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INTERNATIONAL INITIATIVES IN BIOTECHNOLOGY FOR DEVELOPING COUNTRY AGRICULTURE: PROMISES AND PROBLEMS

by

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"International Initiatives in Biotechnology for Developing Country Agriculture: Promises and Problems"

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RÉSUMÉ

Le nombre d'actions internationales engagées pour promouvoir le développement de la biotechnologie agricole dans les pays en développement est en augmentation. Ces actions — qui recouvrent la recherche biotechnologique dans divers domaines, l'information et le conseil — sont financées par des agences bilatérales ou multilatérales, des fondations privées et, parfois, par des entreprises.

Construite à partir des résultats d'une enquête menée par l'Intermediary Biotechnology Service (IBS) de la Haye, cette étude analyse la nature et l'envergure de ces actions et envisage leurs conséquences. Elle préconise en conclusion les conditions de planification, de mise en oeuvre et de politique à remplir par les agences donatrices et les pays en développement pour mener à bien ces actions internationales.

SUMMARY

A growing number of international initiatives are being undertaken to stimulate the development of agricultural biotechnology applications in developing countries. These initiatives, which include a wide range of biotechnology research, information and advisory activities, are supported by bilateral and multilateral agencies, private foundations and, to some extent, by commercial firms.

This study, based on the results of a survey conducted by the Intermediary Biotechnology Service (IBS) at The Hague, attempts to analyse the nature and scope of these initiatives and their potential impact. The study concludes by outlining a number of planning, execution and policy conditions which need to be met, both by donor agencies and by developing countries, if the potential impact of these international initiatives is to be fully realised.

PREFACE

This paper is part of a research project entitled Biotechnology and Sustainable Agriculture, which has been undertaken in the context of the Development Centre's 1993-1995 research theme on Sustainable Development: Environment, Resource Use, Technology and Trade. This project will analyse developments in agricultural biotechnology, development and diffusion in order to determine whether biotechnology is likely to contribute to a more sustainable model of agricultural production in developing countries. This alternative model would be less dependent on the use of agro-chemicals and based more on biological pest and disease control and local genetic resources.

The research comprises a number of different components. These include, firstly, a conceptual study of agricultural biotechnology in the context of a national innovation system. Six country studies are also included: India and Thailand in Asia; Colombia and Mexico in Latin America; and Kenya and Zimbabwe in Africa. Country studies will examine both successes and failures in biotechnology initiatives, identify incentives and constraints in the successive phases of research, technology development and diffusion of biotechnology for plant protection, and assess the coherence of national and international efforts in promoting the development of biotechnology for sustainable agriculture.

The research also includes the present study, which analyses publicly-funded international initiatives to stimulate the introduction of biotechnology in developing country agriculture. The potential impact of these initiatives is examined from the perspective of a national innovation system and suggestions are made to improve their effectiveness.

The paper is intended to stimulate reflection and discussions both among the agencies providing financial and other support for these initiatives and for the developing countries involved. It should also be helpful to donor agencies not at present directly concerned but which envisage contributing to international biotechnology initiatives in the future.

Jean Bonvin
President of the OECD Development Centre
September 1994

LIST OF ACRONYMS

ABN-BIOTECHNET	African Biosciences Network - Sub-Network for Biotechnology
ABSP	Agricultural Biotechnology for Sustainable Productivity
ACIAR	Australian Centre for International Agricultural Research
ACR	Agrobiotechnologia de Costa Rica
AGC	Agricultural Genetics Company
AGERI	Agriculture Genetic Engineering Research Institute
ANSAB	Asia Network for Small-Scale Agricultural Biotechnologies
ARBN	Asian Rice Biotechnology Network (IRRI)
AVRDC	Asian Vegetable Research and Development Centre
BARN	Bean Advanced Biotechnology Research Network, (CIAT)
B/C CRSP	Bean/Cowpea Collaborative Research Support Program
BERC IIT	Biochemical Engineering Research Centre of the Indian Institute of Technology
BST	bovine somatotropin
CAMBIA	Centre for the Application of Molecular Biology to International Agriculture
CATIE	Centro Agronomico Tropical de Investigacion y Ensenanza
CBN	Cassava Biotechnology Network
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Centre for Maize and Wheat Improvement
CIP	International Potato Centre
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement

CNPMS	National Centre for Maize and Sorghum Research
CRIFC	Central Research Institute for Food Crops
CRIHC	Central Research Institute for Horticultural Crops
DBT	Department of Biotechnology (India)
DGIS	Special Programme Biotechnology and Development Cooperation
ELISA	enzyme linked immunosorbent assays
FAO/AGP	UN Food and Agriculture Organisation, Plant Production and Protection Division
FAO/RLAC	UN Food and Agriculture Organisation, Regional Office for Latin America and the Caribbean
IARCs	International Agricultural Research Centres
IAVH II	Institute of Agriculture and Vetinerary Science, II
IBS	Intermediary Biotechnology Service
ICGEB	International Centre for Genetic Engineering and Biotechnology
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IICA	Interamerican Institute for Cooperation in Agriculture
IIRSDA	Institut international de recherche scientifique pour le développement en Afrique
IITA	International Institute for Tropical Agriculture
ILMB	International Laboratory of Molecular Biology for Tropical Disease Agents
ILRAD	International Laboratory for Research on Animal Diseases
ILTAB	International Laboratory for Tropical Agricultural Biotechnology
IRRI	International Rice Research Institute

ISAAA	International Service for the Acquisition of Agri-Biotech Applications
ISCB	Indo-Swiss Collaboration in Biotechnology
ISNAR	International Service for National Agricultural Research
KARI	Kenyan Agricultural Research Institute
MSU	Michigan State University
ODA	Overseas Development Administration (UK)
ODA/PSRP	Overseas Development Administration Plant Sciences Research Programme
PSTC	USAID's Program for Science and Technology Cooperation
REDBIO	Technical Cooperation Network on Plant Biotechnology, (FAO/RLAC)
RFLPs	restriction fragment length polymorphisms
SDC	Swiss Development Cooperation
SR-CRSP	Small Ruminant Collaborative Research Support Program
TDV	Tickborne Diseases Vaccine Development Program
UCR	University of Cost Rica
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

I. INTRODUCTION

Biotechnology is a term which has become familiar to most people, even though it has not yet been satisfactorily or definitively defined[1]. Much has been written both in research literature and in the popular press about the potential of new biotechnology to modify radically agriculture and food production. Much has also been written about the threats and promises of biotechnology for developing country agriculture. One of the difficulties in making objective assessments of the potential impact of biotechnology in food and agriculture stems from the fact that genetically-engineered plants have been much slower to reach the market than originally envisaged. In plants, the scientific constraints were perhaps underestimated, while regulatory procedures and adverse public opinion have served as obstacles for testing and development of both plant and animal biotechnologies. Except in health care, where biotechnology products are now widespread, the costs/benefits of biotechnology over competing technologies are therefore still far from clear, even in industrialised countries.

The potential contribution of biotechnology to increasing food security or to more sustainable agricultural production in developing countries is also uncertain. Many products emerging in OECD Member countries (for example, herbicide-tolerant rapeseed, longer shelf-life tomato) are not necessarily relevant to the problems confronting developing country agriculture. The ability of developing countries to avail themselves of the promises of biotechnology will therefore depend in large measure on their capacity to integrate modern biotechnology within their own research and innovation systems, in accordance with their own agriculture and food priorities.

An increasing number of new techniques, such as those related to plant cell and tissue culture, improved diagnostic procedures for plant and animal diseases and the identification and mapping of useful genes, have become valuable tools in agricultural research programmes in industrialised countries. These developments have stimulated a growing number of developing country governments to invest in infrastructure and human resources for agricultural biotechnology.

The context in which biotechnology is being developed is very different from that of the earlier Green Revolution, when the new high-yielding varieties of rice and wheat were both produced and distributed largely by the public sector. Significant changes have occurred in the role and involvement of private, commercial interests in agricultural research in general — and in biotechnology research in particular — in the global movement towards the strengthening of intellectual property rights protection for innovations in agriculture.

In developing countries, budget stringency resulting from the adoption of structural adjustment and privatisation programmes and policies in many countries, has led either to reduced funding for public research, or to a reallocation of resources away from public institutions. The problems experienced at national level are compounded by wavering support for the international agricultural research system constituted by the International Agricultural Research Centres. Although the system

has been criticised for real or perceived shortcomings, the IARCs have nevertheless been an important source of material and technical support for national agricultural research systems in developing countries.

Despite the broad trend towards a higher level of involvement of the private sector in agricultural research generally, and in biotechnology research in particular, at present most developing countries still rely almost exclusively on the public financing (national or international) of research. Against this background a number of publicly-funded international efforts to stimulate the introduction of biotechnology in developing country agriculture have been initiated. This paper represents a first attempt to review these initiatives and to examine their potential impact. Technological change and innovation do not occur in a vacuum, but take place in a national context which differs from one country to another, we have, therefore, sought to examine these initiatives from the unifying perspective of a national innovation system.

The paper is the result of a collaborative effort between the OECD Development Centre and the recently-created Intermediary Biotechnology Service (IBS)[2] based at ISNAR in The Hague. It draws extensively on a survey conducted by IBS — the first of its kind — to review international initiatives in agricultural biotechnology. These international initiatives are aimed at stimulating applications of agricultural biotechnology in developing countries.

The principal aims of the paper are:

to analyse the nature and scope of international initiatives in support of biotechnology in developing countries;

to examine the extent of developing country participation in the design and execution of these initiatives; and, finally,

to draw conclusions regarding the potential impact of these initiatives, and to stimulate discussion — among both the agencies providing financial support and participating developing countries — to improve their effectiveness.

The paper is organised as follows. In Section II which follows, the concept of a national innovation system is introduced. This links research, technology development and diffusion as a continuous, interactive process in which **local** scientific and technological effort is crucial. It provides the analytical framework in which the international initiatives in support of agricultural biotechnology, which are the subject of this paper, are analysed.

Section III reviews the findings of the IBS survey on international initiatives in agricultural biotechnology. It outlines the scope of the survey, the institutions and programmes included and funding. It then discusses training opportunities, the focus of research programmes and biotechnology policy activities included in the programmes.

In Section IV the major bilateral aid programmes in support of biotechnology in developing country agriculture are discussed. The different approaches of donors to programme design and execution are also highlighted.

A number of international initiatives which involve public/private sector collaboration are described in Section V. Questions of intellectual property rights are also raised.

Section VI examines the extent of developing country participation in the design and execution of international initiatives in biotechnology and draws conclusions with respect to their potential impact from the viewpoint of national innovation systems in developing countries.

This is followed in Section VII with planning and policy implications, as they concern both the organisations which are financing international biotechnology initiatives and the developing countries for which the programmes are targeted.

II. BIOTECHNOLOGY IN THE CONTEXT OF A NATIONAL INNOVATION SYSTEM

The success or failure of a technological innovation to take root is extremely difficult to predict. Successful research effort does not automatically lead to a product in the farmer's field and, indeed, the incorporation of research results into the development of a particular technology and the subsequent widespread diffusion of that technology in the form of a useable product are fraught with uncertainty. The concept of a national innovation system[3] is useful in highlighting the complexities and difficulties inherent in this process.

Figure 1 below presents a simplified schema of a national innovation system in which biotechnology should be integrated. This system encompasses agricultural research, technology development and diffusion as interactive, linked research, production and distribution systems. These three sets of activities are, in turn, linked to a national financial system and to a national regulatory framework.

Agricultural research

Agricultural research may include basic, applied and adaptive research. Adaptive research can be very important in agriculture, as elements of "transferred" technology (for example, germplasm or a new seed variety) may require a lengthy period of adaptation to different agro-ecological and production conditions. Ideally, biotechnology research should be closely integrated with national science and technology objectives, with the priorities set for the agriculture sector and with national agricultural research.

Within agricultural research, biotechnology may have **dual** functions: firstly, as a set of enabling techniques which are complementary to other techniques (for example, the use of genetic markers in plant breeding); secondly, as research intended to lead to a new biotechnology product (for example, a pest-resistant seed variety) or innovation.

As indicated, a diversity of public and private actors may be active in agricultural research[4]. In the public sector they include government departments or ministries (agriculture, livestock, science and technology, environment and natural resources, etc.), national research councils and institutes, universities, international agricultural research centres. In the private sector they include, firstly, non-commercial foundations and NGOs and, secondly, commercially-oriented input companies (seeds, agro-chemicals, machinery and equipment); farmer cooperatives and producer associations, plantations and estates, commodity institutes, food and food-processing companies and consultancy and management companies.

Figure 1: **Biotechnology in a National System of Innovation**
Public and Private Actors and Institutions

In principle, close interaction between the research and farming communities is necessary and between research, farming and industry, both in identifying the major production or other problem areas to which research should give priority and in providing feedback on the acceptability or appropriateness of technology products generated by the research community and industry. One of the notable features of agricultural research in the United States has been the interaction between agricultural producers, the Land Grant Universities and industry. In many developing countries, these links are weak or, at best, tenuous.

Technology development

Development encompasses the activities which translate the results of successful laboratory research into a tangible technology product, such as a genetically-modified seed or disease-free planting material. The development phase may include a diversity of activities such as small and large-scale field testing; seeds multiplication; the provision of biotechnology supplies (such as germplasm, fermentation equipment); setting up a pilot plant. Product development generally involves both public and private actors: for example, commodity boards, parastatals, individual farmers, producer organisations, industrial firms. Under the structural adjustment policies adopted by a growing number of developing countries in recent years, there has been an important trend towards privatisation of public companies involved in product development.

As in research, feedback from and interaction with farmers is an important aspect of technology development.

Technology diffusion

This phase in the cycle of research, development and diffusion of technology relates to the introduction of a new technique or innovation and, in due course, its widespread distribution to and acceptance by producers or other users. Technology may be diffused by both private and public channels, or through both market and non-market mechanisms. The former include seeds and agricultural input and veterinary supply companies, producer associations and co-operatives and commercial agricultural services. The latter include publicly-financed extension systems, and non-profit foundations and NGOs.

The farming community (or other consumers) will be the final arbiters of the success or failure of a new technological innovation. While the need for interaction between farmers and both the research and production systems is therefore clear in principle, in practice the links are often weak in developing countries.

Technology transfer

The term "technology transfer" means different things to different people. For the purposes of this paper technology transfer refers to the introduction, in a variety of forms, of new elements of knowledge. This can take place through non-commercial channels (for example, through education and training, publications) or through market

transactions (commercial firms and consultants). Within a national innovation system, technology transfer will occur between individuals and institutions, at local and national level and at international level.

In international technology transfer transactions between countries of widely-differing levels of economic and scientific and technological development, two caveats should be kept in mind. Firstly, while in the past the view prevailed that developing countries could accelerate technological change by selecting "off-the-shelf" technologies produced in and for "developed" countries, the inadequacy of this approach is now conceded. Due to the "implicit" or "disembodied" nature of technology[5], in all transfer of technology transactions (whether knowledge is exchanged or communicated in the form of products, equipment, methods or skills), there is an element of uncertainty regarding what is actually transferred. Inevitably, the supplier possesses more knowledge about the nature, use and eccentricities of a technology than can be conveyed to the recipient in blueprints, documentation or training. An added complication in the case of agricultural technologies is their need for adaptation to particular climatic, soil and other production conditions prevailing in different geographic locations. Thus, even the most successful technology transfer has inherent limitations.

Secondly, the relative success or failure of international technology transfer transactions depends on the level of technological capability — defined as the "ability to make use of technological knowledge"[6] — in the country to which the technology is transferred. National technological capability which will to a large extent determine what elements of technology can be absorbed and assimilated through international technology transfer. Thus, while technology acquired from external sources may be an essential input to technological change and innovation, it can only **complement** local scientific and technological effort. It cannot be a **substitute** for the consolidation of national capacities through local knowledge, education and training and learning-by-doing.

* * *

In the context of a national innovation system, innovation in agriculture is influenced by macro-economic policies and their impact at the farm level, by levels of investment, domestic or foreign, by science and technology policies and capabilities, and by agriculture policies. It is also influenced by institutional arrangements, both public and private, by farmer support institutions (such as rural credit, producer cooperatives), physical infrastructure and by an appropriate regulatory framework. These factors will affect both the supply of and effective demand for, new technology — including biotechnology.

If biotechnology is to be developed within this context, a number of simultaneous or consecutive steps will be necessary. These include: firstly, the strengthening of appropriate scientific capabilities and institutions; secondly, development of the necessary productive infrastructure and regulatory framework to

underpin the development of biotechnology products; and, thirdly, the establishment of effective channels (market or non-market) to ensure that biotechnology products are made available in response to demand.

It is against this background that the international initiatives, which target one or more of these steps, are analysed in the following sections.

III. INTERNATIONAL INITIATIVES IN AGRICULTURAL BIOTECHNOLOGY: THE IBS SURVEY

This section draws on the findings of a survey conducted by the Intermediary Biotechnology Service (IBS) between June and December 1993. This survey, conducted by IBS as a first step in developing a registry of expertise on international agricultural biotechnology, was the first systematic effort to review international initiatives in agricultural biotechnology. For the purposes of the survey, these international initiatives have been defined as those organisations or programmes that conduct, fund, or coordinate biotechnology-related research focusing on developing country agriculture.

Scope and limitations of the survey

Four categories of international initiatives in agricultural biotechnology were identified:

. Research programmes for crops or livestock carried out at national or international public institutes

. Advisory programmes which concentrate on policy and research management issues

. International or regional biotechnology networks for specific crops or regions

. Bilateral or multilateral donor programmes which finance international biotechnology activities.

IBS spent some time in designing and, in consultation with the Development Centre and others, in refining a questionnaire which, in June 1993, was sent to some 45 organisations. Following an initially encouraging response rate, considerable effort was devoted to increasing this and to follow-up work with each organisation, in order to complete and clarify responses. The preliminary findings of the survey were presented to an international workshop organised by IBS in November 1993, attended by some 50 participants involved in different capacities in these activities[7]. By March 1994 a response rate of around 90 per cent had been achieved and to date IBS has received completed questionnaires from:

. 28 research and advisory programmes
. 6 networks
. 5 donor agencies

It is appropriate, at the outset, to point to the limitations and strengths of the survey. Firstly, it does not pretend to be an exhaustive review of international activities in agricultural biotechnology. Undoubtedly some of the growing number of institutions, networks or donor agencies active in supporting biotechnology initiatives were not identified in the course of the survey and were therefore not included, or simply did

not respond to the questionnaire. Others were not able to respond with accuracy as the information sought in the questionnaire had not yet been analysed within the organisation. Nevertheless, the information generated by the survey constitutes the first systematic effort to examine these initiatives and to make the information generated by the survey publicly available. It also highlights the wide range of activities and organisations involved in international agricultural biotechnology.

Secondly, the questionnaire was designed to be as comprehensive as possible and therefore has its limitations regarding the level of detail of information requested. Finally, it is not possible to verify all information submitted. This implies, first and foremost, that although they do provide a clear indication of the relative importance of various funding organisations and programme elements, the figures on funding and expenditures should be regarded with caution.

This paper focuses principally on the international research programmes for which comparable information was obtained.

Institutions and programmes included in the survey

Table 1 provides an overview of the institutions and programmes included in the survey in terms of host institution, priorities, product focus and region or country focus.

Table 1: **Summary of International Agricultural Biotechnology Initiatives**

NAME (host institution)	PRIORITIES	AGRICULTURAL FOCUS (crop / livestock)	REGION / COUNTRY FOCUS
CROP RESEARCH PROGRAMMES			
Agricultural Biotechnology for Sustainable Productivity, ABSP (Michigan State University)	• genetic engineering of crops for pest/disease resistance • development of micropropagation systems • integration of biotechnology within a general agriculture and business framework • biosafety • IPR • technology transfer	• maize • potato • coffee • sweet potato • cucurbits • banana • pineapple	• Costa Rica • Egypt • Kenya • Indonesia
Bean/Cowpea Collaborative Research Support Program, B/C CRSP (various US universities)	• control of pests and diseases • increase crop yields • increase nutritional quality	• bean • cowpea	• Africa • Latin America and the Caribbean
Biotechnology-Assisted Breeding to Reduce Pesticide Use in Potatoes (CIP)	• durable resistance to pests and diseases • integrated pest management	• potato	• international
Centre for the Application of Molecular Biology to International Agriculture, CAMBIA	• novel biotechnologies and methods for agricultural innovation • genetic markers and diagnostics • apomixis	• rice • cassava • bean • agroforestry	• international
CATIE - Biotechnology Unit	• enhance regional program capabilities • genetic improvement of tropical crops	• banana/plantains • coffee • cocoa • roots and tubers	• Latin America and the Caribbean
CIAT - Biotechnology Research Unit	• increasing the efficiency of CIAT strategic research • institutional development in biotechnology	• cassava • common bean • rice • tropical forages	• international

NAME (host institution)	PRIORITIES	AGRICULTURAL FOCUS (crop / livestock)	REGION / COUNTRY FOCUS
CIRAD - Plant Breeding Division	• develop genetically improved crops	• cotton • rice • sorghum • tropical perennials • tropical fruits • forestry	• international
Feathery Mottle Virus Resistant Sweet Potato for African Farmers (USAID)	• human resource development • production of virus-resistant, African varieties of sweet potato • enhance capacity in biosafety regulation of transgenic crop plants • export of transgenic sweet potato to Africa for field testing • technology transfer	• sweet potato	• Kenya
ICGEB - Plant Biotechnology Sub-Programme	• capacity building • genetically improved rice	• rice	• international
ICRISAT - Biotechnology Program	• support and complement conventional crop improvement programs at ICRISAT	• sorghum • pearl millet • groundnut • chickpea • pigeonpea	• international
IIRSDA - Plant Biotechnology Program	• conservation and characterisation of yam germplasm • micropropagation and genetic improvement of yam and other crops	• yam • African eggplant	• Sub-Saharan Africa
IITA - Biotechnology Research Unit	• tackle recalcitrant problems in crop improvement • enhance national research capabilities	• cowpea • yam • cassava • banana/plantain	• Sub-Saharan Africa
International Laboratory for Tropical Agricultural Biotechnology, ILTAB (Scripps Research Institute)	• genetically engineered food crops with virus resistance	• rice • cassava • tomato • sugarcane	• international
International Program on Rice Biotechnology (Rockefeller Foundation)	• rice genetic improvement • capacity building	• rice	• international

NAME (host institution)	PRIORITIES	AGRICULTURAL FOCUS (crop / livestock)	REGION / COUNTRY FOCUS
International Service for the Acquisition of Agri-biotech Applications, ISAAA (Cornell University)	• acquisition and transfer of near-term applications of agricultural biotechnology applications, particularly proprietary technology • biosafety	• vegetables • fruits • field crops • agroforestry	• international
ODA Plant Sciences Research Programme (University of Wales)	• genetically improved crops	• cereals • roots and tubers • legumes • oilseeds • fruit and vegetables • fibres	• Côte d'Ivoire • Niger • India • Nepal • Pakistan • Peru
Reducing Maize Losses to Insect Pests by Enhancing Host Plant Resistance with *Bacillus thuringiensis* Toxin Genes (CIMMYT)	• enhanced insect-resistance maize germplasm	• maize	• international
Regional Program of Biotechnology for Latin America and the Caribbean (several UN organisations)	• collaborative research projects • training	• maize • potato • sugarcane	• Latin America and the Caribbean
LIVESTOCK RESEARCH PROGRAMMES			
CIRAD - Animal Production Division	• development of heat-stable vaccines through genetic engineering • improved diagnostic tests • determination of genetic resistance to diseases	• cowdriosis • dermatophilosis • rinderpest • peste des petits ruminants • mycoplasmosis • trypanosomiasis	• international
International Laboratory of Molecular Biology for Tropical Disease Agents, ILMB (University of California)	• live recombinant virus vaccines for animal diseases • technology transfer	• rinderpest • bovine virus diarrhea • equine influenza • peste des petits ruminants • foot and mouth disease • vesicular stomatitis virus	• international

NAME (host institution)	PRIORITIES	AGRICULTURAL FOCUS (crop / livestock)	REGION / COUNTRY FOCUS
ILRAD - Tick-Borne Diseases Program	• novel vaccines • improve current control methods	• theileriosis • cowdriosis • anaplasmosis • babesiosis	• international
ILRAD - Trypanosomiasis Program	• improve diagnosis and parasite characterisation • novel vaccines • breeding for genetic resistance	• trypanosomiasis	• international
Indo-Swiss Collaboration in Biotechnology, ISCB (Swiss Federal Institute of Technology)	• capacity building • animal disease diagnostics and vaccines • biopesticides	• foot and mouth disease • contagious caprine pleuropneumonia	• India
Small Ruminant Collaborative Research Support Program, SR CRSP - Animal Health Component (Washington State University)	• improve the efficiency of milk and meat production from small ruminants • virus-vectored vaccines for sheep and goats	• heartwater • contagious caprine pleuropneumonia • Nairobi sheep disease	• Kenya • Indonesia • Bolivia
Tickborne Diseases Vaccine Development Program (University of Florida)	• development and commercialisation of improved vaccines and diagnostic tests	• heartwater • anaplasmosis • babesiosis	• Egypt • Mali • Kenya • Zimbabwe • Thailand • Costa Rica • Mexico
ADVISORY PROGRAMMES			
Biotechnology Advisory Commission, BAC (Stockholm Environment Institute)	• review biotechnology projects involving field testing and/or the planned introduction of genetically modified organisms		• international
Intermediary Biotechnology Service, IBS (ISNAR)	• biotechnology research program management and policy formulation • country reviews • identify international program expertise		• international
Support to Agricultural Biotechnology Policies (IICA)	• biosafety, IPR • industry development		• Latin America and the Caribbean

NAME (host institution)	PRIORITIES	AGRICULTURAL FOCUS (crop / livestock)	REGION / COUNTRY FOCUS
NETWORKS			
African Biosciences Network - Sub-Network for Biotechnology, ABN-BIOTECHNET (University of Nigeria)	• genetically improved crops and farm animals • disease control through new vaccines • capacity building		• Africa
Asia Network for Small-Scale Agricultural Biotechnologies, ANSAB	• plant tissue culture • biopesticides • biofertilizers • mushroom technology	• potato • kapok tree • rice • mushroom	• Asia
Asian Rice Biotechnology Network, ARBN (IRRI)	• DNA fingerprinting of pests and pathogens • low-cost marker-aided selection • transgenic rice	• rice	• Asia
Phaseolus Bean Advanced Biotechnology Research Network, BARN (CIAT)	• constraint identification • technology transfer • information exchange	• beans	• international
Cassava Biotechnology Network, CBN (CIAT)	• stimulate cassava biotechnology research on priority topics • integrate priorities of small-scale farmers, processors, and consumers in cassava biotechnology research planning • information exchange	• cassava	• international
Technical Cooperation Network on Plant Biotechnology, REDBIO (FAO/RLAC)	• generation, transfer and application of plant biotechnology • national and regional policies • information exchange	• vegetables • roots and tubers • cereals	• Latin America and the Caribbean
DONOR AGENCIES			
Australian Centre for International Agricultural Research, ACIAR	• use biotechnology wherever appropriate as a research tool within any of ACIAR's projects		• international
DGIS Special Programme Biotechnology and Development Cooperation (Ministry of Foreign Affairs, The Netherlands)	• improve developing-country access to biotechnology, with special emphasis on small-scale producers and women • technical cooperation • international collaboration and coordination	• "orphan" commodities • cassava	• Colombia • India • Kenya • Zimbabwe

NAME (host institution)	PRIORITIES	AGRICULTURAL FOCUS (crop / livestock)	REGION / COUNTRY FOCUS
FAO/AGP Programme on Plant Biotechnology (Food and Agriculture Organisation of the United Nations)	• information dissemination and cooperation • advisory services • capacity building • promote research, technology transfer and adoption	• rice • roots and tubers • horticulture • industrial crops	• international
United Nations Development Programme	• productive and sustainable agriculture	• food crops • cash crops • livestock	• international
World Bank	• invest in biotechnology as a contribution to economic development in World Bank member countries		• international

CATIE = Centro Agronomico Tropical de Investigacion y Ensenanza; CIAT = International Centre for Tropical Agriculture; CIMMYT = International Centre for Maize and Wheat Improvement; CIP = International Potato Centre; CIRAD = Centre de coopération internationale en recherche agronomique pour le développement; FAO/AGP = UN Food and Agriculture Organization, Plant Production and Protection Division; FAO/RLAC = UN Food and Agriculture Organisation, Regional Office for Latin America and the Caribbean; ICGEB = International Centre for Genetic Engineering and Biotechnology; ICRISAT = International Crop Research Institute for the Semi-Arid Tropics; IICA = Interamerican Institute for Cooperation in Agriculture; IIRSDA = Institut international de recherche scientifique pour le développement en Afrique; IITA = International Institute for Tropical Agriculture; ILRAD = International Laboratory for Research on Animal Diseases; IRRI = International Rice Research Institute; ISNAR = International Service for National Agricultural Research; ODA = Overseas Development Administration (UK); USAID = United States Agency for International Development.

Note: For the purpose of the survey, ACIAR was considered as a donor agency as it does not conduct its own research, but arranges collaborative research projects between scientists working in existing research institutions in Australia and in the overseas partner countries.

Funding

Bilateral and multilateral aid agencies, international organisations, national agricultural research institutions, universities, private foundations and commercial companies are all involved in the financing and/or execution of international biotechnology initiatives for developing countries. Some of the research programmes described below receive funding from several different sources. Similarly, a number of countries which provide support for biotechnology through bilateral aid programmes are involved in a wide range of activities.

Since 1985, the various organisations covered by the survey contributed an estimated $260 million in *grant funds* to international biotechnology initiatives. These activities included: research programmes, advisory programmes, networks and specific projects. In the same period, the total biotechnology component of World Bank *loans* and credits for national agricultural research projects in developing countries has been estimated at around $150 million. Consequently, total international investment (grants plus loans) since 1985 can be estimated at $400 million.

Tables 2 (Funding sources) and 5 (Expenditures) below relate to the 25 crop and livestock biotechnology research programmes listed in Table 1, for which comparative information is available. For these 25 programmes, total grant funding committed so far has amounted to $140 million. The relative importance of the different sources of funding is indicated below:

Table 2: **Funding sources**

Foundations	40.9 per cent
Bilateral donors	31.6 per cent
Multilateral donors	16.5 per cent
National institutions (matching funds)	4.6 per cent
Miscellaneous Research Grants	3.9 per cent
Private commercial	2.3 per cent

The overwhelming share of funding by foundations is provided by the Rockefeller Foundation and, while the Rockefeller Foundation does support a number of smaller biotechnology research programmes, the major share of its effort is directed to its International Rice Biotechnology Program. This programme involves an international network of researchers in universities and public research institutions in both developed and developing countries, as well as at IRRI and CIAT. Since the programme was initiated in 1985, more than $50 million have been invested.

Two countries contribute a large share of the total commitment to research programmes in agricultural biotechnology. These are France (through the plant and livestock programmes of the Centre de Coopération Internationale en Recherche Agronomique pour le Développement, CIRAD — Centre for International Cooperation in Agricultural Research for Development) and the United States (through the United States Agency for International Development, USAID).

The Netherlands is also a major contributor to international initiatives in biotechnology, but rather than concentrate on research programmes, its efforts encompass a diversity of activities. The major share of grant funds from multilateral donors is contributed by the United Nations Development Programme.

As indicated above, since 1985, an estimated $260 million have been contributed in grant funding to the various international initiatives in biotechnology covered by the IBS survey. While it has been stressed that the survey was not exhaustive and that these figures should be regarded simply as orders of magnitude, it is useful to compare them with other orders of magnitude for biotechnology research and also with agricultural research expenditures more generally.

Estimates of expenditure on agricultural biotechnology research vary widely and are available for very few countries. For the United States, a recent report[8] estimates Federal investment in agricultural biotechnology at $207.5 million for the financial year 1993, with United States Department of Agriculture (USDA) investment alone at $119.5 million.

One of the more reliable estimates for research and development spending by some of the leading US companies in the biotechnology industry (not including pesticide and see companies) provides the figures shown in Table 3 below for 1991 and 1992:

Table 3: **Company Commitments to R&D**

Company	RESEARCH & DEVELOPMENT SPENDING			
	Latest FY spending ($ million)	Change from last FY (%)	Versus revenue (%)	Per employee ($)
AGBIOTECH COMPANIES				
Agridyne Technologies	4.008	20.3	325.6	62 625
Biosys	2.554	11.6	56.1	n.a.
Calgene	9.256	61.1	42.3	32 823
Crop Genetics International	6.511	8.9	206.6	72 344
DNA Plant Technology	9.134	41.1	76.4	63.874
DNX	6.121*	83.1	82.2	18 003
Ecogen	4.127	40.9	51.4	30 799
EcoScience	4.554*	127.4	3 098.0	65 057
Embrex	2.491	4.5	356.4	38 922
Escagenetics (3/91)	3.004	5.4	178.2	55 630
Idexx Laboratories	3.477	-9.9	6.0	10 934
Mycogen	8.500	28.8	25.0	7 529
Neogen (5/91)	0.993	15.9	15.0	9 548
Ringer	1.686	55.0	8.3	28 100
Syntro	2.129*	1.4	41.1	38 709
Total	**68.545**	**n.a.**	**n.a.**	**n.a.**
Average	**4.570**	**39.6**	**298.8**	**38 634**

Results are for the fiscal year ending 12/92, except as noted
* R*D includes customer-sponsored or government-sponsored expenses
n.a. means not available
N.C. means no change
Source: Standard & Poor's Compustat Services (Englewood, CO).

Thus, 15 of the leading agbiotech companies spent a total of $68.5 million in 1992. Compared with these R&D figures, the total contributions to the various international initiatives in agricultural biotechnology are quite small.

Within the IARCs, approximately 10 per cent of total core budgets is spent on biotechnology. Thus, in 1993, when the funding for core activities of all IARCs combined amounted to $236 million, the amount devoted to biotechnology was in the order of $23.6 million.

Expenditures

The survey assessed the share of research-programme expenditures received by the different categories of institutions involved in these programmes: IARCs, universities and national research organisations in developed countries and in developing countries, and the commercial sector in developed and developing countries. Shares received are as follows:

Table 4: **Expenditure Shares**

Developed countries	43.2 per cent
Developing countries	40.4 per cent
IARCs	14.3 per cent
Other	2.1 per cent

Table 5 provides a breakdown of different categories of expenditure within the research programmes, as listed in the questionnaire:

Table 5: **Categories of expenditure**

Research & Development	50.2 per cent
Human Resources Development	18.3 per cent
National Program Participation	9.6 per cent
Infrastructure Support	8.1 per cent
Information Products	5.6 per cent
Policy and Program Management	5.3 per cent
Other	2.9 per cent

This table indicates the strong emphasis on research and development (R&D), followed at a distance by human resource development. These programme elements will be discussed in the following sections.

In contrast to research and training, infrastructure development and national program participation receive limited attention. Only about 8 per cent of expenditures are allocated to infrastructure support, which includes activities such as:

- supply of laboratory equipment (either in developing or industrialised countries)
- service agreements for equipment
- construction of facilities
- supply of genetic material
- follow-up support for scientists in developing countries

In only one programme, the Indo-Swiss Collaboration in Biotechnology (ISCB) programme (discussed below), is a major share (45 per cent) of total expenditures devoted to infrastructure development, although a small amount of discretionary funds are available in other programmes for equipment purchase, supplies, etc. National program participation includes expenditures for developing country institutes or individuals which are not included within R&D, training, or infrastructure development. This covers, for example, the cost of travel to attend planning or review meetings of the international programmes, or the cost of setting up and maintaining networks.

Research programme emphasis

Within the 25 research programmes for which comparative information is available, 142 discrete research activities were recorded. A very large share of total research activities is devoted to research on plant production and protection (78 per cent). Livestock production and health accounts for slightly over one-fifth (21 per cent) of total research activities, with food-processing accounting for only 1 per cent.

Crops

Among the research activities devoted to crops, the survey attempted to analyse both the principal objectives of the programmes and the types of techniques being used to achieve these objectives. It has also examined the types of crops on which research effort is concentrated.

Table 6 indicates the objectives of 111 crop research activities by crop category.

In order of priority, research objectives are:

Virus resistance/control	25 per cent
Insect resistance/control	19 per cent
Quality	18 per cent
Disease resistance/control	17 per cent
Micropropagation	14 per cent
Not available	6 per cent

In terms of the techniques which are being applied in order to achieve these objectives:

Transformation	39 per cent
Cell and tissue culture	27 per cent
Diagnostics	12 per cent
Genetic mapping	11 per cent
Microbiology (including nitrogen fixation, biopesticides, fermentation)	5 per cent
Not available	7 per cent

When the relative importance of different crops in the total research effort is examined (see Table 6), the focus is clearly on food crops. Cereal grains account for some 28 per cent of the total, root crops for 19 per cent and legumes for slightly over 14 per cent. Whereas research efforts are more or less evenly spread among root crops, legumes and perennial crops, within the cereals, the effort devoted to rice (23 per cent of total research effort) far outstrips that on maize or sorghum. This again illustrates the relative importance of the Rockefeller Foundation rice biotechnology programme.

Horticulture, essentially for export, accounts for some 10 per cent of total effort. The category termed "Perennial", which includes coffee, cocoa, sugarcane, and bananas and plantain — also predominantly export crops — accounts for some 10 per cent of effort.

Table 6: **Crop Research Objectives** (by number of projects)

CROP	OBJECTIVE						
	Disease resistance	Insect resistance	Virus resistance	Quality traits	Micropro-pagation	N.A.	All
CEREALS	**5**	**7**	**10**	**9**			**31**
rice	5	4	9	8			26
maize		3	1				4
sorghum				1			1
ROOT CROPS	**4**	**6**	**8**	**2**	**1**		**21**
potato	1	4	2				7
cassava	1		3	2			6
yam	2		2		1		5
sweet potato		2	1				3
LEGUMES	**3**	**3**	**2**	**3**		**5**	**16**
bean	1	2	1	2			6
cowpea	1	1					2
other	1		1	1		5	8
HORTICULTURE	**4**		**5**		**2**		**11**
PERENNIAL	**2**	**2**	**2**	**3**	**10**		**19**
banana\plantain	2		1	1	4		8
coffee		1			4		8
sugarcane		1	1	2	1		5
cocoa					1		1
MISCELLANEOUS	**1**	**3**	**1**	**3**	**3**		**11**
N.A.						**2**	**2**
ALL	**19**	**21**	**28**	**20**	**16**	**7**	**111**

As indicated in Table 6 virus resistance and insect resistance and control rate highest as objectives of international research programmes in biotechnology, with quality characteristics third in order of importance. It is also recalled that the emphasis in these programmes is on food crops. These priorities contrast sharply with those which emerge from biotechnology developments in OECD Member countries. Apart from animal vaccines, the only 2 animal or plant products which have already reached the market are: bovine somatotropin (BST), for increasing milk production in cows, which is available in the United States and some developing countries, but is not available in the European Community; and the Flavr Savr tomato, the delayed-ripening tomato, launched in the United States in June 1994.

Taking the example of field releases of transgenic plants in OECD Member countries to the end of 1992, Tables 7 and 8 below show, firstly, all approvals granted according to the trait introduced. Of the 1250 releases, herbicide tolerance accounts for by far the greatest number of releases (38.9 per cent), followed by the use of genetic markers (30.4) and then by traits expected to influence virus resistance, insect resistance, crop quality, male sterility and disease resistance.

Table 7: **Summary of Field Release Approvals Granted, by Trait**

Trait	Approvals granted	
	Number	Percentage of total
Herbicide tolerance	489	38.9
Disease resistance	35	2.8
Virus resistance	115	9.1
Insect resistance	89	7.1
Use of markers	382	30.4
Quality traits	72	5.7
Flower colour	5	0.4
Research studies	18	1.4
Male sterility	39	3.1
Resistance to stress	9	0.7
Heavy metal tolerance	3	0.2
Other	1	0.1
Total releases involves	**1 257**	**100.0**

Source: Field Release of Transgenic Plants, 1986-1992: an Analysis, OECD, Paris 1992.

As shown in Table 8 which presents an overview of approvals granted between 1986 and 1992 according to crop, while release approvals have been granted for 30 different crop hosts, 7 only account for more than 80 per cent of total approvals: these are oilseed rape or canola, potato, tobacco, tomato, corn, flax and soybean. In terms of the numbers of trial sites, 7 crops (as above, except that flax has been replaced by cotton) account for more than 80 per cent of individual site releases.

Only 5 countries — the United States, Canada, United Kingdom, France, Belgium — account for 94.7 per cent of all releases.

Livestock

In research programmes related to livestock, vaccine development and diagnostics for tropical livestock diseases are of almost equal importance, with a very limited number of programmes focussing on reproductive techniques or on productivity (for example, embryo transfer techniques). The bulk of the effort relates to cattle, although one programme is exclusively concerned with small ruminants. The main objectives for the animal health related research comprises the development of new diagnostics and vaccines for tick-borne diseases (theileriosis, anaplasmosis, babesiosis, and cowdriosis), trypanosomiasis, rinderpest, and foot-and-mouth disease.

Table 8: **Annual Approvals Granted, by Crop**

	Numbers granted each year							Total
	1986	1987	1988	1989	1990	1991	1992	
Alfalfa			1	7	4	3	6	21
Allegheny							1	1
Apple						1		1
Asparagus			1					1
Broccoli					1			1
Cantaloupe					7	3	4	14
Carnation							1	1
Cauliflower						1	1	2
Chicory					1	1	3	5
Chrysanthemum						2	1	3
Corn					2	23	40	65
Cotton				5	9	9	14	37
Cucumber				1	1	1		3
Flax			1	5	6	13	24	49
Kiwifruit						1		1
Lettuce							1	1
Melon					1	1	2	4
OSR/canola			5	15	41	54	175	290
Papaya							1	1
Petunia					1	1		2
Poplar			1	2	2	1		6
Potato		2	8	12	21	38	52	133
Rice					2	1	1	4
Soybean				4	5	5	26	40
Squash					7	2	4	13
Sugarbeet				1	8	9	10	28
Sunflower					1	1		2
Tobacco	1	3	7	9	20	19	13	72
Tomato		3	12	7	14	18	18	72
Walnut					1	1		2
Others	1	1	1					3
Total	**1**	**9**	**37**	**69**	**154**	**209**	**399**	**878**

Source: Field Release of Transgenic Plants, 1986-1992: an Analysis, OECD, Paris 1993.

Training opportunities

Most programmes include a human resources development component which involves training in research institutions in the United States, in Europe or in institutions in developing countries. In the latter case, a majority of training opportunities are offered in the IARCs located in developing countries, while the rest are offered in universities which form part of collaborative research networks with

universities in industrialised countries. In a very few cases, opportunities are provided for developing country scientists to receive training in the laboratories of major commercial firms (for example, Monsanto, ICI Seeds, DNA Plant Technology).

Table 9 provides a breakdown of training opportunities for the 25 crop and livestock programmes. The information throws light on the numbers of organisations which offer training opportunities and the levels at which training opportunities are offered. Almost all of the research programmes offer positions at post-doctoral level, while training at doctoral and master level is offered by 18 and 14 programmes respectively. Actual numbers of opportunities available are again concentrated at the post-doctoral and doctoral levels with considerably fewer opportunities available at master level. There are fewer opportunities available at the level of technician than at either doctoral or post-doctoral level.

Table 9: **Training Opportunities provided by Crop and Livestock Research Programmes**

Training category	No. of programmes providing training	Total No. of positions available
Post-doctoral	22	202
Doctoral	18	179
Master	14	43
Technician	17	144
Management	3	10
Internship	5	98
Other		
19	273	

Biotechnology policy activities

In addition to research and technical training, a number of international biotechnology initiatives include advice and training on policy issues in their activities. Analysis of information collected on this subject indicated that biosafety and intellectual property rights rank high as priority areas. In some cases, this entails practical exposure to, for instance, field trials as an integral part of scientific training programmes. In most cases, it takes the form of workshops and seminars, to increase awareness in developing countries of the implications of biosafety and intellectual property rights protection. As illustrations of this type of activity, the Agricultural Biotechnology for Sustainable Productivity programme (ABSP — discussed in the following section) has conducted biosafety and intellectual property rights workshops in Indonesia, Egypt, Jamaica and the United States. In addition, ABSP initiated a biosafety internship programme in 1993. Biosafety workshops have also been organised by the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) in Argentina and Costa Rica (in collaboration with the Interamerican Institute for Cooperation in Agriculture [IICA]) and Indonesia.

Apart from the research programmes, other international initiatives concentrate entirely on policy issues. The IBS is an advisory service to developing countries on matters of biotechnology research programme management and policy, which include biosafety and intellectual property rights, as well as socio-economic and technical issues.

The recently-created Biotechnology Advisory Commission, based at the Stockholm Environment Institute in Sweden will provide advice, on request, to government and inter-governmental authorities on field testing and/or on the planned introduction of genetically modified organisms. Finally, IICA provides support to policy formulation in Latin America and the Caribbean. IICA encourages the formulation and harmonization of biosafety and intellectual property policies in this region through workshops, technical assistance and policy studies.

IV. BILATERAL AID PROGRAMMES

A limited number of bilateral aid agencies are supporting international biotechnology initiatives. This section is not intended to provide an exhaustive description of such activities, but rather to stress major differences in the types of approaches adopted by the different countries and agencies in the design and execution of these programmes. The discussion is confined to activities supported by the Netherlands, Switzerland, the United Kingdom and the United States.

The Netherlands

In the Netherlands, several government ministries (Housing, Physical Planning and the Environment; Welfare, Health and Cultural Affairs; Agriculture, Nature Management and Fisheries; Economic Affairs; Social Affairs and Employment; Justice; Foreign Affairs; Education and Science) are involved in the development of policy related to biotechnology and in the coordination of biotechnology regulations.

At the beginning of 1992, the Netherlands Government launched the Special Programme Biotechnology and Development Cooperation (DGIS) for a period of 5 years. A total of $27 million has been allocated to the programme, which has two distinctive features. Firstly, it is specifically directed towards small-scale producers and women in developing countries. The programme therefore focuses essentially on "orphan commodities" and, in particular, on cassava. In the process of implementing the programme, which is based on a "participatory, bottom-up" approach[9], considerable effort has been made to involve a broad range of actors in the programme's target countries — policy-makers, researchers, NGOs and producers or their representatives — and to stimulate interaction in identifying needs and research priorities.

Secondly, while focusing on a limited number of countries — Kenya and Zimbabwe in Africa, Colombia in Latin America and India — the programme covers a diversity of activities. These have thus far included: biotechnology priority-setting exercises in Zimbabwe and Kenya; a regional workshop on biosafety for southern Africa, held in Harare in October 1993; the commissioning of a paper on the implications of intellectual property rights in biotechnology and plant breeding in developing country agriculture. The Netherlands also provides financial support for the Biotechnology and Development Monitor, a quarterly journal published jointly with the University of Amsterdam.

The DGIS programme is the main supporter for IBS, and for the Cassava Biotechnology Network (CBN) at CIAT. CBN was created to serve as a forum on cassava biotechnology issues and to foster the use of biotechnology where it can help address priority areas of cassava research. In particular, priority problems of small-scale farmers, processors and consumers for which biotechnology research may offer a solution, have been identified.

Switzerland

By far the longest-established of the bilateral initiatives in biotechnology is the Indo-Swiss Collaboration in Biotechnology programme, based on a bilateral agreement between the Indian (Department of Biotechnology DBT) and Swiss (Swiss Development Cooperation SDC) governments. This programme was initiated in 1974 as a result of the personal efforts of Swiss and Indian scientists, as a collaborative project between the Biochemical Engineering Research Centre (BERC) of the Indian Institute of Technology (IIT) in New Delhi and the Institute of Biotechnology of the Eidgenossische Technische Hochschule Zurich (Swiss Federal Institute of Biotechnology).

In 1988 the programme was restructured and currently involves the Department of Biotechnology, New Delhi, and 5 Indian scientific institutions in Madras, Baroda, Madurai, Bangalore and Izatnagar and 4 partner institutes in Switzerland. Projects included in the programme range from research activities in veterinary diagnostics and the immunology of leprosy, to bioprocess development for the production of extracellular enzymes or biopesticides.

In addition to collaborative Swiss-Indo research and strong emphasis on the training of Indian scientists in Swiss institutes, the programme provides other kinds of support. These include, for example, documentary support and joint scientific publications. A unique feature of the Swiss-Indo programme is the importance attached to infrastructure support and, specially, to the transfer of material, equipment and instruments which are not available in India.

Total funds allocated to the programme for the period lst April 1988 to 31st March 1995 are $3 700 000.

United Kingdom

The United Kingdom's Overseas Development Administration (ODA) supports international agricultural biotechnology research through two programmes. The first and largest is the Plant Sciences Research Programme, which is managed by the Centre for Arid Zones Studies at the University of Wales. The programme is composed of several advanced plant breeding and crop physiology projects at various British public and private institutions, and IARCs. ODA contributes approximately US $1.6 million annually to this programme.

The second programme, with funds totalling around $600 000 per year, is the Biotechnology Programme, managed directly by the Natural Resources and Environment Department of ODA. It acts as "a pump-priming mechanism to encourage collaboration between commerce, research institutions and international centres." Funds are distributed over some 12 research projects, mostly at British public institutions[10]. Plant biotechnology projects cover, for example, the use of RFLPs in cassava, biological nitrogen fixation in rice, and bacterial wilt control in potato[11].

The United States/USAID

The United States is a major contributor to international biotechnology initiatives both with respect to livestock and plants. Its major activity related to livestock is the Tickborne Diseases Vaccine Development Program (TDV), based at the University of Florida. This programme, which was initiated in 1985, has been conducting research on improved vaccines and diagnostic tests for tick-borne diseases in livestock: heartwater, anaplasmosis and babesiosis, in collaboration with research institutes in Africa (in Egypt, Kenya, Mali and Zimbabwe), Thailand, Mexico and Costa Rica. To date, USAID has contributed around $17 million of the total $21.5 million committed to this programme.

Another biotechnology programme to which USAID contributes is the Small Ruminant Collaborative Research Support Program (SR-CRSP) which, in its Animal Health Component, has a biotechnology research programme on vaccines to protect sheep and goats against prevalent diseases. USAID also contributes to the International Laboratory of Molecular Biology for Tropical Disease Agents (ILMB) based at the University of California at Davis, which is developing recombinant virus vaccines for both animal and human diseases. The contributions of USAID to the two latter programmes are, however, modest compared to those for the TDV programme.

The current efforts of USAID in support of plant biotechnology initiatives originated from a 1990 report of the National Research Council which brought together the views of a panel drawn from National Agricultural Research Systems, industry, academia, IARCs, United States Department of Agriculture, the Rockefeller Foundation and developing countries to suggest the future orientation for AID involvement. The report[12] recommended a collaborative programme which would integrate research, biosafety and intellectual property rights issues and human resource development.

It was decided that the research programme should focus on biotechnology areas expected to yield results within a 3 to 5 year time frame: tissue culture, micropropagation and transformation; applications for controlling plant diseases and pests. Proposals for a plant biotechnology programme were then invited from both public, private non-profit and private commercial firms and, following external peer review, an agreement to set up the ABSP project was made in September 1991. An original feature of ABSP is the strong emphasis on public and private sector collaboration. While the lead institution — Michigan State University (which works in collaboration with Cornell, Texas A&M and Stanford Universities) — is public, the programme includes subcontracts to commercial companies in the United States (DNA Plant Technology, ICI Seeds) and in Indonesia (Fitotek Unggul).

Biosafety and IPR are incorporated as integral parts of the research programme which covers a diversity of crops, including one cereal, horticultural crops, potato and sweet potato, as well as plantation and ornamental crops. The relative importance of the different crops within the programme is indicated below:

Maize	20 per cent
Potato	15 per cent
Cucurbits	14 per cent
Pineapple	12 per cent
Banana	12 per cent
Coffee	12 per cent
Tomato	7 per cent
Palm	4 per cent

The developing countries involved in the programme include: Kenya (potato, maize, sweet potato for insect resistance), Egypt (melons, squash, cucumbers, maize, potato, tomato), Indonesia (pineapple cloning, genetic engineering of maize for insect resistance, potato, sweet potato), Costa Rica (banana, coffee and pineapple cloning, potato, sweet potato, maize). Table 10 provides programme elements in terms of crop, productivity constraint being addressed by biotechnology research, the United States institution(s) involved and the corresponding developing country institution and/or private firm involved.

Table 10: **Constraint-Oriented Research Collaboration Supported through the Agricultural Biotechnology for Sustainable Productivity Project**

Crop	Productivity constraint addressed	US institution	Developing country institution
Potato	Tuber moth resistant/genetic engineering	M.S.U.[1]	KARI (Kenya) AGERI (Egypt) CRIHC (Indonesia
Sweet Potato	Weevil resistance/genetic engineering	M.S.U.	CRIFC (Indonesia)
Maize	Stem borer resistance/genetic engineering	M.S.U. Cornell, Texas, A&M, ICI Seeds	KARI (Kenya) CRIFC (Indonesia) AGERI (Egypt) UCR (Costa Rica)[2]
Cucurbits	Potyvirus resistance/genetic engineering	M.S.U. Asgrow, Cornell	AGERI (Egypt) IAVHII (Morocco)[2]
Banana, Pineapple, Coffee, Ornamental palms	Novel micropropagation through liquid culture or bioreactor vessels	DNAP	ACR (Costa Rica)
Pineapple	Novel micropropagation through liquid culture or bioreactor vessels	DNAP	Fitotek Unggul (Indonesia)
Tomato	Gemini virus resistance/genetic engineering	Scripps Research Institute	AGERI (Egypt)

[1] Abbreviations: ACR, Agrobiotechnologia de Costa Rica; AGERI, Agriculture Genetic Engineering Research Institute; CRIFC, Central Research Institute for Food Crops; CRIHC, Central Research Institute for Horticultural Crops; IAVHII, Institute of Agriculture and Vetinerary Science, II; KARI, Kenyan Agricultural Research Institute; M.S.U., Michigan State University; UCR, University of Cost Rica.

[2] Probably collaborators

To date, USAID has contributed some $6.7 million to this major biotechnology programme, while smaller sums have been committed to less ambitious, more sharply-focused biotechnology programmes. These include the Bean/Cowpea Collaborative Research Support programme based at several universities in the United States and two programmes (discussed below) which involve proprietary technology (Feathery Mottle Virus-Resistant Sweet Potato for Africa through Biotechnology, and ISAAA).

*** * ***

The foregoing, which concerns only four countries, illustrates a number of different approaches to the design and execution of international biotechnology initiatives. Most programmes have been to a large extent science-inspired, with scientists and science administrators from developed countries playing a leading role in project formulation. In the case of ABSP, input by the scientific communities from the target countries was solicited as part of the design phase of the programme. Another feature of this programme is that the eventual commercialisation of products generated by the research programmes has been anticipated and active involvement of the private, commercial sector sought from the outset. Switzerland, whose aid programme is concentrated in a very limited number of countries, has chosen the path of research collaboration with a single country.

In strong contrast to the "top-down" or science-driven approach of many international biotechnology initiatives, the Netherlands, whose programme involves four developing countries, seeks primarily to reach and involve disadvantaged groups in those countries and to contribute to research effort on crops of crucial importance for those particular groups.

V. PUBLIC/PRIVATE INITIATIVES AND INTELLECTUAL PROPERTY RIGHTS

The involvement of the private commercial sector in international biotechnology initiatives is limited, both in terms of financial contribution and as suppliers of proprietary technology. The discussion below focuses on the few examples of collaboration between the public sector and private industry on which information was provided.

Indo-Swiss Collaboration in Biotechnology

The Indo-Swiss programme has reached the stage where the production and commercialisation of bioinsecticides based on *Bacillus thuringiensis* (Biocide-T) and *Bacillus sphaericus* (Biocide-S) are being envisaged. To date, the private sector is involved to the point where memoranda of understanding have been exchanged between the public research institutions involved and commercial companies which would be responsible for bio-processing, large-scale field testing, the commercial development of products following the successful completion of field testing and, eventually, commercialisation. In each case, the agreements involve a commitment on the part of the public research institute or university to offer the commercial company first option on commercialisation, following product development and assessment of commercial viability, as well as payments to the universities for their research input.

Beyond 1995, a third phase of the Indo-Swiss programme, which would more directly support product development and the direct involvement of the private sector, is envisaged.

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

One of the activities in this programme, to which $750 000 has been allocated over a three-year period, seeks to introduce proprietary insect-resistant genes into both potato and sweet potato. A private company which holds the gene patents, Agricultural Genetics Company (AGC) of the United Kingdom, has been commissioned by ODA to produce transgenic germplasm of both sweet potato and potato expressing a number of its proprietary insect-resistance genes. ODA is funding the research effort by AGC which, for its part, has granted ODA a non-exclusive royalty-free licence to the proprietary technology. This will enable ODA to distribute any transgenic germplasm resulting from the research programme to plant breeders in developing countries.

The transgenic germplasm will be tested at the University of Durham before being tested in a developing country. ODA will be responsible for the coordination of field trials and for the incorporation of the novel transgenic breeding lines in conventional breeding programmes. The programme began early in 1990 and already has transgenic germplasm ready for testing in developing countries. In this particular instance, field-testing is being delayed because, in the developing countries envisaged, biosafety procedures are not yet in place.

ABSP

The ABSP project, supported by USAID, has been described on page 19 above. One of the specific objectives of ABSP is to direct its research programmes towards product development and commercialisation. Private firms have therefore been involved in the project from the outset, with respect to providing developing country scientists opportunities for working in private labs, and to offering short in-house courses on management or particular industrial techniques (bioreactor). Firms have also been expected to have a financial stake in the programme and their financial contribution has so far amounted to around 18 per cent of the total.

The particular research efforts in which private firms are involved are as follows:

ICI Seeds	Stem-borer resistance in maize
DNA Plant Technology Corporation) Agribiotechnologia de Costa Rica)	Bioreactor cloning of banana, pineapple, coffee, ornamental palm
DNA Plant Technology Corporation) Fitotek Uggul, Indonesia)	Micropropagation of pineapple

While the ABSP programme has reached the stage of field trials, it has not yet reached the stage of final product development and commercialisation.

Feathery Mottle Virus Resistant Sweet Potato for African Farmers through Biotechnology

The Feathery Mottle Virus Resistant Sweet Potato for African Farmers through Biotechnology project is another public/private sector biotechnology activity funded by USAID. This project, proposed by Monsanto Chemical Co., is the first where AID has provided research grant funding to a commercial company. It concerns the development of virus-resistant sweet potato by means of coat protein recombinant technologies, using proprietary expression vectors.

The project was initiated at the end of 1991, following recruitment of a Kenyan scientist for training at Monsanto's laboratory in St. Louis. The project involves three years of post-doctoral training in the techniques of genetic transformation of sweet potato for virus-resistance and 15 months' training for a technician. In addition to the scientific training provided, the scientist will participate in ongoing Monsanto biosafety field trials and procedures with a number of transgenic crops, as well as take part in biosafety and intellectual property rights seminars and workshops.

Monsanto provides a royalty-free non-exclusive licence as well as funding to the Kenyan Agricultural Research Institute (KARI) to develop the technology in sweet potato grown and sold in Africa. The USAID financial contribution to the project amounts to $238 000 over a three-year period.

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

ISAAA is a not-for-profit initiative set up in 1991 which performs the role of "honest broker" in facilitating the transfer of **proprietary** biotechnology to developing countries. It is co-sponsored by bilateral and multilateral agencies, private foundations and private sector companies. Financial contributions have amounted to some $6 million to date, with commercial enterprises contributing around 10 per cent.

The activities of ISAAA are confined to three specific areas of biotechnology — tissue culture, diagnostics and transgenic plants. ISAAA's five-year pilot programme focuses on ten countries chosen, firstly, because they have relatively high levels of scientific and technological capability and, secondly, because their governments are committed to the development of biotechnology. The countries include: Egypt, Kenya and Zimbabwe in Africa; Indonesia, Malaysia, the Philippines and Thailand in Asia; Brazil, Costa Rica and Mexico in Latin America.

ISAAA fulfils its honest broker function by identifying sources (public or private) of proprietary technology perceived as appropriate to meet specific developing country needs, and acting as broker in negotiating arrangements for the transfer of the technology to public institutions in the country concerned. Thus far, all technology has been donated, either by commercial companies or by universities holding the relevant patents. ISAAA also helps to mobilise financial and other resources needed for training, testing, regulatory supervision, etc. to ensure effective technology transfer. It also provides advice on biosafety procedures, commercialisation and trouble-shooting.

To date, ISAAA has brokered and secured funding for several projects. These include:

— Introduction of virus coat protein technology developed by Monsanto for conferring non-conventional resistance to PVX and PVY viruses in potato in Mexico. The project is funded by the Rockefeller Foundation.

— Development of a DNA diagnostic probe for determining the presence of pathogens in seed and to monitor epidemiological developments. Collaborating institutes are: Washington State University Research and Extension Centre and the Asian Vegetable Research and Development Centre (AVRDC) in Taiwan. The project is funded by USAID's Program for Science and Technology Cooperation (PSTC).

— Development of non-conventional resistance to the important CMV disease of criollo melons in Costa Rica using Asgrow Seed Company's proprietary coat-protein technology. The institutions involved are: The University of Costa Rica, San Jose and the Asgrow Seed Company, Kalamazoo, USA. This project is funded in part through USAID's ABSP programme.

— Use of enzyme linked immunosorbent assays (ELISA) donated by Pioneer Hi-Bred International, USA, for the use of maize viruses in Brazil. The collaborating institute in Brazil is the National Centre for Maize and Sorghum

Research (CNPMS).

The Monsanto/Mexico project is the most advanced of ISAAA's projects. CINVESTAV, at Irapuato in Mexico, is the institution which has conducted the research and which was responsible for field-testing which began in March 1993. It is envisaged that the multiplication, production and marketing of the transgenic potato variety will be carried out both by a commercial potato producer group and by INIFAP, the National Institute of Forestry, Agriculture and Livestock Research, through its extension services[13].

Intellectual property rights

Few of the research programmes have yet **generated** proprietary biotechnology, in the sense of taking out patents. This has already occurred in livestock programmes for vaccines and diagnostics, where patents are considered necessary to encourage private sector collaboration in large-scale production, but not yet in plant biotechnology. In the TDV programme, for example, three patents have already been taken out (the patents being owned by the University of Florida and, where appropriate, other collaborating universities) and a number of others are pending, both in the United States and in Africa. It is anticipated that the first product generated by the programme (an attractant tick decoy) should be ready for commercialisation during 1994. ILRAD owns a patent for a novel vaccine for East Coast Fever. It is collaborating with the pharmaceutical company SmithKline Beecham on the large-scale production of the vaccine. ILRAD's host country, Kenya, also granted the institute a patent for the vaccine under the country's new industrial property act. ABSP has filed two plant patents with the US Patent Office which are currently under review.

Elements of proprietary technology developed by the commercial biotechnology industry form part of at least three of the international initiatives concerned with plant biotechnology: ODA/PSRP, ABSP,ISAAA. In the case of ODA/PSRP, ODA has been granted a non-exclusive, royalty-free licence. ISAAA seeks to negotiate equitable arrangements on behalf of the developing country entity concerned and, to date, technology has been made available at no cost.

In the case of ABSP, where partner institutions in the programme are confronted with questions of intellectual property rights, licensing arrangements or the division of royalties, the advice of an external, independent legal council is available. Legal contractual arrangements are thus drawn up early to clarify and assign rights to technologies and to sources of germplasm or other biological resources. These agreements are intended to establish effective technology and germplasm transfer mechanisms from the outset while ensuring at one and the same time, the return of royalties, where appropriate, to both United States and developing country institutions. ABSP has thus made provision for IPR protection in two ways: by taking out patents and by providing participating organisations with advice on IPR.

VI. INTERNATIONAL INITIATIVES IN BIOTECHNOLOGY IN PERSPECTIVE

Developing country participation in international biotechnology initiatives

As shown in Table 4, developing countries are recipients of some 40 per cent of the financial commitment to biotechnology research programmes and networks. Given that the IARCs receive over 14 per cent and that a majority of these centres are located in developing countries, clearly more than half of the total financial commitment to international initiatives in biotechnology is actually spent in developing countries.

Developing countries have participated in policy workshops, particularly on biosafety and intellectual property rights, a majority of which have been organised in developing countries, sometimes on a regional basis. With respect to training opportunities, although this question was not explicitly addressed in the IBS survey, responses suggest that most are offered either in universities in industrialised countries or in the IARCs located in developing countries.

International biotechnology initiatives are more or less evenly spread among the different geographic regions. While a relatively large number of developing countries are involved — over 60 — efforts are concentrated in a small number of countries within each geographic region: Kenya, Zimbabwe, Egypt and Cote d'Ivoire in Africa; Indonesia, Thailand and India in Asia; and Costa Rica, Mexico and Brazil in Latin American and the Caribbean. For some of these countries, these — and other — donor-funded efforts constitute a large share of their total research effort in agriculture. Kenya and Indonesia, for example, have become increasingly dependent on donor support in recent years. In Kenya, donor support in funding agricultural research has increased from 19.6 per cent of total funding in 1986 to 37.0 per cent in 1991[14]. In Indonesia, donors accounted for more than 75 per cent of all agricultural research financing during the latter half of the 1980s[15]. In the case of Costa Rica (excluding CATIE, the international applied research institute located there) it has been estimated that international agencies provided over 44 per cent of total investments in agricultural biotechnology R&D in 1989[16].

The earlier analysis of the emphasis of research programmes suggests that effort is concentrated at the most science-intensive end of the biotechnology spectrum. Similarly, training opportunities are concentrated at the highest levels of achievement: post-doctoral and doctoral. Clearly then, the programmes are intended primarily for countries which have already achieved relatively high levels of scientific and technological capability.

While the number taking part in international biotechnology initiatives is quite high, developing countries have not been closely involved in the planning and design of most international biotechnology initiatives. The most notable exception to this rule is provided by the Netherlands biotechnology programme — which is not confined to research — in which consultation at the "grass roots" level and effort to involve small-scale, resource-poor farmers is an essential element of the design and implementation

process. Few instances where developing countries contribute matching funds to international programmes were recorded in the survey. The most substantial contributions by participating national institutions emerged in the Rockefeller Foundation's International Rice Biotechnology Programme, to which China, India, Indonesia, Korea and Thailand contribute.

International initiatives in the context of national systems of innovation

In Section II it has been suggested that the development and integration of biotechnology in developing countries will require at the very least: the strengthening of national scientific and technological capabilities and institutions; strengthening of the links between biotechnology research and other elements or sub-systems comprising the national innovation system. In that process international technology transfer will play an essential part.

A majority of the programmes included in the IBS survey concern biotechnology **research** and scientific collaboration. Others provide scientific and/or policy advice, while a number of international networks provide information on different facets of biotechnology.

Many of the research programmes provide training opportunities in the methods of biotechnology for developing country scientists. While training and scientific collaboration are essential in enhancing national scientific and technological capabilities, for the most part the research programmes have been designed, and the research priorities determined by, industrialised country scientists and administrators. In most cases, they have not been designed as a function of developing country priorities and capabilities. Similarly, few of the programmes are explicitly concerned with **local** capacity and institution-building.

Although the expectation that new biotechnology products will result from programmes and that they will eventually become available to developing country producers is usually implicit, most of the international initiatives we have been discussing are not yet directly concerned with **product development**. Some programmes are, however, at the field-testing stage, set for multiplication prior to entering production, or set to go into production. This is the case, for example, with the ODA/PSRP, livestock vaccines and diagnostics and ISAAA/Monsanto/Mexico virus-free potato programmes.

At this stage a number of constraints, which had either been overlooked or were not taken into account when designing and implementing programmes, are being encountered. Some of these are inherent in the programmes, while others relate to situations in developing countries.

In the former case obstacles in donor countries concern, for example, the costs to public research institutions of taking out patents (including in developing countries), or the costs of field-testing. In addition to the costs of IPR protection, the policies of donor agencies on "public good" versus proprietary knowledge are often unclear, if not ambiguous. Finally, particularly with respect to the livestock vaccine programmes,

difficulties are being encountered where private sector capital is not forthcoming for product development.

As far as developing countries are concerned, the process of conducting field trials through a collaborative programme can be a valuable learning experience as it may involve setting up an appropriate regulatory framework and infrastructure for the first time. This does, however, require both time and money. At the same time the lack, in many developing countries, of guidelines for conducting field trials can seriously hamper further collaboration in international research programmes.

The obstacles to be encountered in product development and technology diffusion are linked to issues of both supply and demand for new biotechnology products. Where biotechnology will need to be incorporated in seed, its distribution will depend on a seeds sector producing adequate quantity and quality to meet demand. In the case of vaccines, production facilities may not be readily available and in the absence of incentives domestic firms may show little interest in producing biotechnology products. At the same time, there may be little interest on the part of major foreign firms to produce for developing country markets where the potential for growth is viewed as unpromising. Inadequate intellectual property rights protection may also negatively influence foreign firms. This has, indeed, been the case for at least one of the international biotechnology initiatives which has approached commercial firms regarding the production of animal vaccines for developing countries.

Another area of uncertainty is the level of effective demand — as opposed to perceived needs — for new biotechnology products on the part of agricultural producers and/or consumers in developing countries. In those situations where a majority of farmers save their own seed rather than purchase improved varieties, demand would need to be stimulated.

None of the activities discussed in this paper has yet resulted in the **diffusion** or marketing of a new biotechnology product in a developing country. In the ABSP programme, in anticipation of the successful engineering of pest-resistant maize, discussions are under way in Indonesia among the private and public partners involved in the programme to negotiate the terms of commercial production and marketing.

In other programmes, however, questions concerning the ways in which biotechnology products would be produced and distributed to developing country consumers or farmers, and whether this would occur in a market or non-market context, have not yet been addressed. Increasingly, these questions will be linked to reconciling the roles of the public sector and private commercial interests and to resolving questions of intellectual property rights.

Conclusions

When compared to total expenditures in agricultural research in developing countries or to biotechnology R&D in industrialised countries, the total financial effort devoted to international biotechnology initiatives, as estimated from the IBS survey,

is small. A large share of that effort is devoted to a very limited number of research programmes and other activities, with the rest dispersed among a much larger number of small programmes. At the same time, research programmes cover a wide range of scientific activity and a relatively large number of crops.

A number of programmes also provide opportunities for training and research collaboration for developing country scientists in "centres of excellence", either in universities or in the IARCs. These opportunities can be important for building developing country scientific and technological capability.

Biotechnologies being developed in OECD Member countries are not necessarily those most relevant to the problems of food sufficiency or sustainability with which developing countries are confronted. An important feature of some of the international initiatives is that the research is being conducted using germplasm originating in the developing country for which the research results are destined. This has the obvious advantage of facilitating adaptation to local agro-ecological conditions and, at the same time, of preserving local plant genetic resources, and of producing more "appropriate" technology.

As shown above, international biotechnology initiatives are focussed on a limited number of countries, including some which already receive substantial donor support for agricultural research. At present, they also benefit primarily countries with relatively advanced scientific capabilities.

Biotechnology research programmes are concentrated at the higher end of the scientific/biotechnology spectrum and it is difficult to determine, except in a few cases, exactly what type of research is being conducted in national institutions in the participating developing countries. Few programmes give priority to support for infrastructure in research programmes being conducted in developing country institutions although, clearly, this is an important aspect of capacity building. Similarly, effort is focused principally on research, with little or no provision made for product development or, eventually, marketing or distribution of biotechnology products.

One major shortcoming of the large majority of programmes included in the IBS survey is that developing countries have not been actively involved in decisions regarding the nature and scope of international initiatives.

Finally, while the process of bringing a research programme to a successful conclusion, of integrating successful research results in a useable product and making that product widely available is, as we have argued, complex and of necessity long-term, most international initiatives in biotechnology are funded on a short-term basis.

VII. IMPLICATIONS FOR PLANNING AND POLICY

It is important to keep in mind that the context in which biotechnology is being developed is very different from that of the earlier Green Revolution. Particularly for those developing countries where private sector biotechnology research is weak and where technology markets are undeveloped, there will be a continuing need for donor support if biotechnology is to contribute to improved food production and more sustainable agriculture.

Against the background of stagnating or shrinking financial resources and "aid fatigue", it is important to ensure the cost effectiveness of international biotechnology initiatives. This requires that the objectives should be clear, with respect both to donors and to the developing countries which take part, and that projects or programmes be sharply focused.

For donors, the broad, long-term objective should be to help in creating conditions **in** developing countries whereby they are able to take advantage of what biotechnology has to offer, and to integrate biotechnology methods and products within their national innovation systems. This can be done in a number of ways: by capacity building, as in collaborative research programmes and in the training of developing country scientists. It can also be done by providing objective advice and, where necessary, technical and legal assistance in devising workable regulatory frameworks for, for example, biosafety and IPR. In some countries, it may be appropriate to provide financial support and technical assistance for capacity-building in techniques needed to underpin biotechnology (for example, plant breeding and seeds production and certification).

In selecting "target" countries, donor agencies should be aware of conditions prevailing in those countries. This would require knowledge of levels of scientific and technological capability and of domestic constraints not only in research capacity, but in overall capacity to bring to fruition the basic aim of international biotechnology initiatives, which is to assist in making biotechnology applications widely available. It would also be necessary to take these conditions into account when formulating programmes and projects.

If biotechnology programmes are to be successful, it is important that developing country scientists and decision-makers should be closely involved early in the planning stage. Each country has its particularities and intimate knowledge of the functioning of the national innovation system, of agricultural priorities, and of scientific and technological capabilities needs to be brought to bear if biotechnology initiatives are to be integrated effectively.

One potential problem which emerges is that of duplication of effort among the various initiatives, for example in national priority-setting exercises; in the research priorities and objectives of livestock programmes; and in the proliferation of biosafety workshops in the recent past. This suggests a need for coordination of effort both among donors and within "target" developing countries.

One of the useful functions of the IBS survey is that it has provided both donors and developing countries with information regarding international initiatives in biotechnology. Exchanges of information among the different donors and/or programmes are clearly important both to avoid possible duplication and to learn from other's experience. It is also important that this information should be accessible to developing countries.

The respective roles of the public and private, commercial sectors are changing in agricultural research, technology development and diffusion, and these changes may have important implications for the design and execution of international biotechnology initiatives. In some cases and in some countries, public and private sector roles may be complementary. In others, it may be important to acknowledge that markets are either not functioning or are not developed and that, if a biotechnology product is to reach the small, resource-poor farmer, it may be necessary to keep public distribution mechanisms in place, or to engage "intermediaries" — NGOs — in the process. It would then be important to calculate the costs of product development and technology diffusion and to include them in programme costs.

While the contribution of international technology transfer is essential, it is for individual developing countries to determine where biotechnology solutions may offer advantages over more traditional technological means and to formulate national biotechnology policies and strategies in the light of their own needs and priorities. It is also for developing countries to ensure that biotechnology strategies are compatible with overall agricultural research objectives and priorities and that biotechnology research complements, and is not isolated from, traditional agricultural research.

At present little public funding for biotechnology research and development is available in most developing countries and there is still little commercial activity in biotechnology. Innovative ways of encouraging private sector involvement should therefore be explored. These might include an expanded role for "honest broker" intermediaries between private sector interests and public institutions, or joint ventures between small and medium-sized biotechnology firms (domestic and/or foreign). Small or medium-sized firms may be more flexible, both in responding to developing country needs in terms of technology and in negotiating market shares, than multinationals.

One issue on which the IBS survey did not yield much information was the level of counterpart funding contributed to international initiatives by developing countries. Financial participation may be one way of ensuring that countries are indeed committed to particular projects or programmes.

A policy issue which requires rapid solution is that of biosafety. Developing countries and NGOs have often expressed concern that private companies might conduct clandestine, indiscriminate field-testing of genetically-modified organisms in developing countries. At the present time, the absence of established biosafety procedures in developing countries constitutes a major constraint to field-testing — and, indeed, to product development — by the public programmes set up to facilitate the introduction of biotechnology in developing country agriculture.

Another policy issue of concern in international biotechnology initiatives, both for donors and developing countries, is that of intellectual property rights. The legal arrangements made thus far in the cases where proprietary technology has been used suggest that proprietary technology need not **necessarily** imply high costs, nor constitute an insurmountable obstacle for developing countries in gaining access to a particular technology. Here again, the role of the "honest broker" may be important, particularly where neither the donor nor the developing country concerned has expert legal knowledge of rapidly-changing developments in intellectual property rights, especially with respect to plants, following the conclusion of the Uruguay Round.

Finally, lessons drawn from the development co-operation experiences of OECD Member countries over the years suggest that the "top-down" approach has severe shortcomings and that the success of aid programmes and projects depends to a large extent on the participation of developing countries at all levels and phases of design and implementation. Lessons also suggest that, if biotechnology is to have significant impact on developing country agriculture, long-term commitment will be required.

NOTES

1. OECD has retained the following definition: "The application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services". See Alan T. Bull, Geoffrey Holt, Malcolm D. Lilly, *Biotechnology: International Trends and Perspectives*, OECD, Paris, 1982. Appendix 1 lists 11 definitions.

2. The Intermediary Biotechnology Service (IBS) was established by an international group of donor agencies to act as an independent advisor to organisations in developing countries on matters of biotechnology research, management and policy. The project is supported by the governments of The Netherlands and Switzerland, who also provided special support for the IBS survey and the organisation of the international workshop of November 1993.

3. "A system of innovation is constituted by elements and relations which interact in the production, diffusion and use of new, and economically useful, knowledge...a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state". See *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, edited by Bengt-Ake Lundvall, Pinter Publishers, London, 1992.

4. Colin Thirtle and Ruben G. Echeverria, "Privatization and the roles of public and private institutions in agricultural research in sub-Saharan Africa" in *Food Policy*, Vol. 19, No. 1, February 1994.

5. *National Innovation Systems: A Comparative Analysis*, edited by Richard R. Nelson, Oxford University Press, 1993.

6. Howard Pack and Larry E. Westphal, "Industrial Strategy and Technological Change: Theory versus Reality", *Journal of Development Economics*, Vol. 22, No. 1, June 1986, p. 105.

7. Meeting on *International Agricultural Biotechnology Programs: Providing Opportunities for National Participation*, IBS/ISNAR, The Hague, 9-11 November, 1993, and *International Initiatives in Agricultural Biotechnology: A Directory of Expertise*, IBS/ISNAR, The Hague, May 1994.

8. *Biotechnology for the 21st Century*, a report by the FCCSET Committee on Life Sciences and Health, February 1992, US Government Printing Office.

9. *Appropriate Biotechnology in Small-Scale Agriculture: How to Reorient Research and Development*, edited by Joske F.G. Bunders and Jacqueline E.W. Broerse, C.A.B. International, UK, 1991.

10. ODA, Report on Research and Development 1991/1992, prepared by the Natural Resources Institute, 1993.

11. RFLP = Restriction Length Fragment Polymorphisms; DNA-based genetic markers used to map the location of genes of interest.

12. National Research Development Council, *Plant Biotechnology Research for Developing Countries*, National Academy Press, Washington, 1990.

13. Personal communication from Dr. Ariel Alvarez-Morales, Director, Cinvestav, Irapuato, Mexico, 27th July, 1994.

14. Johannes Roseboom, Philip G. Pardey, *Statistical Brief on the National Agricultural Research System of Kenya*, ISNAR Statistical Brief No. 5, November 1993, ISNAR, The Hague.

15. *Structural Adjustment and Agricultural Research*, edited by Steven R. Tabor, ISNAR and Economic Development Institute of the World Bank, May 1994, draft manuscript.

16. Walter Jaffé, "Agricultural Biotechnology Research and Development Investment in Some Latin American Countries", in *Science and Public Policy*, August 1992.