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STRATEGIC DECISIONS FOR AGRICULTURAL BIOTECHNOLOGY: SYNTHESIS OF FOUR POLICY SEMINARS

Joel I. Cohen, Cesar Falconi, and John Komen

Innovation is essential for sustaining and enhancing agricultural productivity in developing countries. In recent decades, agricultural innovation has involved new, science-based products and processes. Moreover, scientific advances are considered a reliable way to increase future productivity. The set of techniques commonly referred to as "biotechnology", in particular, provides new opportunities for achieving production gains. However, introducing biotechnologies to agricultural research involves changes in resource allocation and new responsibilities for policymakers, research managers, and scientists. These responsibilities include determining the extent to which the agenda for agricultural research should embrace biotechnology, managing biotechnology, and clarifying who should benefit from biotechnology investments.

Recognizing the importance of these issues for developing-country governments, ISNAR has, since 1988, conducted a research program on biotechnology policy, organization, and management. Findings of this work recommend that governments should develop a formal policy and research agenda for agricultural biotechnology. However, public budgets for agricultural research are severely constrained in most developing countries. The question, therefore, for national agricultural research systems (NARS) is "how can new initiatives in biotechnology be balanced and integrated with ongoing, conventional agricultural research?"

This Briefing Paper presents the findings of four regional policy seminars held by the ISNAR-based Intermediary Biotechnology Service (IBS) (box 1). It first reviews a framework for decision making in biotechnology that provided the foundation for the seminars. It then discusses and analyses the seminars' results. A final section relates the seminar findings to three recommendations on biotechnology. These are, first, that developing countries should develop a clear policy on and agenda for biotechnology research. Second, partnerships should be forged between developing countries, international research institutions, and public and private research institutes in industrialized countries. Third, incentives should be provided to the private sector for undertaking biotechnology research targeted at the production problems of poor farmers. For a more detailed review of issues of intellectual property rights in agricultural biotechnology, see Briefing Paper number 39, also published in May, entitled Proprietary Technologies and International Agricultural Research.

A Framework for Decision Making

An increasing number of developing countries are investing in human resources and physical infrastructure for agricultural biotechnology. Analyzing this trend, in 1993 IBS conducted a comparative review of 10 developing countries and their experiences in stimulating the use of biotechnology in agricultural research. The re-

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Box 1. ISNAR's Intermediary Biotechnology Service (IBS)

ISNAR, in collaboration with a group of donor agencies, established the Intermediary Biotechnology Service (IBS) in February 1993, with the purpose to provide independent advice to national programs in developing countries on matters of biotechnology policy and research program management. The goal of the IBS project is to support innovation in agricultural research by responding to policy and management needs for biotechnology.

The specific objectives are as follows:

(1) supporting policy and strategy development that enhances capacity in agricultural biotechnology

(2) assisting the development of leadership skills among policy makers and research managers for integrating biotechnology into agricultural research programs;

(3) harnessing the internationally available expertise to respond to identified technical, policy, and management needs.

The products and services provided through ISNAR's biotechnology initiative are based on the systematic analysis of policy, management and organizational requirements for countries considering their plans for biotechnology. IBS is unique among CGIAR centers and other international agricultural biotechnology programs. It distinguishes itself in four ways:

- facilitating contacts and exchange of views in client countries on policy and management issues related to agricultural biotechnology;
- facilitating needs assessments carried out by developing countries themselves, involving policy makers, research managers, and representatives of the private sector and non-governmental organizations, and end users;
- building a program of work based on locally identified policy and management needs;
- working closely with expert organizations to promote complementarity and collaboration.

Research institutes, universities, private institutions, non-governmental organizations, and end-user representatives form the primary client base for IBS. Among these groups, the greatest emphasis is placed on creating a body of scientists, research managers and policy makers from public agricultural organizations who will provide expertise on the challenges facing them with regard to policy, management and organizational issues specific to biotechnology. The ultimate beneficiaries are the rural communities and urban populations in developing countries.

view found that the institutional arrangement adopted in a country for biotechnology-based agricultural research depends on three main factors: the size of the country, its scientific capacity, and its existing research infrastructure. Indeed, some developing countries may be unable to use biotechnology due to a combination of pressing needs not requiring biotechnology, inability to maintain a strong base for research, and lack of funding.

In 1994, IBS introduced a decision-making framework for agricultural biotechnology. The framework considers the national policy environment. It also incorporates institutional, financial, and program issues involved in priority setting and in determining needs and objectives for biotechnology-based research. Using the framework, decision makers can help ensure that resources allocated to biotechnology—including the activities and contributions of international research centers and donors—are consistent with agreed national objectives. Examples of such objectives are efficiency, equity, food security, and environmental protection. The framework has four phases, which are analogous to those used in planning conventional agricultural research programs. But they also introduce characteristics particular to biotechnology. A few such characteristics are high development costs, integration with conventional research programs, opportunities for international collaboration, and challenges of public perception, biosafety, and intellectual property rights (IPR).

The framework suggests that an overview of existing national policies, priorities, and research activities for agricultural biotechnology be prepared as an introduction to the decision-making process. The subsequent phases are as follows:

1. identify research priorities for which biotechnology offers a comparative advantage

2. determine relevant national policies

3. formulate and implement an appropriate research agenda based on agreed priorities

4. provide for the transfer and delivery of research products to users

Each of the phases requires interaction between technical, financial, and policy specialists. In addition, periodic meetings with stakeholders are essential for the selection of appropriate research activities. Decision makers can foster these interactions by encouraging scientists to focus their research on agreed priorities and supporting policies that facilitate the development and delivery of research products.

The Agricultural Biotechnology Policy Seminars

ISNAR refined and tested the decision-making framework through a series of agricultural biotechnology policy seminars. The seminars addressed issues of strategic planning, priorities, and policies for agricultural biotechnology through three main tasks:

1. examining planning, investments, and priorities for biotechnology research related to agriculture

2. analyzing case studies on future needs in planning and managing biotechnology-based research in agriculture

3. identifying follow-up initiatives and suitable collaboration tailored to the needs of each participating country

The overall goal was to enhance biotechnology's integration with broader national priorities and strengthen the management of demand-driven, user-oriented biotechnology programs in agriculture.

Between September 1994 and October 1996, four regional policy seminars were held—in Southeast Asia, in Eastern and Southern Africa, in the West Asia/North Africa region, and in Latin America and the Caribbean. To emphasize the interactive and multilevel nature of the decision-making process, each was attended by country delegations that included a mix of government planners, agricultural policymakers, research managers from public and private-sector organizations, and end-user representatives. The mixture of delegates ensured that practicing scientists and managers conversed with end users and policymakers, thus broadening the perspectives of each regarding research priorities and focus. At the same time, policymakers learned of issues unique to biotechnology, such as time horizons and regulatory and technical questions.

Seminar methodology

Each seminar was seen as a first step in planning a process of decision making for agricultural biotechnology. In-depth analysis of the country-specific findings was therefore left for subsequent national or institutional meetings. Plenary sessions were based on case studies or examples (technical, policy, or managerial) that illustrated each of the different phases of the decision-making framework. In working groups, the national delegations discussed issues raised in plenary, identifying gaps and needs in their own country and suggesting follow-up activities for overcoming them. The working-group exercises were an essential part of the seminars. They served not only to record possibilities for in-country follow-up activities, but also to guide ISNAR on future issues it should address on agricultural biotechnology.

The agenda included six general themes: (1) introduction and overview, (2) needs and priorities for biotechnology research, (3) identifying national policy issues, (4) mobilizing and allocating resources, (5) delivering benefits through product development and technology transfer, and (6) follow-up planning at the national level. Specific topics to be addressed under each theme were identified during preparatory travel. Special sessions were included on issues under research by ISNAR, such as "socioeconomic considerations" and "international initiatives in agricultural biotechnology."

Analysis of Seminar Findings

At each seminar, "needs" and "suggestions for follow-up actions" were recorded by each national delegation on standardized response sheets. ISNAR then entered the information into a data base. In total, 227 needs were identified by delegations representing 17 countries. Table 1 provides an overview of the relative importance accorded to the various need. These were grouped into two categories: "policy needs" and "program management needs" (table 1). The most important of these needs are discussed in this section, following the four phases of the decision-making framework. The methodology called for a "needs-based" approach, thus beginning with needs and priorities. However, an enabling policy environment to actualize these priorities is essential, and conditioned by development of policy, such as biosafety.

Phase 1: Identifying needs and priorities

Priority setting is the complex process of choosing between alternative sets of research activities. A formal priority-setting exercise aims to make the most effective use of available resources by selecting the best portfolio of projects for a research system, institution, or program.

The priority-setting needs reported by the seminar participants reflect their strong interest in establishing formal priorities for biotechnology research programs. They also reflect more general issues faced by developing-country research institutes in initiating and implementing a priority-setting exercise. For example, participants raised concern about the continuity of the priority-setting process, as the ability to initiate concrete proposals after priorities are defined is not always

Table 1. Summary of Policy and Management Needs Identified at the Agricultural Biotechnology Policy Seminars

Topic	Number of Countries Responding	Number of Needs Identified	Examples of Issues Discussed
NEEDS RELATED TO NATIONAL POLICIES			
Biosafety	15	19	Developing biosafety guidelines; strengthening current biosafety system; methods for risk assessment
Priority setting	13	17	Defining research priorities; involvement of stakeholders; weak links between research and national objectives for agriculture
Socioeconomic assessment	12	19	Impact assessment; integration of social scientists in research teams
Integration	9	11	Integration of biotechnology with conventional agricultural research
Government policy	9	9	Absence of policy for agricultural research in general, or biotechnology in particular
Coordination	9	10	Coordination of different government agencies; balancing various sectoral policies
End-user linkages	9	10	Weak links between research and extension
Technology transfer system	7	8	Limited access to foreign technologies; weak technology transfer system
Intellectual property rights	6	7	Need to introduce IPR regulations
Biodiversity	6	7	Adding value to genetic resources; national policy on genetic resources
Public awareness	5	5	Increase public awareness on benefits and risks
NEEDS RELATED TO PROGRAM MANAGEMENT			
Human-resource development	15	15	Lack of qualified human resources
Financing:			
Private sector	15	19	Incentives for private-sector investment
Public sector	12	22	Financial management; focusing of public investments
Foreign	2	2	
Program management	12	23	Research management skills; peer review of proposed research; delays in project approval
Infrastructure	12	12	Limited facilities available
Information	9	11	Information needs for biosafety review and IPR; developing an information system
International collaboration	6	6	Strengthen links with international programs

Note: Table is based on needs identified by members of 17 country delegations attending policy seminars for Southeast Asia, East and Southern Africa, and Latin America.

assured. Discussions confirmed the need for participatory processes involving end users, such as farmers and private companies.

A range of approaches to priority setting for biotechnology, including their costs and benefits, were presented as case studies during the seminars. These ranged from top-down priorities set by government, to bottom-up priority-setting methodologies used by donor-supported initiatives, scoring methods for national and international research, and, finally, application of the analytic hierarchy process (AHP).

The basic steps for priority setting in agricultural biotechnology are not different from those for research in general. However, a number of issues require special attention due to particular characteristics of this emerging technology. Among these are (1) uncertainty created by lack of experience and availability of data on the performance of biotechnology, (2) the difficulty of estimating research and development costs in this area, (3) qualitative factors related to human health and environmental effects of biotechnology products, and (4) other factors complicating the measurement of technology performance, for example, the fact that biotechnology research often generates intermediate products for use by related research programs rather than products to be used by farmers or other such end users.

In response to these issues, ISNAR, in collaboration with partner countries, is applying and testing AHP, in combination with economic analysis. AHP is a multi-objective, multi-criterion approach to decision making. Using AHP, participants compare pairs of alternative solutions to a problem. So doing, they prioritize the potential solutions and formulate them in hierarchical terms. The AHP methodology allows for multidisciplinarity in priority setting, incorporating, for example, the different perspectives of economics, fundamental research, and end users. AHP enables those determining research priorities, at an institutional level or for national programs, to select among alternatives using biotechnology by taking into account the special characteristics that such research poses, as outlined above.

Phase 2: Formulating national policies

Biosafety. "Biosafety" means the policies and procedures adopted to ensure the environmentally safe application of biotechnology. As shown in table 1, biosafety is one of the top concerns of the countries that participated in the seminars. There are many reasons for this. One is the attention given to biosafety in international forums such as the negotiations on an internationally binding "biosafety protocol" under the Convention for Biological Diversity.

Case studies discussed at the seminars, especially those presented by representatives of international agricultural research centers, emphasized that biotechnology products are being introduced in a growing number of developing countries. Moreover, a range of products can be expected from international collaborative programs. Some of these products, for example, transgenic plants and recombinant livestock vaccines, require biosafety reviews. Donors supporting international collaborative research programs often request that a formal biosafety review be done before technology transfer can take place. While much experience has been gained in genetically improving crops in developing countries through conventional breeding, there is still concern about the limited knowledge available on transgenic products. In industrialized countries, too, the public often perceives problems related to genetically modified organisms.

The three most important biosafety-related needs identified at the seminars were to develop biosafety guidelines, establish a responsive national system, and increase capabilities to perform risk analysis of genetically-modified organisms. However, it was also acknowledged that discussions on potential benefits and environmental risks are hampered by a lack of data. This is particularly true regarding the introduction of transgenic organisms into tropical ecosystems and centers of diversity. The concerns can be summarized as follows:

- risks related to the introduction of transgenic plants in centers of diversity, such as crops becoming weeds, geneflow to wild plants, or erosion of genetic diversity
- development of new viruses as a result of genetic recombination between virus genes
- accelerated emergence of pest resistance to genetically engineered insect control proteins
- deleterious effects on nontarget organisms, such as beneficial microorganisms, insects, animals, and humans

Establishing a system for biosafety review, in itself, has many facets and challenges. These include the formulation and adoption of safety guidelines, establishing national and institutional biosafety committees, and ensuring infrastructure for contained and large-scale field testing of genetically-modified organisms. As suggested by Traynor (1997), an effective biosafety system is one that allows the environmentally responsible use of agricultural biotechnologies. This can be accomplished when four conditions are met:

- the framework (policies, guidelines) defines clearly the structure of the biosafety system, the roles and responsibilities of those involved, and how the review process is to operate
- the people involved are knowledgeable and well-trained and have the support of their institutions
- the review process is scientifically sound and uses available information to make decisions that balance benefits and risks
- feedback mechanisms are used to incorporate new information and revise the system as needed

Intellectual property. "Intellectual property rights" (IPR) is a broad term for the various rights granted by law for the protection of economic investment in creative effort. The main categories of intellectual property relevant to agricultural research are patents, plant variety rights, and trademarks. In most developing countries, policies for the application of IPR to biotechnology products are still under formulation. Some countries have never explicitly excluded living material from patent protection. Others have recently adopted IPR for biotechnology, or are discussing IPR legislation in which the inclusion of living material is envisaged. The seminars highlighted the need to explore options and implications for agricultural research of national IPR policy decisions on biotechnology.

One reason that the topic of IPR receives such attention is that agricultural development, including the release of improved planting materials through formal breeding and production, has benefited from a long history of public-sector "public-good" investment. At the core of this system has been the free availability of plant genetic resources. Thus, increased IPR protection in agricultural research does not always seem fully in line with either the long-standing tradition of public-sector investment or with innovations contributed by international agricultural research or by informal or indigenous communities. Many practitioners fear that invoking such protection destroys the public-good nature of agriculture, especially as it relates to the needs of the rural poor.

Most of the countries that participated in the seminars are members of the World Trade Organization (WTO). They are therefore bound to introduce international standards for IPR protection. The extent to which changes in the IPR legislation of developing countries will, in fact, lead to accelerated technology transfer and to greater domestic innovation in advanced technology remains to be seen. Only limited evidence exists with regard to IPR in developing countries and their relationship to welfare and development. Consideration of stronger intellectual property protection should entail an analysis of both costs and benefits—and the costs involved are more foreseeable.

Given the increasing importance of IPR in relation to agricultural innovation, research managers must carefully consider which type of protection is appropriate for each innovation, whose needs are being served, and how to weigh expected costs and benefits. Their decisions must reconcile various factors: scientists' "perceived need" for IPR protection, institutional goals, the interests of end users of the innovation, and national policy objectives.

Phase 3: Developing and implementing a research agenda

Biotechnology management. A number of program management issues were highlighted by the national delegations. The most important of these included the need to enhance general management capabilities for biotechnology and improve infrastructure, access to information, and international collaboration. The consensus was that, ultimately, good research depends on the quality and critical mass of human resources available for biotechnology. At the same time, it was acknowledged that there is a lack of qualified human resources in agricultural biotechnology, as well as a range of factors inhibiting human resource management and a lack of information on opportunities for human resource development in this area.

Considering the emphasis that participants placed on human resource development and management, ISNAR is now addressing this theme as part of a course it is conducting on *Managing Biotechnology in a Time of Transition*. Strategic planning for human-resource development and management can integrate needs for biotechnology with other resources necessary for research. Holloway and Cohen (1997) describe steps that enhance the human skills needed for research and development in agricultural biotechnology. The first step is to identify the skills needed in relation to the overall objectives of the institution with respect to agricultural biotechnology. Thereafter, three basic components are necessary for strategic planning:

- identification of all the skills needed for success on a continuing basis
- a process for auditing the skills already present and knowing what to change to reach strategic objectives
- merging total resource management of people, equipment, consumables, and financial provision into a comprehensive plan

Financial constraints. Most of the country delegations indicated that biotechnology institutes or programs have suffered from funding limitations, or simply that the amount of public and private investment in biotechnology is too small. Research in agricultural biotechnology is affected by this uncertainty of funding, due to its long-term and continuous nature. Reasons reported for funding constraints include (1) implementation of fiscal austerity policies, (2) lack of understanding of biotechnology among decision makers, (3) lack of research impact, (4) dependence on a single source of funds, particularly government, and (5) the lack of political and financial support from farmers and their organizations and agribusiness.

The country delegations suggested several alternatives to reverse the situation. Among others, they recommended that political support be built for public-sector funding by documenting and publicizing research impacts, developing strong and articulate client organizations that have political influence, building closer relations between biotechnology leaders and policy makers, and broadening the funding base to include environment and commerce departments.

Strategic alliances between public and private-sector entities were also suggested as a means to expand the financial resources for agricultural biotechnology research. The development of institutional mechanisms, such as competitive funds, could promote public-private interaction. In addition, the introduction or promotion of mechanisms that do not require new institutions, such as joint ventures, collaborative research, research levies, and contract research should be encouraged.

Socioeconomic considerations. Results of the seminars indicate that all of the country delegations consider socioeconomic analysis to be a necessary tool for decision making. Twelve delegations mentioned specifically that socioeconomic assessment is necessary to enhance the productivity of biotechnology research. In particular, impact assessment was discussed. Scientists and research managers are increasingly asked to demonstrate the expected or actual impact of agricultural research projects.

In the Latin America seminar, held in October 1996, a discussion and survey were conducted on some aspects of socioeconomic research. The findings were, first, that socioeconomic analysis around biotechnology is essential and that it cuts across the various levels of decision making. Second, such analysis should provide tools and guidelines for enhancing strategic planning on biotechnology. Third, the most relevant socioeconomic research topics on biotechnology were seen to be impact assessment and priority setting. Participants said that socioeconomic analysis could support managers and leaders of biotechnology research by providing an information base for the decision-making process. This would include solid arguments on biotechnology's potential and guidelines for adequate investment. It could also assist in acquiring financial resources from diverse sources beyond the public sector, defining who executes and finances the activities of biotechnology, and determining market niches for biotechnology products.

A strong need was recognized for the institutionalization of both *ex ante* and *ex post* socioeconomic analysis of (planned) biotechnology research. The analysis could occur at the national policy level as well as at the project or program level. International partnerships could stimulate the development of socioeconomic analytical capacity through collaboration in research, training, and internships and by supplying information on market and research and development trends. However, funding for research on the socioeconomic implications of biotechnology remains an issue. The involvement of social scientists in natural-science projects is not widespread. Success stories are needed to promote such multidisciplinarity. In addition, the analytical methods available for assessing the impact of biotechnology products—particularly *ex ante* assessment—have not been extensively employed.

Phase 4: Delivering the products

Product delivery and technology transfer were most intensely discussed during the seminars in Southeast Asia and Latin America, reflecting the stage of development that agricultural biotechnology has reached in those regions. In particular, participants at those seminars discussed the products expected from international collaboration and technology transfer. ISNAR's analysis of data on international initiatives in agricultural biotechnology, recorded in its *BioServe* data base, was presented and reviewed at the policy seminars. The analysis shows that most collaborative research initiatives are now in the experimental, laboratory phase. Tables 2 and 3 provide a summary of the techniques being applied and the objectives of international biotechnology research on crops. Some of the work has already resulted in products that are ready for wider diffusion. Some examples follow:

- **Diagnostics and vaccines for livestock diseases.** This appears to be the most significant area for product development to date, with diagnostic tests and rDNA vaccines for rinderpest, cowdriosis (heartwater), theileriosis (East Coast fever) and foot-and-mouth disease.
- **Disease-free planting material.** Various tissue-culture techniques are applied for the micropropagation of disease-free planting material. They involve mainly export crops such as coffee, cocoa, banana, oil palm, and sugarcane.
- **Biocontrol agents.** Products include biopesticides based on *Bacillus thuringiensis* and *B.sphaericus* and pheromone-based attractant decoy for tick vector control.
- **Transgenic plant varieties.** Virus-resistant potatoes have been planted in Egypt and Mexico as part of international programs. The range of crops is expected to expand.

Decisions about the production and delivery of products to users must be considered at an early stage of a research program. An important finding of the seminars regarding product delivery is that collaboration or joint ventures between the private, commercial sector and public institutes or universities is essential. In some cases, national or international intermediary organizations have facilitated technology transfer from public to private-sector organizations. The strong relationship between the public and private sectors in product development was emphasized, specifically in the areas of product price regulation and registration; offering on-farm demonstrations, pilot production facilities, and science parks for startup companies; and procuring and distributing planting material.

In summary, analysis of this data and the cases and examples presented at the seminars reveals that applications of biotechnology developed through international collaborative research, including transformation, are being applied to a range of crops of significance to developing countries (table 2). These same programs have also targeted traits of importance to sustainability and of use in limited-resource farming conditions (table 3).

Elements of a Strategy

Following the analysis of needs summarized in the previous section of this paper, IBS related the seminar findings to three recommendations on biotechnology. These are, first, that developing countries should develop a clear policy on and agenda for biotechnology research. Second, partnerships should be forged between developing countries, international research institutions, and public and private research institutes in industrialized

Table 2. Biotechnology Techniques Applied to Crops of Importance to Developing Countries, from the IBS BioServe Data Base, 1997

Crop	Number of Activities Reported by Technique				Total
	Transformation	Molecular markers	Cellular techniques	Others[1]	
Cereals					**53**
rice	12	9	3		24
maize	6	7	4	1	18
sorghum	1	4	1		6
other[2]		3	2		5
Perennial crops					**44**
industrial crops[3]	4	3	5	2	14
banana and plantain	1	3	8		12
coffee	1	2	5		8
sugarcane	2	1	3		6
cocoa		2	2		4
Root crops					**29**
cassava	5	4	2	1	12
potato	6	3		1	10
yam	1	2	1		4
sweet potato	3				3
Legumes					**22**
bean	1	1	2	2	6
groundnut	2		4		6
chickpea		1	3		4
cowpea	2	2			4
pigeonpea	1		1		2
Forestry species	1	4	6	1	**12**
Horticulture[4]	3	1	4		**8**
Generic applications[5]		4	1	7	**12**
All					**180**

Notes:
1. Primarily includes microbial-based techniques, for example for biological pest control or biological nitrogen fixation.
2. Wheat, triticale, pearl millet
3. For example, coconut, cotton, oilpalm
4. For example, citrus, pineapple, tomato
5. Activities targeting a range of crops

countries. Third, incentives should be provided to the private sector for undertaking biotechnology research targeted at the problems of poor farmers.

Develop a policy on and agenda for biotechnology research

Capacity and competency. New capacity is needed on the part of decision makers, managers, and scientists to provide clarity on biotechnology policy and research agendas. The seminars underscored the need for human resource development. An ISNAR course in *Managing Biotechnology in a Time of Transition,* initiated in 1997, is already contributing to meeting this need.

Supportive policies. In some countries, an overall national policy for biotechnology has been developed. However, in most cases, other more specific and supporting policies are needed, including those for socioeconomic considerations, biosafety, IPR, and the interface of biotechnology research with biodiversity. Capacity can be built for such policy development through policy internships and experience in policy analysis.

Research priorities. The research agenda set should respond to national needs. Therefore, a priority-setting process that allows for participatory dynamics and accounts for biotechnology's special characteristics is now under development and evaluation by IBS and its partner countries. Developing priorities for biotechnology-

Table 3. Crop Research Objectives by Number of Projects, IBS BioServe Data Base, 1997

Crops	Biotechnology Research Objectives					Total
	Disease resistance	Insect resistance	Virus resistance	Quality traits	Micro-propagation	
Cereals	**9**	**13**	**8**	**12**		**42**
rice	5	4	6	6		21
maize	1	6	2	3		12
sorghum	1	3		2		6
other	2			1		3
Root crops	**4**	**5**	**7**	**2**	**1**	**19**
potato	1	3	2			6
cassava	1		3	2		6
yam	2		1		1	4
sweet potato		2	1			3
Legumes	**4**	**6**	**4**	**6**		**20**
bean	1	2	1	2		6
groundnut	1	1	3	1		6
chickpea	1	1		2		4
other	1	2		1		4
Horticulture	**2**	**3**	**1**			**6**
Perennial Crops	**2**	**1**	**2**	**2**	**15**	**22**
banana/plantain	2		1		5	8
industrial crops				1	4	5
coffee		1			4	5
sugarcane			1	1	1	3
cocoa					1	1
Forestry species				**2**	**5**	**7**
Miscellaneous	**3**	**3**		**2**	**2**	**10**
All	**24**	**28**	**24**	**26**	**24**	**126**

Note: Figures are based on information gathered from 22 international research programs that include activities in crop research. This table includes research activities with a specific applied objective, excluding those activities aimed towards general technology development.

based research serves an important role, which should be carefully coordinated with expectations for funding and implementation of priorities identified.

Impact analysis. The importance of demonstrating impact from biotechnology-derived inputs was stressed, particularly as a means to familiarize policymakers and mangers with the benefits of such products, especially for small farmers. Impact studies are being designed to provide such information.

Research indicators. Countries setting their agendas for biotechnology need information on the resources and options available. In collaboration with developing countries, ISNAR is collecting indicators of human and financial investments in biotechnology. This will help determine how these resources are mobilized and used, providing new information to enhance informed decision making on agricultural biotechnology.

Forge partnerships

Case studies. The seminars developed a number of illustrative cases documenting various forms of partnerships. The data base maintained by ISNAR, *BioServe,* also provides an important instrument to analyze such partnerships. The challenge ahead will be to maintain international funding and support for these collaborations, to overcome hurdles of licensing and technology transfer, and to develop strong partner organizations in developing countries.

Benefits and end-user relations. The information gathered at the policy seminars and in the ISNAR data base will be disseminated to help demonstrate the utility and benefit of biotechnology products. Such products can target the problems faced by small farmers, sustainability issues, and address developing countries' productivity constraints. Information can highlight examples of partnerships that have successfully targeted end-user needs.

Provide incentives for the private sector

Private-sector incentives. The seminars and the ISNAR data base show examples of how countries can provide incentives to the private sector to do research targeted at the problems of poor farmers. But such information remains limited, and suitable policies in developing countries to enhance private-sector involvement are virtually nonexistent. Public policies are needed to promote private-sector investment in general in the agricultural sector, to remove constraints and relax regulations as appropriate for import and use of new technologies, and to establish relevant policies on IPR for biotechnology products. In addition, the scientific community should educate the agribusiness sector on the potential benefit of biotechnology in the production chain of their products.

Alternative financing arrangements. The seminars provided some options on promoting financial sustainability for biotechnology research. Competitive bidding, for example, is an institutional financial mechanism being implemented in many countries. In addition, the introduction or promotion of mechanisms that do not require new institutions, such as joint ventures, collaborative research, research levies, and contract research should be considered.

Assessing and mobilizing resources. Most of the delegations attending the seminars recognized the need to clarify the respective roles of the public and private sectors in the execution and funding of biotechnology research. How should the public sector motivate, regulate, and promote private-sector participation on biotechnology activities? What should be the role of the public sector in supporting biotechnology beyond commercial agricultural interests, for example, to focus on the needs of small farmers, "orphan" commodities, and environmental issues.

Conclusion

This paper reviewed findings and needs on agricultural biotechnology applied by and for developing countries. These findings are based on research, data analysis, and policy and management experience from agricultural systems in more than 20 countries. The decision-making framework proved a useful foundation for the four regional policy seminars initiated by IBS. The framework helped participants to complete a number of tasks:

- explore each country's context for agricultural biotechnology and compare and contrast the various approaches taken

- identify factors unique to strategies and policies for agricultural biotechnology

- think systematically about decision making and options for implementing biotechnology research

- understand that decision makers in developing countries act in a context of uncertainty and risk in making policy on agricultural biotechnology

Analysis of data from the seminars confirmed and focused attention on a few overall points of significance. While some of these may seem obvious, they are mentioned here as they may go unsaid:

- Building capacity and competency in biotechnology poses complex and difficult investment decisions for many developing countries.

- Using biotechnology to address agricultural objectives necessitates building on a strong foundation of conventional research.

- Diversity of ideas regarding policy, planning, and managerial experiences was evident, reflecting the heterogeneity of participating countries.

- Time frames for development of biotechnology products, capabilities, and polices are long-term, often taking 10-15 years.

- Use of institutional partnerships and collaboration are crucial to building competency. However, they are also complicated by the nature of the private sector, proprietary technologies, and regulatory concerns.

- Socioeconomics, priorities, and end-user relations have gained renewed importance, as these are means to ensure that broader segments of the agricultural sector benefit from biotechnology research.

- Biosafety competence is of highest national importance, regardless of the technological level of the country.

- The utility of biotechnology has been demonstrated in wide a range of crops that are important for developing-country food security.

- International biotechnology programs have identified traits of potential utility to small farmers and are advancing this work towards field trials.

- Enhancing management of biotechnology research is given high importance. However, training opportunities are limited, with most support provided instead for fundamental research

The findings of the seminars were related to three recommendations on biotechnology. These are, first, that developing countries should develop a clear policy on and agenda for biotechnology research. Second, partnerships should be forged between developing countries, international research institutions, and public and private research institutes in the industrialized countries. Third, incentives should be provided to the private sector for undertaking biotechnology research targeted at the problems of poor farmers. ISNAR has identified and developed follow-up actions in partnership with developing countries and other international collaborators for each of the three recommendations. These now form part of its future and ongoing research activities on issues of biotechnology.

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About the Authors...

Joel I. Cohen *is project manager of ISNAR's Intermediary Biotechnology Service.* ***Cesar Falconi*** *is economist and research officer.* ***John Komen*** *is the project's information specialist.* *The series of Agricultural Biotechnology Policy Seminars summarized in this report has been supported by the Netherlands' Ministry of Foreign Affairs' Directorate General for International Cooperation; the Swiss Agency for Development Cooperation; the Technical Centre for Agriculture and Rural Development (CTA); the Swedish International Development Cooperation Agency (SIDA); the OECD Development Centre; and the Canada - Latin America Initiative on Biotechnology for Sustainable Development (CamBioTec).*

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Laan van Nieuw Oost Indië 133, 2593 BM The Hague
P.O. Box 93375, 2509 AJ The Hague, The Netherlands
Tel: (31) (70) 349 6100 • Fax: (31) (70) 381 9677
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