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Hands over the Atlantic: exploring opportunities for microbial resource use for Africa

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Executive summary

Appropriate conservation and use of microorganisms will address many challenges that face society today. Food security, healthcare, the environment and livelihoods are all issues that can benefit from microbial innovations and solutions. It is essential that organisms with such potential are made available for study and that these strains are authentic, well maintained and characterized. It is also a fact that the majority of microorganisms are yet to be discovered and that there are many environments and areas around the world which are yet to be explored. Africa is considered to be one of these regions which is biodiversity rich but little explored. Activities are already underway to better understand and utilize its microbial diversity. However, it is important that new initiatives benefit from lessons learned from activities elsewhere and that new exploration is designed to meet specific local needs. A workshop held in Accra, Ghana, on 16–17 July 2014 demonstrated how Brazilian experience with microbial resources could benefit Africa, specifically focusing on Kenya and Ghana. The workshop brought together partners from Brazil, the UK, Kenya, Ghana, South Africa and Uganda with experienced scientists and biotechnologists, to exchange protocols, mechanisms and know-how on microbial diversity conservation and a regulatory expert to accelerate development in Africa. The goal of the background study and workshop was to explore the chain from organism isolation to identify hurdles and solutions. The workshop made recommendations to prepare the way for projects delivering sustainable funding for Biological Resource Centres (BRCs) in Kenya and Ghana, prepare business plans for local BRCs and develop project proposal concepts.

The CABI Development Fund (CDF)-funded workshop was designed to follow up the initial findings of a workshop funded by the Leeds Africa College and the Worldwide Universities Network (WUN) which sought to build on expertise in using microbes to control insect pests and their broader use in other biotechnology approaches. The Leeds workshop developed a strategic approach to microbial use, initially built around an established market of microbial use in pest control. The opportunities to learn from the Brazilian experience and explore the potential for funding opportunities from Brazil into Africa were a key driver in this activity. The Africa follow-up workshop had the objectives:

- To share Brazilian experience with Africa on the conservation and use of microbial resources
- To develop concepts for case studies and projects to deliver resources, practical and regulatory compliant protocols, know-how, technologies and activities using biopesticide products as a model for other resource-to-product delivery mechanisms
- To design activities to meet Kenya Agricultural Research Institute (KARI) specific requests for culture collection and utilization

Planned activities from workshop discussions:

1. Report on workshop output: highlighting the gateways to microbial diversity access and use.
2. Publishable versions of the workshop report to be written, for example:
    - a bullet-point pamphlet for policy makers, heads of research and higher education institutions, extension workers, farmer groups and Civil Society Organizations;
    - a paper on gateways for the microbial use – microbial domain Biological Resource Centres (mBRCs) and their users;
    - outlook in pest management – audience mainly scientists and potentially politicians and researchers; and
    - a book project for the future.
3. Raise awareness with stakeholders using appropriate mechanisms. Victor Clottey and Francis Dabire to look at the possibility to market biopesticides to stakeholder groups (listed below).
    - Policy makers and funders
    - Researchers and their administrators
    - Private sector (manufacturers, distributors, retailers, etc.)

- End users (extension workers, farmer groups, regulators, etc.)
- Public (Civil Society Organizations, journalists, general public)
- Educational system

4. Explore opportunities with Plantwise to include biopesticide solutions in their information, plant doctor training and recommended treatments to farmers.
5. Project proposals to demonstrate that the development of the bioeconomy from microbes in the environment to product on the market can improve livelihoods (detail, scope, etc. to be defined), for example the South–South collaboration on mBRC development listed above and in collaboration with Microbial Resources Research Infrastructure (MIRRI).
6. Other bioeconomy areas of BRCs' exploitation include pharmaceuticals, brewery/fermentation industries, food/beverage industries, etc.

Recommendations from the workshop:

1. Publish a shortened version of the workshop report.
2. Prepare the way for project delivering sustainable funding for BRCs in Kenya and Ghana through raising awareness with stakeholders; CABI and MIRRI are partners in a H2020 INFRASUPP6 proposal to help the Kenyan BRC Network build its infrastructure.
3. Draft an outline business plan for local BRCs.
4. Develop the project proposal concepts identified and submit to appropriate funders.
5. Prepare further project proposals to demonstrate that the development of the bioeconomy from microbes in the environment to product on the market can improve livelihoods (detail, scope, etc. to be defined). Other bioeconomy areas of BRCs exploitation can be included besides biopesticide production, for example in pharmaceuticals/brewery/fermentation industries, food/beverage industries, etc.

Conclusions

The project delivered the results anticipated in the project initiation document by delivering three project proposals, was within budget and has defined concrete actions for future development.

Introduction

The workshop, funded by the CABI Development Fund (CDF), formed a strategic part in the process of CABI responding to the request of its Member Countries to help them understand, protect and utilize their microbial diversity. CABI has a long history of working with its Member Countries in this regard and has carried out projects and capacity building activities in Europe and Asia but, to date, has not succeeded in any sustainable way in Africa. CABI working with Jomo Kenyatta University of Agriculture and Technology and latterly the Kenyan Biological Resource Centre Network (KBRCN) established interest in Biological Resource Centres (BRCs) about a decade ago. The KBRCN arose through partnership with the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung – BMBF) funded, Global Biological Resource Centre Network (GBRCN) demonstration project (www.gbrcn.org). An opportunity arose to further these efforts with a research group from Leeds Africa College, CABI, the University of Greenwich and Queensland University of Technology in collaboration with colleagues from Africa and Brazil. This was through a workshop funded by the Leeds Africa College and the Worldwide Universities Network (WUN) which sought to build on expertise in using microbes to control insect pests and their broader use in other biotechnologies. This group brought a focus on identifying and developing microbial pesticides and biological control in sub-Saharan Africa as a model system to demonstrate organism-to-market use. North–South relationships have proved difficult when they involve genetic resource use, often based on accusation of biopiracy. The workshop took a different tack and highlighted the Brazilian experiences in the sustainable and profitable use of microbial resources in ethical ways with the goal to establish South–South collaboration.

The understanding and use of microbial diversity to provide solutions to our grand challenges and to underpin the development of our bio-based economy has never been so important or timely. Africa has a vast wealth of biodiversity and is rich in microorganisms yet little is known about their potential and few activities are on-going to harness this hidden resource. There are efforts globally to develop mechanisms to access this diversity, conserve and sustainably utilize it in our everyday lives and to develop marketable products; so why not in Africa? The reasons may be many and concern: knowledge, technology, resources, regulatory hurdles and strategy. The Leeds workshop (mentioned above), attended by representatives from South Africa and Kenya, identified the need for awareness raising and capacity development to appreciate and determine courses of action to maximize sustainable exploitation of microbial resources. At the Ghana workshop it was agreed that it was necessary to better understand the hurdles in the chain from isolation to the market and determine whether the Brazilian experience could facilitate the process in Africa. Kenya is in the process of developing bioscience regulation and implementing plans to establish facilities for biodiversity conservation and use. In preparation for this, capacity and strategy are needed to harness local microbial diversity.

1 Microbial conservation in Brazil

The Brazilian biological collections are positioned well in the Brazilian Government agenda and are encompassed in the Ministry of Science, Technology and Innovation. This offers a perfect model for establishing activities in Africa, even if on an initial smaller scale. A National Policy for Biological Collections is proposed for Brazil which intends to establish the National Commission of Biological Collections. The latter will be composed of several Ministries, scientific societies, including the Brazilian Microbiological Society, and several research institutions, including Embrapa (Empresa Brasileira de Pesquisa Agropecuária – Brazilian Agricultural Research Corporation) and Fiocruz. The World Data Centre for Microorganisms (http://www.wfcc.info/ccinfo/) lists the 75 collections that this activity encompasses; these collections hold 103,140 organisms. In total there are 30 Fiocruz biological collections (17 microbiological, 12 zoological and one histopathological) spread across its institutions in Rio de Janeiro: Instituto Oswaldo Cruz (IOC), Instituto Nacional de Controle de Qualidade em Saúde (INCQS) and Instituto de Pesquisa Clínica Evandro Chagas (IPEC); in Belo Horizonte, the Centro de Pesquisa René Rachou (CPqRR); in Recife, the Centro de Pesquisa Aggeu Magalhães (CPqAM) and in Manaus, the Instituto Leônidas e Maria Deane (ILMD). These collections include a wide range of microorganisms including Archaea, Bacteria, Filamentous Fungi and Protozoa. These collections have established a web presence not least for visibility but to provide online

access to the services such as strain identification, distribution and deposit of strains into the collection. All adhere to national law and take every action possible to comply with international conventions impacting on microorganism access and use. To facilitate access and sharing of microbial resources, the Convention on Biological Diversity was ratified by the Brazilian Government in 1994. The Provisional Act Nº 2.186-16, from 23 August 2001 is based on the Convention on Biological Diversity (CBD), particularly addressing the access to genetic resources, the protection and the access to the associated traditional knowledge, the benefit sharing deriving from its utilization and the access to technology and technology transfer for its conservation and use (http://www.cbd.int/convention/text/). This Act also created the national competent authority, the Genetic Heritage Management Council (CGEN) within the Ministry of Environment, whose activities began in April 2002.

The main executing organization is the CGEN which is composed of nine ministries and ten federal organizations. Fiocruz is a member and provides a crucial link between the resource holders and the providers of policy.

- CGEN authorizes and amends the complementary rules regarding Access and Benefit Sharing (ABS).
- Foreign institutions can only access the Brazilian biodiversity in partnership with a Brazilian institution that, for legal purposes, will be responsible for the activities of access to genetic resources.
- From 2003 CGEN tried to address, as far as possible, the demands of sectors of society, publishing acts that clarify concepts that are fundamental for its enforcement (41 resolutions and ten technical orientations).
- As a way to improve national regulation related to ABS, the Brazilian Government is developing a new regulation that was recently sent to the National Congress, which will facilitate research and development of industrial products from biodiversity.
- This new regulation will provide resources for scientific research and biodiversity conservation, as well as foreseeing technical or financial aid to the traditional communities holding knowledge related to these genetic resources.
- The Provisional Act Nº 2.186-16 Article 16 includes the requirement to deposit a subsample of materials accessed into a Trusted Depositary Collection. Such functions to support government commitments positions collections well and thus justify their funding. Each Trusted Depositary Collection must go through an accreditation process by CGEN to be recognized and take on the roles of: (i) conservation of the biological materials; and (ii) their traceability from source to recipient.
- To be accredited the collection has to prove:
    - availability of infrastructure;
    - technical capacity; and
    - funding for the conservation activities.
- When a researcher accesses Brazilian's genetic resources abroad, as allowed by the Provisional Measure, a subsample of the genetic resource must be deposited in a Trusted Depository Collection before shipping overseas.

Up to the end of 2013 CGEN had accredited 358 Trusted Depository Collections within 70 public institutions, most of them in universities.

Authorization for accessing and shipping subsamples is a fundamental requirement. However, initially there were several criticisms of CGEN and one of them was the exceedingly long time needed for issuing such authorizations – some of them exceeding 1 year, mainly in cases when the purpose for access was commercial. This delay had been a huge drawback. Therefore, the National Council for Scientific and Technological Development (CNPq) was accredited with the challenge to issue authorizations faster and in a simpler and less bureaucratic way. A specific system for granting access and shipping genetic resource authorizations was developed in order to allow the whole process to be conducted online and electronically, avoiding the need to send any paper documents. The authorizations are also issued electronically. This

system is a functionality added to the Carlos Chagas Platform of CNPq, a computerized management system for CNPq researchers (http://carloschagas.cnpq.br/english/index.html) (Niederauer and da Silva, 2015). Additional documents, such as the research project, the prior informed consent (PIC) and the mutual agreed terms (MAT) can be attached electronically to the proposal in specific fields.

The majority of authorizations are for non-commercial purposes with researches being conducted mainly by universities and public research institutions. There are situations that the Provisional Measure, 2186-16, 23 August 2001 does not apply to, for example some research and scientific activities. The following four items are the English translation of the Resolution 21 that is available at the website below:

i. research that aims to elucidate the evolutionary history of a species or taxonomic group from the identification of species or specimens; the evaluation of phylogenetic relationships; the assessment of the genetic diversity of the population or the relationship of living beings with each other or with the environment;

ii. paternity tests, sexing techniques and karyotype analyses intended to identify a species or specimen;

iii. epidemiological research or research that aims to identify the etiologic agents of diseases, as well as measurement of the concentration of known substances whose relative quantities in the body indicate disease or physiological state;

iv. research intended to build DNA, tissues, germplasm, blood or serum collections.

A special arrangement has been made for academic access, available at:
http://www.diversitas-international.org/resources/outreach/abs-docs/ABS%20Implementation%20Brazil.pdf
and http://portal.fiocruz.br/sites/portal.fiocruz.br/files/documentos/relatorio-kate-colecoes-2013.pdf.

Brazilian BRC networking experience

Brazil has placed biological collections as a foundation stone in its research infrastructure and has given high priority to the maintenance of reference material to calibrate processes and instruments along with the key role of provision of study material for the development of new technologies. They have a global function to maintain representative samples of the world's heritage. Brazil is investing in knowledge production and education to face the challenge of sustainable development.

Scientific collections are an essential part of the research infrastructure of all countries and are critical to many areas of science, from microbiology to aerospace. For such reasons, in 2007 a workshop on Policy Issues Related to Scientific Research Collections under the auspices of the Organisation for Economic Co-operation and Development (OECD) Global Science Forum was held in Leiden, the Netherlands. A second, follow-up workshop was held in Washington, DC, in July 2008. These first workshops identified a series of needs regarding scientific collections, including: (i) the general need for development of common standards and best practices for managing scientific collections; (ii) the improvement of electronic cataloguing and accessibility of collections; (iii) the fact that some research questions can only be answered by combining information across multiple collections; and (iv) although collections comprised fundamental infrastructures for the scientific research enterprise, they were generally not managed as such. These initiatives evolved into the Scientific Collections International – SciColl (http://www.scicoll.org/) – which has an executive board constituted by representatives from several organizations, including Fiocruz.

Brazil took on these challenges, identifying opportunities to reduce the technology and industrial vulnerability of the country and transform knowledge into policies/decision making and improve infrastructure for biotechnology and bioprospecting. Of great importance to Fiocruz and its collections was that biodiversity offers solutions to health problems: this is demonstrated by the facts that more than half out of the 150 most-prescribed healthcare treatments are derived from biodiversity and the market value of medicines derived from biotechnology is about US$75–150 billion. In the low and middle income countries 80% of the populations depend, at least partially, on traditional medicines derived from local plants.

The Brazilian culture collection community and user base decided to build the Brazilian Biological Resource Centre (BRC) infrastructure from the bottom up, beginning with the collections themselves and their information resources to better serve the identified needs. Their goal was to make the resources more visible and accessible for research and development (R&D). This would facilitate the transformation of knowledge

into innovation, insert this innovation into the market and stimulate the national strategy and policies to do this, including appropriate governance structure and financial support.

The Brazilian National Science, Technology and Innovation Strategy for biodiversity and ecosystems' main lines of action were particularly helpful:

1. Innovation infrastructure
2. Knowledge, conservation and monitoring
3. Management and value aggregation of biodiversity goods/services resulting from the biodiversity
4. Mitigation and adaptation to the global and regional environmental changes

The main objective of this strategic plan is to develop innovative biotechnologies able to add value, to promote the sustainable use of the biodiversity and integrate new technologies and it prescribes a number of actions:

- Development of technological parks for the economic use of the Brazilian biodiversity
- To support and stimulate the implementation of biotech companies
- Amplification of knowledge, conservation and monitoring of the Brazilian biodiversity
- Establishment of the National Network for Molecular Identification of Biodiversity (at BR-Bol, Brazilian Barcode of Life) and a Germplasm National Bank (held by Embrapa)
- Organization, storage and data access of the biodiversity and ecosystems
- Development of a Biotechnology Innovation Observatory
- Creation of a BRC Network and consolidating the Brazilian Centre of Biological Materials (CBMB)

Key to the infrastructure working was the large user group that existed in Brazil. A study organized by the Brazilian Association of Biotechnology has mapped a total of 237 biotech companies that could be potential users:

- Of the potential users 40% are in São Paulo State.
- Of the biotech companies 40% have a focus on human health.
- Animal health, agriculture, environment and bioenergy altogether make another 40%, but each one has a significant role since they have a strong contribution in the bioeconomy chain.

The development of the Brazilian Network has roots that extend before the OECD initiative but it started to accelerate when the BRC report was published in 2001. This report was translated into Portuguese giving a pathway to policy makers to launch guidelines for conformity in the evaluation of biological material and to design a strategic plan for research on biodiversity. As a result in 2007 the Decree 6.041/2007 Policy for Biotechnology Development was enacted, prioritizing four main economic sectors: (i) human health; (ii) agribusiness; (iii) industry; and (iv) the environment. This decree also includes the decision to create BRCs that will operate as collections offering products/services in accordance to national and international requisites of safety, security and traceability, and accredited by certifier authorities. Brazil collections joined the GBRCN demonstration project and in 2011 the Brazil Major Plan, which describes the strategies for industry, technology and external trade, was initiated. Four BRC prototypes were selected following the survey and audit of the Brazilian collections. Through partnerships with INPI-INMETRO (Instituto Nacional da Propriedade Industrial - Instituto Nacional de Metrologia, Qualidade e Tecnologia) and with support from the National Biotechnology Committee, the Biological Resource Centre – Brazilian Network (BRC-BRN) was established.

Throughout this development financial backing was successfully sought through various national initiatives and support from national organizations. In 2005 a BRC workshop, entitled the Evaluation of Biological Material Conformity, developed a strategy to establish the collections as suppliers of reference materials essential for certified and accredited processes in industry. Audits of collections to ISO (International Standards Organization) 17025 were carried out resulting today in a specific standard in Brazil for the accreditation of BRCs. Several collection candidates to be accredited by the INMETRO have been selected: CLIOC (Coleção de Leishmania do Instituto Oswaldo Cruz) – Fiocruz, CBMAI (Coleção Brasileira de Micro-

organismos de Ambiente e Indústria) – UNICAMP (Universidade Estadual de Campinas), CENARGEN (Embrapa Recursos Genéticos e Biotecnologia) – Embrapa, Cell Bank – UFRJ (Universidade Federal do Rio de Janeiro). This has led to the establishment of a prototype, the BRC-BRN.

A governmental transversal research project has helped fund the transition process from traditional culture collection to BRC and the subsequent network. The main objectives of this project are:

a. Identification of collections which could associate to the BRC-BRN
b. Governance model of the network
c. Consolidation of the quality system
d. Recognition of the BRC-BR Network in the national and international community
e. Establishment of an integrated information system

The expected results are:

- Establishment of a BRC-BRN that is inclusive and integrated, acting transversally with all the stakeholders
- Establishment of a governance model for the National Network
- Establishment of a business plan for the whole network
- Accreditation of the BRCs of the BRC-BR Network
- Integration of all data
- Establishment of a solid and long-term Government programme

The project does not aim to set up a profitable business but to:

- Contribute to the conservation of the biodiversity
- Be a pillar for research on biotechnology development
- Contribute to the technological development
- Strengthen the national industry therefore minimizing the country dependency and, mainly, protect part of the Brazilian [mega] biodiversity and generate value for society

The main idea is to tailor the strategies that will allow the sustainability of the network for the long term, leading to a State plan, and not only a Government plan, therefore positioning BRCs as a strategic tool for biotechnology development and ultimately protecting and giving a responsible use of the national biodiversity.

It is clear that the operational environment and the market in Africa are quite different to that of Brazil and the immediate opportunities are not as prolific. However, there are several principles that can be adopted in establishing the momentum for culture collection transition to BRC and creating a portfolio of projects that can address microbial sustainable conservation and use in Africa.

Brazilian experiences with microbial insecticides

Mycoinsecticides and mycoacaricides can be defined as biopesticide products based on living propagules of entomopathogenic fungi developed for inundative and inoculative biological control of insects and mites. Most Brazilian mycopesticides are not registered; 2.5% of the products are commercialized as technical material (conidial powders), 72.5% correspond to technical concentrates (liquid or solid fungus-colonized substrates) and 25% are formulations, all of them oil dispersions (Rangel and Faria, 2010). In Brazil, mycopesticides have not consistently met users' expectations, partly due to inconsistency in field trials. After 40 years of research, technological advances in Brazil have been lower than expected. However, there is an expectation of increasing demand for entomopathogenic fungi due to emergent market niches, development of new markets for crops such as fruit and also increases in field crops due to new beef and dairy production systems (Filho *et al.*, 2009; Rangel and Faria, 2010). According to Rangel and Faria (2010), approximately 3 million ha of agricultural cropland in Brazil are treated annually with microbial pesticides, with the total area treated with entomopathogenic fungi ranging from 600,000 to 1,000,000 ha (Rangel and Faria, 2010).

In the early 1970s, *Metarhizium anisopliae* var. *anisopliae* was used to control sugarcane spittlebugs (*Mahanarva posticata*) in the Northeast. This was the first large-scale microbial pest control programme in Brazil. The successful programme reduced the area treated with synthetic insecticides by 90% and encouraged the use of parasitoids for biological control of sugarcane borers (Alves, 1998).

During the growing season of 2007/2008, in the state of São Paulo alone, *M. anisopliae* var. *anisopliae* was applied to 250,000 ha for control of the sugarcane root spittlebug, *Mahanarva fimbriolata* (Rangel and Faria, 2010). Furthermore, more than 15,000 ha of rubber trees are treated with *Sporothrix insectorum* isolates to control lace bugs *Leptopharsa heveae* (Hemiptera: Tingidae) (Rangel and Faria, 2010). From 1997 to 2000, 5,000 ha of rubber trees were treated with biopesticides distributed in the states of São Paulo, Goiás, Mato Grosso, Minas Gerais and Mato Grosso do Sul (Almeida and Filho, 2001).

There are about 40 registered products produced by 19 for-profit companies with a further 20+ on-farm production laboratories found on sugarcane plantations (Rangel and Faria, 2010). Not all products need to be registered. If an isolate is obtained from the land it can be mass produced and reapplied to the same plantation without the need for registration; although this may be changing (Rangel and Faria, 2010).

Rangel and Faria (2010) gave an overview of registration of biological products in Brazil and below is a summary of their findings. Brazil realized that their registration system did not suit biological products so they began to differentiate between chemical and biological products. Priority was given to those products with low toxicity and few environmental hazards. In 2002, the publication of Law 4072 unified earlier regulations initiated jointly by the Ministry of Agriculture, Livestock and Food Supply (MAPA), the Health Surveillance Agency (Anvisa) and the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama), resulting in many tests that are required for chemicals, not being required for biopesticides.

In order for a company to carry out biopesticide registration field trials, for use in non-organic fields, they must first apply for Special Temporary Registration (Registro Especial Temporário – RET) (Rangel and Faria, 2010). The company must provide a dossier on the product including biology and taxonomy of the active ingredient, along with information such as host range and characteristics of the formulated product. Within the dossier there must be detailed information on the proposed field experiments. All experiments must be carried out at experimental stations with MAPA accreditation (Rangel and Faria, 2010).

Once the registration process has begun there are strict legal timeframes to adhere to. Ibama and Anvisa have 60 days to send the toxicological and environmental preliminary evaluations to MAPA. In return, MAPA has 15 days to accept or reject the RET application. As soon as the RET is granted the company can start experimental trials. Definitive registration requirements were determined in Directive 3/2006. Tier testing is done for toxicology and non-target organisms. Toxicology tests start with short-term trials (e.g. dermal irritation, and toxicity and pathogenicity via acute intravenous injections) (Rangel and Faria, 2010). If these tests are negative no further testing to Tiers II or III is required, which saves a lot of time and money. Furthermore, if crops are intended for human or animal feed, no residue studies are required if the product has negative results for Tier I (Rangel and Faria, 2010). Likewise if there are no adverse effects of the product on non-target organisms then testing of Tiers II–IV are unnecessary (Rangel and Faria, 2010).

Once all the toxicity, non-target and field trail data is submitted to the official agencies, Ibama and Anvisa must send their evaluations to MAPA within 4 months (Rangel and Faria, 2010). MAPA has 30 days to either accept or reject the application for the Certificate of Registration (Rangel and Faria, 2010).

To get a product through Tier I testing costs approximately US$70,000 including charges by federal agencies for the examination of the documents, and the issuing of the RET and the Certificate of Registration (Rangel and Faria, 2010). The company then needs to register the product at the state level and each state has their own rules. Although greatly improved, the registration process is still relatively expensive and bureaucratic for small companies (Rangel and Faria, 2010).

2 Biological resources in Kenya

The need for activities and facilities to maintain Kenyan biodiversity was formalized through the enactment of the Environmental Management and Coordination Act (EMCA) 1999, which implemented compliance with the Convention of Biological Diversity (CBD). Jomo Kenyatta University of Agriculture and Technology (JKUAT) had a history of studying the microbial diversity of the salt lakes but facilities to maintain the isolated

resources were needed. *Ex situ* conservation facilities were not available and cultures were simply maintained by individual scientists. Kenya was lacking reference and commercial strains; there was neither a patent depository facility nor a facility to keep isolated and characterized strains arising from in-country studies. CABI offered help to bring together the scattered initiatives and a scoping study for an East African Biological Resource Centre was carried out focusing on Kenya, Tanzania and Uganda. It quickly became evident that each country wanted to maintain its own resources and Kenya had a head start already having some activities initiated.

The Kenya Agricultural Research Institute (KARI) had established a germplasm collection; the Kenya Medical Research Institute (KEMRI) carries out health science research in Kenya and has reference collections of pathogenic organisms; the International Centre of Insect Physiology and Ecology (ICIPE) houses the Arthropod Pathogen Germplasm Centre; the National Museums of Kenya (NMK) have built a seed bank; the College of Veterinary and Agricultural Sciences where the Microbial Resource Centre (Mircen) of the University of Nairobi is situated has isolated legume nodulating rhizobia from across the country and used the isolates to develop biofertilizers for use in subsistence farming; added to these initiatives are a plethora of individual researcher collections.

The first workshop organized by CABI was held in March 2004 in Nairobi and the East African Biological Resource Centre (BRC) Network was proposed following subsequent country-level consultations. Professor Agnes Mwang'ombe led a steering committee for which the Kenyan National Council for Science and Technology (NCST) was to provide a neutral secretariat. The focus of activity was on microbial resources, justified by the arguments to support BRCs as proposed by the OECD that:

- No one collection or country can maintain all biodiversity.
- It is neither efficient nor possible to get all experts and facilities into one physical entity.
- There is a need to identify and prioritize national needs and attempt to provide microbial solutions to local problems.
- There is a requirement for the implementation of internationally accepted common standards, policies and approaches.
- There is a need for capacity building.
- It would provide access to new technologies.

A proposal to establish the Kenyan Biological Resource Centre Network (KBRCN) to address local *ex situ* conservation of microorganisms, organize training, underpin research with microbial resources, address national bioprospecting, ensure controlled exchange of biomaterials and to underpin good science by ensuring correct identification of the deposit of voucher specimens and type strains was designed and submitted. The Kenyan Government was interested but required national policy first. A national committee was established to draft the Bioscience Policy and Bill which provide a good environment for establishment of conservation and sustainable use activities but this still remains a lower priority for the Kenyan Government. Actions have been taken to move the process up to consultation with the relevant parliamentary committee, and hopefully the end product should be a BRC or at least a Microbial Culture Collection Centre. For it to be successful international cooperation was considered essential and the Institute of Biotechnology Research, JKUAT, led by Hamadi Boga, joined the Global Biological Resource Centre Network (GBRCN) demonstration project with the aims: (i) to share technical expertise; (ii) to develop local capacity for the authentication of organisms, establish best practice, management and use of microorganisms; and (iii) address issues of quality, safety and controlled access, especially to dangerous materials.

A third KBRCN workshop was held in 2011 sponsored by Bundesministerium für Bildung und Forschung (BMBF) bringing together partners from Kenya, Uganda, Nigeria, Germany, the UK, Brazil, Portugal and the Netherlands. A pilot BRC proposal for Kenya was agreed and the network of collections in Kenya was established. The next steps were outlined and auctioned as follows:

Step I

- Finalization of draft policy
- Sensitization of stakeholders
- Building trust

- Agree on network and pilot project

Step II

- Consolidation of institutional collections
- Improved documentation and handling of institutional collections

Step III

- Implement the World Federation for Culture Collections (WFCC) and Common Access to Biological Resources and Information (CABRI) Guidelines
- Define the guidelines for the pilot KBRCN (Figure 1)
- Establishment of the pilot KBRCN (public and confidential service)
- Develop the human resource and capacity building programme for the pilot KBRCN
- Establish the long-term plans including the implementation of the OECD Guidelines for BRCs

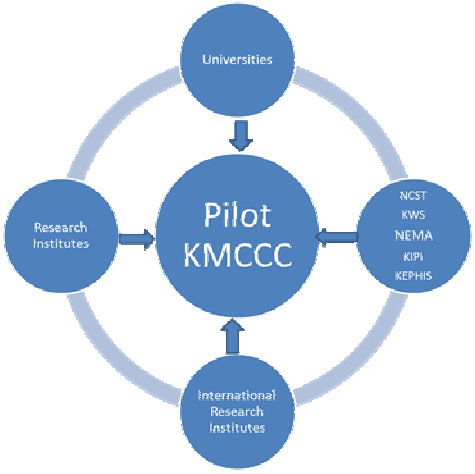

Figure 1. The pilot Kenya Microbial Culture Collection Centre (KMCCC)

The KBRCN will build on the KMCCC to bring together the institutions outlined in Table 1.

A Kenyan Biological Resources Database is envisaged to be housed centrally in the KMCCC pilot coordinating centre offering an ICT infrastructure and collection management system (Figure 2). It would extend beyond microorganisms to cover all species (numbers, diversity, geography, sequences), higher plants and animals, fungi, bacteria, viruses/phages and would include publications/theses, published gene and genome sequences and would have an area on published patents.

The KBRCN will have a management committee that will define a partnership MoU and prescribe membership rules. A web portal will be developed and training programmes with the support of international partners will be offered.

Table 1. The institutions proposed to be brought together for the KBRCN

Universities	**Research institutes**	**International research organizations**
Jomo Kenyatta University of Agriculture and Technology (JKUAT) University of Nairobi Kenyatta University (KU) Moi University Egerton Maseno University Masinde Muliro University of Science and Technology (MMUST) Others	Kenya Agricultural Research Institute (KARI) Kenya Medical Research Institute (KEMRI) Kenya Forestry Research Institute (KEFRI) National Museums of Kenya (NMK) Veterinary Laboratory Tea Research Coffee Research National Public Health Laboratories	The International Livestock Research Institute (ILRI) The International Centre of Insect Physiology and Ecology (ICIPE) The World Agroforestry Centre (WAC), formerly the International Centre for Research in Agroforestry (ICRAF) International Potato Centre (CIP)

The network receives knowledge and technology transfer from the GBRCN partners and ensures its compliant operation by working closely with the regulatory agencies (NCST, the Kenya Wildlife Service (KWS), the National Environment Management Authority (NEMA), Kenya Plant Health Inspectorate Service (KEPHIS) and the Kenya Industrial Property Institute (KIPI)).

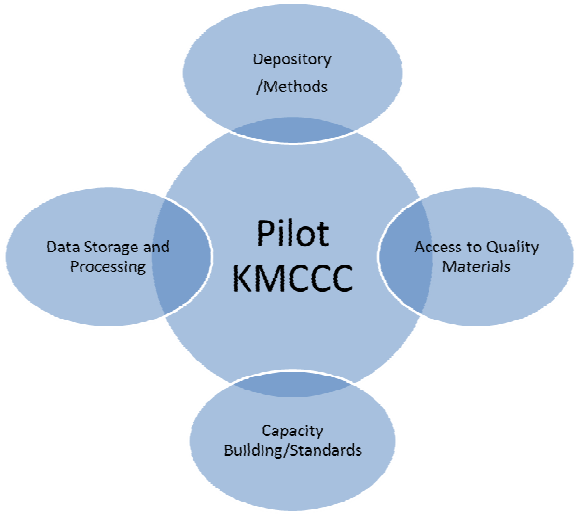

Figure 2. Functions of the proposed pilot Kenya Microbial Culture Collection Centre (KMCCC)

In 2014 the position was that the draft Bioscience Policy and Bill had been shelved since 2012 and no progress has been made. Changes at NCST (now NACOSTI) may see further delays. However, Global Environment Facility (GEF) funding for the project *Access and Benefit Sharing (ABS) Protocols for Soda Lake Microorganisms* was awarded with the partner institutions: KWS, JKUAT, Moi University, Verenium and the local United Nations Environment Programme (UNEP). One key focus of the GEF is to strive to improve the framework for the ABS laws in Kenya which are hampered by long delays experienced by researchers wishing to access genetic resources for research. The other major output is the establishment of the pilot

KBRC at JKUAT. This will involve the isolation of microorganisms from soda lakes, their identification and curation. The activities will include PhD-level training, training on ABS and the initiation of a capacity building programme on BRC operations.

The GEF proposal takes a major step in BRC development in Africa but additional initiatives are needed if they are to meet international standards and be part of a network. Kenya has the opportunity to take advantage of international developments and cooperation particularly offered following this GEF-funded workshop and South–South collaboration will take this activity to the next level. Long-term sustainability requires a sound business plan to harness microbial diversity, to provide solutions to national needs and to identify priorities. Partnership is necessary to create the required network.

The GBRCN activity continues with regional efforts, in particular through Europe where the Microbial Resources Research Infrastructure has outreach activities that will continue to offer support for development in Kenya.

Biopesticides: Kenyan perspective

Real IPM, a company operating from Thika Town in Kenya provides biopesticides and predators to control pests and diseases in Kenya, Southern Africa, Ethiopia and Ghana. There are numerous organisms being prepared as products (see Table 2).

Table 2. Microorganisms being prepared as products and used in Kenya

Source	Biological organism	Target
Imported (I)	Ampelomyces quispualis	Powdery and downy mildew
Kenya (K)	Bacillus subtilis	Powdery mildew
I	Bacillus thuringiensis varieties aizawai, israelensis and kurstaki	Lepidoptera
I & K	Beauveria bassiana	Thrips, white fly, aphid
K	Helicoverpa armigera SNPV	Boll worm
I & K	Lecanicillium lecanii	Aphids, thrips, white fly
K	Metarhizium anisopliae	Mites
I	Myrothecium verrucaria	Nematodes
I & K	Paecilomyces lilacinus	Nematodes
I	Pseudomonas fluorescens	Botrytis, Septoria, Sclerotinia
K	Trichoderma asperellum	Root diseases in French beans
I & K	Trichoderma harzianum	Root diseases in carnations

The indigenous production was compared with the multinational approach. The advantages of indigenous companies were considered to be local knowledge and low cost of production and therefore affordable products using indigenous isolates. However, the disadvantages were described as the lack of resources, mainly investment, low spend on R&D, external assistance is usually required and collaboration is often

essential with little opportunity for scale up and the resultant economies being realized. There were a number of issues raised, including the question whether fresh was best. Organisms grown for immediate use as needed potentially on farm means that there are no losses due to storage. However, the major disadvantage is the delay from when the product is requested until it is ready for application. The barriers to biopesticides in Africa were related to the importation of non-indigenous isolates and their registration, although this appeared to be fairly straightforward and not expensive. The farmer always compares the biopesticide to the quick knock down that often follows chemical applications; there are many generic pesticides all over Africa, for example there are over 15 “abamectins” available in Kenya. Often broad spectrum and low cost far outweighs the residue issues associated with chemical use. Further, the not uncommon need to store the biopesticide at low temperature (as shelf life is generally short) may be prohibitive.

3 Microbes from source to product

The Ghana workshop was structured around exploring the chain from organism isolation to its use (Table 3) in order to identify hurdles and solutions not only in product development but in regulatory compliance, access to microorganisms, funding and the capacity needs including development of human resources and facilities. The focus was on biopesticide production as there was already a market for such microorganisms and their products but essentially many of the issues concerned all microbial diversity use.

Kenya had been working over the last two decades to establish culture collections to support research and thus they had a sound platform on which to build. The priority identified was coordinated efforts to attract long-term funding to strengthen this base and to develop a maintenance strategy and business plans for local microbial domain Biological Resource Centres (mBRCs). The priority for Ghana was to learn from the Kenyan experience and draw its microbial resource provider and user communities together to establish a similar platform and thus the two countries could then progress together. Brazil had already established a sound funding mechanism and had placed its mBRCs as a key element in the research infrastructure there. Priority actions were agreed to strengthen private sector engagement, and raise awareness by preparing an advocacy paper to sensitize national and regional politicians. Arguments to support this would be built around, for example, exploiting economies of scale leading to more rapid discovery and product development and the addressing of biosecurity issues at both national and regional levels. Sound business plans were considered essential, all the way to production and for each level communication plans to engage funders and regulatory bodies from various sectors (public and private) were needed. The concept of South–South collaboration was welcomed and the proposal concept uses the big picture to support the case for development of the microbe to product chain and utilizes the experience from Brazil, South Africa, Kenya, Ghana and CABI to support further development of expertise and current practices in Africa.

The initiative needs to come from the ground level too and efforts to evolve sub-national laboratories and institutes into national BRCs are underway. This effort needs to be coordinated so as to avoid unnecessary duplication and establish cost-effectiveness by sharing expertise, technology and facilities through networking. Policies and guidelines are essential if the user community are to be engaged in deposit of their research strains and their development must involve depositors, resource holders and users. Incentives are needed to attract participation (e.g. sound policies for ABS) and convince researchers that isolates are public collective resources and should be preserved for future use (building the culture for conservation). Plans must focus on providing solutions to national priorities and convince policy makers of the importance of preserving microorganisms as part of the national biodiversity action plans to conserve genetic resources. A key issue identified in all sections of the source to product chain was the need to enhance capabilities of national laboratories to preserve isolates for the long term.

To add value and facilitate the use of African microbial resources it is necessary to generate knowledge from isolates in mBRCs through research and educational systems. It is essential to build networks around universities to facilitate characterization of isolates around educational programmes and build databases from research results. CABI has 100 years of experience in building databases and has created a knowledge bank specifically around plant health.

Table 3. Isolation to product chain: regulatory environment and capacity needs

Microbial product chain	Regulatory environment	Capacity needs
Isolation and selection of microorganism	Convention on Biological Diversity (CBD) – Nagoya Protocol – in country provisions Quarantine Health and safety Patenting Ownership of Intellectual Property Rights (IPR)	Training Funding Technology
Characterization of microorganism	Health and safety Patenting Ownership of IPR	Training Funding Technology Facilities
Storage of living material	CBD – Nagoya Protocol – in country provisions Health and safety	Training Funding Technology Facilities
Selection of organism		Knowledge
Product and formulation development	Patenting	Training Funding Technology Facilities
Product trials	Need to be done to regulatory standards	Training Funding Technology Facilities
Registration	Registration (which law?) Ownership of IPR	Training Funding Information Knowledge
Manufacture	Health and safety Environmental regulation	Training Funding Technology Facilities
Use	Registration	Market Licence
Marketing		Market survey Publicity material
Research and Development (R&D)	CBD – Nagoya Protocol – in country provisions Quarantine Health and safety Patenting Ownership of IPR	Training Funding Technology Facilities

It is not only at resource level where action is needed; there is also a need to address the use to ensure there is a market for the microbial product. Currently there is not wide-scale adoption of biocontrol agents and there is a need for awareness raising at several levels, including the farmers and national authorities. There is also a need to: (i) improve facilities at local distribution agents (shops); (ii) improve shelf life in available storage conditions; (iii) improve formulation to improve field results; (iv) explore local production on farm or by local companies. New and improved products for a wider range of pests and diseases will help expand the market in Kenya. Lessons learned can be shared with Ghana to expand usage there. Of course biopesticide products are just one use and there are several markets for microbial products to be explored.

Although the situation is improving there is a general absence of appropriate biosafety laws in most African countries. Working with policy makers to ensure new regulations are implementable and appropriate can highlight the importance of microorganisms and help get support into BRC networks. It is important that good communication channels are established and best practices in this regard can be shared from the Brazilian and European experiences. It was recommended that local case studies were needed to generate convincing arguments, provide the information on best practices and resulting information adapted to suit the different stakeholders.

A common fear of African practitioners is "biopirating" whole organisms and products but by creating local mechanisms and managing local resources this can be controlled and partnerships with users compliant with the Nagoya Protocol on ABS can be established. In Europe and South Africa bar coding of strains and patenting the use of the strain for a specific use is possible. Clear guidelines and processes on these issues are needed and an African International Depository Authority (IDA) may help the process.

4 South–South collaboration in Africa to enhance microbial conservation and use

Proposal for Kenya

A project concept is proposed that will require a mixed model of funding and a well-conceived strategy considering the many years invested since the turn of the century to get activities underway. The Global Environment Facility (GEF) funding for the project ***Access and Benefit Sharing (ABS) Protocols for Soda Lake Microorganisms*** with the partner institutions: KWS, JKUAT, Moi University, University of Nairobi, Kenya Industrial Research Development Institute (KIRDI), Verenium (BASF American division) and the local UNEP office may well stimulate the Government to take a fresh look at the Biosciences Policy and Act they "shelved" 2 years ago or take steps to address issues raised over many years. Collaboration between Brazil and Kenya facilitated by CABI built around this initiative will form the platform for development.

The Ghana workshop discussions resulted in a number of actions that could lead to a sustainable programme of work to help establish the Kenyan Biological Resource Centre (BRC) and position it in the global activities so that it can accelerate its development:

1. Carry out a SWOT analysis for the Kenyan Government and build a strategic plan with them to include the process and procedure for Kenya to implement the Nagoya Protocol
2. Concentrate on research and infrastructure
3. Establish the business plan with Brazil supporting the process but ensuring that it is locally owned and developed
4. Exchange of knowledge and technology transfer in a three-way collaboration between Brazil, Kenya and CABI, UK
5. Capacity building including a postgraduate course, run in country
6. Exchange of scientists
7. Look for African funding programmes to support a project to extend linkages and position Kenyan Biological Resource Centre Network (KBRCN) in Government strategy using the GEF project as leverage
8. Accreditation of the Kenyan BRC should be part of the future strategy in the "business plan"

Proposal for Ghana built around specific pest control needs

There is a need for a driver in Ghana as there are no established coordinated actions in microbial conservation and use. This could be from the private sector or built around existing communities/networks, for example the National Fruit Fly Committee which looks to both the public good as well as the commercial possibilities. ECOWAS – Economic Community of West African States – could also be a starting point.

CABI have allocated funds and support with further investment "catch up" actions to:

a. Identify the actors in microbiology in Ghana

b. Bring key partners together in a local workshop to review what the KBRCN has achieved and plan steps to position Ghana to establish its own network

c. Arrange a joint meeting with the KBRCN and CABI Africa to help develop their proposal based on the outlined actions for Kenya above

The established links, the developed strategy and the technocrats can be used to form a bridge to get onto the Government agenda. The proposal can work in parallel with that of Kenya or it can utilize the basic plan followed by the Brazilian collections.

5 Recommendations from the workshop

There were 18 participants in the workshop representing six countries (see Annexe 1). Discussions were built around the steps from organism isolation through characterization to placing a product on the market. The output of these discussions is summarized in Annexe 2.

1. Prepare the way for project funding and the sustainable funding for Biological Resource Centres (BRCs) in Kenya and Ghana through raising awareness with stakeholders; CABI and MIRRI are partners in an H2020 INFRASUPP6 proposal to help the Kenyan BRC Network build its infrastructure
2. Draft an outline business plan for local BRCs
3. Develop the project proposal concepts identified above and submit to appropriate funders
4. Explore opportunities with Plantwise to include biopesticide solutions in their information, plant doctor training and recommended treatments to farmers
5. Prepare further project proposals to demonstrate that the development of the bioeconomy from microbes in the environment to product on the market can improve livelihoods (detail, scope, etc. to be defined). Other bioeconomy areas of BRCs' exploitation can be included besides biopesticide production, for example in pharmaceuticals, brewery/fermentation industries, food/beverage industries, etc.

Conclusions

Three proposals for follow up are being developed: one submitted on 2 September 2014 to the European Commission (INFRASUP6 – Biological Resources Infrastructures for Health in Africa) and the South–South collaborations with Kenya and Ghana to be supported by both Brazilian development funds for Africa and national funding. This paper serves to raise awareness of the work and activities in Africa. These activities, linked to the actions planned to implement all recommendations, will ensure a long-term legacy and future development from the investment made by the CABI Development Fund (CDF).

Acknowledgements

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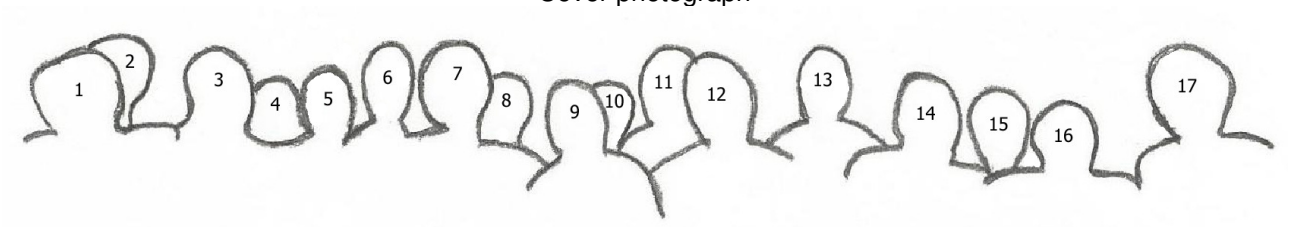
Acronyms

ABS	Access and Benefit Sharing
Anvisa	Health Surveillance Agency
BASF	Badische Anilin- und Soda-Fabrik – Baden Aniline and Soda Factory
BMBF	Bundesministerium für Bildung und Forschung – German Federal Ministry of Education and Research
BR-Bol	Brazilian Barcode of Life
BRC	Biological Resource Centre
BRC-BRN	Biological Resource Centre – Brazilian Network
CABI	CAB International
CABI E-UK	CABI Europe – UK
CABRI	Common Access to Biological Resources and Information
CBD	Convention on Biological Diversity
CBMAI	Coleção Brasileira de Micro-organismos de Ambiente e Indústria
CBMB	Brazilian Centre of Biological Materials
CDF	CABI Development Fund
CENARGEN	Embrapa Recursos Genéticos e Biotecnologia
CGEN	Genetic Heritage Management Council
CIP	International Potato Centre
CLIOC	Coleção de Leishmania do Instituto Oswaldo Cruz
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico – National Council for Scientific and Technological Development
ECOWAS	Economic Community of West African States
Embrapa	Empresa Brasileira de Pesquisa Agropecuária – Brazilian Agricultural Research Corporation
EMCA	Environmental Management and Coordination Act
Fiocruz	Fundação Oswaldo Cruz
GBRCN	Global Biological Resource Centre Network
GEF	Global Environment Facility
H2020	Horizon 2020 (European Commission projects call)
Ibama	Brazilian Institute for the Environment and Renewable Natural Resources
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	International Centre for Research in Agroforestry
ICT	Information and Communications Technology
IDA	International Depository Authority
ILRI	The International Livestock Research Institute
INMETRO	Instituto Nacional de Metrologia, Qualidade e Tecnologia – National Institute of Metrology, Standardization and Industrial Quality
INPI	Instituto Nacional da Propriedade Industrial – National Institute of Industrial Property
IOBC	International Organisation for Biological Control
IPM	Integrated Pest Management
IPR	Intellectual Property Rights
ISO	International Standards Organization
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KARI	Kenya Agricultural Research Institute

KBRCN	Kenyan Biological Resource Centre Network
KEFRI	Kenya Forestry Research Institute
KEMRI	Kenya Medical Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
KIPI	Kenya Industrial Property Institute
KMCCC	Kenya Microbial Culture Collection Centre
KU	Kenyatta University
KWS	Kenya Wildlife Service
MAPA	Ministry of Agriculture, Livestock and Food Supply
MAT	mutual agreed terms
mBRC	microbial domain Biological Resource Centre
Mircen	Microbial Resource Centre
MIRRI	Microbial Resources Research Infrastructure
MMUST	Masinde Muliro University of Science and Technology
MoU	Memorandum of Understanding
NACOSTI	National Commission for Science, Technology and Innovation (formerly NCST)
NCST	National Council for Science and Technology
NEMA	National Environment Management Authority
NMK	National Museums of Kenya
OECD	Organisation for Economic Co-operation and Development
PIC	prior informed consent
R&D	research and development
RET	Registro Especial Temporário – Special Temporary Registration
SciColl	Scientific Collections International
SWOT	Strengths, Weaknesses, Opportunities, Threats
UFRJ	Universidade Federal do Rio de Janeiro
UNEP	United Nations Environment Programme
UNICAMP	Universidade Estadual de Campinas
WAC	World Agroforestry Centre
WFCC	World Federation for Culture Collections
WUN	Worldwide Universities Network

Annexe 1: Workshop participants list

Cover photograph



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[a] ASARECA, Association for Strengthening Agricultural Research in Eastern and Central Africa; CRI, Crops Research Institute; CSIR, Council for Scientific and Industrial Research; EPA, Environmental Protection Agency; ICIPE, International Centre of Insect Physiology and Ecology; PPRSD, Plant Protection and Regulatory Services Directorate; SARI, Savanna Agricultural Research Institute; WAC, West Africa Centre.

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Annexe 2: Summary report of Ghana workshop discussions

The issue	How to address the issue	Workshop recommendations
Session 1		
Coordinated efforts to attract long-term funding; develop a maintenance strategy and business plans for mBRCs	Strengthen private sector engagement Exploit economies of scale Address biosecurity issues at both national and regional levels Raise awareness (e.g. prepare an advocacy paper to sensitize national and regional politicians) Develop business plans all the way to production and for each level develop sub-plans to engage funders from various sectors (public and private) South–South collaboration	Use the big picture to support the case for development of the microbe to product chain Design the case study as a first step (proof of concept) Base the proposal on a sound and sustainable business plan Use the experience from Brazil, South Africa, Kenya, Ghana, CABI, etc. to support further development of expertise and current practices in Africa South–South Kenyan enhancement Proposal for Kenya: Make a SWOT matrix for Kenyan Government and build a strategic plan with them to include Nagoya Protocol Concentrate on research Then infrastructure Establish the business plan Brazil supporting the process Locally owned and developed Exchange of knowledge and technology transfer Capacity building including a postgraduate course run in country Exchange of scientists Project with KBRCN to extend their linkages and position them in Government strategy Look for African funding programmes to support this Link to GEF programme Accreditation part of the future strategy in the “business plan” Proposal for Ghana: To be built around specific pest control needs Need a driver – from private sector or build around existing communities/networks (e.g. National Fruit Fly

		Committee which looks to both the public good as well as the commercial possibilities). Another possibility involved control of cocoa swollen shoot virus by microbial control of the mealybugs that vector the disease. ECOWAS – Economic Community of West African States – could also be a starting point Use these links and the technocrats forming the bridge to get onto the Government agenda
Grow sub-national labs and institutes into national BRCs and network them into regional BRCs	Develop policies and guidelines (input from depositors, resource holders and users) Create incentives to attract participation (e.g. sound policies for ABS) Focus on a solution to some problems of a national industrial commodity around which to get stakeholder interested in the initiative (a stepwise approach) Convince researchers that isolates are public collective resources and should be preserved for future use (building culture for conservation)	Identify institutions/potential mBRCs (Done in South Africa and Kenya – KBRCN) Working group needed to identify national priorities and develop plans First step article/publication/social media/Internet Delivered in the next step strategy Convince policy makers of the importance of preserving microorganisms which are genetic resources
Enhance capabilities of national labs to preserve isolates for the long term	Designate and upgrade repositories (national or/and regional)	South–South collaboration Need to see what is contained in the GEF-funded project on soda lake microorganisms secured by Hamadi Boga, JKUAT
Generate knowledge from isolates in BRCs through research and educational systems	Characterization of isolates using students and researchers Build databases from research results	Work with CABI knowledge bank and data activities plus South–South collaboration Also valid above: Look at *Trichoderma* biofertilizer products and potentially see if there could be Innovate UK support Research into biodiversity use potential with potential Department for International Development (DFID) involvement Information resource generation
Session 2 key points: Regulatory environment and Registration		
Don't have wide-scale adoption of biocontrol agents, despite the interest; there is a need for special storage facilities/conditions for some	Awareness raising; Encourage use of biopesticides in organic production; Strong lobby groups; Improve facilities at local distribution agents (shops), improve shelf life in available storage conditions, improve formulation to extend shelf life; Local production on farm	Awareness raising – publicity campaign Engage with stakeholders Knowledge and technology transfer Change hurdles to gateways – as all hurdles identified had solutions and therefore most of the solutions are

biocontrol agents	or by local companies Plant Protection and Regulatory Services Directorate (PPRSD) registration will be required if this local product is sold more widely and not only used on farm)	delivered through the publication of: 1. A bullet-point pamphlet for policy makers 2. Paper on gateways for the microbial community 3. Book project for the future Persuade Plantwise to look at making biopesticides more broadly available Currently no biopesticides going through the Ghana system mainly because of the requirements for the registration dossier; some non-Ghana products are being registered via Real IPM Governments should have Policy on IPM in order to promote biopesticides
Difficulty in registration; content of the dossier may be an expensive activity	Registration process is relatively quick in Ghana – it takes 90 days at US$2,400 for a period of 3 years (being increased to 5 years). The situation in other countries needs to be reviewed to see if further efficiencies can be made Stop sale orders can be issued for non-registered products (including out-of-date licences). Simplify registration process and then regulate more heavily Try to get as many products on the market to increase range of products and encourage the use (however, efficacy must be proved – this suggestion provoked debate: one view is that the market will reward the producers who are good). Producers must produce as much information and evidence of efficacy as possible. Must not put ineffective biocontrol agents on the market as this can undermine confidence of farmers; again, speed and ease (reduced cost) is the most important factor and good products will eventually succeed, is another view. The good producers aren't the worry, it's the pirates who would not go through the registration process and just produce counterfeit products. Regulation of the market is more important than registration of products is another view. Need to improve the image of the biopesticide industry (be careful that it is done by the experts). There is a difference between biocontrol agents and pesticides in that more toxicology testing is in place for chemicals; bio-efficacy testing is not so easy for biopesticides as expertise and protocols	Review the situation in other countries Share best practices Great deal of this is already there so this needs to be brought to the attention of practitioners and can be included in the paper Look for further support to gather information for the publication

	are not as straightforward as for chemicals. Must ensure back-up systems are available	
Quality along the retail chain; capacity not currently in place	Capacity needs to be established to enable this as it is critical for both efficacy and ensuring safety. There is a need to build capacity through group partnerships to ensure quality along the supply chain	Share best practice Knowledge and technology transfer There are solutions to these issues that can be included in the publications
Biosafety and appropriate laws	Absence of appropriate safety laws in most African countries; ECOWAS is providing guidance; EPA wish to turn "blue book" into a regulation, system in place for use, needs promulgating – raise awareness; Need to develop a biosecurity/biosafety risk assessment	Work with policy makers to ensure new regulations are implementable and appropriate Establish communication channels The proposed projects can include aspects of this Best practices to be included in publications Share best practices for MIRRI Explore the feasibility for safety data sheets for biocontrol agents and biopesticides for inclusion in the knowledge bank Consider what can be done to raise awareness of the increasing number of organisms infecting the immunocompromised Cover the health issues in best practice papers above Always remember that biopesticides are measurably safer than chemical insecticides and that the pursuit of absolute safety is pointless. Do the least harm and most good rather than try to do no harm and end up doing no good
Inadequate information	Must inform farmers about the mode of action and time needed to get results (ensure adequate field tests have been done); Guidelines are required; Need to take into account past applications of chemicals (responsibility of the producer to test compatibility with the most common chemicals); Inform on what can and can't be done (compatibility tests should be part of the registration process to place on the label but not compulsory)	Share best practices Targeted publications Prime stakeholders: distributors; extension staff; policy makers Making sure they are fully informed with the facts and not simply guided by emotions Marketing campaigns potentially through Plantwise to demonstrate the benefits
Low adoption by farmers and dealers towards biopesticides	Perceived need for immediate knock down which is common with chemicals; Costs and ease of application are also important; Need local evidence to help promote use; Biopesticides are often compatible with chemical pesticides so IPM is made easier but not an issue at the moment as biopesticide use is limited currently; Need to	Raise awareness Generate case studies to generate convincing arguments Provide the information on best practices in IPM Circulate Pam Marrone (2007) publication in the *CABI*

	provide the information on best practices in IPM (what can be mixed)	*Reviews* Adapt information to suit the different stakeholders Investigate possibility of producing evidential data and mechanisms (proposals) to deliver Include some aspects in the above publications Frequency of applications of biopesticides is an important issue because of their short persistence in the field
Plagiarism or "pirating" products	Active ingredient can be taken from a product and used in another product; A means to protect the organism's use (exclusivity); In Europe and South Africa bar coding the strain and patenting the use of the strain for a specific use is possible; Patent the process (can't patent the organism); Clear guidelines on these issues are needed and an African International Depositary Authority under the Budapest Treaty may help the process	Raise awareness and get specialist advice Place relevant information in the aforementioned papers Investigate the regulation of use of counterfeit products Propose protection within registration systems/laws against pirating or copy-catting of products, particularly if the product was a novel pathogen/isolate (i.e. first on the market)
Business planning	Understand your market from the outset as this impacts on all the issues; Use of the appropriate expertise and good communication channels are essential throughout	Establish and implement business plans for the various sections of the chain utilizing appropriate expertise Included in the Kenyan and Ghana mBRC proposals To be included in publication of the future book
R&D and commercialization Increasing product range Handling intellectual property in joint development	Source potential agents from mBRCs Early investigative work done by research institution and access what has been done and final development achieved by the companies; Always begin with the end point in mind (e.g. registration dossier); Make contact personally and discuss early with authorities; Registration should not be onerous; Assess the pros and cons of in-house or outsourcing R&D but build a sound relationship with your R&D partners; Have mechanisms to use data generated on use by farmers to enable the updating of "labels" (information on product use) so modifications are notifications rather than re-registration (use in field is where most information on actual use is generated) Increasing product range; Extend use of existing agents and explore new isolates; This is facilitated by a good two-way relationship with organism supplier (research institute) providing agents with properties requested Intellectual property arrangements must be in place;	Provide expert advice Investigate information resource development for a biopesticide knowledge bank network

	Shared ownership is possible, alternatively, Material Transfer Agreements can be used with royalty payments for commercial use; Need to engender trust and sound partnerships can be established; In South Africa the Intellectual Property Act requires that if public money is used in any part of the development then intellectual property is owned by the country	
Product and formulation development	Begin with best organism to ensure an effective product (avoid use of weak pathogens as formulation will not improve them); Formulation is relatively simple and different formulations for different organisms and uses are in place (using the correct one that is fit for purpose, which is essential); The formulation may make a significant impact on efficacy and transportability; Need to be aware of all problematic areas and give appropriate guidance in use; Need to be sure of the safety of the inactive ingredients as well as the active component, bearing registration in mind	Share best practice Facilitate access to relevant information Include in best practice publication A candidate biopesticide should be selected based on its virulence, yield and tolerance to environmental factors Much can be accessed in published literature and global experts can be contracted as consultants
Product trials Should proof of efficacy be required for registration (see above)	Could take a long time and providing registration details takes time and money; Always be fully aware of what is required; If you use an outside party ensure they understand the biologicals; Reduce field trial requirements on minor crops; Registrar should use independent expert scientists for trial protocols and data analysis; Need to balance the depth of testing with its value, costs and time; Trial design must reflect the end use (on-farm) conditions and goals (reducing damage and improving yield) while meeting the registration needs; Must also emphasize ALL the benefits from using biopesticides including the farmer's health and impact on the environment	Share best practice Include relevant information in aforementioned publications Opinion: Adopt the policy of making registration of a product dependent only on having a named, traceable, identified organism based on the common genera used. Leave everything else to the market but ensure REGULATION of that market is strict and producers are RESPONSIBLE for their products.
Manufacture: normally not complicated; information and training available	Quality control is a priority; In Africa manufacture is low cost but economy of scale must be taken into account; Different in terms of market being supplied (i.e. local use or global use present different challenges); Must be aware of market needs (i.e. regulatory requirements in contaminant levels, etc.); Need to be aware of potential bottlenecks and use appropriate means to circumvent them (i.e. mixed model recommended); Biopesticide use is growing and demand is expected to expand – scalability	Share best practice All relevant information for small-scale production in the public domain Include relevant references in aforementioned publications Africa can produce and export to the global market at prices that can outcompete production in the Western world (due to low cost and availability of labour; and weakness of currencies)

Marketing is extremely important	Have the market in mind from the beginning; Use independent scientists involved in the R&D to present the science to enhance credibility; Key issues are that the product is effective, easy to use and affordable; R&D should include a market study – social aspects; Use market experts but ensure sound relationship to ensure each fully understands the product to ensure best outcome; Need a marketing plan (encompassed in the business plan); Timing of the marketing can be important; Use appropriate opportunities/events for market campaigns; Work in partnership with your users throughout to inform the development process; Accreditation and operational standards are important to give consumer confidence; Weave the science behind the concept into the educational system	Employ appropriate expertise giving appropriate priority to market needs Include relevant information in aforementioned publications

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