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JOINT UNIDO/UNCTAD STUDY ON THE IMPACT OF BIOTECHNOLOGY ON DEVELOPING COUNTRIES'AGRICULTURAL TRADE

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I. INTRODUCTION

Rewrite of Sections 4 and 5.

4. The Technologies

Biotechnology (BT) is defined as any laboratory-based methodology used for crop and plant product improvement, including:

a. Macro- and micropropagation;

b. Cell and tissue culture;

c. RFLP (Restriction fragment length polymorphism) mapping;

d. Development of diagnostics;

e. Gene cloning and gene transfer;

f. Gene cloning and gene transfer.

These techniques allow:

i. The propagation of plants;

ii. The creation of new varieties;

iii. Improved agronomic practice.

They complement, but do not replace, classical plant breeding, i.e. they are used as essential adjuncts to it.

5. Time Horizon

Following the analysis of Machleidt, the technologies listed under Chapter 1., Section 4, are in mid-growing phase with the establishment of the basic technology, but developments continuing to occur, for instance the development of fully automated DNA sequencing. In the main the developing plant technologies are product oriented; the extent to which technologies can be applied in their mature phase to different vegetables, crops, etc. coupled with market sizes and values, will determine the overall importance of plant biotechnology for the agricultural industries. As will be discussed later, factors, other than economic, for instance social and environmental, will play an important role. However, it is generally thought that biotechnology will become a dominant technology and one which will begin to have major economic effects from the second decade of the next century onward.

Machleidt, H. (1988). Industrial Biotechnology: Future Applications and Need. BTF Biotech-Forum, Vol. 5, 343 - 346.

CHAPTER 1.2: BIOTECHNOLOGICAL DEVELOPMENTS AND THEIR OVERALL EFFECTS ON PRODUCTION AND TRADE.

1.2.1 Introduction

Over the last decades, technological breakthroughs enabled scientists to draw on a large variety of methodologies to achieve these improvements. In particular, new methods of gene transfer have become possible very recently. These are accepted as powerful and safe and have opened a whole spectrum of applications. In this section, these methodologies will be briefly reviewed, the trends in the development of the biotechnological research analyzed and shown how they can fit into overall agricultural and horticultural research. How biotechnology is expected to affect agricultural output will also be discussed and which desirable objectives can be defined for products of major importance for developing countries in a selected few areas. We wish to stress at the onset that in future these biotechnological methods will be an essential element of plant breeding and agronomy.

1.2.2. State of the Art and Future Developments

In plant biotechnology, different methodologies require different levels of sophistication both of equipment and know-how, and this has implications for the rate of application of the technology to different crops and for the rate of diffusion of the technology to developing countries. Thus, methods (a)-(d) set out in chapter 1 are less sophisticated than (e) gene cloning and gene transfer.

A.Clonal propagation

Clonal or vegetative propagation of plants has been practiced since ancient times. It allows genetic improvement to be exploited rapidly and on a large scale. It is particularly important for species whose seed is genetically variable such as trees and ornamentals, and although well established in the horticultural and agricultural industries, it is now being adopted by forestry, particularly for the multiplication of inter-specific hybrids. Four different techniques are used: macropropagation, micropropagation, somatic embryogenesis and apomixis.

Macropropagation: Well established in horticulture, now being applied to forest trees. Difficulties can occur with rooting cuttings which in addition often have slow rates of growth. Various methods for regeneration of trees and for the identification of juvenile tissues within mature trees, are making progress. At present there are a few selective applications. Considerable technical success with a range of trees is expected in the last decade of this century with widespread commercial applications in the first decade of the next. Much more recent is micropropagation.

Micropropagation: The first applications were in the 1950's and a large number of commercial companies now exist in the horticultural industry. Although of less potential importance in forestry, micropropagation of shoots from mature trees through a few cycles for rejuvenation prior to micropropagation, may become important. Micropropagation of oil palm (*Elaeis guineensis*), coconut (*Cocus nucifera*) and rust resistant coffee plants (*Coffea arabica*) has also been achieved. Developments for the future which should reduce the costs are automation of handling linked to computer vision technology.

Somatic embryogenesis: The third method of clonal propagation will depend on advances in our understanding of basis biology. The aim is to grow cells in fermenters and produce embryos in large numbers, either to produce plantlets which would be processed as in micropropagation, or encapsulated to produce artificial seeds. Selective application of this technology for horticultural crops are expected at the turn of the century, with applications to forestry a decade or so later.

Apomixis: The production of normal seed without sex is known to occur in a number of wild species. Transfer of apomixis to forest trees would be of particular importance for the clonal propagation of inter-specific hybrids.

B. Plant Breeding

Plant breeding has been practiced since time immemorial. Developments in biotechnology such as the use of gene probes, RFLP technology, immunochemistry, wide-crosses (embryo rescue) and advanced analytical procedures, are likely to greatly increase the precision of plant breeding, thereby reducing costs and increasing reliability. These changes, employed on a small scale, will become widespread within the next decade.

C. Gene Cloning and Gene Transfer

One of the most fascinating breakthroughs in plant biotechnology was the establishment of techniques which allow stable introduction of foreign DNA into the plant genome. This technology overcomes the natural barriers that prevent species to exchange genetic material. It became possible, in principle, to incorporate genetic material from any source (human, bacterial,...) into the plant genome. Therefore, any characteristic which is already present in nature and which is thought desirable to transfer to plants, can be isolated, modified in such a way that it will be integrated and expressed in the host plants' genome. In addition, existing genetic material can be modified to code for proteins with improved qualitative value, for instance for proteins that have an increased stability. Although several groups have argued that this technology is not without risk for human society or its environment, it should be stressed that these technologies are commonly accepted as safe, i.e. they are not a threat, neither to human health, nor to the environment. A very convenient way to deliver new DNA to a plant cell exploits the naturally occurring DNA transfer mechanism of a soil bacterium, *Agrobacterium tumefaciens*. This bacterium is able to transfer a part of its genome, the T-DNA, to the genome of dicotyledonous plants where it is stably integrated and expressed. The expression of this DNA causes tumorous growth of plant cells. It became possible however, to eliminate the genes coding for abnormal cell proliferation, while retaining the ability to transfer DNA. In this way, any DNA that is properly inserted in the genome of specific *Agrobacterium* derivatives will in turn be transferred and integrated. The plants obtained through this technology are called 'transgenic plants'.

How does the *Agrobacterium* mediated genetic transformation works? Let us assume we want to introduce a gene conferring insect resistance into a particular plant species. First, this gene has to be isolated. In nature, there is a bacterium, *Bacillus thuringiensis*, that produces under specific conditions a crystalline protein that interacts with the mid-gut of some insect larvae. The gene, responsible for the production of this toxic substance can be isolated from *Bacillus*. Then it has to be modified in such a way that it will be recognized by the specific machinery that the plant cell uses to build up proteins. Controlled expression of genes in transgenic plants using different promoters, anti-sense constructs and ribozymes are the object of intense research activity. Finally, these constructs ('gene cassettes'), have to be introduced in an *Agrobacterium* strain which can transfer it to the plant cell. *Agrobacterium* serves as an intermediate in the DNA transfer strategy. It can introduce the DNA in any given plant cell, restricted only by its natural host range. Therefore, once a cassette is constructed, it can be introduced in a large variety of plant species. The only limitations are:

1. The plant should be susceptible to *Agrobacterium*-mediated transformation. Researchers have identified a specific molecule which has to be excreted by plants to induce the gene transfer machanism in *Agrobacterium tumefaciens*. Monocotyledonous plants, which include the most important industrial crops such as cereals, are recalcitrant for gene transformation. It is possible for instance that some of this plants, do not synthesize this molecule and therefore, are not susceptible to transformation. Therefore, many scientists believe that these barriers will quickly be overcome.
2. The transformed plant material has to be regenerated to a normal, fertile plant. For this reason, tissue culturing is of great importance for biotechnological applications.

Recently, other methodologies have been developed to deliver foreign DNA to plant species. These include micro-injection of pollen, transformation using a 'particle gun' and direct DNA transformation of plant protoplasts using either PEG or electroporation. The latter techniques are also limited in the extent of their use by the need to regenerate plants from isolated protoplasts.

Gene transfer and plant regeneration are a prerequisite for the construction of transgenic plants and in general, the economically more important traded crops, such as maize and wheat, are the most difficult in this respect. However, the enormous commercial interest in some species in this category, such as maize and wheat may drastically decrease the period necessary to obtain stable transformants. By the year 2000, transformation is expected to be routine for all commercial useful species.

Much has already been achieved using these 'gene cassettes'. The first transgenic plants were constructed about six years ago, and now, transgenic tomato, potato, tobacco and rape are in the fourth year of field trials on a rather limited scale. Among the major results can be quoted, the production of insect, fungal, bacterial, nematode and viral resistance plants, of herbicide resistant plants and of male sterile plants. In addition, it has been demonstrated that the nutritional value of plants can be improved as well as other quality characteristics, and that plants can be used to synthesize and store in seeds, very complex metabolites such as human hormones. Although results are very encouraging, the developmental aspects will require considerable trials and breeding over a period of about five years.

Furthermore, primary concerns for farmers and breeders alike are to increase yield, reduce crop losses due to pests and pathogens, and to increase tolerance to various stresses, including cold, drought etc. Some of these, as well as other important objectives such as bread quality are multigenic traits and it remains difficult to identify and introduce in the plant genome such multigenic traits. However, insertional mutagenesis, gene tagging and RFLP mapping, can be very important tools in helping to isolate desirable genes, including even multigenes. Some of these projects should therefore be carried out in the next coming decade, others however will not be achieved for several decades, such as the construction of nitrogen fixing plant species. Lastly, either whole plants, or plant cells and tissue cultures, can serve as a source for the production of secondary plant metabolites and even, pharmaceuticals and other high value products.

The technological potentialities of the newest molecular biotechnological methodologies are vast and it can be expected that the number of applications will grow exponentially. The slope of advance will probably not be influenced so much by technical difficulties but rather by political decisions (see later).

1.2.3. Biotechnological research in developing countries

A global research program aimed at the improvement of agriculture involves three major areas of research: gene technology, tissue culture and plant breeding; no success can be obtained by omitting any of these. This is of great importance for biotechnology in developing countries, because it implies that new biotechnological efforts should always fit into the existing agricultural infrastructure and should not detract from conventional plant breeding etc. Biotechnological research can be carried out at different levels of technical complexity investment. Low-cost facilities for plant tissue culture or clonal propagation of plants can be implanted in research centers of most developing countries and function with a good chance for success.

"The impact of biotechnologies on societies will be considerable and their will be winners and losers. But no country, and no community is condemned to become a loser. This will depend on which strategies are adopted by the community, country, or group of countries in order to reap their legitimate portion of the benefits of biotechnologies. In view of the fact that the "biotechnological revolution" will affect even the most isolated societies, it is neither wise nor justified not to participate in this revolution and not to fight for gaining some of its expected advantages "

"It is clear however, that the two sorts of operations - the advanced biological research department and the low cost facilities - have not the same objectives. The choice of targets or objectives is of extreme importance as they have to be within the reach of developing countries and serve their needs and hopes. It is also essential' to identify accurately the promises brought to developing countries by biotechnologies, so that the right selection can be made."(Albert Sasson: Biotechnologies and Development, UNESCO 1988).

The objectives of biotechnological research depend on the crop and on the geographical area where it is grown. Competent breeders will have already identified desirable objectives to which biotechnology can be directed. Several large industrial companies are already investing heavily in alternatives to improve the characteristics of crops that are important for developing countries'agriculture. We can expect that, where objectives of North and South do not coincide, a large spin-off from research carried out in industrial laboratories, which are concentrating their efforts on a limited number of traded crops, will be adapted to specific problems in developing countries. Results obtained in for example corn research may well have a spin-off for millet. On the other hand, many of major breeding objectives for crops in developing countries are not of much interest in developed countries. One reason for this is that the market for a specific crop is too small. The overall market for beans (*Phaseolus vulgaris*), for instance, is very large and enough to justify research in industrial laboratories. On the other hand, in a country such as Mexico, hundreds of different bean varieties are consumed. Therefore, whilst no company will improve each of these particular varieties, Mexican research could co-operate with industrial research laboratories and adapt the latters's achievements to Mexican agriculture. Other examples where North and South priorities differ are the brown plant hopper resistance in rice, or the aflatoxin production in stored groundnut, each posing a severe loss to agricultural production. The lack of research by industrial laboratories in these areas creates a niche for research specifically aiming at solving problems related to agriculture in developing countries.

These considerations suggest that a qualitative improvement of developing countries-crops can only be achieved by first linking advanced research groups in the North to low-cost facilities in the South with objectives integrated into the existing research and breeding networks. Depending on the budgetary and scientific possibilities of the local centers involved, the next step would be to increase the regional molecular effort. This can be effective if, on the one hand a close contact between the regional center and the developed world laboratory is assured and if the regional center acts as a center of intelligence for the whole region. Two examples can be found in Latin America: the Institute for Genetic Engineering in Irapuato, Mexico and BioRio in Rio de Janeiro, Brazil.

Chapter 1.3.: OVERALL INCIDENCE ON PRODUCTION

1.3.1. Introduction

In this section the opportunities and constraints to engineering the major crop plants of developing countries are briefly reviewed. Initially the majors factors to be considered in this respect are stated and these are then briefly discussed.

Major factors of importance in considering the likely impact of plant biotechnology on production in the developing countries are:

1. the importance of the crop as food and whether it is exported or imported, or if local production is consumed internally;
2. the amount of research and development being carried out in the developed'countries laboratories and whether the results are likely to be commercially protected, together with an estimate of 'near' and 'far' realisation of objectives;
3. whether commercially funded, crop improvement "objectives" coincide with those of developing countries;
4. whether avenues exist for commercial arrangements between developed and developing countries whereby technology could be transferred;
5. the extent and availability world-wide, of non-constrained biotechnological R&D.

1.3.2. Factor 1.

The important food crops'of developing countries in rough order of priority are: rice, wheat, maize, sorghum, sweet potato, cassava, millet, grain legumes, oil seeds, other cereals, potatoes, vegetables, fruits, other roots and tubers. Also important, but not as food, are trees, coffee, cocoa, tobacco, cotton and forage legumes (animal food). (*Export/import local consumption figures will need to be added*).

1.3.2. Factor 2.

Targeted crops of industrial laboratories are: wheat, maize, barley, sugar, soya, rape, potatoes, tomatoes, forage legumes, tobacco, cotton, trees (saw log and pulp), trees (for oil) and ornamentals. Table 1. is "state-of-the-art" of biotechnological methods for all crops.

If a crop is targeted by industry (see above) and is an important food crop (for instance maize), or plant product (for instance cotton) which the Third World also produces, then production of biotechnologically improved varieties in the developed world could seriously affect the developing world. A different example for which there are already precedents, is where a developed country's improvement of a crop were to substitute for an alternative Third World export crop. This is well known to have already happened with sugar-beet substituting for sugar cane, and a future biotechnological example might be rape oil for tropical oil tree crops. We can expect a major activity of the food industry in developed countries to try and develop better quality and/or cheaper primary biotechnologically improved food constituents as an alternative to South-grown ones, in much the same way that the chemical industry did fifty years previously.

1.3.3. Factors 3 and 4.

The genetic traits targeted by industrial laboratories, such as herbicide resistance in U.S. cotton, resistance to major Lepidopteran or Coloepteran pests in U.S. maize, will be used to construct transgenic plants that have a large market. As already noted, industry has a major commitment to biotechnology and if mutual satisfactory arrangements could be made where there was no conflict of interest, there could be a spin-off for the Third World from research and development in the developed world. An example of this might be the use of herbicide technology developed in the North applies to Striga and Orobanche resistance in faba beans, an important protein crop of the Middle East but not of great importance in the international traded seed market. Transfer of technology for insect resistant cowpeas from an industrial laboratory to Third World, is another possibility.

Another example is with flowers. The flower market is dominated by the Netherlands, but because of a steady annual growth of about 10%, there is an increasing import of flowers from developing countries such as Kenya, Morocco, Côte d'Ivoire, Thailand, Guatemala and Costa Rica. In Kenya, the African Agricultural Biotechnology Company was formed to promote biotechnology in flower production.

The flower market is an important niche for developing countries: they have favorable climatic conditions and low labor costs. When a flower is introduced in this new environment, it's cultivation will have to deal with new problems, especially viruses. However, because flowers are multiplicated *in vitro*, it is relatively easy to develop virus-free lines. Also, since flowers need to have a stable variability, numerous varieties are propagated clonally, without breeding. A biotechnological support of these industries is essential and appears feasible.

New flower varieties can be obtained through genetic engineering. A classical example is the construction of a blue rose. These could be constructed in industrialized laboratories and in developing countries, the essential biotechnological contribution could be in the tissue culturing of new and existing species to adapt them to their new environment.

A negative example can be illustrated with potato. Seed potatoes farmed in developing countries are imported from industrial countries where high quality and highly productive material is guaranteed. A major concern in the cultivation of potatoes in developing countries is the damage done by the tuber moth. This insect harms the potato in two ways. First, it attacks the leaves, resulting in a severe yield reduction. Secondly, the insects'eggs are harvested together with the tubers. When the potato is stored, larvae will develop that damage the tuber. In addition, the wholes they make render the potato susceptible to other attacks, such as by *Erwinia* or *Phytophtora*.

Laboratories in the North have the technology whereby potatoes resistant to the tuber moth could be developed but these laboratories would be hesitant to carry out such a program for fear of losing control over their engineered material. Whether developing countries could also develop the transformation technology independently, raises questions of the difficulty involved, the presence of infrastructure and of the propriety rights of the gene.

The other problem in potatoes is having virus-free stocks which involves micropropagation. It is feasible for the South to establish and maintain their own materials in this respect.

1.3.4. Factor 5.

The extent worldwide of non-constrained biotechnological R&D with "near"applicability is relatively limited. The amount of biotechnological R&D on non-industrially targeted crops is sparse. However, expertise exists in research institutes and universities of developed countries, which could be welcomed by suitable funding.

Thus, a suitable target for the development of plant biotechnology for developing countries might be a highly important crop where the necessary infrastructure, for example breeding programmes, already exist in developing countries and where the world wide technology is reasonable close to success.

Rice is such an example of a major crop that is cultivated and consumed mainly in developing countries; rice grain is not an important traded crop in the North. Therefore, amelioration of the crop is basically a decision that will be made by agricultural scientists in the South.

Several breakthroughs in rice research were reported in the last years and we can therefore expect that, at least primitive transgenic varieties will soon be constructed. These will have to go through an extensive breeding program. Although rice is difficult to work with in the laboratory, we can expect the first major benefits for agriculture in this crop.

These criteria were used by the Rockefeller Foundation to target rice and instigate the Rockefeller Foundation's International Programme on Rice Biotechnology, which should serve as a model. Table 2. (modified from Toenissen) sets out the criteria on which targeting could be based.

Just as the first positive biotechnological effects can be expected in rice for the above reasons, the first negative effects could be expected in maize. It is the main target crop of several industrial laboratories, protection of property (hybrids) is possible and needed technology is starting to be successful. Cotton is another negative example. Cassettes are available for herbicide and insect resistance and primitive cottons have been transformed so that a breeding programme to intergress the genes into commercial cultivars is all that is now needed. Potato, rape and soya are also at about this stage of readiness. Potential negative biotechnological effects of wheat and barley are less likely in the nearer future, as the technology is not yet in place.

On the other hand, positive biotechnological effects for the Third World will require considerable input of time and effort. The reasoning along the lines used by the Rockefeller Foundation to target rice, suggest cassava, sorghum/millet, sweet potato and grain legumes, as primary input targets.

Table 1. **State-of-the-art of Biotechnology Methods for All Crops**

Legend:

1= Many problems to be solved

2= Some success was reported, but the technology cannot yet be used routinely

3= The methodology can be routinely carried out.

cultivated crop	**micropropagation**	**callus culturing**	***in vitro* selection**	**DNA transfer**
Cereals				
wheat	2	1	2	1
rice	2	2-3	2	2
maize	2	2	2	2
barley	2	2	1	1
sorghum	2	2	3	-
millet	1	1-2	2	-
Vegetables				
potato	3	3	2	3
tomato	3	3	3	3
Grain legumes	1	1-2	1	1-2
Other foods				
rape	1	1-2	2	1-2
cassava	3	3	-	1
bananas and plantains	3	1	1	1
apples	3	1	1	1
sugar beet	2	2	1	2
coffee	3	2	2	1
cocoa	2	1-2	1	1
				1
Others (non-food)				
tobacco	3	1	1-2	3
cotton	1-2	1-2	1	2
trees (saw log and pulp)	1-2	2	1	1-2
horticultural plants (flowers)	1-2	2	2	1

Table 2. **Priority for Crop Focus of Biotechnology Programme for Less Developed Countries.**

Legend: **** = relatively high

* = relatively low

IARC = International Agriculture Research Centers

LDC = Less developed country.

	Importance of crop in LDC	Maturity of IARC and LDC Breeding Programmes	Sparcity of Biotechnology Research Effort Worldwide	Probability of Near term succes
Rice	****	****	***	**
Cassava	**	**	****	***
Wheat	***	****	**	*
Millet	**	**	****	*
Maize	***	***	*	**
Sorghum	**	***	***	*
Sweet Potato	**	*	***	***
Potato	*	***	*	****
Grain Legumes	***	***	***	**
Cotton	*	**	**	***
Vegetables	**	*	***	***
Oils	**	*	***	***

CHAPTER 2,2.:INSTITUTIONAL FACTORS THAT AFFECT BIOTECHNOLOGY TRANSFER

2.2.1. Level of Training and Education

Technology transfer requires an elevated level of training and education. As stated previously, micropropagation and plant breeding are the backbone for technology transfer to developing countries and strong links should be established between biotechnological and agricultural research.

A research program in a developing country should be centered around a qualified staff. These researchers should have access to laboratories in developed countries for training so that a North to South network will help to disseminate information about the newest technologies. Thus, qualified researchers in developed countries should be motivated to train scientists in developing countries, both at theoretical and practical level. These scientists during visits can help to design and execute biotechnological programmes and to up-date senior research staff members. Finally, compatible laboratories should be encouraged to co-operate through a regional network, preferentially in close collaboration with the International Agricultural Research Centers, an important task for them, which is already developing.

An example is the molecular biology unit in Irapuato, Mexico. Mexican researchers in this unit were trained in centers in developed countries and then returned to their home country to conduct, together with visiting scientists, excellent research on well-chosen topics that deal with very specific problems of Mexican agriculture. There is a close relationship with CIMMYT on maize biotechnology and they also collaborate with several regional centers. In addition, there is a close contact between this laboratory and many centers in Europe and the U.S.A.

2.2.2. Regulatory Procedures.

Public opinion towards biotechnology differs strongly from country to country. In some countries, like in West-Germany, there is a strong opposition towards biotechnological research and the release of transgenic plants. As a consequence, the national government and private companies have severely reduced the financing of such research programmes and industrial laboratories prefer to carry out research in countries with less strict regulations. This is just one example of how public opinion can, based on little foundation, can delay research drastically.

It does not seem very likely a consensus will be reached rapidly among industrialized countries that defines biotechnological risk assessments. Therefore, each countries has either no firm regulations, or regulations based on the United States'N.I.H. guidelines. In most of the developing countries there are no regulations and it is therefore probable that unregulated experimentation with a potential environmental risk will be carried out in these countries. It is urgent therefore that developing countries need to develop a code of conduct on the release of genetically altered organisms. Again, international organizations, should play a key role in guiding developing countries with advise and expertise on how field trials with genetically altered organisms should be executed. In the next paragraph, we will propose a general scheme on how international organizations can act to implement biotechnology in the agriculture of developing countries.

2.2.3 Patent Regulations

New transgenic plant are protected plant materials. Even though it is still difficult to protect a patent, industry is exploiting new approaches to control the release of material. A company will not execute a research project however, even with a potential important economically value if it is not assured that it will receive suitable financial remuneration. We gave earlier the example of transgenic potato and explained that, although a tuber moth resistant potato could be constructed, companies are unlikely to do it.

One way to overcome patent protection, is that a particular country that has an urgent need for, let us say, tuber moth resistent potato, sets up a joint project with a private company to construct a transgenic variety. But again, since this variety is beneficial for a large region, this may not be the best policy as the execution of this project, including genetic engineering, tissue culturing and breeding, is too expensive and laborious for an individual country.

A better solution would be to incorporate biotechnology in an integrated multi-lateral co-operation. International organizations can act as honest brokers to negotiate with private companies to set up research activities, including training and breeding programs, and to transfer the technology to different geographic areas where it is needed. A carefully thought out co-operation that includes economical reality and aims at the transfer into developing countries of know-how, has a stimulating effect on the general transfer of technology. These large, integrated projects are beneficial to the agricultural activities of developing countries. Within this framing, in which international organizations channel technology transfer, developing countries themselves will execute specific projects much faster. In addition, the international organizations will be able to stimulate biotechnological education and to asses potential risks.

It may well be that this is the only long lasting solution for developing countries to benefit from biotechnological innovations and to participate in these promising research areas.

Table 1

Production and Trade Balance of Agricultural Commodities (Average for 1985 - 1986)

Crops	Production % in volume	Trade Balance in million U.S. $	
		crop	processed product
Cereals	100.0	-10720	-1663
Rice	44.9	-650	---
Wheat	21.5	-6678	-1314
Maize	18.8	-1587	
Sorghum	6.9	-127	-349
Millet	3.8	-6	
Barley	3.4	-1582	
Others	0.7	-90	

Sources: Production: FAO Production Yearbook
Trade: UNCTAD estimates

Note: —— means : 0
--- means : not available

Table 2

Production and Trade Balance of Agricultural Commodities (Average for 1985 - 1986)

Crops	Production % in volume	Trade Balance in million U.S. $ crop	 processed product
Vegetables	100.0	+944	+31
roots, tubers	45.9	+561	---
of which			
cassava	33.3	---	
yams	6.6	---	
sweet potatoes	4.0	---	
potatoes	10.1	-67	---
leguminous veg.	7.5	-94	---
of which			
dry beans	3.0	---	
chick peas	1.7	---	
tomatoes	5.4	+194	---
others	31.1	+350	---

Table 3

Production and Trade Balance of Agricultural Commodities (Average for 1985 - 1986)

Crops	Production % in volume	Trade Balance in million U.S. $	
		crop	processed product
Fruits/nuts	100.0	+2731	+1398
bananas/plantains of which	37.7	+1591	---
bananas	23.4	---	
citrus fruits of which	19.6	+340	+1257
oranges	15.7	+262	+1303
other tropical fruits of which	10.5	+43	---
mangoes	8.4	---	
grapes	8.0	+158	---
pineapples	4.4	+113	+40
apples	4.2	-117	---
nuts of which	0.9	+582	---
cashew nuts	0.2	+239	
hazelnuts	0.0	+228	
brazil nuts	0.0	+133	
other fruits nuts	14.7	+21	---

Table 4

Production and Trade Balance of Agricultural Commodities
(Average for 1985 - 1986)

Crops	Production % in volume	Trade Balance in million U.S. $ crop	 processed product
Sugar cane, beets	100.0	0.0	+5038 (sugar)
of which			
sugar cane	95.9		
sugar beets	4.1		
Tropical beverages	100.0	+13188	+714
Coffee beans	62.4	+9925	—
Cocoa beans	20.4	+2165	+714
Tea	17.2	+1098	—
Spices	---	—	+526
of which			
pepper	---		+369
vanilla			+64

Table 5

Production and Trade Balance of Agricultural Commodities (Average for 1985 - 1986)

Crops	Production % in volume	Trade Balance in million U.S.$		
		seeds	oils	oilcakes
Oilseeds	100.0	+212	+1036	+1433
seeds for soft oils	60.0	+73	-1136	+1359
of which				
soyabeans	26.4	+44	-703	+1278
ground nuts	11.8	+45	+136	+76
cottonseeds	11.3	-3	-99	+60
sunflower	4.0	+3	-10	+3
rapeseed	3.0	-49	0	-32
seeds for other fixed oils	40.0	+139	+2172	+74
of which				
coconuts	31.2 [1]	— [1]	+678	---
copra	4.0	+91		
palm kernels	2.3	+16	1538	+91

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[1] Production includes coconuts used as fresh or dried. Their trade is included under fruits; it amounts to U.S.$ 64 million.

Table 6

Production and Trade Balance of Agricultural Commodities
(Average for 1985 - 1986)

Product	Production in thousand MT	Trade Balance in million U.S. $
Raw materials		+6188
Tobacco	+2419	+1097
Rubber	+4012	+2285
Vegetable fibers	+10840	+579
of which		
cotton	+6504	+506
Jute and jute fibers	+3600	+8
sizal	+455	+56
Trees for wood	---	+2019
of which		
conifers		+55
non-conifers		+1964
Vegetable crude materials	---	+208
of which		
pharmaceutical plants		-161
seeds		-129
cut flowers, foliage		+198