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January 2008

Center for Science, Technology & Public Policy, University of Minnesota, 2008

Policy Options of Agricultural Biotechnology R&D in Sub-Saharan Africa: Key Issues and Aspects

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ABSTRACT

This paper reviews the status of Agricultural Biotechnology in Sub-Saharan Africa. It addresses the potential economic benefits to Sub-Saharan Africa and the effect biotechnology policies may have on growth, production and poverty reduction. The extent to which agricultural biotechnology will compound or mitigate the constraints faced by smallholders/subsistence farmers is also discussed. The status of crop biotechnology research worldwide is reviewed and the influence of intellectual property rights (IPRs) and market concentration on the development and diffusion of biotechnology in Sub-Saharan Africa is analyzed. The paper also explores the potential of public-private partnerships and recommends policy measures and investments that could focus more biotechnology research on the problems of the poor and alleviate some of the concerns about the impacts of biotechnology.

Introduction

The Convention on Biological Diversity[1] defines biotechnology as: *"any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use"*. With this interpretation, the definition of biotechnology covers many of the tools and techniques that are commonplace in agriculture and food production. The Cartagena Protocol on Biosafety[2] defines "modern biotechnology" more narrowly as the application of:

a. *In vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or*

b. *Fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection.*

Interpreted in a narrow sense, which considers only the new DNA techniques, molecular biology and reproductive technological applications, the definition covers a range of different technologies such as gene manipulation and gene transfer, DNA typing and cloning of plants and animals.

Although the technology has received widespread media coverage in the past few years, it is a technology with a long history; dating as far back as 6000 B.C. Advances in science and technology have transformed traditional biotechnology techniques, such as selective breeding, hybridization and mutagenesis, into modern ones, such as recombinant DNA techniques and tissue culture. This transformation has opened the door to more varied applications in areas such as health care, the environment, forestry, industrial processes and others. Current trend includes research into nutritionally enhanced GM foods and transgenic animals, biochips and protein drugs.

One of the most extensive applications of biotechnology has been in agriculture. Biotechnology techniques such as recombinant DNA techniques and mutagenesis have been used to develop plants with novel traits. These traits include herbicide tolerance and pest, insect and virus resistance. Biotechnology techniques have been used to produce bio-pesticides which are toxic to targeted plant pests. Also, experiments into genetic modification of aquatic organisms such as salmon, for such novel traits as enhanced growth, have been carried out using recombinant DNA techniques. Increasing yield potential and desirable traits in plant and animal food products has long been a goal of agricultural science. That is still the goal of agricultural biotechnology, which has the potential to be a key driver of development, poverty alleviation, food security, and natural resource conservation in the developing world if practiced responsibly. Increasing public interest in and attention to biotechnology have generated a variety of complex, interrelated policy issues that needs to be addressed.

Sub-Saharan Africa (SSA) is one of the most food insecure regions in the world. The available FAO statistics indicates a worsening scenario. Africa's overall food production capacity is said to be increasing at the rate of 1.4% while its population is expanding at about 2.4% per year[3]. The continuing decline in food production will have to be reversed if massive food insecurity, poverty, and social and political instability are to be averted. Area expansion and irrigation are estimated to account for 45% of the increase expected while the remainder 55% will have to come from intensification of production from land under cultivation[4].

The majority of biotech research and almost all of the commercialization of genetically engineered crops have been done by private firms based in industrialized countries. The dominance of the private sector in biotechnology research and product development has raised concern in developing countries that their farmers – particularly poor farmers – may not benefit from biotechnology either because it is not available or is too expensive. Several of these concerns exist, and raise questions the answers to which in fact must be pursued in a concerted and collaborative manner if it is to be ensured that the technology benefits and does not harm society and the earth. Some of the questions are these: What biosafety regulatory frameworks should be established? What policies are required to guarantee that the production of GM crops serves poor farmers and consumers? And what research and information are needed to develop frameworks and policies on these issues and other important ones?

Raising agricultural output could increase smallholders' incomes, reduce poverty, increase food access, reduce malnutrition, and improve the livelihoods of the poor. That in turn will reduce farmers' crop protection costs and benefit both the environment and public health. A real problem is how to provide adequate incentives for crop breeders to focus on orphan crops and adaptations to difficult environments, which are of greater interest to poor farmers. Public funding and the involvement of international organizations will be crucial to such research.

BIOTECHNOLOGY IN SUB-SAHARAN AFRICA: A STATUS OVERVIEW

Africa is a hungry continent and the poorest, most food insecure region of the world. Africa's bleak prospects for improving food security have been addressed by a number of study teams that point to increased GM food production as a solution to Africa's food crisis.

There are numerous studies that attest to the beneficial impacts of agbiotech on poverty, food security, and agricultural development, although most include the proviso that agbiotech is not a panacea for poverty[5]. Several studies have also argued that these impacts are influenced by the extent of private sector investment[6], the effectiveness of biosafety and other regulatory regimes and the efficiency of plant genetic material flows between researchers[7]. However, simple facts tell the story: Commercialization of genetically modified (GM) or transgenic crops was first approved for use by farmers in the United States, Mexico and Australia in 1995. But, after two decades of rapid growth of GM crops, South Africa is the only one of the 53 countries on the African continent that is currently commercializing GM crops.

Sub-Saharan African (SSA) countries have not taken conscious efforts to understand biotechnology, tap its potential, and use it to address some of the basic agricultural problems. This is a strong statement, but, a truism, despite evidence that the last two decades have witnessed increased investment in biotechnology research and development (R&D) by a number of African countries. Indeed, national agricultural research institutes, public universities, international institutions, and private companies have engaged in some form of agricultural biotechnology. Closer examination, however, reveals that many African governments are skeptical of GM foods. Also there are a number of complex barriers to the development and testing of new GM crops in Africa; including limited capacity – human, financial, and infrastructural; ill-defined or non-defined institutional arrangements for biotechnology R&D; and ambivalence to or indecision on biotechnology as stated earlier. The origins of African policy makers' ambivalence or indecision are partially a spillover from concerns in Europe about food safety, the environment and generalized public mistrust of multinational seed companies as being manipulative and unscrupulous[8].

Most of the current biotechnology R&D activities in Sub-Saharan Africa are focused on improving productivity in the agricultural sector. The direction of biotechnology research in Africa is influenced by the traditional research agenda. It is clear that while the SSA countries have some form of biotechnology activities in place, they are at different levels of biotechnology research and development. SSA countries can broadly be grouped into five classes in terms of biotechnology R&D capacity:

- Countries that are generating and commercializing biotechnology products and processes using third-generation techniques of genetic engineering (e.g. South Africa, Kenya and Zimbabwe)
- Countries engaged in third-generation biotechnology R&D, but which have no products or processes yet (e.g. Ghana, and Uganda)
- Those engaged in second-generation biotechnology – mainly tissue culture (Tanzania and Nigeria)
- Those who are neither engaged in second nor third generation biotechnology but planting GM Crops (e.g. Burkina Faso)
- The fifth group are those who are practically not using any form of second or third-generation biotechnology; and not planting GM crops (e.g. Angola, Botswana and the Gambia)

The main players in agricultural biotechnology R&D in SSA countries can be distinguished from those in the developed countries where private corporations are the main drivers of biotechnology R&D, and consequently own and control biotechnology information. Most biotechnology research in SSA is still in the public domain. The main private sector actors in biotechnology are multinational corporations. There is clearly need for institutional articulation and collaboration between diverse actors, which would imply public-public and public-private institutional articulation to ensure that there are synergistic interactions between diverse biotechnology actors[9]. It is the contention that viable research and development institutions are needed for achieving sustainable change in areas of national importance. However, there is as yet no proven evidence that the public sector biotechnology

R&D is having any impact. It can be argued that the current R&D technologies in use in SSA are as a result of spill-ins, with perhaps the exception of South Africa.

The globalization of the world economy and the emergence of the giant transnational corporations (with economic potential greater than that of SSA countries put together) are shaping the development of countries in Africa and elsewhere in the developing world. The concentration of agricultural biotechnology R&D in a handful of companies has implications for access to the technology and products thereof, given the trend toward tighter control of intellectual property promoted by the World Trade Organization's agreement on trade-related aspects of intellectual property rights (TRIPS). This concentration and the provisions of TRIPS have resulted in the progressive privatization of biotechnology innovations that have resulted from material provided freely by communities of farmers around the world; this is an issue of great concern to most Africans.

GLOBAL TRENDS IN BIOTECHNOLOGY

The use of modern biotechnology in agriculture is a global success story. Since the introduction of biotech crops in 1996, more than 570 million hectares have been grown cumulatively[10]. In 2006, 22 countries, representing more than half of the global population, saw the cultivation of biotech crops on more than 100 million hectares, grown by over 10 million farmers, 90% of whom live in developing countries; mainly Brazil, India, China, Argentina and South Africa[11]. The first generation of biotech crops has yielded significant socio-economic and environmental benefits at the farm level, mainly through higher yields and better yield protection, through reductions of chemical pesticides, fuel use and greenhouse gas emissions and through the implementation of effective and environmentally-friendly farming practices like conservation tillage[12]. Products from the second generation, with new traits and direct benefits for other parts of the food chain, are about to enter the marketplace e.g. the Swiss Golden Rice.

Governance: international regulation: There are five main elements of international regulation relating to research into, and the trade and use of, GM crops:

i. Agreements by the World Trade Organization (WTO) which aim to control barriers to international trade[13]. It is within this framework that the US and a number of other states challenged the EU on the authorization of GM crops.
ii. The *Codex Alimentarius*, a set of international codes of practice, guidelines and recommendations pertaining to food safety[14]. The WTO currently relies upon the *Codex* in making its adjudications.
iii. The *Cartagena Protocol on Biosafety* under the *Convention on Biological Diversity*[15], a multilateral agreement covering the movement across national boundaries of living modified organisms (LMOs) that might have an adverse effect on biological diversity.
iv. The *International Treaty on Plant Genetic Resources for Food and Agriculture* by the UN FAO, a multilateral agreement relating to any genetic material of plant origin of value for food and agriculture[16].
v. Directives and Regulations by the EU and its regional policies on agriculture, environment GMOs[17].

ECONOMICS AND POLICY ISSUES FOR AFRICA

Ample empirical data exists on the production, productivity, income and human welfare impacts of modern agricultural science and the international flow of modern varieties of food crops. The adoption of modern varieties (averaged across all crops) increased rapidly during the two decades of the Green Revolution, and even more rapidly in the following decades, from 9 percent in 1970 to 29 percent in 1980, 46 percent in 1990 and 63 percent by 1998[18].

The Green Revolution defied the conventional wisdom that agricultural technology does not travel well because it is either agro-climatically specific, as in the case of biological technology, or sensitive to relative factor prices, as with mechanical technology[19]. The Green Revolution strategy for food-crop productivity growth was explicitly based on the premise that, given appropriate institutional mechanisms, technology spillovers across political and agro-climatic boundaries could be created. Hence the Consultative Group on International Agricultural Research (CGIAR) was established specifically to generate technology spillovers, particularly for countries that are unable to capture all the benefits of their research investments[20]. The question now is, can this be replicated for agricultural biotechnology or what is now popularly referred to as Gene Revolution? In considering an answer to this question, another question that comes up is; how come Africa did not benefit from the Green Revolution?

The Green Revolution never arrived in Africa for several reasons. First, Norman Borlaug, "the father" of the Green Revolution, sought improved seeds for just a few varieties of wheat and rice; Africans farm hundreds of crop varieties. Second, with its drier terrain, Africa is not as suited to irrigation. Finally, Asian roads in 1960 were better than African roads today; their terrible condition makes seed and fertilizer distribution difficult. Africans use the least amount of fertilizer in the world and pay the most for it.

In September, the Rockefeller Foundation and the Bill and Melinda Gates Foundation announced a $150 million Alliance for a Green Revolution in Africa (AGRA). AGRA will support the Program for Africa's Seed Systems (PASS). PASS will mount an across-the-board effort to improve the availability and variety of seeds that can produce higher yields in the often harsh conditions of Sub-Saharan Africa[21]. Specifically, PASS will help:

i. Develop improved varieties of African crops
ii. train new generation of African crop scientists
iii. ensure improved seeds reach smallholder farmers
iv. develop a network of African agro-dealers
v. monitor, evaluate and manage

These are wonderful objectives which I believe can kick-start an African Green Revolution *ceteris paribus*. However, AGRA, has started generating a lot of controversy with the announcement by its chairman, the former UN Secretary-General, Kofi Annan of Ghana that AGRA will not use genetically modified (GMO) seeds to fight the war on hunger in Africa; instead, AGRA will focus on creating new seed varieties from familiar local seeds using conventional breeding methods. I find that rather unfortunate. I believe the combination of biotechnology and conventional breeding methods will have been more appropriate.

Much of the increase in agricultural output over the past 40 years has come from an increase in yield per hectare rather than an expansion of area under cultivation[22]. FAO data indicate that for all developing countries, wheat yields rose 208 percent from 1960 to 2000; rice yields rose 109 percent; maize yields rose 157 percent; potato yields rose 78 percent and cassava yields rose 36 percent[23]. Trends in total factor productivity are consistent with partial productivity measures, such as rate of yield growth[24].

The primary effect of agricultural research on the non-farm poor, as well as on the rural poor who are net purchasers of food, is through lower food prices. The wide-spread adoption of modern seed-fertilizer technology led to a significant shift in the food supply function, increasing output and contributing to a fall in real food prices: ***The effect of agricultural research on improving the purchasing power of the poor - both by raising their incomes and by lowering the prices of staple food products - is probably the major source of nutritional gains associated with agricultural research. Only the poor go hungry. Because a relatively high proportion of any income gains made by the poor is spent on food, the income effects of research-induced supply shifts can have major nutritional implications, particularly if those shifts result from technologies aimed at the poorest producers[25].***

Studies by economists have provided empirical support for the proposition that growth in the agriculture sector has economy-wide effects. In a study by Anderson and Jackson using the global economy-wide computable general equilibrium model known as GTAP[26]; had results suggesting that welfare gains are potentially very large, especially from nutritionally enhanced GM rice and wheat, and that – contrary to the claims of numerous interests – those estimated benefits are diminished only slightly by the presence of the European Union's current barriers to imports of GM foods. In particular, if SSA countries impose bans on GM crop imports in an attempt to maintain access to EU markets for non-GM products, the loss to domestic consumers due to that protectionism boost to SSA farmers is far more than the small economic gain for those farmers from greater market access to the EU.

The stakes in this issue for Sub-Saharan Africa are thus high, with GM food technology potentially offering welfare gains that could alleviate poverty directly and perhaps substantially in those countries willing and able to adopt the new technology. SSA countries need to assess whether they share the food safety and environmental concerns of Europeans regarding GMOs.

If not, their citizens in general, and their poor in particular, have much to gain from adopting GM crop varieties and especially second generation ones. And, unlike for North America and Argentina where there is a heavy dependence on exports of maize and oilseeds[27], the welfare gains from GM crop adoption by Sub-Saharan African countries would not be jeopardized by rich countries banning imports of those crop products from the adopting countries.

An economic model was developed to predict the economic impacts to consumers and producers from the introduction of Bt crops in the smallholder cotton farms of Mali[28]. Impacts of Bt cotton and Bt maize were measured using the economic surplus method[29]. Since farmers rotate cotton and maize in three-year rotations, the analysis considered the introduction of both Bt cotton and Bt maize. Results from the model indicated that the potential economic impacts to West African consumers and producers would be significant, potentially reaching $89 million in an average year. For Bt cotton, the benefits would primarily accrue to producers. At a technology premium of $60 per hectare, where seed company revenue is maximized, Malian producer would capture 74% of the benefits and the seed company would capture the other 26%. Marra *et. al*.[30] have also concluded that transgenic field crops have been profitable: For every transgene type, crop, and state combination, the average profit is higher for the transgenic crop than for the conventional counterpart.

DISCUSSIONS AND RECOMMENDATIONS

***Public R&D Institutions in SSA*:** Research institutions in the developing world are facing various challenges. It is the contention that viable research and development institutions are needed for achieving sustainable change in areas of national importance including biotechnology R&D[31]. There is the need for a principle of integration across stakeholders involved in the development and delivery of biotechnology R&D, to enable cross-walking where appropriate to add value; and a principle of internal development of approaches, measures and indicators and assignment of roles in performance measurement and management. It is very possible that the Public sector biotechnology R&D in SSA is not having any impact and may not have any meaningful impact. In recognizing that the developmental impact of research is notoriously difficult to assess, my recommendation is that indicators of organizational uptake can provide reliable proxies, or 'leading' indicators of development impact. This implies that overcoming the lack of connection between research outputs and development impacts should not be pursued through impact assessment studies alone, but through appropriate systems that account for organizational uptake and research outcomes which provide the clearest evidence of likely developmental impact[32].

The precautionary approach: It is easier to forgo possible benefits in the light of assumed hazards, if the status quo is already largely satisfactory. Thus, for developed countries, the benefits offered by GM crops may, so far, be relatively modest. However, in SSA countries the degree of poverty and the often unsatisfactory state of health and agricultural sustainability is the baseline, and the feasibility of alternative ways to improve the situation must be the comparator. It is my recommendation that an adequate interpretation of the precautionary approach should require comparison of the risks of the status quo with those posed by other possible paths of action. Such assessments must be based on sound scientific data. The precautionary approach should not be used as a pretext for inhibiting agbiotech in SSA.

Availability of choice*:* It is a fact that whenever a decision is made to introduce new varieties of crops, whether GM or non-GM, problems might arise because the new seed might be more costly. Problems can also arise in cases where one single monopolistic seed supplier controls the provision of seed. It is therefore desirable that as far as possible farmers have a genuine choice. To provide a genuine choice it is important that support for the public sector be sustained, so that suitable seeds (whether GM or non-GM), which can be retained by farmers with minimal yield losses, are available. Policies also need to be in place to keep the private supply of seeds reasonably competitive

Decision making processes about the use of GM crops*:* Local communities must be included as far as possible in processes of decision making. The dissemination of balanced information, and the education and training of those involved is essential. In particular, farmers need to be informed about the technological potential and management requirements of GM crops. Expectations are sometimes inappropriately high, and knowledge about specialized farm management practices may be absent. I recommend that companies marketing GM crops in SSA countries share, with governments, the costs of:

i. locally appropriate schemes to elicit the preferences of small-scale farmers regarding traits selected by plant breeders;
ii. their participation, where appropriate, in plant breeding; and
iii. subsequent mechanisms to improve dissemination of balanced information, education and training about the use of GM crops.

Regulation of GM crops in SSA*:* Biosafety Laws should not stand in the way of adoption and use of GM technology. In most SSA countries, it will be a major financial and logistical challenge to provide the capacity and resources to undertake stringent biosafety evaluations and risk assessments. The proliferation of diverse regulations, resulting in every new GM crop being assessed for possible risks to human health and the environment in each SSA country will cause problems. It is therefore my recommendation that particular attention should be given to measures that will enable the sharing of methodologies and results. For example an environmental risk assessment done in Brazil which has similar ecological environments like SSA could be adopted. It should also be considered whether harmonized regional policies can be established, for example, by the ECOWAS, Southern African Development Community (SADC) and the Common Market for Eastern and Southern Africa (COMESA).

Current and future research: Since duplication of effort can be counter-productive, and since administrative resources in SSA countries are scarce, it is essential that international development efforts are coordinated. Current situation where each international organization is doing it own thing is not appropriate. For an array of reasons, many of the crops such as rice, white maize, millet, sorghum, yams, cocoyams, cassava and others, which provide food and employment income for the poor in SSA countries, have been ignored by the private sector. Much of the current privately funded research on GM crops serves the interest of large-scale farmers in developed countries. Consequently the needs of small-scale farmers in SSA countries are neglected. Research on these crops will have to be supported primarily by the public sector. My recommendation is that; national governments and donors should fund a major expansion of public GM-related research into tropical and sub-tropical staple foods, suitable for the needs of small-scale farmers in SSA countries. In determining which traits and crops should be developed, funding bodies should be proactive in consulting with national and regional bodies in SSA to identify relevant priorities.

***Exploitation by multinationals*:** It has been suggested by some that the use of GM crops by farmers in SSA might be exploited by the multinational seed industry in such a way that seed of questionable quality would be provided. I personally do not subscribe to this view. However, it is clear that the same standards of liability need to apply to both SSA countries and developed countries. Where there is clear evidence of damage attributable to the seed producer, compensation will need to be provided, regardless of whether the seed is GM or non-GM.

Micronutrient-enriched GM crops: The development of GM crops which can provide increased levels of crucially important micronutrients has been the focus of much discussion. Strong claims with regard to the potential of Golden Rice have been made by both proponents and opponents, sometimes in the absence of validated empirical evidence. Vitamin A deficiency is a public health problem in 118 countries where over 200 million preschool children are suffering from it, according to the WHO[33]. In Ghana for example, it has been estimated that adding vitamin A to the diet could reduce child mortality by 23% while helping to prevent blindness, malaria and general infection diseases. But disseminating vitamin pills has been costly and non-sustainable, and planting vitamin A-rich fruits or vegetables has not always been feasible. So how can the children's diet be improved? Golden Rice could make a valuable contribution where rice is the principal staple crop and other means of obtaining sufficient levels of vitamin A are more difficult to provide.

Intellectual property rights (IPRs): The provision of GM seeds and important research technologies are tightly consolidated around a small number of multinational companies. There are concerns that growth of patents in both the private and public sectors could have an inhibiting effect on publicly funded research. The challenge for the public sector, especially where research is directed at agriculture in developing countries, is how to access GM technologies without infringing IPRs. There is therefore the need for new initiatives which recognize the potential of these constraints to inhibit research into crops relevant to SSA countries. Access to plant genetic resources is critically important for the development of GM crops which are suited to the needs of SSA countries. Usually, access to such resources is governed by Material Transfer Agreements (MTAs). The perception that the recent proliferation of MTAs is not necessarily in the public interest is widespread.

Access to resources falling under the *International Treaty on Plant Genetic Resources for Food and Agriculture* is of crucial importance in the development of crops suited to SSA. I recommend every SSA country to ratify the treaty. Provisions should also be made to exempt users in developing countries from payments, where commercial applications arise from material covered by the MTA. Where exemptions are not appropriate, differentiation of payments should take into account the level of development of the country in question.

CONCLUSION

Sub-Saharan Africa faces an uphill battle with regards to the adoption and use of Agricultural biotechnology. The potential to improve the livelihoods of resource-poor farmers is a strong incentive to meet the challenge. However, this incentive will lose it reality if it is seen as simply a cynical strategy to gain support, or if it turns out to be a vain hope, unable to realize its good intentions.

The policy options available to SSA are varied. Getting GM crops into the hands of African farmers will require progressively minded policy makers. Policies should outline priority areas in biotechnology that are of relevance to Africa's development; identifying critical capabilities needed for the development and safe use of biotechnology; establishing appropriate regulatory measures that can advance research, commercialization, trade and consumer protection; and setting strategic options for creating and building regional biotechnology innovation communities and local innovation areas in Africa.

Acknowledgements & Notes

We would like to thank Professor Philip Pardey of the Department of Agricultural Economics, University of Minnesota for his review comments of the initial draft as a Term Paper. Although this review was undertaken at the Center for Science, Technology and Public Policy, University of Minnesota, the views expressed are solely those of the authors and do not reflect the views of any organization the authors are affiliated. This review article was initially accepted for publication in *Tailoring Biotechnologies*, but did not make it to print before the Journal Suspended all its publications. So this same document may appear in some citations as “accepted for publication in *Tailoring Biotechnologies*”.

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