respect to agricultural production and trade that biotechnology may widen the gap, not only between rich and poor nations, but also between the rich and poor countries in the Third World.

The change in the institutional structure of agricultural research in the developed countries and new laws providing for the patenting of genetically engineered organisms, have led to the growing prominence of the private sector in biotechnology research. This can be viewed as a mixed blessing. On the one hand, there is likely to be more total research investment in biotechnology. Hence, more rapid technological change can be anticipated although the rate of productivity gain is unpredictable. On the other hand, private sector research is likely to be focused in areas with high return to private investment. The failure to maintain adequate public sector investment in capacity to transfer and adapt biotechnologies for situations where the private sector cannot institutionalize profits could widen the gap between developed and developing countries and between the rich and poor countries in the Third World.

Biotechnology is knowledge-intensive, and in the case of agriculture, often location specific. Considerable investment is needed in research capacity in the developing countries to facilitate the transfer of technology and adaption to local conditions. However, most developing countries, faced with mounting foreign debt and budget constraints, are finding it difficult to increase the level of investment in agricultural research. At the same time the developed countries, facing budget constraints of their own and fearing export competition from Third World countries, are reducing their commitment to support the IARCs and other organizations designed to strengthen technology transfer.

If the existing protectionist policies continue, the Third World debt problems go unresolved, and too little attention is given to the development of agricultural research capacity in the developing countries, the slowdown in trade between developed and developing countries and the slow agricultural and economic growth witnessed in the past few years will become a chronic problem. Technological change cannot be a substitute for needed institutional and policy reforms. Advances in biotechnology will tend to exacerbate existing inequities.

RECOMMENDATIONS

This section contains three sets of recommendations which relate in turn to each of the last three sections of the paper: public and private sector research, technology transfer and equity, and trade between developed and developing countries.

PUBLIC AND PRIVATE SECTOR RESEARCH

The change in the interpretation of U. S. patent laws makes it possible for firms and research institutions, whether public or private, to capture a major share of the profits from investment in biotechnology research. The private sector is already playing a major role in the development of biotechnologies. Although the evidence is not yet clear, concern has been expressed that a new division of labor is developing between public and private sector, with the former concentrating on basic research and the latter on technology development and dissemination. Furthermore, there are already signs of a conflict between public and private sector interests in cereal grain research.

Without strong public sector capacity in biotechnology development, advances in biotechnology in the Third World would be limited to those handful of countries where private transnational firms would find it profitable to locate. Lack of access to biotechnologies would have a negative impact on income distribution whether at the local, national, or international level.

Encouragement should be given for both public and private sector development and diffusion of biotechnologies. Ways should be found to strengthen collaboration in biotechnology research between public and private sector in the developing countries. (Suggestions for implementation of this recommendation can be found in USAID, 1989). It might be desirable in some instances for public institutions to purchase key patents in biotechnology and give them to the developing countries. Greater support must be found for public sector research conducted in advanced-country laboratories on problems and commodities that are important to the Third World.

TECHNOLOGY TRANSFER AND EQUITY

Biotechnology is knowledge intensive. Most of the advances in basic research and technology development are likely to occur in the industrial countries. While the potential for increasing the productivity of developing country agriculture is great, most of these countries are not in a position to attract private investment in transnational firms. Appropriate technologies tend to be very site specific, and many developing countries lack the capacity to adapt biotechnologies to local conditions. However, many applied biotechnologies such as tissue culture are already being widely used and are proving extremely valuable. Perhaps in the future simplification of procedures will enhance the capacity for technology transfer to the Third World.

Although advances in biotechnology may lead to a general increase in productivity, there is likely to be a widening of the productivity gap between developed and developing countries, and between the dozen or so most advanced developing countries and the rest, who lack the basic institutions and infrastructure to take advantage of advances in biotechnology.

Steps should be taken to lesson this negative distributional impact. First, and perhaps most important for the immediate future, developing countries will need to strengthen research capacity in the traditional applied research fields, such as plant breeding (Buddenhagen, 1989). Second, as noted above, more public sector funds should be made available in developed countries for biotechnology research on commodities and problem areas that are important to developing countries. Third, the IARCs need to expand their capacity to assist NARCs in all aspect of biotechnology transfer, including the encouragement of biosafety (The potential role of the IARCs in biotechnology technology transfer is discussed in this volume in Plucknett and Cohen, 1989). Finally, to facilitate technology transfer, direct communication linkages will have to be expanded in the future between researchers in the developed country laboratories and developing countries. Advances in information and communication technology will greatly facilitate this two way flow of information.

TRADE BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

Biotechnology enhances the capacity of industrial countries to create substitutes for imports from developing countries. The protectionist policies of the developed countries create further incentives for scientists to search for substitutes.

An example of the impact is seen in sweeteners. Policies designed to protect domestic sugar beet producers encouraged the development of the corn sweetener resulting in a sharp drop in the demand for cane sugar produced largely in the developed countries. How successfully and how rapidly other substitutes can be developed using biotechnology is hard to predict.

In the current GATT negotiations, efforts are being made to encourage trade liberalization in agriculture. This should be coupled with greater efforts to strengthen applied research and technology transfer capacity in the developing countries. Strengthening trade linkages between developed and developing countries should work to everyone's advantage. Failure to achieve this could lead to a continuing slowdown in world trade and growing worldwide self-sufficiency in agricultural commodities, which could be to the detriment of both developed and developing country agriculture.

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