Innovation and Policy Process

Case of Transgenic Sweet Potato in Kenya

Biotechnology is being integrated into the existing science and technology policy process in Kenya. This process is embedded in the country's history of agricultural development, characterised by conventional technology, public goods research, and centralised and hierarchical organisation. This study employs the case study of the transgenic sweet potato project to explore how the development and introduction of modern biotechnology influence institutional and policy change in the generation and retention of (in)appropriate agricultural innovations for smallholders in Kenya.

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I Introduction

Biotechnology in Kenya was developed and introduced into an existing history and structure of agricultural development. Since the early 1970s, the Kenyan government's investments in agricultural research and extension (R and E) increased rapidly. This was a result of expanded GR technologies and financial and technical assistance to developing countries. For instance, the 1960s and 1970s experienced an increase in collaboration between the international agricultural research centres (IARCs) and the national agricultural research institutes (NARIs). With increased financial and technical assistance, the state had the means to expand its role in agriculture and rural development. From the mid-1970s, agricultural research focused on consolidating yield gains by broadening desirable traits as well as extending the benefits of GR to other crops, areas and other types of farmers.

In the 1980s and 1990s, the traditional model of technology transfer was criticised on the basis that economic growth had rarely 'trickled down' to the rural poor in most developing countries [Nyangito and Okello 1998]. The need for technological solutions that were compatible with Africa's diverse farming systems was discernible. In Kenya, the advent of biotechnology and its ease of integration with conventional plant and animal breeding provided an opportunity address the problems of poverty, hunger and malnutrition through sustainable agricultural productivity. A major problem facing Kenya's agriculture is declining agricultural production and available food. The main constraints to agriculture and food production include political, economic, technological, social and environmental factors. In particular, smallholders have few technological innovations that are compatible with their socio-economic conditions [Nyangito and Okello 1998]. Their access to government extension and external inputs such as seed/planting materials, fertilisers and pesticides has been reduced since the government began implementing the structural adjustment programmes (SAPs) in the mid-1980s.[1] It is within this history of agricultural development policy that modern biotechnology is being developed and introduced in Kenya. This paper is organised in six sections. The following section is an overview of Kenya's S and T policy. Sections III and IV respectively present the contemporary states of biotechnology and transgenic sweet potato programmes. How the case study influences S and T policy is discussed in Section V. Section VI concludes the paper.

I Contemporary S and T Policy in Kenya

Science and Policy Planning

Kenya's current development plan (1997-2001) acknowledges that given the difficulties of increasing land area under agriculture, sustained agricultural output will come from intensified production and rising productivity, especially to provide inputs for agro-based food processing. Considerable reform is needed, however to ensure sustained growth of agricultural sector, stable supply of food and availability of industrial raw materials in the country. Since the mid-1980s, agriculture and production has largely declined (Figure). This is attributed mainly to poor rainfall but also declining input use and general erosion of producer incentives arising from payment delays, weak implementation of structural reforms and inadequate support services to the sector [Beynon et al 1998; MOA&RD 1993-2000]. The policy reforms within SAPs were aimed at improving the supply of agricultural inputs, provision of producer incentives, reduction of subsidies, deregulation of agricultural markets, rationalisation of budgets, reduction of government shares and restructuring of public enterprises.

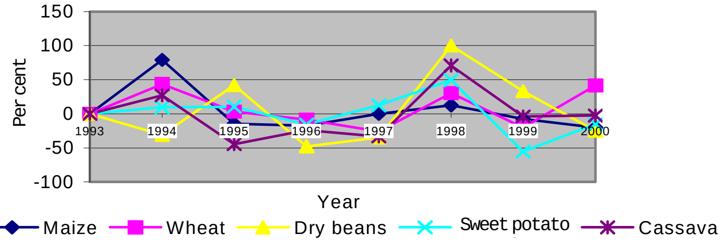
For instance, it was originally expected that use of modern inputs by smallholders would increase due to increased competition and marketing efficiency, but the majority of smallholders are now unable to afford the high prices of modern varieties of maize and fertilisers. Consequently, many are withdrawing from the use of MVs and reverting to the use of local varieties, which has a negative impact on maize yields [Egerton University 1990]. It is in this context that biotechnology is considered a viable option for improving agriculture and food production in Kenya.

Although Kenya has a broad science and technology policy constituency, it lacks a specific national policy and legal framework on biotechnology. Biotechnology R and D is evolving rapidly in a policy vacuum. Biotechnology is not mentioned in the current development plan (1997-2001), although it was mentioned for the first time, as a specific policy for agricultural development, in Kenya's Seventh Development Plan (1994-1996):

> The application of biotechnology in agriculture and livestock production will be nurtured and developed [GoK, Development Plan 1994-96:127].

While a certain degree of political will has been demonstrated, political commitment is still inadequate. This has not been forth-

Figure: Percentage Change in Production of Selected Crops



Source: Computed from MOA and RD Food Situation Reports 1990-2000.

coming in terms of increased allocation of financial resources for biotechnology R and D. Only 2.3 per cent of the total agricultural research expenditure is earmarked for biotechnology [ISNAR 2000]. Statements on biotechnology-related policy are often made by policy-makers during national or international events or meetings. This has led to the fragmentation of biotechnology programme and policy activities among various actors in the national agricultural research systems (NARSs). For instance, many of the scientific activities in the public research sector often reflect the interests of the concerned individuals or particular institutions, with minimum sharing of information among the stakeholders. Biotechnology activities are influenced by institutional research preferences and resources, which may not necessarily be guided by national priorities [Anyango and Shiundu 1999].

Policy and Institutional Environment

Structure of national agricultural research systems: As indicated in Table 1, there are five broad categories for analysing the structure of NARSs in Kenya, namely, academic, public, private, civil society and government regulators. Academic refers to agencies that combine university-level education training and research. The earlier variant employed scientists from particular disciplines who possessed conventional agricultural scientific knowledge. Academic research organisations were also hierarchical in their pursuit of academic prestige and scientific values.

The NARIs refers to collective research organisations employing scientists from different disciplines to respond to diverse agricultural needs by producing public goods. The most prominent NARI in Kenya is the Kenya Agricultural Research Institute (KARI). The NARIs include commodity research organisations, in which scientists are organised in a particular discipline or serve specific groups of producers. At the global level, corresponding and working closely with the NARIs are the CGIAR[2] systems, established in the early 1970s.

The opposite of academic and the NARI categories are the private research organisations, with the primary activity of generating private goods (mainly marketing and distribution of agro-chemicals and seeds) for profit. Many of the locally registered companies have global connections. Civil society groups are emerging, as agencies not directly controlled by the public or private sectors. But local traders, farmers' associations, NGOs and CBOs can be formal because they are registered by the state for the purpose of taxation and control.

Table 1: Organisational Synergy

Organisation Category	Number of Ties to Sector	Average Score of Tie Performance [b]
Academic: university	50	3.20
NARIs[a]	52	3.04
NGOs	19	3.37
Private	14	3.37
International	56	3.37
Government	36	2.83
Total	227	

Notes: a: KARI (ties =32 and score = 2.96), Other NARIs (ties =20 and score = 3.15)
b: 1= poor; 2= fair; 3= good; 4=very good; 5=excellent

Source: Odame and Mbote (2000).

The government or regulatory agencies are those that recruit personnel from universities and colleges, regardless of discipline, institute or commodity research focus. These include the Kenya Council of Science and Technology (NCST),[3] Kenya Plant Health Inspectorate Services (KEPHIS), and Kenya Intellectual Property Organisation (now KIPI or Kenya Intellectual Property Institute). These agencies regulate activities of several research organisations. This structure gives them greater political power to mobilise researchers and policy-makers. But it has led to divisiveness and instability when the research organisations are regulated by more than two agencies.

A survey of organisations conducted by Odame and Mbote (2000), which is summarised in Table 1, reveals that the highest number of ties is with IARCs having their head offices in Nairobi. These include the International Livestock Research Institute (ILRI), International Centre on Research and Agroforestry (ICRAF), International Centre for Insect Pest and Ecology (ICIPE) or having regional offices (such as CYMMIT, CIP, ISAAA) in Nairobi. This was followed by ties to NARIs (including KARI, which accounts for 32 of the estimated 52 ties. There are 50 ties to the universities, with 19 and 14 ties to NGOs and the private sector respectively.

Approximately 70 per cent of all the ties are linked to the three organisational categories, namely, international agencies,

Table 2: The Proportion of Scientific Staff to Total Employees

Organisation	Number of Employees	Number of Scientific Staff of	Per Cent of Scientists
JKUAT –Biotech centre	8	6	75
Plant Pathology –UoN	30	10	33
KARI-NVRC	342	35	10
KEFRI	1200	8	1
KETRI	690	10	8
TRF	165	5	3
Oserian Development Co	4000[a]	9	0.2
KEPHIS	315	80	25
KIPO	85	21	25

Note: a: A large number of these employees are casual labourers, working in the flower industry.
Source: Odame and Mbote (2000).

Table 3: The Ratio of Scientific Staff in Selected Research Organisations

Organisation	Number of PhD Staff	Number of MSc Staff	Number of BSc/other Staff	Total
JKUAT-Biotech centre	1	1	4	6
Plant Pathology-UoN	3	1	6	10
KARI-NVRC	8	8	19	35
KEFRI	1	1	6	8
KETRI	1	1	8	10
TRF	1	1	3	5
Oserian Development Co	0	0	9	9

Source: Odame and Mbote (2000).

NARIs and universities. Ties to government agencies account for 16 per cent, which leaves only 14 per cent ties with NGOs and the private sector. This demonstrates the dominance of research networks in S and T policy. It further confirms the prominence of upstream institutional linkages in the production of public goods research. In terms of tie performance, with the exception of ties to the government agencies, which are rated fair at 2.83, most of the scores fall within the range of good (3.04 to 3.37). The ties to KARI are rated fair at 2.96 and those to the other NARIs are rated good (at 3.15). A large number of ties are reported to be informal (personal relationships). Even where respondents indicated the existence of memorandums of understanding (MOUs), they were not sure about their contents.

I
Biotechnology in Kenya

Programme Initiatives

The systematic decision to invest in agricultural biotechnology was taken in the mid-1970s as part of the University of Nairobi's research initiative to generate appropriate technology with potential to augment or replace expensive and often unavailable chemical fertilisers [Odame 1997; Odame, forthcoming]. A second initiative in traditional biotechnology regards tissue culture. The decision was based on the belief that Kenyan researchers could rapidly supply diseasefree clean planting materials to farmers who needed appropriate technologies. Investments in tissue culture began in the early 1980s with its incorporation in the production of pyrethrum and citrus by KARI and University of Nairobi respectively. The market for tissue culture in agroforestry was also promising [Wafula 1999].

With the support of the Dutch ministry of international cooperation (DGIS), the Kenya/Netherlands Biotechnology Programme was set up in 1993 under the auspices of the KABP or Kenya Agricultural Biotechnology Platform (now BTA or Biotechnology Trust of Africa). The programme provided an opportunity for building the capacity of developing countries' to shape the technology towards their unique circumstances, and not to allow it to bypass them as was the case with the initial GR technologies. Apart from applying tissue culture to several crops, KABP also employed molecular marker technology for selection and maize breeding at KARI. This project aimed to develop cultivars resistant to insect pests, maize streak virus and for drought tolerance. It is with the scientific infrastructure and training established with the support of KABP that the current IRMA project is founded [Wekundah 2000]. In linking modern biotechnology with the problem of poverty, KARI in collaboration with Monsanto established a collaborative research programme to develop transgenic sweet potato (see details of the case study in Sections IV and V). The development and introduction of transgenic sweet potato and Bt maize had a direct or indirect impact on human resource development in Kenya.

Over the years, capacity building in agricultural research has tended to focus on hardware (physical facilities) and postgraduate training in MSc and PhD). However, the rapid expansion of physical facilities implied a low proportion of scientists to total employees in a given research organisation. A large number of non-scientific staff relative to scientific staff were required to maintain the physical facilities (Table 2).

Table 3 shows the quality of staff available in terms of ratio of PhDs, MSc and BSc/other technicians. It is difficult to determine the optimum proportion of scientific staff. However, agricultural research institutions often aim to achieve a target ratio of 30:30:60 for PhDs, MSc and BSc/other technicians, respectively.

According to sources at the CGIAR centres in Nairobi, a majority of scientists in Kenya may have basic scientific knowledge in genetics and molecular biology, but lack practical experience to effectively apply their existing knowledge to modern biotechnology. For instance, universities produce scientists with BSc and MSc but without practical training in modern biotechnology. The capacity of available scientists is also underutilised due to low levels of funding in terms of scientific infrastructure and actual research grants and staff salaries [Odame and Mbote 2000].

As Table 4 shows, agricultural biotechnology-related research activities are largely donor-funded. With the support of US $ 4.2 million from the Netherlands Directorate-General for International Cooperation (DGIS), the Kenya/Netherlands programme implemented under the BTA is the largest biotechnology programme in Kenya. The programme has since, mid-1990s supported biotechnology research projects on the potato, cassava and sweet potato, banana, citrus, macadamia, biopesticide dust, marker assisted breeding (MAB) in maize, animal health and institutional support [Wekundah 2000]. Within this programme MAB in maize projects received the largest funding US $ 1.1 million. The average funding for the other research projects was US $ 3,00,000 [Odame and Mbote 2000].

At US $ 2 million, the transgenic sweet potato project is the largest single biotech-

Table 4: Selected Biotechnology Projects and Funding

Organisation	Commodity/Policy	Objective	Technique	Funding Source	Level of Funding (US$)
UoN-Soils and Botany	Beans, soyabean	Nitrogen Fixation	Biofertilisers	Various	na
JKUAT -Biotech	Bananas, sweet potato, cassava	Micro-propagation	Tissue culture	BTA/DGIS	2,50,000
KEFRI	Multi-purpose tree species	Micro-propagation	Tissue culture	EU	3,82,000
TRF, Oserian Co	Tea, cut flowers	Micro-propagation	Tissue culture	Company	na
KARI, KEPHIS	Pyrethrum, potato, sweet potato	Micro-propagation	Tissue culture	Government	na
KARI-Katumani	Maize	Drought tolerance	Marker techno	BTA/DGIS	11,00,000
KARI-Katumani	Bt Maize	Insect resistance	Bt technology	Norvatis Found.	4,0,00,000
KARI	Transgenic sweet potato	Disease-resistance	DNA Technology	Monsanto/others	20,00,000
KARI-NVRC	Livestock	Disease control			
KETRI	Livestock	Disease control		IAEA	25,70,000
		Tryps resistance		DFID	1,00,000
TRF	Tea	Gene Mapping	Marker techno	Brooke Bond	
ICRAF	Priority tree species	Biodiversity	Marker techno	CGIAR	na
ILRI	Livestock	Biodiv./diseases	DNA Technology	CGIAR	60,00,000
KIPI	IPRs	Training	Short courses	WIPO	na
NCST	Biosafety Guidelines	Training	Short courses	BTA/DGIS	1,20,000
				UNEP-GEF	na

Source: Odame and Mbote (2000).

nology research contribution by a private sector company, Monsanto. Kenya Trypanosomiasis Research Institute (KETRI) has since the early 1990s, received public funding of US $ 25,70,000 from IAEA for livestock disease control and US $ 1,00,000 from DFID for trypanosomiasis tolerance research. Due to geographical proximity, Kenya also benefits from research activities of supranational organisations such as ICRAF, ILRI, and ICIPE. For instance, ILRI spends approximately US $ 6 million per year on biotechnology-related livestock research. Some research organisations and farmers in Kenya may benefit through their collaborations with ILRI and other centres.

Excluding the international organisations, over US $ 10 million has been spent on tree, crop and livestock biotechnology-related research in Kenya in the past 10 years. All ag biotechnology research projects are donor-funded for a period of five years.

It appears that the history and level of use of available biotechnology tools, human resources and funding has a direct influence on the state of agricultural biotechnology in developing countries [Sasson 1998] such as Kenya [Mbote and Wafula 2000]. For instance, traditional techniques such as biofertilisation and tissue culture are the dominant feature of biotechnology research in Kenya (Table 4). Agricultural biotechnology R and D activities take place in public universities, NARIs and IARCs located in Kenya or have regional offices in Nairobi. However, increasingly, there are opportunities for engaging in modern biotechnology R and D programmes and policies through collaboration with national and international agencies. One such initiative is the transgenic sweet potato project.

IV
The Case of Transgenic Sweet Potato in Kenya

Background

Transgenic sweet potato (TSP) research project involved the development of varieties that are resistant to virus diseases. The most common viral diseases affecting sweet potato are sweet potato feathery mottle virus (SPFMV), sweet potato chlorotic stunt virus (SPCSV) and sweet potato mild mottle virus (SPMMV). These diseases simultaneously cause the sweet potato virus disease (SPVD). Conventional approaches to breeding varieties resistant to SPVD have not been effective in combating the disease. It was realised that this could be complemented by non-conventional means involving the use of biotechnology.

Transgenic sweet potato is resistant to the feathery mottle virus (FMV) and has the potential of increasing the yields of sweet potato roots and foliage. With financial assistance from USAID/ABSP, a collaborative research project between Kenya Agricultural Research Institute (KARI) and Monsanto was launched in 1991 to develop a virus-resistant sweet potato. The initiative was an innovative undertaking based on public/private partnerships. The project is considered to be a groundbreaking initiative for the introduction of the first transgenic crop into Kenya.

Results of laboratory tests at Monsanto (US) and initial field trials in Kenya reveal that transgenic sweet potato has good yield potential. Already, selected lines of CPT560 achieved a minimum yield increase of 18 per cent of sweet potato from an annual average production of 6 $tha^{-}1$. Apart from yield potential, the cost of transgenic sweet potato planting materials will be negligible. Hence the technology will be more affordable poor farmers. Furthermore, sweet potato is transplanted by cuttings, which are lighter to transport and do not require new skills to use. Although the project began in 1991-92, farmers have not yet received the virus resistance technology for adoption. The underdeveloped biosafety system resulted in delays in the transfer of technology. However, it is expected that the technology will officially be released for commercial use in 2002.

Smallholder Needs of Transgenic Sweet Potato

Sweet potato has been cultivated in Kenya since the end of the 19th century and is the second most important and widely distributed food security crop after maize. It is considered a staple food crop for many rural and urban families and is increasingly becoming an important cash crop for urban markets [Durr and Lorenzyl 1980]. The crop is mainly grown by poor farmers and is cultivated on about 75,000 ha spread over various agroecological zones in the country [Qaim 1999]. The ability of sweet potato to adapt to a wide range of growing conditions, in both fertile and marginal areas, makes it a versatile crop for Kenya's farming systems [Gibbons 2000].

However, over the years, the major problem facing sweet potato farmers is low yield, which is the result of high losses due to pests and diseases and inadequate quantities of clean planting materials. Sweet potato harvests have declined over the years and remained low due to attacks by pests and the sweet potato virus disease. Yield losses due to the virus can be as high as 80 per cent, according to KARI (2000). Kenya's average sweet potato yield stands at 6 tha^{-1}, less than half the world's average of 14 tha^{-1} [Mungai 2000]. China has realised yields of 18 tha^{-1} [Hinchee 1998]. The advent of modern biotechnology motivated researchers to conceive a collaborative programme to address the low yields of African sweet potato.

Collaborative Research and Training

Transgenic sweet potato research in Kenya was conceived within the framework of the Agricultural Biotechnology for Sustainable Productivity (ABSP) project, supported by the United States Agency for International Development (USAID). The ABSP project is coordinated by the Michigan State University (MSU). The project involves research collaboration between (and among) public and private research sectors in the US, and mainly public research sector in developing countries, namely, Egypt, Indonesia, Costa Rica and Kenya.

The initiative to develop genetically modified sweet potato that is resistant to the virus is mainly composed of researchers from Monsanto and KARI, with some contribution from the Central Research Institute for Food Crops (CRIFC) in Indonesia. Within the ABSP framework, the mandate of transgenic sweet potato is technology access/generation and technology transfer to developing countries such as Kenya. This includes germplasm collection, transformation and testing in the US and developing countries, training scientists, administrators and policy-makers on the application of biosafety procedures and intellectual property rights (IPRs) [Ives et al 1998:1].[4]

The development of virus resistant sweet potato transformation began in 1991. Financial support for the project came from USAID and Monsanto. KARI and Monsanto scientists carried out research and studied the technical aspects of transformation involving six Kenyan sweet potato varieties against SPFMV using a Monsanto donated virus coat protein (*cp*) gene. The basic research components of the project such as the development of suitable biotransformation and plant regeneration protocols were conducted at Monsanto in St Louis, US, in collaboration with KARI scientists [Gibbons 2000].

Initially, only one of the six original sweet potato varieties, the CPT560, was successfully transformed using SPFMV *cp*, but 195 lines of CPT560 had been transformed by the year 1997. Transgenic sweet potato is developed using genetic engineering techniques, although in other parts of the world, such as China, research efforts on sweet potato are still using conventional plant breeding methods to induce disease resistance [Odame forthcoming].

The actual transfer of the recombinant sweet potato technology from Monsanto to KARI took place in April 2000. This process lasted three years because it coincided with global concern over transgenic crops, especially with respect to IPRs and biosafety issues. Arrangements to introduce the transgenic sweet potato into the country took place at a time of establishment Kenya's biosafety guidelines and the National Biosafety Committee (NBC). As a result, approval for field evaluation was a slow and learning process given that this was the first case of a genetically modified organism (GMO) to be handled in the country. The NBC also acknowledged being constrained by human resources in terms of molecular scientists as well as the need to follow stringent and precautionary biosafety procedures and measures. Following two years of reviewing the application, NBC approved the introduction of transgenic sweet potato in the country. The Kenya Plant Health Inspectorate Services (KEPHIS), a regulatory authority responsible for enforcing biosafety regulations, issued the plant importation permit to KARI in December 1999.

At present, on-station trials are being conducted in at least five different agro-ecological zones in Kenya. The country is characterised by diverse agroecocological conditions, which in turn influence farmers' preferences for particular sweet potato varieties or clones. The project is reported to be undertaking crop transformation of popular Kenyan varieties for disease resistance to develop a variety of clones that can satisfy the diverse varietal preferences of sweet potato producers and consumers.

Aside from varietal trials, biosafety evaluations are being done at various KARI stations to generate sufficient data before the technology is taken to farmers.

On-farm evaluation will be done with the involvement of farmers to establish protection, agronomic performance, consumer valuation and acceptance of the technology. Regarding intellectual property rights (IPRs), transgenic sweet potato technology is not patented. It was donated as a public good (orphan commodity[5]) [Qaim 1999].

To summarise, the Monsanto and ABSP project made concerted efforts to facilitate the transfer of transgenic plants developed at Monsanto to Kenya. ABSP project also provided a framework for technology transfer to developing countries and supported post-doctoral research at Monsanto and short-term visits of several Kenyan scientists to Monsanto. The International Service for Acquisition of Agbiotech Applications (ISAAA) supported a number of researchers from KARI to travel to the US for short-term capacity building courses including establishment of institutional biosafety structures, preparation and submission of biosafety permit applications, and laboratory and field biosafety evaluation of transgenic crops [Gibbons 2000]. Kenya Intellectual Property Office (KIPO) personnel and other government officials were also encouraged to attend workshops on IPRs. In retrospect, the programme has contributed to the technical and legal capacity building for modern biotechnology at the national level. However, the project is yet to show a shift in its research orientation towards closer interaction with user groups at the local level. These user groups will ultimately influence the wider use of transgenic sweet potato in Kenya.

V
Policy and Legal Implications

It appears that a team of scientists from the KARI, Monsanto and ABSP project attributed the low production of sweet potato in Africa to primarily pests and diseases. They stressed the need to increase the yields of sweet potato using the coat protein approach towards resistance to sweet potato virus disease, especially the SPFMV. However, evidence shows the problem of low production of African sweet potato may be attributed to several factors. These include the complexity of sweet potato virus disease (SPVD), selectivity of sweet potato clones on the basis of their preferred agronomic, quality and quantity characteristics, cultural practices of freely exchanging planting stock, and the need for product markets to stimulate use of inputs.

This raises questions about the appropriateness of transgenic sweet potato for farmers' priorities and the interests of scientists in the choice of sweet potato.

For example, does the development and introduction of modern biotechnology in Kenya lead to a change in the scientists' attitudes towards stronger linkages with key stakeholders in the generation of appropriate innovations for smallholders? In addressing this question, we reflect on the transgenic sweet potato project as a model where scientists from the public and private sectors collaborate to adapt a commercial technology for subsistence farmers in Kenya and elsewhere in Africa. In particular, we discuss the change related to each of the four elements (production, science, regulation and organisation) of the S and T policy process.

Production

Modern biotechnology is often justified on the basis of addressing food insecurity and poverty in Kenya [Wafula 1999]. In particular, transgenic sweet potato is promoted for its potential to reduce the incidence of disease infestation and increase yields. It has the potential to increase yields of roots by 40 per cent for food and sale as well as fodder for livestock feed [Wambugu 2001]. The technology is relatively cheaper because farmers can freely exchange planting materials. It is also easy to use because of its compatibility with existing production practices.

However, critics point out that given that viral infection on sweet potatoes is a complex of three viruses, of which the feathery mottle virus (FMV) is only one part, the extent to which CPTO 560 will control the complex virus remains uncertain. The complexity of the technology and biophysical conditions of farmers' fields will remain major constraints in generating and retaining satisfactory innovations for farmers [Odame forthcoming]. According to sources at CIP in Nairobi, the ideal situation is that there should be at least two sweet potato clones per each agroecological zone. Therefore, any research strategy ought to recognise the diversity of sweet potato varieties that farmers produce to meet different agronomic and nutritive qualities [see for example FAO 2000]. But this process requires money and time. Yet public expenditure in agricultural research has been declining.

Even if funds become available, there will still be problems of whether the desired local germplasm will be amenable to transformation and regeneration. This contradicts the general claim that the technology will improve food and agricultural production of farmers, and hence their livelihoods. Supposing that an appropriate technology is made available, it will still have to be diffused to farmers [Egerton University 1990]. KARI researchers are rethinking delivery systems to farmers as they prepare to move the technology from the research stations to farmers' fields. Closely related to this issue is linking research with downstream institutions. Although still weak, the programme under the agricultural research competitive grant [Odame forthcoming], is attempting to make some links with NGOs and farmer groups. But missing in these linkages is the private sector, especially local seed traders. Yet an increase in the availability of markets for sweet potato (roots and leaves) will stimulate farmers to increase yields through intensification (use of high-yield varieties) and/or extensification, through increased area under the crop [Odame forthcoming].

Apparently, the transgenic sweet potato programme did not directly involve farmers, especially women farmers, in the setting of research agenda. This might partly explain the divergence in priorities of farmers and those of scientists. Whereas scientists are focused on generating virus-resistant sweet potato to increase yields, the farmers are more concerned with the existing constraints to utilisation and marketing of sweet potato. Under these circumstances, the research project is unlikely to result in an appropriate or profitable technological innovation for smallholders in Kenya.

Science Issues

The development and introduction of the transgenic sweet potato research programme resulted in capacity training for KARI scientists. This allows scientists to apply the knowledge to other crops. The programme also enhanced the career of some scientists through post-graduate training programmes, publications and overseas trips to attend international conferences. It also contributed to scientific infrastructure for field evaluation and further development of transgenic sweet potato in the country. In particular, the programme contributed to the updating of the laboratory facilities. As an international requirement, the ABSP project and Monsanto insisted that KARI put in place minimum requirements of a containment laboratory prior to the importation of transgenic sweet potato material for field evaluation [Odhiambo 2000].

However, critics of the programme have pointed out that it was limited to a few scientists and short courses. There was limited contribution to the long-term strategy for achieving a critical mass of human resources needed to effectively engage in modern biotechnology. For instance, the programme acknowledges that due to lack of human resources, especially molecular scientists, NBC had to delay the approval of the application to import transgenic sweet potato plants into Kenya. The country is currently facing a crisis of training and retaining scientists. The few scientists that are highly trained leave the country for better opportunities in Europe, North America and South Africa (report in the *Daily Nation*, 2000-2001). This points to underutilisation of existing capacity, mainly as a result of poor scientific infrastructure and funding. For instance, apart from US $ 2million spent on the laboratory phase of transgenic sweet potato programme, KARI had to look for funding for field testing and further development of the technology.

The programme is also faced with the challenge of linking science and production. It appears that scientists did not effectively engage the public to create awareness about transgenic sweet potato. They are also yet to address farmers' real needs and priorities in the production and marketing of sweet potato. In recent fieldwork in western Kenya, farmers identify sweet potato utilisation and marketing as major constraints in for its increased production [Odame forthcoming]. This implies that unless there is a radical change in innovation at the local level, the existing cultural practices of selecting planting stock, production and utilisation of the sweet potato will persist. This shows that although transgenic sweet potato is a radical innovation in terms of high intensity of science, costs and regulatory frameworks in the upstream research networks, it is characterised by incremental changes in the downstream research.

Regulatory Matters

Intellectual property rights: Recent initiatives on modern agbiotech transfer to KARI involved proprietary technologies donated by international organisations. The IPR implications for the donated technologies will be through plant breeders rights (PBRs) granted to KARI. PBRs in Kenya are implemented under the UPOV convention. Kenya acceded to the 1978 UPOV Convention in 1991 and incorporated it under the Seeds and Plant Variety Act 421 laws of the country. This act excludes farmers and encourages commercialisation and privatisation of plant-breeding activities (see the UPOV 1978 version).

For instance, by December 2001, there were 541 applications for PBRs in Kenya – with 259 applications originating from Kenyans. Approximately 123 (47 per cent) of the Kenyan applications involved food crop varieties that were previously bred by public institutions as goods for the benefit of the public. These include maize (54), wheat (30), sorghum (6), pearl millet (3), dry beans (13), peas (6), pigeon pea (4), potato (4), cassava (2) and sweet potato (1).[6] Although the individual or institutional applicants are yet to reap the benefits of their research efforts, the situation is likely to change soon. For some critics, this trend is likely to lead to greater uniformity and a further narrowing of the genetic base of sweet potato and other major food crops in the country. The introduction of transgenic sweet potato in smallholder agriculture may increase the transaction costs of accessing the planting stock. Additionally, there is the potential cost of loss of livelihoods, knowledge and materials [Odame forthcoming].

In general, the promotion of IPRs in Kenya is a long-term challenge for the existing knowledge systems in the changing face of technology transfer. Although many of the basic standards enshrined in the PBRs in the UPOV 1991 are held to be universally valid, other standards are contingent on particular historical, economic and institutional circumstances or linked to particular geographical and cultural contexts. Over time, the current systems of protecting traditional knowledge and indigenous innovations may lose to regulatory power and coverage of IPRs. As such, there is a need to establish new institutional arrangements such as the sui generis system which is sensitive to impropriety of monopoly rights to agricultural knowledge. At the institutional level, employment contracts should incorporate benefit sharing from innovation for the employer and employee [BIO-EARN 2001]. IPR training also becomes consistent with a human resource development focus for scientists, lawyers, bureaucrats and the general public (ibd).

In the absence of these innovations, agricultural and livestock research in developing countries will be stifled. As a public policy concern, the TRIPs agreement requires that available patents enjoy patent rights without discrimination of place of origin, field of technology and whether products are imported or locally produced. Indeed, the agreement works against developing countries [see also Belcher and Hawtin 1991:29]. Consider the following scenario in Kenya. By December 2001, of 934 patent applications granted in Kenya through the Kenya Intellectual Property Institute (KIPI),[7] only 33 patent applications originated from Kenya; and only two were granted to the

Kenyan R and D institutions [BIO-EARN 2001]. This implies that Kenya and other developing countries have to pay fees and royalties if they need to access these intellectual assets [see also Persley and Lantin 1990:337; UNESCO 1998].

Biosafety framework: The establishment of Kenya Biosafety Guidelines and the National Biosafety Committee (NBC) by the National Council of Science and Technology (NCST) coincided with the transgenic sweet potato project. The guidelines aimed at harmonising the country's national laws with the international biosafety framework as articulated by the Convention of Biological Diversity (CBD) [Republic of Kenya 1998]. As a result, NCST received support from international organisations. For instance, the Kenya Agricultural Biotechnology Platform (now BTA, a Biotechnology Trust of Africa) provided US $ 1,20,000 as part of initial support for capacity building in biosafety [Wekundah 2000]. Later on, NCST also received support from UNEP-GEF as part of the pilot scheme for the formulation of a national biosafety framework.[8] At the project level, the transgenic sweet potato programme supported short courses for KARI scientists and administrators. This externally-funded project process directly or indirectly contributed to the current state of biosafety framework in Kenya.

In this context, critics of the process have accused NCST of being influenced by external pressure in formulating the National Biosafety Guidelines. In particular, some critics singled out KARI researchers for making the government believe that NCST could effectively implement the international biosafety regulations. For example, they charge that many of the training courses provided during the formulation of the guidelines since 1994 were really geared towards adapting some blueprints of other biosafety regulations rather than seeking to build the capacity of NCST on a long-term basis [see for example Paarlburg 2000]. Moreover, they argue that NCST completed biosafety guidelines in 1998, only a few months before issuing a permit to KARI to import transgenic sweet potato (TSP) plants for field trials in Kenya. That of Bt Maize soon followed the approval of transgenic sweet potato in 1999.

Thereafter, NBC has received several applications from KARI for field testing of transgenic crops. The applications still pending approval include Bt Cotton, Bt Potato, Bt carnation. Given that KARI has made most applications, it is claimed that KARI and its collaborators exerted pressure on the NBC to speed up the formulation of biosafety guidelines. It is further alleged that NBC was taking undue risks by approving GM crops for field trials, given its lack of capacity and legal instruments to assess risks and enforce compliance.

According to some critics, KARI was used by the industry to introduce GM into Kenya and other African markets. This argument is based on the fact that Kenyan scientists are yet to develop their own GM product. In dealing with imported transgenic crop varieties, the committee is often forced take precautionary measures to cover its lack of capacity to conduct its own comprehensive risk assessments. For instance, a flurry of print media exchange (reports in the *Daily Nation* 2000-01) between KARI and NBC brought to the fore the disagreement over the pace of the approval process between the research body and the regulatory agency. KARI was incensed with the persistent delays in the approval process of GM crops. Some KARI scientists accused the NBC of inefficiency, saying the committee even lacked a secretariat to facilitate effective communication. For instance, the application for transgenic sweet potato took at least two years before it was given approval for field trials, partly due to lack of molecular scientists to inform the process. This means that NBC lacks capacity not only to process applications, but also to assess and manage risks at the local level, especially as preparations are underway to move transgenic sweet potato plants from the research stations to farmers' fields.

Organisational Issues

Following the poor public image of agricultural biotechnology industry in developed countries, a series of initiatives by the corporate sector emerged to build scientific and regulatory capacity of developing in this area. One such initiative was the programme to develop virus-resistant sweet potato. Scientists at USAID, and Monsanto, an international agribusiness company, conceived the programme in the early 1990s.

Aware of some scientific interests to link biotechnology and food security in Kenya, the programme sought to form a partnership between KARI and Monsanto. The programme, through the support of Cyrus Ndiritu, director of KARI, and John Wafula, biotechnology programme director, identified Florence Wambugu. Wambugu was then a research scientist responsible for formulating disease resistance strategies for sweet potato in the roots tuber programme at KARI, in Nairobi, Kenya. The research team of KARI and Monsanto scientists used donated coat protein technology, which was developed by Monsanto, and germplasm brought in from KARI by Wambugu, to produce the SPT560 variety that is resistant to SPFMV.

Essentially, some KARI scientists had to collaborate with the private sector. This allowed them to learn more about balancing public and private interests and values. At the organisational level, public goods research and weak downstream linkages, especially with the local entrepreneurs, characterise KARI, whereas Monsanto is motivated by private goods research, which is mediated by IPRs. Therefore, does transgenic sweet potato as a donated technology by Monsanto to KARI serve as a market opener, thus forcing KARI to link with local businesses?

Regarding media communication, there is a tendency for negative reporting, especially the association of modern biotechnology with uncertain risks while being reluctant to highlight its certain benefits. Indeed, a majority of scientists in Kenya acknowledge that the negative views on modern biotechnology are often shaped by the media, but they are yet to embrace professional use of the mass media such as radio. For instance, KARI researchers on the transgenic sweet potato programme have been rather defensive in dealing with the media. For some critics, this may be attributed to their inertia and lack of innovative ideas to communicate to the public.

Therefore, without KARI rethinking the inter- and intra-organisational interactions and communication, the development and diffusion of transgenic sweet potato reverts to the traditional model of organising technology transfer. This raises the question of how the developments in transgenic sweet potato have contributed to organisational changes at KARI and the entire science and technology (S and T) system in Kenya.

VI
Conclusion

This paper has attempted to show that there is no explicit policy and legal framework for the development and introduction of modern biotechnology in Kenya. Rather, it is integrated in the existing structure of science and technology in the country. This structure is characterised by a history of inertia and even rigidities. At the same time, it is changing in response to market and macroeconomic conditions brought about by the implementation of structural adjustment programmes since, mid-1980s. Another source of change is the advent of modern technologies, especially agricultural biotechnology. However, there are efforts at various levels to formulate a biotechnology policy and framework legislation.

The transgenic sweet potato programme generated some new activities in Kenya's S and T policy and institutional environment in terms of capacity building for scientists, private-public partnerships and the development of biosafety guidelines in the country. However, the extent to which this example can be replicated remains uncertain. The lack of clear policy on modern biotechnology, while not restricting individual initiatives, leads to fragmented programmes with indeterminate effect on policy and institutional change in the country. This has long-term effect on capacity building for scientific infrastructure and funding, institutional synergy and regulations to shape modern biotechnology innovations towards societal needs of the majority smallholders. For instance, as a result of lack of molecular scientists and minimum containment facilities, the testing of transgenic sweet potato was delayed for over two years. This situation becomes more critical as KARI researchers prepare to move the technology from their research stations to farmers' fields.

Apart from donated technologies such as transgenic sweet potato and Bt maize research projects, there are no other private-public projects in Africa. This has led critics to argue that these token transgenic crops were used by the industry as market openers for more transgenic crops in Kenya and elsewhere in the county. Indeed, in the absence of a biotechnology policy framework, the stakes are left in the hands of the industry to influence the scientists and policy-makers in the country. Therefore, biotechnology serves the interests of the few as opposed to the wider Kenyan society. EPW

Notes

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1 Pests and diseases are one of the limiting factors of crop production including cassava and sweet potato in Kenya. In western Kenya, the cassava mosaic virus has destroyed much of the cassava crop. The significant reduction in cassava production has led to increased pressure on sweet potato.

2 Among IARCs, CIMMYT and IRRI were established in the early 1960s. Today, there are 16 such centres worldwide with five of them located in Africa (ICRAF, ILRI in Kenya, IIATA in Nigeria and WARDA in Mali).

3 NCST, which is responsible for Science and Technology (S and T) policy in Kenya, was established in 1977 under the Science and Technology Act, Chapter 250 of the Laws of Kenya.

4 The specific objectives of the virus resistant sweet potato programme were: (i) to develop transformed Kenyan sweet potato varieties with resistance to sweet potato feathery mottle virus (SPFMV) at Monsanto and to transfer these to Kenya, (ii) to train KARI scientists and technical staff in all aspects of technology including biosafety evaluation and Intellectual Property Rights (IPRs) and (iii) to evaluate and improve production of transgenic sweet potato in Kenya [KARI 2000].

5 'Orphan commodities' refers to technologies developed by the industry to address problems of resource-poor farmers.

6 These figures were extrapolated from BIO-EARN (2001a).

7 KIPO (now KIPI) is the responsible authority for the implementation of industrial property law in Kenya [see Republic of Kenya 2000].

8 NCST worked under Biosafety framework for Kenya. Prepared under UNEP/GEF pilot 'Biosafety Enabling Activity Project'.

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