*Agricultural Biotechnology in Developing Nations: Place, Role and Contradictions**

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> *"Scientific activity, the scientists role and the scientific community have always been dependent; they exist, are valued, and are supported insofar as the State or its various agencies see point in them."* (Steven Shapin and Simon Schaffer in *Leviathan and the Air–Pump*; 1985, p. 339)

> *"Collaborative research with the Third World has benefited U.S. agriculture...through the infusion of yield–producing genetic materials into seeds of our cultivated crops....Continued scientific and technical assistance to the developing countries is essential and in the long run will provide expanded trade opportunities for U.S. agriculture and industry....Countries such as Taiwan, Korea, Brazil, and Nigeria, which were recipients of U.S. technical assistance, are now among the major purchasers of U.S. food exports."* (Nyle C. Brady, Senior Assistant Administrator for Science and Technology, U.S. Department of Agriculture (USDA), in *Science*, November 1, 1985, p. 499)

Scientific neutrality is a myth; over time, science has become a factor of both development and inequality. Historical evidence clearly demonstrates that the unequal development pattern of agricultural research between developed and developing nations has been associated with the way Western science spread in the New World and has always been shaped by strategies influenced by the level of (under)development of science and technology over time. Thus, the contemporary place, role and contradictions of agricultural biotechnology in developing nations are largely a historical outcome of a process which is shaped by socioeconomic and political forces and has evolved from the era of economic botany to the era of Mendelian genetics to the era of molecular genetics.

The contemporary dependent and distorted state of the development of agriculture and of agricultural biotechnology in developing nations can

* The view and opinions in the paper are those of the author, not necessarily representing those of his institution, the Brazilian Public Enterprise for Agricultural Research (EMBRAPA), or of his country, Brazil.

be linked back to their colonial past; a historical process where collusion and the dialectical interplay of external and internal socioeconomic and political factors have had a bearing on agricultural research. This paper 1. traces the historical formation of agricultural research in developing nations; 2. synthesizes the present state of agricultural biotechnology development in African, Asian and Latin American nations; and 3. unravels the major contradictions of such reality in developing nations with regard to the global and multidimensional phenomenon of the biorevolution.

WESTERN AGRICULTURAL RESEARCH IN HISTORICAL PERSPECTIVE

Western European science spread throughout the New World as an extension of geographical exploration where only the sciences closely related to the project of colonial expansion predominated (Basalla 1967). The role of science was to understand how the physical dimension of geographical variation would support or inhibit the incidence of species in different favorable environments in order to permit the transfer of commercially profitable species from one part of the world to another. That was an *era of economic botany*—then a descriptive science, when scientists, amateur botanists, priests, physicians and missionaries were hunting new plants to be scrutinized for their use as food, fiber, timber, dye or medicine (Brockway 1979).

Western European empires created an extensive network of botanical gardens; these were the first systematic efforts to establish monopolies on tropical plants. By 1800 there were over 1,600 botanical gardens in tropical colonies aiming at advancing the political and economic interests of European empires disguised as scientific interests (Brockway 1979). In Brazil, the Rio de Janeiro Botanical Garden, created with the suggestive name of Esta^ao dẽ Aclimaifão, was an example of that past kind of institutional effort (de Souza Silva 1989). Later, following the success of Justus Liebigs agricultural chemistry after the mid-19th century, there was a worldwide experiment station movement which affected the original importance of botanical gardens. By 1930 there were over 1,400 experiment stations. In Europe these stations emerged in response to a changing socioeconomic environment and tended to focus on domestic crops. In contrast, they were forced upon tropical nations as a result of colonization and tended to focus on export crops, such as sugar, jute, rubber, coffee, cocoa, tea and bananas (Busch and Sachs 1981). The Instituto Agrondmico de Campinas (IAC), originally called Imperial Esta<^ao Agronomica de Campinas, was Brazil's first agricultural experiment station created as part of that European institution-building movement (de Souza Silva 1989).

Early in this century, the reinterpretation of Mendel's work made it possible for genetics to offer society its most famous product, hybridization, which led to the genetic patent. Then, design replaced accident in plant breeding. But hybridization gained its momentum only with its use in the so-called "Green Revolution," the most far-reaching and systematic application of Mendelian genetics to crop improvement to date. Mendelian genetics deals with the whole plant, and selection is the major force behind production of desired traits. With its birth rooted in politics[1] (Lewontin 1983), the Green Revolution has altered a large part of the sociotechnical and economic basis of world agriculture through its achievements (Borlaug 1984), negative impacts (Byres 1972) and contradictions (Cleaver 1972). Late in the *era of Mendelian genetics,* experiment stations lost their relative importance to the emerging strategic leadership of the International Agricultural Research Centers (IARCs). Created under the leadership of the U.S. most IARCs were established in tropical nations located in the world regions of greatest biodiversity, institutionalizing the process of access to tropical genetic resources by developed nations (de Souza Silva 1989).

Despite all the positive claims regarding the increased world production and productivity of grains as a result of the application of Mendelian genetics (Borlaug 1984), most of the Green Revolution economic contributions were appropriated by the transnational chemical industry. For instance, the former chief economist of the U.S. Department of Agriculture (USDA), J.W. Mellow, believed that the entire program for the Green Revolution was in the first place a fertilizer project (quoted in Shilling 1982:42-43). Indeed, as a representative of the chemical corporations declared in *U.S. News & World Report.* one of the most important results of the Green Revolution is the increased demand in U.S.-made agricultural machines, fertilizers, pesticides, irrigation installations and agricultural equipment (quoted in Shilling 1982:43).

Today, agricultural research in developed and developing nations is again being shaped by global changes (Busch 1992) entering now into the *era of molecular genetics* (de Souza Silva 1994). Under the umbrella of biotechnology, science is now providing scientists with the tools to enter the plants and scrutinize their molecules and cells. While Mendelian genetics allowed plant breeders to perform some genetic transformations in a few crops, molecular genetics provides the key not only to the manipulation of the internal structure of plants but also to their crafting according to plan (Busch et al. 1991). Modern biotechnologies—techniques that use living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for specific uses—include a wide range of technologies from fermentation to genetic engineering. This is why developments in biotechnology can be divided into three generations. The first generation of biotechnologies incorporated the productive use of microbes such as bacteria, yeast and mold in making, for instance, beer, wine, bread and cheese. During the 50s, 60s and 70s, the second generation of biotechnologies came into existence—the developments in molecular biology and the use of microorganisms

[1] Politics was a very important dimension of the Green Revolution since its beginning. Later, Norman Borlaug, also known as the father of the Green Revolution, became a Nobel recipient for Peace, not for biology. And this is politics.

for the production of antibiotics. During the 1970s onwards, the third generation of biotechnologies were developed, comprising a set of different technologies of which the most important is recombinant DNA technology (Commandeur et al. 1993; Sasson 1993).

Biotechnology makes use of basically two sets of technologies: culture and genetic transfer technologies. *Culture technologies* function at the cellular level and above, and involve regenerating entire plants from protoplasts, single cells, tissues, organs or embryos. *Genetic transfer technologies* function at the subcellular level and involve the transfer of one or a few genes between cells, usually of different species. Thus, in contrast with traditional plant breeding, biotechnology 1. utilizes molecular genetics, 2. focuses on the cellular and subcellular levels and 3. uses knowledge about the interior of cells to direct and manipulate the products made (Busch et al. 1991). Again, developing tropical nations witness the growing importance of their genetic resources to fulfill several economic interests of developed countries. For instance, molecular genetics has magnified the existing possibilities in the modern business of biodiversity prospecting—the screening and exploration of biodiversity for commercially valuable genetic and chemical resources (Reid et al. 1993). Because of their biochemical potential for industrial profit, life forms (plants, animals and microorganisms) are now seen by the pharmaceutical industry as biochemical-synthesizers, and forests, like Amazonia, as biochemical industrial complexes (de Souza Silva 1994).

It is following the logic of this historical context that this paper identifies the present role, place and contradictions of agricultural biotechnology in developing nations.

AGRICULTURAL BIOTECHNOLOGY IN THE DEVELOPING WORLD[2]

Developing nations do not form a homogeneous block. They do not have similar social formations, equal scientific-technological capacities and/or convergent socioeconomic and political goals and interests (de Souza Silva 1989). There is no such thing as an average developing country that would allow one to make generalizations about the nature and direction of what developing nations are doing in agricultural biotechnology and about how they will benefit from and be affected by agricultural biotechnology and the impacts of the biorevolution. Thus, developing nations have unequal capacities to develop agricultural biotechnology and to deal with its overall impacts. Actually, they are divided into developing nations with and without such ca-

[2] For restrictions of space, this paper focuses only on those countries which are better off with regard to their capacity to develop agricultural biotechnology and to couple it with the overall impact of the world application of the new biotechnologies. The most detailed description of the development of biotechnology in African, Asian, Latin American, Caribbean and Arab countries can be found in Sasson (1993). An excellent analysis of the overall impacts of the new biotechnologies on developing nations can be found in Commandeur et al. (1993).

pacity. That is why, according to Commandeur et al. (1993), 1. Brazil and Malaysia which are net exporters of agricultural products and have a high technological potential are better off than 2. India and China, countries that are net importers of agricultural products and have a high technological potential, which in turn are better off than 3. most African and Caribbean countries that are net exporters of agricultural products and have low technological potential, which in turn are better off than 4. Bangladesh and Ethiopia, countries that are net importers of agricultural products and have low technological capacity.

Following the same logic, according to the development stage of their involvement in biotechnology, developing nations may be categorized as follows:

1. Countries which have an interest but no direct involvement in modern biotechnology as yet;

2. Countries with a national policy and a research program in, mainly, conventional biotechnology, but with little in-country biotechnology as yet;

3. Countries with a national policy and a research program in, mainly, conventional biotechnology, combined with established linkages with industrialized countries for the training of scientists and technology transfer; and

4. Countries which have a national policy and a research program in modern biotechnology together with strong international linkages in both public and private sectors (Sasson 1993:25).

Within this categorization, Bangladesh, Bhutan, Burma, Nepal, Sri Lanka and Viet Nam fit into category 1; Indonesia, Malaysia, Pakistan, Philippines and Thailand fit into category 2; Argentina, Brazil, China, India and Mexico fit into category 3; the Republic of Korea fits into category 4 because its programs, infrastructure, support to the private sector, patenting regulations, etc., are almost analogous to those in developed nations (Sasson 1993). Although most developing countries belong to categories 1, 2 and 3, some of them, such as Argentina, Brazil, India and Mexico have been able to move quickly towards category 4.

AGRICULTURAL BIOTECHNOLOGY IN AFRICA

Africa is by far the world region where agricultural biotechnology is least developed, especially for factors associated with the long standing economic recession affecting the continent, along with the low capacity in more conventional research areas such as conventional plant breeding, which are fundamental for supporting the development of scientific capacity in agricultural biotechnology (Commander et al. 1993; Sasson 1993). In a few countries, such as Kenya and Zimbabwe, biotechnology programs and priorities are currently defined; Kenya gives high priority to the micropropagation of disease-free planting materials, and Zimbabwe expects to develop high-yielding crops, food technology, improved horticultural crops and improved animal breeding.

Nigeria has defined the reduction of food imports as a major goal for agricultural biotechnology. Sasson (1993:647-745) has written detailed information about the development of agricultural biotechnology in most African countries.

AGRICULTURAL BIOTECHNOLOGY IN ASIA

Most Asian countries have a large involvement in modern biotechnology, though the goals for its application and the means for stimulating its development are highly different in the various countries. South Korea, Singapore and other Asian newly industrialized countries (NICs) have moved from a labor-intensive to a technology-intensive economy in which modern biotechnology is being applied for the production of high added-value products, mainly pharmaceuticals (Commandeur et al. 1993).

By their size, natural resources and large population, India and China deserve some attention. Among Asian developing nations, India has one of the most impressive research efforts in the public sector regarding agricultural biotechnology (Sasson 1993). State-owned companies play a strategic role in India's industrial and agricultural sector. One of the greatest comparative advantages of India regarding the development of agricultural biotechnology is its large capacity in traditional plant breeding. With the recent move towards economic liberalization in India, however, the trends are 1. the decline of public sector and the rise of private sector research in agricultural biotechnology; 2. opening of new sectors for private investments; 3. adaptation of the legal framework; and 4. stimulus to foreign investments in biotechnology (Commandeur et al. 1993).

Starting in 1986, China's economic policy defined biotechnology research and development (R&D) as a national priority. What is most impressive about China with regard to its capacity to enter the biotechnology race is its enormous experience and long established scientific capacity in traditional forms of biotechnology such as the production of antibiotics, biopetrol, alcohol, etc. However, in order to stimulate the development of the new biotechnologies, China has become too dependent on foreign technology. Moreover, scarcity of highly skilled labor, limited property protection, difficulties with foreign exchange and political instability have restricted foreign investors' enthusiasm (Pistorius 1991). See Sasson (1993:45-371) for detailed information on agricultural biotechnology in most Asian nations.

AGRICULTURAL BIOTECHNOLOGY IN LATIN AMERICA

Most Latin American countries established national biotechnology programs in the 1980s for the coordination of research in order to channel international cooperation and to stimulate linkages with industry. Argentina, Brazil, Cuba and Mexico have long-established, special R8cD institutes. Argentina, Brazil and Chile are the countries holding the most important stimulation programs on the continent, emphasizing the introduction of agricultural biotechnology within applied research and having created special biotechnology centers within their national agricultural research systems (Correa 1992). However, the relationship between public biotechnology research and industry is still weak due mainly to the scarcity of personnel qualified to convert laboratory results into production at an industrial scale and the scientific bias of public research which prevents the traditionally strong basic biological research capacity in this region from producing concrete applications useful to agriculture and industry (Commandeur et al. 1993). Nevertheless, Latin American countries already present a substantial industrial activity in biotechnology, and about 75 percent of the existing industry is locally owned. In Latin America, increasingly, industry has been seen as the motor of biotechnology policies where the emphasis is being put on technological innovation of industry instead of on the stimulation of the science and technology sector. Thus, national technology policies focus more on access to global biotechnology than on the development of a national biotechnology (i.e., biotechnology developed in the country itself through basic research). Though limited by scarcity of capital, Argentina, Brazil, Cuba and Mexico are among the few nations consciously investing in basic research. Argentina, Brazil, Chile, Colombia, Cuba, Mexico and Uruguay are the Latin American nations where agricultural biotechnology is most developed. See Sasson (1993: 373-586) for detailed information on agricultural biotechnology in most developing nations of Latin America and the Caribbean.

CONTRADICTIONS OF THE BIOREVOLUTION FOR DEVELOPING NATIONS

Potentially, agricultural biotechnology may contribute to developing nations with positive, quantitative as well as qualitative changes. However, all the promises made in the name of biotechnology are based on its scientific/technological potential. Generally, the political process through which economically strong social factors influence the nature and direction of the development of agricultural biotechnology in developed and developing nations is either underemphasized or simply neglected. Agricultural biotechnology, like most other technological breakthroughs before it, will lead to considerable structural changes in food and fiber production, international trade and cooperation. Historical evidence demonstrates that such processes have not occurred without contradictions. The biorevolution with its scientific/technological, social, economic and political/ideological dimensions is also producing some major contradictions which will affect developing nations differentially (de Souza Silva 1988). Four of these contradictions are discussed below.

Social Problems and Technical Solutions

In most of the literature regarding the potential contributions of the biorevolution to developing nations, socioeconomic problems have been reduced to their technological dimension so that agricultural biotechnology seems to be the most plausible technical solution. However, reality shows that socioeconomic problems are multidimensional problems. For instance, hunger still persists even in countries which produce more than their population can eat such as the U.S.—the world largest food producer, exporter and donor. Also, Brazil, considered the world's third or fourth largest exporter of agriculture-based products, holds the sixth or seventh most ill-fed population on the planet (de Souza Silva 1988). Thus even excess does not guarantee access to food. Income distribution problems are not solved by production technologies such as agricultural biotechnologies.

Industrial and Agricultural Revolutions

The biorevolution promises an industrial revolution, mainly in developed countries, at the same time as it promises an agricultural revolution, mainly in developing nations. However, the achievement of both revolutions will promote 1. the separation of crops from their natural environments; 2. the separation of crops from their intrinsic characteristics; and 3. the separation of agriculture from food production (Commandeur et al. 1993). For example, genetic engineering may weaken the tropical-temperate dichotomy in agriculture making possible the horizontal dislocation of food and fiber production from developing to developed nations. Also, the appropriation of scientific/technological advances in biotechnology by the food and fiber industry makes possible the vertical dislocation of food and fiber production from agricultural fields to industrial assembly lines. Horizontal as well as vertical dislocations may not just disrupt the market of some specific tropical products, they may also lead to the collapse of entire developing economies. Massive labor displacement is the least that may happen in the tropical world (de Souza Silva 1988; RIS 1988; Busch et al. 1991; Hobbelink 1991; Commandeur et al. 1993).

Social Goals and Private Gains

Some of the world's most pressing social goals that could be achieved with the support of agricultural biotechnology are not necessarily economically attractive. Yet one of the most striking characteristics of developments in agricultural biotechnology is its trend towards privatization. With the increasing establishment of strong property-protection systems worldwide, the biorevolution has been strengthened as a profit-driven business. Now, humankind is witnessing the trend towards the commodification of nature—the extension of the commodity logic and form to the natural and cultural resources of biodiversity. Is the commodification of nature compatible with developed countries' claims regarding biodiversity conservation? Their claims to save the rainforests sound like the ideology of philanthropy. The most powerful chemical and pharmaceutical industries from developed nations are willing to invest and support conservation in tropical countries because this is the best policy strategy to assure their continuous access to crucial tropical genetic resources (de Souza Silva 1994).

The Cooperation-Competition Paradox

We are living through the era of the cooperation-competition paradox: the situation in which any country in the world needs to cooperate with their actual or potential competitors and to compete with nations from which it needs cooperation (de Souza Silva 1989). However, not all countries are aware of that. Although most of the existing literature regarding agricultural biotechnology talks about the need for cooperation between developed and developing nations, reality shows that competition and temporary alliances are prevailing over cooperation and continuous partnerships in the international arena. The most striking example of such a posture is the well-known attempt made under the leadership of the U.S. to press developing-nation governments to introduce strong intellectual property-protection systems. Why impose equal property-protection procedures in developing nations which have unequal scientific/technological capacities? It is ironic that most developed countries did not have strong legal systems for intellectual property protection while they were developing. The U.S. in the 19th century and Japan through most of the 20th century were engaged in technology/product piracy. For instance, industrialized nations refused to grant product patents on drugs until their pharmaceutical industries were well established: France in 1958, West Germany in 1968, Japan in 1976, Switzerland in 1977 and Italy in 1978. As late as 1990, Finland, Norway and Spain did not patent pharmaceutical processes and products. More recently, the four tigers of East Asia—Taiwan, South Korea, Hong Kong and Singapore—became industrialized with the support of weak intellectual property protection (Chudnovsky 1983; Lesser 1990; Vellvé and Hobbelink 1992).

These are just a few examples of major contradictions permeating the development of agricultural biotechnology in developed and developing nations. For further analysis on these and other contradictions see, for instance, de Souza Silva (1988), RIS (1988), Juma (1989), Busch et al. (1991), Hobbelink (1991) and Commandeur et al. (1993).

CONCLUSION

Agricultural biotechnology holds the scientific/technological potential to deliver many benefits to developing nations; yet, its present development worldwide is not without contradictions. This paper has presented historical evidence to demonstrate that, as with other previous technological revolutions, there is a socially constructed political process through which powerful socioeconomic and political forces interact to shape the nature and direction the biorevolution will take regarding its positive as well as negative impacts on tropical agriculture. In such a context, agricultural biotechnology is a necessary, but not a sufficient, condition to assure access to food by all social groups. If agricultural biotechnology is to be developed for the public good, developing nations should address at least eight policy strategies to deal with the present unequal situation regarding agricultural biotechnology to establish:

• "Early warning systems" to monitor major developments in agricultural biotechnology worldwide in order to have the strategic information to project their likely impacts on tropical agriculture so that special policies could be set up to take advantage of the emerging opportunities and to avoid or reduce the emerging negative implications;

• A set of national as well as transnational cooperation policies which could increase South-South solidarity aiming at improving scientific/technological capacity with regard to the development of agricultural biotechnology and the conservation of tropical biodiversity. National capacity to develop and use agricultural biotechnology and to transform genetic resources for the benefit of society must be the major goal;

• A set of negotiation mechanisms to strengthen developing nation bargaining power in agreements with developed countries and with international aid agencies;

• Concrete mechanisms to assure the direct participation of organized social segments of society in the decision and policymaking processes regarding the nature and direction that agricultural biotechnology development should take;

• Motivation/development programs aiming at mobilizing and maintaining the intelligence/creativity of the existing national human talents regarding agricultural biotechnology in order to avoid a brain-drain from developing to developed nations;

• Effective mechanisms to increase national integration between public and private sectors aiming at strengthening domestic industrial capacity in order to reduce the existing dependence on multinational industries;

• Specific policies to strengthen public sector agricultural biotechnology aimed at taking care of research and development agendas which are not economically attractive to the private sector; and

• Intelligent investment policies; policies which promote investments in factors that hold the power to transform other factors. In this perspective, investments in education, science, and technology if well articulated by a set of converging national development policies, may be the difference between the present development distortions and technological dependence in tropical nations and a future with relatively greater national self-sufficiency in those matters.

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