POLICIES

BIOTECHNOLOGY CAN IMPROVE FOOD SECURITY IN AFRICA

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ABSTRACT

By the year 2025, 83% of the expected global population of 8.5 billion will be living in developing countries. The capacity of global resources and technologies to satisfy the demands of this growing population for food and other agricultural commodities is not assured. In 25 years, Africa's population is projected to increase to 1.3 billion, bringing about intense interest in Africa's agricultural and economic performance, and the potential impact of biotechnology on the economy and the welfare of the continent. Under Trade-Related Intellectual Property Rights (TRIPS), most processes and many products of biotechnology research are patentable. African countries generally have weak national scientific infrastructure and capacity to innovate and patent new materials as well as enforce biosafety requirements. In order for countries to access biotechnology products or technologies, it will become increasingly important to have policies and procedures on intellectual property rights in place at the national and institutional levels. In view of the extent of the collaborative international programs taking place, strong local partners are required to expedite the adaptation of technologies and materials that are developed through collaborative research. Lack of biotechnological innovations or their limited diffusion by farmers has increased the technological gap with developed countries. Biotechnology will affect even the most isolated villages in various ways. It will neither be wise nor justified for African countries not to effectively participate in this revolution and fight for gaining some of its expected advantages. The current policy indifference will not help our farmers.

Key words: biotechnology, patent, global, agriculture, genetically modified (GM), transgenic, biosafety, food security

LA BIOTECHNOLOGIE PEUT AMÉLIORER LA SÉCURITÉ ALIMENTAIRE EN AFRIQUE

RÉSUMÉ

D'ici l'an 2025, 83% de la population mondiale prévue à 8,5 milliards vivront dans des pays en développement. La capacité des ressources et des technologies mondiales de satisfaire les demandes de cette population croissante en matière d'alimentation et d'autres ressources agricoles n'est pas assurée. Selon les projections, dans 25 ans la population de l'Afrique augmentera de 1,3 milliards et s'accompagnera d'un intérêt intense aux performances agricoles et économiques de l'Afrique, ainsi que l'impact éventuel de la biotechnologie sur l'économie et le bien-être du continent. D'après les Droits de Propriété Intellectuelle en matière de Commerce (TRIPS), la plupart des procédés et des produits de la recherche en biotechnologie sont brevetables. En général, les pays africains ont des infrastructures scientifiques faibles au niveau national et de faibles capacités d'innover et de breveter de nouveaux produits et de mettre en vigueur les exigences de la prévention des risques biotechnologiques. Pour que ces pays aient accès aux produits ou aux technologies de la biotechnologie, il deviendra de plus en plus important d'avoir en place des politiques et des procédures sur les droits de propriété intellectuelle aux niveaux national et institutionnel. Etant donné l'ampleur des

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programmes internationaux de collaboration qui sont introduits, des partenaires locaux solides sont nécessaires pour expédier l'adaptation des technologies et des produits qui sont mis au point à travers une recherche conjointe. Le manque d'innovations biotechnologiques ou leur diffusion limitée de la part des agriculteurs ont élargi l'écart technologique par rapport aux pays développés. La biotechnologie affectera même les villages les plus isolés de plusieurs manières telles que celles associées à la baisse de la production et des coûts des transactions. Il ne sera ni sage ni justifié pour les pays Africains de ne pas participer efficacement à cette révolution en vue de lutter pour gagner certains des avantages qui en sont attendus au lieu de l'indifférence de la politique actuelle.

Mots clés: Biotechnologie, breveter, mondial, agriculture, génétiquement modifiés (GM), transgénique, prévention des risques biotechnologiques, sécurité alimentaire

INTRODUCTION

By the year 2025, four fifths of the expected global population of 8.5 billion will be living in developing countries. Currently, it is doubtful whether existing global resources and technologies will satisfy the demands of this growing population for food and other consumer commodities. The challenge therefore is how to meet these needs mainly by increasing production. To avoid damaging environmentally sensitive areas and hence ensure greater food insecurity, new methods need to be utilized to increase farm output on cultivated land. Increasingly biotechnology seems to be an important part of the solution.

Although global food production is sufficient to meet the needs of every citizen on earth, the *per capita* food production and availability remains lowest in Africa. While Western Europe's per capita food availability stands at some 3500 kilocalories/day and those of North America at 3600 kilocalories/day, in sub-Saharan Africa, food availability stands at only 2100 kilocalories per person per day, the lowest level of *per capita* food availability in the world. Cereal availability varies greatly from one country to another with developed countries having more than three times the poorer countries [1]. Inadequate means of production for the world's poorest peasant farmers who cannot meet their food requirements, and insufficient purchasing power of other poor rural and urban non-farmers are probably more crucial to food insecurity than technology. It is thus obvious that biotechnology is not a panacea in solving Africa's food crises.

Productive agriculture is a source of livelihood for most of Africa's people. According to 1998 World Bank figures [2], in 1996 agriculture accounted for 24% of sub-Saharan Africa's GDP and in 1990, 68% of employment. In 1999, for the third consecutive year, overall agricultural production rose by only 2.1%, remaining lower than the population growth rate. Crop production is estimated to have increased by 2.2%, while livestock production expanded by a modest 1.7%. In *per capita* terms, however, agricultural production continues to stagnate, with 2000 production levels being virtually identical to those attained in 1990 [3]. Agricultural development is therefore critical to the improvement in food security in Africa. Increases in incomes from a productive agriculture can raise food purchasing power and reduce pervasive poverty. Agrarian growth is also known to drive industrial development thus providing the rural poor with alternative sources of income as well as reducing pressure on land. Such economic growth will ultimately imply reduced food insecurity.

This paper discusses agricultural biotechnology and its implications for Africa's efforts towards food security. It explains TRIPS (Trade Related Intellectual Property Rights) in the context of biotechnology and examines the current status of biotechnology in Africa. It raises issues related to the controversy surrounding the subject and its challenges in the context of African countries. Some existing collaborative biotechnology research programs in developing countries are highlighted. The paper concludes by highlighting policy issues that African countries need to pay attention to if they are to benefit from the biotechnology.

ROLE OF BIOTECHNOLOGY IN CROP IMPROVEMENT

Biotechnology programs in the field of crop improvement are rapidly emerging in Kenya and Zimbabwe, to address resistance to maize stem borer and drought tolerance. Examples of the use of genetic engineering in Africa include Kenya's virus-resistant transgenic sweet potato project (which is under development with Monsanto Company of the United States), Egypt's transgenic potato, maize, faba bean and tomato developments, and South Africa's new tobacco and cotton varieties with resistance to herbicides. The relevance of genetic modification in producing transgenic crop varieties with resistance to pesticides, insects, and diseases cannot be ignored, given the prohibitive costs to farmers of chemical inputs and yield losses [4].

CONTROVERSY

The controversial issues surrounding the application of genetic engineering technologies to food crops can be

broadly categorized into food safety, environmental and ethical/economic issues. The ethical issues are largely related to cultural background and levels of public perception and awareness. According to the FAO Committee on Agriculture [5], biotechnology has attracted some controversy because some see it as "interfering with the workings of nature and creation" which might involve risk taking for commercial gain. Economic controversies relate to the implications of the commercialization of genetically modified germplasm. Will small-scale farmers or communities be perpetually dependent on the terminator technology products, and hence, reduced agricultural production? Will poor countries become increasingly dependent on developed countries for food? Progressive reduction of trade barriers through organizations such as the WTO are likely to make export of food from developed to developing countries become easier and more commonplace. Biotechnology may make this trade more profitable, thus creating or increasing the food dependency of developing countries on developed countries [6]. Subsidies given to developed country farmers result in even lower prices with farmers in developing countries being forced to absorb costs that are higher than the prices they can get for their commodities locally and internationally. This leads to them producing only for their limited domestic markets or for subsistence use, thus undermining their incomes.

Issues relating to food safety and the environment question whether biotechnology products such as transgenic plants or other genetically modified organisms (GMOs) are safe for consumers and the environment. In general, the controversy has also been characterized as pitting rich against poor, ethicists against pragmatists, and environmentalists against business opportunists. It has also been a battle between the scientifically informed versus the less informed; between those who understand the long ancestral lines of biotechnology, and those who believe that we are leaping blindly across an unknown genetic fault line. The latter maintain that although safety is paramount, biosafety concerns should not be confused with market protectionism [7].

Another emerging aspect of the debate is the impact of the substantial differences in perception of the risks and benefits associated with biotechnology. Neilsen has argued that farmers in North America and a few other countries such as Argentina, Mexico, and China are rapidly adopting genetically modified (GM) varieties, as they become available and attributes consumer acceptance of this development to the lower retail prices [8]. However, in Europe and, to some extent Japan, there is concern about the environmental impact of cultivation of GM crops and the safety of GM foods, separate production systems for GM crops and non-GM crops are emerging such as for maize and soybean. This points to the potential for a viable non-GM market alongside the GM varieties [9].

If African countries are to extensively develop agricultural biotechnology, they could target both GM-resistant and GM-indifferent markets. The GMO-free food market is likely to attract consumers who are willing to pay a premium price much like the situation in the organic food market. In this equation, countries that are net food importers can also benefit from lower world market prices assuming their consumers are not averse to GMOs.

Opportunities exist for African countries to strategically utilize ethical considerations to their benefit. African policymakers and stakeholders need to take up the challenge and have their views incorporated. The debate about biotechnology should not be necessarily whether or not the continent needs biotechnology, but how biotechnology can be promoted, supported and applied in safe and sustainable ways that contribute to improved agriculture and livelihoods. Biotechnology can help fight the widespread poverty, hunger and destitution.

The issue of biosafety remains a contentious one. At the international level, potential environmental hazards from new products of biotechnology have raised concerns that companies may use African and other developing countries as "test sites" for their products. Some of the potential environmental risks concern plant pests, where gene escape from GMOs could result in increased weediness in sexually compatible wild species. The inclusion of novel genes for herbicide resistance in plants may increase the occurrence of weeds with resistance to certain agrochemicals. Another worry about GMOs is the possible inadvertent production of toxins and allergens. This situation places African countries in a precarious position and in need of assistance for designing appropriate legislation and setting up regulatory bodies for all aspects of biosafety. National legislation must reflect national positions and be consistent with international instruments [10].

TRIPS AND AFRICAN AGRICULTURE

Many biotechnology products are under some form of protection in the West. Following a series of negotiations under the World Trade Organization (WTO), an Agreement on Agriculture (AoA) was finally reached in 1994 at the Uruguay Round. The AoA sought to address four broad categories of issues including domestic support to agriculture, increased market access, request for special and preferential treatment such as lower commitment obligations and longer transitional periods to implement WTO Agreements.

Under the WTO agreements, TRIPS require protection of pharmaceuticals and genes, exclusion of living plants and animals for patentability, and breeders' rights. Although TRIPS allow countries some flexibility in the

precise form and the extent of protection, it nevertheless promotes the fundamental idea of extending Intellectual Property Rights to agricultural genetic resources [11]. The Plant Variety Protection (PVP) also referred to as Plant Breeders' Rights (PBRs) allows one to protect new varieties of sexually reproducing plant varieties for a term of 20 years (25 for tree crops). It is considered a *sui generis* system, in other words, a system of rights designed to fit a particular context and need that is a unique alternative to standard IP protection. Its advantages over plant patents include lower cost, simple application and fewer requirements for similar protection. Generally PVP is sought for plant or varieties that have been developed through traditional breeding rather than for transformed plants [12].

Since most biotechnology research is conducted in industrialized countries, very often by private companies, developing countries may have to pay to use a new procedure or product. African countries generally have weak national scientific infrastructure and capacity to innovate and patent new materials and enforce biosafety requirements. Because IPRs are central to the growth of the biotechnology industry, lack of patent protection can limit access to the results of biotechnology originating elsewhere in an environment where the economies lack the capacity to either purchase or participate in developing the technology. An agreement for negotiating for a favorable position and partnering would be preferable.

In some quarters, IPRs are viewed as having had a negative effect on agricultural biotechnology research in developing countries because they interfere with the traditional system whereby potentially useful technologies could simply be transferred from developed to developing countries [13]. Whereas the "green revolution" was made possible by publicly-funded agricultural research, current concerns are that public sector institutes are hindered from playing a leading role in the "biotechnology revolution" because of IPRs. This is illustrated by the common concern that biotechnology companies in developed countries are patenting genetic resources of developing countries to develop new products in food and agriculture. African countries must therefore, explore strategies to alleviate the negative impacts of IPRs on food and agriculture.

The area of Intellectual Property is controversial and complex. Within the parameters of the Convention on Biological Diversity (CBD) and TRIPS, African countries have international commitments that they will have to meet. Access to biotechnology products increasingly requires that countries have IP policies and procedures both nationally and institutionally. In addition to taking into account national interests such as farmers' rights and compensation to indigenous people, these policies have to incorporate ways to promote collaboration and private sector investment while securing the greater public good.

DONOR-FUNDED BIOTECHNOLOGY INITIATIVES

International collaboration is already taking place through donor-funded initiatives. While the application of biotechnology in industrialized countries is dominated by the private sector and large international companies often launch new products, research is still predominantly carried out by the public sector in developing countries. A wide range of international collaborative opportunities is available for agricultural research organizations in developing countries. Such organizations plan or implement research programs in agricultural biotechnology. Since around 1985 onwards, a number of international initiatives that provide an important source of information or assistance in agricultural biotechnology have been established.

According to Komen [14], seven out of twenty-eight or so worldwide initiatives were on-going in Africa as of 1997. Of these, five were crop-oriented, one on livestock and one in both crop and livestock research. The host institutions involved in crop biotechnology programs included the following:

1. Agricultural Biotechnology for Sustainable Productivity, ABSP (Michigan State University, USA),
2. Feathery Mottle Virus Resistant Sweet Potato for African Farmers (Agency for International Development, USA),
3. IIRSDA - Plant Biotechnology Program (Institut international de recherche scientifique pour le dévelopment en Afrique, Côte d'Ivoire),
4. IITA - Biotechnology Research Unit (International Institute for Tropical Agriculture, Nigeria,)
5. Research on the Date Palm and the Arid Land Farming Systems (Estacion Phoenix, Spain).

The Small Ruminant Collaborative Research Support Program - Animal Health Component (Washington State University, USA) - was the only livestock biotechnology program exclusively for Africa, while crop/livestock programs were carried out by ICIPE - Biotechnology Research Unit (International Centre of Insect Physiology and Ecology, Kenya). In addition, several networks were involved in the initiatives:

1. African Biosciences Network - Sub-Network for Biotechnology, ABN-BIOTECHNET (University of Nigeria, Nigeria),
2. DGIS Special Program Biotechnology and Development Cooperation (Ministry of Foreign Affairs, The Netherlands),
3. FAO/AGP Programs on Plant Biotechnology (Food and Agriculture Organization of the United Nations, Italy).

Cereals such as rice, maize and sorghum, are major research crops. Root crops (potato, cassava, yam, sweet potato) and tropical perennials came second. The projects in crop biotechnology tended to be at the advanced end of the research spectrum with around 30% in crop transformation, 29% in molecular markers and 31% in cell biology (micropropagation, regeneration). The crop biotechnology programs are generally aimed at improved tropical food crop production with reduced levels of pesticides, a contrast to "mainstream" research in agricultural biotechnology, which emphasizes temperate crops and mostly aims at developing herbicide-tolerant crops.

Livestock research programs concentrate on the development of new vaccines and diagnostics for tropical livestock diseases such as trypanosomiasis, tick-borne diseases (e.g., *theileriosis* and *cowdriosis*), rinderpest, and foot-and-mouth disease. The major share of the livestock effort relate to cattle, although one program exclusively concentrated on small ruminants (sheep and goats). The main player in livestock biotechnology is the International Livestock Research Institute (ILRI), with research programs for trypanosomiasis and tick-borne diseases. Among the CGIAR centers, ILRI was one of the first to develop biotechnology-based research and it invests heavily in animal biotechnology [15].

In line with their research projects, all crop and animal research initiatives have developed a strong component for human resource development. Training activities are concentrated at the post-doctoral and doctoral levels. In addition to the training opportunities provided through the crop and animal research programs, the UNESCO Biotechnology Action Council is one donor-agency program that considerably promotes human resource development. Most international research programs also provide advice and training on policy and management aspects of agricultural biotechnology. Biosafety and intellectual property rights are priority topics.

Such partnerships as those described above are important for immediate feedback and fine-tuning of technologies. Javier concedes that the shift of agricultural research focus from commodity improvements to resource management and from favorable to unfavorable areas implies greater importance in partnerships with farmers [16]. Farmers possess indigenous knowledge that has remained relatively untapped and can play a crucial role in developing technologies for crop management in the favorable environments, as well as helping match genotypes to specific environmental niches in the unfavorable environments. In addition, closer linkages with advanced basic science institutions are required to provide the knowledge base for strategic and applied research. Collaboration with the private sector that will ensure more equitable access to agricultural technologies are equally important as partnerships with farmers and NGOs. The International Service for the Acquisition of Agri-biotech Applications (ISAAA) is key in this regard as its purpose is to act as an honest broker in the transfer of biotechnologies with application to food systems [17]. It aims at developing institutional mechanisms to facilitate sharing and transfer of agricultural applications in biotechnology from the developed countries, for the benefit of developing countries. African researchers and policy makers will need to tap into such institutions to ensure that their countries reap full benefits from biotechnology research.

Although the specific efforts involving Kenyan researchers have not been many, they are evidence of the benefits of collaboration. Such efforts include the genetically engineered, virus-resistant sweet potato (mentioned elsewhere in this paper), which promises to increase yields in Kenya by up to 60 percent. Another effort has been in developing pathogen-free banana plants with technology that has been developed through collaboration involving the Kenya Agricultural Research Institute (KARI), the Rockefeller Foundation, ISAAA, the South African Institute for Tropical and Sub-Tropical Crops (ITSC), the Canadian International Development Research Centre (IDRC) and two tissue culture companies. The banana plant promises great benefits to small-scale banana producers in Kenya. The Kenyan project participants: Florence Wambugu, Margaret Karembu, Michael Njuguna, and Samuel Wakhusama Wanyangu were recipients of the First Global Development Awards presented in the Tokyo Second Annual Global Development Network Conference in December, 2000. Florence Wambugu and John Wafula have also been involved in research on the Maize Streak Virus Disease. Another Kenyan researcher Fred Kanampiu, has been involved in researching on the destructive parasitic weed Striga at the Mexico-based International Maize and Wheat Improvement Centre (CIMMYT).

BROADENING THE RESEARCH AGENDA

Strong local partners are thus required in collaborating countries to expedite the adaptation of technologies and materials that are developed through collaborative research. Research and training are obviously essential elements for programs aimed at transferring agricultural biotechnology to developing countries. Most international initiatives concentrate on these two elements but a few focus on product development. As African countries develop biotechnology policy, great attention must be paid to national program capacities, biosafety, intellectual property rights and private sector involvement. Presence or absence of a national biosafety system has become a significant factor in international collaboration in biotechnology [18].

Certain mind-boggling issues have to be addressed if African countries can reduce the ever widening biotechnological gap with other countries and enhance competitiveness. What should the optimum amount of investment in biotechnology in any country be and in which area? What role should private investment play in biotechnology? How much should countries be prepared to pay for the burden/costs of conserving and utilizing the principal raw materials for biotechnology? How does biotechnology development impact on rural poverty? What policies, regulations and procedures should be in place to ensure biosafety? In international trade, what conditions govern access to and utilization of biotechnology raw materials/products and how can economically efficient and equitable exchange mechanisms be institutionalized between the owners and the users of the biodiversity? How can legislation on biotechnology be strengthened? How does globalization and liberalization affect biotechnology? What is the minimum amount of resources required to build a critical mass for the biotechnology to flourish? Is there capacity to maintain a degree of self-reliance in analyzing the opportunities and challenges brought about by biotechnology?

CHALLENGES

Africa currently faces a set of stiffer barriers in penetrating meaningfully into the biotechnology industry in comparison to the diffusion of the green revolution. In addition to the weak national scientific infrastructure, many countries face constraints such as budget stringency under structural adjustment and liberalization, accompanied by stagnating investments by the public and private sector research which have increased the biotechnological gap. Lastly, mainly due to uncertainty of the future donor support, international research organizations have hesitated to assist Africa in the area of biotechnology [19].

Many countries are not in a position to catalogue the natural resources of biomaterials under their sovereign possession as well as have adequate legislation in the area of biotechnology. Very few of their biomaterials have been characterized and evaluated, especially for commercial exploitation. Many countries lack the entrepreneurial spirit and capacity to maintain a degree of self-reliance in exploiting opportunities for international trade in biotechnology. There are now about 1,500 biotechnology firms in the US. Britain has 600 biotechnology firms, a quarter of which are publicly quoted in the European Union forums and documents. Other countries with over 100 biotech firms include Brazil, France, Germany, India, Japan, Russia, and most of the Scandinavian countries.

The debate on biotechnology is tainted with mystery and persistent negative literature. The use of biotechnology is debated mainly along ethical lines. There is a rather high official policy resistance to discuss biotechnology ideas. In many African countries, policy and research efforts are considerably donor-driven. There is need for more studies to elaborate the various economic benefits or impacts of biotechnology [20]. Biotechnology has potential for revolutionizing the livestock sector but many governments have not initiated tangible research in either embryo transfer or recombinant DNA for livestock disease/pest vaccines.

Given that the incidence of poverty has increased in many countries, investing in food and particularly cereal and livestock biotechnology is likely to have the maximum impact on the welfare of the poor. One reason why Africa missed the green revolution is because it primarily benefited areas with adequate moisture or irrigation, while large areas of limited rainfall received little or no benefit. GMOs could benefit such areas by increasing yields for drier areas, in addition to creating plants that are resistant to pests or diseases. The latter possibility has been exemplified by a virus resistant sweet potato being developed in Kenya. The significance of this effort is that much of the basic work was done by Monsanto (a private firm) which has made its work available without charge [21]. It is anticipated that the GMO sweet potato will reduce the costs of production by eliminating the use of some chemicals, and would increase yields by 12 to 25% [22]. With widespread adoption, the potential for helping the poorest farmers in developing countries is substantial.

Among the cereals, maize has received the highest attention from private researchers because of its perceived potential for widespread commercialization as hybrid seeds are only used once. Indeed, by 1998, the value of global market in bio-engineered crops stood at US$ 164 billion with maize accounting for 30%. Biotechnology research in cereals addresses several different issues. Some of the research aims to reduce production costs by incorporating characteristics that eliminate the need for pesticides or other external inputs. One famous example is the variety containing genes that code for the toxin produced by *Bacillius thuringienesis* (Bt), an insect bacterial disease, which eliminates the need for spraying against the pests. Other research in cereal biotechnologies targets post-harvest losses attributed to pests and diseases.

Another front is that of enhancing the potential to grow cereals under hostile conditions such as drought and/or salty and toxic soils. Yet another front involves developing yield-enhancing biotechnologies that can enhance the capacity of plants to absorb more photosynthetic energy or convert large portions of that energy into grains rather than stem or leaf, the essence of the green revolution. The possible combinations are

many and it is for the public sector to invest more in biotechnology in order to improve food security.

Regarding the use of biotechnology in medicinal plants, the 'so-called' bio-prospecting for the pharmaceutical industry, is another lucrative area with an annual global turnover estimated at US$ 250,000 million. However, most of the medicinal plants found in Africa have been patented abroad without local knowledge and collaboration. For instance, a Kenyan tree (Pyrunus African tree, locally known as Muiri) is used to make extracts for prostrate cancer treatment and is patented in France. This is a fate suffered by numerous other African medicinal plants extracted. Many African communities have a rich heritage of indigenous knowledge of diagnostic and therapeutic practices relating to medicinal plants that have not been conserved, studied, bio-assessed and incorporated in the medical, veterinary and pharmaceutical industry. It is hoped lucrative commercial value will be realized if such biotechnological resources can be catalogued and protected. As a policy guide, an agreement to jointly award collaborating researchers with the patent should be a pre-condition to participate in any collaborative research [23].

Biotechnology will unquestionably generate employment and profits as well as pose certain threats. Its impacts on economic development are likely to be considerable. In efforts to free themselves from dependence on resources imported from developing countries, many developed countries have invented substitutes for most commodities produced in developing countries. According to a recent study, any substance of plant origin with a market value exceeding $80 per gram can be profitably produced by cell or tissue culture. This applies to many raw pharmaceutical products, aromatic compounds/flavors, condiments/spices, fragrances and sweeteners. The case of enzymatic synthesis of pyrethrins that nearly killed the Kenya pyrethrum industry in the early 70s is a documented consequence of biotechnological innovations. Nonetheless, it is probable that no one will be a net loser in the biotechnology industry, either as a producer or consumer (or both). Reaping the legitimate portion of the global benefits will largely depend on the technical policy options individual countries adopt.

CONCLUSIONS

Biotechnology will perhaps affect even the most isolated villages on the African continent. It may be neither wise nor justified for Africans not to pursue effective participation in this revolution. African nations must fight to gain some of its expected advantages with due recognition of related dangers or risks. Developing policies that encourage investment, education, collaboration, and technology access will promote technology transfer and access to biotechnology products that can improve livelihoods.

Africa's policy makers need to make decisions concerning biotechnology that can adequately respond to and answer the attendant and fundamental biotech and policy questions. Priority setting in agricultural research will be required to take into account the two basics of economic and political objectives. The economic rationale should ensure optimal resource allocation and planning and capacity building for research. The political objectives should include consensus building among the different actors such as governments, researchers, farmers and consumers.

The approaches to be taken must also be considered. For instance, how participatory is the whole process going to be?. Project funding has also to be secured; ideally there should be as much public and private sector funding as possible. While priority setting could help ensure that research projects are more demand-driven rather than donor-driven, there is still a danger of donors having too much power over the whole process since they are the dominant source of funding. There is also the potential danger of the projects stalling or being abandoned altogether should the donors withdraw and funding ceases. Such risks against collaborative efforts need to be evaluated.

Ideally national programs need to ensure that biotechnology benefits all sectors, including resource-poor rural populations, particularly in marginal areas where productivity increases will be more difficult to achieve. This implies the need to set priorities that will help biotechnology expertise complement existing technologies and be output-driven. Since biotechnology research is often more expensive than conventional research, it should be used only to solve specific problems where it has comparative advantage. With reduced funding for research in agriculture, and increasingly privatized research, the consequent danger is that biotechnology could be aimed mainly at resource-rich farmers. In addition to technical considerations, priority setting should take into account national development policies, private sector interests and market possibilities. Different stakeholders should be involved in the formulation of national biotechnology strategies, policies and plans.

REFERENCES

1. **FAO.** Can agricultural biotechnology help to reduce hunger and increase food security in developing countries. In: Electronic Forum on Biotechnology in Food and Agriculture, Nov.-Dec. 2000. [Cited 20 June 2002] **http://www.fao.org/biotech/index.asp?lang=en**

2. **World Bank.** World Development Indicators 1998. IBRD, Washington, D.C. 1998.

3. **FAO**. The State of Food and Agriculture, 2001. [cited 10 May, 2002] **http://www.fao.org/docrep/003/x9800e/x9800e00.htm**

4. **Ndiritu CG** Kenya: Biotechnology in Africa: why the controversy? In: Persley GJ and Lantin MM (Eds) Agricultural Biotechnology and the Poor, an International Conference on Biotechnology, 1999. [cited 10 May 2002]. Portable Document Format. **http://www.cgiar.org/biotech/rep0100/Ndiritu.pdf**

5. **FAO**. Biotechnology in agriculture Report to the FAO Committee on Agriculture (COAG), Rome, January 1999. [cited 10 May 2002]. (Agric. 21 Spotlight). **http://www.fao.org/ag/magazine/9901sp1.htm**

6. **FAO**. Ref. 1.

7. **Ojani W** GMOs What is Kenya's stand? Daily Nation. January 22, 2001. [cited 10 May 2002]. **http://www.nationaudio.com/News/DailyNation/22012001/News/News1.html**

8. **Neilsen CP, Robinson S and K Thierfelder** Genetic engineering and trade: panacea or dilemma for developing countries. World Dev. 2001; 29:1307-1324.

9. **Neilson CP** Ref. 8.

10. **FAO**. Ref. 5.

11. **FAO**. Ref. 5.

12. **Ives CL and F Wambugu** Agricultural biotechnology: current and future trends and implications for Africa. Paper presented at the Agricultural Transformation Workshop, June 1999, Nairobi [cited 10 May 2002]. Portable Document Format. **http://www.aec.msu.edu/agecon/fs2/ag_transformation/atw_wambaugu.pdf**

13. **FAO**. Ref. 1.

14. **Komen J** International initiatives in agri-food biotechnology. Chapter prepared for the volume "Biotechnology Worldwide". 1997. Forthcoming. [cited 10 May 2002]. International Initiatives in Agricultural Biotechnology (ISNAR) Biotechnology Service - Agricultural Biotechnology Initiatives. **http://www.isnar.cgiar.org/ibs/init.htm**

15. **Komen J** Ref. 10.

16. **Javier EQ** Widening circles of research collaboration for greater food security. In: Bonte-Friedheim, Christian and Kathleen Sheridan (eds.). The Globalization of science: the place of agricultural research. New, expanded ed. 1997. [Cited 20 June 2002]. **http://www.isnar.cgiar.org/publications/books/Globalization.htm**

17. **Javier EQ** Ref. 16.

18. **Komen J** Ref. 10.

19. **Omiti J** Why Kenya Must Adopt Biotechnological Science, A Guest Column commentary, Financial Standard (Page FS 10), E. A. Standard, 19th March 2002.

20. **Omiti J, Kamau M and M Waithaka** Constraints in Institutionalizing Impact Assessment in Kenya, Occasional Paper No. 8/2001, Institute of Policy Analysis and Research (IPAR). Downtown Printing Works, Nairobi, 2001.

21. **Quaim MA** A prospective evaluation of biotechnology in semi-subsistence agriculture. Agric. Econ. 2001; 25:165-176.

22. **Johnson D** Biotechnology issues for developing economies. EJB Elec. J. Biotech. [online]. April 2002; 15, [Cited 10 May 2002]. **http://www.ejb.org/content/vol5/issue1/issues/01/index.html#3**

23. **Omiti J** Ref. 14.