Food Security and Biotechnology in Africa

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Module 6
TAILORING BIOTECHNOLOGIES: TOWARDS SOCIETAL RESPONSIBILITY AND COUNTRY SPECIFIC APPROACHES

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Course Structure

Unit 1: **Technology and innovation to the rise of biotechnology: 5H**

Unit 2: **Policy-making and communication: 3 H**

Unit 3: **Value chain, agribusiness, local and global development: 3H**

Unit 4: **Stakeholder participation: 3 H**

Unit 5: **Case studies of tailor-made biotechnology in specific countries: 6 H**

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General introduction

Biotechnology is a multidisciplinary subject that involves knowledge on chemistry, biochemistry, physics, biology, microbiology, engineering, computer science, etc. It is one of the most demanding and rapidly growing fields in science. Modern biotechnology embraces recombinant DNA technology, cellular biology, microbiology, biochemistry, as well as process design, engineering, modeling and control. The role of biotechnology in ensuring food security and food sovereignty in Africa has become the subject of intense academic inquiry and public policy discourse. This debate still stayed at two extremes: one that perceives biotechnology as the source of solutions to many of the economic, social and environmental and food security problems that Africa is confronted with, and the other extreme that treats the technology with considerable cautious as a technology that will bring more tertiary dependence, profit-driven effort regardless of the risk to human health, social equity or environmental quality. This scenario has been replayed more and more in Africa than anywhere else in the globe. Controversies surrounding its development, increased focus on industrial crops, perceived dependency syndrome on few multinational seed companies among others have limited its widespread application. Agriculture in African continues to be plagued with poor planting materials, crops with poor yield, nutritionally deficient, long gestation periods, low biotic and abiotic stress resistance, high post harvest losses, poor distributive channels, etc. However, the situation can be improved through a tailored application of science and technology. Tailoring biotechnology implies that it should fit to the viewpoint and needs of stakeholders, e.g. from small farmers to policymakers. Tailored biotechnology, that may include both classic and modern versions of biotechnology, accounts for the role of stakeholders in the process of technology development. Tailoring biotechnology involves that stakeholders can use the tool within their own context and on their own conditions, and have the opportunity to fulfil the required social, financial, ethical and other conditions for the implementation of the new technology. Associated risks and public perception and the role of medias will be addressed.

Specific cases studies of African countries could give information on the differences among African countries engaged in modern biotechnology: (a) those that are generating and commercializing GMO products and services, (b) those that are engaged in GMO technology R&D with confined field testing, c) those that are engaged in contained GMO research and d) those that are developing capacity for research and development in GMO, e) those are adopting national laws regulating biosafety.

General objective of the module

The objective of this module is to allow students to understand how the innovation and policy making lead to tailor-made of both classic and modern versions of biotechnology to the needs and customs of specific countries.

Modes of lecture delivery

a. Lecture notes
b. Power point slides
c. Discussion groups
d. Mini surveys among stakeholders

Specific objectives

By the end of this module the students will have a deepen comprehension on:

1. How the multiple currently available technologies and innovation contribute to the rise of biotechnology.
2. The role of poly-making and medias on adopting biotechnology
3. How global and local value chain represent for local firms and suppliers in the countries to get access to larger markets and new technologies.
4. The role of the stakeholder perceptions, internalization and appropriation in the process of biotechnology for development.
5. Current experience throughout case studies of African countries that apply GMO crops.

Course structure

The course is subdivided into five units as follows:

- Unit 1. Technology and innovation to the rise of biotechnology: 5 Hours
- Unit 2. Policy-making and communication: 3 hours
- Unit 3. Value chain, agribusiness, local and global development: 3 hours
- Unit 4. Stakeholder participation: 3 hours
- Unit 5. Case studies of tailor-made biotechnology in specific countries: 6 hours

6. 1. Unit 1. Technology and innovation to the rise of biotechnology: 5 Hours

Summary

Ancient biotechnology- early history is related to food fermentation and other domestication. Conventional crop breeding since the birth of agricultural communities, the Green Revolution of later years, and molecular marker-assisted selection can be considered as the second generation of biotechnology. Modern biotechnology was born with DNA engineering and the discovery of novel analytical techniques such as electrophoresis and DNA sequencing. Biotechnology is any technique that uses living organisms or substances from those organisms to make or modify a product, to improve plants or animals, or to develop micro-organisms for specific uses. It is also the use of scientific methods with organisms to produce new products or new forms of organisms.

It involves the direct modification of the DNA (or RNA) molecules, which carry the genetic material of an organism, resulting in a genetically modified organism (GMO). Except specified elsewhere, Biotechnology in this unit is referred to modern biotechnology. GM crops were first introduced in the United States in the mid-1990s. They have expanded rapidly in Asia, Latino America an Africa but in a limited number of countries, of which only atom-weight countries have adopted GM crops.

Food biotechnology employs the tools of modern genetics to enhance beneficial traits of plants, animals and microorganisms for food production. It involves adding or extracting select genes to achieve desired traits. Thus, biotechnology impacts all aspects of our lives, but non-specialists can be unclear about what biotechnology is and what it is not. The general public has a vested interest in how modern agricultural practices affect the food we eat, the progress of efforts to develop new drugs, the ethics and benefits of cloning, forensic science, bioterrorism, and improving the environment.

From academic point of view, biotechnology is an excellent avenue for the enhancement of science literacy, as measured by increase in content knowledge and improved understanding of the life science methods. However, the adoption of biotechnology because of public concerns and societal issues have focused on both applications and ethical implications. This has created two polarities. One who believes that biotechnology firms and biotechnologists

have framed the issue as one of science and technology applied to enhancing the quality of life. The other biotechnology opponents have framed the issue as a profit-driven effort regardless of the risk to human health, social equity or environmental quality.

Innovative biotechnology will be expected to make major contributions as we emerge from the current period of economic uncertainty. This, however, is against the backdrop of the vast majority of university students, farmers and employees in the bioscience industries having received little or no training in techniques that could greatly enhance their creative and innovative potential.

The urgent need to look for alternative biotechnologies and the actual accelerated rate of adopting plant molecular biotechnologies since the breakthrough report of the first transgenic plant in 1982–1983 (Otten et al., 1981; Barton et al., 1983) is due to four major causes:

- increase in world population and the need for more food
- recognition that human health is affected by disease-causing pathogenic organisms and by the nutritional quality of foods, especially vitamins and minerals
- adverse global climatic changes accompanied by detrimental biotic and abiotic stresses to crops and ecosystems
- human societies searching for novel, non-food plant products such as biomaterials, therapeutics, biofuels, etc.

Nevertheless, general public needs to adopt the technology throughout equilibrated communication. For instance even in USA where GM crops have been introduced since 1990, only 75% of the population is aware on the existence of GMO crops, while only 33% of consumers know that GMO foods are now in supermarkets without any labeling.

The objective of this unit is to show how the different Biology related technologies, innovation, and the capacity to handle the processes have impacted the development of Biotechnology.

6.1.1. Section 1. Multiple technologies

6.1.1.1. Process of adaption of new technology and societal issues

The etymology of Biotechnology = bios (life) + logos (study of or essence). Literally it is 'the study of tools from living things'. The word "biotechnology" was first used in 1917 to describe processes using living organisms to make a product or run a process, such as industrial fermentations (Robert Bud). According to UN-Convention on Biological Diversity (Art. 2) "**Biotechnology is the use of living systems and organisms to develop or make products, or "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use**".

Biotechnology is a multidisciplinary subject that brings together aspects of chemistry, biochemistry, physics, biology, microbiology, engineering, computer science and is one of the most demanding and rapidly growing fields in science. Modern biotechnology embraces recombinant DNA technology, cellular biology, microbiology, biochemistry, as well as process design, engineering, modeling and control.

Biotechnology is any technique that uses living organisms or substances from those organisms to make or modify a product, to improve plants or animals, or to develop micro-organisms for specific uses. It is also the use of scientific methods with organisms to produce new products or new forms of organisms. Modern biotechnology involves the direct modification of the DNA (or RNA) molecules, which carry the genetic material of an organism, resulting in a genetically modified organism (GMO). Except specified elsewhere, Biotechnology in this unit is referred to modern biotechnology.

Genetically engineered organisms (GEO) or Genetically Modified organisms (GMO) are created by transferring genetic material from one organism to another through a process called genetic engineering (GE). The transferred genes are called ***cis*** or ***trans*-genes.**

The introduced gene confers a particular trait or characteristic to the recipient organism. The transferred genes are called transgenes, and biotech plants are therefore also known as transgenic plants or genetically modified (GM) crops. In some cases such as the Bt Cotton, these genes produce proteins that are responsible for the desirable characteristics of the GMO e.g. Bt genes produces

Cry proteins which confer insect resistance. ***Bt*** stands for *Bacillus thuringiensis*, a toxin (cry proteins) producing bacterium found naturally in soils.

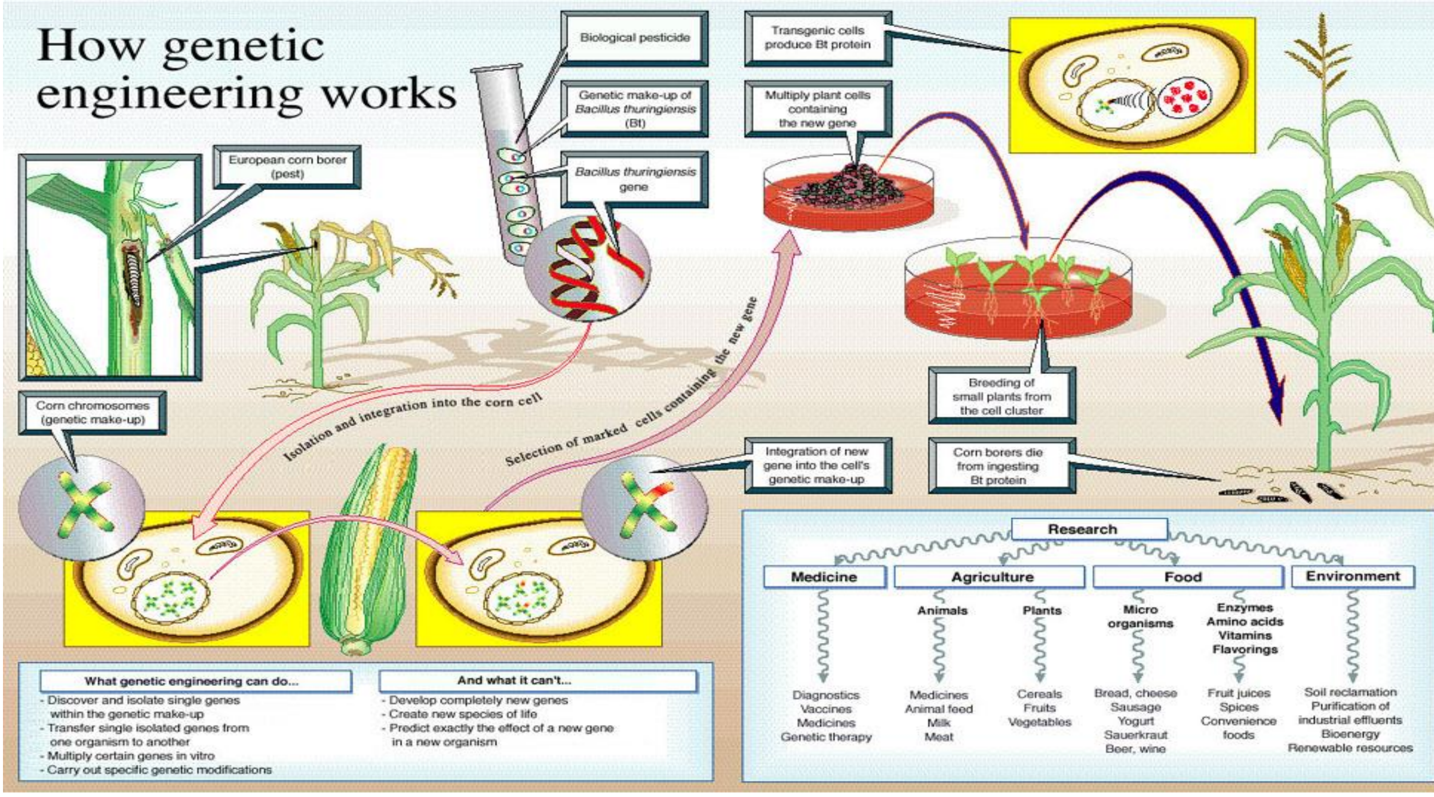


Figure 1. The GM crop involves the transfer of a gene from for instance the soil bacteria *Bacillus thurengiensis* into plant seed.

GM crops were first introduced in the United States in the mid-1990s. They have expanded rapidly in Asia, Latino America an Africa but in a limited number of countries, of which only few countries have adopted GM crops.

Food biotechnology employs the tools of modern genetics to enhance beneficial traits of plants, animals and microorganisms for food processing. It involves adding or extracting selected genes to achieve desired traits. Thus, biotechnology impacts all aspects of our lives, but non-specialists can be unclear about what biotechnology is and what it is not. The general public has a vested interest in how modern agricultural practices affect the food we eat, the progress of efforts to develop new drugs, the ethics and benefits of cloning, forensic science, bioterrorism, and improving the environment.

Current applications are ranging from the development of new medicines and drugs to the farming of transgenic plants and animals as well as the clean-up of environmental pollutants.

In Africa biotechnology is primarily considered and used as an exogenous instrument for the on-going modernization of agriculture and rural development because farmers do not have a hand in the development of the technology. Nevertheless, biotechnology has several potentials to raise agricultural systems in order to meet the needs for food for the growing African population.

Figure 2. Example of modern biotechnology laboratory with high-tech equipments.

The role of biotechnology in ensuring food security and food sovereignty in Africa has become the subject of intense academic inquiry and public policy discourse.

This debate still stayed at two extremes: one that perceives biotechnology as the source of solutions to many of the economic, social and environmental and food security problems that Africa is confronted with, and the other extreme that treats the technology with considerable cautious as a technology that will bring more tertiary dependence, profit-driven effort regardless of the risk to human health, social equity or environmental quality. This scenario has been replayed more and more in Africa than anywhere else in the globe.

Controversies surrounding the development of biotechnology in Africa increased focus on industrial crops, perceived dependency syndrome on few multinational seed companies such as Monsanto among others have limited its widespread application.

Figure 3. Ethical concerns of biotechnology: example mouse with ear.

However African Agriculture continues to be plagued with poor planting materials, crops with poor yield, nutritionally deficient, long gestation periods, low biotic and abiotic stress resistance, high post harvest losses, poor distributive channels, etc.

Nevertheless the situation can be improved through a tailored application of science and technology. Tailoring biotechnology implies that it should fit to the viewpoint and needs of stakeholders, e.g. from small farmers to policymakers. Tailored biotechnology, that may include both classic and modern versions of biotechnology, accounts for the role of stakeholders in the process of technology development.

The urgent need to look biotechnology as an alternative is accelerated since the breakthrough report of the first transgenic plant in 1982–1983 (Otten et al., 1981; Barton et al., 1983) for four major reasons:

- increase in world population and the need to ensure food and nutrition security
- recognition that human health is affected by the nutritional quality of foods, especially vitamins (A), essential amino acids (Lysine, tryptophan, etc) and minerals (zinc, selenium, etc,),

- adverse global climatic changes accompanied by detrimental biotic and abiotic stresses to crops and ecosystems

- human societies searching for novel, non-food plant products such as biomaterials, therapeutics, biofuels, etc.

Nevertheless, general public needs to adopt the technology throughout equilibrated communication. For instance even in USA where GM crops have been introduced since 1990, only 75% of the population is aware on the existence of GMO crops, while only 33% of consumers know that GMO foods are now in supermarkets without any labeling.

Although the introduction of green revolution got a great success, it has some limits that can be seen below.

6.1.1.2. Green Revolution: Impacts and limits in African Context

The Green Revolution (GR) to agricultural research and development occurring between the 1940s and 1980s, that increased agricultural production worldwide. This revolution (Norman Borlaug, Nobel Prize in 1970) has contributed to food security by the development of high-yielding varieties of cereal grains, expansion of irrigation infrastructure, modernization of management techniques, distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers. India was the first country which has experienced the benefit of GR by increasing its rice production.

GR has greatly increased global food production (Figure 1, Table 1).

Impact of GR for African Agriculture…

Before GR agricultural growth in Africa was driven by land expansion. Since further expansion of cultivated agricultural land is reaching its limits in the process of rapid urbanization and population growth in many countries, the need for a shift towards productivity led agricultural growth becomes urgent in Africa. That limits have urged governments to shift towards a green revolution type of productivity-led growth, using Asian, notably the Indian example.

Table I. Example of impact of GR on Agricultural Production

Commodity	Production in 1950 (Million tons)	Production in 2011 (Million tons)
Food grains	50.00	252.0
Vegetables	58.50 (91-92)	125.0
Fruits	28.60 (91-92)	63.6
Milk	17.00	104.8
Eggs	1.80	53.5 billions
Fish	0.75	7.3

Impact on Productivity and Food Prices

The GR experience in Asia has demonstrated that rapidly increasing agricultural productivity is possible in a relatively short time period. The Asian experience has also shown that such growth has to be supported by a combination of adequate public investments, promoting pro-rural policies and a bundle of measures that enable farmers to access modern inputs, agricultural extension services, financial services, and markets.

In Asia, it has been estimated that each 1% increase in crop productivity reduces the number of poor people by 0.48%. In India, it is estimated that a 1% increase in agricultural value added per hectare leads to a 0.4% reduction in poverty in the short run and 1.9% reduction in the long run, the latter arising through the indirect effects of lower food prices and higher wages. For low income countries in general, the impact on the poverty headcount has been found to be larger from agricultural growth relative to equivalent growth in the non agriculture sector at a factor of 2.3 times.

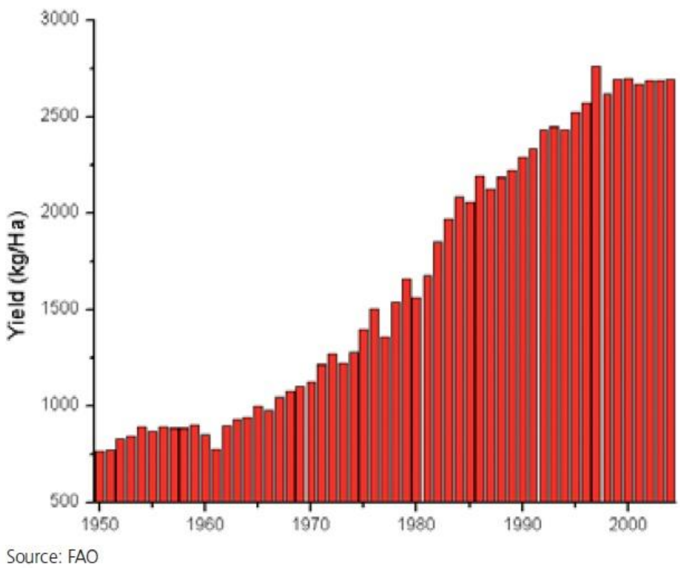
Although it lagged behind in the GR period, Africa has witnessed positive growth in the post-GR period. Adoption of improved varieties across sub-Saharan Africa reached 70% for wheat, 45% for maize, 26% for rice, 19% for cassava, and 15% for sorghum by 2005 (Binswanger H, McCalla A, 2010).

Widespread adoption of GR technologies led to a significant shift in the food supply function, contributing to a fall in real food prices. Between 1960 and 1990, food supply in Africa increased 12–13%.

Without GR World food and feed prices would have been 35–65% higher. Overall, these efforts benefited virtually all consumers in the world and the poor relatively more so, because they spend a greater share of their income on food.

In sub-Saharan Africa, agriculture’s contribution to poverty reduction was estimated to be 4.25 times the contribution of equivalent investment in the service sector. Because the GR strategy was based on intensification of favorable areas, its contribution to poverty reduction was relatively lower in the marginal production environments.

One of positive example of GR could be the program in western Africa is introducing a new high-yielding 'family' of rice varieties known as "New Rice for Africa" (NERICA). NERICA varieties yield about 30% more rice under normal conditions, and can double yields with small amounts of fertilizer and very basic irrigation. However, the program has been beset by problems getting the rice into the hands of farmers.



Source: FAO

Figure 4. Impact of GR in wheat yield in developing countries.

Limitations of GR-Led Growth Strategies

The GR contributed to widespread poverty reduction, averted hunger for millions of people in Africa, and avoided the conversion of thousands of hectares of land into agricultural cultivation. At the same time, the GR also spurred its share of unintended negative consequences, often not because of the technology itself but rather, because of the policies that were used to promote rapid intensification of agricultural systems and increase food supplies. Some areas were left behind, and even where it successfully increased agricultural productivity, the GR was not always the panacea for solving the myriad of poverty, food security, and nutrition problems facing poor societies.

Poverty and Food Insecurity persisted despite the GR success.

In general, the poorest areas that relied on rain-fed agriculture were also the slowest to benefit from the GR, contributing to widening interregional disparities and an incidence of poverty that still remains high.

Impact on Environment

GR had a controversial environmental impact. The original purpose of the GR was to intensify areas where production yield would be high, with a focus on irrigated or high rainfall areas. GR driven intensification saved new land from conversion to agriculture, and allowed for the release of marginal lands out of agricultural production into providing alternative ecosystem services, such as the regeneration of forest cover. However, unintended consequences in water use, soil degradation, and agrochemical runoff have had serious environmental impacts beyond the areas cultivated.

The environmental consequences were not caused only by GR technology but rather, the policy environment that promoted injudicious and overuse of inputs and expansion of cultivation into areas that could not sustain high levels of intensification, such as the sloping lands. The international breeding programs aimed to provide broadly adaptable germplasm that could then be grown across a wide set of geographies, but adoption was greatest in favorable areas.

Limits of the introduction of hybrid varieties

Based on the early successes of GR for some cereals, the **Consultative Group on International Agricultural Research (CGIAR)** was established specifically to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring sustainable management of natural resources. After CGIAR-generated knowledge, invention, and products (such as breeding lines) were made publicly available, national public and private sectors responded with investments for technology adaptation, dissemination, and delivery.

Despite that success, in the post-GR period, the need for continued agricultural innovation and productivity growth is still remaining.

Sustaining productivity gains, enhancing smallholder competitiveness, and adapting to climate change are becoming increasingly urgent concerns across all production systems. That has led to the introduction of new technology such as modern biotechnology with respect to genetically modified crops.

Table 2. Comparison of food production between 1950 and 2011.

Commodity	Production in 1950 (Million tones)	Production in 2011 (Million tones)
Food grains	50.00	252.0
Vegetables	58.50 (91-92)	125.0
Fruits	28.60 (91-92)	63.6
Milk	17.00	104.8
Egg (nos.)	1.80	53.5 billion
Fish	0.75	7.3

Figure 5. High throughput and pesticide use in GR.

6.1.1.3. Current biotechnological processes

Overview of new technologies

Current modern technologies include genetic engineering; culture of recombinant microorganisms, cells of animals and plants; metabolic engineering; hybridoma technology; bioelectronics; nanobiotechnology; protein engineering; transgenic animals and plants; tissue and organ engineering; immunological assays; genomics, transcriptomics, proteomics, metabolomics; bioseparations, bioreactor technologies, synthetic biology or xenobiology, etc.

Synthetic biology aims to bring engineering practices common in other engineering disciplines to the field of molecular genetics and thus create a novel nanoscale computational substrate. Synthetic Genomics is a scientific field which aims to create unique life form. With broadening knowledges of genetics of bacteria it may be possible to create a unique form of life. It's proved by effort and results of many research laboratories. Their genome will be composed from a series of segments originated from different species or they will be completely new. Their potential is to become a component of future industrial world.

Expected applications of synthetic biology are:

- Autonomous biochemical sensors
- Biomaterial manufacturing
- Programmed therapeutics
- Smart agriculture
- Engineered experimental systems for biologists
- Diagnostic of disease, etc.
- Creation of new cell or even organism!!!

The Clustered Regularly Interspaced Short Palindromic Repeats (**CRISPR**) are segments of prokaryotic DNA containing short, repetitive base sequences. The CRISPR/Cas system is a prokaryotic immune system that confers resistance to foreign genetic elements such as those present within plasmids and phages that provides a form of acquired immunity. RNA harboring the spacer sequence helps Cas proteins recognize and cut exogenous DNA. Other RNA-guided Cas proteins cut foreign RNA. CRISPRs are found in several organisms.

The CRISPR/Cas9, has been modified to edit genomes. The CRISPR/Cas9 system is based on RNA-guided nucleases, which has great potential due to their simplicity, efficiency and versatility. The most widely adopted system is the type II CRISPR/Cas9 system from *Streptococcus pyogenes.* By delivering the Cas9 nuclease complexed with a synthetic guide RNA (gRNA) into a cell, the cell's genome can be cut at a desired location, allowing existing genes to be removed and/or new ones added. The CRISPR/Cas9 gene editing tool appears to work in nearly every organism, from *Caenorhabditis elegans* to monkeys, and in every cell type: kidney, heart, T-cells, etc.

The CRISPR/Cas9 genome editing techniques have many potential applications, including medicine and crop seed enhancement.

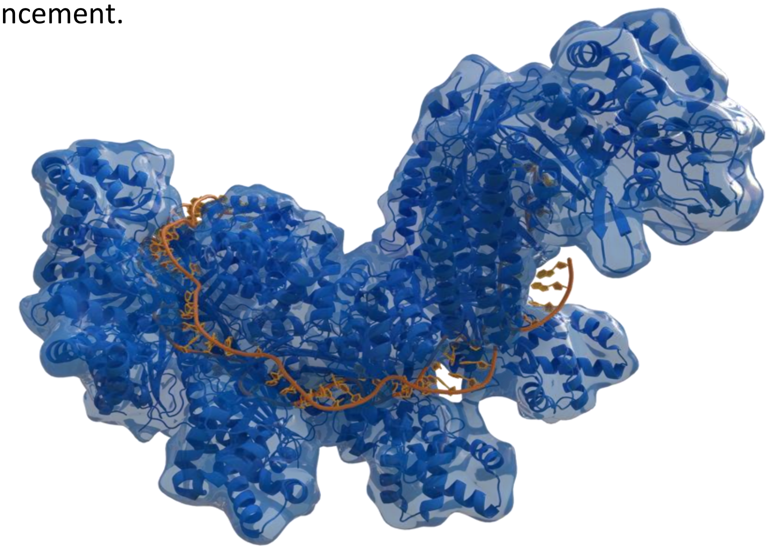


Figure 6. Cascade (CRISPR-associated complex for antiviral defense). Structure of crRNA-guided E. coli Cascade complex (Cas, blue) bound to single-stranded DNA (orange).

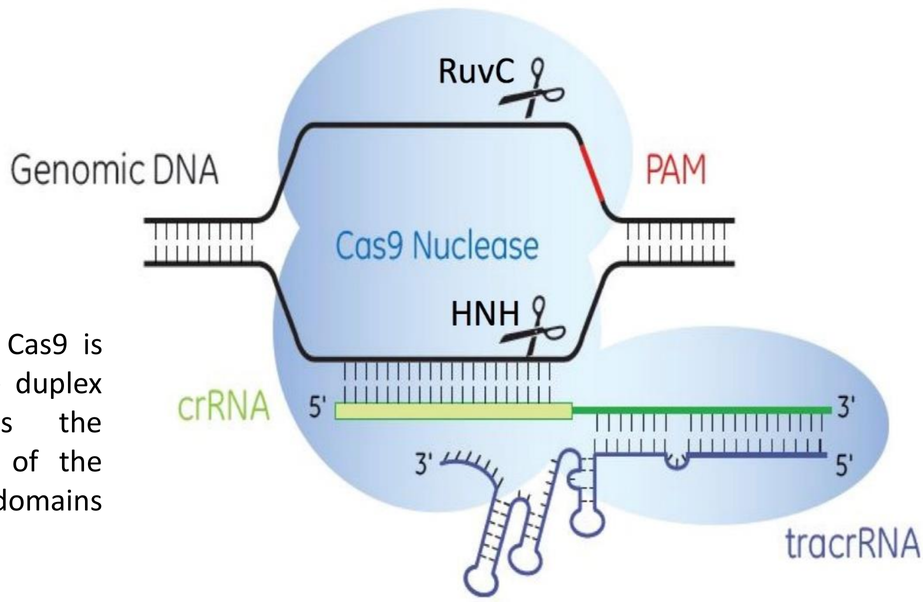


Figure 7. Mechanism of Cas9 catalysis. Cas9 is recruited to the DNA target site by the duplex tracrRNA:crRNA. The crRNA binds the complementary DNA strand upstream of the PAM sequence. Cas9 HNH and RuvC domains generate a DS break.

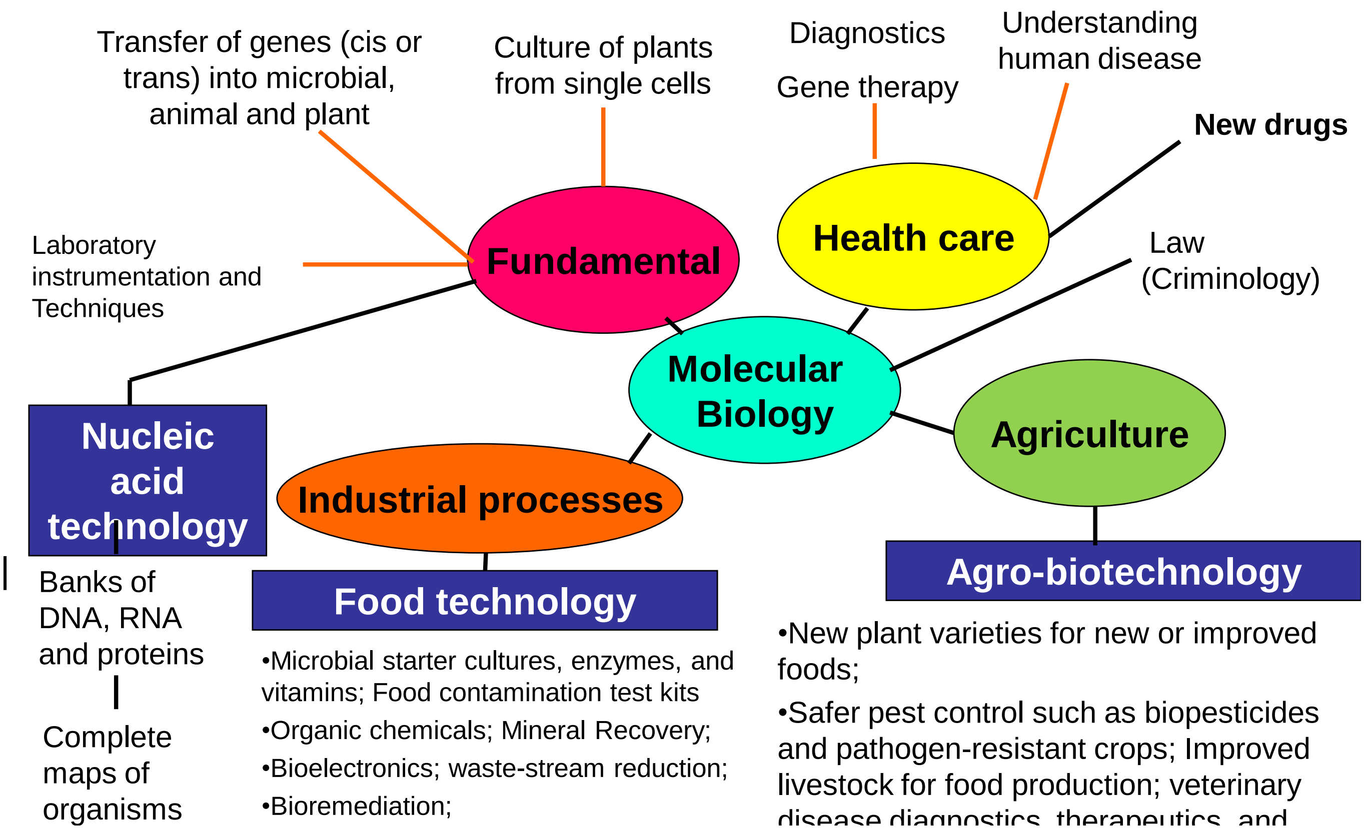


Figure 8. Overview of biotechnology processes. daily invented to face new challenges.

All most all biotechnological processes cited above are currently used to increase food and nutrition security. Innovation techniques are daily invented to face new challenges.

6.1.2. Section 2. Innovations in Biotechnology

6.1.2.1. Innovation techniques

Innovation is the mechanism by which individual or organization produce new ideas, products, processes and systems required for adapting to changing markets, technologies and modes of competition.

Innovative biotechnologists will be expected to make major

Contribution for food and nutrition security. However, the vast majority of university students in the bioscience industry having received little or no training in techniques that could greatly enhance their creative and innovative potential. Here, it is presented a range of approaches and strategies designed to promote creativity in bioscientists working in academic and industrial environments.

Effective brainstorming techniques.

In 'Post-it', participants record ideas on Post-it notes, and these are, reviewed and analysed. In 'Grid', a participant records

some solutions to a problem on a grid that is completed by other members of the group. These techniques encourage simultaneous generative activity, but some participants might remain reluctant to share an idea for fear of ridicule or loss of ownership. The latter concern might be addressed by implementation of intellectual property rights protocol.

Checklists

A series of brief questions and/or statements is used to stimulate creativity when it is proving difficult to think in new and original ways. This method can be used for idea generation and evaluation but it is a systematic method that might not appeal to all personality traits.

Lateral thinking

Solutions are proposed by looking at a problem using random associations, provocation, challenging current solutions and divergence. This approach requires both curiosity and confidence a wide range of alternative solutions. Robust evaluation of ideas is necessary to identify worthwhile concepts to develop.

Mind mapping

Connections between associated pieces of information are emphasized by clustering the information on a visual map: this can stimulate creativity. Some people are hesitant to reveal a perceived weakness in sketching, but this can be overcome with practice.

Six hats

A parallel thinking process in which team members wear coloured hats representing data, creativity, positivity, feelings, criticism and control. The approach can minimize conflict and encourage participation and consideration of a problem from a wide range of perspectives. However, some participants might be hesitant to take this broad-minded approach.

Morphological analysis

A matrix-based technique in which a problem is broken down into component parts and a range of approaches and/or solutions are suggested for each of these elements. This technique encourages combinations of features and solutions that otherwise might not have been considered, but the large quantity of combinations generated means that good ideas can be overlooked. Weighting criteria can be used to guide the selection of solutions.

Synectics

This method exploits our capacity to connect apparently irrelevant elements to spark new ideas and solutions. The approach helps participants to break existing mind sets and internalize abstract concepts but is time-consuming, requiring practice and expert facilitation.

Theory of Inventive Problem Solving. TRIZ (Russian acronym) provides a framework and toolbox for systematic, inventive problem solving but is sometimes viewed as complicated and difficult to use; this can be overcome by sustained use and practice.

Predisposition

Provide a work environment that: allows expression of individual creativity; promotes a creative culture; and clearly identifies those who will lead and facilitate creativity. This can be achieved through training not only in creativity and innovation but also in change management processes.

External mapping

Analyse the environment outside the organization to identify, for example, new needs and opportunities, talented individuals and the economic implications of entering a market. A questionnaire survey and analysis approach, known as Attribute Value Chain (AVC), can be used to produce a mental map to stimulate the next phase of idea generation.

Internal mapping

Use, for example, SWOT (Strenghs, Weaknesses, Opportunities, Threats) analysis to identify strengths, weaknesses, opportunities and threats in organizational structure, environment and resources.

Idea generation

Promote creativity at individual and group level using a wide range of techniques and approaches.

Evaluation

Select the best ideas to emerge using, for example, de Bono's 'six hats' technique procedure can be used effectively during both idea generation and evaluation phases.

Triple Helix (THRIP):

TH is one model that is internationally used to stimulate innovation. Triple Helix model, which formalises collaboration between three role-players or "spheres", namely the university, private companies (industry) and government. The model represents interaction between university, industry and government, working together towards research focused on immediate implementation in industry. In South Africa Triple Helix is driven under the name THRIP: The Technology and Human Resources for Industry Programme (THRIP) aims to boost South African Industry by supporting research and technology development. Various universities take part in this project.

6.1.2.2. Integrated local innovations (Learning motivation and innovation)

The idea of a different social embedment of biotechnological developments is often lacking. Local stakeholders often follow this path of total dismissal because they are not able to imagine an alternative coalition of social and technical elements in biotechnology and genomics. Nevertheless various examples of multi-stakeholder platforms should be found to follow a more constructive approach and aim to develop a balanced and dialectical approach towards integrating and indigenizing some (biotechnological) innovations, attuned to location-specific development trajectories.

The central question for innovation is whether and how biotechnology as an exogenous instrument can be re-appropriated by local initiatives and become a catalyst for endogenous developments. How the partners are aiming to reconnect agriculture to environment as well as to local food consumption by redesigning traditional and modern biotechnologies?

Local motivation and innovation in Biotechnology suppose a strong processes of the transformation of agriculture, by appropriation and substitution.

Appropriation refers to the gradual take-over of the controllable biological activities from farming practices by external institutions, especially industry. A concrete example is the breeding of new cultivars and the maintenance and propagation of basic seeds that was originally done by farmers but is now increasingly taken over by public research institutions and private companies.

Substitution refers to the historical development by which the wild type of crop is gradually being replaced by crop, like the case in of Bt cotton in Burkina Faso.

For the transformation of biotechnology, as an exogenous instrument into a catalyst for endogenous developments, it is crucial to create a new relationship between agriculture and its environment. Local innovation aims to connect agriculture to local as well as to local food consumption by redesigning traditional and modern biotechnologies.

For example the development of several purpose crop can be done by integrating the local need of farmers.

For example, in India a dual purpose, early maturity sorghum variety (CSV 15) in which different social issues have been directly taken into consideration, such as the possibility of changing the crop rotation system, in order to reduce the ecological problems of actual agricultural production systems, increase the income of marginalized farmer groups, etc. The CSV 15 is illustrative of *a social/technical ensemble approach, in which the variety itself* *catalyzes social changes.* It has enabled the farmers to plant chickpea almost one month earlier as a rotation crop, minimizing the incidence of wilt in chickpea and reducing usage of chemicals.

The short duration, dual purpose sorghum variety enables farmers to get an assured higher grain yield, to obtain a higher monetary return because its dual (food/feed) purposes, and ensures a higher income because of the improved rotation with chickpea. Instead of harvesting one unsecured, long duration local sorghum variety, farmers can now cultivate and get income from two assured crops in a year. The CSV 15 sorghum variety shows that eth-Instead of harvesting one unsecured, long duration local sorghum variety, farmers can now cultivate and get income from two assured crops in a year. So, there is a need to find new ways of *ensuring increased access to the professionally developed seeds.*

6.1.3. Section 3. Capacity to handle approval processes

6.1.3.1. Evaluation of scientific data of GMO risks (Environmental issues, economical issues, technological risks, etc.).

The proven improvement of crops productivity, and quality through the use of GM-crops have encouraged several countries to adopt these new crops embedding these tools with strict regulations with respect to biosafety and environmental protection. GM crops were grown on 170 million ha in 2012, of which at least 3 millions ha in Africa, with South Africa being the leading country.

The advent of GM crops was marked by a parallel evolution of the regulation of GM activities, spanning from laboratory to end-use. The conclusion of the Cartagena Protocol on Biosafety (**CPB**) to the Convention on Biological Diversity (**CBD**) was a major turning point in the regulation of GM organisms particularly those destined for intentional environmental release. The CPB has guided the development of biosafety laws, regulations and guidelines in many developing countries that are party to the Protocol. The Protocol is based on the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development. However, different countries have interpreted and implemented this approach differently.

Some countries such as Burkina Faso have taken precaution to be decision making based on scientific assessment and have consequently put in place regulatory measures that include science based risk assessment. This has opened doors for testing and commercialization of GM crops such as Bt cotton. Other countries have issued prohibitive legislations that deny farmers a powerful tool to tackle some crop production constraints. Farmers in South Africa, Burkina Faso, Sudan and Egypt have well adopted GM crops. A number of other African countries are experimenting with them. Despite this demonstration of interest, the establishment of functional biosafety regulations is moving very slowly and arriving at concrete commercialization decisions remains on the whole difficult. As a result of these challenges, the New Partnership for Africa's Development (NEPAD)-African Biosafety Network of Expertise has been assisting African Union member countries to build functional biosafety systems that are flexible and responsive to the needs of African farmers while ensuring safety of this novel technology to the environment and human and animal health,.

The rapid adoption of GM crops in some African countries is due experienced genetic stability of the grain, farm profitability, decreased crop loss, increased income stability, ease of operation, savings on labor and pesticide use, time savings, and less exposure to toxic chemicals. However, socio-economic concerns include dependence of farmers on large corporations for seed; unaffordable planting materials; possible unsuitability of GM crops for small-scale farm operations and for resource poor farmers (interestingly 90% of GM crop farmers are small-scale and resource poor farmers in developing countries); unethical patenting of life; possible limited access and increased price of seeds due to technology fees; lack of food distribution infrastructure rather than simply producing more; products needed in developing countries not being developed due to market or profit considerations, developing countries having to eat food others such as europeans had rejected (colonization dependence), etc.

6.1.4. Section 4. Discussion with students.

- What are new concepts or definition of biotechnology?
- What are the current principles of innovation techniques and which examples in biotechnology can be shown?
- Try to use the current innovation techniques to generate new idea on how biotechnology can improve food security in Africa.
- What is the impact of biotechnolgy in Africa to ensure food security?

Supporting literature:

Doc 1. Presentation power-point Unit 1
Doc 2. ABNE Policy brief. September 2013. Adoption Processes and Regulatory Challenges for Genetically Modified Crops in Developing Countries: Lessons for Africa.
Doc 3. Clemens Breisinger, Xinshen Diao, James Thurlow, Ramatu M. Al Hassan. Potential Impacts of a Green Revolution in Africa – The Case of Ghana. 27th IAAE Conference, Beijing, China, 16-22 August 2009
Doc 4:THRIP Potgieter, Doreta, and Jordaan, Johanb. Procedia - Social and Behavioral Sciences. 115 (2014) 19 – 33. THRIP, a mechanism driving creativity and innovation in South Africa.

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6. 2. Unit 2. Policy-making and communication: 3 hours

Summary

Policy-makers must evaluate the societal significance of scientific and technological issues such as biotechnology. Without a " policy-maker will" a country bears the brunt of non-functional legislative and regulatory frameworks, negligible investment in biotechnology R&D, low public awareness and inability to handle approval processes (Adenle, 2013).

A common citizen clearly cannot be expected to have an in-depth understanding of all the facts, relationships and issues of biotechnology.

In general, a broad understanding of biotechnology by citizens is imperative to ensure their personal integration into the technical and scientific aspects of culture; for the public to appreciate the importance of biotechnology and the need for adequate funding; to enhance national and regional effectiveness and competitiveness in a global knowledge-based economy; and to help solve some of the overwhelming problems. In practice, the non-specialist member of the public obtains his knowledge of all biotechnological things from the wider dissemination of information, mainly by the media but also through books, exhibitions, displays, TV and museums. Although biotechnology has made some people's lives in industrialized countries safer, freer of material constraints and more comfortable, it is also perceived as having its drawbacks. For some people such limitations become dominant, and they may show a deep seated fear of all that appears to be biotechnology. Many different ethical, religious, political and even commercial reasons all contribute to these attitudes. People often include not only a failure to understand the facts and reality but a denial that facts are important when compared to other considerations.

Communication proceeds primarily through both the electronic and the print media, but many special interest groups may disseminate their own information and interpretations, often in printed form but also verbally in meetings and elsewhere. In various countries, to varying extents and with varying quality, newspapers, magazines, radio and television report and discuss topics of public concern; biotechnology is fairly prominent among them, especially when dealing with genetically modified crops and foods or with new and potentially important advances in medicine.

The public perception of biotechnology is dominated by modern biotechnology, notably the application of GMOs in food and agriculture. With GM foods and crops, some countries have mounted “national debates” which have themselves acquired some prominence, although the overwhelming proportion of the population played no part and appeared indifferent and rely on specialist and politician decisions.

The aim of a public understanding of biotechnology as well as other scientific and technology issues might be defined as a knowledge of the facts, findings and methods of science, without necessarily an ability to think creatively in specific areas. Existing national policy should be known to allow citizens to be familiar to biotechnology, and gain access to reliable and balanced information. Risk assessment based on specific guidelines and sound scientific evidence should be available to ensure efficiency, transparency and safety so as to build confidence with the public and policy-makers; and by demonstration through trials to show farmers the benefits. The current risk assessment of GMOs is primarily focused on potential risks, while potential benefits are usually not considered by medias.

The objective of this unit is to illustrate the role of scientists, medias as well as policy-makers in national and international systems on adopting biotechnology.

6.2.1. Section 1. Policy-making theories

6.2.1.1. Role of scientists in determining policies related to biotechnology

The current risk assessment of GMOs is primarily focused on potential health and environmental risks, while the benefits are usually not considered by the public.

Risk assessment based on specific guidelines and sound scientific evidence **should be made available by scientists** to ensure efficiency, transparency and safety so as to build confidence with the **public** and **policy-makers**. Farmers should be demonstrated through trials to show the advantages and drawbacks of Biotechnology.

The public understanding of biotechnology as well as other scientific and technology issues might be defined as a knowledge of the facts, findings and methods of science, without necessarily an ability to think creatively in specific areas. Existing national policy such as laws or strategies should be known to allow citizens to be familiar to biotechnology, and gain access to reliable and balanced information.

The scientist should also:

- Provide to African decision-makers up-to-date information on global scientific and technological trends in order to enable them to effectively engage in policy-making on STI issues;
- Provide right information to civil society
- Strengthen national capacities for technology prospecting, acquisition or procurement;
- Reinforce regional and international science technology and innovation cooperation for sharing experience and knowledge.

6.2.1.2. International approaches

In general, a broad world-wide understanding of biotechnology by citizens is imperative to ensure their personal integration into the technical and scientific aspects of culture. In practice, the non-specialist member of the public obtains his knowledge of all biotechnological things from the international dissemination of information, mainly by radio, TV, books, exhibitions, conferences, news papers, museums, Internet, etc.

For the public to appreciate the importance of biotechnology and the need for adequate funding it usually refers to the adoption of the technology by the rest of the world. Usually, Europe or USA is taken as example for most african countries.

Although biotechnology has made some people's lives in industrialized countries safer, freer of material constraints and more comfortable, it is also perceived as having its drawbacks. For some people such limitations become dominant, and they may show a deep seated fear of all that appears to be biotechnology. Many different ethical, religious, political and even commercial reasons all contribute to these attitudes. People often include not only a failure to understand the facts and reality but a denial that facts are important when compared to other considerations.

6.2.1.3. Government approaches

Policy-makers such as government and parliament evaluate the societal significance of scientific and technological issues such as biotechnology. Without a "policy-maker will" a country bears the brunt of non-functional legislative and regulatory frameworks, negligible investment in biotechnology R&D, low public awareness and inability to handle approval processes.

The public perception of biotechnology is dominated by modern biotechnology, notably the application of GMOs in food and agriculture. Interested Governments by the modern biotechnology communicate on the advantages and drawbacks, specially for GM crops such as *Bt* cotton by using experts TV panels, workshops and close explanation to stakeholders. With GM foods and crops, some countries have mounted **'national debates**' which have themselves acquired some prominence, although the **overwhelming proportion of the population played no part and appeared indifferent and rely on specialist and politician decisions.**

6.2.1.4. Citizen and Civil society perception

The goal of public policy is to maximize the welfare of all its citizens and biosafety regulation can help achieve that by providing certainty, stability and disciplinary rigor to the social framework required for risk assessment, management and communication.

A common citizen clearly cannot be expected to have an indepth understanding of all the facts, relationships and issues of biotechnology. Former scientific achievements and technical advancements in **"traditional" agriculture** and **green revolution** were not accompanied by negative public reactions; on the contrary, they were usually welcomed and adopted (e.g., use of **selected and improved varieties**, inorganic fertilizers and pesticides, precision irrigation, etc.).

However, the very recent use of the generation of transgenic plants and the use of molecular tools have evoked public and regulatory concerns and sociological issues. It is now clear that public acceptance and full commercialization of genetically enhanced crop plants and forest trees depend, in addition to breakthrough science, on proper public awareness of the issue and good perception.

The negative perception of GMOs in some western European countries has negatively influenced GM debates in Africa and reinforced the need for a transparent process of engaging the public in decision-making. The first adopter countries of biotech in the continent also lead the way in formalizing strategies to promote public awareness, education and participation.

For example, the Burkina Faso National Agency of Biosecurity (ANB) created since 2003 launched the program for public understanding of Biotechnology targeting all segments of society with emphasis on consumers, cotton breeders and learners. The ANB activities aim to promote public awareness and understanding of modern biotechnology and to stimulate dialogue on its current and potential future applications. Public awareness was enhanced by translating the biosafety law into local languages (Moore´, Jula and Gulmacema) most commonly spoken by cotton growers.

In 2008, Kenya implemented a national biotechnology awareness strategy (BioAWARE-Kenya), a six-year (2008–2013) strategy meant to enhance public understanding and awareness through the dissemination of accurate, timely and balanced information to catalyze informed decision-making.

National communication efforts are strengthened by platforms such as the Open Forum on Agricultural Biotechnology in Africa (OFAB). The OFAB enables interactions between and among scientists, journalists, the civil society, industrialists, policy makers, and farmer groups and consumer associations, which explore avenues of bringing the benefits of biotechnology to the grassroots level (http://www.ofabafrica.org).

6.2.2. Section 2. Instruments of Policy-making

6.2.2.1. Current international and national policies

Policy-makers evaluate the societal significance of scientific and technological issues such as biotechnology.

Without a " policy-maker will" a country bears the brunt of non-functional legislative and regulatory frameworks, negligible investment in biotechnology R&D, low public awareness and inability to handle approval processes (Adenle, 2012).

A common citizen clearly cannot be expected to have an in-depth understanding of all the facts, relationships and issues of biotechnology.

The adoption of a any technological innovation implies a certain amount of risk and managing this risk is an important component of decision-making. Assessment of the socio-economic impact of biotechnology is an invaluable input in regulatory decision-making. The conclusion of the Cartagena Protocol on Biosafety (**CPB**) to the Convention on Biological Diversity (**CBD**) was a major turning point in the regulation of GM organisms particularly those destined for intentional environmental release.

The CPB is significant for the agriculture sector as it recognizes both the benefits and the potential risks arising from GM technology. Hence, it stresses the need to do scientifically sound risk assessment and management practices to minimize adverse effects.

As of February 2014, the only countries in Africa that have not yet ratified or acceded to the Cartagena Protocol on Biosafety are Côte d'Ivoire, Equatorial Guinea, Säo Tomé and Principe, and Sierra Leone. However, Côte d'Ivoire has ratified it in 2016.

A national policy is required to frame a country's unified approach to biotechnology and biosafety. Problems arise when one sector of government has a positive approach to the development of biotechnology (often led by ministries responsible for agriculture or science), whereas other ministries (often those responsible for the environment or trade) adopt a negative view. The diversity of approaches of different government departments leads to considerable uncertainty and can be considered partially to blame for regulatory delays and poor decision making. However, African countries currently have different regulatory approaches to GM-crops. Some have co-existence policy measures between GM and wild crop without legislation, others have legislation and guidelines in various laws, and some have no provisions at all. Thus the absence of legislation may not be an insurmountable barrier. In absence of law good agricultural practices for guidance on farm and post-production processes are used for some countries (example Spain).

The focus of national policy should be on adopting available, safe and useful biotechnologies rather than a policy of exclusion that serves the narrow interests of some to the detriment of others.

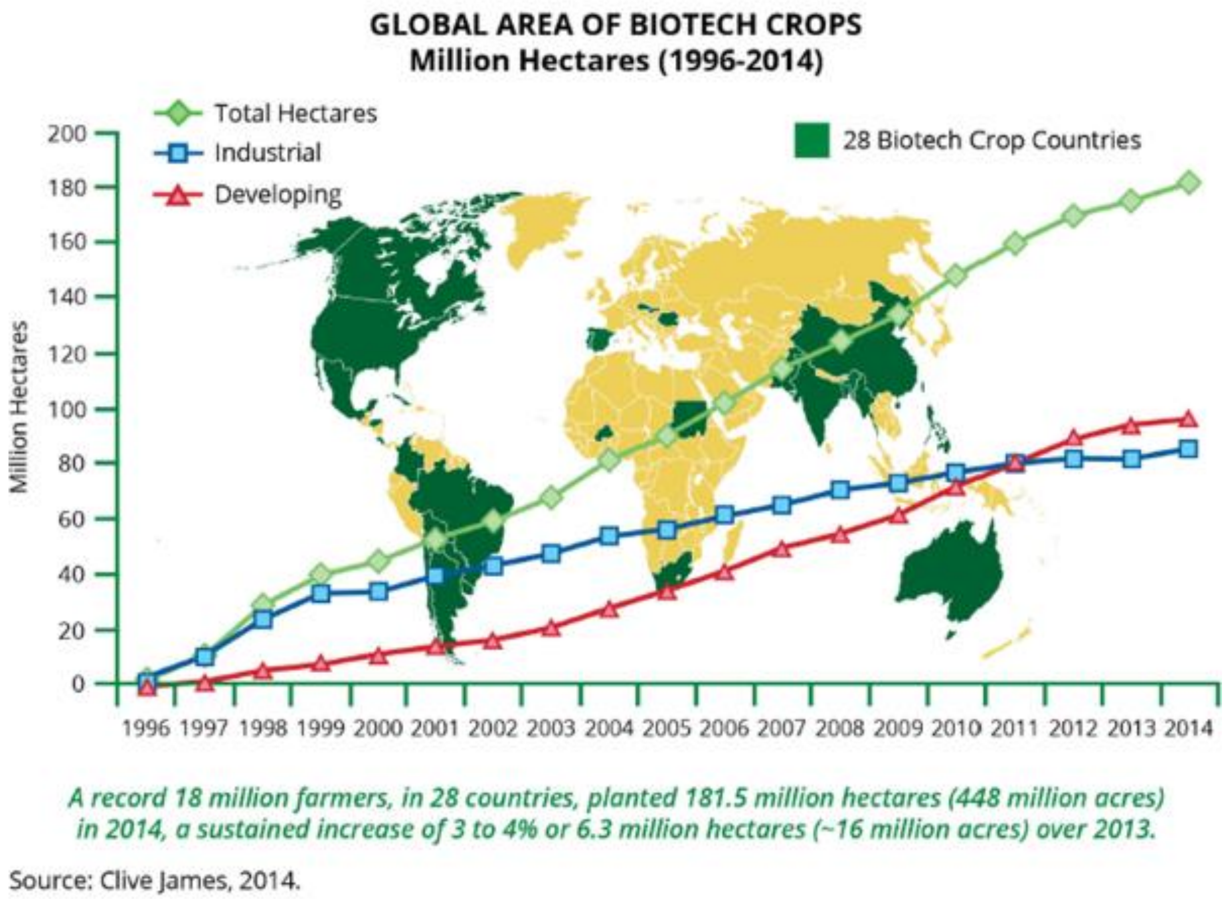

Figure 9. Worldwide global area of biotech crops production

6.2.3. Section 3. Roles of medias

Communication proceeds primarily through, radio, print media and the electronic (Internet, sms, etc…), but many special interest groups may disseminate their own information and interpretations, also verbally in meetings and elsewhere. In various countries, to varying extents and with varying quality, newspapers, magazines, radio, television, Internet fora, report and discuss new technological topics of public concern. But biotechnology is fairly prominent among them, especially when dealing with genetically modified crops and foods.

However, the main role of medias are to increase public awareness of biotechnology in impartial matter. Medias should present the technology as simply as possible for a better understanding of general public. Information exchange between media people and scientists on biotechnology and its best practices is necessary. The trust between medias and african scientist needs to be improved.

6.2.4. Section 4. Discussion with students

- What are current local laws in the country in relations to biosafety or why they don't exist?
- What can be done to parliament for a better comprehension and adoption of biotechnology?
- What can be done to government for a better comprehension and adoption of biotechnology
- Is it necessary to have specialized medias in the country dealing essentially with science technology and innovation?
- Can the african observatory of science, technology and innovation (http://aosti.org) play a role for better public understanding and adoption comprehension of biotechnology?

Supporting material:

Unit2. Doc 1. Ademola A. Adenle et al. Analysis of open source biotechnology in developing countries: An emerging framework for sustainable agriculture. Technology in Society 34 (2012) 256–269.

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6. 3. Unit 3. Value chain, agribusiness, local and global development: 3 hours

Summary

Value chain research provides a capacity to increase efficiencies, business integration, responsiveness and ultimately market competitiveness.

Biotechnology has the potential to improve living standards in low-income countries. The biotechnology sector is comprised of biotechnology firms, research institutions, and related industrial companies, and farmers that discover, develop, and commercialize biotechnological products and processes. Biotechnology business can be divided into four major market segments: biomedical, environmental, industrial, and agricultural. The later is the most visible sector in Africa. Successes in Agricultural biotechnology are built upon by both the public and private sectors, thus firms that can best utilize their research and development assets toward successful innovation performance in biotechnology.

. Only through private investment in biotechnology firms, will investors be able to capitalize on the benefits of R&D efforts. Without the prospect of profitability, private-sector incentives for investment in research and development in biotechnology would decline. However, one should keep in mind that all actors in the chain, from the small farmer to end users have to benefit equitably to the technology. Applications of biotechnology can increase food output, improve nutritional quality, and raise health status.

Although it remains an area of controversy, biotechnology in Africa has already achieved significant productivity gains and improvement in health status of farm workers. However, due to the privatization and increased intellectual property rights (IPRs) protection, many people in Africa find it very difficult to access modern biotechnology research tools (e.g. genetic engineering, micro-propagation, mutation breeding etc.) to ensure food security. To have a good value chain, it important to understand and tailor the strategic alliances and gain to gain policy between firms, agribusiness sector, government agencies, educational institutions, and local communities.

The objective of this unit is to determine how global and local value chain represent for local firms and suppliers in the countries to get access to larger markets and new technologies.

6.3.1. Section 1. Agricultural value chain

6.3.1.1. Definition of value chain

A value chain is the whole series of activities that create and build value at every step. The total value delivered by the company is the sum total of the value built up all throughout the company. The value chain concept separates useful activities (which allow the company as a whole to gain competitive advantage) from the wasteful activities (which hinder the company from getting a lead in the market).

Impact of global and local value chain for local firms and suppliers for access to larger markets and new technologies.

Biotechnology has the potential to improve living standards in low-income countries. The biotechnology sector is comprised of biotechnology firms, research institutions, and related industrial companies, and farmers that discover, develop, and commercialize biotechnological products and processes. Biotechnology business can be divided into four major market segments: biomedical, environmental, industrial, and agricultural. The later is the most visible sector in Africa. Successes in Agricultural biotechnology are built upon by both the public and private sectors, thus firms that can best utilize their research and development assets toward successful innovation performance in biotechnology.

Focusing on the value-creating activities could give the company many advantages. For example, the ability to charge higher prices; lower cost of manufacture; better brand image, faster response to threats or opportunities. Value chain research provides a capacity to increase efficiencies, business integration, responsiveness and ultimately market competitiveness.

Since 1996, 57 countries have granted regulatory approvals for GM crops for import for food and feed use and for release into the environment.

Through private investment in biotechnology firms, will investors be able to capitalize on the benefits of R&D efforts. Without the prospect of profitability, private-sector incentives for investment in research and development in biotechnology would decline. However, one should keep in mind that all actors in the chain, from the small farmer to end users have to benefit equitably to the technology. Applications of biotechnology can increase food output, improve nutritional quality, and raise health status.

Although it remains an area of controversy, biotechnology in Africa has already achieved significant productivity gains and improvement in health status, income, and living standards of farm workers. However, due to the privatization and increased intellectual property rights (IPRs) protection, many people in Africa find it very difficult to access modern biotechnology research tools (e.g. genetic engineering, micro-propagation, mutation breeding etc.) to ensure food security. To have a good value chain, it is important to understand and tailor the strategic alliances and gain to gain policy between firms, agribusiness sector, government agencies, educational institutions, research structures and local communities.

6.3.1.2. Current impact of the business of biotechnology

By 2012, 14 million farmers in 28 countries had planted 170 million ha of GM crops. The global market value of GM crops in 2009 was US$10.5 billion with the accumulated global benefit estimated at US$51.9 billion. The global net economic benefit to GM crop farmers in 2008 was US$ 9.2 billion of which US$4.7 billion went to farmers in developing countries and US$4.5 billion to farmers in industrial countries (ABNE, 2014).

Area devoted to GM crops in South Africa has expanded considerably since 1998 so that by 2010, it stood at 2.2 millions ha. Burkina Faso first commercially planted Bt cotton in 2008 on 8500 ha. In 2015, that has increased several fold, indicating a 126% growth rate and an adoption rate of more than 70%. The same holds true for Kenya; Egypt and South Africa.

It is estimated that in West Africa, growing Bt cotton can earn net benefits per year of $7–67 million for Mali, $5–52 million for Benin, $4–41 million for Burkina Faso, $4–38 million for Côte d'Ivoire and $1–7 million for Senegal. The same figures appear If Benin were to grow Bt cowpea or Ghana to grow GM tomato resistant yellow leaf curl virus. By delaying the approval of GM banana, Uganda foregoes potential annual benefits ranging from about $179 million to $365 million per year (James A. Okeno).

Other non-african countries leading and economic blocks that have given approval on positive economic impacts include Japan, USA, Canada, South Korea, Mexico, Australia, the Philippines, the European Union, New Zealand and China.

6.3.1.3. Business and scientific partnerships benefices to society

The Cartagena Protocol on Biosafety's Article 26, emphasized the need, before application approval, for determining socio-economic impacts arising from GMOs on the conservation and sustainable use of biological diversity, as regard to indigenous and local communities. So far in Africa, it is not well elaborated in the law how socio-economic impacts will be measured and analyzed, and factored into biosafety decision-making process (James A. Okeno, 2013).

The **CPB** recognizes both the benefits and the potential risks arising from GM technology. It clearly indicated the need to do scientifically sound risk assessment and management practices to minimize adverse effects. Some African countries have taken precaution to be decision making based on scientific assessment and have consequently put in place regulatory measures that include science based risk assessment. For example in Burkina Faso, the National Agency on Biosafety (**ANB**) has a group of multidisciplinary scientific experts who advice the government.

Scientific experts should not only advice the government on law related to GM crops but give their authorization for GM crops field trials and subsequent commercialization, if any. Other countries have issued prohibitive legislations that deny farmers a powerful tool to tackle some crop production constraints. Currently, several African countries are testing GM crops and many are expected to progress towards commercialization. Since there is a great chance of cross-border leakage of GM crop seeds from one country to the other without regulatory approval, all African countries should anticipate by set-uping GM regulations using the **CPB** as guide. This can open doors for testing and commercialization of GM crops.

6.3.1.4. Strategies for value chain management

-Encourage International Partnerships;

-Across global agro-biotechnology, the expansion of production for the global market can be associated with increases in women's employment.Gender plays an important role in shaping outcomes of participation within value chains. Employment of women in firms participating in global value chains may provide economic independence, an alternative to domestic labour

-Develop a significant in-state venture capital capacity;

-Continue to fund and advance a bio-safety network program.

Good management of co-existence between wild type and GM-crops. Co-existence in biotechnology refers to GM, conventional and organic agricultural production systems that operate in proximity without mixing of produce or compromising their economic value. Co-existence, with its possible implications for national economies, requires management to ensure different cropping systems operate in tandem without interfering with or excluding any other agricultural production method.

The principles of co-existence are: context, consistency, proportionality, equity, and practicality. The co-existence facilitates access to niche markets, ensures good returns on investment, provides safeguards to sociocultural norms and values, protects biodiversity and permits diversification in production as a coping mechanism under variable environmental conditions. Stakeholders such as governments, consumers, producers, traders and industry have requested a system that is demand-driven and offers freedom of choice while protecting the interests of indigenous communities. The goal is to cater for different niche markets that support the economic interests of the various commercial groupings.

6.3.2. Section 2. Local and global requirements and developments (glocalisation)

The socio-economic concerns of public include dependence of farmers on large corporations for seed; unaffordable cost of planting materials; possible unsuitability of GM crops for small-scale farm operations and for resource poor farmers (interestingly 90% of GM crop farmers are small-scale and resource poor farmers in developing countries); unethical patenting of life; possible limited access and increased price of seeds due to technology fees; lack of food distribution infrastructure rather than simply producing more; products needed in developing countries not being developed due to market or profit consideration.

6.3.3. Section 3. Discussion with students

-why should GVCs spread to these countries and outsource part of their activities to their enterprises?

-what opportunities for upgrading would this offer to these countries' firms?

-under what conditions could these opportunities be exploited?

-how do these opportunities differ from manufacturing to agriculture and to agro-food processing?

Supporting documents

Doc 1.: ABNE. 2012. Socio-Economics Policy Brief No. 3. Co-existence of GM and non-GM Crops: Implications for Africa. Samuel E. Timpo,
Doc 2. Carlo Pietrobelli Carlo Pietrobelli.Global value chains in the least developed countries of the world: threats and opportunities for local producers. Int. J. Technological Learning, Innovation and Development, 2008, Vol. 1, No. 4, 459-481.
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6. 4. Unit 4. Stakeholder participation: 3 hours

Summary

The attitudes and interests of stakeholders involved in national public debates on the risks and benefits of genetically modified crops are having a significant influence on public opinion as well as public policy outcomes related to the use of genetically modified organisms (GMOs) in agriculture in developed and developing countries. The role of the stakeholder participation, internalization and appropriation in the process of biotechnology development is very important for the adoption of the technology.

Biotechnology is expected to play an important role in transforming the economy from a predominantly agricultural one with low productivity to a diversified and semi-industrialized economy with a modern rural sector and high productivity in agricultural production that generates reasonably high incomes and ensures food security and food sovereignty.

Biotechnology can contribute significantly to sustainable agricultural development and enhanced food security by improving local crop productivity, reducing chemical inputs, protecting crops against pest and post-harvest losses, improving nutrition, increasing crop tolerance to stress, and by producing value-added products.

For agricultural biotechnology to be effective, it must be based on clear and realistic research priorities based not only in formal science but also taking into account indigenous knowledge, which are closely linked to farmers' needs. Lack of pragmatic approach may result in limited biotechnology adoption and inability to meet the demand of African farmers and other stakeholders. The potential of biotechnology can only be realized if due attention is paid to the whole array of policies and programs needed for sustainable development.

Some African countries are making some effort to build a national capacity in biotechnology in terms of the physical human organizational or institutional resources. Biotechnology stakeholders can be enumerated as follow: scientists (universities, research institutes, etc.), policy makers (ministries, UN organizations, etc.), regulatory agencies, legislators (parliaments), civil society, community based society, donors (NGO's, bilateral and multilateral agencies), farmers, industrialist and end-users (consumers).

The importance of the functions of each category of stakeholder generally connects to the other. It is vital that all functions are addressed properly for the realization of the systematic synergy required for making the desired impact of biotechnology.

End-users of biotechnology products are paramount to biotechnology activities, since are key persons for the adoption and appropriation of the technology. The stakeholder perspectives on the adoption of GM technology in African countries is very important to consider but difficult to assess (Adenle, et al., 2013) in order to lead for development. Current study on views and positions of stakeholder groups in Africa with respect to GM crops revealed that small farmers are willing to adopt new technology to improve their crop productivity so as to secure enough food to eat (Adenle, et al., 2013).

Food self-sufficiency and improved quality of life of resource-poor farmers should be targeted as ultimate socio-economic impacts for products resulting from the application of biotechnology including GMOs in Africa. Thus GM technology has to make his impact more visible on food security after one decade of implementation in some African countries. Stakeholders should be sensitized to understand the technology and its potential impact to enable them contribute to its development. Moreover, a consensus is needed to regulate GMO products and controversy surrounding the adoption of GMOs.

The objective of this unit is to analyse the role of the stakeholder perceptions, internalization and appropriation in the process of biotechnology for development.

6.4.1. Section 1. Stakeholder involvement and public engagement.

6.4.1.1. Potential benefit of the technology for stakeholders

Biotechnology is expected to play an important role in transforming the economy from a predominantly agricultural one with low productivity to a diversified and semi-industrialized economy with a modern rural sector and high productivity in agricultural production that generates reasonably high incomes and ensures food security and food sovereignty.

6.4.1.2. Stakeholders involvement on internalization and appropriation in the process of biotechnology

The attitudes and interests of stakeholders involved in national public debates on the risks and benefits of genetically modified crops are having a significant influence on public opinion as well as public policy outcomes related to the use of genetically modified organisms (GMOs) in agriculture in developed and developing countries. The role of the stakeholder participation, internalization and appropriation in the process of biotechnology development is very important for the adoption of the technology.

Biotechnology can contribute significantly to sustainable agricultural development and enhanced food security by improving local crop productivity, reducing chemical inputs, protecting crops against pest and post-harvest losses, improving nutrition, increasing crop tolerance to stress, and by producing value-added products.

6.4.1.3. Perception of the technology by different stakeholder groups

Some African countries are making some effort to build a national capacity in biotechnology in terms of the physical human organizational or institutional resources. Biotechnology stakeholders can be enumerated as follow: scientists (universities, research institutes, etc.), policy makers (ministries, UN organizations, etc.), regulatory agencies, legislators (parliaments), civil society, community based society, donors (NGO's, bilateral and multilateral agencies), farmers, industrialist and end-users (consumers).

The importance of the functions of each category of stakeholder generally connects to the other. It is vital that all functions are addressed properly for the realization of the systematic synergy required for making the desired impact of biotechnology. In several African countries, the survey on key stakeholder groups indicated that successful production of GM crops is due to the availability of effective biosafety regulatory frameworks and extensive capacity building on modern biotechnology research and development (R&D). These were accompanied by adequate training of farmers and scientists, increasing public awareness through active media programs (e.g. radio, television, printed media) such as AfricaBio in South Africa (NGO). (Adenle et al, 2013).

Most of African stakeholders found that the adoption of GM crops is relatively high among commercial and small-scale farmers due to the benefits of high-yielding varieties, disease-resistant traits and herbicide tolerant traits, except in the case of subsistence farmers who rarely use hybrids due to the cost. A witness of farmer representative in South Africa stated that ''GM maize requires 3 man days for weed control while non-GM maize needs 28 man days of weeding, and using GM maize saves 25 man days, which gives them more time to do something else''. Although small-scale farmers cultivating GM maize in South Africa have to pay 35% more for seed than non-GM maize producers, they achieve high yields and pay 42% less per hectare for labor (Literature: Adenle et al, 2013).

Adoption of GM crops can be justified by the mere fact that the additional costs outweigh premiums paid over GM crops in the light of opportunity cost for family labor. Other cited advantages are the reliability and agronomic qualities (yield, traceability, etc.) of the seeds. Discussions with cotton breeders in Burkina Faso in the framework of this course development also revealed that those stakeholders prefer Bt cotton rather than the wild type for the same reasons. The main disadvantage using GM-crops remains the dependence on seeds to international firms such as Monsanto.

Figure 10. Example of local market of *Bt* cotton in Burkina Faso.

6.4.1.4. Safety issues and precautionary principles

Safety issues addressed the avoidance of risk to human health and care, and to the conservation of the environment, as a result of the use for research and commerce of infectious or genetically modified organisms. End-users of biotechnology products are paramount to biotechnology activities, since they are key persons for the adoption and appropriation of the technology. The stakeholder perspectives on the adoption of GM technology in African countries is very important to consider but difficult to assess in order to lead for development. Current study on views and positions of stakeholder groups in Africa with respect to GM crops revealed that small farmers are willing to adopt new technology to improve their crop productivity so as to secure enough food to eat. Food safety; preservation of the ecological balance and the environment; socio-economic considerations; regulatory aspects and intellectual property rights (patents); and ethical aspects are the major concern of public.

The important concern of public is the limited capacity and lack of scientific expertise or trust of the existing one particularly with regard to the risk analysis of GM products. Thus, the need **to label GM foods is often raised** for some public. This is a controversial issue. While some people think that labelling must be in place to ensure consumers know what hey are eating others don't think this necessity. In Burkina Faso, GMO labeling is mandatory, while in South Africa it is not obligatory and 78% is not aware of the introduction of GM maize.

6.4.1.5. Precautions of gene flow

Gene flow refers to the introgression of genes or genetic materials from one plant population into another.

There are concerns that the integration of transgenes from a Biotech crop into its non GE counterpart and/or wild or weedy relatives (crop to wild relative) could trigger a range of possible environmental consequences. The strict respect of the CPB is important avoid the appearance of new weeds, and changing the related characteristics and loss of genetic diversity in the wild relatives of crop landraces caused by transgene flow.

Food self-sufficiency and improved quality of life of resource-poor farmers should be targeted as ultimate socio-economic impacts for products resulting from the application of biotechnology including GMOs in Africa. Thus GM technology has to make his impact more visible on food security after one decade of implementation in some African countries. Stakeholders should be sensitized to understand the technology and its potential impact to enable them contribute to its development. Moreover, a consensus is needed to regulate GMO products and controversy surrounding the adoption of GMOs.

6.4.2. Section 2. Indigenous knowledge and adoption of new technology

6.4.2.1. Indigenous knowledge

For agricultural biotechnology to be effective, it must be based on clear and realistic research priorities based not only in formal science but also taking into account indigenous knowledge, which are closely linked to farmers' needs. Lack of pragmatic approach may result in limited biotechnology adoption and inability to meet the demand of African farmers and other stakeholders. The potential of biotechnology can only be realized if due attention is paid to the whole array of policies and programs needed for sustainable development.

6.4.2.2. Strategies of adoption of the new technology with endogenous knowledge

A study views and positions of stakeholder and NGO groups on development, regulation and adoption of GM agriculture in six African countries (South Africa, Kenya, Egypt, Tunisia, Ghana and Nigeria), revealed the challenges leading to the development of biosafety regulatory frameworks and the role of individual stakeholders in the facilitation of GM crops across African countries. This study showed that among strategies for GMO adoption, countries may go through a **Fiber–Feed–Food** (**F3**) approach to adopt GM crops. This means that Bt cotton will be adopted first followed by GM crops for livestock feed while undergoing all the necessary assessments before producing GM foods for human consumption (Adenle et al, 2013).

According to the point of views the African Union-New Partnership for Africa's Development (AU-NEPAD), the African Development Bank (AfDB), the Alliance for a Green Revolution in Africa (AGRA) and the European Commission (EC) introducing new agricultural technology is based on a demand-driven approach, and the introduction of modern biotechnology tools including GMOs in agricultural development should be decided by individual sovereign African countries.

There is a need to mobilize stakeholders including both the public and private sector, and to have a correct perception of the problem for which the biotechnology is developed for adoption and diffusion of new innovation.

6.4.3. Section 3. Discussion with students

- – Food security and GMOs-why and how?
- – Research capacity for GMOs?
- – Risk analysis of GMOs-by whom and how?
- – Development and regulations of GMOs-by whom and how?
- – Application of biosafety regulatory system-how?
- – Decision-making for GMOs-by whom and how?
- – Field tests and adoption of GMOs-how and when?
- – Awareness creation for GMO products-how and when?

- – Problems affecting the use of GMOs-how?
- – Transfer of GMO technology-how?
- – Prioritization of GMOs in agricultural policies-how?

Supporting material:

Doc 1. Adenle, AA, Morris, EJ & Parayil, G (2013) Status of development, regulation and adoption of GM agriculture in Africa: Views and positions of stakeholder groups. Food Policy **43**, 159-166.

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6. 5. Unit 5. Case studies of tailor-made biotechnology in specific countries: 6 hours

Summary

The adoption of GM crops in Africa has increased steadily over the two decades due to the socio-economic and environmental benefits.
Worldwide there are currently 75 countries that have signed the Cartagena protocol of biosafety, among which there is up to 45 African countries. Although the great number, only 20 countries have ratified the protocol and adopted internal law on GMOs. However, some countries perform confined field trial without adoption of specific law (Uganda). Some African countries have better experience of scientific research in the field of Agriculture than others. Their knowledge base and accumulated expertise have made it possible for them to leap into GM crops. Five categories of African countries engaged in biotechnology could be distinguished: (a) those that are generating and commercializing biotechnology products and services, (b) those that are engaged in third generation biotechnology R&D with confined field testing, c) those that are engaged in contained research and d) those that are developing capacity for research and development and e) those that are developing internal laws. Cases studies will focus on the following countries: South Africa, Burkina Faso, Kenya, Nigeria and Egypt.
The objective of this unit is to understand current experiences in African continent throughout case studies of five countries that are involved in GMO crop experiments or commercialisation.

6.5.1. Section 1. Overview of status of Biotechnology and Biopolicy in Africa

African countries have different experience in biotechnology. This is mainly due their institutional capacity to monitor the new technology, the lack of political support and anti-GMO activism. Most African governments still lack commitment to science, technology and innovation and as a result fewer donors have been attracted. The application of GM crops has been an alternative within the technology mix to improve Africa’s agricultural productivity.

Of the 27 countries which planted GM crops in 2013, 19 were developing and 8 were industrial countries. Each of the top 10 countries, of which 8 were developing grew more than 1 million hectares providing a broad-based worldwide foundation for continued and diversified growth in the future. More than half the world's population, 60% or (4 billion people), live in the 27 countries planting GM crops.

The adoption of GM crops in Africa has increased steadily over the past years due to the socio-economic and environmental benefits (James, 2013).

Worldwide there are currently 75 countries that have signed the Cartagena protocol of biosafety, among which there is up to 45 African countries. Although the great number, only 20 countries have ratified the protocol and adopted internal law on GMOs. However, some countries perform confined field trial without adoption of specific law (Nigeria and Uganda). Some African countries have better experience of scientific research in the field of Agriculture than others.

Over the last few years, there has been an increase in research and development in Africa aimed at developing transgenic crops to address constraints to agricultural productivity on the continent. These include projects aimed at developing, amongst many others:

Nigeria, Malawi: Bt cowpea, Insect resistant cotton

Kenya: Insect resistant maize, Virus resistant cassava; biofortified cassava; biofortified sorghum; drought tolerant maize

Uganda: Insect resistant cotton, fungus resistant banana ; virus resistant cassava; biofortified banana; drought tolerant maize

South Africa: Bt potato; virus resistant maize, Drought tolerant maize; biofortified sorghum

Burkina Faso, Insect resistant cotton, biofortified sorghum, insect resistant soybean, drought tolerant maize,

Mozambique, Drought tolerant maize

Tanzania: Drought tolerant maize

Based knowledge and accumulated expertise have made it possible for countries to leap into GM crops. In 2014, out of the 54 African member states, 22 countries have biosafety laws, regulations, guidelines or policies in place related to genetic engineering and modern biotechnology. In 2014, globally more than 175 million hectares of GM crops were world wide grown at an annual increase rate of 3%. By this date, four African countries planted 3.2 million hectares (ha) and commercialized them: South Africa, Burkina Faso, Egypt and Sudan. To date, however, only South Africa, Burkina Faso and Sudan grew GM crops as the Egyptian Government placed a temporary planting restriction.

Table 2. Most important GM crops in African countries[1]

COUNTRY **Crop**	BFA	EGY	GHA	KEN	MWI	MOZ	NGA	ZAF	SDN	TZA	UGD	ZWE
Banana											CFT	
Canola								CR, CFT				
Cassava				CFT			CFT	TR			CFT	TR
Cotton	CR[2], CFT	CR, CFT	CFT	CFT	CFT	CFT		CR, CFT	CR		CFT	CFT
Nebié	CFT		CFT				CFT					
Maïs	GH	CR, CFT		CFT		CFT		CR, CFT		~CFT	CFT	~CFT
Pomme de terre		CFT						TR			CFT	TR
Riz			CFT								CFT	
Sorgho	GH			GH			CFT	TR				
Soja	GH							CR, CFT				
Canne à sucre								CR, CFT				
Patate dce				TR							GH	
Tomate		GH										
Blé		CFT										

[1]**Abbreviations:** Commercialisé (CR, CR[2] suspension temporaire en Avril 2016), Essais confinés en milieu (CFT), Chambre verte (GH), and Transformation (TR). BFA-Burkina Faso; EGY-Egypte, KEN-Kenya, MWI-Malawi, MOZ-Mozambique, NGA-Nigeria; ZAF- Afrique du Sud, SDN-Soudan, TZA-Tanzania, UGD-Uganda, ZWE-Zimba

6.5.2. Section 2. Case studies of 5 countries

The following countries were selected as case study for introduction or commercialization of GMP crops: Burkina Faso, Egypt, Kenya, Nigeria and South Africa.

6.5.2.1. Burkina Faso

Agriculture contributes almost 40% of the Burkina Faso GDP and provides employment to 85-90% of the country's total population. Cotton is the main cash crop from which over 3000 stakeholder associations are involved in its production and commercialization. With average cotton holding at 3.25 hectares per farm, there were approximately a total of 76,000 Bt cotton farmers in Burkina Faso in 2011. Benefits from Bt cotton include an average yield increase of almost 20%, plus labor and insecticide savings (2 rather than 6 sprays), which resulted in a net gain of about us $66 per hectare compared with conventional cotton. It is estimated that Bt cotton has the potential to generate an economic benefit of up to us $100 million per year for Burkina Faso. National benefits to Bt cotton farmers is that over 2.2 million people derive their income.

Because of chemical resistance and several damage of the cotton caused by insects, the government, through a partnership with Monsanto, decided to explore the use of Bt cotton. The Government of Burkina Faso signed the Cartagena Protocol on Biosafety in 24 May 2000 and ratified it in 04 August 2003. The national biosafety rules enabled the country to start confined field trials of Bt cotton in 2003. Later, the national biosafety law (*Loi n°005-2006/AN*) that was voted on March 17, 2006, by the parliament. Stakeholders realized that the use of biotechnology must go hand-in-hand with biosafety measures as required by the CPB.

To date, Burkina Faso is the only francophone West African country to have a functioning biosafety regulatory system that has approved the commercial release and use of GM products. Burkina Faso is one of four countries in Africa that has approved since 2006, field trial and commercial planting of GM crops. Farmers in Burkina Faso have been successfully growing Bt cotton since 2008. The biosafety is controlled by the national Biosafety Agency (Agence National de Biosecurite) according to the following biosafety scheme:

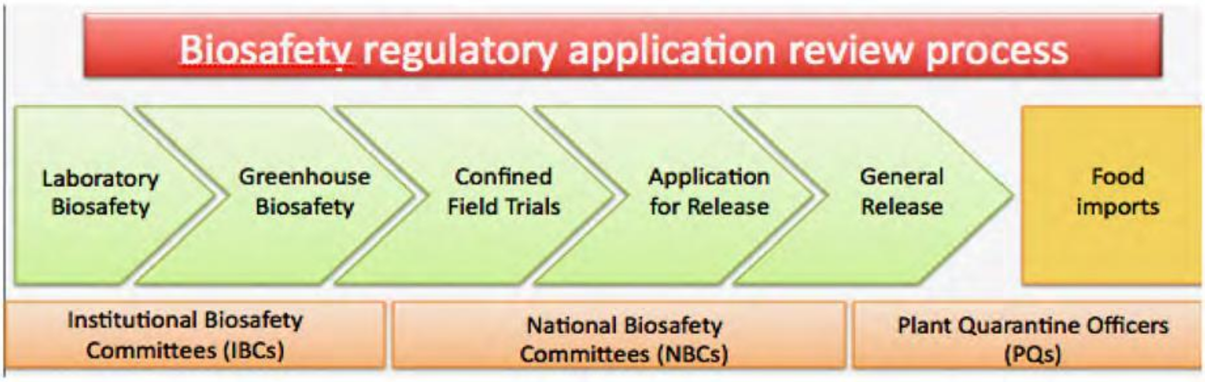

Figure 11. Biosafety regulatory application process in Burkina Faso

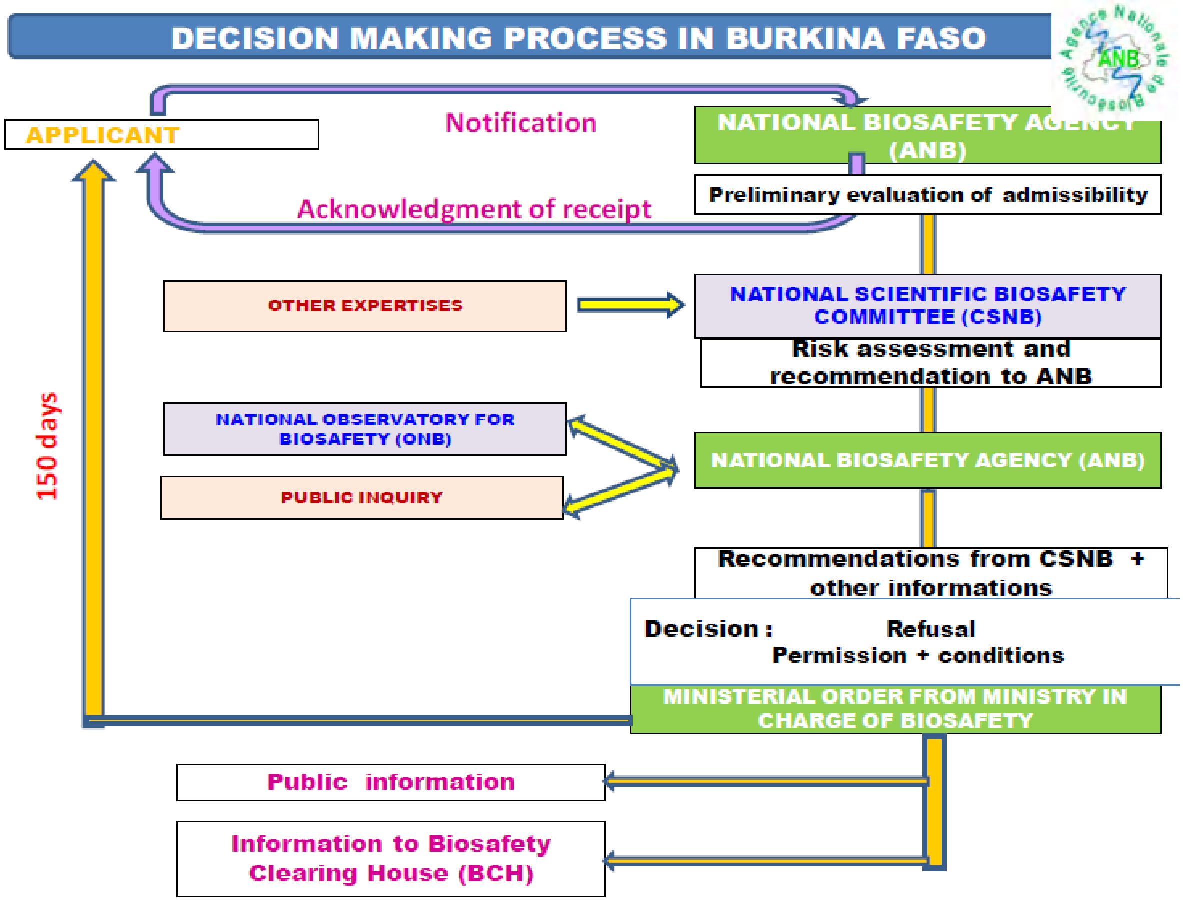

Figure 12. Decision making process in Burkina Faso

In addition to Bt cotton, confined field trials are currently ongoing for improved nutritional sorghum (vitamin A and lysine), *Maruca*-resistant cowpea and RoundupReady® cotton. There is significant increase in the area planted under Bt cotton in Burkina Faso (over 50% increase from 2012). The adoption of Bt cotton was very fast in Burkina Faso, from an initial area of approximately 8 500 hectares in 2008 to more than 500,000 hectares in 2014

(Sofitex; 2014). Bt cotton has increased cotton yields by an average of 21.3%, and increased income by $106.14 per ha. It also allowed for a significant reduction in the number of applied pesticides sprays, from 6 or 8 to 2. Cotton farmers justified their choice for Bt cotton from the benefits gained in better health for themselves and their families thanks to the reduction of pesticide sprays and time savings for other activities.

Although Bt cotton is generally adopted by cotton farmers some civil societies still oppose to the introduction of GM crops in the Country. Nevertheless, parties that oppose modern biotechnology are continuously working to stop and reverse the development of enabling legislation. It is clear that the fight for the safe and responsible use of modern biotechnology in Burkina Faso has not been completely won. Most recently in march 2016, the gorvement of Burkina Faso has decided to suspend the use of Bt coton for this year. The reason behind this decision is that the fiber from Bt cotton is shorter that the wild type, which impair its commercial value for exportation. Nevertheless, the debate is still going on because cotton breeders have a preference for the Bt cotton. Thus the application of this decision is a controversy.

Figure 13. Cotton farmers enjoying Bt Cotton in their farms.

6.5.2.2. Egypt

Egypt takes a permissive approach to genetically modified organisms (GMOs), and its public policy does not oppose growing, importing, and exporting genetically modified crops. Egypt ranks third in Africa in planting and importing genetically modified crops, after South Africa and Burkina Faso. In 2008, Egypt became the first North African country to grow genetically modified crops, and it is now one of the five countries worldwide to introduce biotech crops to other countries. Since December 2010, genetically modified crops have been planted without restrictions in ten different Egyptian provinces, including one thousand hectares of genetically modified maize in 2012.

Egypt does not have any restriction on researching, producing, or marketing genetically modified crops and food products. In March 2008, the Ministry of Agriculture approved the domestic cultivation of GM corn, and the Egyptian Ministry of Agriculture allowed the importation of GM corn seeds into markets. Since 2011, Egypt commercialized Bt cotton. Egyptian activists have voiced their rejection of the country's policies. In an attempt to curb the proliferation of GM crops and food products, activists have collaborated with the Nature Protection Section of the Ministry of Environment to draft legislation, titled the Biosafety Law, that would regulate genetically modified crops and food products in Egyptian markets. In November 2011, the draft legislation was approved by the Council of Ministers. However, the measures have not been approved by the parliaments (lower and up ones). Currently the following field trial (FT), Green house trial or lab experiments are conducted for traits of several GM crops in Egypt (Table .

Table 3. GM crops in Egypt.

Maize	Insect resistance	FT
Cotton	Salt tolerance	GHT
	Drought tolerance	FT
Wheat	Fungal resistance	GHT
	Salt tolerance	Lab
Potato	Viral resistance	FT
Banana	Viral resistance	Lab
Cucumber	Viral resistance	FT
Melon	Viral resistance	FT
Squash	Viral resistance	Lab
Tomato	Viral resistance	Lab

6.5.2.3. Kenya

The first institutional biosafety guidelines in Kenya were developed in 1992 by the Kenya Agricultural Research Institute (KARI) with help from the United States Agency for International Developments (USAID) and the new Agricultural Biotechnology for Sustainable Development (ABSD) project. Kenya is the first country in the world to sign the CPB in May 2000. The country was selected as one of the pilot projects for the UNEP Global Environmental Facility (UNEP-GEF) biosafety project in 2001.

The Biosafety Act allows the marketing and release into the environment of approved GMs and their products. This is controlled by the Biosafety (environmental release) Regulations. Until now, there has been no release into the environment of any GM crops in Kenya but several crops are in the pipeline for release with the confined field trials on Bt cotton, Bt maize and virus resistant cassava at an advanced stage. Confined field trials have also started on bacterial wilt resistant banana, nematode resistant yam, and bio-fortified sorghum. There is still an interest in the Government to exploring all possible strategies to food sufficiency using GM crops.

6.5.2.4. Nigeria

Although Nigeria derives about 80% of its income from oil, agriculture contributes about 38% of the Gross Domestic Product. About 70% of the population derives its livelihood from agriculture, and the national economy is characterized by a large rural-based traditional sector. Nigeria signed the **CBD** in 1992 and ratified it in 1994. The country signed (2002) and ratified (2003) the **CPB** which is intended to conserve biological diversity from the adverse impact of GMO.

A National Biotechnology Development Agency (NABDA) became established in the latter part of 2001 to promote modern biotechnology activities in the country.

Since 2015, the National Biosafety Bill has led to an Act to regulate the practice of modern Biotechnology, handling and use of its products (genetically modified organism).

The country has several biosafety instruments (policy, protocols, guidelines, etc.) to monitor GM crops. The government has adopted biotechnology, including modern biotechnology, as one of the approaches to achieve sustainable development but especially to address challenges that have been difficult to resolve using conventional methods.

Confined field trials on GM crops are ongoing in several research institutions such as National Root Crops Research Institute (Umudike), and at Institute for Agricultural Research (Zaria). The experiments focused on bio-fortified cassava with increased vitamin A , bio-fortified cassava with an increased bio-availability of iron, sorghum with increased bio-availability of zinc, iron, protein and vitamin A and cowpea resistant against the soybean pod borer, *Maruca vitrata*.

The commercialization of GM is not yet effective and hampered among others the following factors:

- Inadequate qualified human resource and capacity building
- Inadequate knowledge of biosafety by the public,
- Misconceptions about modern biotechnology and GMOs,
- Control of the distribution of GMOs
- Inadequate funding of biosafety and research activities,
- Issues surrounding liability and redress, etc.

6.5.2.5. South Africa

South Africa has ratified the Cartagena Protocol on Biosafety. The country has a fully functional regulatory framework to manage the use of genetically engineered organisms.

The total area planted to soybeans increased from 500, 000 ha in 2012 to 520, 000 ha in 2013. Of this, the adoption rate of HT soybeans was 92% (478, 000 ha). The total cotton area was 8, 000 ha, with the adoption rate of GE cotton reaching 100%, 95% of which was the stacked Bt/HT traits and the remainder the HT trait which was used as a mandatory refuge. Although small-scale farmers cultivating GM maize in South Africa have to pay 35% more for seed than non-GM maize producers, they achieve high yields and pay 42% less per hectare for labor (Regier et al., 2013). In South Africa inverse relationship between number of local hospital admissions classified as related to cotton production, and adoption of Bt cotton (Carpenter, 2010).

6.5.3. Section 3. Overall advantages and drawbacks of modern biotechnology

6.5.3.1. Overall known positive aspects of biotechnology

- ✓ Improved resistance to drought and salt stress, pests and diseases;
- ✓ Higher yields &/or reduced input use;
- ✓ Increase of nutritional quality
- ✓ Increase delay of ripening ;
- ✓ Enhanced environmental protection;
- ✓ domestication of forest trees;
- ✓ Reduction of pesticide treatements
- ✓ Reduction human labor;
- ✓ Increase food production;
- ✓ Reduce post-harvest losses;
- ✓ Increase of micronutrient contents;
- ✓ Edible vaccines;
- ✓ Increased farm profitability;
- ✓ Molecular farming where microbes or plants are used to produce biopharmaceuticals;

14. Insect resistance plant

15. Grain with improved nutritive value

- ✓ Molecular farming where microbes or plants are used to produce biopharmaceuticals;
- ✓ Biological recovery of heavy metals from mining and other industrial sources;
- ✓ Bioremediation of soil and water polluted with toxic chemicals
- ✓ Production of biomaterials (bioplastics), biofuel, etc.
- ✓ Sewage and other organic waste treatment;
- ✓ Greater access to export mark (this is controversial), etc.

16. Fruits with edible vaccins

6.5.3.2. Concerns if any of GMOs

- Lack of appropriate GM crops/cash crops only
- Loss of export markets;
- Endangers indigenous crops/loss of biodiversity
- Creation of superweeds;
- Higher seed costs / licensing agreements;
- Fear of “terminator” gene technology;
- Low input use already in place;
- Introduction of new proteins into foods;
- Plants used to make nonfood substances.
- Undesired gene flow
- Increases of known toxins, decreases in nutrients;
- Activation of dormant pathways;
- Allergenicity;

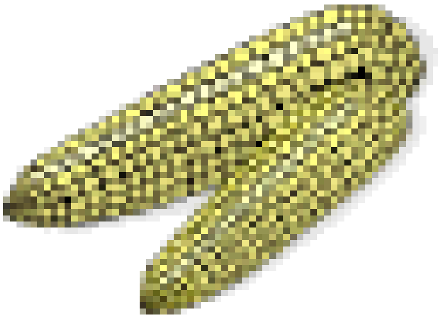

Figure 17. Maize with undesired Gene Flow

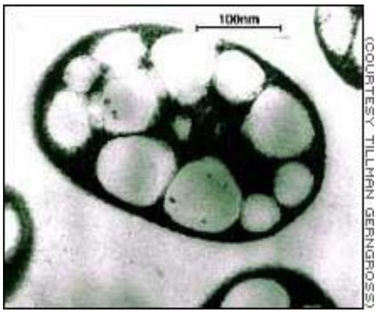

Figure 18. Antibiotic resistance

- Antibiotic and other insects resistance;
- Gains to wealthy landowners and multinationals;
- Dependance on genomic databases;
- Unknown disease and future health consequences;
- Weak public trust in government since the problem of mad cow (bovine spongiform encephalopathy, prion protein disease or Creutzfeldt-Jakob disease);
- Consumer concerns, etc.

Figure 19. Consumer concerns. Freedom to chose foods they eat.

6.5.4. Section 4. Discussion with students

What is the societal impression of biotechnology?

- What are the negative impacts that biotechnology may have?
- What are the potential ethical issues associated with biotechnology?
- Why are biotechnology companies targeted by anti-globalisation protesters in Africa?
- How can the image of biotechnology to the public be improved? Should it be improved?
- What are the potential dangers of biotechnology?
- How the African stakeholders can be involved for the adoption of Biotechnology.

Supporting documents

Doc 1. ABNE in Africa. 2015. Towards Building Functional Biosafety Systems in Africa.

SELECTED WEBSITES
http://www.nepadbiosafety.net
http://www.loc.gov/law/help/restrictions-on-gmos/egypt.php
http://www.isaaa.org/resources/publications/briefs/46/executivesummary/

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