International Environmental
Law Research Centre

Public / Private Partnerships for Biotechnology in Africa:

The Future Agenda

Published by
African Centre for Technology Studies, Nairobi
2001

Patricia Kameri-Mbote, David Wafula & Norman Clark

International Environmental Law Research Centre
International Environmental House
Chemin de Balexert 7 & 9
1219 Châtelaine
Geneva, Switzerland
E-mail: info@ielrc.org

Table of Content

I. Introduction

This monograph is concerned with the role of public/private sector partnerships in the development of African biotechnology. Its basic message is that since the role of such partnerships is becoming increasingly common in the Northern industrialized countries, it seems sensible to consider similar possibilities in countries at an earlier stage of economic development. Arguably, the need is especially pressing in technology development since it is technological change that will drive such countries forward in the coming decades. And of course biotechnology is crucial in this respect simply because its generic status has implications for economic production in sectors as widely dispersed as agriculture, health, industry and the environment. In fact, world growth in biotechnology Research and Development (R&D) has been rapid in recent years but most takes place in the private sector. Thus private agricultural R&D expenditures grew from $3.9 billion in 1981 to more than $7 billion in 1993. In 1998 Monsanto alone allocated some $1.2 billion for biotechnology research while in the same year Novartis announced the establishment of its *Agricultural Discovery Institute* (for genomic studies) at a cost of $600 million. In contrast the CGIAR[1], the largest public spender in the same area spends around $370 annually, only 7 per cent of which is on biotechnology.[2]

The issue here is really quite simple: By concentrating R&D in areas of interest to corporate profitability there is a real danger that the needs of poorer groups in poorer countries will gel by-passed. Moreover, although this has something to do with possible impacts on the conditions facing law-income farmers (such as on seed supply and environmental stress), the main reason is simply that there are few mechanisms available to harness the technology for poverty alleviation. Jefferson,[3] for example, argues that much of the relevant information in plant biotechnology is already in the public domain (and has been produced through public R&D). But there is still a great deal of ignorance on the part of Third World groups about where it is and how to get access to it. Mugabe and Clark[4] make a similar point in relation to the impact of intellectual property rights (lPR) on the transfer of biotechnology to the Third World. And Juma[5] in a review of a recent publication states that "– it is not only the genetic resources that matter, but the knowledge that is generated about the value and use of these resources. The countries that have invested in the use of genetic resources seem to have benefited more than the countries that simply provide the resources"[6]

Both Jefferson[7] and Mugabe and Clark[8] go on to argue that it is not so much the "privately biased" nature of the R&D that is the problem as is the failure of Third World countries to build up autonomous capacity in this key technology for the 21st century. Paradoxically, it is here that the private sector can be of great help, since one important mechanism for building such capacity is to use alliances with private firms to gain access to aspects of biotechnology but to do so in a context that permits autonomous learning to take place. And there are now many examples of innovative mechanisms that have been developed for precisely this purpose. The question is how best can Third World governments develop policies that will assist in this regard.

The potential role of biotechnology in economic development has been the subject of inquiry for some time and has been stimulated by interrelated concerns such as food insecurity, population pressure and intensifying poverty levels. The most crucial issue is the lack of congruence between world food production levels and global population levels. Projections show a decreased world agricultural growth rate from three per cent in the 1960s to two per cent in the last decade. And it is likely that world population growth will continue to outpace food production up to the year 2020. The linkage between poverty and food security is also an issue of grave concern. Currently it is estimated that more than 1.3 billion people in the developing countries are absolutely poor, with incomes of a dollar a day or less per person.[9] It is widely believed that poverty alleviation and increased food security are two sides of the same coin. In this regard, biotechnology has been proposed as an important and powerful tool.[10] The ability of individual countries to tap the potential benefits of and to manage biotechnology for national development is predicated on national competitiveness in technology generally and biotechnology in particular.

It is in this context that we explore the merits of public sector-private industry collaboration in agricultural biotechnology research and development. Using examples from the industrialized countries, the paper shows that public-private partnerships in biotechnology are an expression of more general trends towards a changing role for the state in economic production. Section II begins by setting out the core arguments for the respective roles of public and private modes of resource management. Whereas the traditional view was that there is a hard and fast distinction between the two, modern developments see resource mobilization more as a continuum. There are some types of commodities that clearly should be produced either by private firms or by the state. However, there are others where the distinction is not so clear and where some combination may be more desirable on a variety of grounds. Section III goes on to show how public/private partnerships in biotechnology have become increasingly commonplace in many industrialized countries, often promoted by new forms of institutional arrangements and public policy. Section IV explores recent developments in developing countries and provides a range of illustrative case studies (including importantly a number of African examples) that show what can be possible in this context. Section V goes on to suggest possibilities for future policy on the part of Third World governments before, finally, Section VI draws some general conclusions. The paper ends by arguing that stimulation and enlargement of public-private partnerships in developing countries and specifically in African countries where such arrangements are underdeveloped, is the key to any meaningful engagement in biotechnology and to its contribution to national development.

II. Public and private goods

One of the fascinating features of contemporary economic development as we move into a new millennium is the way in which institutional reforms are breaking new ground. And nowhere is this clearer than in the area of public/private sector partnerships. The traditional view, based largely on the neo-classical position in economic analysis, is that there is a natural division of labour between the public sector which is responsible for the production of public goods, and the private sector which does the same for private goods. The former are commodities such as "defence" that cannot be given a market price and are therefore best funded out of collective tax revenues. Conversely, the latter are commodities that can be allocated using prices and therefore the market mechanism is the correct institutional form to be used. Arguably, what has changed this polarization is the growth of public sector expenditures as a proportion of national product in most countries, but especially in the richer industrial North. The resultant need for increased taxation to pay for these has proved bath politically unpopular and in some cases simply unmanageable. And where revenues cannot be raised, the result has often been a decline in the level and quality of such "public" goods and services.

The factors behind such "skewed" growth are many and complex but for this paper two are especially important: The first is the increased scarcity of environmental resources in relation to other forms of production, which in turn is a result of very rapid (and global) industrial expansion. During the early stages of industrialization it was reasonable to assume that environmental pollution could be largely discounted. Since industrial production was a relatively minor activity the environment was essentially a “free good”. But nowadays, environmental resources are a key constraint on economic growth as seen by the sheer volume of environmental regulations common in many countries and by the growth of international environmental agreements. And since environmental resources have many of the characteristics of public goods, paying for their use involves similar revenue-raising considerations. The second factor is the growing knowledge intensity of economic production. Whereas economic production in the 19th and early 20th century was largely craft based, as time has gone on the role of organized scientific knowledge has become increasingly important. Nowadays, there is a range of key generic technologies that impinge on every sector of an industrial economy and their propagation has placed excessive burdens on a publicly financed Research and Education (RE) sector that has difficulty in coping with available resources.

As to why demands for “private” goods are continuing to rise, even in relatively affluent countries, there is no definitive answer. One of the most persuasive sets of ideas, however, may be found in Hirsch’s theory of “positional goods” which he proposed in the late 1970s.[11] Hirsch’s view is that as economic growth takes place consumers shift purchases from commodities like food, clothing and shelter that fulfil fundamental needs, to commodities whose utility has a strong social component. This second class he calls “positional goods” to demonstrate that their capacity to provide satisfaction is determined by how widely they are bought and sold. In an era where a car is owned by the very few, its purchase may provide great satisfaction but where practically everybody has one, that same car’s capacity to provide utility is substantially diminished. Factors such as congestion, pollution and envy intrude to a high degree. Similarly, with education. If everybody has a high school diploma it may soon be necessary to acquire a university degree to be successful in any job market. Hirsch uses this analysis to explain why growing affluence does not cause the demand for public goods to increase proportionately but precisely the opposite. Galbraith’s “affluent society” (in which glaring poverty co-exists with ostentatious wealth) is not so much a paradox as an inevitable result of the growth of modern capitalism.[12]

But given that there is a distinction between alternative modes of management, what are the essential differences and how are these differences beginning to become diffuse? The theory of public goods sets out the distinction in terms of divisibility[13] and excludability. In the former case, the property of divisibility increases the ease with which property rights can be assigned to commodities and therefore the ease with which the private market can function in its allocation. Once consumer A buys an ice cream from a shop, that unit of ice cream is no longer available to consumers B, C, etc. Conversely the consumption of defence or street lighting services cannot be sub-divided in this way and so on these grounds alone the free market is not normally used to provide them. The property of “excludability” refers to the capacity of a commodity’s owner to prevent access to it (and so to exclude its consumption by others). The owner of a gold mine, for example, can prevent access to the gold if he/she chooses to do so. Thus public goods in general are non-divisible and non-excludable, whereas the opposite is the case for private goods.[14]

In reality, of course, things are not so clear cut. Some commodities may traditionally have been publicly provided (e.g. services of public lending libraries) but could in principle be privatised. Such goods are often called “merit goods” and much of the recent privatisation debate has revolved around the issue of the extent to which specific commodity classes like health, education and research, power and transport (traditionally the responsibility of the state) comprise merit goods rather than public goods. Developing countries are no strangers to this debate though here the backdrop has not been so much a response to taxation pressures as much as to the requirements of stabilization finance. It may well be that the issues are quite similar but the reality is that privatisation measures are an intrinsic component of Structural Adjustment Policies (SAPs) specified by bodies like the IMF as a condition for obtaining loans. One area that is central to this generic issue is that of technological development. It has now been clear for some time that the capacity to harness technology in the service of economic production is a key component of sustainable development. The problem lies, however, in how best it should be provided.

The traditional view has been rather analogous to the private/public distinction outlined above and is based upon the idea of technology as “knowledge led”. Under this view a distinction is made between the knowledge discovery process (scientific R&D) and the use of this knowledge for economic purposes (technological change). The former is a “public good” activity since pure knowledge is non-excludable (it is hard for the producer of information to exclude its use once it enters the public domain) and non-divisible (it is hard to divide up such information into units to which property rights can then be attached). As such it should best be produced through some form of collective action (usually by the state) and this is how universities and R&D bodies are normally funded. Conversely, as soon as knowledge is directly connected to economic production (i.e. as soon as it becomes “productive technology”) then to that extent it becomes private property and should be given the character of a private good.

Though we now know that this type of thinking grossly oversimplifies a complex reality, nevertheless much of the institutional dualism we see around the world stems from precisely this source. The publicly funded research sector (universities, R&D institutes) produces “shelves” of raw technology. Private interests (firms) then draw on this source to aid the process of production for profit. But just as the privatisation debates are breaking down the old sharp public/private distinction for production as a whole, so the viability of such dualism is increasingly being called into question as being unsuited to modern needs of technology development. And it is precisely on this point that international trends in biotechnology are so significant since in practically all countries public/private partnerships appear to have been a key component.

In 1991 Echeverria and Thirtle came up with a useful typology of public sector and private industry establishments. In their view, private industry can be characterized as either commercial or non-commercial. In the commercial context, private sector means input companies, farm sector and food processing companies. Non-commercial organizations comprise foundations and non-governmental organizations. Public sector on the other band, includes national institutes for agricultural research, universities and parastatal organizations.[15] From this typology, we can define public-private partnerships for biotechnology as strategic collaboration links forged on the basis of converging research needs and interests, with the purpose of advancing in research and development. Collaboration is based on the premise that common problems can be solved easily and objectives met more efficiently when research is conducted jointly. However, the partnership perspective is not a static process. It is a process that continually seeks better and more appropriate linkages.[16]

The impetus for public-private partnerships for biotechnology is in broad terms a search for synergy in existing institutions and the direction of this towards common goals. Among the benefits that these partnerships can provide is access to proprietary technologies and research infrastructure, enlarged managerial and technical expertise and enhanced intellectual capacity. These arrangements allow the participants to benefit and complement each other on the basis of comparative advantages that they possess. The public sector can, for instance, benefit from the specialist knowledge, know-how and patented intellectual property at the disposal of the private sector. At the same time the flow of information that public enterprises are repositories of, such as government policies having a direct impact on the operations of the private sector, is of immense importance. For example, a seed producing company can be trying to increase seed sales at the same time as the government is interested in lowering such prices or subsidised government seed companies may sell their seeds at less than real cost. Such measures can drive private firms out of business or at least discourage them from investing in research.[17] Partnerships between public and private actors can thus be tailored to find common ground and to achieve a balance in the benefits the various participants gain from the relationship. At the international level, collaboration bridges the gap in biotechnology research and development by facilitating the transfer of technology and expertise from the developed countries to the developing ones. Such partnerships act as a conduit, making it possible for international biotechnology companies to diffuse their technologies, products and services to developing countries.

Private industry accounts for about eighty per cent of biotechnology research and development in the industrialized countries. This may be due to the shifts in economic policies in these countries towards an emphasis on market forces, trade liberalisation and macro-economic stabilization, which have accelerated the trend towards increased involvement of the private sector. In the Netherlands, the United Kingdom and the United States, private sector agricultural research surpasses that of the public sector.[18] Privatisation of scientific research in agricultural biotechnology has been promoted further by legal mechanisms like strong patent laws and enforced Intellectual Property Rights (IPRs). For example, Plant Breeders' Rights (PBRs) encourage the private sector to carry out biotechnology research and development activities on new varieties of plants and have played an important role in the development of the seed industry.[19] Public-private partnerships for biotechnology are therefore not a new phenomenon. Although confined originally to relationships between universities and industries, collaboration between the private industry and the public sector, in the industrialized countries, has existed for at least two decades and as we shall see in the following sections has recently begun to take on interesting and novel institutional forms.

III. Evolution of biotechnology and current trends

Brief history

The 1992 Convention on Biological Diversity (CBD) defined biotechnology as "any technological applications that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific uses".[20] Biotechnology covers diverse applications including genome mapping, tissue culture, immunological techniques, molecular genetics, genetic transformation and recombinant DNA techniques in all facets of production. Biotechnology is sometimes referred to as 'locomotive technology' because of its pervasive, rapidly evolving and dynamic nature.[21] It has contributed to tremendous transformation and revolution in many areas of the pharmaceutical, agricultural and chemical industries characterized by major institutional and scientific developments.

The evolution of modern biotechnology can be traced back to 1900 when Mendel's laws of genetics were rediscovered. The technology has gone through three major stages, namely, from household traditional fermentation to large scale fermentation industry using 'low-level' techniques to the now modern biotechnology characterized by high-level techniques of genetic engineering, embryo transfer, tissue culture and others. A major step in human control over genetic traits was taken in the 1920s when Muller and Stadler discovered that radiation could induce mutations in animals and plants. In the 1930s and 1940s, several new methods of chromosome and gene manipulation were discovered, such as the use of colchicine to achieve a doubling in chromosome number, commercial exploitation of hybrid vigour in maize and other crops, use of chemicals such as nitrogen mustard and ethyl methane sulphate to reduce mutations, and techniques such as tissue culture and embryo rescue to make viable hybrids from distantly related species. Since then there has been steady progress in the understanding of the genetic make-up of all living organisms ranging from microbes to humans.[22] The discovery of the double helix structure of DNA in 1953 by James Watson and Francis Crick was another turning point in the understanding of genetic material.[23]

Laboratory research in the United Kingdom and the United States of America gave rise to modern biotechnology in the early 1970s. Investment in scientific research and new information technologies contributed significantly to this development. It is noteworthy that in the early stages motivations and interests of scientists and scientific institutions (as opposed to industrial or economic demands) drove research and development (R&D)

activities leading to the establishment of the biotechnology industry. Indeed developments in molecular biology rDNA and biotechnology stimulated the entry of pharmaceutical and chemical companies into the field in the late 1970s. The time lag between developments in biotechnology and the entry of these two industries was by no means short. Chemical companies took an even longer time to invest in biotechnology because of lack of awareness of the implications of the technology. For instance, Monsanto and other chemical companies were initially sceptical and remained passive observers. Another reason for the late entry of industry into biotechnology is that molecular biology research had been for the most part concentrated in, and confined to, the medical schools and biology departments of universities, where pharmaceutical companies funded much research.

Chemical companies began to invest in biotechnology in 1977 when they realized that biotechnology could be used to create new products for agriculture. By 1980 a number of multinational companies had made initial commitments to biotechnology and by 1983 things had changed drastically. Large chemical and pharmaceutical companies began to make heavy investments in biotechnology. This trend was accompanied by a rapid transition from Mendelian to molecular genetic applications in agriculture, medicine and industry.[24] The 1990s have seen dramatic advances in our understanding of how biological organisms function at the molecular level, as well as in our ability to analyse, understand, and manipulate DNA molecules. The entire process has been accelerated by the Human Genome project, which has invested substantial public and private resources into the development of new technologies to work with human genes. The same technologies are directly applicable to other organisms, including plants and animals. This has given rise to the scientific discipline of genomics, which has contributed to powerful new approaches to identify the functions of genes and their application in agriculture and medicine. These new discoveries and their commercial application have helped to promote the biotechnology industry mainly in North America and Europe. Indeed several large corporations in Europe and the United States of America have made major investments to adapt these technologies to the production of improved plant varieties of agricultural importance for large-scale commercial agriculture.[25]

In 1999 over 70 genetically modified (transgenic) varieties of crops were registered for commercial cultivation worldwide. These include new varieties of cotton, potato, pumpkin, tobacco, tomato and clove. More than 15,000 field trials have been undertaken globally. New genetic modifications of more than 100 plant species are growing in laboratories, greenhouses, or in the field, providing farmers with new agronomic traits, particularly herbicide tolerance and pest resistance that enable them to grow these crops more easily and profitably. In 1999 the global area under genetically improved crops was 40 million hectares mainly of corn (maize), soya bean, cotton, canola (rappelled) and potatoes. Eighty five per cent of this area is in North America (USA and Canada) and the remaining fifteen per cent in developing countries notably Argentina, China, Mexico and South Africa.[26]

Key components of modern biotechnology

Genomics:	the molecular characterization of all species.
Bioinformatics Transformation:	the assembly of data from genomic analysis into accessible forms the introduction of one or more genes conferring potentially useful traits into plants, livestock, fish and tree species.
Molecular breeding:	the identification and evaluation of desirable traits in breeding programs by the use of marker assisted selection, from plants, trees, animals and fish.
Diagnostics:	the use of molecular characterization to provide more accurate and rapid identification of pathogens and other organisms.
Vaccine technology:	the use of modern immunology to develop recombinant DNA vaccines for improving control against lethal disease.

Source: Persley and Doyle[27]

Partnerships in the North

At the level of individual industrialized countries public/private partnerships can be seen in a number of different forms but with striking similarities at the same time. In the US, for example, the impetus for closer university-industry relations was fostered by the goodwill of the federal government which perceived the university as a source of new technologies that could spark sustained long-term recovery. It put in place numerous initiatives to reinforce university-industry linkages. Specific programmes included passage of the 1980 Tax Reform Act, which provided tax write offs for industry-funded university research and development. The government also provided 'seed' money to finance research arrangements consisting of a consortium of universities and several industries.[28]

Industries on their part perceived universities as areas concentrated with highly trained professionals and experienced technicians. Collaboration between the two in biotechnology R&D has taken place along two main dimensions: The first has involved university professors working as consultants, or sitting on scientific advisory boards of companies. The second dimension has consisted of formal contractual arrangements between the university or departments of the university, and industry. Some universities have succeeded in securing industrial funding to create research centres or institutions. In 1974, for instance, the Harvard Medical School and Monsanto entered into a twelve-year agreement with funding of $23 million. The agreement was driven by the realization on the part of Monsanto that biochemistry was centre-stage for universities. In this arrangement, the collaboration had the objective of utilizing the human capacity of the university biochemistry department. The contract among other things made provision for construction of industrial facilities to supply biological research materials. In return, Monsanto was given the right to secure an exclusive worldwide license for all inventions or discoveries made in connection with the project agreement.[29]

The Harvard-Monsanto agreement, though not involving genetic engineering, represented a new type of industry-university relationship in which substantial resources were directed to specific researchers who undertook their work while remaining at the university. The first major biotechnology contract was signed between Massachusetts General Hospital (MGH) and Hoechst of Germany, one of the world's largest chemical companies in 1981.[30] The MGH-Hoechst contract embraced a number of components including purchase of equipment, training in genetic engineering techniques and consulting services. In 1981, one month after, the coming into force of the agreement between MGH and Hoechst, Harvard Medical School signed a $6 million, five-year contract with Du Pont to fund the formation of a genetics department.[31] It is noteworthy that university-industry linkages were spurred by the convergence of industry's goals with university priorities and policies.[32] Some institutions used traditional patent marketing entities such as the Research Corporation or new entities such as University Genetics to keep their interactions with industry indirect. Other private companies tried to employ licensing to decrease costs to each university of having its own licensing operation. For example Stanford advanced a proposal to form a university "licensing pool for biotechnology" for the bulk of university biotechnology products. This was geared towards simplifying the patent negotiation for companies that wished to secure a number of licenses.[33]

In the UK developments have taken rather a different form with the government playing a more direct stimulative role. The UK Biotechnology Directorate was established in 1981 to exploit biotechnology innovations emanating from publicly funded research in the UK. There were two primary reasons for its inception. One was the realization that inventions coming from the UK research system were not being nationally exploited and that the commercial benefits were going to other countries (the most famous biotechnology example being the failure to patent the discovery of monoclonal antibodies by the UKMRC).[34] The associated fear was that this pattern would continue unless the UK Government look countervailing action. The second was the impact of the Rothschild Report publIshed in 1971, which advocated a customer-contractual pattern of funding for public R&D. The Rothschild Report had been bath controversial and bitterly contested by established institutions.[35] But its recommendations were substantially implemented by the then UK government and subsequently proved to be only the beginnings of widespread institutional reforms. In particular the concept of science/technology “directorates” was established in 1974 very soon after the Rothschild Report was published. These were conceived as alliances of ministries, research bodies and private industry designed to promote specially promising technological avenues like polymer engineering, marine technology and biotechnology. And in the words of Senker and Sharp,[36] they were specifically designed in response to “the failure of universities and polytechnics to keep pace with a growing national need for underpinning”[37] these new and important fields. Later on the idea of “*Foresight*” was really an extension of the directorate principle, that is an attempt to identify and plan for important technological areas likely to have significant economic impacts.

In the field of biotechnology the UK Government had set up the Spinks Commission to explore ways in which relevant commercialisation could be encouraged. The Commission produced a report in 1980 which recommended that public funds should be used to set up a research based company which would have preferential access to research emanating from UKMRC facilities.[38] Although the government’s response was initially lukewarm another research council (Science and Engineering-SERC) established the Biotechnology Directorate (BD) in 1981 “to foster and promote the British scientific base in biotechnology, specifically university researchers, and to build links between the scientific community and industry”[39]. Key players here were the large pharmaceutical companies who became actively involved in the BD and as a result were able to influence the prioritisation of R&D while at the same time only paying a proportion of the costs involved.

Senker[40] shows how several things resulted from this initiative. First of all different organizations began to interact, probably for the first time in a comprehensive sense. Industry began to appreciate what the public research sector could offer while research communities that had previously not really integrated (such as engineers with natural scientists) were forced into communicating purposefully.[41] This was almost a pre-condition for receiving what were considerable sums of “targeted” research money. A related feature is that of learning how to interact. Since the traditional approach of academic researchers and industrialists was always to hold each other apart it took some time for them to learn new traits. Webster[42] has shown, however, that the last twenty or so years have significantly changed attitudes and that many large US and British companies are entering into long-term “strategic research alliances” with centres of academic excellence. And each partner has clearly built up knowledge about how to make these collaborations successful ones. Another advantage for industry was that of commercial risk reduction since participation in BD research enabled the large pharmaceuticals forms to keep a close eye on basic research advances without having to commit their own funds until the results began to show promise.[43] Nowadays, dominant firms like Glaxo, Beecham, Wellcome and SmithKline maintain close links with universities. Several foreign multinationals, particularly those with research facilities in the UK, have contract research links with the universities. This includes the Monsanto link with Oxford. Other companies such as Sandoz, Merck, Johnson and Johnson and Lilly also have well-established links with Universities.[44]

In continental Europe similar developments have taken place. For example, the former West Germany was recognized as a centre with the largest concentration of biotechnology activities in basic research and industrial activity. Government policy gave strong support to basic research in the universities and institutions such as the Max Planck Society. The Federal Ministry of Research and Technology promoted technology transfer by funding gene centres at four academic locations (Cologne, Heidelberg, Munich and Berlin), establishment of two biotechnology centres, and support of joint university-industry projects through grants and contracts. The German Science Council, which is the highest body responsible for the co-ordination of science policy, is composed of representatives from federal ministries, universities, research institutes and industry. For example Merck, which today is one of the largest pharmaceutical companies in the world, in collaboration with two German companies Rohm and Grvenenthal, and the University of Darmstadt, established a gene centre with Ministry of Research and Technology (BMFT) funding over 50 per cent of the projects. Merck has also collaborated with the University of Heidelberg and the Society for Biotechnology Research (GBF).[45]

In the Netherlands, the government announced a policy of Innovation-Oriented Research Programmes (IOP) in 1979. Its objective was to change the priorities of the government-funded research and make it more relevant to the economic development of the Dutch Industry. The programme enabled university researchers to become acquainted with industrial requirements. This was also facilitated by the creation of Transfer Offices at the universities. The Transfer Offices at the universities had three functions:

(1) to arrange contracts;
(2) to identify research findings of commercial significance and
(3) to assist companies with technical problems by referring them to the appropriate university laboratories.

In addition to the IOP-programmes, there were two types of relationships with individuals namely, contractual and direct. Contracts on the one hand, involved industrial sponsorships that provided some financial support (typically salaries for graduate students) and access to research information. Direct relationships on the other hand involved funding of a project with specific goals, where the university retained property rights. The Holland Biotechnology Company, which functions in the same way as the Transfer Office obtained contracts for university laboratories and sold some of their products (e.g., monoclonal antibodies). These Rand D contracts have been an important source of funds for universities.[46]

These trends show that the need for the private sector research to complement public sector research cannot be overemphasized. Public research usually focuses on basic, long-term work while private sector research operates on a short term, demand-driven and product-specific basis. The importance of private sector participation in agricultural research and development has grown tremendously in the recent years varying from country to country depending on the level of each country's economic development, patents and plant breeders' rights legislation, and various market factors. As economies are transformed and biotechnology becomes more commercialised, the scope of private sector research is expected to broaden. Currently, the aggregate research role of the private sector in developing countries is still small and tends to be concentrated on proprietary technologies. While appreciating that the private sector has enormous resources and can bring about dynamism in biotechnology, the role of the public sector still remains vital in facilitating the operations of the private sector. Sound and stable operations of the private sector to a larger extent depend on favourable and conducive policies put in place by public sector governance mechanisms.

The role of the public sector also remains important in the provision of public goods which do not attract private sector investment because of their accessibility to free riders (groups of people who benefit from goods or services and cannot be forced to pay for such consumption). This discourages the private sector from supplying goods where it is unable to capture benefits. Many of the outputs from biotechnology research exhibit the features of a public good. For example, the private sector cannot exclude access to new seed varieties. Once purchased they can easily be reproduced on the farm. Categorically, their research falls in the public domain. This implies that development of biotechnology R & D cannot successfully take place in the absence of either the public or private sector. A joint approach based on synchronizing and calibrating the strengths and weaknesses of each sector (i.e. a study of comparative advantages) therefore has to be adopted.[47]

Private sector investment in agricultural biotechnology

Particularly important here for developing countries is the status of agricultural biotechnology. Here the scale and scope of private sector investment has been growing drastically over the years. In 1985 of the total $900 million spent in agricultural biotechnology R&D by the public and private sectors, $550 million, the equivalent of almost two-thirds of total expenditures, was spent by the private sector. In 1990 estimates indicated that global R&D expenditure in biotechnology by the private sector was $2.7 billion, slightly more than twice the

$1.3 billion by the public sector. More recent data on investment, and R&D expenditure show that there has been a drastic increase in the decade between 1985 and 1995. It is estimated that investments by the private sector will grow at 12 per cent per year to reach $34 billion by the year 2006.[48] The development of biotechnology applications is capital intensive, requiring substantial long-term investments, which often can be mobilized only by the private sector. Significant investment of the private sector in biotechnology clearly demonstrates the need for the public sector to forge linkages with the private industry in biotechnology R&D to access resources of the private sector.

1985 Global Estimates of R&D Expenditures on Biotechnology by country or Region ($millions)

Country or Region	Private sector	Public sector	**Total**
United states	1,500	600	2,100
European Union	700	300	1,100
Japan	400	200	600
Others	100	200	300
Total	2,700	1,300	**4,000**

Source: Persley, 1990

1985 Global Estimates of Rand D Expenditures on Biotechnology, Private and Public Sectors ($ millions)

Sector	Agricultural Biotechnology	Other	Total
Private	550	2,150	2,700
Public	350	950	1,300
Total	900	3,100	4,000

1985 Rand D Global Expenditures on Agricultural Biotechnology, by Application ($ millions)

Application	Private sector	Public sector	Total
Seeds	350	250	600
Microbiology	200	100	300
Total	550	350	900

Source: Persley, 1990.

IV. The recent Third World experience

Actors in public-private partnerships for biotechnology in developing countries

While most of these developments have taken place in the industrialized countries it is instructive to show some examples of Third World initiatives that have already had some effect. We shall start off at the global level but also give examples from regional and national levels.

A global perspective

At the international level, a number of public-private partnerships exist. The four we focus on here are the International Service for the Acquisition of Agri-biotech Applications (ISAAA), the International Co-operative Biodiversity Group (lCBG) agreements, the Merck/INBio agreement and the Overseas Development Administration/Plant Sciences Research Programme (ODA/PSRP).

The International Service for the Acquisition of Agri-Biotech Applications (ISAAA)

The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) was established in 1992 as a pioneering institutional mechanism for the transfer of agricultural biotechnologies to the Third World. The rationale was that increasingly biotechnologies are becoming proprietary as large companies move into large scale R&D in these areas. Whereas in the past developing countries enjoyed relatively free access to germplasm based technology it was felt that this growing privatisation of knowledge might close off options for Third World agriculture. The lead sponsor was the McKnight Foundation in the US but other foundations and private corporations also contributed funds. Another interesting feature of the ISAAA arrangement is its existence as a network with the key “nodes” being centres of excellence in different countries. For example the AmeriCenter at Cornell University is one such node. It has built up a comprehensive database of relevant biotechnologies, and orchestrates projects under the scheme, usually acting as a middleman between the private sector and recipient institutions in the Third World.

In all there are three network offices that monitor availability of biotechnology for transfer in developing countries (AfriNet for Africa, AsiaNet for Asia and LatiNet for Latin America).[49] For example, AfriNet was established in 1994 and is located in Nairobi. It has been involved in brokering the transfer of tissue culture techniques for rapid multiplication of bananas in Kenya. ISAAA-AfriNet has also made arrangements for scientists from Jomo Kenyatta University of Agriculture and Technology (JKUAT) to be trained in a commercial tissue culture laboratory for banana multiplication in Costa Rica. The network office has also identified private sector investors to both finance commercial tissue culture laboratory work in Kenya and to commercialise the products of that work. In addition ISAAA-AfriNet has contributed towards the purchase of equipment, the identification of marketing and distribution agents for biotechnology products and the establishment of a business plan.

The ISAAA scheme focuses on proven near-market biotechnologies, which have a good chance of productive success and emphasises applications that are environmentally friendly. It concentrates on plant biotechnology (tissue culture, diagnostics and transgenic plants) and places priority on horticulture and forestry. There have been many projects established under the ISAAA scheme ranging from diagnostic probes to detect crucifer disease in vegetables (transferred from a US university to a major regional research centre in Asia with links to many client countries in the region) to a joint project between a British and an Egyptian institute designed to transfer virus resistant tomato technology. But an interesting feature of the scheme is the way it acts as an intermediary for proprietary corporate technology to be channelled to the developing world. Typically, technologies and training are provided free by the corporate sector as an intrinsic part of a project that has been brokered by ISAAA. Recipients are usually R&D bodies in the Third World. Their responsibility is to complete its applicability to local problems and then to facilitate its transfer to the ultimate client – i.e. the poor farmer.

The scheme is not without its critics, however. One view, for example, is that the agreements have tended to focus at the "high-tech" end of the biotechnology spectrum despite the original intention to concentrate more at the "low-tech" end such as tissue culture technology. Another is the worry that problems of crop disease may actually have causes that go beyond that of a specific vector and that there may well be a tendency to settle for too facile "technical fixes". Yet another is the "top-down" flavour of the scheme whereby systemic links to the poor farmer are conspicuous by their absence. This is part of a wider criticism of international agricultural R&D that has been widely stated in the literature over the past decade.[50] In short all the normal criticisms associated with a "science push" approach to technological developments have been presented. Nevertheless, there are also clearly major benefits as well.

It may be helpful to take one of these projects to illustrate these issues more concretely – viz. the Monsanto-CINVESTAV agreement for the transfer of transgenic virus resistant potato technology. CINVESTAV is the acronym for the Centre of Research and Advanced Studies, a Mexican public R&D institute that has been actively building plant biotechnology capacity for some years now. Under the arrangement Monsanto transferred a technology that can protect the potato from two major viruses plus relevant training for scientists and the legal rights to exploit that technology in Mexico. For CINVESTAV the advantages were that the arrangement would add to their long-term capacity in this general field rather than lead to immediate benefits for the poor farmer. There are a number of factors here but according to Bustamente[51] they are mainly concerned with the economics of potato production. For the small farmer the risks associated with normally highly unstable market prices and the high investments typically necessary in this sector (for fertilizers, seed potatoes, insecticides, fungicides and nematocides) make the marginal benefits from this technology very small. And in fact the large production groups in the north of the country have shown the main interest because the technology will improve the profitability of the seed potato sub-sector. However, Commandeur[52] points out that there are likely longer-term benefits from the technology in that there are now better possibilities to apply the resultant capabilities to areas with more direct applicability to problems of poor farmers.

For Monsanto the benefits are also mainly long-term. Potato production in Mexico is exclusively for a home market which is minute in comparison with the company's global perspectives.[53] On the other hand through the collaboration Monsanto has been able to gain insights into Mexican commercial agriculture that could well pay off in the longer term especially as it also is doing similar things in other Third World countries. In this sense the company's technology transfer activities are part of a global market strategy the fruits of which are probably still some distance away. Combined with these strategic advantages there are also possibilities for recruiting skilled labour plus the benefits of image building that always accompany activities of this kind. Commandeur[54] believes that the Monsanto-CINVESTAV agreement will also act as a model for other public/private sector arrangements in the future though he adds the following proviso:

> It can be expected, however, that the character of these collaborations will slowly change. Because of the interests of both the receiving organizations and the target groups, it is likely that their content will show moderate growth in importance in economic value. But along with a growing value of these gene donations, the Donor Company will want to share in the profits. Consequently, the agreements are likely to become less altruistic, and will gradually evolve into commercial agreements between Northern private companies and Southern partners following the principles of the market more and more.[55]

One might also add that to this extent while there may well be benefits for commercial agriculture, the subsistence sector is not likely to benefit to the same extent.

The International Co-operative Biodiversity Croups (ICBC) Programme

The ICBG Programme started its first operational phase in 1993. Its objectives arose directly out of the Convention on Biological Diversity (CBD) agreed at the UNCED "Earth Summit" at Rio in June 1992 and, in particular, those articles concerned with benefit-sharing (10), access to genetic resources (15) and transfer of biotechnology (19). These objectives were to create a programme that would combine conservation with sustainable economic development and drug discovery by linking different types of organization having complementary capacities in this regard. These were Third World R&D institutes and NGOs with interests in the problems and aspirations of indigenous peoples, US academic bodies, and private industrial firms. The main sponsors at the time were three US organizations, the Agency for International Development (USAID), the National Institutes of Health (NIH) and the National Science Foundation (NSI). The programme made five awards in the first round, one of which is summarized in the box above by way of illustration.[56] What is noteworthy from this arrangement is the involvement of quite different types of organization in a "technology system" that combines quite different sorts of capability in the service of a common goal. Moreover, the incentive for the collaboration is not only financial (though that is clearly important). It also has to do with longer-term goals that are highly valued by each participant. The ICBG venture has now entered a second phase with an additional round of bids having been negotiated and agreed upon, on a similar basis to that of the first phase.[57]

The INBio/Merck Agreement

As outlined above, a key element in the 1992 UNCED "Earth Summit" was the bargain struck between the North and the South. In the area of biodiversity the North would provide finance and technology in return for commitments on the part of the South to conserve biological resources and provide access to germplasm to northern firms interested in using such resources commercially. However, as Reid[58] have pointed out, "bioprospecting" on an informal basis had been taking place for some time and there has been considerable anxiety on the part of developing countries that equitable returns have not been forthcoming. It was for this reason that Article 15 of the CBD was negotiated.[59] The INBio/Merck agreement was announced in September 1991. Its main content was an undertaking on the part of the Costa Rica National Biodiversity Institute (lNBio) to supply Merck & Co Ltd. with chemical extracts from wild flora and fauna and micro-organisms from Costa Rica's conservation areas in return for a range of financial and other benefits. These were a "two year research and sampling budget of $1,135,000 and royalties on any resulting commercial products – Merck also agreed to provide technical assistance and training to establish drug research capacity in Costa Rica".[60]

In addition to assistance in putting conservation measures into place an important feature of this agreement has been the building of relevant capacity in biotechnology.[61] As Juma[62] has pointed out, an important ingredient in conservation is the need to "increase returns – by investing in efforts to understand and characterize the genetic composition of the conserved material – INBio's 'production process' starts with basic research and development and moves through the stages of product development. This approach could provide some developing countries with a new base from which to leapfrog into the next wave of technological innovations, based on biotechnology and genetic engineering". He goes on to point out that the Government of Costa Rica has provided considerable legislative and political support to INBio and that that also has improved the capacity of the institution to absorb new technology.

What is also interesting about the INBio case is that the institution has now learned from its experiences with Merck (the agreement has now finished) and has begun to build on these in new ways, in particular by itself transferring know-how to other Third World countries. It has, for example, signed a statement of co-operation with the Indonesian Institute of Sciences and the Ministry of State for Population and the Environment. The objective here appears to be one of providing services that will assist Indonesia to establish similar types of institution and institutional arrangements.

Overseas Development Administration/ Plant Sciences Research Programme (ODA/ PSRP)

Finally, one of the most outstanding examples of public-private partnership for biotechnology at the international level is the Indo-Swiss collaboration in Biotechnology and the Overseas Development Administration/ Plant Sciences Research Programme (ODAIPSRP). Initiated in 1974 as a joint venture between an Indian and Swiss research institute, the project stands out as the longest bilateral initiative in Biotechnology. The programme involves the Department of Biotechnology, New Delhi and five Scientific Institutions throughout India, as well as four partner institutes in Switzerland. Under the auspices of ODA/PRSP the programme is involved in introducing proprietary insect-resistant genes into the sweet potato. A private company in the United Kingdom, which holds the gene patents (Agricultural Genetic Company), has been commissioned by ODA to produce transgenic germplasm of sweet potato expressing proprietary insect-resistance genes. ODA funds the research activities of AGC, which in turn has granted ODA a non-exclusive royalty-free license to the proprietary technology. This arrangement enables ODA to distribute transgenic germplasm resulting from the research programme to plant breeders in developing countries.[63]

Partnerships at the regional level

Regional networks in Biotechnology have taken various forms both formal and informal and functioning at the interinstitutional or intergovernmental level. They offer rare opportunities for sharing or pooling scarce resources. One of the reasons that has led to the emergence of regional partnerships is the realization that biotechnology research was being undertaken in an uncoordinated way with considerable duplication of work.[64] This was viewed as expensive and wasteful in terms of human and material resources. Poor co-ordination is attributed to problems of information flow due to lack of the capacity to exchange information adequately across regions.

Latin America, for example, has a long history of regional collaboration in biotechnology traceable back to 1986/87 when the United Nations Development Programme initiated a regional programme for biotechnology. The programme funded and supported collaborative research and training in different areas of biotechnology. It sought to train, mobilise and facilitate the creation of a network of people with shared interests in biotechnology. Another initiative in Latin America is the Canada-Latin America initiative in Biotechnology, Environment and Sustainable Development, incorporating Mexico, Colombia, Argentina, Cuba, Brazil and Chile. Supported financially by the International Development Research Centre (IDRC) in Canada, the programme had the objective of enabling participating countries to identify national priorities in biotechnology using a common methodology and then, through local focal points, to identify opportunities for public-private sector collaboration. Essentially the programme seeks to facilitate technology transfer by brokering public-private sector collaboration.[65]

In Sub-Saharan Africa, most partnerships and networks deal with plant biotechnology. They encourage dialogue between farmers, scientists and decision-makers to benefit from biotechnology activities of relevance to national and regional needs. They include the following:

- African Association for Biological Nitrogen Fixation (AABNF),
- The International Society for Tropical Root Crops (ISTRC),
- The African Biosciences Network (ABN),
- The MIRCENS in East and West Africa, and
- The Cassava Biotechnology Network (CBN)

Table – ABN Member Countries and Priorities

Regions

Central Africa	Eastern and Southern Africa	West Africa
Burundi, Cameroon, Central African Republic, Chad, Congo, Gabon, Rwanda, Zaire.	Angola, Botswana. Ethiopia, Guinea, Kenya, Lesotho, Malawi, Mozambique, Uganda, Swaziland.	Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Ghana, Guinea Conakry, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone.
Priority areas		
Animal breeding, endemic diseases, forest resources, insect pests, medicinal plants, microbiology, nutritional problems, ornamental plant-breeding, water resources.		

Source: Electronic Journal of Biotechnology Vol.1 no. 3 issue of December 15, 1998.

It is worth noting at this juncture that these partnerships are between public institutions and public universities. The African Biosciences Network (ABN) is a co-operative mechanism linking biological institutions and bioscientists in Sub-Saharan Africa in a common effort aimed at improving the level of know-how and the applications of the biosciences throughout the region. The ABN is the African regional arm of the International Biosciences Networks (IBN) through which the expertise of the international scientific community is brought into close contact with the African network. The main activities of member countries in the African Biosciences Network include research projects carried out by two or more countries on a partnership basis, conferences, symposia, training courses. and workshops. The ABN has also been involved in capacity-building through for example, the training of young African scientists from Cameroon, Cote d'Ivoire and Senegal in Brazil, in the area of nitrogen fixation and biofertilizer production.[66] The African Association for Biological Nitrogen Fixation (AABNF), is a non-governmental association founded in 1982 to promote scientific use of biological nitrogen fixation (BNF) in Africa, for purposes of increasing food production while reducing the need for purchased fertilizer inputs. The International Institute of Tropical Agriculture (IITA), Ibadan and the Microbial Resources Centres (MIRCENS) in Kenya, Senegal and Egypt, played a central role in the founding of this multidisciplinary association of soil scientists, microbiologists, agronomists, climatologists, social economists, breeders, biotechnologists and policy makers interested in the promotion of biological nitrogen fixation systems in Africa. Numerous conferences have been organized by AABNF to share experiences and information, to evaluate what has been done and to chart a course for efficient exploitation of BNF systems in Africa.[67]

The MIRCENS for East Africa at the University of Nairobi encompasses Burundi and Rwanda, while the West Africa MIRCEN has members in Senegal, Cote d'Ivoire and Burkina-Faso. Among the main mandates of the Nairobi MIRCEN are the collection, preservation, storage and distribution of microbial materials for deployment in environmental management in the southern and eastern Africa region (especially Kenya, Uganda, Tanzania, Malawi, and Zimbabwe) and to serve as a taxonomic reference centre. Likewise, the West African MIRCEN has similar mandates and cooperates with research institutes in the region. Culture collection, preservation, and testing are one of the main services provided by the MIRCENS to the regions of East and West Africa. Since most of the collaborating laboratories are not very well equipped, culture identification, testing and preservation are generally carried out in Dakar and in Nairobi with emphasis on rhizobia. The Nairobi MIRCEN has a programme to educate farmers and agricultural extension officers on the merits of proper use of innoculations produced by the MIRCEN in collaboration with a Kenya seed company.[68] The Biotechnology Action Council (BAC) of the United Nations Educational Scientific and Cultural Organization (UNESCO), established a Biotechnology Education and Training Centre (BETCEN) for the African continent at the Roodeplant Vegetable and Ornamental Plant Institute of the Agricultural Research Council (ARC) in

Pretoria, South Africa in 1995. The main objective of the BETCEN for Africa is to provide short and medium term training in plant biotechnology to scientists of Africa. The BETCEN also forms part of the BETCEN network that includes centres in Mexico, Hungary, Palestine and China.

In Burundi the Institute of Agronomic Sciences of Burundi (ISABU) collaborates with the International Centre for Potato Research (CIP) in Peru through a United States Agency for International Development (USAID) grant on micropropagation of the potato for distribution in rural areas. ISABU has modest facilities for media sterilization and weaning of vitro plants. The Institute for Agronomic and Animal Research (IRAZ) is a tripartite regional research body incorporating countries of the Great Lakes region namely: Zaire, Rwanda and Burundi. Research activities are funded partly by the three co-operating countries and partly by donors. At inception a major objective of the institute was to supply disease-free in-vitro plants to ISABU, to the National Institute of Agronomic Studies and Research in Zaire and to the Institute of Agronomic Sciences in Rwanda. The institute has expanded gradually to facilitate other programmes such as capacity building. Notably, IRAZ has made arrangements for technicians from Rwanda to be trained at ISNAR.[69]

The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) is a subregional organization for the National Agricultural Research Systems (NARS) in the ten eastern and central Africa countries. Member NARS include those from Burundi, Democratic Republic of Congo, Eritrea, Ethiopia, Kenya, Madagascar, Rwanda, Sudan, Tanzania and Uganda. The broad objective of ASARECA is to promote agricultural technology transfer collaborations between research and partner organizations in Eastern and Central Africa. This is done by providing competitive grants for researchers to work together with partner institutions and beneficiaries dedicated to the transfer of promising technologies. ASARECA does not aim to replace national research efforts but seeks to complement these efforts by initiating, facilitating and implementing regional collaborative programmes. The association seeks to strengthen partnerships and innovative approaches in technology transfer. Under ASARECA there are different levels of regional co-operation. These comprise: (1) projects created to tackle a specific problem (for example, internet and electronic mail connectivity by the African link project); (2) programmes established to build capacity in an area in which all member NARS are weak (for example, the eastern and central Africa programme for Agricultural Policy Analysis); and (3) initiatives established in areas where there is capacity in the NARS which is not systematically co-ordinated (for example, natural resource management by the African Highlands Initiative).[70]

Public-private partnerships at the national level

The debate on the negative and positive impacts of genetically modified organisms (GMOs) has taken centre stage in the biotechnology discourse in the recent past. While countries like South Africa and Egypt have already asserted their positions, the majority of the African countries are either undecided or driven by scepticism about biotechnology. Major constraints that have hindered the acquisition and use of GMOs include lack of biosafety infrastructure and capacity in most countries to deal with the assessment of risks and benefits. Indeed in Africa, only South Africa and Egypt have an infrastructure sound enough to manage impacts resulting from the use of biotechnology)[71] Any meaningful engagement in biotechnology research and development partnerships will essentially depend upon the availability of the requisite institutional and human capacity for risk assessment and management. The field of biotechnology requires joint and well-informed entry for both the public sector and the private industry in Africa.

We have pointed out above that at the global level, most biotechnology activities are concentrated in the private industry domain. It is possible for the public sector to augment private sector initiatives by putting in place supportive policies and long-term agenda to accommodate the acquisition and use of novel biotechnology processes and products. In this regard, the acquisition and dissemination of biotechnology products and processes broadly depends on how fast governments move to put in place informed policies and decisions that can expedite private sector investment. Biotechnology R&D in the developing countries is predominantly in the bands of public institutions.[72] However, revolutionary transitions are underway, propelled by liberalization, structural adjustment programmes and privatisation policies whose effect has been the sidelining of the public sector and the enhancement of the role of the private sector. Liberalization measures have often been accompanied by privatisation of activities formerly conducted by public institutions.

Kenya

In Kenya, public research institutes like the Kenya Agricultural Research Institute (KARl) and public universities including Egerton University and Jomo Kenyatta University of Agriculture and Technology, have been working in collaboration with local private institutions and international agricultural research centres as well. Mechanisms of collaboration include joint research proposals with the universities, contract research or through activities involving individual researchers. KARl has, for instance, been conducting research on contract basis for Kenya Breweries Limited; Oserian Company, British American Tobacco and the Pyrethrum Board of Kenya.[73]

More specifically, Kenya Breweries (KBL's) research department collaborates with KARl on the control and management of Barley Yellow Dwarf and barley variety improvement. Research efforts aim at producing high yielding, disease resistant, agronomically superior barley varieties with improved malting quality. KBL also has linkages with local universities through training and field attachments for students. Collaboration between KARl and the Oserian Flower Company, one of the three largest companies in Kenya's floriculture industry, can be traced back to 1989 when KARl successfully developed tissue culture techniques for multiplication of *statice*, a flower important to Oserian. The new technology was put on trial and after being certified as effective, a research contract was signed between KARl and Oserian in 1990. This facilitated fast and effective transfer of the tissue culture technology to Oserian.[74]

Another private sector actor in biotechnology is Brooke Bond Tea. It has had research relationships with public research bodies in the tea and coffee sectors. Brooke Bond works in close collaboration with two government parastatals namely, the Tea Research Foundation and the Coffee Research Foundation. It has been particularly active in providing funding to the Tea Research Foundation.[75] Another example of institutional collaboration is that involving Egerton University, KARl and the International Centre for Maize and Wheat Improvement (CIMMYT) with support from CIDA. This has resulted in the establishment of crop management research training, which involves university academic staff and serves the eastern and southern Africa region. The project research work targets maize and beans which are major food crops in the region. Egerton University also has a collaborative venture with IDRC that has developed a framework for extensive evaluation of the economic benefits, production and utilisation and processing of several oil crops grown in Kenya such as simsim, groundnuts and sunflower.[76]

Zimbabwe

In Zimbabwe, partnerships between parastatals and private companies have also been recorded. For instance, the Tobacco Research Board (TRB) entered into an agreement with an agro-chemical company, Agricura, to undertake product development studies and developed a suitable delivery and application system for a myco-fungicide known as *Trichoderma Harzianum* initially developed by the Tobacco Board.[77]

Egypt

Egypt presents an example of a public-private partnership at the national level forged on the grounds of common business interests as opposed to technology transfer. The Agricultural Genetic Engineering Research Institute (AGERI) in Egypt, a public sector body, has made a number of significant achievements including the manufacture of a biopesticide known as Agerin through such an arrangement. The biopesticide is capable of protecting a broad range of important agricultural commodities, of controlling a number of biomedically significant pests, and has the potential for sales on a worldwide scale. To fulfil its commitments to translate research into application and large-scale commercial distribution to farmers, AGERI in collaboration with a private investor, succeeded in establishing a commercial business entity under the name “BIOGRO International”. This company is responsible for the commercialisation of research results conducted by AGERI and to sell AGERI products. Revenue generated from product’ sales is invested back into the institute to support the continuation of its activities. AGERI ascribes high importance to collaboration with the private sector, which it perceives as a necessary partner in carrying out R&D in the field of genetic engineering and biotechnology in Egypt. Such collaboration can take one of several forms, namely:

- Circulation of newsletters and reports.
- Having representatives of the private sector participate in the design of product R&D and
- Representation of the private sector on the governing board of AGERI.

As one of the leading institutions in agricultural genetic engineering in West Asia, North Africa, and the Middle East, AGERI plans on sharing its know-how and experience with other countries within the framework of technical co-operation among developing countries (TCDC). This could be achieved though specialized workshops, seminars and internships. The institute can also provide professional consultation in the field of molecular biology and agricultural genetic engineering.[78]

Latin American examples

Generally in Latin America, efforts have been made to encourage public-private sector collaboration in biotechnology. These include tax incentives to companies and soft loans. They also include innovative institutional arrangements, such as the university institutions set up specifically to explore commercial possibilities and partnerships (such as CIT in Mexico and the Public-Private Corporation (CORPOBIOT) in Colombia). In Mexico, there have been a number of university-private firm research contracts. These have included an agreement between Sabritas (Pepsico) and the Colegio de Post Graduados for potato snacks. A research agreement between CINVESTAV-Irapuato and Bajio Vegetable Producers has resulted from those agreements. It is pointed out, however, that Mexico’s policy of creating centres of excellence and giving priority to basic research tends to discourage collaboration with the private industry.

In Colombia, producer associations, which are sometimes overlooked as a private source of funding for research, play an important role in financial contributions to the research effort for specific crops like sugarcane, banana and plantain.[79] Funds for research and other activities are raised from levies on producers, which vary from product to product. In addition, Colombia public research institutions are involved in collaborative research projects with overseas universities (for example, in Florida, Nottingham and Mexico) for research in passion fruit and on insect-resistance in cotton, which have been commissioned by private companies and groupings by processors and exporters.[80]

V. Implications for the Third World

The challenge

With these examples in mind, what then is the scope for biotechnology development in the Third World? Looking at global demographic trends, world population is increasing at an alarming rate and is expected to exceed 8 billion by the year 2025. Ninety per cent of the global population will be found in the developing countries. The greatest challenge of all will be to produce additional food on smaller sizes of land. This also requires the achievement of food security without undermining the natural resource base. However, despite this prediction foreign assistance is apparently falling off. A report by International Food Policy Research Institute (IFPRl) reported that the proportion of official development assistance (ODA) devoted to agriculture decreased from 20 per cent in 1980 to 14 per cent in 1990. The study also showed that real external assistance to agriculture for developing countries declined from $12 billion in 1980 to $10 billion in 1990.[81] More recent estimates suggest that in the decade between 1987 and 1997 Official Development Assistance for agriculture declined by 50 per cent. One of the reasons attributed to the decline is that during the 1980s and 1990s, the bilateral and multilateral agencies that provided development assistance, shifted funding priority from agricultural support to environmental protection. It should also be noted that the decline in external support has come at a time when developing countries are themselves providing less support to agricultural R&D as a result of structural adjustment policies. There is actually growing concern that declining investments will not be adequate for the technology contribution necessary to increase food productivity sufficiently to ensure food security in future.[82]

It is unlikely that this trend will change, which raises the need to source alternative funding for biotechnology R&D. Partnerships between public and private sectors can be particularly useful in this regard. Along these lines, it is instructive to note that public sector ODA funding for all sectors is US $60 billion annually, whereas private sector investment from the North to the South is US $170 billion per year, and growing equivalent to almost three times the public sector ODA rate. There is also growing evidence to show that the private sector has overtaken the public sector in funding for biotechnology.[83] In the l960s in the United States, private sector R&D investments were 5 per cent less than corresponding investments by the public sector. By 1995 however, private sector R&D investment was 27 per cent more than that of the public sector. This demonstrates the growing presence of the private sector in research and underscores the need for partnerships between the public and private sectors to maximize benefits for both sectors.

The private sector has a wide-ranging spectrum of activities in agricultural research revolving around development, production, dissemination and distribution of goods and services. The private sector's major activities have however, for a long time been concentrated in the developed countries where greater opportunities for commercialisation exist as compared to developing countries. Private companies operate in a number of important areas including the fertilizer industry, crop protection and the seed industry. Doubling food production will require increased application of fertilizers especially for crops grown in marginal areas. The private sector is responsible for more than half of total global fertilizer production. In the area of crop protection, on-farm and post harvest losses account for a large proportion of global food, feed and fibre losses, particularly in developing countries. A combination of weeds, insect pests, and pathogens, are estimated to reduce yields by approximately 35 per cent. The private sector continued to lead in the production of pesticides until it was discovered that excessive use has negative environmental impacts. In response to environmental concerns the private sector is now investing in reduced use of fertilizers through use of conventional insecticides for example *Bacillus thuringiensis* (Bt) that confer resistance to insects through development of transgenic crops in which the active gene has been incorporated. Although concern for the environment, large scale commercialisation of transgenic crops with resistance to insects and widespread implementation of integrated pest management (IPM) are all factors that now have a significant effect on the structure of the crop protection market today, the private sector will probably continue to dominate this market and will become more dominant as technologies become more advanced.[84]

Potential areas for private sector participation in biotechnology R&D in developing countries

Crops

We have already seen that numerous examples documenting private sector participation in biotechnology are available. Thus in 1993 in Mexico, Monsanto (an international US based private company) donated proprietary virus coat protein technology conferring resistance to PVS and PVY viruses in the potato in a Mexican project. The project was funded by the Rockefeller Foundation and brokered by ISAAA. It involved a local institution in Mexico, CINVESTAV (Research Centre for Advanced Studies).[85] Another arrangement brokered by ISAAA and involving Monsanto, is that of proprietary technology developed for Bt.-induced resistance to lepidopteran pests in cotton. Under the agreement, the Cotton Research Institute (CRI) of Zimbabwe was involved in testing imported Bt. cotton (developed by Monsanto) against local pests. A widely cited example where Monsanto has been involved again in the area of crop protection is the donation of a proprietary technology to the Kenya Agricultural Research Institute (KARl). The collaboration between KARl and Monsanto led to the development of a virus resistant-sweet potato by means of coat protein recombinant technologies. The project, initiated towards the end of 1991, also involved the training of a Kenyan scientist at Monsanto's laboratory in St. Louis. Monsanto has provided a royalty-free nonexclusive licence as well as funding to (KARl) to develop the technology in sweet potato grown and sold in Africa.[86]

Seeds

The seed industry is one of the most important are as in biotechnology and food production. Commercial seed is mainly dominated by the private sector. The global commercial seed market accounts for over $15 billion annually. The principal seed companies that are internationally active are mainly in the private sector of industrialized countries. They include Pioneer, Novartis, Limagrain, Advanta, Seminis and Cargil.[87] Partnerships between the private sector and public sector in the seed industry can result in benefits of economies of scale. They can also enhance business strategy and enlarge experience and expertise in the public sector. Merging of public companies with private industry can also be one way of creating the necessary critical mass for R&D. Benefits of complementarities in respective areas of operation can also be realized. Co-operative R&D agreements, together with cross licensing, becomes possible. For example in 1996, Sandoz and Ciba merged to form Novartis, which is NOW the second largest seed company in the world. In Africa and other developing countries, farm-saved seed and seed from government institutions account for over 80 per cent of seed needs. Delivery systems that take the products of biotechnology research (such as seeds) to the farmers are no longer efficient. [88] The old distribution systems undertaken for many years, mainly by public bodies, have crumbled. The merging of leading private companies with public ones can be beneficial in trying to build the minimum critical mass necessary for efficient R&D and for production of high quality and competitive products. The private sector can also play a significant a role in the distribution by setting up agencies and funding initiatives aimed at delivering products of biotechnology to the end-user.

Factors preventing public-private partnerships

There are a variety of factors that hinder the growth of public-private partnerships at the global, regional and national levels. First, there is lack of information and awareness on possibilities for these kinds of collaboration on the part of the public sector. Problems of communication across the continent include poor exchange of scientific information and research results.[89] Modern communication systems like the e-mail and Internet are also lacking in large areas of Africa. This seriously hampers the acquisition of relevant and necessary knowledge about the application of biotechnology that is a rapidly changing and developing this field. Secondly, the public is often suspicious of the private sector and perceives it as an entity only interested in maximizing profits. This forecloses opportunities for collaboration in mutually beneficial factors.

Thirdly, there is a mismatch in technological and financial resource capability between the public and private sectors. This makes the finding of common ground for research on an equal basis difficult. For instance, the requisite cadre of biotechnology experts trained in composite disciplines is often lacking in the public sector as compared to the private sector. Further, the general infrastructure (skilled human resources, research equipment and facilities) in the public sector is in some cases not supportive of meaningful partnerships with the private sector.[90] In several African countries, basic infrastructure and facilities even for the simplest tissue culture techniques such as micro propagation are not available. For example, successful production of transgenic plants requires an adequate infrastructure, expertise in tissue culture and molecular biology, and a critical mass of researchers with supporting sustainable funding to cover the high cost of such research. Only a few laboratories in South Africa, Nigeria and in Egypt have the capacity to produce transgenic plants or genetically engineered products but they still lack the ability to commercialize the products or to ensure that these plants reach the end-user, that is, the African farmer. To bridge this gap, it is arguably necessary to form partnerships with either seed companies, producer organizations or government institutions which can ensure that new technologies reach the end-users.

Coupled with this is the question of Intellectual Property Rights (IPRs). Many developing countries and African ones in particular, do not have effective IPR regimes in place for large-scale biotechnology research to develop new genetically improved crops. African countries for instance, are taking too long to appreciate that IPRs and patents are strong tools that can enable them to advance in modern biotechnology. These tools are either absent or narrowly entrenched in the legal and institutional frameworks of such countries. In the last decade, African countries, like most developing countries, were guided by the belief that establishing IPRs was likely to have a detrimental effect to their growth and development. The argument was that new technologies were being developed by the industrialized countries and therefore IPR regimes were tailored to benefit transnational companies licensing their new technologies to developing countries.[91] There is also a major shortage of experts with knowledge and experience of dealing with IPR issues.

Fourthly, there are virtually no policies that directly encourage the forging of these partnerships in most of the African countries. As outlined above, experience from countries that have developed effective partnerships between the public and private sector shows that these are fuelled significantly by supportive policies. Fifthly, the dearth of public-private sector linkages undermines biotechnology transfer and the exchange of vital information. Biotechnology activity is concentrated within the public sector (public universities and agricultural research institutions) whose financial and technological constraints impinge on the capability to engage in state of the art biotechnology activities. Finally, political instability, uneven distribution of research benefits among members and the gap in socio-economic development also stifles the effectiveness of both national and regional research institutions and this has implications for their capacity to forge partnerships with the private sector.

Ways of enhancing public-private partnerships for biotechnology

For public-private partnerships in biotechnology to flourish it would therefore seem that a number of conditions have to be put in place. There must be government support and political goodwill. Intellectual property rights must be enacted and strengthened as stipulated and recommended by World Intellectual Property Organization (WIPO). Plant breeders' rights should also be protected with a view to encouraging greater involvement of the private sector. Greater collaboration can also be achieved through exchange programmes involving staff from private industry working in laboratories owned by public institutions like universities. Many countries have unnecessary Science and Technology Councils/Commissions. These can provide the institutional framework for stimulating and fostering public-private partnership initiatives. For example, joint public-private coordination bodies in biotechnology can be set up under such Councils.

Provision of sound infrastructure is also a fundamental precondition for public-private partnerships to prosper. Governments should provide services and incentives that can attract the participation of the private industry in biotechnology R&D. Tax incentives for equipment acquisition should be introduced to reduce the burden of research and product development. They can also stimulate private industry to import modem equipment needed for investment in advanced biotechnology applications. Tax incentives should also be introduced and extended to companies investing in new products or new biotechnology techniques. Policies that have led to the establishment of Export Processing Zones in many countries can equally lead to the development of Science and Technology Packs in Africa. Export Processing Zones (EPZs) are defined as "industrial zones with special incentives to attract foreign investment in which imported materials undergo some degree of processing before being exported again."

EPZs are proliferating worldwide. In Africa there are 47 EPZs, 14 of which are in Kenya.[92] The establishment of Science and Technology Packs can lead to the convergence of companies in information technology, biotechnology and other high-tech areas thereby enhancing the level of exchange of knowledge and ideas. Companies within the park can have access to advantages and benefits accruing from proximity to a wide network of mentors, service providers and providers of capital. This can offer opportunities for companies to develop and grow. Symbiosis (mutual giving and taking) between firms can be fruitful in advancing biotechnology research and development in Africa. Once created, firms operating in the parks should be entitled to preferential treatment including attractive benefits and tax incentives. Governments should set aside pieces of land at subsidised rates specifically for this purpose. Convergence of expertise, skills, resources and a critical mass of scientists in a science and technology park can result in the following benefits between the private industry and the public sectors:

- to access to data and vital information on local needs and capabilities. Current trends and status of the biotechnology industry can easily be accessed.
- to assist in venture assessment prior to adoption of a technology strategy and/or transfer. This will help to minimize duplication of effort and should promote innovative and demand-driven biotechnology R&D. On the basis of venture assessment, firms can also diversify to other biotechnology applications where no investment has been made.
- to enable public research bodies to have access to research facilities and a critical mass of expertise round in the domain of private industry. On the other hand nascent and medium-sized private companies unable to build up their own research and development structure and infrastructure can benefit from the public sector.
- to facilitate the creation of linkages between like-minded public and private biotechnology actors.

Experiences indicate that science and technology parks have spearheaded an impressive growth of biotechnology in Latin America and the industrialized nations.

Benefits for the public from partnerships with the private sector

The private sector has a number of comparative advantages that the public sector can benefit from. They include the following:

- The private sector has large R&D resources for funding long-term and sometimes high return agricultural projects.
- It has extensive networks of linkages ranging from small biotechnology-intensive companies to leading large multinational companies in the world.
- It has a critical mass of scientific research resources, which ensures efficiency and demand-driven R&D.
- It has a good understanding of market knowledge and distribution systems.
- It has access to global markets and associated advantages of economies of scale.

To maximize these benefits, it is imperative that policies that encourage and nurture increased participation of the private sector in areas where it has comparative advantages be put in place or strengthened where they exist but are weak. Developing countries should depart from the tradition of viewing the private sector as being made up of profit propelled establishments. The sector should be viewed and acknowledged as a utility player in biotechnology research and development.

VI. Conclusions

The main aim of this monograph has been to show in some detail that public-private sector partnerships are an essential component in the establishment of a biotechnology capacity in developing countries and especially from the standpoint of Sub-Saharan Africa where the needs and opportunities are arguably greatest. Thus we have seen that public-private partnerships are not a new phenomenon but have actually played a fundamental role in the advancement of biotechnology in developed countries and many parts of the developing world. But they have not been pursued on the African scene where most activity is both limited and is still within a public sector domain, with glaring constraints. Conversely, state of the art biotechnology knowledge is increasingly to be found in the private sector. It is therefore clear that African policy makers must now place heavy priority on building appropriate links with the private sector both to revitalize existing capacity and more importantly, to build enough new capacity in biotechnology to ensure its effective deployment in dealing with the region's major problems of food security, health and environmental degradation.

But how should this be done? The paper has also shown a range of interesting examples of institutional innovations that have been adopted internationally to achieve these goals. From these examples alone, therefore (and there are many others that could be cited), there is clearly a rich field of "inspirational models" that might be used as the basis for policy formulation in the important area of biotechnology development for Africa. The central message, however, is that policy must be oriented towards building capacity that integrates the operational alongside the technical since, in the absence of this, it is unlikely that the overriding goal of poverty alleviation will be attained. Put another way, the limiting factor is not the research/technical capacity of Third World scientists. Nor is it even the poor resource conditions within which many of them are often forced to work. It is the ability to relate this capacity directly to the most pressing social problems that these countries are currently facing. And this will almost certainly require institutional reforms. One important aspect of these reforms will be the capacity of different types of bodies from different sectors, private and public, to integrate their skills in progressive ways. And we have seen from the examples cited above that there are many ways in which this can be done.[93] The agenda is clear. It is now up to governments to muster the political will (and associated policies) to put intention into practice.

References

Agriforum. 1999. *Considering Biosafety and Biotechnology from an ASARECA Perspective: A study commissioned by the Association for Strengthening Agricultural Research in Eastern and Central Africa* (ASARECA).

Agriforum. 2000. *Quarterly Newsletter of the Association for Strengthening Agricultural Research in Eastern and Central Africa* (ASARECA) No. 11, April 2000.

Alston. J.M. and G.P. Pardey. 1996. "Making Science Pay" *The Economies of Agricultural Rand D Policy*. Washington D. C.: The AEI Press.

Brenner, C. 1999. *Integrating Biotechnology in Agriculture: Incentives, Constraints and Country Experiences*. Paris: OECD Development Centre.

Brown, L. and L. Haddad. 1994. "Agricultural Growth as a Key to Poverty Alleviation" *Brief 7, 2020 Vision of IFPRI*, Washington, D.C.

Cailliez, B. 1997. "The Twenty Leading Seed Companies in 1996" *Cultivar, May Edition*, 42-43. Paris. France.

Clark, N.G. 1991. "Development Policy, Technology Assessment and the New Technologies", *Futures 25*, November, pp. 913-931.

Clark, N.G. 1995. "The Interactive Nature of Knowledge Systems: Some Implications for the Third World" *Science and Public Policy 22*, August.

Commandeur, P. 1996. "Private-Public Co-operation in Transgenic Virus Resistant Potatoes", *Biotechnology and Development Monitor, No. 28*, September, pp. 14-19.

Culliton. 1977. "Harvard and Monsanto: The $23 Million Alliance" *Science 211*, 2 5 t h February.

Culliton. 1982. "The Hoechst Department at Mass General" *Science 216* (11 June).

Echeverria, R. and C. Thirtle. 1991. "Potential Roles of Public and Private Sector Agricultural Research in Sub-Saharan Africa" Paper presented at SADCC/ISNAR Agricultural Research Policy Makers Workshop, Namibia.

Edwards, M.G. 1983. "Business Plan for a University Licensing Association for Biotechnology (ULAB)" [VOLUME].

Ernst & Young. 1995. *Biotech 96: Pursuing Sustainability. The Tenth Industry Annual Report*. U.S.A: Ernst and Young, Palo Alto, Ca.

Essegbey & Stokes. 1998. "Building Capacity for Biosafety Policy in Ghana: Issues and Options for Policy-Makers", *Science. Technology and Development. 16* (2), August.

Feinschreiber, R. 1981. "New Tax Benefits for Genetic Engineering Rand D." *GEN 1* (November/ December).

Grifo, F.T. 1994. "Chemical prospecting: An Overview of the International Cooperative Biodiversity Groups Program" in J. Feinsilver, (ed.) *Emerging Connections: Biodiversity. Biotechnology and Sustainable development in Health and Agriculture*. Proceedings of Pan American Health Organization Conference, San Jose, Costa Rica.

Gummett, P. 1980. *Scientists in Whitehall* (Manchester: Manchester UP).

Hall, A. and N. Clark. 1995. "Coping with Change, Complexity and Diversity in Agriculture: The case of Rhizobium Inoculants in Thailand", *World Development. Vol. 2*, No. 9, pp. 1601-1614. B. de Hoop. 1996. "The Effects of External Funding on Biotechnology Transfer" *Biotechnology* *and Development Monitor, No. 28,* September, pp. 18-22.

International Development Network. 1998. “Export Processing Zones Growing Steadily, Providing a Major Source of Job Creation” *Information Resources for Sustainable Development.*

James, C. 1996. *Chairman’s Commentary: The first Decade of Crop. Biotechnology in Advancing Altruism in Africa*. ISAAA Annual Report 1996.

Juma, C. 2000. “Review of R. Pistorius and J, van Wijk. 1999.” *Biotechnology and Development Monitor, No. 41*, March.

Kenny, M. 1986. *Biotechnology: the University-Industrial Complex* Yale University press, London.

Kern, M. *Commercial Applications of Biotechnology in Crop Agriculture*. Aventis Crop Sciences. 1999. In *Agricultural Biotechnology and the Poor* Proceedings of an International Conference on Biotechnology Convened by CGIAR and U.S National Academy of Sciences in Washington, D.C, Oct. 2122, edited by G.I. Persley and M.M. Lantin.

Knudsen, H. 1993. “ISAAA: Proprietary Biotechnology for Small Farmers”. *Biotechnology and Development Monitor, No. 14*, March.

Lynch, A.J and B.E Tasch. 1989. In Felon, J.R and S. Huntington (eds.) *Management Perspectives for Agricultural Research*. Hobbs IV: ISNAR.

Madkour, A.M. 1999. “Egypt: Biotechnology from Laboratory to the Market Place. Challenges and Opportunities” In *Agricultural Biotechnology and the Poor*. Proceedings of an International Conference on Biotechnology Convened by CGIAR and U.S National Academy of Sciences in Washington. D.C, OCI. 21-22, Persley G J and M.M. Lantin (eds.) 1999, The World Bank.

Massieu, Y, R.L Gonzalez, M. Chauvet, Y. Castaneda, R.E. Barajas (2000) “Transgenic Potatoes for Small-Scale Farmers: A Case Study in Mexico” *Biotechnology and Development Monitor. No. 41*, March, pp. 6-10.

Massola, R. 1992. “Plant Biotechnology in Sub-Saharan Africa Today” in Sasson, A. and V. Costarini *Plant Biotechnology for Developing Countries*. The Netherlands: CTA/FAO.

Mbote, P. and C. Cullet. 1999. *Agrobiodiversity and International Law*. Nairobi: ACTS Press.

Mugabe, J and N.G. Clark. 1996. “Technology Transfer and the Convention on Biological Diversity: Issues of Conservation and Sustainable Use”, *Science, Technology and Development, Vol. 14*, No 3, December.

Mugabe, J. 2000. *Biotechnology in Developing Countries and Countries with Economies in Transition: Strategic Capacity Building Considerations*. ACTS Working Paper April 2000.

Mulongoy, K. 1993. *Current Situation of Plant Biotechnology Activities in some African Countries*. Draft paper submitted to FAO.

Oakey, R, W. Faulkner, S. Cooper and V. Walsh. 1990. *New Firms in the Biotechnology Industry: Their Contribution to Innovation and Growth*. London: Pinter.

Obongo, N. 1996. “Kenya Breweries Ltd.” *Proceedings of the First National Agricultural Research System Forum in Kenya.* Nairobi: KARI

Olembo N. 1996. “Ownership of Research Output” *Proceedings of the First National Agricultural Research System Forum in Kenya*. KARl: Nairobi.

Onyango, C.A. 1996. “Agricultural Research at Egerton University (Research and Extension)” *Proceedings of the First National Agricultural Research System Forum in Kenya*. KARl: Nairobi. .

Perman, R.J., McGilvray, Y. Ma and M.S. Common. 1999. *Natural Resource and Environmental Economics*. London: Longmont.

Persley, G J and M.M. Lantin (eds.). 1999. *Agricultural Biotechnology and the Poor* Proceedings of an International Conference on Biotechnology Convened by CGIAR and U.S National Academy of Sciences in Washington, D.C, Oct. 21-22.

Persley, G.J and J.J. Doyle. 1999. "Overview Brief in Biotechnology for Developing Country Agriculture: Problems and Opportunities". *Brief 1 of 10 2020 vision Focus 2.* Washington D.C.: International Food Policy Research Institute.

Persley, G.J. 1990. *Beyond Mendel's Garden: Biotechnology in the Service of World Agriculture*. Wallingford: AB International.

Persley, G.J. 1999. *Agricultural Biotechnology and the Poor*: Promethean Science.

Pistorius, Rand J. van Wijk. 1999. The Exploitation of Plant Genetic Information: Political Strategies in Crop Development. Wallingford, Oxford: CABI Publishing.

Raman. K.V., et al. 1987. *Agricultural Research Systems and Management in the 21st Century* Proceedings of the International Seminar, Dec. 8-10 NAARM, India. .

Reid. W V, S.A Laird, C.A. Meyer, R. Gamez, A. Sittenfeld, D.H Jansen, M.A Gollin, C. Juma. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development*. Washington D.C.: World Resource Institute.

Rothschild, Lord. 1971. "The Organization and Management of Government R&D", *Framework for Government Research and Development*. London: HMSO, Cmnd. 4814.

Sasson, A. 1993. *Biotechnologies in Developing Countries: Present and Future: Vol. 1*. France: Regional Survey, UNESCO.

Senker. J. and M. Sharp. 1989. *The Biotechnology Directorate of the SERC*. mimeo SPRU, University of Sussex.

Senker, J. ed. 1998. *Biotechnology and Competitive Advantage: Europe's Firms and the US Challenge*. Cheltenham: Elgar.

Serageldin, 1. and C. Wanda (eds.). 1999. *Biotechnology and Biosafety* Proceedings of an Associated Event of the Fifth Annual World Bank Conference on Environmentally and Socially Sustainable Development. U.S.A.: World Bank Washington. D.C.

Sharp, M. 1989. *Biotechnology in the UK*. Mimeo. Brighton: Science Policy Research Unit, University of Sussex.

Sharp, M. 1999. "The Science of Nations: European Multinationals and American Biotechnology" *International Journal of Biotechnology, 1* (1), pp. 132-162.

UNCTAD. 1999. Colombia: *The Science. Technology and Innovation Policy Review*. Geneva: UNCTAD/ITE/IIP/5.

Universidad Catolica de Valparaiso. 1998. "Plant Biotechnology: A Tool for Development in Africa" *Electronic Journal of Biotechnology in Africa. Vol. 1* No. 3, December 15, Chile. http://www.ejb.org/content/vol1/issue 3/full/6/.

Van Wijk, J. 2000. "Biotechnology and Hunger: Challenges for the Biotech Industry" *Biotechnology and Development Monitor, No. 41*. March, pp. 3-7.

Villalobos, V.M. 1995 "Biotechnology in Agriculture. How to Obtain its Benefits while Limiting Risks" in *Induced Mutations and Molecular Techniques for Crop Improvement*, p. 477-486. Austria: IAEA publication.

Wambugu, F.S. 1996. "Kenya Agricultural Research Institute Priority Setting" *Proceedings of the First National Agricultural Research System Forum in Kenya*. KARI.

Webster, A. 1989. "The Incorporation of Biotechnology into Plant Breeding", in I. Barcoe (ed), *Demystifying Science and Technology*. London: Macmillan.

Wilkie, T. 1991. *British Science and Politics since 1945*. Blackwell: Oxford.

Wood McKenzie Consultants Ltd. 1997. *Data on Pesticides and Animal Health Products*. Edinburgh: Wood McKenzie Consultants Ltd.

World Bank [1]. 1997. *World Development Indicators* Washington, D.C.

World Bank [2]. 1997. *Annual Review. Environmental Matters. Fall* Ed.. World Bank, Washington D.C. pp. 38-39, also in ISAAA Brief 1997.

Yuan, R.T. 1987. *International Trade Administration* U.S Department of Commerce Washington, D.C.

Endnotes

[1] The Consultative Group for International Agricultural Research.

[2] See van Wijk, 2000, p. 5.

[3] Jefferson, 1993.

[4] Mugabe and Clark, 1996.

[5] Juma, 2000.

[6] Juma, 2000 in a review of Pistorius and van Wijk, 1999. See p. 23.

[7] Jefferson, 1993.

[8] Mugabe and Clark, 1996.

[9] World Bank, 1997.

[10] World Bank, 1999.

[11] See Hirsch, 1977. We are grateful to Mick Common for bringing this source to our attention.

[12] See Galbraith, 1958.

[13] Sometimes the term "rivalry" is used instead of "divisibility". Thus where a good is once consumed by A, and is no longer available to B, C, D etc., then all consumers are potential rivals for the consumption of that good.

[14] See Perman et al., 1999, pp. 136-139, for a fuller discussion on the applicability of these concepts in an environmental context.

[15] Echeverria and Thirtle, 1991.

[16] Lynch & Tasch, 1989.

[17] Raman et al., 1987.

[18] Brenner, 1999.

[19] Mbote and Cullet, 1999.

[20] Article 2 Convention on Biological Diversity, Rio de Janeiro, 5 June 1992. reprinted in 31 *ILM* 818, 1992.

[21] Kenny, 1986. See p. 240.

[22] Persley, G.J., 1999.

[23] Kenny, 1986. See pp. 195-197.

[24] Ibid., pp. 195-197.

[25] Persley and Lantin, 1999.

[26] Kern, 1999.

[27] Persley and Doyle, 1999.

[28] Feinschreiber, 1981.

[29] Culliton, 1977.

[30] Culliton, 1982.

[31] See *Harvard Gazette*, 1981.

[32] See *Genetic Engineering News*, 1982, Monsanto, Rockefeller University -- announcing basic research accord (May/June).

[33] See Edwards, 1983.

[34] The UK Medical Research Council. This is one of 5 bodies that carry out publicly funded R&D in the UK.

[35] See for example Gummett, 1980 and Wilkie, 1990.

[36] Senker and Sharp, 1988.

[37] Senker and Sharp, 1989, p.14.

[38] This recommendation was implemented in the shape of *Celltech*, a firm with a London Stock Exchange quotation, which seems to be performing well according to recent press reports.

[39] This section of the paper draws heavily on Senker, 1996.

[40] Senker,1996.

[41] See Senker and Sharp, 1988, for a complete account of this. The failure of disciplines to interact is often discounted in policy analysis but is arguably, however, a major weakness in the effectiveness of public research.

[42] Webster, 1994.

[43] See Oakey et al., 1990, for a detailed analysis of this aspect from a UK standpoint.

[44] Sharp, 1989.

[45] Yuan, 1987.

[46] Ibid.

[47] See Sasson, 1993, for a fuller treatment of these points.

[48] Ernst & Young, 1995.

[49] See Agriforum, 2000.

[50] See, for example, Hall and Clark, 1995.

[51] Bustamente, 1995.

[52] Commandeur, 1996.

[53] And in any case the agreement explicitly prohibits exports from Mexico to the US.

[54] Commandeur, 1996.

[55] SeeCommandeur, 1996, pp.18-19.

[56] The content of this box is taken directly from Grifo, 1994, p. 9.

[57] USAID has withdrawn from this next phase.

[58] Reid et al., 1993.

[59] i.e. the article that deals with terms and conditions of access to national genetic resources.

[60] See Reid et al, 1993, p. 1.

[61] And also at the level of local collection. The training of "parataxonomists" has been a key element in moving down the skill chain and in this way to preserve the systemic coherence of the technology more generally within the country.

[62] Juma, 1993.

[63] Brenner, 1999.

[64] Agriforum, 1999.

[65] Brenner, 1999, *Op. Cit*.

[66] See Plant Biotechnology: a Tool for Development in Africa, 1998.

[67] Ibid.

[68] See Mulongoy, 1993.

[69] Ibid. ISNAR is the International Service for National Agricultural Research based in the Hague, Netherlands.

[70] Agriforum, 2000 op.cit.

[71] Mugabe, 2000.

[72] Olembo, 1996.

[73] Wambugu, 1996.

[74] Obongo, 1996.

[75] Brenner, 1999, op.cit.

[76] Onyango, 1996.

[77] Brenner, 1999, op.cit.

[78] Madkour, 1999.

[79] See also UNCTAD, 1999.

[80] Brenner, 1999, op.cit.

[81] Brown and Haddad, 1994.

[82] World Bank [2], 1997.

[83] Alston and Pardey, 1996.

[84] Wood McKenzie Consultants Ltd., 1997.

[85] Brenner, 1999, op.cit. See also discussion above.

[86] Ibid.

[87] Cailliez, 1997.

[88] Persley, 1990.

[89] Massola, 1992.

[90] Villalobos, 1995.

[91] James, 1996.

[92] International Development Network, 1998.

[93] See also Clark, 1990 for an analysis of how Third World governments might approach technology policy making in this regard. For an interesting account of the issue in the context of biosafety in Ghana, see Essegbey and Stokes, 1998.