Developments in Agricultural GM Technologies

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OVERVIEW

- Technical developments.
  - Crops, genetic engineering technologies, other organisms
- Sustainability developments.
  - Biosafety R&D, socio-economics
- Regulatory developments.
  - Regulatory status in Africa, regional harmonisation
- Role players in African biotech & biosafety.
  - BSA as example
- The development of sustainable GM technologies for African agriculture.
  - Defining sustainability, integrated sustainability assessment

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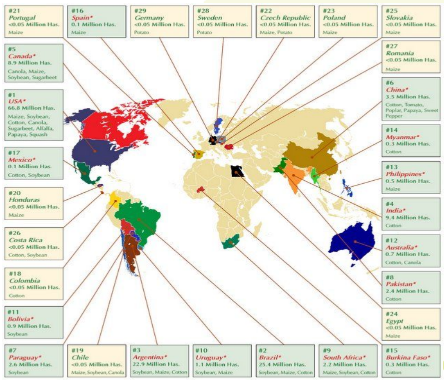
2

3

GM CROP PLANTINGS - 2010



Source: ISAAA

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4

FUTURE GM CROPS FOR AFRICA

Table 1. Pipeline of GM crops for African agriculture. Only GM crops which are at field trial stage, in at least one of the mentioned countries, are listed and already commercialised GM crops are excluded.

GM crop	Countries
Banana, biofortified	Uganda
Banana, fungal resistance	Uganda
Cassava, biofortified	Nigeria, South Africa
Cassava, modified starch	South Africa
Cassava, virus resistance	Kenya, Uganda
Cotton, insect resistance	Kenya, Uganda
Cowpea, insect resistance	Burkina Faso, Ghana, Nigeria, Zimbabwe
Maize, insect resistance	Kenya
Maize, virus resistance	South Africa
Maize, Striga resistant	Kenya, Ghana, Nigeria, Uganda
Maize, drought tolerant	Kenya, Mozambique, South Africa, Tanzania and Uganda
Melon & cucumber, virus resistance	Egypt
Potatoes, virus resistance	Egypt
Potatoes, insect resistance	South Africa
Sorghum, biofortified	Burkina Faso, Kenya, Nigeria, South Africa
Sugarcane, virus resistance, increased yields, alternative products	South Africa
Sweet potato, virus resistance	Kenya,
Wheat, drought tolerant	Egypt

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5

FUTURE GM CROPS FOR AFRICA

Disease resistance

Misshaped eggplants due to tomato bush virus infection.
http://www.dpvweb.net/intro/index.php

Fusarium resistance in GM *Arabidopsis* leaves.
www.genetwister.com

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6

FUTURE GM CROPS FOR AFRICA

Abiotic stress resistance

Drought tolerant maize
http://www.monsanto.com/droughttolerantcorn/WEMA.asp

Flood tolerant rice
http://txtwriter.com/Onscience/Articles/floodtolerantrice.html

Salt tolerant wheat
bch.cbd.int/database/attachedfile.aspx?id=3235

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7

FUTURE GM CROPS FOR AFRICA

Improved nutrition

Multi-vitamin maize
www.pnas.org/content/early/2009/04/27/0901412106.abstract

Biofortified banana
http://www.banana.go.ug/biofortification.php

Biofortified sorghum
http://biosorghum.org/

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8

FUTURE GM CROPS FOR AFRICA

Seedlessness

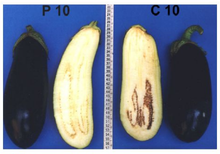

Figure 2
Eggplant fruits from the open field summer trial. Left, uncut and cut fruit of the transgenic hybrid P10; Right, cut and uncut fruit of the C10 control hybrid.

Acciarri et al, 2002. BMC Biotechnology 2002, 2:4

Figure 2
Cut tomato fruits of the four genotypes used: UC 82, Allflesh and GM UC 82 lines Ri4 and Ri5. GM fruits (Ri4 and Ri5) are seedless. UC 82 and Allflesh fruits contain seeds.

Rotino et al, 2005. BMC Biotechnology 2005, 5:32

Induced by the tissue specific (ovules and placenta) expression of the auxin IAA. Promoter from *Antirrhinum* and gene from *Pseudomonas*.

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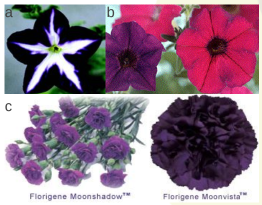
9

FUTURE GM CROPS FOR AFRICA

New ornamentals



The influence of gene expression (a) & pH (b) on flower colour . (c) Commercial application.
http://www.bio.vu.nl & http://www.florigene.com/

Blue rose
http://www.suntory.com/news/2004/8826.html

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10

STATUS OF GM ANIMALS

Animals as the product

- Glofish. First GM animal approved for commercialisation.
  http://www.glofish.com
- Salmon with growth hormone. Has been in regulatory process for more than 12 years.
  http://www.aquabounty.com

Products made by GM animals

Timeline

1987	Transgenic mice produce a human enzyme, tissue plasminogen activator (tPA). tPA is used to treat blood clots
1988	GM sheep 'Tracy' was produced by the Roslin Institute, Scotland, with human alpha-1-antitrypsin protein expressed in her milk
1990	Gene Pharming in the Netherlands produce first GM bull, 'Herman', with a modified version of the human lactoferrin (hLF) gene
1994	Expression of human lactoferrin in the milk of GM mice
1997	A GM sheep was produced to express a pharmaceutical protein for human blood clotting factor IX in her milk[3] A GM tobacco variety producing haemoglobin was produced
2003	Transgenic cattle produce altered milk proteins with important nutritional and processing properties
2006	GTC Biotherapeutics market a human protein isolated from the milk of GM goats in Europe. This is the first protein made in a GM animal to receive regulatory approval for human therapy anywhere in the world

Source: Biotechnology Australia

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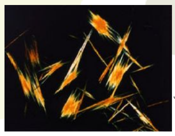
11

STATUS OF GM MICROORGANISMS

- Pharmaceutical products, vaccines, additives, amino acids, vitamins, flavours, enzymes and many other substances are produced with the help of GM microorganisms.
- Examples include: insulin, HBV vaccine, ascorbic acid, glutamate, aspartame, citric acid, chymosin and vitamin B2.
  www.gmo-compass.org
- GM algae for biofuel production.
  http://algaeinstitute.net/



Vitamin B2 crystals

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12

TECHNOLOGY DEVELOPMENTS

Transformation systems

– Directed/specific trans DNA integration in target genome.
DOI: 10.1007/s00438-004-0994-8 and 10.1371/journal.pone.0003084

– No trans DNA modifications (e.g. using transposases, recombinases, integrases and DNA repair enzymes and Zn-finger nucleases).
DOI: 10.1016/j.tibtech.2005.06.005 and 10.1038/nature07845

– Nano targeting (use of nanotechnology to target genes/vectors to specific cells).
http://news.bbc.co.uk/2/hi/health/7935592.stm

Genetic resources

– The $1,000 genome (human) by the end of 2009!
DOI: 10.1126/science.311.5767.1544

– Metagenomics allows the characterisation of uncultured organisms.
http://dels.nas.edu/metagenomics/overview.shtml

– Regulatory sequences (synthetic) for fine regulation of transgene expression.
doi:10.1016/j.tplants.2007.01.002

13

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14

GM SUSTAINABILITY INCLUDES…

Environmental safety

Food safety

Socio-economic sustainability

15

RATIONALE FOR ESTABLISHING A BIOSAFETY SERVICE PLATFORM

- **Benefits** of modern biotech should be balanced with potential health, environmental and socio-economic **impacts**.
- SA GMO regulatory framework is good but requires **practical and technical support** to help ensure it fulfils its mandate.
- SA developers of direct genetic enhancement technologies need support to get products through the **complex and costly regulatory system**.
- Regulatory guidelines should be developed for **new technologies** with similar biosafety issues.

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16

BSA VISION

To support innovation in biotechnology by ensuring the development of safe, sustainable biotechnological products.

BSA GOALS

- Ensure access to regulatory and biosafety **information, data and services**.
- Stimulate and facilitate **strategic biosafety research** and risk assessment studies.
- **Increase SA's capacity** for (GMO) risk assessment through skills development and funding.
- **Forging partnerships** with individuals, organisations and countries where these collaborative efforts will lead to safer products and more efficient systems.
- **Stimulate sustainable growth** in the local biotechnology industry by ensuring regulatory compliance of biotechnological (GM) products.

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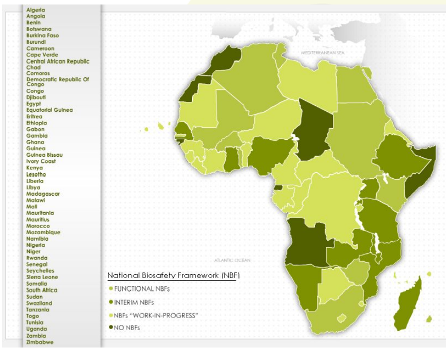
17

Status of biosafety regulatory frameworks



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18

HARMONISATION

Table 2. Overview of regional harmonisation options.

Type	Advantages	Possible issues
TIGHT HARMONISATION		
Pre-emptive disapproval (GMO free zone)	Reduced costs – no testing infrastructure	Sacrifice potential farm gains, reduced access to food imports and aid, enforcement difficult, establishment of new institutions at regional level
Centralised Approvals	Reduced costs, immediate access to regional markets	Loss of sovereignty, biosafety requires localised environmental scrutiny
Mutual policy recognition	Access to regional markets	Political minefield result in policy paralysis, establishment of new institutions at regional level
LOOSE HARMONISATION		
Type	**Advantages**	**Possible issues**
Acceptance at CPB minimum standards	Flexible, minimise trade disruptions, reduced export/import risks	Uncertainty and lack of effective coordination

Adapted from Paarlberg, 2006.

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19

EVOLVING REGULATORY ENVIRONMENT

Biosafety regulations

- Regular review and adapt / deregulate if necessary.
- Balanced interpretations based on benefits and risks.
- Conflicts, inconsistent rulings and overlaps between regulations addressed.
- World's best systems and practice identified and used as benchmark.
- Regional (international) harmonisation.

Regulators

- Robust scientific understanding and communication of risk.
- Stimulate biosafety research and innovation.
- Strengthen appropriate, credible, transparent and co-operative regulatory structures.
- Achieve mutually reinforcing relationship between safety, environmental protection, trade policy and economic development.

20

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ROLE PLAYERS

Table 4. GM crop projects in Africa undertaken by research consortia.

GM Crop	Research Consortium
Striga Resistant Maize	International Institute for Tropical Agriculture (IITA); African Agriculture Technology Foundation (AATF)
Water efficient maize	African Agricultural Technology Foundation (AATF); Monsanto (USA); National Research and Development Organisations
Insect resistant cowpea	African Agricultural Technology Foundation (AATF-Nigeria), National Agricultural Research Institutes (NARI-Nigeria, Burkina Faso, Ghana), Commonwealth Scientific and Industrial Research Organization (CSIRO-Australia), Network for Genetic Improvement of Cowpea in Africa, Rockefeller Foundation, PBS (USA), Monsanto (USA)
Maize resistant to MSV	University of Cape Town, Pannar Seed Company
Biofortified Sorghum	International Crops Research Institute for the Semi Arid Tropics (ICRISAT), the University of Pretoria, the Kenya Agricultural Research Institute (KARI), the Agricultural Research Council for South Africa (ARC), the Burkina Faso Environmental and Agricultural Research Institute (INERA) and the Institute of Agricultural Research (IAR) in Nigeria
Insect resistant potatoes	Agricultural Research Council (South Africa), Michigan State University (US)
Biofortified banana	Africa Harvest, National Biotechnology Development Agency (Nigeria), Queensland University Technology (QUT), Donald Danforth Centre (USA)
Biofortified cassava	HarvestPlus, Consultative Group on International Agriculture Research (CGIAR)

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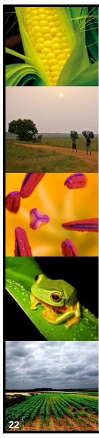
21



DEFINING SUSTAINABILITY

- Why focus on sustainable GM technology?
  (post-release endurance, safety, diversity and productivity of GM crop and its receiving environment but ALSO of strategic importance to allow unlocking of biotech's potential)
  …technology ≠ product
- Sustainable technology = safe + relevant + accessible
- Safe
  Food & feed safety and environmental safety
- Relevant
  Traits / technology (impart real benefit to targeted community)
  Crops (often "orphans")
  Technology fit (real need & most appropriate delivery mechanism)
- Accessible
  IP (freedom to operate: humanitarian or to generate income)
  Acceptable (sensorial, varieties, GM & affordability)
  Realistic deployment (logistics & costs)

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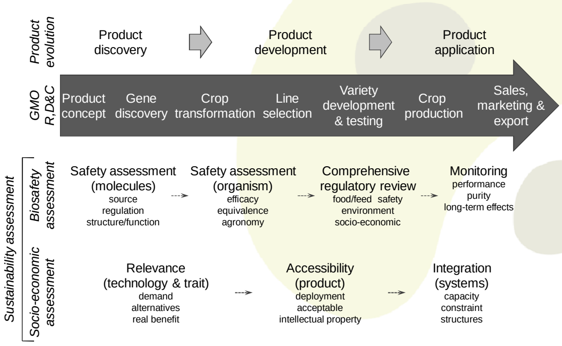
22

INTEGRATED SUSTAINABILITY ASSESSMENT



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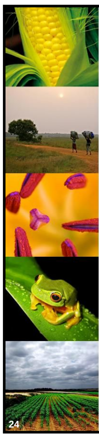
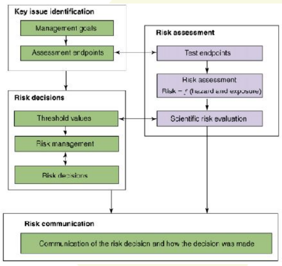
23



RISK ANALYSIS TO ASSIST DECISION MAKING



Stages of risk analysis:
Key issue identification, **risk assessment**, **risk decision-making** and **risk communication**. Progression through the system is not linear, but iterative. Feedback loops, although not included in this diagram, are an integral part of risk evaluation.
Green boxes - driven by society; **Purple boxes** - driven by science

Johnson et al. 2007. Trends in Plant Science 12(1): 1-5.

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24

TAKE HOME MESSAGES

1. Sustainable, safe **GM technologies hold great potential** for African agriculture and the end consumer and should be harnessed to benefit all Africans.
2. More emphasis should be placed on the **local development of locally relevant GM products** as identified by local farmers and consumers.
3. **Political will** and support is vital to ensure the timely and sustained development and implementation of a **national GM strategy**.
4. Governments should be urged and supported to establish **effective biosafety regulatory frameworks** and adapt them as the sector matures.
5. The availability of **local biosafety and sustainability expertise, infrastructure and baseline data** is crucial for the safe and effective utilisation of GM technologies.
6. **Integrated risk analysis** plays a critical role in the successful commercialisation of GM crops and help ensure the safety, relevance and accessibility of the technology.

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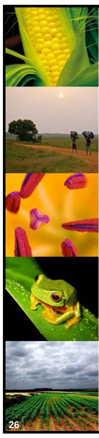
25



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THANK YOU

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26