The Biotechnology Revolution and its Implication for Food Security in Africa

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Acronyms

ACTS	African Center for Technology Studies
ATPS	African Technology Policy Studies Network
AU	African Union
CBD	Convention on Biological Diversity
CIMMYT	International Wheat and Maize Improvement Centre
CNA	Cisco Networking Academy
COMESA	Common Market for East and Southern Africa
EAC	East African Community
ECOWAS	Economic Community of West African States
EU	European Union
FAO	Food and Agriculture Organisation
FAPESP	San Paulo State Research Support Foundation
GDP	Gross Domestic Product
GMOs	Genetically Modified Organisms
IITA	International Institute of Tropical Agriculture
IT	Information Technology
ITU	International Telecommunication Union
KARI	Kenya Agricultural Research Institute
LDC	Least Developed Countries
M T	Metric Tonnes
NEPAD	New Partnership for Africa's Development
ONSA	Organization for Nucleotide Sequencing and Analysis
R&D	Research and Development
SADC	South African Development Communities
SSA	Sub-Saharan Africa
TIGR	The Institute of Genomic Research
TRIPS	Trade Related Aspects of Intellectual Property Rights
UNDP	United Nations Development Programme
UNV	United Nations Volunteer Programme
USAID	United States Agency for International Development
WTO	World Trade Organization

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Abstract

Agricultural biotechnology presents many opportunities and challenges to Africa. Biotechnology promises to help meet food security needs, reverse declining per capita food production and improve the incomes and lives of farmers in Africa. However, the limited international markets for agricultural products, especially GMOs, the complex regulatory regimes, the weak scientific base, lack of biotechnology development strategies and investment, and poor science and technology diplomacy skills, among others, are threatening to limit the impact of biotechnology.

This paper addresses a number of these issues from an African perspective and seeks to bring out alternative models that Africa could adopt to realize the maximum benefits. It draws lessons for other countries, sectors and past agricultural initiatives to illustrate ways of meeting the different challenges under the current public debate on safety and developing regulatory regimes.

Introduction

Agricultural biotechnology presents many opportunities and challenges for Africa. Biotechnology promises to help meet food security needs, reverse declining per capita food production and improve the incomes and livelihoods of farmers in Africa. The international community through Agenda 21 acknowledged the potential of biotechnology to change lives. Chapter 16.1 states "biotechnology ...promises to make a significant contribution in enabling the development of, for example, better health care, enhanced food security through sustainable agricultural practices, improved supplies of potable water, more efficient industrial development processes for transforming raw materials, support for sustainable methods of afforestation and reforestation, and detoxification of hazardous wastes. Biotechnology also offers new opportunities for global partnerships". Since then, biotechnology has grown into a global industry affecting many aspects of life.

Globally, the biotechnology industry was estimated to have generated US$34.8 billion in revenues and employed about 190,000 persons in publicly traded firms worldwide in 2001. An estimated 4,200 public and private biotechnology firms were in operation. These are impressive results given that in 1992, the biotechnology industry was estimated to have generated only US$8.1 billion [[1]].

Biological catalysts or enzymes have penetrated almost every industry and have an estimated global market of about US$2 billion. These products are already used in many industries, such as food processing, leather and textiles, personal care, pharmaceuticals, mining and cleaning. The demand for other biotechnology-related products, such as feed additives, has continued to grow with vitamins and amino acids accounting for about US$3 billion and digestive enhancers for US$1.3 billion [[2]]. Currently, there are about 600 different products and more than 75 types of enzymes that are used in industries.

It is estimated that the number of biotechnology derived drugs and vaccines for human health increased from about 23 in 1990 to over 130 by 2001. An additional 350 biotechnology-derived drugs and vaccines were in clinical trials targeting over 200 diseases. The number of genomes of organisms related to human health sequenced completely has continued to grow. In 2002, the sequencing of the genomes of the human, mosquito and that of the malaria-causing organism,

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[1] Ernst & Young (2002) Beyond Borders: Global Biotechnology Report 2002

[2] UNCTAD, 2002 The New Bioeconomy; Industrial and Environmental biotechnology in developing countries, UNCTAD/DITC/TED/12

Plasmodia falciparum, were completed. These activities are expected to increase the number and pace of drug and vaccine discoveries.

Biotechnology has also been used to reclaim wasteland through the use of micro-organisms and plants that remove and/or degrade toxic compounds. Some firms have incorporated biotechnology techniques in their production to decrease energy and water consumption, improve productivity and reduce the number of processing steps [3]. Many of these applications have led to an improved environment, sustainable use of resources and increased productivity.

1.1 Plant biotechnology

A number of genetically modified plants or organisms (GMOs) have been commercialized. Over the past 6 years, the acreage of transgenic crops has grown by about 10% annually and the number of countries growing transgenic crops has increased from 6 to 16. The acreage grown with transgenic crops has also increased from 1.7 million hectares in 1996 to 58.7 million. This is a substantial growth in the adoption of the technology by farmer.

Many of the crops grown widely have agronomic traits. Of the total acreage under transgenic crops, 75% was planted with herbicide tolerant crops and 17% with pest protected crops (*Bt [bacillus thurengiensis]*-based). In terms of crops, 62% was planted with soybean, 21% with maize and 12% with cotton in 2002[4]. In Africa, South Africa planted *Bt*-yellow maize for feed on 175,000 hectares and Bt-white maize for food on 58,000 hectares.

In terms of environmental and economic impact, the adoption of transgenic plants has increased profits and reduced pesticide use. It is estimated that Bt-cotton alone in the US has led to 860,000 kg reduction in pesticide use and increased the net income of farmers by at least $100 million while Bt-maize has led to a 1.6 million Metric tones (MT) in additional production [5]. In Spain, where European corn borer infestations are high, profitability of *Bt*-maize is at least 13% higher than that of non-Bt maize. These are substantial savings that are promoting the uptake of the technology.

1.2 Animal biotechnology and livestock production

Biotechnology research and development activities in animals have focused primarily in four main areas. These include improvement of animal health, enhancement of animal products, development of human health products using animals (as bioreactors) and conservation of animal species. Biotechnology techniques, such as animal cloning, are enabling researchers to genetically modify animals to produce drugs and vaccines in their milk, enhance animal product quality (e.g. tender

[3] OECD (2001) The Application of Biotechnology to Industrial Sustainability; Organization for Economic Co-operation and Development.

[4] C. James (2002) Global Status of Commercialized Transgenic Crops: 2002, ISAAA Briefs, 27.

[5] L.P. Gianessi, C.S. Silvers, S. Sankula and J.E. Carpenter (2002) Plant Biotechnology: Current and Potential Impact for Improving Pest Management in US Agriculture: An Analysis Of 40 Case Studies, National Center For Food And Agricultural Policy

meat), increase resistance to disease and improve the efficiency of feed conversion [6]. They aim at improving the management of livestock through prevention, quick diagnosis and effective treatment of diseases and generating industrially useful products in animals.

Other biotechnology activities address the use of animal products, such as blood, heart, kidneys and liver, for treating human diseases (xenotransplantation) and the producing molecules for therapeutic and industrial use in animals (e.g. therapeutic proteins). Biotechnology applications are promising to help the conservation of endangered species.

Roughly 2,494 different biotechnology derived products were available in 2001 for use against 197 different animal diseases [7]. Currently, the market of animal-based products and services is estimated at about $2.8 billion. Further, transgenic fish and animals have been developed mainly in developed countries and some developing countries. Currently, no transgenic animals have been approved for human consumption yet.

1.3 Industrial biotechnology for agricultural development

Industrial biotechnology encompasses two broad areas namely, those aimed at replacing fossil fuel with biomass and those replacing conventional chemical processes with biological systems, such as whole cells or enzymes. Industrial biotechnology has a direct contribution to agriculture and to the quality of life of farmers through the provision of alternative farm inputs, energy and processing reagents, such as biofertilizers and biopesticides.

Biopesticides and biofertilizers are naturally occurring organisms that have been employed to improve the management and productivity on the farm, among other applications. However, most biopesticides have a narrow target specificity which limits their use. Of the global $8 billion pesticide market, biopesticides market is roughly $380 million, of which $306 million is from Bt (*Bacillus thuringiensis*) alone [8].

The use of biofertilizers is well established and has been employed, mainly in farming, in a number of countries in Africa including Kenya, Tanzania, Zambia and Zimbabwe [9]. They are easily produced locally and the technology is not complex. In some countries, the demand outstripped production of the pilot plants. India is one country where biofertilizers have been produced by a number of commercial firms targeting food and ornament plants.

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[6] Fumento, M. (2003). *BioEvolution: How Biotechnology is changing our World.* San Francisco, California, USA: Encounter Books.

[7] See the Biotechnology Organization for details (www.bio.org)

[8] C. Juma, and V. Konde. (2002). The New Bioeconomy: Industrial and Environmental Biotechnology in Developing Countries, ***UNCTAD/DITC/TED/12***.

[9] C. Juma and V. Konde (2002) Industrial applications for Biotechnology; Opportunities for developing countries ***Environment***, 44, 23-35.

The use of biopesticides in the control of pests is also well established. Sterile tsetse fly (the vector of sleeping sickness), for example, was used to control and eliminate the tsetse fly population on the Island of Zanzibar. Similarly, the cassava mealybug, *Phenacoccus manihoti*, was effectively controlled using a wasp, *Apoanagyrus lopezi*, from Latin America and this work was awarded the World Food Prize. However, batch potency variations, short life span and narrow effective target organisms limit the use of many biopesticides and biofertilizers.

2. Food Production and Security in Africa

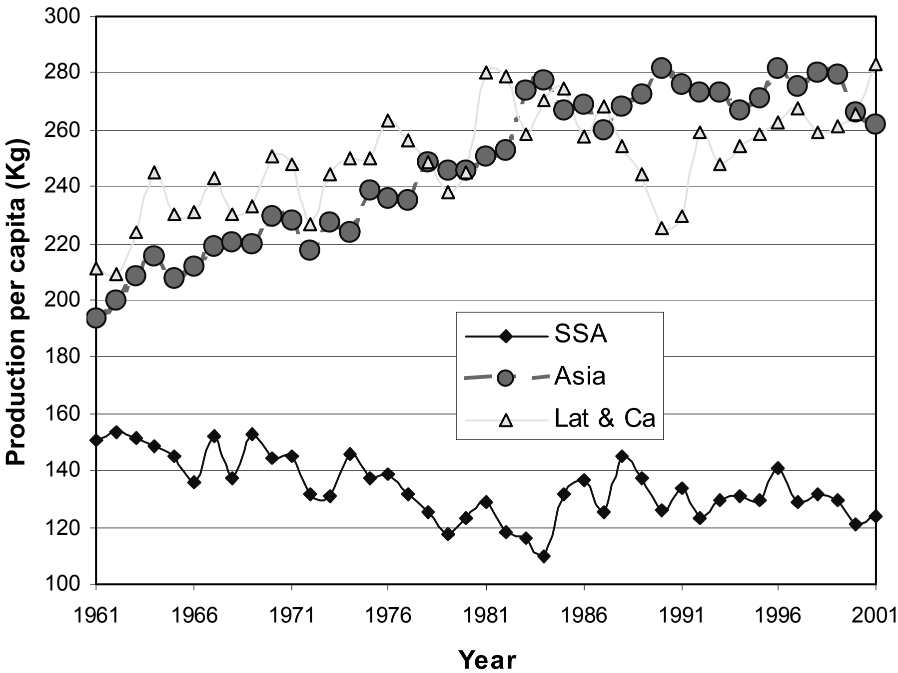
At present, 24% of the global 799 million hungry or malnourished people live in Africa; more than 30% of the African population is malnourished. The World Food Summit [[10]] noted that "hunger is both a cause and an effect of extreme poverty [that] prevents the poor from taking advantage of development opportunities". This is of great importance given that more that 52% of the population in Africa depends on agriculture for their livelihood. Further, agriculture contributes 40-60% of gross domestic product (GDP). Improving the performance of agriculture in Africa may take many people out of extreme poverty.

The methods of food production in sub-Saharan Africa (SSA) are basic and labour-intensive. SSA (excluding South Africa), for example, with 78% of Africa's arable land consumes only 1.2 million MT of fertilizer (less than Egypt's 1.3 million MT). Low fertilizer usage may account for the fast depletion of nutrients on farms that may explain reduced land productivity. Similarly, SSA uses 161,276 tractors in agriculture, about a third of Africa's share on roughly 80% of Africa's arable land.

Therefore, it is not surprising that the per capita food production in Africa has been declining since 1961 while it has increased in other developing regions of the world. Cereal production has increased from about 200kg per capita to 280kg in Asia and Latin America and the Caribbean but it has declined in Africa from about 150kg to 130kg in the last 40 years (see figure 1). During the same period, meat production per capita has dropped from around 13kg to about 11 kg and fish per capita production, though initially grew from 4kg to peak at 9kg by 1972, it has since fallen to 7kg by 2001, according to FAO Statistics (http://apps.fao.org/).

[10] See FAO, Committee on World Food Security; World Food Summit and Millennium Development Goals, CFS:2001/2-Sup.1

Figure 1. Per Capita Cereal Production



Source: http://apps.fao.org/ (The FAO STAT)

This reduced food production per capita is due to poor yields rather than the size of farms. If the yield of maize and rice, for example, reached the levels attained in Asia, SSA will triple its current production level on the same land area. Similarly, if it attained the level of yield in Europe, maize production will go up by at least eight-fold (see figure 2 for comparisons). By increasing yields alone, SSA could almost attain near food security and possible surplus for sale.

Farm animals (Livestock) are thought to account for 20-60% of household income and up to 80% of agricultural gross domestic product (GDP) [[11]]. Increasing livestock production especially in the face of increasing demand for animal products could help reduce poverty. The productivity of some traditional livestock breeds in SSA is lower than that of exotic breeds. The best African cattle breeds, for example, mature in 4-5 years but weigh no more than 300kg while exotic cattle breeds attain 400 kg in one year. African cattle breeds produce 300 litres of milk per lactation while exotic breeds produce more than 5000 litres.

The competitiveness of the African subsistence farmer is eroded by reduced yields even if the labour was priceless. On the other hand, the demand for meat, milk and eggs are on the rise in SSA and is expected to exceed production. Developing countries are net importers of meat and milk mainly due to low productivity in the face of increasing population [12]. Therefore, finding ways of improving the management of livestock may be useful given that the African market demand for animal products is expected to increase.

2.1 Some of the constraints to agricultural productivity in Africa

Many constraints have kept agricultural productivity very low in Africa besides socio-economic factors, such as, land ownership, civil strife, poor infrastructure and underdeveloped market regimes. There are many insects, fungal, viral and bacterial pests that inflict huge losses each year, some of which are found only in Africa, reducing total production by up to 30% [13]. The cassava mosaic virus, for example, is thought to have cost Uganda $60 million annually and cassava insect pests are estimated to cause 20-80% production losses annually in SSA.

Weeding is a highly demanding, backbreaking and expensive activity of African manual-labour intensive agricultural system. Fields have to be cleared of weeds, sometimes, two to three times in a 4-month planting season. Weeds compete with crops for limited nutrients, moisture, space and sunlight, and strangle plant development. The parasitic weed, *Striga*, attacks fields of maize, millet, sorghum and beans, among others, and is found on 40% of Africa's arable land. The weed is estimated to cause annual losses of about $7-10 million [14].

In the past decade, droughts have increased in frequency and intensity in Africa. The 2001/2002 drought reduced cereal production in Southern Africa by up to 30% in Malawi, Zambia and Zimbabwe. Of the cereal crops, maize was the worst affected followed by millet and sorghum in the three countries. In addition to food crops and livestock, drought also affects underground water, reduces vegetation cover, encourages soil erosion and disturbs living organisms supported by the land. Thus they reduce the soil quality and the land's ability to support food production in future. Floods may have a similar effect.

Diseases, such as trypanosomiasis, east coast fever, foot and mouth, swine fever, heartwater and new castle, among others, and poor feeds or pastures, have affected livestock production.

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[11] ILRI (2002) Research at the Crossroads of Livestock and Poverty, ILRI, Nairobi, Kenya

[12] Y. Menesha, S. Ehui, M. Jabbar and B. Shapiro (1998) Livestock Production, Consumption and Trade: Key Indicators, Livestock Policy Analysis Brief 11, ILRI.

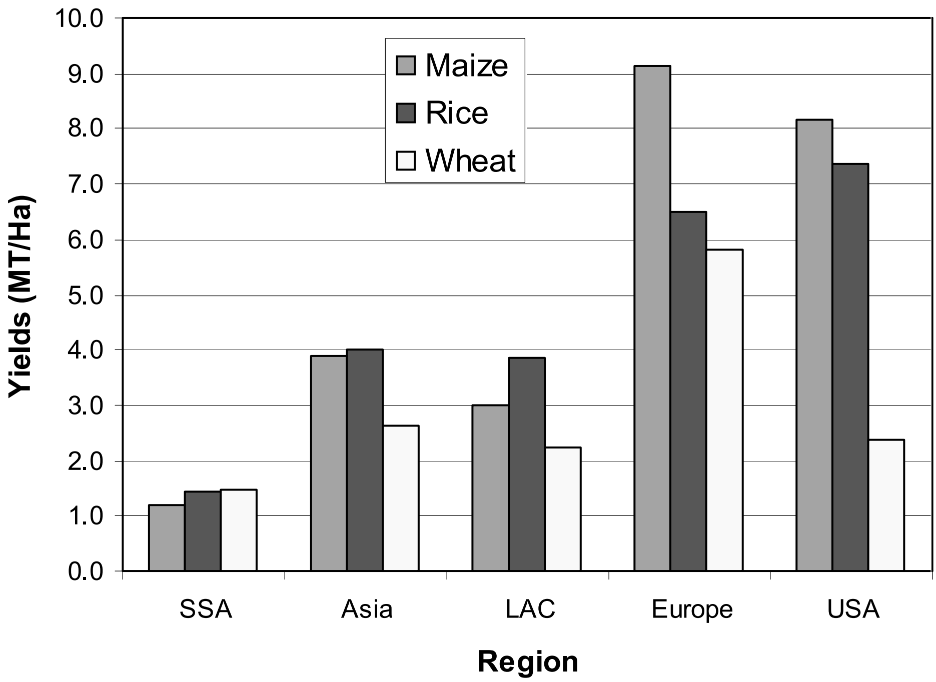
[13] J. Lenne (2000) Pests and Poverty: The Continuing Need for Crop Protection Research, Outlook On Agriculture 29, 235-350.

[14] Z.R. Khan, W.A. Overholt and A. Hassana Utilization of Agricultural Biodiversity For Management Of Cereal Stemborers And Striga Weed In Maize-Based Cropping Systems in Africa- Case Study (ICIPE) see http://www.biodiv.org/doc/case-studies/cs-agr-cereal-stemborers.pdf

Trypanosomiasis alone is estimated to cost the continent about $4.5 billion a year in meat, milk and traction power. Productivity is also limited by poor quality of feed and lack of good veterinary services.

If these constraints could be overcome, productivity on the available land area would increase and so the availability of food. These constraints require concerted efforts from many fronts but bearing in mind the current economic and social needs of different societies and nations. Technology is one of those areas that need to be employed meaningfully not to disrupt further production system but rather empower current practices to achieve higher levels of efficiency.

Figure 2. Comparison of some cereal yields



Source: FAOSTAT (2002)

2.2 Potential impact of biotechnology in Africa

The potential benefit of biotechnology to farmers and corporations is now well acknowledged. The simple fact that the adoption rate of many biotechnology crops has continued to grow very fast is testimony to the benefits farmers are deriving from GM-crops. The fact that farmers in Brazil have been reported to plant GM-soybean seeds smuggled across the border with Argentina also indicates that farmers are realizing the benefits of genetically modified organisms (GMOs.) It makes little business sense for farmers to grow seeds that increase production costs and diminish profit margins.

Africa's past experience in adoption of improved crops varieties is impressive. It was estimated by 1990 that about 42% of the maize acreage was planted with improved varieties of maize (17% open pollinated and 25% hybrids) in SSA, which is comparable to that achieved in Asia and Latin America [[15]]. It is also estimated that about 1% of the 3% annual growth in productivity experienced in SSA was due to adoption of improved varieties [[16]]. Most of the improved varieties were released by national breeders but were primarily based on varieties developed by the International Wheat and Maize improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA).

Therefore, it is reasonable to be optimistic that farmers could benefit from biotechnology especially if there is government support agriculture, markets for the products and goodwill of corporations to relax intellectual property rights for humanitarian products. In addition, the benefits will be higher if the traits target constraints faced by farmers in Africa. The ability of local breeders to adapt and generate GM-plants that suit growing local conditions and animal management practices may determine the impact of biotechnology.

The potential of biotechnology applications in Africa has to be tempered with realism. The support policies and infrastructure that exist in many of the markets where GM-crops have been used do not exist in most of SSA. Some argue that even if initial gains in yield and productivity are made, the poorly developed domestic market systems and the lack of external linkages could easily lead to catastrophic price falls that will make commercial grain production unproductive.

The production of maize in Zambia and Ethiopia by commercial farmers, for example, declined as prices fell during the government driven "green revolution" programs that backed hybrid varieties and inorganic fertilizers. In Zambia, maize yields for small-scale farmers are lower than that for commercial farmers. In 2002, the maize yields for commercial farmers was estimated to be about 3 MT per hectare compared to 1.1 MT per hectare for small-scale farmers [[17]]. Similarly, urban areas had achieved higher yields than rural areas. Different land management and location may not

[15] A. Byerlee and D. Heisey (1996) Past and Potential Impacts of Maize Research in Sub-Saharan Africa: A Critical Assessment. *Food Policy*, ***21**: 2555-77*

[16] M. Maredia, D. Byerlee and P. Pee (1999) Impacts of Food Crop Improvement Research in Africa, *SPAAR occasional paper series*, No. 1.

[17] http://www.reliefweb.int/library/documents/2003/fews-zam-27jun.pdf

necessarily be a major factor, but the presence of functional marketing and distribution channels for inputs may account for some of this difference.

This is why the expectations of biotechnology to improve the incomes and availability of food in rural communities have to be modest, cautious and realistic. Poor farmers would benefit most if the seeds and the supportive inputs could reach them. Herbicide tolerant crops, for example, are only useful if the herbicides for controlling weeds are available and affordable. It is unclear whether farmers who cannot afford fertilizers can afford herbicides. However, if the plant is empowered to fight weeds and pests, then the benefits will only be limited by access to GM-seeds and functional markets that will enable farmers realize their investment.

Other biotechnology techniques utilised in processing of feed, food and agricultural remains may be important in ensuring food security and improving the lives of rural communities. It is now possible, for example, to produce bioethanol from agricultural remains cost-effectively due to advances in enzyme engineering. Production of biofuel from sugarcane and other crops could provide a market for agricultural produce while reducing the import bill for fossil fuel and generation of green house gasses. Similarly, biogas could be generated from livestock refuse to power rural homes and the waste could be used as manure. Enzymes and microbes could also be use to process leather and milk products that could help diversify rural economies and provide employment for the youth. Therefore, the impact of biotechnology should be viewed in the broadest terms possible if Africa has to become food-secure.

3. Governance of Biotechnology

3.1 Legal and regulatory regimes

International and national policies influencing biotechnology are still in the early stages of development. This is partly because biotechnology is developing as an outgrowth of other industries (e.g. agriculture and pharmaceuticals) that are already regulated. However, the unique nature of some biotechnology applications and processes has led to the development of new regulatory regimes that either focus on the product or the process and the product. These fall broadly into intellectual property rights and biosafety regulations.

Of interest is the extension of intellectual property rights to cover living forms. This is particularly significant, given the fact that historically, living organisms fell outside the scope of protection of most intellectual property systems. Industry has argued that the absence of intellectual property protection for living organisms undermined innovations and funding prospects for biotechnology research [[18]].

The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) of the World Trade Organization has been the main instrument for the protection of biotechnology innovations. The TRIPS agreement recognizes that "patents shall be available for any inventions, whether products or processes, in all fields of technology, provided that they are new, involve an inventive step and are capable of industrial application." To encourage innovation around patents the TRIPS agreement encourages full disclosure. It requires an "applicant for a patent to disclose the invention in a manner sufficiently clear and complete for the invention to be carried out by persons skilled in the art [using] the applicant's [recommended] best method".

On the broader aspects, critics have argued that such property rights are inconsistent with morality and are too wide [[19]]. The extension of intellectual property rights to cover living organisms is seen in some sections of society as being against the public interest [[20]]. In response to these claims,

[18] Watal, J. (2000) "Intellectual Property And Biotechnology: Trade Interests of Developing Countries", *International Journal of Biotechnology*, Vol. 2, No. 1/2/3, pp. 44-55

[19] Drahos, P. (1999) "Biotechnology Patents, Markets And Morality", *European Intellectual Property Review*, Vol. 21, No. 9, pp. 441-449

[20] Barton, J. (2000) "Rational Limits On Genomic Patents", *Nature Biotechnology*, Vol. 18, No. 8, p. 805.

patent offices around the world continue to review the scope of patentability to seek a balance between the demand for protecting inventions and the pressure to safeguard public interest.

Another major area of policy development is the emergence of new rules that seek to govern biological inventions on the basis of their presumed risks to human health and the environment [[21]]. These policy measures come under the general umbrella of "biosafety" and are the subject matter of the Cartagena Protocol on Biosafety to the Convention on Biological Diversity. Although the Cartagena Protocol has not yet come into force, it provides a set of policy guidelines that will have implications for the development of biotechnology [[22]]. One of the most significant features of the protocol is the promulgation of the precautionary principle as a tool for risk management in the face of uncertainty [[23]]. This is a contested field, because of the potential for the principle to be used as an instrument for market protection [[24]]. The critical policy issue here is how to establish an international standard for balancing between safety and international trade.

The Convention on Biological Diversity (CBD), for example, has devoted the last five years to developing rules for the safe use and handling of biotechnology. However, over that period, little was done to explore areas that could benefit from the new safety rules. The convention's provisions that call upon countries to cooperate in the field of biotechnology still remain dormant. The Convention is seen by some as a tool for safe use rather than for building sufficient capacity for countries to decide the levels of safety they need.

3.2 Agricultural market access and GMOs

African agricultural products already face many hurdles on the international market. These include high tariffs and standards (sanitary and phytosanitary requirements). Agricultural exports to developed countries suffer most from tariff peaks and tariff escalation [[25]]. The EU and Japan have the highest number of tariff peak products for agricultural imports. Exports of finished textile and clothing products to Canada attract higher tariff levels than raw materials for the same industry. Other products that suffer from incremental applied tariffs by stage of production include leather, rubber, metal, wood and paper. These products represent about 15% of the exports of least developed countries to the developed countries. Taken together, tariff peaks and tariff escalations hinder the efforts by developing countries to export finished products, thereby reducing diversification and skills accumulation.

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[21] Wolfenbarger, L. and P. Phifer. (2000). "The Ecological Risks and Benefits of Genetically Engineered Plants", *Science* , Vol. 290, pp. 2088-2093.

[22] Gupta, A. (2000) "Governing trade in genetically modified organisms: the Cartagena Protocol on Biosafety", *Environment* , Vol. 42, No. 4, pp. 22-33

[23] Soule, E. (2000) "Assessing the precautionary principle", *Public Affairs Quarterly*, Vol. 14, No. 4, pp. 309-328.

[24] Hagen, P.E. and Weiner, J.B. (2000) "The Cartagena Protocol on Biosafety: New Rules for International Trade in Living Modified Organisms", *Georgetown International Law Journal*, Vol. 12, pp. 696-717

[25] Peak tariffs are tariffs of 15% or higher, or three times the tariff in developed countries. Tariff escalation refers to increasing tariff with level of downstream processing.

This is compounded further by high levels of subsidies to agriculture and export products in developed countries [[26]]. Subsidies undermine the comparative advantage of poor farmers by supplying cheap products on the local and international market. In the absence of 'fair' market regulations, it is not surprising that Africa does not invest heavily in export industries linked to the processing of raw materials.

GMOs may help Africa achieve higher productivity and improve agricultural competitiveness. However, Africa faces many challenges in adopting GMOs. Countries that will produce GMOs will be seeking to find markets for their products while those that will not produce GMOs would like to keep their current market share for conventional crops and animals. Countries that import food may wish to retain the right to accept or reject GMOs based on the flexibility of biosafety regulations. These conflicting positions may affect trade and the flow of aid. Complex transportation arrangements, for example, may be required to move GMOs across other countries that may wish to be GMO-free. Similarly, the complex labelling and traceability regimes for GMOs may affect conventional varieties.

3.3 Strategic alliances in biotechnology

Strategic alliances are a product of complex linkages among a wide range of enterprises designed to reduce the risks associated with the development of new products and facilitate information exchange. Strategic alliances between industries and research institutions can help overcome funding difficulties through licensing and other arrangements. Such arrangements are particularly important in areas with limited access to other forms of financing, such as venture capital. Even where venture capital is available, these arrangements still have an important risk-reducing function. Partnership arrangements could also play a key role in the development of technological capabilities in the firms and institutions in developing countries. Such capacity would be related to specific products and services. Partnering would also be useful in promoting the adoption of good management and industrial production standards in developing countries.

Different shades of public-private partnerships have become common in biotechnology. University-industry-government relations, for example, [[27]] have existed for a long time but their nature has changed. There is a movement from 'linkage of independent institutions' to 'integration of various players' (creating what is termed 'porous society'). The location of research and development (R&D) activities of private firms in universities, the founding/ownership of private companies by public institutions and the training of students in industries may point towards the establishment of a more porous knowledge society.

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[26] The OECD support to agriculture is estimated at $1 billion per day (see Inge Kaul, Katell Le Goulven and Mirjam Schnupf, Financing Global Public Goods: Policy Experience and Future Challenges [via www.undp.org] and van Beers, Cees, and André de Moor (2001) *Public Subsidies and Policy Failures: How Subsidies Distort the Natural Environment, Equity and Trade, and How to Reform Them*. Cheltenham, U.K.: Edward Elgar Publishing.

[27] Leydesdorff, L and Etzkowitz, H (2001). Transformation of University-Industry-Government Relations. *Electronic J. Sociology, Vol 5.*

However, these alliances may lock out public research institutions that may not be part to these arrangements. The complex agreements and web of networking may curtail transfer of technology to public research institutions that have been the mainstay of African agricultural development. The ability of African countries and institutions to actively seek alliances that compensate their weaknesses, exploit the strengths of others, uses global resources effectively and generate solutions to empower their economies is limited.

One example of partnership in information technology (IT) is the agreement between Cisco Systems and the United Nations Development Programme (UNDP) to provide Internet education in the Asia Pacific region in 1999 [[28]]. By 2002, the non-profit organization had trained 150 students and had another 500 on training in 18 Cisco Networking Academies (CAN). In 2000, the programme expanded the CNA to include the Least Developed Countries (LDCs). The programme benefits from the United Nations Volunteer (UNV) Programme and the support of United States Agency for International Development (USAID) through the Leyland Initiative. The joining of the International Telecommunication Union (ITU) in 2002 to the Cisco Programme has provided further support as well as recognition of its achievement.

This programme provides a basis for partnerships that involve local partners, private firms, donor agencies and international organizations to deliver quality service. There is no reason why a similar biotechnology strategy in Africa should not take this shape and achieve similar impact. Organisations such as NEPAD, ACTS, ATPS and regional bodies, such as the East African Community (EAC), the Economic Community of West African States (ECOWAS), Southern African Development Community (SADC), Common Market for Eastern and Southern Africa (COMESA) and African Union (AU) could be used in such an initiative to bring agricultural business, research institutions and policy makers to focus on specific problems.

[28] For further Information see www.cisco.com, http://www.itu.int/wsis/ and www.undp.org

4. Making Biotechnology Work for Africa

4.1 Capacity-building in biotechnology; Lessons from other countries

Biotechnology is a knowledge intensive industry that has developed around areas with a critical mass of skilled individuals. In the US, the early biotechnology clusters developed in locations with good research universities [[29]]. Similarly, India's biotechnology industry is also associated with established research institutions and universities. However, different strategies have been employed to fit unique technical, political and economic circumstances. This section highlights three different approaches.

4.1.1 Biotechnology development in the Republic of Korea

The biotechnology development strategy of the Republic of Korea, as contained in the Korea Biotech 2000 plan, is composed of three main phases. The first phase (1994-1997) aimed at acquiring and adapting bioprocessing and improving performance of research and development investments. The second phase (1998-2002) focused on consolidation of the scientific foundation for development of novel products [[30]]. The last phase (2003-2007) will target biotechnology market expansion locally and internationally.

To meet these goals, the Republic of Korea has since 1982 encouraged universities to open biotechnology-related departments and research institutions. The country has also established strategic partnerships with centres in China and the United Kingdom for research. The Government is estimated to have invested US$500 million while the private sector invested an additional US$ 1 billion in the first four years. It also set aside funds to help establish 600 biotechnology-related ventures [[31]] by the end of 2003 and train an additional 13,000 nanotechnologists by 2010.

The Republic of Korea has developed a complete biotechnology industry strategy addressing all the core aspects, such as human resource, research facilities, financial needs, marketing and management capabilities. It involves the public and private sector partnerships and helps its local institutions access international centres to stay abreast with new developments. The biotechnology sector has imported most of the enabling technologies such as fermentation, vaccine and drug production know-how.

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[29] Chapter 4. Biotechnology in the US (see http://www.dti.gov.uk/biotechclusters/chapt04.pdf)

[30] The Korean Herald (12th February, 2001) Ministry announces a major initiative to boost biosciences and nanotechnology.

[31] San Diego Business Journal (4th March, 2002) South Korea Eye Local Bio-investment.

4.1.2 Cuban biotechnology strategy

Since 1980, biotechnology has expanded from a single laboratory to over 190 research units [[32]]. Cuba developed a manpower base in medical sciences through training programmes at home and in countries such as France, Mexico, Japan, Switzerland and the United States. This manpower formed the backbone for the biotechnology industry. Most of the equipment was also imported from abroad.

Cuba's research and development expenditure as percentage of GDP was estimated at 1.2 per cent and the country is thought to have invested about $1 billion over the last 20 years. In return, Cuba's biotechnology centres have produced at least 160 medical products, 50 enzymes and probes for diseases among others [[33]]. By 1998, the biotechnology sector was making up to $290 million in sales and placed the sector as the fourth largest foreign exchange earner after tourism, tobacco and nickel exports.

The Cuban biotechnology industry is a closed network or cluster of supportive institutions. It comprises R&D, exports and imports, manufacturing, information and communication, maintenance, advisory and policy, and regulatory institutions. This structure promotes recombination of knowledge and is cost-effective. Although the Cuban biotechnology is government-managed and driven, it has all the characteristics of a mature privately managed business unit.

4.1.3 Development of the Organization for Nucleotide Sequencing and Analysis, Brazil

Genome sequencing is a highly specialized biotechnology field that has been largely executed by large organizations, such as The Institute of Genomic Research (TIGR) and the Sanger Center among others. However, the Organization for Nucleotide Sequencing and Analysis (ONSA) in Brazil captured the headlines when they announced that they had successfully completed the sequencing of *Xylella fastidiosa,* an organism that infects oranges and causes Citrus Variegated Chlorosis, two months ahead of time and $2 million within budget. The organism causes losses of approximately US$100 million to the citrus industry in Sao Paulo.

With $11.6 million dollars from the São Paulo State Research Support Foundation (FAPESP), ONSA established two central sequencing laboratories, a bioinformatics unit and equiped all the 34 selected sequencing laboratories [[34]]. The central sequencing laboratories prepared the samples and served as training centres. FAPESP decided to fund the genome project to expose as many laboratories to the modern tools of biotechnology. Plans to create a single centre were rejected.

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[32] C&EN Washington (1999, 11th January) Cuba at a Crossroads, News Focus CENEAR 77,2, 8-13.

[33] Elderhorst, M. (1994) Will Cuba's Biotechnology Capacity Survive the Socio-Economic Crisis? Biotechnology and Development Monitor, 20, 11-13/22.

[34] See Http://aeg.lbi.ic.unicamp.br/xf/project/organisation.html.

They settled for a virtual institute that networked about 34 laboratories located in geographically distant places and involving about 200 participants managed via the Internet.

By 2001, ONSA and its partners have contributed three genomes to the public genetic databases; *Xanthomonas axonpodis*, *Xanthomonas campestris* and *Xylella fastidiosa*, founded three companies and trained 200 young geneticists (by design the project encouraged young participants). In addition, ONSA became one of the main contributors to the human genome project by submitting about 10,000 ESTs from its human cancer genome project.

Virtual research centres are faster to build, easy to abandon, rearrange and recreate to meet new challenges. They expose a large number of centres and professionals to new techniques and quickly concentrate limited expertise scattered around the region. They render geographical isolation irrelevant, foster collaboration and stimulate quality research activities. The individual participating laboratories expand their research activities based on the lessons learnt and use the tools acquired to create and attract new partnerships and sources of funding.

4.1.4 Lessons for Africa on capacity-building in biotechnology

These cases reveal that Africa can still catch up with the rest if it develops a manpower base, involves the private sector, uses its universities and research centres, provide financial and political support. Africa could also use the goodwill of donor agencies, bilateral and multilateral technical agreements to acquire the needed technologies.

It is important to note that a number of programmes and research institutions have been developed in Africa to build capacity building in biotechnology [[35]]. However, there are reasons why many of these have not achieved the desired impact. First, biotechnology is a collection of technologies, such as, bioprocessing, metabolic pathway engineering, breeding processes, chemical engineering and molecular designing, among others, each of which is also a collection of many other technologies. Therefore, training a few individuals may not be useful. Cuba, for example, had 12,000 scientists employed in biotechnology related research in 2000; training has to be long term, planned and realistic.

In addition most biotechnology research in Africa is in isolated research centres, sometimes, far away from universities and related institutions. Moreover, most African research centres have manpower establishments that do not promote mobility. These structural issues limit the continuous flow of knowledge and ideas needed in a field that is rapidly evolving. Some countries, such as, South Africa, Kenya and Zimbabwe have research institutions that collaborate with universities on graduate student research and training. This is one of the strengths of the US research community.

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[35] John Mugabe (2000) Biotechnology In Developing Countries and Countries with Economies in Transition; Strategic Capacity Building Considerations, UNCTAD, Geneva, Switzerland (available at http://www.acts.or.ke/)

In addition, the convergence of biotechnology with information technology, nanotechnology and materials technology complicates capacity-building at all levels. Africa does not have sufficient capacity in the technologies recombining and, consequently, is unlikely to participate in the emerging fields and most of the institutions lack the flexibility to re-orient their activities during changing times. Africa may need to rethink again on development of standalone laboratory or institutions if it has to benefit from multidisciplinary technologies.

4.2 Biotechnology and diplomacy

The skills of nations to analyze, discuss, negotiate and lobby technically complex issues are needed in biotechnology. In biotechnology, issues surrounding trade in GMOs, commercial release of GMOs, intellectual property rights protection of plant and animal varieties, and those related to protection of traditional knowledge are of considerable interest. Weaker countries, negotiating and lobbying from a disadvantaged position face many challenges in ensuring their interests are seriously taken into consideration.

The case of HIV/AIDS drugs present lessons that countries can use to negotiate and lobbying international corporations for technology transfer at affordable rates, be it embroiled in products or processes. The virus resistant potato developed by a collaborative project involving the Kenya Agricultural Research Institute (KARI) (Kenya)-Monsanto (USA) is another example of where technology transfer occurred on favourable user-friendly terms. Similarly, the case of vitamin A enriched "Golden Rice" was developed by public research and funding but used patents that were private.

Public research institutions have negotiated with private firms or individuals that owned the patents to be used in a way that does not disadvantage the firms or individuals, and the potential users. One of the agreements reached is that farmers in poor countries that earn less than $10,000 annually will not pay the technology premium over the seed for growing Golden Rice and retain the right to save the seeds.

It is, therefore, possible to negotiate and lobby private firms and research institutions for intellectual property rights. Navigating around rigid regulatory regimes is difficult. Taking a product through approvals could range from thousands of dollars to several millions mainly due to numerous demands. Many publicly funded research products will never manage to raise such astronomical amounts just to go through approval. Africa may have to find other ways of ensuring regulations do not strangle innovations. This could include commercialization based on regional or internationally recognized approval. Above all, the market sizes of many African countries are so small that returns on such scale of investment may not be recovered without passing the cost to poor farmers.

Africa also needs to develop skills to negotiate for market access without giving up on innovation. The TRIPS agreement is one arrangement where developing countries are thought to have traded technology for market access. Yet, developing countries needed technology to build a productive base to develop the products to sell on the international market. Instead, developing countries have spent more money building patent offices instead of capacity to develop innovations. While developed countries have benefited from TRIPS, termed “global tax cut”, developing countries have spent money establishing regulatory regimes to protect innovations owned by others.

Africa has to negotiate for market access for GM-products and for non-GM products. They should exploit the goodwill of proponents of biotechnology to build capacity and access innovations. Similarly, they should exploit the will of opponents to acquire technologies for food safety assessment, which is important in expanding markets for food exports, and monitoring health and environmental impacts of GMOs. However, balancing their needs and ones interests may be vital. India, China and South Africa are using this approach and there is no reason why most of Africa should not survive the turbulent diplomatic storm over biotechnology.

Africa’s success in biotechnology will require significant donor support in terms of technical assistance, training and funding of research. At least all donors agree that building biotechnology capacity is necessary for innovation and biosafety. The technical levels of competence needed to safely manage food and drug regulatory agents and that to conducts research and develop activities is not very different. The support from donors is important, as donor funding for agricultural research in Africa could be as high as 80% in some countries [[36]].

4.3 Promoting co-existence of agricultural systems

Africa has three main options for commercializing GMOs:

1. Africa could decide not to adopt GMOs on the basis that their traditional markets for agricultural products, Europe, will not allow the use or consumption of GMOs in a long time to come.
2. Africa could decide to adopt wide spread use of biotechnology on the basis that markets for GMOs will open up in Europe that already grow some GMOs and have invested heavily in research.
3. Africa could decide to partly adopt GMOs in those areas that do not threaten its traditional market to benefit from the choice of consumers to buy GM or non-GM foods.

Africa may need to promote co-existence of different agricultural practices, such as conventional, organic and GM-based farming. Such a policy could help both the producers and consumers to choose what they wish to grow and buy. By so doing, African countries would still retain their current market share for non-GMO while benefiting from GM technology in emerging markets.

African countries could also use GMOs for different reasons. They could encourage GMOs for animal feed, textiles, rubber, oil and timber among others, that could help diversify incomes and enhance earnings. India and China, for example, have selectively commercialized *Bt*-cotton but not the other major crops. Indeed, each crop should be evaluated on its merits rather than by the technology used to generate it.

[36] M. Maredia, D. Byerlee and P. Pee (1999) Impact of Food Crop Improvement Research in Africa, SPAARS Ocassional paper series, No. 1.

Africa needs to bear in mind that the battle over GMOs is being won and lost at the market place, or appropriately, public sentiments. GM sweet corn, potato and sugar beet, for example, are among crops approved for commercial release in the US but have not been grown for major use. Organizations, such as McDonalds, have declared themselves GM-free, practically locking out the crops. Similarly, the current debate in Europe is keeping GMOs and their use out of the shelves. Maybe a closer look at Spain, the only EU country with significant GM-maize acreage could provide a valuable lesson.

5. Conclusion

All technologies have benefits and opportunities that have to be harnessed, and risks that have to be managed. GMOs present farmers with the ability to overcome weeds, pests and diseases that cause huge losses annually in ways never imagined before. However, few African countries have enthusiastically embraced the technology to build industries, health services and agricultural sector. There are even fewer strategies to ensure that these technologies become global participants.

Budgets to universities and research institutions have continued to decline in most of Africa and donor support for basic and applied research have declined as the focus has shifted to experimental development. This has affected manpower training, research activities and conditions of service [[37]] that have been the mainstay of biotechnology industry development.

However, it is clear that biotechnology holds many opportunities for developing countries and Africa in particular. However, Africa will need to develop it manpower base, stimulate industrial participation and donors to develop a biotechnology sector. It should provide incentives that encourage formation of strategic alliances and participation of various players.

The wider adoption of biotechnology will be influenced by the global governance regimes that are emerging. Flexible enforcement of intellectual property rights and responsive regulatory policies may be needed to help Africa benefit from biotechnology. Similarly, partnerships and alliances will have to be formed between those with resources and those with the technologies if the poor have to benefit.

It is sad that at a time when some countries are suffering from "global obesity", Africa is suffering from malnutrition. Those in developed countries and large cities in poor countries may afford to be sentimental about food but the majority of Africans just need food.

[37] L. Zuker, M. R. Darby, M. B. Brewer (1999) Intellectual Capital and the Birth of U.S. Biotechnology Enterprises, NBER Papers.

References

A. Byerlee and D. Heisey (1996) Past and Potential Impacts of Maize Research in Sub-Saharan Africa: A Critical Assessment. *Food Policy*, ***21**: 2555-77*

Barton, J. (2000) “Rational Limits On Genomic Patents”, *Nature Biotechnology*, Vol. 18, No. 8, p. 805.

Biotechnology Organization (www.bio.org)

C. James (2002) Global Status of Commercialized Transgenic Crops: 2002, ISAAA Briefs, 27.

C. Juma, and V. Konde. (2002). The New Bioeconomy: Industrial and Environmental Biotechnology in Developing Countries, *UNCTAD/DITC/TED/12.*

C. Juma and V. Konde (2002) Industrial applications for Biotechnology; Opportunities for developing countries *Environment*, 44, 23-35.

C&EN Washington (1999, 11th January) Cuba at a Crossroads, News Focus CENEAR 77,2, 8-13.

Drahos, P. (1999) “Biotechnology Patents, Markets And Morality”, *European Intellectual Property Review*, Vol. 21, No. 9, pp. 441-449

Elderhorst, M. (1994) Will Cuba’s Biotechnology Capacity Survive the Socio-Economic Crisis? Biotechnology and Development Monitor, 20, 11-13/22.

Ernst & Young (2002) Beyond Borders: Global Biotechnology Report 2002

FAO, Committee on World Food Security; World Food Summit and Millennium Development Goals, CFS:2001/2-Sup.1

Fumento, M. (2003). *BioEvolution: How Biotechnology is changing our World.* San Francisco, California, USA: Encounter Books.

Gupta, A. (2000) “Governing trade in genetically modified organisms: the Cartagena Protocol on Biosafety”, *Environment*, Vol. 42, No. 4, pp. 22-33

Hagen, P.E. and Weiner, J.B. (2000) “The Cartagena Protocol on Biosafety: New Rules for International Trade in Living Modified Organisms”, *Georgetown International Law Journal*, Vol. 12, pp. 696-717

http://www.reliefweb.int/library/documents/2003/fews-zam-27jun.pdf

http://www.itu.int/wsis/ and www.undp.org

http://www.dti.gov.uk/biotechclusters/chapt04.pdf)

http://aeg.lbi.ic.unicamp.br/xf/project/organisation.html.

ILRI (2002) Research at the Crossroads of Livestock and Poverty, ILRI, Nairobi, Kenya

Inge Kaul, Katell Le Goulven and Mirjam Schnupf, Financing Global Public Goods: Policy Experience and Future Challenges

John Mugabe (2000) Biotechnology In Developing Countries and Countries with Economies in Transition; Strategic Capacity Building Considerations, UNCTAD, Geneva, Switzerland (available at http://www.acts.or.ke/)

The Korean Herald (12th February, 2001) Ministry announces a major initiative to boost biosciences and nanotechnology.

Leydesdorff, L and Etzkowitz, H (2001). Transformation of University-Industry-Government Relations. *Electronic J. Sociology, Vol 5*.

J. Lenne (2000) Pests and Poverty: The Continuing Need for Crop Protection Research, Outlook On Agriculture 29, 235-350.

L.P. Gianessi, C.S. Silvers, S. Sankula and J.E. Carpenter (2002) Plant Biotechnology: Current and Potential Impact for Improving Pest Management in US Agriculture: An Analysis Of 40 Case Studies, National Center For Food And Agricultural Policy

L. Zuker, M. R. Darby, M. B. Brewer (1999) Intellectual Capital and the Birth of U.S. Biotechnology Enterprises, NBER Papers.

M. Maredia, D. Byerlee and P. Pee (1999) Impacts of Food Crop Improvement Research in Africa, *SPAAR occasional paper series*, No. 1.

Peak tariffs are tariffs of 15% or higher, or three times the tariff in developed countries. Tariff escalation refers to increasing tariff with level of downstream processing.

UNCTAD, 2002 The New Bioeconomy; Industrial and Environmental biotechnology in developing countries, UNCTAD/DITC/TED/12

OECD (2001) The Application of Biotechnology to Industrial Sustainability; Organization for Economic Co-operation and Development.

San Diego Business Journal (4th March, 2002) South Korea Eye Local Bio-investment.

Soule, E. (2000) “Assessing the precautionary principle”, *Public Affairs Quarterly*, Vol. 14, No. 4, pp. 309-328.

van Beers, Cees, and André de Moor (2001) *Public Subsidies and Policy Failures: How Subsidies Distort the Natural Environment, Equity and Trade, and How to Reform Them*. Cheltenham, U.K.: Edward Elgar Publishing.

Watal, J. (2000) “Intellectual Property And Biotechnology: Trade Interests of Developing Countries”, *International Journal of Biotechnology*, Vol. 2, No. 1/2/3, pp. 44-55

Wolfenbarger, L. and P. Phifer. (2000). “The Ecological Risks and Benefits of Genetically Engineered Plants”, *Science*, Vol. 290, pp. 2088-2093.

Y. Menesha, S. Ehui, M. Jabbar and B. Shapiro (1998) Livestock Production, Consumption and Trade: Key Indicators, Livestock Policy Analysis Brief 11, ILRI.

Z.R. Khan, W.A. Overholt and A. Hassana Utilization of Agricultural Biodiversity For Management Of Cereal Stemborers And Striga Weed In Maize-Based Cropping Systems in Africa- Case Study (ICIPE) see http://www.biodiv.org/doc/case-studies/cs-agr-cereal-stemborers.pdf

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