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Review

The fate of politically modified crops in Africa

Woldeyesus Sinebo[1,2], Kazuo N. Watanabe[1,3]*

[1] Gene Research Center, Graduate School of Life and Environmental Sciences, University of Tsukuba, Ibaraki 305-8572, Japan; [2] Institute of Advanced Studies, United Nations University, Yokohama 220-0012, Japan; [3] International Plant Genetic Resources Institute (IPGRI), Rome, Italy

* E-mail: nabechan@gene.tsukuba.ac.jp Phone: +81-29-853-4663 Fax: +81-29-853-7723

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Abstract Current GM crops may not appeal to Africa because of relevance, proprietary issues, and a negative reaction towards GM foods in Europe. Nonetheless, Bt cotton may hold a promise if fair access to the technology is ensured and biosafety structures are put in place. However, Africans may continue raising the biosafety flag in order to avoid being cornered by unfair trade rules. Africans should not overstretch biosafety and socio-economic concerns to the extent of putting barriers against biotechnology adoption than the circumstances on the ground merit. African countries should build domestic capacity through formation of linkages with advanced research institutes and international organizations to make use of biotechnology. However, constraints to coordinating the existent but fragmented domestic capacity across organizational barriers ought to be overcome. In Africa, presence of vocal scientists that articulate the merits of biotechnology and experience with the private sector are positive signals and a strong political clout of the Ministry of Environment a negative signal for a GM-friendly national policy. A transparent dialogue among stakeholders should result in a shared vision required to balance GM regulation with the need to adopt available technologies and develop technological capability. Biotechnology-proficient countries may need to understand the concerns of the poor and may put the trade magic behind to reassure Africans to see biotechnology through biosafety lenses only.

Key words: Africa, biosafety, genetically modified crops, trade.

Crop production contributes for about 92% of the food needs of humanity (Borlaug 2002). The unprecedented crop yield increases from the Green Revolution varieties have dramatically improved the level of food supply particularly to the world's poor since the 1960s. The roots of such crop yield increases lie in the advent of the science of genetics in the early 20th century. Genetics continues to provide the knowledge base for the recombination of agronomic traits of economic importance through plant breeding. In recent decades, the incremental understanding of the molecular basis of genetics and associated sciences has yielded powerful tools and techniques collectively termed as biotechnology. Advances in biotechnology offer opportunities to improve crop productivity and to enhance crop product quality. Increased yields mean reduced environmental degradation brought about by agricultural land expansion, which is a common feature of African farming systems.

In crop agriculture, biotechnology encompasses the production of genetically modified crops, micropropagation, marker assisted breeding, genomics and bioinformatics (DeVries and Toenniessen 2001). Of all these, advances in genetic modification came along with uncertainties this technology might entail on biodiversity, human health and socio-economic development. Cognizant of these potentials and pitfalls, Agenda 21 (Chapter 16) of the United Nations Conference on Environment and Development (UNCED) detailed program of action to create enabling conditions, including technology transfer, for the safe application of biotechnology for sustainable development particularly in developing countries. UNCED explicitly noted the opportunity biotechnology offers for international partnership between biodiversity rich countries in the South and technologically proficient countries in the North. Modalities to enhance such partnership and avert inter-country disputes arising from expansion of biotechnology were further agreed in the succeeding Convention on Biological Diversity (CBD) and, more recently, the Cartagena Protocol on Biosafety to the CBD. Cartagena Protocol re-defined modern biotechnology and GMO (genetically modified organism), which has been commonly used at OECD basis, was renamed as LMO (Living Modified Organism) (See the text of the Cartagena Protocol on Biosafety Homepage, http://www.biodiv.org/biosafety/default2.aspx). This might have caused decent confusion in

Abbreviations: CBD, Convention on Biological Diversity; GM, genetically modified; LMO, Living Modified Organism; TRIPS, Agreement on Trade-Related Aspects of Intellectual Property Rights; UNCED, United Nations Conference on Environment and Development.

various countries, particularly in scientific societies as a law defined science. In practice, however, biotechnology has brought bitter arguments between countries that export GM crops and countries that are destined to be LMO recipients, largely because of differences in issues in the trade-biosafety nexus. In Africa, this precipitated in the total rejection of food aid containing LMOs in countries such as Zambia. Africa was bypassed by the Green Revolution and is again facing the double risk of being left behind the biotechnology bandwagon. In Africa, biotechnology has been much talked rather than transferred and developed even by the pro-biotechnology stakeholders. The apparent challenges span from biosafety concern to politics and economics in the international and domestic arena. Our objective in this paper was to assess these challenges in light of the spirit of Agenda 21 and suggest policy options for biotechnology development in Africa in support of food security, poverty alleviation and environmental preservation.

Biotechnology for Africa: myth vs. reality

Many reports on the role of agricultural biotechnology in enhancing food production in Africa were emotional either hyping (e.g. Gillis 2003; Taverne 2004) or disparaging the technology. In most of Africa, development of biotechnology is in its rudimentary stage (DeVries and Toenniessen 2001). In a few countries, low-end modern biotechnology such as tissue culture is being used for rapid multiplication of disease free planting materials and for animal vaccine production. Molecular marker technologies are being used in diversity studies and marker assisted breeding often in cooperation with advanced research institutes or international agricultural research centers. Although some African countries are building capacity, practical use of marker assisted plant breeding in Africa remains challenging because of cost and also breeding gain considerations (FAO 2004; Dekkers and Hospital 2002; Thro et al. 2004).

Genetic engineering offers potential opportunities for improving crops of economic importance to Africa against stresses such as salinity, drought, diseases and insect pests and also for improved end-use qualities (Cohen 2005; DeGroote et al. 2004; Zhang 2001). So far, genetic engineering for herbicide tolerance and insect resistance has produced successful technologies adopted to a greater extent in middle and high income LMO-friendly countries. In 2004, only four crops, namely soybean (60%), maize (23%), cotton (11%) and canola (6%) made up for the total GM crop area of 81 million hectares (James 2004). Herbicide tolerance accounted for 72%, insect resistance for 19% and stacked genes for both traits for the remaining 9% of the total GM crop area. Expansion of GM crops is largely a result of ease of crop management and cost reduction rather than yield increase per se. For instance, in Argentina, increase in total GM crop area was a result of expansion of soybean crop area made possible by both better weed management with and a cheap access to the new seeds (Trigo 2003). In a less chemical-intensive cotton farming in India, yield advantage due to Bt cotton was reported (Qaim and Zilberman 2003) but such yield increase was a result of better bollworm control than the intrinsic nature of the Bt gene to boost yields. Both soybean and herbicide tolerance trait which cover most of the world's GM crop area remain unimportant in Africa. However, the Bt gene may have practical applications if introduced to crops of economic importance in Africa including maize and cotton. In regard to crop quality, GM rice with enhanced vitamin A has been reported but its promise to meeting the daily requirement through eating rice alone is yet to be realized (Dawe et al. 2002). Nonetheless, a many-fold increase in total carotenoids over the older 'golden rice' reported recently may give more hope to realizing expectations (Paine et al. 2005).

Almost all the known traits with economic appeal for genetic engineering are simply inherited qualitative traits that have already been made use of. Further advances in GM crop development are constrained by the lack of economically useful genes for transformation (Gepts 2002; Goodman 2004). In fact, the promise modern biotechnology holds for enhancing yield under critical stresses in Africa such as drought is yet to come by (Goodman 2004). Moreover, since crop yield is a polygenic trait, the value of gene knowledge and genetic engineering for breaking the yield barriers across the board is limited (Bernardo 2001; Goodman 2004). Besides, the inherent physiology of crop yield formation by itself may limit major yield increases due to engineering of "a few, or even a complex of genes" (Sinclair et al. 2004).

In Africa, South Africa is the only country producing GM crops. The reaction of other countries towards LMO spans from those that are experimenting such as Kenya and Zimbabwe to those that are strongly defensive such as Zambia and Ethiopia. Poor adoption of GM crops in Africa stems equally from the absence of relevant technology with proven benefit for the smallholder farmers as with biosafety concerns and the pending intellectual property issues. Recently, there have been efforts to develop insect resistant maize in Kenya using non-proprietary Bt genes (DeGroote et al. 2004). While the Bt genes tested were effective against the insect pest *Chilo partellus* (Swinhoe), they were not against the more important *Busseola fusca* (Fuller). Because of this, an ex-ante estimation of economic benefits accruing from GM maize technology indicated only "modest profitability with the currently available Bt genes".

Besides, even if the Bt maize was resistant against all the insects, the irreversible contamination of local varieties remained a challenge. In view of this and a public relations fiasco from the failure of highly publicized GM sweet potato (from the technology point of view per se) in Kenya, the pompous claims about the value of transgenic crops for hunger and poverty reduction (Gillis 2003; Taverne 2004) may need to be tamed. Despite all these downsides, the Bt cotton remains to be a promising technology for cotton growing African countries if fair access to the technology is ensured and biosafety structures are put in place.

Moreover, modern biotechnology is a rapidly evolving field with continuous improvements over existing tools and techniques and new applications with immense opportunities for economic catch-up and wealth creation. Africa needs this technology to increase its competitiveness in this era of globalization. The argument that the world should formulate policies for equitable distribution of foods from places of abundance to scarcity such as in Africa instead of using modern biotechnology is unsound. The reason: Africans should be able to put their destiny on their own hands. This means, African governments should embrace all the useful technologies they can reach to in order to increase incomes and ensure access to food for their citizens. In Africa, tailor-made biotechnology can be used to enhance agricultural production in marginal environments where the world's most food insecure people live hence narrowing the livelihood gap between the poor and the well of. In high potential production environments, biotechnology can increase the competitiveness of the agricultural sector in particular and the economy in general. All the more, Africa can use biotechnology to harness its genetic resources and traditional knowledge, easing the frustration of being exploited by the technologically proficient North.

Processes for high end biotechnologies such as genetic engineering are fairly well documented. Crops have already been successfully transformed for important traits in developing countries such as China and India in Asia and Egypt and Nigeria in Africa (Cao et al. 2004; DeVries and Toenniessen 2001; Sawahel 2004). Some countries in Africa (e.g. Kenya) are in the process of building capacity for genetic engineering mainly through external financial assistance. Despite the many challenges African countries face in meeting the basic needs of their growing population, such a technological foresight and capacity building should help in maximizing opportunities by rapid integration of useful genes found elsewhere into locally adapted genetic background.

Trade-biosafety tit for tat

Biotechnology transfer to Africa has been mired by the raging trade-biosafety arguments. The debate, in part conditioned by the North-South technological divide, traces its roots back to the differing positions of the negotiating countries of the Cartagena Protocol on Biosafety to the CBD (Mayr n.d). Countries with the capacity to produce and commercialize agricultural biotechnology (e.g. USA) and countries for which biotechnology increases product competitiveness in international markets (e.g. Argentina) upheld the importance of trade. African countries do not have the capacity to produce homegrown GM technology. They do not anticipate significant advantage from the adoption of current GM crop technologies either, both because of relevance and proprietary nature of the technology. Besides these, a negative reaction towards GM foods in Europe provides little incentive to open up space for GM technology.

In Africa, benefit sharing from biotechnology is a concern as equally important as biosafety (Gebre Egziabher n.d). Availability of technology per se is not an adequate condition to improve farmers' livelihoods. A good example in Africa is the continued deterioration of soil fertility and low yields because of nutrient mining. This is despite the availability and knowledge of commercial fertilizers. Even when farmers dared applying fertilizer at a rate sufficient to realize high yields, farmers' indebtedness increased leading to a negative feedback towards technology adoption. In the region as a whole, the cost of knowledge-intensive agricultural technologies is higher and the margin of agricultural productivity accruing from the introduction of a technology lower than in other parts of the world. The implication of this is the worsening of competitiveness of African products in domestic as well as international markets. This is more so as developed countries continue to subsidize their agriculture but aggressively seek rent from their technology in the global market. The lesson: technology adoption in Africa is not a function of only technology supply but also of favorable input-output prices, infrastructure and a fair international trading regime to dispose of the extra produce arising from technology adoption.

So what is the way forward? Since biotechnology is often delivered in seeds which can easily be adopted by the poor subsistence farmers, biotechnology can be tailored to benefit Africa. But for this to materialize, the cloud surrounding the biosafety-trade-economic justice debate should clear. In principle, the Cartagena Protocol on Biosafety to the CBD was developed to reconcile trade imperatives of LMO producing countries with the biosafety concerns of the rest including those in Africa. However, whether this objective would be achieved remains to be seen. The key to success hinges on whether biotechnology will help close the yawning wealth gap between the continent and the North. We feel that agricultural biotechnology is needed in Africa and will have a role in increasing food production in the continent. Nonetheless, we reiterate that agricultural biotechnology should be introduced to Africa on the premises that the technology would improve the livelihoods of the poor first. This in turn should create a market sink for commercial products in the future, providing a global developmental synergy and dispelling fear of expropriation on the part of the world's poor. African countries are concerned that once they allow GM agriculture, pressure to observe international trade rules including IPR may give an unfair advantage for biotechnology proficient countries denying a leeway for African countries to protect their interests. Provisions in the Cartagena Protocol to address economic injustice related to biotechnology in tandem with the biosafety concerns are weak. This means even if Africans recognize the potential role of biotechnology, they are likely to continue raising the biosafety flag to avoid being cornered by unfavorable provisions in multilateral trade agreements. In essence, the protocol stands as a "genuine reward" for the agreement on the TRIPS. This means disputes at the trade, environment and equitable development nexus are likely to continue. This enigma may be unpacked if LMO-proficient countries accommodate the concerns of the poor and put the trade magic behind in order to reassure Africans to see biotechnology through biosafety lenses only. After all, this is what the spirit of Agenda 21 demands!

Meanwhile, Africans and international stakeholders from both the North and the South concerned with unfair trade practices and environmental injustices have made their point during the negotiation of various multilateral trade and environmental agreements. The processes proved the difficulty of politically engineering the poor in the South. The outcome of this is that agricultural GM technology has not been the hot cake it was supposed to be both in developed and developing country markets. Rather, the technology has been watered down to the extent that "donations" were refused in Africa, taming the ambition of transnational agric-biotechnology corporations to extend their commercial sphere of influence. In the future as well, Africans can use ambiguities in both multilateral trade and environmental agreements including the Cartagena Protocol and the TRIPS to ensure that they have derived fair benefit while discharging their obligations. This means there will be little room left for using biotechnology as a tool for exploitation by global commercial interests. In the face of this, Africans may not need to overstretch biosafety and socio-economic concerns (to the extent of putting barriers against biotechnology adoption) than the circumstances on the ground merit.

LMOs of agricultural importance cannot be shunned across the board as each single transgenic event is a separate product the risks of which ought to be determined on a case by case basis. Moreover, recent reports indicate absence of risks arising from GM products once the gene or trait for transformation has been proved safe further easing biosafety concerns (Bradford et al. 2005). Given these evidences, it is unlikely that a confrontational stance and a defensive wall against biotechnology would help advance the cause of African countries. African countries should disengage from locking horns in anti-biotechnology debate but should seek ways for acquiring both the basic knowledge and semi-finished technologies to develop technological base and usable products. To this effect, African countries should provide clear and unencumbered biosafety guidelines and build biosafety capability in order to facilitate research and product development partnership. This should particularly provide the all important ground to experiment with and make use of GM technologies developed elsewhere.

Wages of wisdom or divine trickery

Once clarity with the biosafety regulation is achieved, the major concern is ensuring access to technology. This is where the responsibility should heavily weigh up on developed countries and the private sector from these countries. At this juncture, it is worth noting that successful expansion of GM crops in advanced developing countries such as India, China, Argentina and Brazil is a result of both farmer-friendly IPR legislation and the existence of extensive underground seed markets (Jayaraman 2004; Pray et al. 2001; Trigo 2003). For instance, in Argentina farmers readily adopted GM soybean but were less enthusiastic about GM maize and cotton because of the ease of technology protection and the resulting increase in seed prices for the latter crops (Trigo 2003). African countries may design IPR regimes that would ensure farmers' rights to seed saving and exchange and allow use by breeders in order not to leave farmers under the mercy of transnational companies. If, however, stronger IPR is deemed in a country's interest, which is unlikely for most African countries, a consensus should be developed on the part of technology users that technology developers deserve a rent on their technology as a wage for their wisdom. This will help technology recipients not to perceive technology protection as a divine trick designed by Jacob to negotiate all the streaked or speckled young born flocks of Laban (Genesis Chapter 30, The Holy Bible, New International Version. International Bible Society, New Jersey), thus avoiding grudge about economic injustice, and thereby trade disputes. In Africa, this requires dialogue with smallholder farmers that seeds of modern biotechnology are to be bought but not to be owned, to be eaten but not to be replanted. No doubt, however, this will represent a paradigm shift that is bound to yield a cultural shock, a sense of confusion and uncertainty to the poor.

Apparently building domestic capacity is a sure way of targeting biotechnology to African problems (Machuka 2001). However, technology owners willing to help with the transfer of basic GM science and its applications are few and far between. In fact, despite some arguments otherwise (Wagoner 2004), it is naïve to think that the highly publicized GM technology "donations" (the popular Bt cotton has rarely been donated) and public-private partnerships mediated by "honest brokers" is solely humanitarian aimed at supplying poor African farmers with biotechnology in order to increase food production. Evidences point out to mutual gains for both the public and the private sectors. The deals often included building physical facilities and human power for the public partner and expansion of frontiers for the technology, installation of technology protection systems (IPR) and socio-economic data such as public acceptance and prospects for technology fee for the private stakeholders.

A point of further concern for African countries regarding IPR is the current practice of a two-stage licensing process, one for experimentation and the second for product commercialization. Such an arrangement may not allow technology receivers to negotiate from a position of strength. This means both the public and the yet-to-emerge private sector in Africa should seriously consider the implication of such a multistage licensing agreements before committing scarce resources for product adaptation and extensive testing. In short, the poor in Africa is only likely to benefit from biotechnology if its transfer is less encumbered by complex and frustrating licensing agreements.

How does biotechnology reach the poor in Africa?

Technology transfer is a complex issue governed by a multitude of domestic and external factors in a given country. In Africa where technology adoption is beset by economic difficulties, the simple purchase of transgenic seeds may not constitute sustainable biotechnology transfer. Rather the acquisition of biotechnological capabilities is an important element to ensure affordable product supply. Biotechnology is essentially the domain of the private sector tied up with IPR provisions. However, biotechnology supply by the private sector to the poor in Africa has not been effective because of market failures. As a result, public-private partnership is said to be a necessity for technology acquisition and adaptation. Such partnerships were used in attempts to develop virus resistant sweet potato, insect resistant maize and fast-growing multi-purpose trees, all in Kenya. The significance of such partnership has so far been more in both physical and human capacity development rather than product delivery. Recent suggestions to induce the private sector to play greater roles in Africa include an international fund to bid for the supply of key technologies for the poor (Byerlee and Fischer 2002) and a pull program in which developers of specific technologies would be rewarded based on the extent of technology adoption through donor funds (Kremer and Zwane 2005). In our opinion, the pull approach appears to be pro-poor though its practicality remains to be seen. Nonetheless, international fund to buy biotechnology for the African poor may be an unwise investment in view of its potential to perpetuate dependency and unsustainability. Rather, such a fund could be used to retain talents, provide facilities, and thereby develop biotechnological capability in Africa itself.

The public sector is the major player in agricultural biotechnology development and transfer efforts to the poor in Africa. National institutions in Africa are the core of such efforts through targeted training of their scientists and facility development. Multilateral organizations such as FAO contribute through capacity building and consultancy on technical as well as policy aspects. Other multilateral channels such as UNEP's Global Environmental Facility (GEF) provide the wherewithal for genetic resource conservation and for biosafety regulation both of which support some capacity development on biotechnology. IARCs feature strongly in seed-embodied technology transfer to developing countries, particularly during the era of Green Revolution. Schematic representation of technology flow to NARS through IARCs, their outreach offices and regional networks is given in Figure 1. In short, each crop-based IARC develops germplasm with adaptation to mega-scale stresses of global importance for free distribution. Outreach programs in collaboration with the national programs address technology needs specific to a target region. Moreover, the IARCs foster crop-based research networks and backstop technology transfer from one NARS to another within such networks. However, modalities of seed technology transfer are evolving differently during the era of Gene Revolution because of the proprietary nature of modern biotechnology. Proactive formation of strong linkage with the international private sector, advanced research institutes and international organizations are important considerations for biotechnology sourcing and transfer to developing countries. Figure 2 gives a representation of the interplay between stakeholders and the various stages in technology transfer process typical of the Gene

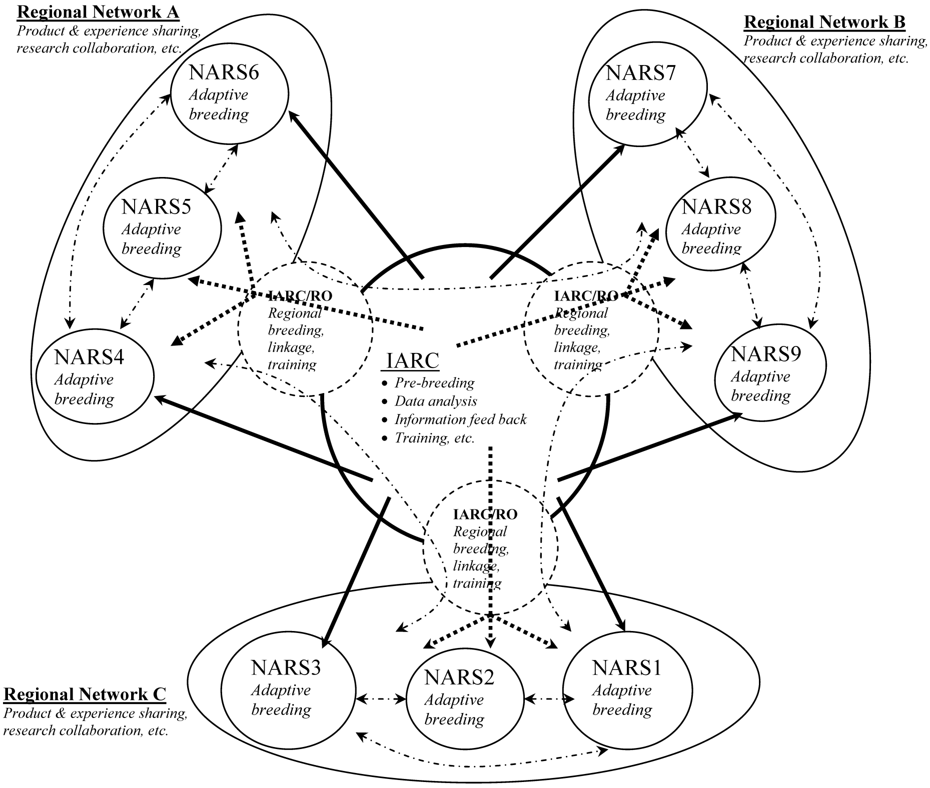

Figure 1. Schematic diagram of agricultural technology flow to national agricultural research systems (NARS) through international agricultural research centers (IARCs), their regional offices (RO) and regional networks. Note: Flow of best practices and enhanced germplasm within and among regional networks (←·→); flow of pre-breeding germplasm and skills from IARCs to NARs (→); flow of germplasm and skills from IARCs through their regional offices to NARs direct or via regional networks (·····→).

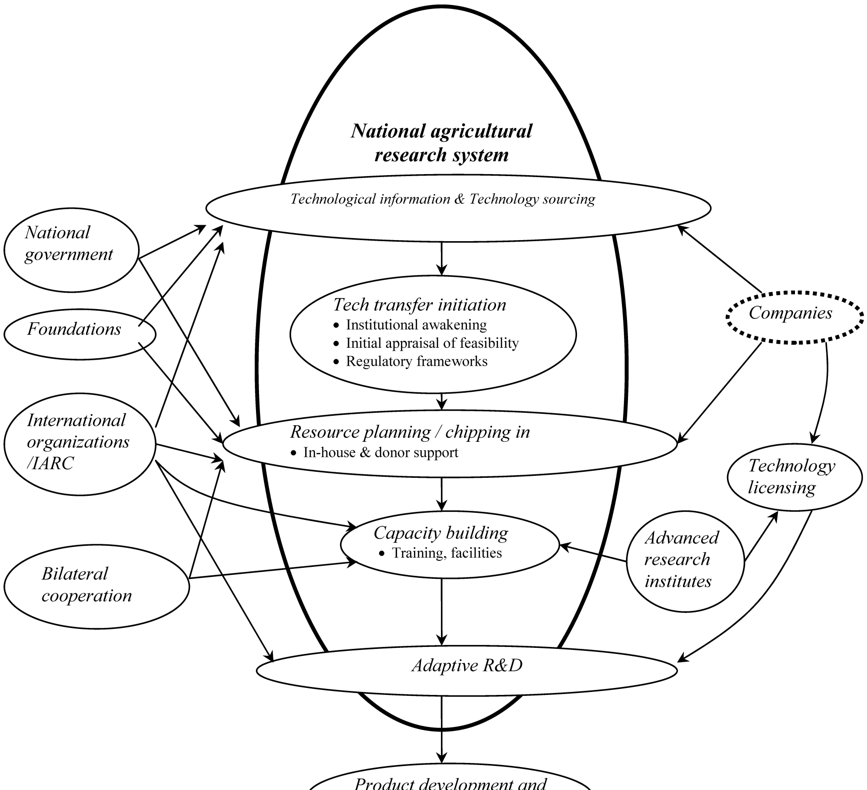

Figure 2. Schematic representation of public sector agricultural technology transfer to developing countries.

Revolution era. Crop-based IARCs do some research on high-end biotechnologies such as molecular marker assisted breeding and genetic engineering at times in cooperation with advanced research institutes. The centers liaise with advanced research institutes and the private sector in acquiring technology. The technology is adapted at the centers before transferred to NARS (with due consideration of IPR conditionalities) as intermediate products for further adaptation. The centers also train NARS scientists in biotechnology and biosafety tools and techniques.

The public sector biotechnology R&D is often energized through support from foundations, bilateral cooperation projects and other initiatives aimed at delivering products and developing human and physical capability. These include a recent Rockefeller Foundation's project on Biotechnology, Breeding and Seed Systems for African Crops, which supports technology development and transfer using expertise at IARCs, advanced research institutes, and African universities and research centers. The goal is to develop and supply crop varieties appropriate for smallholder farming systems in Eastern and Southern Africa. In addition, the program envisions sustainability through indigenous capacity development by training future scientists at PhD and MSc levels in plant biotechnology and breeding in African universities. Added to this is a new initiative for a facility for world-class research in biosciences in Africa (Biosciences Eastern and Central Africa) housed at the International Livestock Research Institute in Nairobi, Kenya. The facility is hoped to provide a platform for conducting research and developing pro-poor crop biotechnologies targeted at eastern and central Africa but with possible applications for the whole region. The center is also expected to provide a first rate post-graduate training for African scientists. The laboratory is just starting and its effectiveness and sustainability remains to be seen.

A notable example for bilateral development cooperation is the East African Research Network for Biotechnology (BIO-EARN) funded by the Swedish International Development Cooperation. The network provides a platform for exchanging expertise and experiences on biotechnology, biosafety and biotechnology policy development among the four network countries. The project linked institutions, scientists and policy makers within the region and with advanced research institutes in Sweden and also provided post-graduate training to young scientists on priority areas of the respective network countries. A major challenge with this and similar projects: how to leave a lasting legacy when the projects phase out? Organizing regional and national short-term trainings to scale up the existing knowledge base and maintaining the knowledge networks in the region is one means of achieving this. However, in practice the scientists, once back from training, are left to their own devices without a follow up to engage them in productive activities creating a fertile ground for disappointment and thereby brain-drain.

Domestic challenges to biotechnology transfer

Challenges to biotechnology development in African countries are many and diverse. Although Africa is rich in traditional biotechnological knowledge, the culture for modern science-based innovation in much of Africa is poorly developed. In many countries, low-end biotechnologies such as tissue culture have not been used let alone GM technology. Based on our observation, shortage of physical facilities and competent scientific staff are part of the story but do not form sufficient ground for the current state of affairs. In fact, in some countries, there are significant laboratory and human capacities fragmented across a number of research and training institutes. The problem remains with coordination of such capacity across organizational barriers. Scientists, research managers and policy makers should be able to do away with the wall of territoriality to foster interaction among institutions and scientists from different institutions.

Lack of critical mass of scientists arising from persistent brain-drain continues to pose a serious threat to biotechnology development in Africa. Even within a country, retention of competent staff in R&D institutions charged with technology development for the poor has been a major challenge. Neither are those scientists who remain in R&D institutions productive, partly, because of lack of motivation and adequate incentives. In some countries attempt was made to provide a better salary structure for R&D scientists. Although this could attract some talents from within a country, it may not promise a better R&D output unless remuneration is based on competence and product delivery. Countries need to emphasize merit-based promotion more than service-year-based promotion.

Decision making on GM technology in Africa is a complex process which depends on the extent of political influence organizations and even individuals muster in a country. In African countries, GM technology appears to have favorable reception where there are vocal scientists to articulate the pros and cons of biotechnology (e.g. Kenya and Zimbabwe) and a negative image where the political clout of the Ministry of Environment is strong (e.g. Ethiopia). A country's experience with private sector agricultural technology delivery appears to be a positive factor towards GM-friendly policy. Non-governmental organizations and civil societies are not yet a strong voice against biotechnology in Africa. African countries are likely to gain from the introduction of less contentious non-food GM crops such as cotton if a consensus among decision makers is achieved and institutions such as biosafety regimes are in place. In this regard, a transparent interaction among stakeholders should result in a shared vision required to balance GM regulation with the need to adopt available technologies as well as develop technological capability.

Conclusion

Biotechnology transfer to Africa has been mired by the raging trade-biosafety arguments, which in part is conditioned by the North-South technological divide. Many African countries do not anticipate significant advantage from the adoption of current GM crop technologies because of relevance, proprietary nature of the technology, and a negative reaction towards GM foods in Europe. Moreover, higher cost of knowledge-intensive technologies, lower margin of productivity and unfair trading regimes worsen the competitiveness of African products in domestic and external markets and discourage risk-taking with controversial GM crops. Nonetheless, Bt cotton may hold a promise if fair access to the technology is ensured and biosafety structures are put in place.

Impending pressure to observe unfair trade rules and IPR are likely to prompt Africans to continue raising the biosafety flag more than needed in order to avoid being cornered by unfavorable trade agreements. Africans may, however, not need to overstretch biosafety and socio-economic concerns to the extent of putting barriers against biotechnology adoption than the circumstances on the ground merit. Rather, African countries should seek ways for acquiring biotechnology to develop technological base and products appropriate for their conditions.

The private sector or public-private partnership has so far not delivered appropriate technology for the poor. Building domestic capacity is a sure way of targeting biotechnology to African problems. This calls for proactive formation of strong linkages with advanced research institutes and international organizations to source and transfer biotechnology to Africa. To this end, the current attempts to energize the public sector R&D through support from foundations, bilateral cooperation projects and other initiatives aimed at delivering products and developing human and physical capability should be strengthened. In many African countries, absence of adequate coordination of the existent but fragmented capacity across organizational barriers is a major constraint to biotechnology development.

Decision making on GM technology in Africa depends on the extent of political influence organizations and individuals muster in a country. GM technology appears to have a favorable reception where there are vocal scientists to articulate the merits of biotechnology and experiences with private sector technology delivery, and a negative image where the political clout of the Ministry of Environment is very strong. A transparent interaction among stakeholders should result in a shared vision required to balance GM regulation with the need to adopt available technologies as well as develop technological capability. Finally, biotechnology-proficient countries may need to understand the concerns of the poor and may put the trade magic behind to reassure Africans to see biotechnology through biosafety lenses only.

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