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Article

Modern Biotechnology—Potential Contribution and Challenges for Sustainable Food Production in Sub-Saharan Africa

E. Jane Morris

African Centre for Gene Technologies, PO Box 75011, Lynnwood Ridge 0040, Pretoria, South Africa (The African Centre for Gene Technologies is a collaborative initiative between the CSIR, Agricultural Research Council, and the Universities of Pretoria, Johannesburg and Witwatersrand); E-Mail: ejanemorris@gmail.com; Tel.: +27-82-566-2210; Fax: +27-86-560-2221

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Abstract: Modern biotechnology, including the application of transgenic techniques to produce Genetically Modified Organisms (GMOs), can play a significant role in increasing agricultural production in a sustainable way, but its products need to be tailored for the developing world. In sub-Saharan Africa, the capacity to develop GMOs and ensure they meet stringent regulatory requirements is somewhat limited. Most African governments contribute little to science and technology either financially or through strong policies. This leaves the determination of research and development priorities in the hands of international funding agencies. Whereas funding from the United States is generally supportive of GM technology, the opposite is true of funding from European sources. African countries are thus pulled in two different directions. One alternative to this dilemma might be for countries in the sub-Saharan Africa region to develop stronger South-South collaborations, but these need to be supported with adequate funding. African governments as well as external funding agencies are urged to consider the important role that biotechnology, including GM technology, can play in contributing to sustainable development in Africa, and to provide adequate support to the development of capacity to research, develop and commercialize GMOs in the region.

Keywords: agricultural biotechnology; GMO; Africa; South Africa; science and technology; research and development; biotechnology policy; biosafety policy

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1. Introduction

The concept of sustainable development encompasses environmental, economic and socio-political sustainability. The world population, currently around seven billion [1], has doubled in the last 50 years, and constitutes a major threat to sustainability. The African population of around one billion (15% of the total world population) is growing at a faster rate than any other region of the world. One of the major challenges faced by mankind today is how to feed this growing population while at the same time preserving the environment and promoting socio-economic development.

In sub-Saharan Africa (SSA), more land is continually being brought into agricultural use. Almost 45% of the land area is now classified as agricultural [2], yet this expansion threatens the naturally rich biodiversity of the continent. In South Africa, one of the most developed countries on the continent, as much as 82% of the land is classified as agricultural. The sustainability challenge demands that agricultural production per hectare should increase to meet the needs of the population, but at the same time this needs to be done in a way that preserves the environment for future generations.

The organic farming lobby suggests that the organic route is the best way to achieve sustainability. This lobby inherently rejects genetically modified (GM) crops, disregarding their potential to contribute to the organic objectives of reduced agricultural inputs. Yet yields from organic farming are low, implying that more pristine land will need to be brought into cultivation to feed the population, with associated loss of natural biodiversity. A recent UK study showed a 55% drop in yield on organic farms compared with conventional farms, whereas there was only a 12.5% increase in biodiversity. The increase in biodiversity would therefore be rapidly offset by the need to cultivate more land for the same production output [3,4].

Instead, the best aspects of agricultural technology need to be harnessed to address the challenge of increased productivity with sustainability. Modern biotechnology, including GM technology, represents one of the tools that can play a significant role in this endeavour, but its products need to be tailored for the developing world. This paper explores some of the challenges to the introduction of GM technology in sub-Saharan Africa, and examines the responses of African countries, paying particular attention to the South African situation.

2. The Research, Development and Innovation Agenda

2.1. Overview of the Status of R&D in Sub-Saharan Africa

The capacity to undertake agricultural biotechnology research and innovation is limited in many developing countries, particularly in Africa, due to lack of public funding, poorly equipped laboratories, salary disincentives and lack of policy and regulatory support. Although South Africa spends over 0.9% of Gross Domestic Product (GDP) on research and development (R&D) and aims to increase this figure, only 5.5% of this is spent on agricultural research [5]. No other country in sub-Saharan Africa has been reported to spend more than 0.5% of GDP on R&D [6]. Considering the already low level of GDP, the absolute amount spent on R&D per capita is particularly worrying, with only Botswana and the Seychelles approaching the level of South Africa. The relative R&D strength of countries in SSA can be judged by their scientific output. South Africa dominates scientific publications, representing 46.4% of the sub-continent’s share, far ahead of the two next most prolific countries, Nigeria (11.4%) and Kenya (6.6%) [6]. Two thirds of South Africa's publications are in the life sciences. Sadly, many countries in SSA either have no record of the share of GDP they devote to R&D or simply allocate no funds at all to R&D [6]. Africa's Science and Technology Consolidated Plan of Action (CPA) [7] was approved by heads of state in 2006, and followed up on the earlier commitment by African Ministers of Science and Technology to commit at least 1% of GDP to Science and Technology. Unfortunately, the CPA has not delivered on its promise [8]. The UNESCO 2010 report [6] points out that, in many African countries, the frequency of cabinet reshuffles results in instability among top officials in the ministries responsible for science and technology, leading to weak strategies and research systems with little innovative or inventive potential.

2.2. The Influence of External Donor Funding

Given the lack of practical government commitment to science and technology in SSA, it is little wonder that scientists in the region turn to external funding to keep their hopes and dreams alive. Financial support comes from agencies of governments in the developed world [e.g., United States Agency for International Development (USAID), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Department for International Development (DFID), EU Framework Programmes, Swedish International Development Cooperation Agency (Sida), CIDA (Canadian International Development Agency), the Australian Agency for International Development (AusAID)] and philanthropic organizations (e.g., Bill and Melinda Gates Foundation, Rockefeller Foundation, Carnegie Corporation). Of course, most funding agencies have their own agendas, and the scientists have to adhere to these agendas if they are to have hopes of obtaining funding. One of the goals of the CPA was meant to better coordinate science aid and put a stop to the tradition of donors cherry-picking projects that fit their own agendas, but this has not yet been achieved [8]. The net result of this situation is that agricultural R&D priorities are often not determined by the African countries themselves, but rather by the funding agencies. Even in South Africa, where there is more local funding available, scientists in most cases need to supplement their funding with external income and frequently bow to the agendas of the funding agencies.

It is therefore interesting to examine a few externally funded R&D projects and programmes to determine to what extent they are impacting on the development of GMOs in the region. It is noteworthy that of the projects and programmes outlined below, those focusing on GMOs are exclusively funded from the USA, while those with broader (mainly non-GM) objectives source their funds primarily from Europe.

2.3. Externally Funded Projects that are Focused on Development of GMOs

2.3.1. Projects Coordinated by the African Agricultural Technology Foundation (AATF)

The AATF coordinates public-private partnerships involving project in banana improvement, cowpea improvement, control of Striga, and drought tolerance in maize. The banana, cowpea and maize projects all involve GM technology; the maize project is highlighted here as an example of the application of GM technology in the sub-region. The Water Efficient Maize for Africa (WEMA) project [9] aims to produce drought tolerant maize through a combination of conventional breeding, marker assisted breeding, and GM technology. Scientists from Tanzania, Kenya, Uganda, South Africa and Mozambique are involved. The project is coordinated by the AATF and is funded by the Bill and Melinda Gates Foundation and the Howard G. Buffet Foundation. Both of these foundations, being located in the USA where GM crops are widely disseminated, are inherently positive towards the development of GM technology for Africa. Monsanto is a partner in the project, providing technological support, including drought tolerant transgenes developed in collaboration with BASF. The project is still at the R&D stage, with some field trials taking place. It will be interesting to see whether it manages to progress to full scale implementation.

2.3.2. The Africa Biofortified Sorghum (ABS) Project

Like the WEMA project outlined above, the ABS project [10] is funded by the Bill and Melinda Gates Foundation as a USA-Africa collaborative project that also involves the private sector (in this case Du Pont, through its subsidiary Pioneer Hi-Bred). The aim of the project is to develop a nutritionally enhanced GM sorghum that contains increased levels of essential nutrients, especially lysine, vitamin A, iron and zinc. The nutrition-enhanced sorghum will be used by the product development team for introgression of the nutritional traits into high-yielding, African and farmer-preferred varieties. Unfortunately, the project has already encountered hurdles at the stage of regulatory approval for field trials, particularly in South Africa, resulting in field trials being relocated to the USA. There is a marked lack of consensus on the wisdom of developing GM sorghum for release into its centre of origin or diversity, and it might have been beneficial for discussions on this issue to have been prioritized with governments in the region before the project was approved as one of the Gates "Grand Challenge" projects.

2.3.3. The Bt Potato Project

The project to develop insect-resistant potatoes for uptake by small scale farmers has been funded by the U.S. Agency for International Development (USAID) and is a collaborative effort between Michigan State University Potato Breeding, Genetics Program (East Lansing) and the Agricultural Research Council, South Africa. The original aim of the project was largely to develop capacity in Africa to generate the information that would be required for a general release application [11,12]. Unfortunately, despite considerable sums of money having been spent to generate safety information, the project has now foundered in regulatory disputes in the South African government system [13].

2.4. Externally Funded Programs that do not Focus on GMO Development

There are a multitude of projects and programs involving African scientists that seek to increase capacity in the broader area of biotechnology, with little focus on the development of GMOs. Some examples are given below. These projects and programs are funded mainly by European organizations.

2.4.1. Sida Supported BioEARN and BioInnovate Regional Programs

The Bio-EARN (East African Regional Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development) program commenced in 1999 with funding from the Swedish International Development Cooperation Agency (Sida) and has since gone through 3 phases of funding support, focused on capacity building in biotechnology for the East African region. Subsequently, Bio-EARN has been succeeded by Bio-Innovate (Bio-resource Innovations Network for Eastern Africa Development) [14], which provides a new multidisciplinary competitive funding mechanism for biosciences and product orientated innovation activities in Eastern Africa. Bio-Innovate is funding projects focusing on the genetic improvement of sorghum, millet, cassava, beans, potato and sweet potato using a variety of (non-GM) techniques.

Although the earlier phases of Bio-EARN supported PhD students who were undertaking transgenic research, as well as supporting Biosafety policy and capacity building activities, in more recent times GM technology has not been a focus of research activities. This has probably been driven less from a policy perspective, than from the consideration that the development of GM crops is long term and expensive, and is difficult to justify in the context of a time-limited program that aims to deliver meaningful outputs.

2.4.2. EU Framework Programs

The EU Framework Programs offer significant opportunities for collaborative projects to be undertaken by African scientists in collaboration with EU researchers. The current 7th Framework Programme makes provision for International Partner Cooperating Countries (which includes most African countries) to participate as funded members of project teams in the same way that European scientists participate. However, the project agenda is largely determined by the EU, and African scientists participating must demonstrate that they can add value to the project. Apart from South Africa, scientists in other African countries have had limited success in participating.

A survey of the projects involving GMOs funded from 2001 to 2010 [15] reveals that the majority of these projects address aspects of food and environmental safety, rather than the development of GMOs themselves. None of the projects have specific relevance to Africa, and apart from two projects focusing on food safety and regulatory issues (SAFEFOODS and SCIENCE4BIOREG) there is a complete absence of involvement of African scientists. One project not mentioned in the survey (EU-SOL) had some potential downstream implications for future development of GM tomatoes and involved South African scientists [16]. Another project not mentioned in the survey, SAFEMAIZE [17], was funded under the INCO-DEV funding instrument, targeted to developing countries, and involved both South Africa and Zambia in the development of GM maize with resistance to fungal attack. Unfortunately the INCO-DEV funding, which facilitated stronger African involvement in EU projects, is no longer available.

2.4.3. Generation Challenge Programme

The CGIAR Generation Challenge Programme (GCP) was created by the Consultative Group on International Agricultural Research (CGIAR) in 2003 as a time-bound 10-year program, its mission being to use genetic diversity and advanced plant science to improve crops by adding value to breeding for drought-prone and harsh environments. Apart from the CGIAR centres located in Africa, the African Centre for Gene Technologies is one of the only consortium members located in Africa. In the early stages of the GCP, there was some limited involvement in the development of GMOs. However, there were ongoing concerns about both the time frames necessary to develop a GMO, and the use of GMOs was also prejudiced by the fact that some major donors that fund the GCP are governments that oppose or restrict the use of crop varieties with improved traits created by transgenic technologies (notably the European Commission). This resulted in a shift away from GM technology towards marker assisted breeding [18].

2.4.4. NEPAD Regional Programs

The New Partnership for Africa's Development (NEPAD) has established a network of biotechnology hubs and nodes in each of the regions of Africa. However, as identified by Juma [19], "*the NEPAD science and technology program is bedevilled by its isolation from the local economy…..the NEPAD science and technology effort seems divorced from the African reality*". As a result, there is insufficient local investment and a strong reliance on external funders. As outlined by Morris [20] these hubs and related nodes have all identified the development of GM technology as one of their strategic objectives. Two of the most active regional initiatives are Biosciences Eastern and Central Africa (BecA), with its hub in Kenya, and SANBio, with its hub in South Africa. Although the five year business plan of SANBio listed projects involving transgenic technology, in fact none of the current activities do involve GMOs, largely on account of the fact that the majority of funding is sources from Europe [21]. The BecA website [22] also does not include any GM projects in the list of featured projects even though their funding comes from more diverse sources, particularly from Canada (CIDA).

3. Adoption of GM Technology in Sub-Saharan Africa

3.1. General Trends

Those countries that have made progress towards the adoption of GMOs have largely done so using imported technology. As described above, R&D programs that might lead to introduction of locally developed GMOs are limited in number, and those that do exist have encountered various hurdles and setbacks. Meanwhile, the large multinational seed companies have actively marketed the benefits of GM cotton and maize in particular.

Although South Africa has taken the lead on the continent with respect to adoption of GM crops, Burkina Faso has more recently made large advances in the planting of GM cotton. Bt cotton hectarage in 2010 increased by 126% to reach 260,000 hectares (65% adoption) farmed by 80,000 farmers [23].

Other countries in Africa are also moving towards adoption of GM technology. Egypt has planted 2000 hectares of GM maize. Kenya, Uganda, Egypt, South Africa and Nigeria have ongoing field trials with numerous genetically modified crops including maize, rice, wheat, potatoes, sweet potatoes, cassava, bananas, sorghum and cotton [23]. Despite these developments, the challenge of producing sufficient information to achieve approval for general release remains a major hurdle.

3.2. Adoption of GM Technology in South Africa

Approved GM events in South Africa are restricted to cotton, maize and soybean, with insect resistance, herbicide tolerance or a combination of the two predominating. In 2010 the area under GM crop production equaled 2.2 million hectares, placing it as the ninth largest producer of GM crops in the world [23]. Relative to the total production area reported for 2010, the adoption rate for GM maize was estimated to be 76.9%, GM soybean was 85% and GM cotton approaching 100%. Cumulative benefits (income gain) to farmers for the 10 year period 1998 to 2009 for GM maize, soybean and cotton crops in South Africa have been estimated at US$ 676 million [23].

A trial release permit was issued to the Agricultural Research Council in 2010 for starch enhanced cassava, three years after an officially constituted Appeal Board recommended that the trial release should go ahead. Greenhouse trials of nutritionally enhanced sorghum were finally approved in 2009 after a prolonged appeal process. An application for general release of Bt potatoes has met with considerable resistance and has not yet been approved. These cases all give rise to considerable concern that the environment in South Africa is not conducive to local development of GMOs, and that it is only the large multinational companies with considerable financial resources who are able to successfully tread a path through the South African legislative quagmire.

4. The Regulatory Bottleneck for New GM Products

4.1. The Precautionary Approach

The precautionary approach to GMOs, as laid out in the Cartagena Protocol on Biosafety [24] and encapsulated in most national legislation, has focused attention word-wide on the risks associated with GM technology. The exclusive focus on risks, rather than on both risks and benefits, has limited the introduction of the technology in many countries [25]. In Africa, the impact of the Cartagena Protocol has been particularly strong, due in large part to the capacity building activities that were funded in many countries to assist countries to put in place regulatory systems to handle GMOs, but focusing exclusively on risks [20].

A number of fears have been expressed by Africans with relation to the introduction of GMOs that have little relationship to actual safety issues, but that relate to ancillary issues such as

- Market dominance by large multinational companies
- Loss of crop landraces and traditional practices
- Loss of access to export markets in Europe
- High cost of seed
- Legal restrictions on farmers saving seed
- High input cost of fertilizers etc required to achieve maximum benefit from the GM seed
- Poor transport infrastructure hindering access to local markets
- Perceptions of “dumping” of untested food, particularly where food aid is concerned

General concerns of this nature have largely led to the drafting of the restrictive African Model Law on Biosafety. A draft revised version of this Model Law, produced under the auspices of the African Union, was published in 2008 with support from the German Development Corporation (GTZ, now GIZ) [26].

3.2. Common Regulatory Requirements

The process of gaining regulatory approval for a GMO is not for the faint-hearted. Multinational companies such as Monsanto and Syngenta have deep pockets and are prepared to undertake large-scale studies to compile dossiers for regulatory approval. Table 1 gives an indication of the types of safety data that are commonly supplied. On top of this, socio-economic information may be required and may in fact have a considerable impact on the decision to approve or refuse the application. The compilation of extensive dossiers has become standard practice for these companies, and effectively sets a high barrier to entry which is difficult to overcome for publicly funded projects or crops with smaller market potential. Regulators have come to expect that they will be provided with a full spectrum of data, and seldom question the necessity for some of the tests, failing to distinguish the "need to know" from the "nice to know". As pointed out by Cooke and Downie [13] who examined the situation in South Africa and some other African countries, "*Many South African scientists complain that….their applications to the Executive Council* (for release of a GMO) *are passed over in favour of those submitted by the large commercial companies like Monsanto and Syngenta, which are able to put more time and resources into their submissions*". Various estimates have been given for the cost of obtaining regulatory approval; most recently Miller and Bradford [27] have highlighted the regulatory bottleneck and indicate a cost of at least $15M to obtain regulatory approval for each new GM event.

Table 1. Examples of safety data commonly supplied in Genetically Modified Organisms (GMOs) general release applications (derived from [29]).

Category	Data supplied
Molecular characterization	Southern blots Sequence analysis Determination of genetic stability Protein expression levels Protein mass spectrometry
Field performance	Trait effectiveness in a variety of locations and growing conditions
Nutritional quality	Digestibility Broiler chicken feeding trial
Compositional analysis	Proximates, minerals, amino acids, vitamins, anti-nutrients, secondary metabolites
Toxicity	Acute oral toxicity study in mice with bacterially expressed protein Amino acid sequence comparison with known protein toxins 90 day subchronic rat feeding study
Allergenicity	Amino acid sequence comparison with known allergens Rate of degradation in simulated mammalian gastric fluid Heat stability Glycosylation profile Digestibility
Environmental impacts	Likelihood of outcrossing to wild relatives Pollen dispersal patterns Weediness potential Horizontal gene transfer Effect on target organisms Effect on non-target organisms (e.g., birds, fish, predators and parasitoids, soil invertebrates and pollinators) Resistance management Control of volunteers

With the advent of new "-omics" techniques that facilitate genomic, transcriptomic, proteomic and metabolomic profiling, it is possible that the bar will be raised even higher, as the potential of such techniques to detect unintended effects is realized more fully, even though the mandatory use of such techniques is not recommended [28].

It is ironic that such a wide spectrum of information is required for GMOs, while the same set of information for the non-transgenic counterpart of any crop has normally never been required in such detail. Therefore the burden (and cost) of obtaining baseline data for a particular crop falls almost entirely on its GM derivative. In the circumstances it is hardly surprising that the range of crops and traits that have been commercialized to date is relatively small.

5. Do Partnerships Between Developing Countries Offer an Alternative Strategy?

To reduce their dependence on the agendas of developed countries and in the absence of critical mass in most developing countries to develop GMOs from laboratory to market, as well as in the absence of sufficient regulatory know-how, countries may turn to collaborative efforts to support their endeavors. Such collaborative efforts may involve Public-Private partnerships, large publicly funded international programs, regional networks, and bilateral or multilateral agreements between countries.

South Africa is no exception in this regard and is taken as an example here. Since the advent of democracy in 1994, South Africa has developed a wide range of collaborations with different countries, both developed and developing. Table 2 shows the full range of bilateral science and technology agreements that have been signed by South Africa since the end of apartheid in 1994. Partnership with these countries is mainly based on their willingness to collaborate; the need to develop human capacity; the opportunity for South Africa to learn best practices, share knowledge and seek to strengthen the National System of Innovation. It is clear that more developing than developed countries are included in this list. Some countries are happy with institutional collaborations that do not involve government. The South African Department of Science and Technology (DST) sets aside around R3M per country per year for collaborative interactions with the prioritized countries. In almost all these collaborations, biotechnology features as an important topic in calls for proposals, though there is normally no dedicated budget for biotechnology [30].

Table 2. Signed agreements of cooperation in the field of science and technology between the Republic of South Africa and developed/developing nations, 1994–2010 (derived from [31]).

Developed Country	Year	Developing Country	Year
France	1994	Zimbabwe	1995
UK	1995	India	1995
USA	1995	Tanzania	1995
Germany	1996	Bulgaria	1995
Flanders	1996	Zambia	1996
EU	1996	Croatia	1996
Hungary	1997	Egypt	1997
Italy	1998	Algeria	1998

Table 2. *Cont.*

Developed Country	Year	Developing Country	Year
Sweden	1999	Ukraine	1998
Poland	1999	Tunisia	1999
Norway	2002	Pakistan	1999
Switzerland	2002	People's Republic of China	1999
Spain	2003	Iran	2000
Japan	2003	Nigeria	2001
Republic of Korea	2004	Cuba	2001
Slovak Republic	2006	Belarus	2002
Australia	2006	Malaysia	2003
Greece	2006	Turkey	2003
Switzerland	2007	Brazil	2003
France	2008	Kenya	2004
		Romania	2004
		Vietnam	2004
		Namibia	2005
		Lesotho	2005
		Senegal	2005
		Argentine Republic	2006
		Mozambique	2006
		Mali	2006
		Oman	2007
		Malawi	2007
		Zimbabwe	2007
		Zambia	2007
		Angola	2008
		Saudi Arabia	2009
		Rwanda	2009
		Uganda	2009
		Mexico	2010

The rationale for collaboration with other countries in Africa is clear in the context of South Africa's position as an economic engine for the region, and its need to position itself appropriately within the African Union. In this context, the signing of bilateral agreements with 18 different African countries is hardly surprising. For bilateral collaborations outside of Africa, a prioritization exercise was undertaken by DST in 2008 [30]. This resulted in the following priority countries for collaboration being identified:

- Americas-Brazil, Argentina and, USA
- Asia-Japan, China, South Korea, India
- Europe-Germany, Norway, Switzerland, France, Russia, Poland
- Non prioritized countries but where collaboration exists-Mexico, Australia, Malaysia, Canada, Flanders, Italy and Belarus

It is interesting that the countries selected for collaboration span the full gamut of attitudes towards GM technology. The USA, Brazil, Argentina and India occupy the top four places in terms of global production of GM crops, leading to significant opportunities for collaboration with South Africa. In contrast, most of the European countries as well as Japan have been very reluctant to adopt GM technology, although there are variations between European countries. The conflicting ideologies have also influenced government attitudes and are reflected in the South African regulatory system. The Department of Science and Technology has actively promoted biotechnology, including GM technology, and has promoted scientific collaboration with India and Brazil in particular through the IBSA trilateral agreement [32]. In this agreement, Biotechnology tops the list of priority areas for collaboration.

Meanwhile, other government departments, particularly the Department of Environmental Affairs (DEA) and the Department of Trade and Industry (DTI), have been much more conservative in their approach to GMOs. This has relevance to South Africa's attitude to GMO regulation in general, because although the GMO Act (Act 15 of 1997 as amended by Act 23 of 2006) falls under the Department of Agriculture, decisions are made by consensus in an Executive Council comprised of representatives from a range of government departments. Moreover, the National Environmental Management Biodiversity Act (Act 10 of 2004) makes provision to require an environmental assessment, and also mandates the South African National Biodiversity Institute (SANBI), which falls under DEA to monitor and report on the environmental impacts of GMOs post commercialization, "based on research that identifies and evaluates risk". DEA has a long term engagement with Norway, which has negatively affected their perspective on GMOs.

An Environmental Cooperation Programme between South Africa and Norway was established to run for five years between 2006 and 2010. Under this program, an Environmental Biosafety Cooperation project was established, with a primary focus on the measurement of the impact of GMOs released into the environment.

Despite the fact that Norway has no track record in the introduction of GMOs, has no field trials, and indeed has no policy or strategy regarding the application and use of biotechnology, through the organization GenØk it implemented a program in South Africa to develop a comprehensive monitoring system for post-market GMOs in the long term, by developing and making available improved tools to conduct research, monitoring and assessment, to develop biosafety capacity in SANBI and DEA, and to strengthen the national infrastructure for risk assessment and monitoring [33].

Unfortunately, the very precautionary attitude towards GMOs in Norway has done little to support the concept that the introduction of GMOs can contribute to sustainable development. For example, a workshop held in 2008 at SANBI under the auspices of the Norwegian program, and attended by the author of this paper, was aimed at identifying priorities for environmental monitoring of MON810 Bt maize. The mandate given was only to look at potential negative interactions between MON810 and the surrounding biodiversity, while possible beneficial interactions were ignored.

The workshop participants were asked to examine, in minute detail, interactions between the components of biodiversity in and around the cropping system. In fact, many of the interactions considered were clearly not hazardous, and some could even be considered as beneficial, although the workshop participants were specifically told that they should eliminate beneficial interactions from their considerations. This process elicited concern from some participants regarding the appropriateness of the intervention in its entirety.

6. Conclusions

Government agencies in the developed world, as well as philanthropic donor organizations, generally approach their counterparts in the developing world with intentions that include not only on a well meaning desire to assist, but at the same time are self-serving, aiming to support their own policies and goals. Development aid is most often provided in the context of a paradigm where the parameters of the funding are set by the funder rather than the recipient of funds.

In SSA countries, weak or fragmented science and technology policies are the norm, and attitudes towards agricultural biotechnology are frequently ambivalent with lack of alignment between government departments. This makes it particularly difficult for the countries concerned to counter the priorities of the donors with identified priorities of their own, and when funds are short, there is often a willingness to accept whatever is offered, despite the strings that are attached.

The agenda-setting by the developed world has led to talk of "neo-colonialism" [13] and may be a factor driving increased research collaboration between developing countries in the South. However, productive collaborations need to be supported with funding, a factor that is in short supply in most developing country partnerships. As long as scientists are short of research funds, they will gravitate towards the countries and organizations offering the highest level of support.

Even in South Africa, which has one of the strongest science systems in Africa, external funding is sought, and collaborations are formed, without sufficient consideration of the unintended consequences. It is apparent from the information provided in this paper that agricultural biotechnology policy alignment does not really feature as a determinant for prioritization of bilateral collaborations.

In the author's opinion, it is critical that future cooperative programs between developed countries and countries in SSA should be supportive of agricultural biotechnology in the region, and should not undermine stated policy as was the case in the collaboration with Norway cited above. At the same time governments in the region should start to recognize the important potential of biotechnology to contribute to sustainable development. Governments should also ensure that there is policy coherence between different departments, each of which has its own mandate.

It is to be hoped that both scientists and government departments in the countries concerned will more carefully consider offers of external assistance that may have aspects of a double-edged sword. Without a more rational approach, modern biotechnology, particularly GM technology, is likely to become a victim of international politics rather than living up to its potential to contribute to food security and sustainable development.

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