AgBioForum, 9(1): 23-30. ©2006 AgBioForum.

Will Agbiotech Applications Reach Marginalized Farmers? Evidence from Developing Countries

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Findings from two studies on agricultural research indicate that although developing countries invest in agricultural biotechnology and genetically modified crop research, their policy and investment environments inhibit the contribution of such research to agricultural development and poverty reduction. Findings suggest that valuable private-sector resources are not being brought to bear on the development challenge, thus slowing the pace of innovation. For such research to benefit developing countries, greater effort is needed to enhance the international exchange of safety and efficacy information, remove the isolation of public research institutions, and overcome barriers to public-private research collaboration.

Key words: agricultural research and development, biosafety regulation, public-private partnership.

Introduction

Many in the international research community are promoting agricultural biotechnology (agbiotech) as a partial solution to reducing poverty, stimulating agricultural development, and promoting economy-wide growth in many developing countries. The research and development (R&D) path from advanced laboratories to farmers' fields is, however, fraught with impediments. This paper attempts to isolate some of the main barriers to the dissemination of agbiotech research and genetically modified (GM) crops to resource-poor, small-scale farmers in developing countries. Findings are based on two recent studies that focused specifically on the expectations and limitations on agbiotech research.

First, findings suggest that the regulatory environment governing the introduction of new technologies is slowing the forward movement of research into later stages of product development. The absent, incomplete, or nascent character of many regulatory regimes means that very few GM crops have moved onwards to efficacy and performance trials, testing for human and environmental safety, commercialization, marketing, or distribution.

Second, findings suggest that efforts to move through these later stages of product development have made limited use of available information from other countries on efficacy and safety. Although regional or international sharing of data is not necessarily a substitute for rigorous efficacy and safety testing, cross-country comparisons do provide important information that could be useful to researchers as they navigate complex regulatory testing processes.

Third, findings indicate that the public research organizations heading up much of the agbiotech research in developing countries are largely working in isolation from the private firms that lead the industry. These organizations have proven largely unable to forge effective partnerships with the private sector to exploit complementarities and achieve scale economies in agbiotech research. This means that public researchers are unable to access many of the tools, applications, and information needed to support their research processes.

Collectively, these factors imply that agbiotech is largely caught up in early stages of research, with neither an enabling policy environment nor the creative organizational mechanisms to move into stages of product development that could generate impacts on the rural poor in developing countries. Greater impact requires more investment in the design and implementation of biosafety regulations, construction of easily accessible clearinghouses for information on agbiotech, and development of policy incentives to promote public-private research partnerships.

Background

Although the literature on agbiotech research and GM crops is growing at a rapid pace, there is limited empirical work on two issues that are particularly relevant to developing countries: cross-country analysis of regulatory issues relating to GM crop safety and efficacy, and analysis of the interrelated dynamics of public and private research on agbiotech.

Cross-country data-gathering and/or analysis of transformation events, regulatory processes, and safety/efficacy testing is partly addressed by initiatives such as

Table 1. R&D spending and sales of leading multinational firms, 2004.

Company/parent	Country of headquarters	Total R&D expenditure (million US$)	Sales (million US$)	R&D as a percentage of sales
Syngenta	Switzerland	1,738	6,340	27.4
Monsanto	US	509	5,423	9.4
BASF	Germany	365	4,576	8.0
Pioneer Hi-Bred/Dupont	US	527	4,830	10.9
Bayer CropScience/Bayer	Germany	926	8,113	11.4
Dow AgroSciences/Dow	US	335	3,368	9.9
CGIAR		428	N/A	N/A

Note. N/A—not applicable. Data from corporate annual reports.

the Food and Agriculture Organization (FAO) online database on biotechnology in developing countries, launched to monitor trends in the development, adoption and application of agbiotech in developing countries (FAO, 2003); AGBIOS, a Canadian initiative that assembles information on public policy, regulatory, and risk assessment expertise for biotechnology products (AGBIOS, 2003); and the International Service for the Acquisition of Agri-biotech Applications (ISAAA), which publishes periodic overviews and analyses of adoption of GM crop adoption worldwide (ISAAA, 2004). These resources are complemented by global-level analyses of agbiotech (Falconi, 1999; ISAAA, 2004; Komen, Webber, & Mignouna, 2000; Qaim, Krattiger, & von Braun, 2000); regional studies focusing on Africa (Alhassan, 2003; Johanson & Ives, 2001; Sithole-Niang, Cohen, & Zambrano, 2004), Asia (Asian Development Bank, 2001), Latin America (Trigo, Traxler, Pray, & Echeverria, 2002), West Asia and North Africa (Baum, de Kathen, & Ryan, 2001); and a wide variety of crop-, trait-, and locality-specific studies.

In general, these studies suggest that despite similar starting dates for regulatory development, countries are arriving at different points in terms of their laws, regulations, and guidelines, and are achieving different outcomes in terms of the number of field trials, number of events, or crops approved for planting. These studies also suggest that transformation events and regulatory approvals in developing countries have been moving slowly in many countries, although notable exceptions—specifically, Argentina, Brazil, China, South Africa, and India—do exist.

Analysis of the interrelated dynamics of public and private research on agbiotech is also a growing body of literature. Much emphasis has been placed on the prominent role of private investment in agbiotech research. Estimates from Byerlee and Fischer (2001) and Pray and Naseem (2003) suggest that private investment in plant biotechnology by the leading multinational companies during the mid-1990s totaled approximately US$1 billion per year, most of which is concentrated in industrialized countries (Table 1). By comparison, The Consultative Group on International Agricultural Research (CGIAR), arguably the global leader in agricultural research targeting the needs of developing countries, spends just $25 million per year on agbiotech across its centers and programs (World Bank, 2004), a figure on par with the similarly limited expenditures on agbiotech by public research organizations in developing countries.

To be sure, public investment in agbiotech by developing countries has been extremely limited. Not only has the growth rate of public expenditure on agricultural research slowed or stagnated in many countries, but in countries such as China, Indonesia, Mexico, Colombia, Zimbabwe, and Kenya, it has also lagged behind the rate at which scientists have been allocated to agbiotech research and has become highly dependent on external donor funding (Falck-Zepeda, Cohen, Komen, & Zambrano, 2003; Pardey & Beintema, 2001).

In partial recognition of these limitations, many public research organizations are working to engage the private sector in agbiotech research collaborations. Public-private partnerships—broadly described as any joint effort between public and private entities in which each contributes to planning, commits resources, shares risks and benefits, and conducts activities to accomplish a mutual objective—are among the most popular approaches to agbiotech discussed in the literature (Byerlee & Fischer, 2002; Chataway, 2005; Hall, 2005; Pingali & Traxler, 2002; Pray, 2001; Spielman & Von Grebmer, 2004).

For example, the CGIAR is engaged in several partnerships focusing on enhancing yields or nutritional

Table 2. Public-private partnerships in the CGIAR on agbiotech research, past and present.

Research topic/project title	CGIAR center(s)[a]	Partners
Apomixis	CIMMYT	Pioneer Hi-Bred International; Syngenta; Limagrain (France); others
Golden Rice Humanitarian Board	IRRI	Syngenta; Rockefeller Foundation; Swiss Federal Institute of Technology; others
HarvestPlus	CIAT, IFPRI	Syngenta
Unlocking crop genetic diversity for poor people	CIMMYT, IPGRI, IRRI	MAHYCO; Bayer CropScience; Pioneer Hi-Bred International; national and international agricultural research organizations; advanced research institutes; others
Agronatura science park	CIAT	Private seed companies; Colombian university biotech laboratories; Colombian national commodity researcher centers; others
Potato/sweet potato transformation	CIP	Plant Genetic Systems; Axis Genetics; Monsanto
Genomics for livestock vaccine research	ILRI	Merial; The Institute for Genomic Research; others
Bt genes for rice transformation	IRRI	Novartis; Plantech; and a consortium of public research institutions
Positive selection technology for cassava transformation	CIAT	Novartis
Biotech incubator	ICRISAT	Private biotechnology companies
Fish Genetic Research	WorldFish Center	A private biotechnology company; GIFT Foundation International
Research on mimotop-virosome approach	ILRI	Pevion Biotech
Enzyme-linked immunosorbant assay (ELISA) for tick-borne diseases	ILRI	Savanova Biotech

[a] CIMMYT—International Maize and Wheat Improvement Center; IRRI—International Rice Research Institute; CIAT—International Center for Tropical Agriculture; IFPRI—International Food Policy Research Institute; IPGRI—International Plant Genetic Resources Institute; CIP—International Potato Center; ILRI—International Livestock Research Institute; ICRISAT—International Crops Research Institute for the Semi-Arid Tropics.

content of crops such as rice, wheat, and cassava (Table 2).[1] Several of the larger or more advanced national agricultural research systems (e.g., China, India, Brazil, South Africa, and Kenya) are similarly engaged in collaborative research projects with private firms. However, public-private partnerships still remain fairly few and far between in the international agricultural research community, and there is limited empirical evidence as to their performance or outcomes.

In summary, the limited empirical literature on regulatory issues relating to GM crop safety and efficacy and the dynamics of public and private research on agbiotech indicates a need for closer scrutiny of these issues across countries, regions, and relationships.

Methodology

In an effort to address some of these issues, the International Food Policy Research Institute (IFPRI) and the International Service for National Agricultural Research (ISNAR)[2] initiated a study in 2002 with the goal of examining the expectations and limitations associated with publicly researched GM crops and traits. The IFPRI-ISNAR study surveyed a purposeful sampling of 76 experts (researchers and regulators) from public research organizations in 16 developing countries, from which information was received on 209 transformation events through the year 2003. The survey captured extensive variation in the type and state of research in

1. *The CGIAR is a nonprofit consortium of countries, international organizations, and foundations that promotes agricultural R&D for the benefit of developing countries though a network of 15 international agricultural research centers.*

2. *ISNAR, formerly based in the Netherlands, became a division of IFPRI in April 2004. The ISNAR Division joins IFPRI with a mandate to strengthen innovation in agricultural R&D systems and increase the contribution of research to pro-poor agricultural development, supporting IFPRI's wider mission to identify and analyze policies for sustainably meeting the food needs of the developing world.*

different countries and research organizations and was supplemented by consultations with representatives of responding organizations to validate and analyze the data. Survey data include details on crops under research, desired phenotypic traits, transgenes deployed, techniques used to deploy transgenes, types and sources of genetic resources used, stage of regulatory approval reached, type of collaboration used to conduct the research, and plans for dissemination of research outputs (Atanassov et al., 2004).

A second study was undertaken by IFPRI in 2003–04 to examine partnerships between private firms and the international research centers of the CGIAR. The IFPRI study was based on a purposeful sampling of 42 key stakeholders engaged in or closely associated with public-private partnerships in international agricultural research. Sampled stakeholders included representatives of multinational or national research-based agribusiness firms, international agricultural research centers and programs, multilateral and bilateral donors and foundations, and national agricultural research systems, academia, and nongovernmental organizations. Data were compiled from semistructured interviews and open-ended discussions, further updated with information from a research seminar held in February 2004. Topics covered included respondents' experiences in planning, management, and execution of a partnership, their incentives and motivations for engaging in the process, and their perceptions of the process and their partners (Spielman & Von Grebmer, 2004).

Findings

Data from the IFPRI-ISNAR study show that public research organizations in the sampled countries have conducted a significant number of crop transformations to express a wide variety of traits (Cohen, 2005). When classified by crop type, more than half (55%) of all public events are concentrated among the 15 crops considered critical to achieving sustainable food security and reducing poverty by the CGIAR. Of the 209 transformation events recorded in the study, 32% targeted cereals, followed by fruits (15%), vegetables (16%), roots/tubers (13%), oil crops (9%), and all other crop groups (15%). The remaining 45% of transformation events are focused on cotton, vegetables, and fruits—crops of a more commercial nature that fall outside of the CGIAR mandate. Transformation events were concentrated in Asia more than Africa or Latin America, with the largest numbers of events being recorded in Argentina, China, India, Indonesia, and South Africa.

In terms of R&D processes, however, the study shows that most of these events remain confined to the experimental stage of laboratory and greenhouse trials, with few advancing to field trials for biosafety testing, scaling-up for environmental, health, and efficacy testing, or commercialization for release to farmers (Cohen, 2005). Survey respondents indicated that progress has been delayed not only by slow movement through normal R&D processes, but also by other, more ad hoc, regulatory barriers. Some countries covered by the study have subjected GM crops to multiple years of testing and significant waiting periods for approvals for scale-up or precommercial trials above and beyond the requirements for conventionally bred cultivars. Other countries have only implemented interim guidelines or regulations that do not allow for commercial approvals. Even some of those countries that do have the ability to evaluate and commercialize GM crops lack confidence in their decision-making capacity and have thus delayed commercialization. Some countries are also facing physical limitations, such as growers' inability to produce adequate seed amounts for large-scale or food safety testing.

The IFPRI-ISNAR study also suggests that progress has been hampered by the fact that most public research organizations surveyed are working in isolation from other research actors, both public and private. Only 7% of transformation events generated by these organizations were conducted in collaboration with the private sector, while only 22% were generated in collaborations between or among public institutions (Table 3).[3] Relatedly, only 5% of all genetic resources used in transformation events were obtained from either local or foreign private sector sources. Instead, most genetic materials were derived from public sources (Atanassov et al., 2004). Furthermore, there was no evidence found of any collaborative research links between or among developing countries (i.e., south-south collaboration), whether in the public or private sectors.

In the absence of efficacy or safety data from private firms and other research institutions that have conducted transformations of similar crops and/or traits in other countries, public research organizations often have less information with which to navigate regulatory and commercialization processes. Moreover, in the absence of scientific interaction and information exchanges

3. *In fact, single public institutions generated more than 60% of all events, indicating a high degree of research centralization or intensification in the countries surveyed.*

Table 3. Institutional arrangements used in public transformation events.

Institutional arrangement	Asia	Latin America	Africa	Eastern Europe	All
Single public institution	71	22	28	8	129
Public/public	25	9	13	0	47
Public/private	1	7	7	0	15
Public/foundation/public	8	0	0	0	8
Public/private/other	1	0	5	0	6
All other (no private collaboration)	3	0	1	0	4
Total	109	38	54	8	209

Note. Data from IFPRI-ISNAR Survey (2003).

between sectors and organizations, many of the public researchers who are tapped to serve on biosafety committees, regulatory agencies, or advisory bodies might be less equipped to provide real expertise in such positions.

The relatively small role attributable to the private sector in agbiotech and GM research in developing countries[4] suggests that public-private research collaborations face significant barriers to implementation. Respondents to the IFPRI study indicate that public-private partnerships are constrained by conflicting incentive structures, high transaction and opportunity costs, risks associated with proprietary assets, and mutually negative misperceptions. Their responses indicate that risk, along with negative misperceptions, are the most significant constraints, followed by conflicting incentives and high costs.

Consider first the more obvious issue of conflicting incentives: the fact that there is limited commonality between the interests of private firms that exist to maximize profits and public agencies pursuing wider social mandates. Although respondents acknowledged these differences between the sectors, many argued that public and private interests do, under certain circumstances, coincide. For instance, where the private sector has cutting-edge research tools and technologies or product marketing and distribution channels, then there is scope for public research organizations to beneficially engage the private sector as a means of advancing public research. Likewise, where the public sector offers access to local genetic resources, knowledge about local regulatory processes, inroads to emerging markets, or opportunities for a firm to enhance its reputational integrity, then there is occasion for the private sector to pursue partnership with the public sector.

Yet respondents acknowledged that even where coinciding interests exist, the costs associated with public-private partnerships are not insignificant. Transaction costs were cited as a major constraint to successful partnership and partnership outcomes, specifically with respect to contracting, coordinating, and enforcing relationships between collaborators. This is particularly relevant where the partnership requires searches for information about potential partners and their assets, the exchange and use of valuable proprietary knowledge, navigation through difficult or uncertain regulatory processes, and other complexities associated with collaborative research.

Respondents also cited high opportunity costs as a barrier to partnership, particularly where conventional research investments are foregone in favor of an investment undertaken through an untested, nontraditional, or uncertain modality, such as a partnership. Many private-sector respondents argued that ultimate accountability to shareholders necessarily limits their willingness or ability to engage in partnerships unless the outcomes are fairly certain or if the risk is balanced by the potential benefits of the technology and market in question.

Despite the perceived importance of incentives and cost, the majority of respondents indicated that a set of very specific risk factors were the most significant barriers to partnership. The factor cited most often was that associated with the exchange and use of proprietary knowledge. From the private-sector perspective, there exists the possibility that a public collaborator might share a firm's proprietary knowledge with competitors,

4. *Brazil and India are notable exceptions. In Brazil, the IFPRI-ISNAR study identified 37 private-sector transformation events, compared to just nine events from the public sector. In terms of the crops and types of transformation events, private-sector research in Brazil is focused on primarily commercial crops (maize, cotton, sugarcane, and soybeans) and insect resistance and herbicide tolerance traits. In India, the study found that the private sector was responsible for 17 events, compared to 21 from the public sector. Private research in India, though focused on similarly commercial crops (cotton, rice, soybean), has primarily concentrated on transformations for insect resistance.*

either intentionally or inadvertently (e.g., through detailed public disclosure of research activities). Alternatively, there exists the risk that a public collaborator might share proprietary knowledge with third parties who might use the knowledge for unintended or improper purposes, thereby generating reputational or financial liability for the firm—warranted or not.

From the public-sector side, there are risks such as the possibility that a private partner might obtain property rights on or otherwise appropriate gains from plant genetic materials held in trust by public research organizations for the public good. There is also the risk that public organizations, by associating with the private sector (particularly large and often controversial multinational agbiotech firms), might attract undesirable attention and criticism from the public or public interest, thereby compromising their ability to conduct research.

Respondents suggested that although solid contracts, rigorous contract enforcement, or proactive public relations strategies can reduce many of the risks noted above, it is often difficult to implement these measures in developing countries, where legal institutions are weak. It is also sometimes undesirable where long-term relationships are of greater value than potential losses to competitors or of public trust.

Finally, the IFPRI survey suggests that the willingness of public institutions and private firms to partner is significantly constrained by persistently negative perceptions between the sectors. Typical misperceptions—researchers in multinational firms should be treated with suspicion, while researchers in the public service are slow and inefficient—are prevalent. But more serious misperceptions also result from the use of confidentiality and nondisclosure agreements that accompany many research collaborations. Though common in the private sector, such agreements can generate suspicion and distrust among public researchers who are unfamiliar with the need for confidentiality in highly competitive, knowledge-intensive sectors. Respondents also suggested that misperceptions can result from the relative distribution of bargaining power: Public institutions or private firms might be unwilling to partner where one party can potentially dominate the partnership by virtue of its organizational size, the value of its proprietary knowledge, the size of its research budget, or its ability to influence political and economic decision-makers.

Recommendations

Evidence from the two studies examined here indicates that although public research in agbiotech is advancing in developing countries for a diversity of crops and traits, certain necessary conditions must be met to realize the benefits of the technological opportunities posed by agbiotech. Regulatory processes are holding up testing and commercialization, while institutional and attitudinal barriers to partnerships are preventing the use of private-sector knowledge and assets to provide valuable learning and data exchange opportunities relating to regulatory processes. In short, greater effort is needed to enhance the international exchange of safety and efficacy information, remove the isolation of public research institutions, and overcome barriers to public-private research collaboration.

There are several national, regional, and global policy options that could improve agbiotech and GM crop research in developing countries. One is to enhance the quantity and quality of information on the environmental safety of GM crops in confined testing or commercial use through information sharing among countries and researchers—information such as the characteristics of transgenes, gene constructs, host plants, agro-ecological and agro-climatic zones, experimental designs and observations, and regulatory findings. Placing this information in the Biosafety Clearinghouse (BCH, 2002) would improve access to information so that environmental assessments of crops or traits can be carried out based on accumulated experience among industrialized and developing countries.

This presents opportunities for south-south collaboration and offers possibilities for minimizing redundancies, increasing access to information and expertise based on reliable and comprehensive data sources, improving regulatory proficiency, and minimizing R&D costs. Greater knowledge of the array of available transgenes can also be used to strengthen the public sector's position in negotiating access agreements over proprietary materials and techniques.

However, the advancement of agbiotech and GM crop research in developing countries requires more interaction between public and private players, regardless of whether they are engaged to improve food security, reduce poverty, or reap commercial rewards. As a first step in this direction, greater dialogue between the sectors is needed to reduce misperceptions, facilitate greater collaborative research opportunities, and improve the tenor of the environment in which research is being conducted.

Several innovative approaches to collaborative research or partnership could also improve the pace and level of research on agbiotech and GM crops. One possibility includes an array of incentives to stimulate research in or for developing countries. For instance, tax incentives for strategically pro-poor research and government programs to commercialize existing research can attract private investment (Spielman & Von Grebmer, 2004). Competitive research grants and research awards can similarly stimulate private interest and investment in pro-poor research priorities (see, e.g., Kremer & Zwane, 2005; Masters, 2003). Restructuring of incentives for the management and use of intellectual property, including incentives to encourage philanthropic donations of intellectual property, can improve access necessary methods, tools, and materials for developing country researchers (Byerlee & Fischer, 2002; Falcon & Fowler, 2002; Naylor et al., 2004).

These approaches, when combined by increased public expenditure on complementary research and philanthropic investments (e.g., humanitarian donations of intellectual property) by major private firms, can motivate closer interaction between the public and private sectors. However, more empirical examination of the performance of such incentives needs to be conducted.

Conclusion

Slow progress in agbiotech research in developing countries is not simply the result of the highly politicized debate over the desirability or safety of GM crops and foods. Rather, it is also a product of impediments to the research process itself. The two studies examined here offer several critical findings on these impediments. First, although agbiotech and GM crop research are advancing as a result of public-sector efforts, movement through the regulatory process is inadequate relative to the opportunities offered by the new technologies. Second, critical assets and competencies from the private sector are not being adequately brought to bear on the research challenge in collaboration with public research. Third, research institutions in advanced sciences need linkages, both public and private. There are a variety of institutional incentives and organizational mechanisms that could effectively address these impediments and clear the way for greater agbiotech research that is directly relevant to the poor. Without creative exploration of such incentives and mechanisms, the pace of research will be insufficient to address global priorities of poverty reduction, agricultural development, and economic growth in developing countries.

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Acknowledgement

The authors wish to thank Martha Negash for her assistance in the preparation of this paper. Any and all errors are the sole responsibility of the authors.