6

Kenya's Incipient Innovation Capacity in Biotechnology

6.1 Introduction

The development of biotechnology in Kenya over the last two decades reflects a steady transition from traditional, low-end biotechnologies such as fermentation, bio-fertilizers, and tissue culture techniques (Odame et al., 2003) towards more sophisticated, modern techniques and applications comprising the use of molecular markers, novel vaccines, diagnostic tools, and genetic engineering.

The initial developments in biotechnology in Kenya can be traced to the early 1980s with the application of tissue culture in crops such as citrus fruits (Kenya Agriculture Research Institute, KARI) and pyrethrum (University of Nairobi). In many organizations, the application of these techniques was largely done as an increment to ongoing conventional breeding programmes. By the end of the 1990s, several local research organizations had taken up tissue culture and were applying it across a broad range of products. Table 6.1 below shows the extent of application of tissue culture a decade ago, by organizations and products.

During the same period, the use of biotechnology in livestock research and development also began, mainly focusing on the generation of disease diagnostic technologies employing hybridoma and DNA molecular techniques. KARI pioneered the application of molecular marker selection techniques in 1995, focusing on maize breeding geared towards isolating and developing cultivars resistant to insect pests, maize streak virus, and drought tolerance. Since then, molecular marker assisted breeding has been applied in the following areas in the country (Gichuki, 2006):

- Characterization and mapping of Grey Leafy Spot (GLS) resistance genes using microsatellite markers.

Table 6.1 The state of tissue culture in Kenya as of 1998

Institution	**Crops**
KARI	Pyrethrum, banana, strawberry, cassava, potato, and sweet potato
KEFRI	Camphor wood (*Ocotea usambarensis)*, Silky oaks (*Gravillea robusta*) Mvule (*Chlorophora excelsa*) and *Eucalyptus grandis*
Universities	Banana, citrus fruits, sugarcane, pawpaw
*Oserian Dev. Company	Flowers
*Genetic Technology Limited (GTL)	Bananas, sugarcane, flowers
Kenya Seed Company	Vegetables
Tea and Coffee Research Foundations	Tea and coffee

Source: Wafula (1999).
Note: * Private companies.

- Introgression of MSV resistance into maize lines resistant to GLS disease.
- Selection of smut resistance in sugarcane.
- Diversity studies for sweet potato and cassava.
- Characterization of indigenous species of cattle and forages.
- Characterization of tsetse flies.

The first modern biotechnology-based product to be developed in Kenya was a genetically modified (GM), virus-resistant (VR) sweet potato. This project started in 1991 and was a public–private partnership (PPP) between the United States Agency for International Development (USAID), KARI, and the Monsanto Company. Although the product itself did not stand the rigour of field trials, the GM sweet potato was held up to be an example of successful collaboration between the global private sector and a latecomer public research institution due to three key reasons:

(a) Its capacity building element, where several KARI scientists were trained in Monsanto laboratories during early stages of the project.
(b) Monsanto and KARI signed a non-exclusive, royalty free licensing agreement in 1998 which allowed KARI to develop other transgenic virus technologies for sweet potato building further on the existing work.
(c) KARI is permitted to protect the new creations under Kenya's plant breeders' protection regime.

Table 6.2 elaborates upon the collaborators and partners in the sweet potato project.

Since then, work on several other genetically modified crops has been ongoing in Kenya through the public-private partnership mechanisms (Kirea, Awuor, and Asali, 2003; Clark et al., 2005). Table 6.3 shows the current status of modern biotechnology in Kenya.

Table 6.2 Collaborators and partners in the sweet potato project

Collaborators	**Nature of collaboration**
KARI	• KARI scientists working at Monsanto Company were involved in the development of the gene constructs, transformation protocols, and regeneration systems for the transgenic sweet potato. • KARI staff members carried mock trials on CPT 560 and other local varieties. • KARI has developed an operational biotechnology laboratory for further transformation of local African sweet potato genotypes.
USAID/Agricultural Biotechnology Support Programme (ABSP)	Provided the financial assistance
Monsanto Company (St. Louis, US)	• Donated the genes of interest. • Monsanto also supported the initial research support for the genetic transformation of six Kenyan sweet potato varieties.
International Potato Centre (CIP)	International Potato Centre researchers collected data on crop establishment, crop vigour, vine, and storage root yields and response to sweet potato virus based on protocols during the trials.
KEPHIS	Granted KARI a biosafety permit for on-station field-testing after its approval by National Biosafety Committee.
ISAAA	• Material transfer agreement • Brokered the Intellectual Property Rights (IPR) negotiations between Monsanto and KARI and a royalty-free licence agreement between the two was signed in 1998. • Helped in identification of appropriate partners for the different implementation stages
Danforth Plant Science Centre, US	Offered technical support

Source: Authors' survey (2006–7).

Table 6.3 Status of modern biotechnology (genetic modification) projects in Kenya, 2006

Transgenic crop/product	Desired trait	Institutions involved	Year of approval	Status, 2006
Bt Maize	Insect resistance	KARI/CIMMYT with financial support from Syngenta Foundation	2001 (leaves) 2003 (seeds)	Undergoing contained field trials/ evaluation since May 2005
Bt Cotton	Insect resistance	KARI/ MONSANTO	2003	Contained trials
Transgenic sweet potato	Viral resistance	KARI/ MONSANTO/ Danforth Centre (US); ARC-VOPI; ISAAA	1998	Contained trials
GM Cassava	Cassava mosaic virus	KARI/Danforth Centre (US); USAID (ABSPII)	2003	Contained trials
Rinderpest vaccine	Disease control	KARI, Pirbright (UK), University of California	1995	Contained trials

Source: Modified by authors from IRMA (2004) and Gichuki (2006).

6.2 Key actors generating agricultural biotech innovation and knowledge

The majority of research projects on agricultural biotechnology in Kenya are concentrated in the public sector with a predominance of donor funding. Of these, KARI is involved in the largest number of biotechnology research programmes and projects spanning both crop and livestock domains. Most of the modern biotechnology research projects are collaborative projects (through private–public partnership mechanisms) between KARI and international partners with financial support from the international private sector and international donors (Clark et al., 2005). Table 7.4 shows the range of research and product development activities involving Kenyan scientists and researchers as of 2006. The current agricultural biotechnology projects are as listed in Table 6.4 below.

Table 6.4 Current agricultural biotechnology projects in Kenya (2006)

Technology	**Developed by**	**Description**	**Year**	**Status**
Transgenic sweet potato CPT 560 With resistance top sweet potato feathery mottle virus	Wambugu, F. and Monsanto USA	Sweet potato transgenic lines (CPT) expressing coat protein gene of sweet potato feathery mottle virus (American isolate)	1996	Development discontinued in 2002
Transgenic sweet potato CPT 560 & KSP 36 with resistance to sweet potato feathery mottle virus	S. T. Gichuki, J. Machuka, E. M. Ateka, I. Njagi, J. Irungu	Sweet potato transgenic lines (CPT 500, KSP36) expressing coat protein and replicase genes of sweet potato feathery mottle virus (Kenyan isolate)	2003–5	Still under evaluation at contained biosafety glasshouse level
Transgenic maize with resistance to stem borers	CIMMYT and KARI scientists	Transgenic maize events carrying Cry IAb and Cry IBa genes (isolated *from Bacillus thuringiesis*) for protection of maize against stem borers	2001–5	Undergoing confined field evaluation and conversion
Transgenic maize (MON 810)	E. M. Ateka, H. Ngesa, S. T. Gichuki and Monsanto South Africa Ltd.	A maize hybrid (DKC8073YG) carrying a cry IAb gene (isolated from Bacillus thuringiensis) for protection of maize against stem borers	2005	Application for evaluation under containment has been made to the NBC and waiting approval
Regeneration and transformation protocols for tropical maize	Songa J. Binot J. Sitieney J.	Regeneration of Kenya maize varieties through embryo rescue techniques	2004	Several KARI maize lines have been successfully regenerated and transformed
Bt isolates with potential for controlling Larger Grain Borer (LGB) and Maize Weevil (MW)	Songa J. Wamaitha J.	Local Bt. isolates that have been bio-assayed and have shown potential for controlling the larger grain borer and maize weevil	2004	Characterization of the isolates continuing. Search for more isolates continuing. Genes will be cloned from the best isolates

(*Continued*)

Table 6.4 (Continued)

Technology	Developed by	Description	Year	Status
Transgenic cassava with resistance to cassava mosaic disease (CMD)	Taylor N. Faquet C. Gichuki S.T. Njagi I. Wangai A.	Cassava expressing the AC1 replicase and the DI defective interfering particle gene of cassava mosaic virus	2002–5	Confined field trials proposed. New products of Kenya varieties being developed
Cloning of two genes fro starch branching enzyme IIa(*sbella*) and IIb (*sbellb*) in sorghum	Joel Mutisya	Both genomic and cDNA sequences of *sbella* and *sbellb* were cloned. CDNA sequences were cloned from KARI Mtama 1 sorghum variety. Thyme are between 2.6 to 2.7 kb in size	2003	The *sbellb* sequences were deposited in the gene bank but *sbella* has not yet been deposited
A promoter from sorghum to drive gene expression	Joel Mutisya	Derived from sorghum genome. Used to drive a gene for starch branching enzyme IIb *in vivo*. Size is 2.7 kb. Fully characterized. Ideal for gene expressions in seeds and cereal crops.	2003	Sequence has been deposited in the gene bank. It is being used to make constructs to improve starch quality in sorghum.
Gene transformation construct for sorghum starch	Joel Mutisya Mercy Mbogori	Contains a gene for starch branching enzyme in antisence orientation fused with *gfp* as a reporter and 35S as promoter	2005	Cloned in a binary vector and stored for use in appropriate agro- bacterium strain. Its ready for transformation work

Source: Gichuki (2006).

Besides KARI, there are a number of other national institutions (private and public) as well as international public institutions involved in biotechnology research and development in Kenya.

Some of the other actors in the agricultural biotechnology innovation system that were identified in Chapter 2 were also present, such as farmers, firms providing inputs (such as seeds, pesticides, fertilizers, animal feed energy) or services such as transport, agricultural machinery rentals, credit, insurance, animal health, etc.) to farmers, agro-processing firms, retailers, supermarkets, commodity boards, training, research and development institutes and tertiary colleges, universities and agricultural extension and training services, ministries of agriculture, trade and industry, environment, health and standards, and regulatory and quality control institutions. However, as in the case of Nigeria, Kenya does not have any local firms that are involved in development of biotechnology-based products. Viewed across the five domains that we presented in Chapter 2, they could be schematically represented as below (Figure 6.1).

6.3 Science, technology, and innovation investments

As early as 1990, the National Committee on Biotechnology Advances and its Applications (NACBAA) report recommended the need for strengthening the country's scientific, legal, and bureaucratic capacities in order to harness the benefits of biotechnology. Wafula and Falconi (1998) estimated that by 1996, there were only 56 scientists involved in biotechnology research activities in Kenya. These scientists accounted for 80% of biotechnology research in Kenya while the remaining 20% was conducted by scientists in international organizations in Kenya (Odame 2005). Our survey confirms the result that were arrived upon by earlier studies that even though the majority of Kenyan scientists may have basic scientific knowledge on issues of genetics and molecular biology, only a few of them are specialized enough to conduct research and development activities in what was identified as biotechnology-based work in Chapter 2.

6.3.1 Human resources

Our survey also found that the limited capacity that is being created is focused more on tangible infrastructure (such as labs and equipment) and is not matched by the expansion of human skills to utilize these facilities as part of structured research agendas for the Gene Revolution. This once again confirms earlier results on Kenyan biotechnology

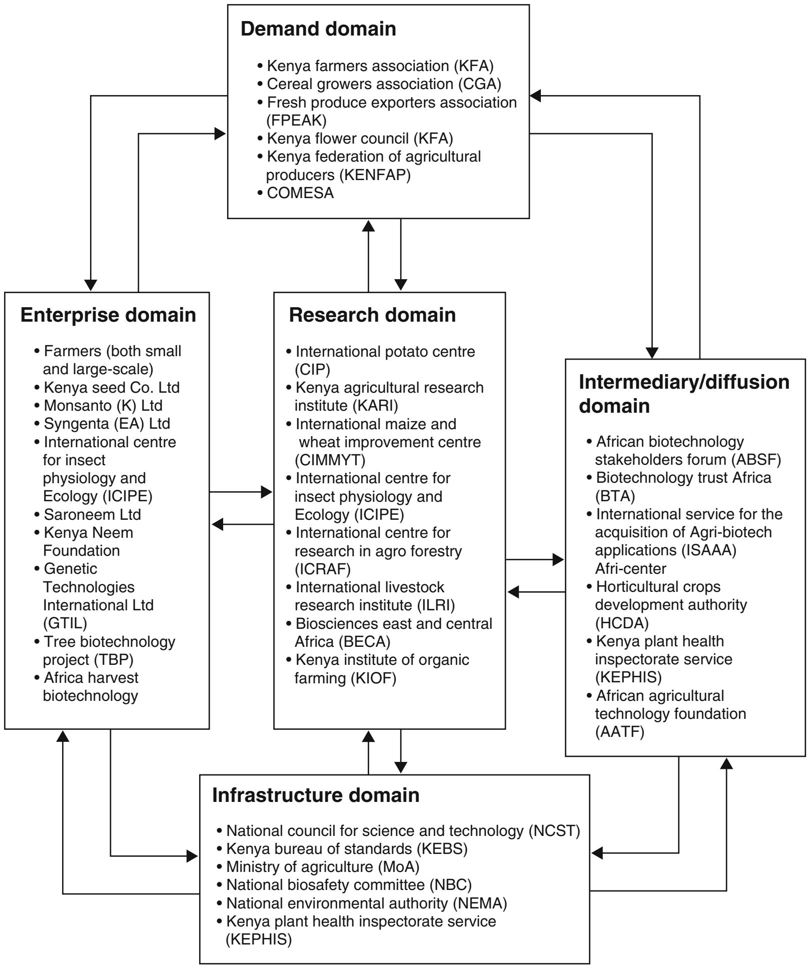

Figure 6.1 Components of the agricultural biotechnology innovation system in Kenya
Source: Authors.

capacity (see for example the survey by Odame and Mbote, 2000) which concluded that over the years capacity-building has focused more on hardware components (expanding the physical facilities) and postgraduate training at MSc and PhD levels. This over-emphasis on hardware components has resulted in an increase on the demand for non-scientific

Table 6.5 School enrolment ratios, Kenya 2000–5

	2000	2001	2002	2003	2004	2005
School enrolment, primary (% gross)	98	–	94	111	111	–
School enrolment, primary (% net)	67	–	63	77	76	–
School enrolment, secondary (% gross)	39	–	41	44	48	–
School enrolment, secondary (% net)	33	34	35	37	40	–
School enrolment, tertiary (% net)	3	3	3	–	3	–

Source: World Development Indicators (2007).

staff to manage the expanded physical facilities, thus explaining the low scientific – non-scientific staff ratios captured in our survey.

Table 6.5 shows once again the low rates of continuation among those enrolled from primary to secondary to tertiary levels of education. Our survey also found that the share of staff with Phd degrees in the public research institutes was extremely small, again confirming the findings that most of the 'core research' staff required to conduct biotechnology-based R&D are missing from the expanding infrastructure endowments.[1] And, as in the case of Nigeria, we found that most of the biotechnology work was again concentrated around tissue culture and other basic biotechnologies, rather than seeing pockets of excellence across a broader range of expertise, given the broad range of international collaborations going on in the country.[2]

The government has sought to address the issue of adequate human and technical capacity by establishing courses in biotechnology in most of the public universities in Kenya. In fact all the six public universities across the country are offering biotechnology courses at undergraduate and post-graduate levels. For example, Kenyatta University offers both BSc and MSc courses in Biotechnology, while Moi University's School of Agriculture and Biotechnology has a BSc course in Agricultural Biotechnology. The University of Nairobi in 2005 established the Center for Biotechnology and Bioinformatics (CEBIB) as a centre of excellence to facilitate capacity-building and generate marketable products by harnessing biotechnology. CEBIB's mandate is to enhance knowledge and skills in biotechnology and bioinformatics to impact on agricultural and industrial output, health, and environmental management.

CEBIB's formation underscores the realization that biotechnology is an interdisciplinary subject with wide ranging applications of scientific and engineering principles in different fields such as agriculture, food and feed, medicine, industry and the environment, which are of profound importance to mankind. The centre has the following key objectives:

1. To strengthen national capabilities in the field of basic sciences and technology and in the development of research in biotechnology and bioinformatics.
2. To promote and conduct basic research in the areas of molecular biology, biotechnology and bioinformatics.
3. To facilitate the application of biotechnology in research and encourage its use for the development of marketable products.
4. To offer training facilities for manpower development in biotechnology and bio-informatics at the national and regional level.
5. To institutionalize links between universities, scientific research institutions, and the private sector.
6. To network with institutions in developed and developing countries as well as the international centres of biotechnology and bioinformatics.

It is expected that the integration of biotechnology courses within the university curricula as well the emergence of training centres such as CEBIB will help boost the country's human capacity in biotechnology, and more specifically, modern biotechnology in the years to come. The bigger challenge, however, is to equip these centres with the necessary training materials and facilities, on the one hand, and relevant manpower, on the other. Considering that Kenya currently allocates less than 0.5% of its GDP to science and technology, this feat may be difficult to achieve if budgetary allocation to science and technology is not increased. It also calls for universities and research institutes to seek alternative, innovative funding mechanisms, the incentives for which are presently not in place.

6.3.2 Funding

The National Council on Science and Technology in Kenya has a broad mandate of focusing on agricultural innovation and new technologies of importance to the country, such as biotechnology and ICTs. Despite this, the amount of resources that are allocated to public-sector organizations for research is negligible. Organizations such as the Kenya Industrial Research and Development Institute (KIDRI) and KARI which have the mandate to develop technologies for the use of local entrepreneurs in both traditional and new technology sectors operate with extreme staffing and funding shortages, and hence are not able to fulfil their mandates even partially. Most researchers at universities and PRIs complain regularly of a lack of funds and initiative on part of the government to support and direct relevant research. The extraordinary reliance on external, donor funding for research, which is at best sporadic and not dependable, means that innovative activities in academic institutions in the country continue at a rate that hardly reflects its true potential.

6.4 Interactive learning

The survey sought to identify the following key issues in the context of agricultural biotechnology system of innovation in Kenya:

- The type/nature of collaborations, for example research, financing, marketing, or distribution?
- Who the key partners and collaborators are (both national and international; private or public)?
- How the linkages were initiated and established, and the factors that play a role?
- The structure and intensity of the agreements with partners/collaborators, for example intellectual property clauses, capacity-building elements among others?

Specifically, we were engaged with questions that stand out when one analyses biotechnology developments in the country. For example, why is KARI's example of the sweet potato, which was regarded as an example of a fruitful collaboration in agricultural biotechnology, not resulted in other variations of the product that are locally suited despite the training that the scientists received as part of the initial phase of the project? Why do we not observe more such collaborations that expressly target innovation capacity for agricultural biotechnology in the country? What is the broader impact of the international collaborations presently ongoing in the country, how do they help in improving Kenya's intrinsic capacity to conduct biotechnology innovation? Our survey found the following factors instrumental in limiting Kenya's capacity to engage and expand in agricultural biotechnology.

6.4.1 Lack of knowledge infrastructure

A review of previous studies all agree on this point: Kenya still has a shortfall of adequate laboratory capacity and facilities needed to effectively exploit biotechnology (Wafula and Falconi (1998); Odame and Mbote (2000); Odame, Kameri-Mbote and Wafula (2004), and Quemada (2002) to mention a few). Human skill, the other component of knowledge infrastructure, is highly limited, a point that has been

Table 6.6 Financial support to entrepreneurial activity, Kenya

Financial Support	2000	2001	2002	2003	2004	2005
Domestic credit to private sector (% of GDP)	28	25	26	24	24	27
Interest rate spread (lending rate minus deposit rate)	14	13	13	12	10	8
Market capitalization of listed companies (% of GDP)	10	8	11	28	24	36

Source: World Development Indicators database.

discussed at length in the previous section. This calls for the need for continuous training in the fields of modern biotechnology and genetic engineering. While local universities have begun to respond to this challenge by designing relevant courses as well as establishing specialized centres to handle capacity development in biotechnology, there is a need to ensure that the courses are relevant, and the manpower being generated is of the kind needed by the private sector and the research institutes. There is also a need for a dynamic biotechnology policy to promote entrepreneurial efforts by academic and research institutes, as well as create a new culture of collaboration between public research and enterprise. Our survey found that the research institutes and their research programmes are not well received by the enterprise sector, and there is very little reliance on the services provided by them in firm-level strategies.

There are inherent weaknesses in several institutions that are fundamental to the creation of new knowledge and the use of already existing knowledge in innovation activities. As Table 6.6, for example, shows financial support institutions to promote local innovation and entrepreneurship in Kenya, which have not been performing well and have been constantly on the decline since 2000. Domestic credit to private sector has been on the decline between 2000 and 2005 and other macro-economic indicators such as net inflows as percentage of GDP (see Table 6.6) show that investing in the economy is not a highly profitable activity. R&D investments in the economy have similarly been very low between 2000 and 2005, further exemplifying the weak institutional environment for innovation (see Table 6.7).

6.4.2 International collaborations and innovation capacity

Although Kenyan PRIs are actively engaged in several projects that involve more demanding biotechnologies such as GM technologies

Table 6.7 Investment and R&D

Investment and R&D	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Foreign direct investment, net inflows (% of GDP)	1	0	0	1	0	..
Merchandise imports (current US$)*	3,104.99	3,192.00	3,244.83	3,725.29	4,552.73	6,360.00
Research and development expenditure (% of GDP)	..	..	..	..	..	..
Researchers in R&D (per million people)	..	..	..	..	..	..

*Amounts in 100,000.
Source: World Development Indicators database.

(see Table 6.1), none of these projects has led to the commercial cultivation of GM crops within the country and most of the products were undergoing contained trials at the time of our survey.

More importantly, these projects have also not contributed to building local research capacity in significant ways because of the observed tendency of international private-sector companies to bring into the country finished (already modified) products for trials, thereby limiting the active participation of local public-sector institutions and their researchers in the research and product development process. This points attention to a criticism that Kenyan biotechnology initiatives have met previously, deeming them to be exogenous, driven largely by international private sector interests and supported by the donor community or international private foundations. This situation does to a large extent mean that local public institutions in Kenya are confined mainly into field-testing of developed products (see Kirea et al. 2003 who arrive upon the same conclusion).

On the question of whether international collaborations are well-absorbed into local innovation system for agricultural biotechnology our survey found in the negative. Primarily, we find that there is a strong relationship between national strategy for biotechnology development, availability of relevant human skills in the local research institutes, and international collaborative efforts. In other words, if there were more relevant human skills that could be deployed and if national and organizational strategies for biotechnology were more clearly set out and implemented to make capacity-building a priority in international research collaborations (both of which rely on policy capacity, see section 7.5), strategic involvement of local researchers in international collaborations could have been effected, which is now not the case.

Our survey also found that most researchers who take part in such capacity building and training are disgruntled by the low state of innovation capacity in the local system which constantly acts as a hindrance to applying their acquired skills to research and innovation activities to the local context.

6.4.3 Strengthening entrepreneurship by providing incentives for collaboration and support

Despite being in compliance with the TRIPS Agreement, Kenya has a very low score of local patent applications when compared to foreign ones, which once again acts as a measure of the low level of local entrepreneurial activity. Patent registrations amounted to 61 in the year 2001, with two of these being registered by residents and the rest by non-residents. In addition to these registrations, the number of international patents in Kenya amounted to a total of 89,180 according to 2002 data available from the WIPO (WIPO, 2007). As our work on cut flowers shows (see section 7.6), intellectual property rights, as provided in Kenya, could have very important negative implications for how local capacity can be built, and Kenya can move higher up from being a mere producer of flowers to a cultivator and creator of newer plant varieties. Furthermore, despite the extremely stringent intellectual property regime, all actors advocating and negotiating for royalty-free access to biotechnologies in Kenya such as ISAAA and the African Agricultural Technology Foundation (AATF) are non-governmental in nature, underscoring the lack of awareness of the impact of the present intellectual property regime.

To enhance access and uptake, there is a need for state created agencies that facilitate technology transfer, and negotiate access to proprietary technologies. The case of Genetic Technologies International Laboratories (GTIL) discussed in box (see Box 6.1) below helps to illustrate some of the issues involved in local entrepreneurship initiatives. Simply put, although GTIL is a very successful private enterprise, its success has been achieved without significant support in several critical areas, including access to technologies and collaboration venues. Providing policy and institutional support for local entrepreneurs through incentives that structure more systematic collaboration between various actors in the biotechnology system, as well as enable development of marketable products needs to be a primary goal of policy reform in this area.

6.4.4 Improve organizational roles and coherence

The survey shows that while most organizations and actors necessary in the biotechnology sector are in place, for example, in the research,

Box 6.1 Genetic Technologies International Laboratories (GTIL) Limited

Genetics Technologies International Limited is a privately owned Kenyan company that started its operations in 1995 and specializes in rapid micro-propagation of healthy superior planting materials through tissue culture (TC) technology. The company has a production capacity of over 20 million plantlets per year, producing a wide range of planting materials including:

Industrial crops such as pyrethrum, sugarcane, sisal, vanilla, coffee, among others.

Horticultural crops such as citrus fruits, mangoes, avocados, passion fruits, pawpaw, and macadamia. Among *flowers*, lilies, eustoma, zantendeseschia, glandiolas and statice are among the varieties that GTIL have engaged in. Most often, GTIL does not produce the flowers varieties but the clientele bring the selected flowers and GITL multiplies/reproduces the number of flowers as required by the client requires.

Food crops include bananas, (i.e. dessert, cooking) and plantains, Irish potatoes and pineapples.

Trees for fuel, wood, furniture, telephone/electric poles. The tree species include eucalyptus, grevillea, acacia, pinus, markhamia, *Croton megalocarpus*, prunus, neem, melia, terminalia, jatropha, moringa, cypress, *Warbugia ugandesis*, and teak

Medicinal plants and herbs such as Artemesia, aloe vera, *Mondia whytei*, bamboo, turmeric, geranium among others.

GTIL came into being as a response to the declining rate of agricultural productivity in Africa and most developing countries, most notably in all crops – food and cash crops. Most surveys carried out attribute this decline to lack of clean planting material to farmers, since many farmers use planting materials infested with disease and pests. There is also lack of improved germ-plasm which could give better yields and resist pests and diseases. Besides, there are other issues such as a lack of farm inputs; high costs of inputs, and the lack of proper technological approach to the farming programmes. Tissue culture seeks to address the inadequacy of clean, disease-free planting materials through a cleaning and multiplication exercise. The enterprise is medium-sized, with 50 employees in total and the staff at the laboratory are trained and supervised by GTIL.

GTIL's Collaborations and linkages

Collaborators/ partners	**Nature of collaborations**	**Remarks**
International Service for the Acquisition of Agri-biotech Applications (ISAAA)	For sourcing technologies from across the world	ISAAA sources for technologies but requires organizations such as GTIL to ensure the technologies are multiplied and reach the end-users
The Tree Biotechnology Project	For multiplication of eucalyptus clones	This collaboration was initiated by ISAAA to enable Mondi Forests International import improved varieties of trees into Kenya. The TBP lacked equipped laboratories to handle the cloning
Kenya Plant Health Inspectorate Service (KEPHIS)	For inspection of all GTIL nurseries to ensure materials are disease-free	KEPHIS is a regulatory body whose role is to ensure sanitary and phytosanitary matters are adhered to
Kenya Forestry Research Institute (KEFRI)	For forestry research	KEFRI handled all the technical aspects of the tree biotechnology project
KARI/Ministry of Agriculture (MOA)	For other research and extension services	KARI conducts research especially on food crops while the MOA provides extension services
Horticultural crops Development Authority (HCDA)	For registration of nurseries and inspection	HCDA supervises and oversees the nurseries operations.
African Biotechnology Stakeholders Forum (ABSF) and Africa Harvest Biotechnology Foundation International (AHBFI)	For information dissemination and training of stakeholders in new varieties' acquisition and use	The exact nature of collaboration with these institutions is unclear but both are NGOs involved in biotechnology.
International Network for the Improvement of Bananas and Plantains (INIBAP) – Belgium	For clean planting materials	INIBAP collects and maintains different varieties of bananas and plantains germplasm.

(*Continued*)

(Continued)

Collaborators/ partners	**Nature of collaborations**	**Remarks**
Biotechnology Trust Africa (BTA)	For marketing GTIL's products in western Kenya (Bungoma)	BTA and GTIL have an MoU in accordance with which BTA buys GTIL's products for their (BTA) nurseries in western Kenya (Bungoma) where farmers can easily access the planting materials.

Source: Authors' field survey (2007).

GTIL is fairly independent and does its own marketing, distribution, and financing without any collaboration. Where collaborations exist, GTIL has been the main initiator of these collaborations, and GTIL has faced numerous problems in structuring these collaborations. Except Biotechnology Trust Africa (BTA) with which GTIL has a MoU, the other collaborations are structured rather loosely and are non-contractual in nature. The international linkages provide GTIL with current information in the biotechnology industry, as do most of other GTIL's collaborators and hence the intensity of these collaborations. GTIL occasionally invites specialities from international countries to come and share knowledge and expertise, for example from India and South Africa as a way of improving and marketing GTIL. GTIL admits that more support from the Kenyan government and its designated agencies in both identifying collaborators, advice on structuring collaborations would be very useful. GTIL only produces plantlets and finds it difficult to move beyond to conduct research due to problems of expanding into research without adequate support from other organizations and institutions within the system, and intellectual property issues.

Source: Authors' survey, 2006.

demand, infrastructure, demand, and entrepreneurs domains, it is the organizational competence which is missing. In other words, there is a lack of relevant human skills to steer the organizations into their respective mandates, and to enable them to coordinate their work well in this area. Apart from the latecomer malady of duplicating research efforts across all PRIs despite the limited resources available, as we saw in the case of Nigeria, there have been other instances of explicit waste of research results due to a lack of coordination. The case of tissue culture bananas is one such example, where several such anomalies were clearly evident. Wafula (2000) note that both tissue culture technology and germplasm were imported from South Africa despite the fact that tissue culture work on bananas had been going on in the country for at least seven years. The tissue culture banana case, where the network succeeded in propagating, producing, and disseminating the crop as the cash-crop alternative for those farmers who were not earning well with other cash crops, such as coffee also shows the lack of planning in governmental strategy as to the livelihood impact of this development (See also Harsh and Smith, 2007). This yet again, shows the limitations in biotechnology development activities in the country – which seem to be largely driven by external interests and missing in focus on local priorities and concerns.

More over, most of the actors interviewed observed that the level of involvement of the private sector in biotechnology is still very low and urged that the private sector should be encouraged by enacting appropriate policies and incentives. Some actors also complained of a weak extension system at the grass roots levels and suggested the need to facilitate better flow of information to farmers by strengthening the extension system.

6.5 The role of the state in promoting agricultural biotechnology

Although Kenya has begun to put in place a regulatory framework for agricultural biotechnology and GM crops, the patchwork of laws remains mostly unenforced partly due to Kenya's lack of ability to put into place mechanisms for the monitoring and enforcement as required. There is no strategic policy vision in place to promote biotechnology-led development, especially one that takes into account the technological requirements of the process. While Kenya has a biosafety bill, biosafety committees, and rules and regulations relating to intellectual property, there is no broader vision that links these to science, technology and innovation policy for the sector (or national science, technology and innovation policy for that matter), local needs of farmers, food security and competitiveness. Kenya has a draft Science, Technology, and Innovation Bill that has been discussed since 2006, but this has not yet come into force mainly due to political delays and its Science, Technology, and Innovation Strategy Plan 2008–12 was unveiled only last year.

In this section, we present the regulatory framework as it presently stands for the governance of agricultural biotechnology and GM crops as well as for intellectual property rights on biotechnology products and plant varieties. Despite the developments, the same questions that were asked in the section on interactive learning remain with respect to the learning and innovation aspects and the relevance of international collaborations in building capacity for agricultural biotechnology in a systematic way. As things stand, even if some capacity is eventually built in the sector, it would mostly be a result of several factors coincidentally acting in tandem within the system of innovation, rather than an outcome of vision and policy action of the Kenyan state. A second aim of the regulatory framework would normally be to provide a guarantee regarding the safety and efficacy of the plant varieties' being planted on Kenyan soil. On this point too, the regulatory framework on agricultural biotechnology is at best informal in nature (Clark et al., 2005).

6.5.1 Kenya's institutional and regulatory framework on agricultural biotechnology

The legal framework for scientific and technological research and development are guided by the *Science and Technology Act* (Cap 250) Laws of Kenya. There has been a new Science, Technology, and Innovation Bill under consideration in recent years (2006 onwards). The Act establishes the machinery to avail to the government advice upon all matters relating to the scientific and technological activities and research necessary for proper development and to coordinate research and experimental development. It creates the National Council for Science and Technology (NCST) comprising all the Permanent Secretaries (PSs) of the relevant (scheduled) ministries and 12 other members representing eminent scientists derived from the various scheduled disciplines. However, the Act has no specific provisions on biotechnology and biosafety. This shortcoming necessitated the formulation of a specific framework to address issues of biotechnology development in the country.

The history of development of the national biotechnology policy and legal framework can be traced back to 1990 when the government appointed a National Advisory Committee on Biotechnology Advances and their Applications (NACBAA), which was given the mandate to identify the national priorities on the basis of comparative advantage and the ability to implement traditional methods in agriculture, facilitate access to new germplasm, reduce high costs of agricultural inputs, and promote cheaper access to environmentally friendly alternatives.

Based on this, one of the chief recommendations of the NACBAA some years later, was the need for immediate applications of tissue culture for mass propagation and disease elimination, development of disease diagnostic kits, and the use of biological nitrogen fixation (BNF) (Odame, 2003).

The second major phase in biotechnology policymaking process began in 1993 as part of the Biotechnology Programme of the Netherlands Directorate-General for International Cooperation (DGIS) that sought to develop biotechnology for poverty reduction in Kenya. The programme was split into two major parts: developing specific technologies and enhancing capacity for national regulatory and biosafety capacity. For the former, DGIS set national priorities similar to NACBAA including tissue culture and other low-end biotechnologies noting the need to commence more intensive biotechnologies.

The United Nations Environment Programme – Global Environmental Facility (UNEP-GEF) project facilitated the third phase of biotechnology policy development from 1997 onwards. The UNEP-GEF project, coordinated by the National Council for Science and Technology (NCST) aimed at helping developing countries to develop their national biosafety frameworks (NBF). The UNEP-GEF project was conceived under the auspices of the Convention on Biological Diversity, 1993, to promote the harmonization of biosafety instruments at subregional, regional, and global levels. The two main components of the project were to facilitate the development of national biosafety frameworks in more than 100 countries and assist in the implementation of the frameworks, Kenya being one of them. The first phase of the project that began in Kenya in 1997 included a survey to identify existing applications of modern biotechnology in the country, the extent and impact of release of GMOs, risk assessment and risk management systems and review all existing legislations relevant to biosafety (Thitai et al., 1999).

Until about 1998, biotechnology and related research activities had been governed by the *Science and Technology Act of 1980*. However, the regulations stipulated under this Act were only geared towards trials and were not applicable to field release and commercialization of GMOs. Therefore, the National Council for Science and Technology (NCST) which is the Kenyan government's appointed authority to oversee the coordination and implementation of the biosafety regulations in Kenya, convened a multidisciplinary committee (including the then Permanent Secretary) to develop regulations and guidelines for the country's biosafety system. The regulations which covered areas of GM research and development (R&D), use of all aspects of recombinant DNA technologies, and the release of plants and animals derived through such techniques had the following broad objectives:

- Promote opportunities for the application and exploitation of products of biotechnology;
- Ensure public and environmental safety particularly in accident prevention, containment and waste disposal when GMOs are used in R&D or industrial processes;
- Determine the measure of risk assessment, management and monitoring of operations involving rDNA technologies and products arising thereof.

The adoption of the national regulations and guidelines for biosafety in 1998 provided for the establishment of the National Biosafety System (NBS) and the procedures to follow in setting up such a system. It spells out the NCST as the government-designated body to oversee the coordination and implementation of biosafety regulations and guidelines. The National Council for Science and Technology operates under the Ministry of Education, Science and Technology (MoEST) and was established by the Science and Technology Act (Cap 250) of 1980. The current provisions of the biosafety regulations and guidelines mandates the National Council for Science and Technology to establish the National Biosafety Committee (NBC) whose membership should be drawn from across different agencies. The NBC is charged with the task of drawing policies and procedures besides vetting research applications to ensure compliance with the laid down regulations. The NBC also coordinates and oversees the establishment of Institutional Biosafety Committees (IBCs) in those R&D institutions applying modern biotechnology in their activities. As such the institutional framework for governing GM products and research in Kenya comprises the NCST, the NBC, and IBCs.

The members of the NBC are drawn from across different agencies including government regulatory agencies, scientists, Ministry representatives, research institutes, universities, non-governmental organizations and the Council. Article 6 of the *Science and Technology Act* permits the NCST to appoint and incorporate other committees and states in part that 'the Council may from time to time appoint such working or other committees as it may think fit, and may provide for the regulation of the proceedings of such committees'. Article 6(2) provides for the composition of such a committee to include a member of the Council, who becomes the chair of such a committee and other members of the Council if found appropriate and the council may co-opt any person(s) as an additional member of the committee. The co-opted member doesn't necessarily have to belong to the Council. Scientific and technical expertise for the NBC stems from the scientists representing academia, research institutes, and some government departments. The NBC has powers to appoint task forces, co-opt individuals with the necessary expertise or seek external expert opinions regarding very specific issues where such expertise is lacking within the local population.

Other than the NBC, there are Institutional Biosafety Committees (IBCs) whose constitution allows both in-house scientists and external experts with a mandate to carry out in-house technical reviews and approval of biotechnology research and GMO release applications before they are submitted to the NBC. Kenya's leading research institutions such as KARI and the International Center for Insect Physiology and Ecology (ICIPE) have established their IBCs. KARI, which is the leading applicant for GM research approvals in the country, has an eight-member IBC comprising representatives from KEPHIS, Department of Veterinary Services (DVS), International Livestock Research Institute (ILRI), the University of Nairobi and KARI's in-house members.

Kenya's Biotechnology Policy and Biosafety Bill were drafted and sent to the Attorney General's office in 2004 and were awaiting approval by parliament at the time this survey was conducted in 2006–7. The Biosafety Bill (2005) proposed the establishment of a National Biosafety Authority whose functions shall be to:

- Receive, respond to and make decisions on applications on GM products;
- Establish administrative mechanisms to ensure the appropriate handling and storage of documents and data in connection with the processing of applications;
- Establish a database for the purpose of facilitating collection and dissemination of information relevant to biosafety;
- Identify national requirements for manpower development and capacity-building in biosafety;
- Maintain directory of experts in biotechnology and biosafety;
- Advise institutions and persons on mitigation measures to be undertaken in case of accidents;
- Promote awareness and education among the general public in matters relating to biosafety.

The authority, which will be the national focal point (presently, the NCST is the focal point) will be managed by a board chaired by an eminent scientist appointed by the minister. Other members in the board shall comprise experts in biological, environmental and social sciences; the Permanent Secretaries (or their representatives) responsible for Science and Technology and Finance, the Director-General of NEMA, the Managing Directors of KEPHIS and KEBS; the Director of Veterinary Services (DVS), Secretary of NCST, and the Agriculture Secretary. The chairperson and board members hold office for term of three years and are eligible for reappointment for a further three years. The appointments and their names are published in the *Kenya Gazette*. The regulatory matters under the proposed Act are spread across the regulatory bodies as described above.

Table 6.8 shows the timeline for the development of biotechnology and biosafety systems in Kenya.

Table 6.8 Biotechnology and biosafety policy development timeline in Kenya

Year	**Key event relating to biotechnology policy development in Kenya**
1990	Government appoints the National Committee on Biotechnology Advances and its Applications (NACBAA)
1993	The DGIS-Netherlands programme begins
1995	*Ad hoc* approval and a permit to import a recombinant animal vaccine
1997	UNEP-GEF phase I begins
1998	Guidelines for biotechnology, biosafety published by NCST
1998	National Biosafety Committee (NBC) formed
1999	Environmental Management and Coordination Act (EMCA) is passed and National Environment Management Authority (NEMA) established
2000	Kenya signs the Cartagena Protocol on Biosafety
2002	Seeds and Plant Varieties Act (1972) amended to accommodate biotechnology
2003	UNEP-GEF Phase II begins – to implement the national biosafety framework
2003	Draft Biosafety Bill prepared
2004	Draft Biosafety Bill submitted to the Attorney-General's office

Source: Authors' survey (2006–7).

6.5.2 The regulatory framework for GM crops and technologies in Kenya

The Kenyan regulatory framework for GM crops comprises five regulatory agencies reporting to different ministries and deriving their legal backing from various Acts of Parliament. The regulatory agencies include: the Kenya Bureau of Standards (KEBS), the Kenya Plant Health Inspectorate Service (KEPHIS), the National Environmental Management Authority (NEMA), the Department of Veterinary Services (DVS), and the Public Health Department (PHD).

The Kenya Bureau of Standards (KEBS) operates under the Ministry of Trade and Industry (MoTI), and is responsible for setting standards for weights and measures, purity and identity. KEBS is the national standards body and is established under the *Standards Act* (Cap 496) laws of Kenya. This Act of 1974 seeks to promote and provide for standardization of commodities and a code of practice. The overarching mandate of KEBS is to ensure consumer safety through setting standards for nutritional content, tolerance levels for food toxins (e.g. mycotoxins) and provide facilities for testing and calibration of precision instruments. In terms of standards, the KS 05-40 labelling for pre-packaged foods exists and covers requirements of labelling all food products. This standard was established in line with requirements stipulated under the codex standards for food labelling. However, the standard doesn't cover genetically modified products.

The Kenya Plant Health Inspectorate Service (KEPHIS) was established as a state corporation under the State Corporations Act (Legal Notice No. 350 of 1996) to regulate all matters of plant health and quality control of agricultural products in Kenya. Its mandate includes overseeing the safe introduction of GM plants, products, and micro-organisms into the country. It derives its regulatory authority from various statutes including the *Plant Protection Act* (Cap 324) dealing with importation of plants and plant products, the *Seeds and Plant Varieties Act* (Cap 326) regulating certification and registration of all seed, the *Agricultural Produce (Export) Act* (Cap 319) governing the exportation of plant and plant-related products from Kenya, the *Suppression of Noxious Weeds Act* (Cap 325) addressing the prevention, suppression, and eradication of noxious weeds among other statutes. Even though the legal notice sets out the role of KEPHIS in biotechnology, this mandate is only limited to plants.

KEPHIS falls under the Ministry of Agriculture (MoA) and has jurisdiction over phytosanitary matters and a full regulatory authority to seize, turn away, quarantine and destroy all materials unacceptable to Kenyan standards. It works very closely with KEBS on phytosanitary issues and routinely inspects and regulates all materials at all entry points through a permit system. KEPHIS also inspects and approves all containment facilities (laboratories, greenhouses and quarantine facilities) and only when satisfied that the facilities meet all the requirements, issues an importation permit.

The Department of Public Health (PHD) under the Ministry of Health (MoH) is charged with regulatory responsibility over health and safety aspects of food and feeds and derives its legal authority from the *Public Health Act* (Cap 242) and the *Food, Drugs and Chemical Substances Act* (Cap 254). Its overall duty is to ensure the public is protected from harmful food, drugs, and other chemical substances.

Matters relating to animal health fall under the jurisdiction of the Department of Veterinary Services (DVS) under the Ministry of Livestock and Fisheries Development. The DVS derives partial authority from the *Crop Production and Livestock Act* (Cap 321) governing the control and improvement of crops and livestock, marketing and processing, *the Veterinary Surgeons Act* (Cap 366) and the *Animal Diseases Act* (Cap 364) dealing with control of animal diseases. In 1994, the DVS permitted the importation of a recombinant vaccine – virus-based rinderpest vaccine developed by the United States Department of Agriculture (USDA) and conducted the testing.

The National Environmental Management Authority (NEMA) operates under the Ministry of Environment and Natural Resources (MENR) derives its regulatory authority from the *Environmental Management and Coordination Act* (*EMCA*) of 1999 and is mandated to coordinate all development activities and ensure all environmental issues are properly and adequately addressed. Section 53 of EMCA empowers NEMA to make regulations on biotechnology matters as they relate to the environment. At present NEMA does not have any direct role in the GM arena since all GM-related work is still at the research stage, being undertaken in contained facilities. When the GM work goes into field cultivation and commercialization, it is envisaged that NEMA will be more involved in environmental risk assessment and mitigation of any harmful effects.

6.5.3 Kenya's intellectual property rights framework

Kenya is a member of the World Trade Organization and is therefore obliged to implement the Agreement on Trade Related Aspects of

Intellectual Property Rights (TRIPS) Agreement of 1995. Despite the fact that Kenya is exempt from complete TRIPS compliance until 2013, it has already enacted a TRIPS-compliant intellectual property regime. The survey shows that the establishment of the Kenya Industrial Property Institute (KIPI) following the enactment of the *Industrial Property Act* (Cap 509) in 1990 has provided the necessary legal framework for intellectual property protection in the country.

The intellectual property rights in Kenya are covered under four Acts of Parliament namely: the Intellectual Property Act (Cap 509), the Trademarks Act (Act 506), the Seeds and Plant Varieties Act (Cap 326), and the Copyrights Act (Cap 150). The creation of the Kenya Industrial Property Office (KIPO) in 1990 (and its transformation into Kenya Industrial Property Institute (KIPI) with greater decision-making power and authority) following the enactment of the Industrial Property Act was a major strengthening act as far as intellectual property protection in Kenya is concerned.

On the question of plant varieties protection, Kenya had already enacted the Seeds and Plant Varieties Act (Cap 326) far back in 1977, providing for the protection of plant breeders rights. The 1977 Act (which was reviewed in 1991) coupled with the 1994 regulations on the same issue, ensure its compliance with the provisions of the UPOV 1978 convention. Kenya is a member party to UPOV 1978 convention since April 2000, as part of which some of the provisions of the parent legislation and the implementing regulations were both revised.

Two important aspects stand out instantly in this context: Kenya's plant variety protection regime does not focus on the needs of local farmers. The Act has no specific provisions addressing the question of farmers' rights. The 2001 Bill contains provisions that prohibit the exchange of seed among farmers, and therefore does not cater to the needs of local farmers' rights. Second, there are no visible impacts of plant variety protection regime on promoting the nascent local private-sector enterprise in the cut- flower sector, which our survey covered extensively and some of these results are presented in the next section.[3] As early as 1999, the ratio of international to national applications in the cut-flower sector was 91% to 9% (See Grain, 1999), and this wide gap still remains.

6.6 Case study: The Kenyan cut flower sector

Globally, the cut-flower sector was worth approximately US$6 billion in 2006, of which Kenya accounted for 6% in total as opposed to the largest contributor, the Netherlands which catered to 54% of the total global demand (Hornberger et al., 2007). In monetary terms, Kenya's exports rose to US$300 million in 2007, and is one of the fastest growing sectors of the economy (Kenya Flower Council, 2007).

Kenya's cut-flower sector emerged in 1970s and picked up in the 1980s when the leading exporters began to plant commercial rose cultivation for exports to European Union (EU) markets. It gradually transformed from being low value and simple open field flower plantations in the 1980s to high value flower farming in green houses by the 1990s. For example, from 2001 to 2005 cut-flower export grew at a compounded annual growth rate (CAGR) of 27% (Hornberger et al., 2007).

The industry employs more than 1250,000 people directly and a further 2 million indirectly through and related auxiliary economic activities thus contributing to employment creation and poverty alleviation efforts. The industry in characterized by a robust private sector comprising largely large-scale growers dealing in flower varieties requiring huge financial inputs grown under greenhouse conditions such as roses, carnations, statice, alstromeria, and veronica, among others, which require high levels of agricultural technical and managerial skills. The local smallholder growers, however, are mainly confined to summer flowers requiring less capital in-put, managerial and technical skills and can very easily grow under open conditions. At present roses are the top varieties exported from Kenya accounting for over 70% of all flowers grown and exported.

The government's strategy in Kenya has been one of limited participation, where a specialized agency, the Horticultural Crops Development Authority (HCDA) was set up as a state corporation under the ministry of agriculture vested with the responsibility to develop, promote, coordinate, and facilitate the horticultural industry in Kenya. Apart from this, an enabling environment was facilitated through its IPR regime, which provided plant breeders rights to new plant varieties and hence promoted foreign plant breeders to set up cultivation farms in the country and promoting quality standards and incentives for exports. Therefore, market triggers were largely relied on for the growth of the sector and direct involvement of the government, however, has been minimal when compared to other agricultural products, such as coffee.

Our survey covered the cut-flower sector extensively as a case study and 49 farms were administered questionnaires apart from conducting a series of interviews with farm owners and other stakeholders. The sector is no doubt performing well and is the largest earner of foreign exchange in the economy. However, the very factors that were initially responsible for attracting foreign investment for the sector and promoting the growth of the sector are now beginning to act as hindrances to local farmers. Small-scale Kenyan farmers find it extremely hard to diversify their export locations, and to compete in the highly competitive value chain that supplies the Dutch auction system. Our interviews show that local infrastructure and agricultural extension services, such as port and aircraft facilities, ease of transportation to the ports and aircrafts apart from the costs of negotiating licences for the plant varieties, all pose serious transaction costs to the local farmers. Local farmers also complain of the lack of policy and organizational support towards producing local cultivars that are based on African horticultural varieties that ranges from the missing research infrastructure, lack of collaboration between existing research and enterprise as well as risk-attenuating mechanisms for investment into such activities. Local growers frequently quoted the intellectual property mechanism, in the form of strictly enforceable plant variety rights, as a major impediment in their own initiatives to produce their seed varieties.

In sum, we find that policy support for the sector was largely meant once again, to promote the production of flowers only, and there has been no focus whatsoever, at enabling the local sector to emerge as a creative entrepreneur of indigenous plant varieties. The system as it presently stands, clearly does not allow the local farmers to engage in technologically intensive activities to move up the global value chains in production and product development initiatives. This is a loss not just to the cut-flower sector, but to local agriculture as a whole, wherein the cut-flower experience if correctly managed could have been replicated to several other products and more knowledge-based initiatives could have been catalysed. The same is true with incorporation of higher environmental standards in local farms, for which technical support from the government is far from sufficient and effective. There is a lesson here to share for other African countries, such as Ethiopia, which have recently embarked upon the task of promoting local cut flower sectors. Policy focus needs to integrate the needs of attracting investment (such as plant variety protection) with the needs of promoting local activity into more knowledge intensive domains. At a more strategic level, the issue should increasingly move away from merely attracting investments, important as it is, to making the environment more conducive to encouraging greater biotechnology activity in the country and to promote the kinds of investment for building innovation capacity. Without this, African agriculture and Kenya horticulture specifically, will remain a periphery player in the core science-based activities and will continue to playing an auxiliary role relative to large foreign-owned firms as long as it neglects it own local needs and capacity.

6.7 Summing up

This chapter has analysed Kenya's experience in developing its agricultural biotechnology systems of innovation. Our main finding is that while Kenya has been successful in promoting several international research and product development collaborations in this area, and while its legal regime has taken note of the need to have both intellectual property and biosafety regimes, there is no systematic evidence of capacity building as a result of these initiatives. We find that this is due to the lack of clear and cogent policy vision for building innovation capacity in the sector, and the policy framework as it presently stands does not balance the biosafety and intellectual property framework with the science, technology and innovation needs of the sector. A range of factors that have been identified stifles interactive learning, and the case study of the cut-flower sector serves to illustrate how more knowledge-intensive activities are stymied by a lack of strategic focus on innovation capacity to meet local needs. Precisely because of these reasons, although Kenya's largest cluster is the Agricultural Products cluster (with 0.26% market share) has experienced a decline in market share (–0.05%) between 1997 and 2004, according to the World Bank.