Policy, Investment, and Partnerships for Agricultural Biotechnology Research in Africa: Emerging Evidence

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Abstract

This paper investigates to what extent the public policy and investment environments across the African continent are enabling the research, development and dissemination of agbiotech and GM crops. Using data from two surveys on agricultural research, this article examines the scope, magnitude and effectiveness of agbiotech and GM crop research in Africa. The findings indicate- that while a growing number of countries in Africa are investing in agricultural biotechnology and genetically modified crop research, their policy and investment environments may significantly inhibit the diffusion of these new technological opportunities. Findings suggest that valuable private sector resources are not being brought to bear on research and development in the region, thus slowing the pace of innovation. For such research to benefit Africa, greater efforts are needed to enhance the international exchange of information on environmental safety and to overcome institutional barriers to public-private research collaboration. Such efforts would significantly improve the effectiveness of public sector research on agbiotech in African countries by promoting a more entrepreneurial culture of innovation and by making research institutions more responsive to emerging needs and opportunities.

1. Introduction

The growing body of literature on the state of agbiotech in Africa includes three areas of inquiry that are critical to the present study: (1) studies on transformation events (please explain to the reader in a short footnote) and regulatory processes; (2) studies of the policy and investment environment in the agricultural research and development (R&D) sector in developing and industrialized countries; and (3) studies on the role of public-private partnerships in agricultural R&D. The literature in each of these areas is reviewed in detail below.

1.1 Studies on transformation events and regulatory processes

The literature on transformation events and regulatory processes includes databases such as the FAO's online database on Biotechnology in Developing Countries (BioDeC, http://www.biodec.com/), launched to monitor trends in the development, adoption and application of crop biotechnologies in developing countries [1]; AGBIOS, a Canadian initiative that assembles information on the global state of GM crops approvals as well as public policy, regulatory, and risk assessment expertise for biotechnology products in different countries [2]; and the International Service for the Acquisition of Agri-biotech Applications (ISAAA), which publishes periodic overviews and analyses GM crop adoption worldwide [3]. The data and analyses accompanying these sources suggest a limited number of transformation events and regulatory approvals for GM crops in developing countries, with the least representation coming from Africa. For example, of all the ten developing countries with regulatory approvals for the commercial release of GM crops listed in AGBIOS dataset (Argentina, Brazil, China, India, Korea, Mexico, Philippines, South Africa, Taiwan and Uruguay), South Africa is the only African country listed.

Studies of transformation events, regulatory processes and/or governance relating to agbiotech in Africa are highlighted by Wafula and Clark [4], Harsh [5], Sithole-Niang et al. [6], Alhassan [7], Mugabe [8], Baum et al. [9], and Johansen and Ives [10]. Complementary studies on the opportunities posed by agbiotech and the political and legislative uncertainty that influences country-specific regulatory systems are offered by Cohen [11], Cohen and Paarlberg [12], Paarlberg [13], and Komen et al. [14], among others. A conclusion that can be drawn from these studies is that timely advancement of agbiotech and GM crop research and its effective use to address local problems in agriculture is often hampered in countries where events and approvals are few and far between, where political interest groups advocate against the design and implementation of agbiotech policies and regulations, or where the innovative capacity of the country's research system is limited..

To date in Africa, agbiotech research is being conducted by Egypt, Ghana, Kenya, Morocco, Nigeria, Tunisia, South Africa, and Zimbabwe. Only Egypt, Kenya, Nigeria, South Africa, and Zimbabwe have developed national biosafety policies so far, though several others (e.g., Ghana, and Uganda) are advancing their policies [16]. There is significant variation in how the policies are framed. In Egypt, for example, while a draft law on agbiotech is under preparation, the current regulatory regime is managed by the Ministry of Environment and based on two decrees issued in 1994, one for GM seeds and a

second one for GM crops. In Kenya, guidelines and regulations developed in 1991 primarily govern biotechnology research, while in South Africa research is regulated under laws enacted in 1999. Many other countries in the region have participated in regional informational meetings on biosafety, signed on to the Cartageña Protocol, and/or engaged in discussions on regional harmonization of biosafety regulations [3, 16]. Yet very few of these countries have moved ahead into testing, approval and commercialization. Only South Africa has any significant number of approved field trials (172), confined field trials (7), commercial approvals (9) and hectares under GM cultivation (0.5 million) [3, 15].

1.2 Studies on the investment environment

Studies of the investment environment are also a good indication of the advancement of agbiotech and GM crop research in developing countries. Most African countries – with notable exceptions such as South Africa and Kenya – are facing declining or stagnating growth rates of public investment in agricultural R&D, and consistently limited investment from the private sector [17]. Based on a sample of 27 Sub-Saharan countries, a recent survey estimates that the growth rate of public agricultural R&D expenditure declined from 2.0 percent in the 1970s to only 0.8 percent in the 1990s. Excluding South Africa and Nigeria from the sample – where R&D expenditure grew during the 1990s – total spending in the region actually declined by 0.2 percent per year, resulting in a halving of average spending per scientist (Table 1) [18]. Research specifically targeted to agbiotech represents a tiny fraction of these figures, is concentrated primarily in South Africa, Kenya, and Egypt, and is often highly dependent on donor funding [19]. While there is some indication of a growth in agbiotech investment by the public sector in these countries and several others, figures still remain relatively low.

Yet at the global level, investment in agbiotech research is not insignificant. Estimates suggest that private investment in plant biotechnology by the leading multinational companies during the mid-1990s totaled approximately $1 billion per year, a figure that amounts to roughly half of all global expenditure on agbiotech R&D [20, 21]. Most of these expenditures, however, were concentrated on crops, traits and technologies directly relevant to industrialized country farming. Again, only a minute fraction of this research expenditure is immediately relevant to Africa.

In short, without consistent investment in agricultural R&D, it is hard to imagine how African countries can augment their investment in conventional research (plant breeding, for instance) with more advanced and more costly agbiotech and GM crop research.

Studies on the investment environment with respect to markets for seed and other planting materials are also a good indication of progress in agbiotech and GM crop research. Functional seed systems are critical because they are the channel through which many agbiotech applications will be deployed and disseminated in Africa. However, seed systems are, by their nature, subject to a variety of unique market and institutional constraints [32, 33]. First, problematic property rights result from fact that improved seeds can, in many cases, be reproduced by the farmer, thus reducing the ability of breeders to appropriate the gains from their innovative activities and investments. Second, information asymmetries result from the inability of farmers to make ex ante assessments of seed quality, since such knowledge is held only by the seller in the absence of certain types of regulation. Third, coordination problems result from difficulties of enforcing and monitoring contracts for seed use: farmers often save and exchange seed without the breeder's knowledge. Finally, inelastic supply responses result from the inability of breeders to respond effectively to rapid changes in seed demand from farmers: often, farmers may reassess their seed type and quantity re-

Table 1: Public and private agricultural research investment, c. 2000

Region/country[a]	Total spending			Shares	
	Public	Private	Total	Public	Private
	(millions 1993 international dollars)			(percentage)	
East Africa (7)	341.4	5.4	346.8	98.4	1.6
South Africa	365.6	15.6	381.2	95.9	4.1
Other Southern Africa	62.4	2.8	65.2	95.7	4.3
Nigeria	106.0	-	106.0	100.0	-
Other West Africa (13)	209.3	1.8	211.1	99.1	0.9
Total (27)	**1,084.7**	**25.6**	**1,110.3**	**97.7**	**2.3**

Source: Beintema and Stads 2006. [a] Numbers in parenthesis denote number of countries sampled in each region/subregion.

quirements just prior to planting based on expectations of rainfall, market prices, and other factors—decisions taken long after breeders have bulked up seed quantities for distribution.

Although seed systems may exist in Africa where markets for a given crop are well-developed, e.g., maize in Kenya, they are more often weak or otherwise incomplete due to the constraints noted above [34, 35]. Seed systems for "orphan" crops of marginal commercial value but critical importance to subsistence farming—sorghum, millet, groundnuts, pigeonpea, cassava, or sweet potato—are rarely functional throughout the region, due primarily to the combined weakness of the markets for these commodities, the non-appropriability of varietal improvements under current technological and legal contexts, and limited incentives to commercialize public research on varietal improvement in most countries [35, 36]. Thus, the market and institutional failures pose a significant barrier to the entry and growth of private seed firms which could potentially commercialize, market, and distribute varietal improvements resulting from public research. This is a major disincentive to increasing investment in GM crops and agbiotech research across the region.

1.3. Studies on the role of public-private partnerships

Next, consider the literature on public-private partnerships in agricultural R&D. Studies by Chataway [22], Hall [23], Spielman and Von Grebmer [24], Vieira and Hartwich [25], and Ozgediz and Nambi [26], among others, argue that 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 – represent an innovative and potentially beneficial approach to promoting agricultural and agbiotech research in developing countries.

R&D partnerships rely on processes of knowledge sharing, resource pooling, cost minimization, scale economies, and joint learning to generate synergies in conducting advanced research, commercializing new technologies, and deploying new products. Ideally, these synergies result in research outcomes of greater quantity, with a greater chance of success, or at lower cost than public, private or civil society actors could expect when acting independently. If the research is strategically focused on the needs of marginalized social groups, outcomes may ultimately translate into significant social and economic benefits. Several partnerships formed around this type of focus include projects on cassava [37], cowpea, sorghum, bananas and plantains [38] in Sub-Saharan Africa, and are expected to deliver beneficial outcomes over the next decade.

Partnerships are particularly useful to larger or more advanced systems that require access to cutting-edge research tools, proprietary knowledge, or other types of information and data; and to smaller systems which do not have the scale economies to conduct independent research efficiently [20]. In recognition of this potential, key public sector actors are engaged in several partnerships focusing on enhancing yields or nutritional content of crops such as rice, wheat and cassava. In Africa, the partnerships have been concentrated only in South Africa, Kenya, and Egypt, and are highlighted by such projects as multistakeholder research initiatives on insect-resistant maize; a livestock vaccine for East Coast Fever; virus-resistant sweet potato; micro-propagated, tissue-cultured banana; and bio-fortified grain crops [27, 3]. In most cases, the research centers of the Consultative Group on International Agricultural Research (CGIAR) play an important role in convening these initiatives, mobilizing resources, and conducting research, often in partnership with national research systems, multinational crop-science firms, and local seed firms. What remains to be seen is whether the partnership approach is yielding the expected outcomes.

2. Two surveys on agricultural research

Two recent studies on agricultural research provide additional evidence on the realities of the policy and investment environment in agbiotech and GM crop research in developing countries.

2.1 Next Harvest 2002

The first is a study entitled Next Harvest, initiated in 2002 by the International Food Policy Research Institute (IFPRI) and the International Service for National Agricultural Research (ISNAR). It was conducted to determine expectations and limitations on publicly researched GM crops and traits. The study was conducted based on a survey distributed to a purposeful sampling of 76 experts (researchers and regulators) from public research organi-

Table 2. Transformation events by country (2003)

Country	No. of events
Egypt	17
Kenya	4
South Africa	28
Zimbabwe	5
Total (Africa)	**54**
Total (all regions)	**209**

Source: Next Harvest survey data, 2003

zations in 16 developing countries. The sample was designed to capture the extensive variation in the type and state of research in different countries and organizations, and to ensure that relevant knowledge, experiences, and insight were provided to participants. Information on 209 transformation events was received through the year 2003, along with data 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 [15]. Fifty-four of the 209 events (26 percent) were attributable to agbiotech research in African countries (Table 2).

2.2. IFPRI's PPP Study 2003-2004

The second study was undertaken by IFPRI in 2003–04 to examine partnerships between private firms and the international research centers of the CGIAR. The 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/national research-based agribusiness firms; international agricultural research centers and programs; multilateral and bilateral donors and foundations; and national agricultural research systems, academia, and non-governmental organizations (Table 3).

At least a quarter of the stakeholders were engaged in or closely associated with partnerships that were directly relevant to research in Africa. Data were compiled from semi-structured interviews and open-ended discussions, and were complemented by 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. [24]

3. Findings

3.1 Insights from Next Harvest

A key finding of the Next Harvest study is that public research institutions in developing countries have conducted a significant number of diverse crop transformations to express a wide variety of crop groups and transgenes [11]. However, while relatively large numbers of transformation events were recorded in Asia and Latin America, the only African countries with any significant number of events were Egypt and South Africa.

3.1.1 Transformation events: confined to the experimental stage

When classified by crop type, more than half (55 percent) of all public events recorded by the survey were concentrated among 15 crops that are critical to achieving sustainable food security and reducing poverty in developing countries. The remaining 45 percent of transformation events were focused on cotton, vegetables and fruits – crops of a more commercial nature. For Africa, the predominant group crop in all 54 transformation events was cereals, followed by vegetables, roots and tubers, and sugar, with each group representing a fairly diverse set of crop species. The greatest numbers of transformation events among all 11 crops were for maize (17.0 percent), potatoes (13.0 percent), and sugar and tomatoes (11.0 percent each) [6].

With regard to regulatory progress, most of these transformation events remained confined to the experimental stage of laboratory and greenhouse trials, while fewer have advanced to later stages in the regulatory process such as field trials for biosafety testing; scaling-up stage for wider environmental and efficacy testing; or commercialization stage for release to farmers [11]. Overall, African events lagged slightly behind their Asian and Latin American counterparts: While 70 percent of

Table 3. Respondents to an IFPRI Study of Public-Private Partnerships (number)

Affiliation	Respondents	
	Number	Percent
Multination corporation	15	36
CGIAR center/program	12	29
Donor agency	8	19
National agricultural research system	2	5
Academia/non-governmental organization	5	12
Total	**42**	**100**

Source: Spielman and Von Grebmer, 2004

Table 4. Institutional arrangements used in public transformation events (no.)

Institutional arrangement	Africa	All Regions
Single public institution	28	129
Public/Public	13	47
Public/Private	7	15
Public/Foundation/Public	0	8
Public/Private/other	5	6
All other (no private collaboration)	1	4
Total	**54**	**209**

Source: *Next Harvest* survey data, 2003

all events in the African countries surveyed were still at the experimental stage, only 60 percent were at a similar stage in Asia and Latin America.

3.1.2 Main research actors: poorly networked

Most of the surveyed public organizations worked in isolation from other research actors, both public and private. Across the study, only 7 percent of transformation events generated by these organizations were conducted in collaboration with the private sector, while only 22 percent were generated in collaborations between or among public institutions. In Africa, the distribution of involvement was somewhat different: half (52 percent) of all transformation events were from a single public institution while the rest was from public-private (22 percent), public-public (24 percent), or some other type of collaboration (2 percent). Africa also had more representation from the private sector regarding origin of genetic materials. While only 5 percent of all surveyed transformation events relied on genetic materials derived from local or foreign private sector materials, 15 percent of all materials used in Africa originated from the private sector.

3.1.3 Traits of GM crops: Limited in focus

In terms of transgenes and gene groups, the figures suggest that agbiotech and GM crop research may be limited in focus with respect to the particular biotic and abiotic stresses facing agriculture in many developing countries. Fungal, bacterial and other types of resistance are still at very preliminary stages of research for developing country crops and agroecologies, while herbicide tolerance, insect resistance, and virus resistance – originally designed for the needs of industrialized country agriculture – continue to dominate the research pipeline.

3.1.4 Agbiotech research: Limited by heavy regulation

in terms of regulatory progress, the figures indicate that forward movement in agbiotech and GM crop research in Africa is limited to very few countries, and that research in those countries are only now reaching the initial stages of the regulatory process. While agbiotech may shorten the time needed to identify transgenes and transform plants, the resulting GM crop still requires time for scaling up, efficacy trials, environmental testing, and other regulatory requirements particular to genetic modification. Agbiotech research in Africa has not moved far along this road.

This reality is, according to many survey respondents, worsened by the fact that some countries have subjected GM crops to multiple years of testing, significant waiting periods for approvals for scale-up or pre-commercial trials; or have only interim guidelines or regulations in place that do not allow for commercial approvals. Even those countries that do have the ability to evaluate GM crops and provide commercial approvals often lack confidence in their commercial decision-making. Others may be facing limitations such as growers' inability to produce adequate seed amounts for large-scale or food safety testing.

3.1.5 The absence of interaction between the public and the private sector

The relatively small role attributable to the private sector in agbiotech and GM research in African countries suggests that public-private research collaborations face significant barriers to implementation. This absence of collaboration could pose difficulties for public institutions as they advance from research to regulatory approval and commercialization. Without exchanges of valuable regulatory data from private firms and other research

institutions that have conducted transformations of similar crops and/or traits in industrialized countries, public institutions are less equipped to navigate the regulatory and commercialization processes with full information. Without scientific interaction and information exchanges between sectors, many of the public researchers who will be tapped for biosafety committees, regulatory agencies, or advisory bodies will be similarly less equipped to provide real expertise.

3.2 Insights from the IFPRI study on public-private sector collaboration

The IFPRI study on public-private partnerships provides some useful insight. Respondents to the study indicate that partnerships are constrained by conflicting incentive structures, high transaction and opportunity costs, competition and risk associated with proprietary assets, and mutually negative misperceptions. Their responses indicate that competition and risk, along with negative misperceptions, are the most significant constraints, followed by conflicting incentives and high costs.

3.2.1 Conflicting incentive structures: People vs. profits?

Consider first the more obvious issue of conflicting incentives. According to respondents, a barrier to successful collaboration results from the obvious differences in incentive structure: private firms exist to maximize profits, while public agencies exist to fulfill wider social mandates. Where common interests do not exist or are difficult to identify, the potential for collaboration and cooperation are necessarily lower, according to survey respondents. But many respondents were quick to point out that public and private interests do, under certain circumstances, coincide. Public agencies may pursue collaborations with the private sector to access their cutting-edge research tools and technologies, or to use their marketing and distribution channels to farmers and other end- or intermediate-users. Similarly, private firms may pursue collaborations to access emerging markets in African and other developing countries, gain knowledge about local regulatory processes, obtain genetic resources held in the public trust, or enhance their reputations and goodwill with the public or with public interest groups. Partnerships may also be a prerequisite to research funding, for instance, in some competitive grant programs, thereby creating an incentive for coincidental interests.

3.2.2 High transaction costs in contracting, coordinating and enforcing rules of collaboration

Yet even where coinciding interest are identified or created, public-private partnerships may face additional challenges. Respondents cited high transaction costs as a major constraint to successful partnership and partnership outcomes. The direct and indirect costs of contracting, coordinating, and enforcing a relationship between collaborators may result in slow and inefficient interactions and negotiations. This is reflected in the costs associated with managing regulatory and contractual aspects of partnerships that rely on proprietary knowledge such as patented transgenes. This is also reflected in the search costs associated with information asymmetries between parties: often, public research organizations and private firms lack a priori knowledge about the opportunities offered by the other party's stock of proprietary knowledge or its way of doing business, and must engage in a negotiation process (of the which the outcome is uncertain) to obtain such information.

3.2.3 High opportunity costs for firms

Respondents also cited high opportunity costs as a barrier to partnership, i.e., where conventional research investments are foregone in favor of an investment undertaken through an untested, non-traditional or uncertain modality such as a partnership. Firms are ultimately accountable to their shareholders, and only a small number of African countries offer the large agricultural markets, strong IP protections, and/or adequate investment incentives, that provide profitable opportunities for firms in the agbiotech sector.

3.2.4 Risk and competition associated with proprietary knowledge

However, the majority of respondents stated that the most significant barrier to partnership was associated with the risk and competition that comes with the use of proprietary knowledge and intellectual property (IP). Here, the main issues cited were not access to patented tools or applications, but concern over the use and misuse of the IP. This is a critical aspect of agbiotech and GM crop research given its overt reliance on plant genetic resources and the tools and methods of genetic engineering. Respondents from the private sector noted that partnerships that revolve around IP run the risk that a public partner might share the IP with the private partners' competitors, inadvertently or through detailed, public disclosure of research activities; or mishandle the stewardship of the IP, potentially allowing for misuse or abuse by third parties. Respondents from the public sector, on the other hand, noted that similar types of partnerships run the risk that a private partner might capitalize on genetic materials held in trust for the public good, appropriating any gains from its use for private gain.

These risks can translate into significant financial and reputational liability for both public organizations and private firms. Respondents suggested that while contractual limitations on the use of IP and other sensitive

resources can help reduce risk and liability, full enforcement of contracts is often difficult in many developing countries and sometimes undesirable where long-term public-private relationships are being forged.

Thus, the constraints posed by risk and competition are not easily mitigated. This may also explain, to some extent, the extremely limited reliance on private sector transformed materials observed in the Next Harvest survey.

3.2.5 Persistent misperceptions

Finally, 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. Other misperceptions are brought about by the process of partnering, for example, the use of confidentiality and nondisclosure agreements that, while standard in private research, are quite foreign in public research. Respondents also suggested that misperception result from the relative distribution of bargaining power: public institutions or private firms may be unwilling to partner where one party can potentially dominate the partnership by virtue of its organizational size, the value of its IP, the size of its research budget, or its ability to influence political and economic decision-makers.

4. Recommendations

Evidence from the two studies examined here indicate that while public research in Africa is advancing in several countries, the policy and investment environments may be hindering the advancement of this research. Regulatory processes are holding up testing and commercialization, while institutional and attitudinal barriers to public-private partnerships are preventing the use of private sector resources and expertise that would provide valuable learning and data exchange opportunities. These findings suggest that the policy and investment environments are insufficient relative to the requirements needed to realize the benefits of these new technological opportunities.

4.1 Improving the sharing of information

There are several regional, national and global policy options that could improve agbiotech and GM crop research in Africa. 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.

An option is to place this information in the recently-established Biosafety Clearinghouse so that environmental assessments of crops or traits can be carried out based on accumulated experience among industrialized and developing countries [28]. This presents opportunities for South-South collaboration, information networking, and data sharing, with the objective of minimizing redundancies while maximizing the flow of information and expertise based on solid and comprehensive sources of information, ultimately increasing 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. In this context, there is also a need to build capacity within research organizations and train local researchers to make effective use of electronic biotechnology research databases and conduct advanced research.

4.2 Improving the effectiveness of collaborative research

Several innovative approaches to collaborative research could also improve the pace and level of research on agbiotech and GM crops. One possibility is for the public sector to take a stronger public negotiation stance, advocate for greater private tax incentives, or promote other mechanisms to improve the willingness of firms to invest in or provide IP donations for research with a public-interest focus.

For example, the Golden Rice Humanitarian Board – a partnership charged with promoting research on beta carotene-enhanced rice – manages not only the transformation work of academic researchers in Germany and Switzerland, but also the intellectual property licensing, financing arrangements, and technology transfer to international and national research systems for more applied research and local adaptation [29].

Other arrangements may be formalized as commercial joint ventures, within which public and private collaborators establish a legal entity to execute a public interest research agenda, and endow it with a mix of governance and management characteristics from the public and private sectors. Lessons can be learned from China where several agbiotech ventures are advancing as commercial entities spun off from public research agencies, often wholly or majority owned by the parent agency [30, 31].

Alternatively, researchers and policymakers may explore the use of "honest brokers" or non-profit, third-party organizations to facilitate interactions between the sectors, manage the research execution, and assume responsibility for the use of proprietary knowledge and technology. The International Service for the

Acquisition of Agri-biotech Applications and the African Agricultural Technology Foundation are playing such a role in agbiotech and GM crop research in Africa.

4.3. Improving interaction among key players

The advancement of agbiotech and GM crop research in Africa necessitates greater interaction between key players engaged in the process. There is sufficient evidence to suggest that both the public and private sectors have an interest in advancing agbiotech and GM crop research, whether to improve food security, reduce poverty, or reap commercial rewards. Greater dialogue between the sectors is needed to reduce misperceptions, facilitate greater collaborative research opportunities, and improve the wider environment in which research is being conducted.

4.4 Improving commercial opportunities

The advancement of agbiotech and GM crop research in Africa also requires greater investment in building systems and markets for seed and planting materials. Enactment of plant variety rights and truth-in-labeling laws, combined with a greater commitment from public research organizations to moving technologies off the shelf and into farmers' fields, would facilitate greater investment in GM research and product deployment in Africa. Public-private partnerships, technology commercialization programs, competitive grants, reward/prize programs, and other such approaches could go a long way in shifting public research incentives toward more commercially-viable outcomes.

5. Conclusion

Slow progress in agbiotech and GM crop research in Africa is not simply the result of the highly politicized debate over the desirability or safety of these new technologies: rather, it is also a product of impediments to the research process itself. The two studies of agricultural research in developing countries examined here offer several critical findings about these impediments. First, while 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. Steps should be taken now to address these issues and the crops under research.

Finally, whatever the steps taken, investment in GM crops and agbiotech research in Africa also requires a real breakthrough—successful navigation through regulatory processes and deployment through commercial channels—to demonstrate the technology's potential contribution to the region's agriculture, and the modalities needed to get there. However, if the impediments discussed earlier persist, the pace of research will be insufficient to generate such a breakthrough, thus slowing the diffusion of new technological opportunities and the potential gains to social and economic welfare in Africa implied therein

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