IKE E: /XARRA //KE

Government Gazette
Staatskoerant

REPUBLIC OF SOUTH AFRICA
REPUBLIEK VAN SUID-AFRIKA

Vol. 482 Pretoria, 26 August / Augustus 2005 **No. 27936**

27936
9771682584003

AIDS HELPLINE: 0800-0123-22 Prevention is the cure

CONTENTS • INHOUD

GENERAL NOTICE

NOTICE 1591 OF 2005

NATIONAL DEPARTMENT OF AGRICULTURE

DRAFT DISCUSSION DOCUMENT ON AGRICULTURAL BIOTECHNOLOGY

August 2004

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Agricultural Foresight Study identified biotechnology as one of the major tools that could be used to attain more rapid and efficient means to diversify and improve food production in South Africa. Despite South Africa's history of traditional biotechnology, it has failed to extract value from the more recent advances in biotechnology. To address this situation, government recommended that a National Biotechnology Strategy be developed. To establish a successful biotechnology sector, the National Biotechnology Strategy recommended specific interventions in terms of institutional arrangements, human resource considerations, funding for biotechnology research and development, commercialisation of biotechnology, policy and legal instruments, as well as ethics and public understanding of biotechnology.

South Africa faces many challenges ranging from increased demand for agricultural products due to increasing population numbers, increased damage to the environment due to unfavourable climatic conditions, and the general lack of understanding of recent advances in biotechnology. The Department of Agriculture and its partners initiated a sector plan (2001) with the aim of addressing poverty alleviation, economic growth and natural resources management in a sustainable manner. Central to this sector plan is recognition of the contribution that biotechnology can make to achievement of a globally competitive, profitable and sustainable agricultural sector. This document sets out the strategic direction in which biotechnological solutions would be applied to support a sustainable agriculture. This strategy aims to complement the broader strategic objectives of the National Biotechnology Strategy and provide a framework for supporting developments in those areas consistent with the National Research and Development Strategy, with particular focus on the agricultural sector. It provides an integrated approach to addressing the opportunities and challenges that we face in a dynamic, knowledge intensive technology.

A National Biotechnology Survey that examined the status of biotechnology in South Africa revealed that the major focus of core biotechnology companies and research groups is plant, rather than animal biotechnology. Traditionally, biotechnology research has been very active in areas such as tissue culture, plant protection, plant breeding and transgenic plants. Animal biotechnology research includes animal nutrition, developments in diagnostics, vaccines and therapeutics on diseases affecting livestock and poultry. Through the National Biotechnology Strategy, three Biotechnology Regional Innovation Centres (BRICs) were created. The level of Agriculture's participation in these BRICs will be improved as a result of this strategy, and one way of achieving this would be to provide centralised facilities and equipment to pursue biotechnology more vigorously. Capital would be made available to improve on biotechnology equipment such as gene sequencers, micro-array equipment and LC-mass-spectrometry equipment.

The Agricultural Biotechnology Strategy identified several key issues that need to be addressed in order to fully extract the value of modern biotechnology to agriculture. These include institutional arrangements, human resources management and development, intellectual property rights, environmental, bio-safety and regulatory considerations, bioethics in agricultural biotechnology, as well as trade issues in agricultural biotechnology. Additionally, several key actions are proposed for these identified issues. A major focus of the Agricultural Biotechnology Strategy will be the promotion of sustainable agriculture through eco-agriculture and improvement of the national regulatory system to ensure quality assurance and the traceability of agricultural products.

To align activities on research, development, technology transfer and commercialisation, four focus areas were proposed; these include improving crop production, the nutritional value of food, animal health and production, as well as support for suitable industrial development. Increased investment in infrastructure and technology transfer management at research institutions also needs careful consideration.

The National Research and Development Strategy and the National Biotechnology Strategy identified biotechnology as one of the scientific fields in which there was a shortage of highly skilled personnel. Similarly, agricultural biotechnology also lacks skilled human resources, and the following interventions are accordingly suggested: establishment of career opportunities, fast-tracking the human resources needs of regional innovation centres, improving the current post-doctoral fellowship system and promoting curriculum development.

The development of new technologies and their use in agriculture continues to present new challenges with regard to intellectual property rights. Due to the large financial investment of government in agricultural research, research institutes are accountable for managing the intellectual property which they generate. Ownership of intellectual property by public research institutes should promote national growth interests and development. This can be achieved through the promotion of further innovation by the research entity in the public interest. It is also imperative that a national policy on intellectual property rights, which is in line with other national and international obligations, be developed. Legislative tools already in place to protect intellectual property rights include the Plant Breeder's Rights Act and the Patents Act.

The reliance of agriculture on chemical control measures has adversely impacted on human health (pesticide residues, etc.) and on the environment (reduction of biodiversity as it impacts on non-target species). Agricultural biotechnology could contribute to sustainable agricultural practices by reducing the amount of chemicals applied, developing and implementing mitigating tools, and improvement of pest management strategies.

Concerns on bio-safety with regard to agricultural biotechnology have tended to focus on the use of genetically modified organisms. These concerns are not limited to agriculture, but also include concerns to human and animal health, as well as the environment. Therefore, an appropriate policy and regulatory framework should form an integral part of the objectives of agricultural biotechnology and national development. The relevant legislation already in place in South Africa includes the Genetically Modified Organisms Act (1997), the National Environment Management Act (1998), the Biodiversity Act (2004) and the Regulations under the Foodstuffs, Cosmetics and Disinfectant Act (1972). Additionally, a wide range of ethical concerns are also related to agricultural biotechnology. Similar to the National Biotechnology Strategy, this document supports the proposal of a Bioethics Council, which will play a key role in enhancing our understanding of the cultural and ethical aspects of biotechnology. Increasing public understanding of biotechnology is also an important consideration for increasing public acceptance of biotechnology products and addressing related concerns. The focus of this Strategy will be on job creation, and the establishment of incubation centres needed for the generation of new technologies for the broader spectrum of agricultural enterprises and the stimulation of economic growth.

Due to the global nature of science, innovation in agricultural biotechnology could be expedited through international collaboration by forming strategic partnerships with equivalent institutions through bi- and multilateral agreements. Establishing regional centres of excellence could also ensure progress in agricultural biotechnology.

The Department of Agriculture will be responsible for a national rollout of the strategy and communicating its purpose to relevant stakeholders. Key initiatives for the implementation of this strategy will include strategic alignment, an audit of agricultural biotechnology in South Africa, and the road-mapping of agricultural biotechnology. The different funding options proposed include: inter-governmental collaboration, participation in existing programmes, additional government support, international collaboration and incentive schemes to support innovation in agricultural biotechnology.

FOREWORD

The challenges facing the agricultural sector in South Africa, often leading to under-performance and low production, are well known: frequent and periodic droughts, and livestock and crop susceptibility to diseases, all of which require new approaches in the form of better animal breeds and plant varieties capable of high yields under extreme conditions. Biotechnology is known to have the potential to address food shortages through the development of crops with increased resistance to diseases and drought, increased tolerance to herbicides, increased nutritional benefits and improved processing qualities.

The approval of the National Biotechnology Strategy by Cabinet in 2001 provided a framework for the different sectors to respond to the role of biotechnology in their respective sectors, and the Department of Agriculture has taken a lead in responding to the challenges. The development of an Agricultural Biotechnology Strategy heralds a new approach towards tackling the perennial problem of under-performance and production in the agricultural sector, and will unlock new resources needed to address the production and processing challenges in the sector. The strategy is a clear indication of commitment by the Government to eradicate poverty, improve food security and contribute towards the conservation of our natural resources.

This biotechnology strategy provides a basis for the agricultural sector to:

- Participate fully within the Biotechnology Regional Innovation Centres (BRICs) identified by the National Biotechnology Strategy
- Add value across a wide range of agro-processing industries
- Improve our bio-safety measures
- Protect our environment and unique biodiversity

The Government has a key investment role in ensuring science and research capability for the implementation of the Agricultural Biotechnology Strategy. Therefore, our growth in the application of biotechnology in agriculture will depend on developing and retaining sophisticated knowledge, skills and research capabilities; and investing in infrastructure to build on our strengths in order to achieve the commercialisation of diverse biotechnology products. To this end, strong linkages between research and industry here and abroad to promote the uptake of biotechnology, would be the key.

The Department of Agriculture will be responsible for rolling out the strategy and communicating its purpose to relevant stakeholders. Key initiatives for the implementation of this strategy will include strategic alignment, an audit of agricultural biotechnology in South Africa, and the road-mapping of agricultural biotechnology. The sector should realise benefits through accelerated delivery of government services as captured in the CASP, IFSNP and LRAD.

Minister for Agriculture and Land Affairs
Ms Thoko Didiza

LIST OF ABBREVIATIONS

ARC	Agricultural Research Council
AIDS	Acquired Immune Deficiency Syndrome
BC	Before Christ
Bt	Bacillus thuringiensis
BRIC	Biotechnology Regional Innovation Centre
CBD	Convention on Biological Diversity
CIGB	International Centre for Genetic Engineering and Biotechnology
CPB	Cartagena Protocol on Biosafety
CSIR	Council for Scientific and Industrial Research
DNA	Deoxyribonucleic acid
EU	European Union
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GM	Genetically Modified
GMO	Genetically Modified Organism
GMF	Genetically Modified Food
HIV	Human Immunodeficiency Virus
IPR	Intellectual Property Rights
LEISA	Low External Input and Sustainable Agriculture
NEPAD	New Partnership for African Development
NSI	National System of Innovation
OPV	Open Pollinated Varieties
TRIPS	Trade-related Aspects of Intellectual Property Rights
UPOV	International Union for the Protection of Varieties
WIPO	World Intellectual Property Organisation

1 INTRODUCTION

1.1 BACKGROUND TO THE AGRICULTURAL BIOTECHNOLOGY STRATEGY

In 1996 Cabinet approved the White Paper on Science and Technology that established a policy framework for science and technology in South Africa, based on the concept of a National System of Innovation (NSI). Briefly, the NSI can be described as a set of functioning institutions, organisations and policies that interact constructively in the pursuit of a common set of social and economic goals. Agricultural research and innovation is part and parcel of the NSI.

This strategy document builds on the work of the Agriculture Foresight Study that formed part of the National Research and Technology Foresight Initiative (NRTF). The goal of the Foresight Initiative was to help identify those sector specific technologies and technology trends that will best improve the quality of life of all South Africans over the next 10-20 years.

The Agricultural Foresight Study highlighted important factors that will contribute towards a competitive agricultural industry. Biotechnology emerged as one of the major tools that could be used for more rapid and efficient means to diversify and improve food production.

Subsequent to the foresight project, the Government recommended that a National Biotechnology Strategy be developed. According to the National Biotechnology Strategy, the South African agricultural situation can be summarised as follows:

> "*South Africa has a solid history of engagement with traditional biotechnology. It has produced one of the largest brewing companies in the world, makes wines that compare with the best, has developed many new animal breeds and plant varieties, some of which are used commercially all over the world, and has competitive industries in the manufacturing of dairy products such as cheese, yoghurt, maas, baker's yeast and other fermentation products*".

However, in spite of the achievements of traditional biotechnology, South Africa has failed to extract value from the more recent advances of technology, such as genomics, bioinformatics and proteomics.

The National Biotechnology Strategy contains a number of issues that are relevant to the agricultural sector. The key issues and challenges that face biotechnology in South Africa are the following:

- Institutional arrangements
- Human resource considerations
- Funding of biotechnology Research and Development (R&D)
- Commercialising biotechnology
- Policy and legal instruments
- Ethics
- Public's understanding of biotechnology

South Africa is still a developing country with its own set of problems that beg for technological solutions to increase agricultural output and improve quality. The majority of South Africans have not benefited from recent advances in biotechnology, as a number of constraints still persist. This could be attributed to the political history of the country, in which large sectors of the population could not access services and technologies in order to respond to agricultural challenges. The Department of Agriculture developed the current document to respond to these challenges.

This document sets out the strategic direction for agricultural biotechnology in South Africa. It is the result of a number of processes and initiatives that are summarised in Figure 1. It aims at providing a framework for supporting developments in those areas consistent with the National Biotechnology Strategy, as well as the National Research and Development Strategy. Furthermore, this document is designed to complement the broader strategic objectives of the National Biotechnology Strategy focusing on the agricultural sector. It provides an integrated approach to addressing the opportunities and challenges that South African agriculture faces in a dynamic, knowledge intensive technology. This document is also, at this stage, designed to promote strategic dialogue and achieve alignment among the different stakeholders.

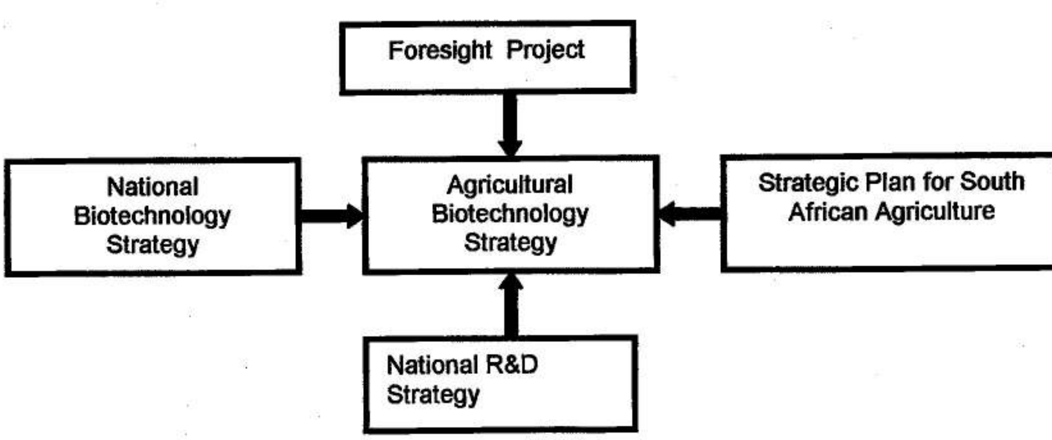


Figure 1. Summary of Initiatives and Processes that served as inputs to the development of the Agricultural Biotechnology Strategy

Creating value from biotechnology is a challenge. We therefore, need to manage the risks and uncertainties. Technology development and commercialisation in this field requires considerable resources, and the failure rate is high when compared to other technology areas. However, as the case studies that are included in this document reveal (Appendix A), success lies in putting in place processes and initiatives that will support the implementation of this document.

1.2 KEY CHALLENGES TO AGRICULTURE

We are at the dawn of a new revolution in which emphasis is put on how best we can grow food and many other products. The green revolution of the 20th century had a major impact on how we used animal and plant genetic resources for food and agriculture. It was an era in which several changes, including the development of tractors, processing equipment and milking machines, to name but a few, took place. The latter part of the century saw the introduction of improved animal and plant breeding techniques that relied on genetic resources at our disposal. These developments have included the identification and isolation of genes that are responsible for specific traits. Consequently, it became possible to select for specific traits through crossbreeding and improved production per unit area. Recent technological advances have allowed us to splice and insert genes across species to create genetically modified organisms (GMOs) that can be used to produce genetically modified foods (GMFs).

The agricultural sector in South Africa faces considerable challenges and constraints. The country has less than 15 % arable land, with an increasing population placing high demands for more food, particularly proteins. The majority of the rural black population are subsistence farmers at a relatively small scale (i.e. one-hectare plots per family). The majority of these small-scale farmers remain poor and obtain their livelihoods from marginal lands, often with dire consequences for crop failure, forcing increasing numbers of them to migrate to urban areas. There is evidence of increasing damage to the ecological foundations of agriculture, such as land, water, forests, bio-diversity and the atmosphere. This has resulted in unprecedented poverty among a large section of the rural population.

In summary, the challenges with which South African agriculture is faced can be spelled out as follows:

a) Firstly, a large section of our rural, small-scale indigenous farming population has been by-passed by the technological advances of the green revolution.

b) Secondly, South Africa continues to face an increasing population, which leads to greater demand for food, and reduced per capita availability of arable land and irrigation water.
c) Thirdly, South African urban areas are growing rapidly, which leads to higher per capita food requirements, particularly grain, and there is increased consumption of animal products.
d) Fourthly, there is no net change in marine fish production; in fact, it appears to be declining.
e) Fifthly, there is increasing damage to the ecological foundations of agriculture, such as land, water, forests, biodiversity and the atmosphere, with possible distinct adverse changes in the climate and sea level.
f) Lastly, the environmental, social, economic and agricultural implications of the recent biotechnology advances are not yet fully understood.

As South Africa continues to face these challenges, agriculture needs to find solutions. To date, Cabinet has identified several priority areas aimed at economic growth and poverty alleviation. Among these priority areas is agriculture's potential to alleviate poverty, food insecurity and health through better nutrition as well as economic growth.

The Department of Agriculture and its partners have produced a sector strategy that aims at addressing poverty alleviation, economic growth and the management of natural resources by farmers in a sustainable manner. Obviously, the strategy will impact on land redistribution, land use in urban environments, zoning in high-potential agricultural land, the preservation of sensitive land areas, biological diversity, water systems etc.

Central to the agriculture sector strategy is the ability "to preserve agricultural biodiversity and to promote the sustainable use of soil and water through the enhancement of crop and livestock productivity in intensified and more sustainable farming systems".

Soil, water and conservation programmes are to be focused on areas where there is a reasonable chance of success, the population pressure is high, opportunity costs for labour are low, land availability is high, productive technologies are available, and where there is access to markets, inputs and services. The selection and use of appropriate technologies becomes, in this regard, critical. Consequently, several programmes that are under consideration to improve sustainability are:

- The development of a biotechnology strategy to serve the best long-term interests of South Africa
- The development of plant breeding strategies that maintain and enhance genetic diversity

- In situ conservation of endangered agricultural species and varieties in economically viable farming systems
- Investment in infrastructure and services to support sustainable land use
- Encouragement of horticultural production for income reasons
- Placing production and sustainability within a farming system perspective. This supports environmentally sound production systems, including integrated production, integrated crop management and organic farming.

The sector strategy has identified biotechnology as central to achieving the objectives of a "globally competitive, profitable and sustainable agricultural sector contributing to a better life for all". It becomes imperative, therefore, to define what biotechnology is.

1.3 WHAT IS BIOTECHNOLGY?

Biotechnology can be defined as follows:

Biotechnology is a set of technologies including, but not confined to, tissue culture and recombinant DNA techniques, bioinformatics and genomics, proteomics and structural biology, and all other techniques employed for the genetic modification of living organisms, used to exploit and modify living organisms so as to produce new intellectual property, tools, goods, products and services.

In simple language, biotechnology is a body of techniques that use biological systems, living organisms, or derivatives thereof to make or modify products or processes for a specific use (e.g. agriculture).

1.4 EVOLUTION OF AGRICULTURAL BIOTECHNOLOGY

In view of the challenges outlined in this section, it is important to examine agricultural biotechnology as a continuum throughout history. First and foremost, biotechnology is not new. For example, ancient Egyptians and Greeks produced seedless grapes about 3000 BC; and around that time, others developed systems of making beer, wine and cheese through fermentation. These developments of biotechnology can be classified as traditional because they involve the use of selected biological organisms to produce food and drink; and are focused upon fermentation techniques.

During the 1920s and 1960s another set of biotechnologies was invented. These were technologies associated with the discovery of units of inheritance (genes), by a Catholic monk, Mendel. It is a cluster of techniques that comprise plant and animal breeding (crop and animal husbandry), tissue culture, mutagenesis and plant regeneration. This set of biotechnologies has been considered conventional.

Plant breeding involves the mixing (hybridisation) of traits between parents in order to select varieties that exhibit traits of interest such as disease resistance. This hybridisation is not specific and often would include traits unwanted by the breeder. Conventional biotechnology has been used in mutagenesis for the selection of strains to improve metabolites such as antibiotics and cultivars for better crop yields. Many of the commercialised crop species have been improved by utilising traditional plant breeding techniques.

The latest technological developments have yielded "modern biotechnology" (or third generation) that is associated with recombinant DNA technology. It involves the "application of *in vitro* nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles". Agricultural applications have included molecular breeding (marker assisted selection) and diagnostics, among others.

Marker assisted selection is based upon naturally occurring genetic variation within and between species. Although marker assisted selection is not a typical modern biotechnology, it involves the use of DNA markers to facilitate the selection of genes of interest. Unlike traditional plant breeding, marker assisted selection facilitates the identification and evaluation of plants and animals carrying useful traits in breeding populations. DNA markers have been utilised in disease diagnostics such as viruses affecting crops, DNA fingerprinting of beneficial microbes, and characterisation of landraces of cassava. As with any technology, marker assisted selection has limitations:

- Level of precision is limited
- Not very useful for clonally propagated crops because they do not breed true
- Cannot be utilised for crops with a long generation time such as citrus

Modern biotechnology typically involves the use of recombinant DNA and genetic engineering techniques to produce a genetically modified organism, which in turn could be utilised for the production of proteins such as insulin, vaccines for viral and bacterial diseases and diagnostics.

A genetically modified organism refers to a living thing (cell or tissue or organism) whereby genetic material has been transferred from another organism, often through various techniques such as genetic engineering, breeding and marker assisted selection. For example, the *Cry* gene from the bacterial species, *Bacillus thuringiensis* (Bt) has been inserted into the DNA of cotton seed. Consequently, such cotton plants obtained resistance to the devastating pest, the bollworm. Due to the built-in resistance of the Bt-cotton, the farmer achieves increased yields with less pesticide spraying. In general, all biotechnology practitioners use third generation techniques, regardless of whether their core processes are traditional, conventional or modern.

1.5 APPLICATIONS OF BIOTECHNOLOGY IN THE AGRICULTURAL SECTOR

As stated above, biotechnology is not new. It has in fact, been utilised for many centuries in the agricultural and manufacturing industries to produce food, chemicals, beverages and many other products that have been of benefit in many areas, including nutrition and health care. Although South Africa has engaged in biotechnology with some success, it remains behind with regard to modern biotechnology, particularly in areas such as genomics and proteomics.

Although developments in modern biotechnology are still in their infancy, there are many opportunities and potential markets. The biotechnology industry is a capital intensive, intellectual property based and knowledge driven one. Due to its rigorous regulatory requirements, this industry has long-term product development periods compared to other high-tech industries. The generic biotechnology value chain from basic research to products and services is illustrated in Figure 2.

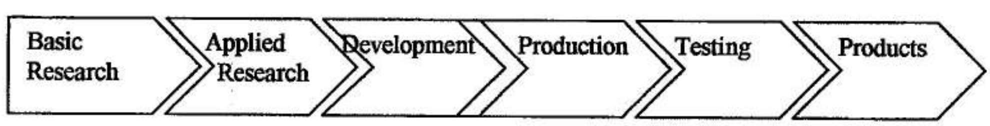


Figure 2. A generic value chain for the biotechnology industry

A significant proportion of biotechnology applications are agricultural; whether they are primary, secondary or tertiary. To date, applications of biotechnology have largely focused on agricultural research and disease diagnostics; however, industrial applications of biotechnology, such as the production of starch from maize, animal and plant vaccines, yeast and yoghurt, to name but a few, exist. Table 1 below provides examples of biotechnology uses in agriculture in South Africa:

Table 1: Examples of Biotechnology Applications in Agriculture in South Africa

PLANT TISSUE CULTURE		
Technique	Plant/Crop/Animal	Application
Embryo rescue	• Table grapes • Dry beans	Seedless table grapes Inter-specific crosses

	• Sunflower • Wheat	Shorten breeding cycle Shorten breeding cycle
In vitro conservation	• Potato • Sweet potato • Cassava • Lachenalia	Conservation at the national gene bank National cultivar collection
Regeneration	• Potato, melon, tomato, tobacco • Apple, pear, apricot, table grapes, strawberry • Groundnut	Gene transfer
In vitro mass propagation	• Banana, guava, eucalyptus • Apple, pear, apricot, seedless table grapes, strawberry	Clonal plant material Virus-free plants, clonal plant material
Meristem culture	• Citrus • Potato, sweet potato • Dry beans	Virus- free plants Disease free plants (certification schemes) Disease free plant material
In vitro selection/somaclonal variation	• Guava • Tomato, cassava	Guava resistant to GWD Nematode resistance
MOLECULAR MARKER		
Technique	Plant/Crop/Animal	Application
DNA fingerprinting	• Potato, sweet potato • Protea populations • Banana, citrus, mango, guava, avocado, litchi • Groundnut, soybean	Cultivar identification Genetic variation Plant or cultivar identification Identification of fungal isolates Cultivar identification
Molecular markers	• Maize, onion • Sunflower • Soybean • Wheat • Groundnut • Farm animals (cattle, sheep, goats etc)	Marker assisted selection Genetic distance and selection Marker assisted selection Marker assisted selection and nematode resistance Marker assisted selection and disease resistance Identification of disease resistance genes
DIAGNOSTICS		
ELISA kits	• Grapevine, legumes, hops • Cucumber, • Tomato	Detection of viruses Detection of cucumber mosaic virus Detection of tomato spotted wilt virus
Diagnosis/Identification	• Agriculture products • Banana	Taxonomy of plant pathogens Taxonomy of viruses Analysis of international in vitro banana germplasm for virus status

	• Cattle	Detection of diseases (e.g. Foot-and-mouth disease)
PCR	• Table grapes • Pome fruit, grapevine • Farm animals	Detection of bacterial disease Detection of viruses Detection of diseases Identification of genes for breeding
	TRANSGENIC APPLICATIONS	
Transformation/gene transfer	• Potato • Tomato • Maize • Tobacco • Groundnut	Virus resistance genes (PLRV, PVY, TSWV) Fungal, virus resistance, delayed ripening Fungal resistance (PGIP) Herbicide resistance (Basta) Marker gene
Transgenic field trials	• Maize • Maize • Cotton • Soybean • Potato	Insect resistance Herbicide resistance Insect and Herbicide resistance Herbicide resistance Insect resistance
	ANIMAL VACCINES,	
Fermentation Recombinant DNA technology	• Cattle • Goat • Sheep • Horse	Botulism Blue Tongue Pulpy kidney African Horse sickness
	PROBIOTICS	
Fermentation	• Domestic animals	Lactobaciilus acidophilus Bifidobacterium longum

While this list is not exhaustive, it shows the broad application and the importance of biotechnology in all aspects of agriculture.

1.6 OVERVIEW OF RESEARCH IN AGRICULTURAL BIOTECHNOLOGY IN SOUTH AFRICA

From the previous sections, it is clear that agriculture plays a significant role in the South African economy. The agricultural sector does, however, face ongoing challenges that include desertification, soil erosion, soaring input costs, increased crime on farms, population growth, and, most importantly, the scarcity of water resources. Biotechnology will play an important role in addressing some of these challenges. In this section, the research and technology development activities in animal and plant biotechnology are summarised.

In 2003, a National Biotechnology Survey that examined the status of biotechnology in South Africa was conducted. The audit revealed that approximately 10% of core biotechnology companies and 11% of research groups fit into the animal health sector, and that the sector ranks 4th out of the 8 sectors among biotechnology research projects. Animal nutrition is increasingly becoming a popular research area, specifically in the areas of probiotics and feed supplements. Most of the research activities involving development in diagnostics, vaccines and therapeutics are conducted on diseases affecting livestock and poultry. A relatively small fraction of groups are researching diseases of domestic animals. Compared to plant biotechnology, relatively few researchers are active in animal health, and most of them are associated with the Onderstepoort Veterinary Institute or the University of Pretoria, BioPAD. The government-funded Biotechnology Research Innovation Centre (BRIC) is the only programme to be awarded funding for the animal health sector. Whilst animal health in SA is small, significant advances have been made. The Onderstepoort Veterinary Institute (OVI) is a reputable institution that has played a prominent role in veterinary health in SA since its establishment in the early 1900s. Although its research capacity has declined, it still enjoys a reputation as the top veterinary institute in Africa. OVI has produced a number of animal vaccines such as anthrax, botulism and blue tongue virus. In addition, the centre has developed a number of diagnostic tests that are in the market place. Innovations from this institute are manufactured and marketed by Onderstepoort Biological Products (OBP), which supplies veterinary vaccines to countries across the continent and overseas. OBP is a State-owned company, established in 1998.

The second critical area of research is plant biotechnology. Traditionally, this area has been very active in areas such as tissue culture and transgenic plants. Plant biotechnology can play an important role in rural development, poverty alleviation, food security, and the conservation of plant diversity. The development of new agricultural and soil science methods has led to the overproduction of agricultural produce and has resulted in SA being a net exporter of agricultural products, in spite of the constraints. The Department established the Agricultural Research Council in 1993; its aim was to promote agriculture and related sectors through research, development and transfer of technology. To date, this research facility has played an important role in new developments in the industry. Existing products in the plant biotechnology sector in SA include biological control products, plant growth stimulants and GM crops/seed[9]. Conditional general release approval has been given to insect resistant cotton and maize, and herbicide resistant soya and cotton. The selection of GM crops is expected to increase in the future to include wheat, barley, sunflower seed, fruit, sugar, potatoes and wood. It must be noted that the strong resistance to GM foods in the EU will impact negatively on exports, particularly if a full moratorium on GM foods is implemented. Countries that have embraced genetic modification of plants need to take such trade barriers into consideration because of the associated commercial risks.

2 KEY ISSUES FOR CONSIDERATION

The new South Africa is committed to economic development and improvement of the quality of life for all its citizens. Agriculture has been identified as one of the critical pillars for us to obtain our national goals. In order for agriculture to fulfil its role, certain strategic interventions will have to be made, particularly within the field of biotechnology. Similarly, the National Research and Development Strategy was developed for the purpose of addressing weaknesses in research and development. It is therefore important to identify key issues that need to be addressed in the agriculture biotechnology programme.

2.1 STRATEGIC CONSIDERATIONS

a) Although biotechnology has been utilised in many areas of agriculture, it has lacked national strategic direction.
b) The research programmes of the different institutions lacked focus in both the private and public sectors.
c) Agricultural biotechnology activities have not been aligned with national imperatives, particularly those focused within the sector strategy.
d) In some instances, duplication of projects in agricultural biotechnology has been identified as a weakness.

2.2 INSTITUTIONAL ARRANGEMENTS

The Foresight Project was preceded by a National Technology Audit which revealed that:

- SA's research and development system has a well developed, but ageing science, engineering and technology infrastructure.
- Activities within the system are in some cases inappropriate and absorb valuable resources.
- There is lack of attention to and investment in public goods, leading to deteriorating infrastructure.
- Opportunities for exploiting the technological base have been missed.
- A significant part of the science system (including agriculture), has been closed, with little Research and Development.
- In the absence of an injection of substantial resources (equipment, human resources, infrastructure) the level of innovation and support for economic growth is in danger of becoming sub-optimal, with implications for the management of risks (e.g. diseases, food security etc).

The National System of Innovation has a significant role to play in achieving the goals of promoting competitiveness and job creation and of enhancing the quality of life through the development of human resources and the promotion of an information society. Therefore, the Agricultural Biotechnology Strategy, as with the sector strategy, is premised on knowledge management and innovation.

Although a number of education and research institutions are conducting research in biotechnology, there is still a lack of focus on agricultural biotechnology. However, the National Biotechnology Strategy has begun to put some directed focus upon biotechnology *per se*. To achieve national priorities of food security and poverty alleviation, it is imperative that the NSI provides a directed focus on agricultural biotechnology.

2.3 HUMAN RESOURCES MANAGEMENT AND DEVELOPMENT

a) The National Research and Development Strategy, as well as the National Biotechnology Strategy, identified biotechnology as one of the scientific fields with a shortage of highly skilled personnel. It should therefore not be surprising to note that agricultural biotechnology also lacks skilled human resources.

b) The shortage of personnel is not limited to those with PhD's, but spreads across, and includes technicians, scientists and managers.

c) As noted by the National Research and Development Strategy, there is also a skewed distribution of skilled personnel:

- Approximately 60% of individuals with PhD are white males aged 55 years and more.
- Less than 10 % of individuals with PhD are black and the majority are below the age of 50.
- Less than 40% of scientists with PhD are women.

d) At universities and technikons the quality of students at undergraduate level within this field is poor.

e) The number of students at post-graduate level in agricultural biotechnology remains low, although it is increasing.

f) There is a lack of consolidated information (such as a national database) on human resources within agricultural biotechnology. Where such information exists, it is often incomplete and inaccurate.

2.4 INTELLECTUAL PROPERTY RIGHTS (IPR)

Agricultural development in many developed countries such as the United States of America, the United Kingdom, Germany, Australia and others, has benefited from a long history of public and/or private sector investment. Such investment has historically placed strong reliance upon the availability of diverse genetic resources, particularly plant genetic resources. South Africa has also benefited in a limited manner from such agricultural developments; hence it has a highly sophisticated commercial agriculture system. However, success in South Africa has been limited to a small sector of the population.

Development of new technologies and their use in agriculture continue to present new challenges with regard to intellectual property. For example, innovative new plant varieties are not only able to be re-sold; they may be reproduced identically and resold in large quantities. In an attempt to resolve this matter, South Africa, along with a number of countries, mainly Europe and the USA, formed a Union for the Protection of New Plant Varieties (UPOV or Union pour la Protection des Obstentions Vegetales) in 1961. This particular international agreement has been reviewed several times, particularly in 1978 to accommodate the problem of conferring a limited "Farmers' Right" to the private reuse (replanting) of registered seeds (so-called farm-saved seed); and was revised in 1991. South Africa is a signatory to the 1978 agreement, and has legislation to this effect.

However, the dilemma with Intellectual Property Rights continues to be a developmental challenge for South Africa, particularly in view of its national imperatives:

a) There is an asymmetry between the nationality of most Plant Breeders' Rights holders and the nationality of most users. Although this asymmetry is not unique to South Africa as a developing country, it has significant implications with regard to development. Approximately 60% of right-holders in South Africa are foreigners (individuals, institutions and corporations) that are largely based in Europe and the North America.
b) The exploitation of local biodiversity and indigenous knowledge presents a challenge for South Africa. For example, if farmers and traditional communities have adapted, improved and produced seed that is environmentally sustainable, who then deserves to reap the benefits of innovation through modern biotechnology? Individuals or the whole community (in a country that often doesn't recognise collective rights)?
c) Why should farmers provide access to landraces if there will not be due consideration for the benefits – in other words, when farmers provide samples of their landraces, which then become new varieties through modern biotechnology, can the developer/innovator exclude them in the sharing of benefits? Farmers argue that there was already value in that particular landrace variety, and that inserting a gene and

patenting/protecting the variety raises concerns with regard to intellectual property rights.

d) Farmers are concerned that the possible introduction of gene use restriction technologies (popularly known as terminator technology), that causes seed sterility, could introduce an additional cost upon agricultural production as well as its potential impact on landraces.

e) The majority of institutions in South Africa lack enforcement mechanisms for intellectual property rights. In fact, few even have an office coordinating intellectual property matters.

f) Strategically, there is no national coordination of intellectual property, particularly with regard to agricultural biotechnology.

2.5 ENVIRONMENTAL CONSIDERATIONS

Technological developments of the green revolution in the 1960s enhanced agricultural productivity through the widespread availability of chemicals such as synthetic insecticides, herbicides and fungicides, as well as elite cultivars (often called hybrids), which made increased agricultural production possible. Such heavy reliance on chemical controls has however adversely impacted upon the environment through:

- Pollution of surface and groundwater
- Development of pest resistance
- Development of poor health in farmers and farm workers
- Destruction of beneficial organisms such as pollinators
- Development of pesticide residues in food
- Reduction of biodiversity, with particularly adverse impacts on non-target species

2.6 BIO-SAFETY CONSIDERATIONS

As with any technology, there are risks involved, hence an assessment is essential to determine if the risks are worth taking. Such potential risks need to be identified, evaluated and, where possible, mitigating factors implemented against them. Bio-safety concerns with regard to agricultural biotechnology have tended to focus on the use of genetic engineering in agriculture, primarily for crop production. However, these concerns are not limited to agriculture; they encompass animal and human health as well as the environment. In that regard, it is important to identify some of the concerns with regard to modern biotechnology, particularly, genetically modified organisms:

a) Farmers: Land use efficiency/productivity – Does the adoption of genetically modified crops, maize, soybean and cotton impact upon crop yields or impact on the need for cultivating forested or marginal land?

b) Health: Do the traits of herbicide tolerance and resistance to pest insects in genetically modified crops pose any new or different animal or human health safety concerns in comparison to conventionally bred crops with similar traits?

c) Health: A concern has been expressed that antibiotic markers that are utilised to produce genetically modified organisms could lead to multi-drug resistance, thereby rendering some common antibiotics useless.

d) Health: Some of the genetically modified organisms could induce allergic reactions when the crop is consumed. This particular concern is with genes from animal proteins transferred into plants.

e) Health: Are claims of the nutritional value of genetically modified food valid?

f) Health: As genetically modified organisms contain genes from other species, are the foods toxic?

g) Health: Consuming genetically modified food leads to decreased immunity, particularly in those suffering from HIV/AIDS.

h) Environment: Does the adoption of genetically modified crops lead to changes in the adoption of no-till and other conservation tillage practices or otherwise impact on soil erosion, moisture retention, soil nutrient content, water quality, fossil fuel use and greenhouse gasses?

i) Environment: Gene flow and out-crossing – Do genetically modified crops release pollen, which in turn would pollinate conventional crops (i.e. movement of genes that causes non-target organisms to express unwanted genes) and impact upon genetic diversity?

j) Environment: What is the potential for non-target pests and insects being harmed by genetically modified organisms (e.g. reference is often made of a study on Monarch butterflies, suggesting that *Bacillus thuringiensis* (Bt) kills beneficial pests and insects related to genetically modified crops).

k) Environment: What is the potential risk of developing pest resistance to the genetically modified organism (e.g. mention is made of major pests developing after a few years of growing genetically modified cotton, maize and potatoes in the USA. These pests are alleged to be resistant to pesticides; therefore could lead to more pesticide use)?

l) Environment: What is the potential risk of developing/encouraging crop weediness, or have genetically modified crops, specifically maize, soybean and cotton acquired weediness traits to date?

2.7 REGULATORY CONSIDERATIONS

Policy and regulatory systems need to form an integral part of the enabling environment to achieve the strategic objectives of agricultural biotechnology and national development. It therefore becomes important to periodically review the impact of policies on their ability to facilitate the attainment of such objectives. Below is a brief analysis of some of the legislation that directly impacts upon agricultural biotechnology.

2.7.1 Genetically Modified Organisms Act, 1997 (Act No. 15 of 1997)

In South Africa, all activities with regard to genetically modified organisms are regulated by the Genetically Modified Organisms Act, 1997 (Act No. 15 of 1997). Specific permits are issued for the deliberate release of genetically modified organisms.

In terms of the requirements of the Act, risk assessments form the cornerstone of any decision making process with regard to genetically modified organisms. Risk assessments are conducted prior to the deliberate release of any genetically modified organisms. A panel of experts, appointed by the Minister under the Act, known as the Advisory Committee (AC), conducts risk assessment to evaluate the merits of a particular application. The AC then advises the Executive Council of the Act on the bio-safety matters concerning a particular genetically modified organism event. As required by the Act, the Executive Council deliberates on the recommendations of the AC, inputs from members of the public and other considerations as determined by their respective government departments, and may then authorise the registrar to issue a permit.

2.7.2 National Environment Management Act, 1998

The purpose of the Act is to provide for co-operative environmental governance by establishing principles for decision making on matters affecting the environment institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state.

2.7.3 Biodiversity Act, 2004

The objectives of this Act are:

(a) to secure –

(i) the conservation of the biological diversity of South Africa

(ii) the sustainable use of biological resources

(ii) the fair and equitable sharing of benefits arising from the use and application of genetic resources and material

(b) to give effect to international agreements affecting biodiversity, and which are binding on South Africa.

Clearly, the Biodiversity Bill will have implications for agricultural biotechnology, as it will impact upon access and benefit-sharing mechanisms for genetic resources. Therefore, it will become imperative to ensure that the biodiversity planning framework takes into consideration the need to achieve the strategic objectives of agricultural biotechnology, while conserving biodiversity.

2.7.4 Regulations under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act No. 54 of 1972)

These proposed regulations would govern the labelling of foodstuffs obtained through certain techniques of genetic engineering. The expectation is that such labels will contain accurate information to identify the product in an unbiased manner, and should not be misleading. As proposed, the regulations will depend upon the existence of an identity preservation system that may have implications on the costs of agricultural biotechnology foodstuffs.

2.7.5 The Patents Act, 1978 (Act No. 57 of 1978)

In terms of this Act, which covers patents, trademarks and copyrights, processes of biotechnology may be patented. However, it is not clear whether products of biotechnology such as plants and animals can be patented. As noted in the National Biotechnology Strategy, there is a lack of clarity on a number of issues that may have implications for the harnessing of both intellectual property and indigenous knowledge in agricultural biotechnology such as:

a) The current non-existent framework for the protection of indigenous knowledge, even though this is under development.
b) SA's lack of capacity for "search and examine" in the patent office, which makes it difficult to ascertain the accuracy of information patented.

c) Poor public understanding of the patent system within SA and how it could impact upon innovation and agricultural biotechnology.
d) There is no equivalent protection of animals such as the one that exists under the plant breeders' rights. (In other words, it is currently not possible to protect new breeds of animals, particularly those that are useful in agriculture).

2.7.6 Animal Improvement Act, 1998 (Act No. 62 of 1998)

This Act is designed to provide for the breeding, identification and utilisation of genetically superior animals in order to improve the production and performance of animals in the interest of the nation. The Act will therefore facilitate, in conjunction with the regulations and the policy, the attainment of the strategic objectives of agricultural biotechnology.

2.7.7 Plant Breeders' Rights Act, 1976 (Act No. 15 of 1976)

The objective of this Act is to provide for a system through which plant breeders' rights relating to varieties of certain kinds of plants may be granted and registered; for the requirements which have to be complied with for the granting of such rights; the protection of such rights and the granting of licences in respect of the exercise thereof; and other incidental matters. Although the Act is designed to facilitate trade in plant varieties that are of particular importance to agriculture, it may not fully accommodate the developmental needs of agricultural biotechnology in SA. Therefore, an analysis of its implications as an enabling policy for development is essential for the success of agricultural biotechnology.

2.8 BIOETHICS IN AGRICULTURAL BIOTECHNOLOGY

Many modern technological advances bring unintended social and environmental changes. Modern biotechnology has raised a lot of ethical issues that continue to be debated intensively. In his publication, Paul B Johnson extensively discusses ethical issues in agricultural biotechnology.

Key issues in bioethics can be understood as problems of anticipating and managing the unintended changes brought by technology. Risk assessment is one of the key tools that society uses to systematically consider and weigh up the positive and negative aspects associated with technological advances. From a management point of view, the key ethical question is whether people should be informed and their consent obtained before they can become bearers of risks, and on how the risks and benefit are to be evaluated.

Genetic modification of foods and animals elicits an immediate reaction of opposition among many people. For example, the announcement of the cloning of Dolly the sheep, though a major biotechnological move, caused public outcry. The range of ethical concerns that have been raised in connection with agricultural biotechnology is wide and complex. The specific technological issues include the following:

- Environmental impact
- Food safety
- Genetically engineered animals
- Impact on farming communities
- Shifting power relations

The National Biotechnology Strategy places considerable emphasis on bioethics and proposes the establishment of a Bioethics Council. The proposed council will play a key role in enhancing our understanding of the cultural and ethical aspects of biotechnology. Furthermore, the Council will ensure that biotechnology development has regard for the values held by all South Africans. This Council will also strengthen provisions for the consideration of cultural and ethical matters. In support of ethical issues, research on the social and cultural aspects of biotechnology will be encouraged in an attempt to foster an understanding of the concerns that are part of South Africa's context for biotechnology development and use.

The Bioethics Council will provide independent advice to the Government on biotechnological issues that have significant cultural and ethical aspects. It will also disseminate the required information and encourage public dialogue on the cultural and ethical aspects of biotechnology.

Opposition to biotechnology is expected from many quarters of our society, but will subside when issues are clarified and adequate communication channels are established.

2.9 TRADE ISSUES IN AGRICULTURAL BIOTECHNOLOGY

The expanding use of, and trade in, agricultural biotechnology products will enhance the health and improve the quality of life of citizens in both developed and developing countries. Despite its benefits in agriculture, the use of biotechnology is clouded by controversy. Some countries have imposed trade restrictions on agricultural biotechnology products. Such restrictions will impede trade in agricultural biotechnology products with some of South Africa's trading partners.

To overcome these impediments, such products must be traded in a fair system that is regulated in a sensible, objective and science-based manner. The trade barriers have serious implications for these products.

For example, the EU, South Africa's major trading partner, has announced a five-year moratorium on the approval of agricultural biotechnology products. In response, the US has taken the matter to the World Trade Organisation (WTO) and has requested this body to settle the dispute. A ban on such products has serious consequences to countries that have embraced this technology, as they too face the risk of being excluded from the European market. Strategies to access these markets need to be developed to assist exporters.

3 STRATEGIC FOCUS AREAS

As with many technologies, the Human Development Report 2001 noted that new technologies provide opportunities for healthier lives, greater social freedom, increased knowledge and more productive lives. In the same report, biotechnology as a tool is highlighted with the potential to increase food quality and production and prevent diseases through the manufacture of vaccines and the tracing of illnesses. Clearly, South Africa should be able to take advantage of this technology.

Biotechnology can be utilised to study the genetic expression of organisms and their interactions in complex ecological systems; hence generating solutions for degraded ecosystems, reducing or eliminating pathogens and improving rural livelihoods.

To exploit the potential of biotechnology, government needs to focus on encouraging and facilitating innovation in the target areas of research, development, technology transfer and commercialisation. The following is a list of strategic focus areas of research, development, technology transfer and commercialisation:

3.1 IMPROVEMENT OF CROP PRODUCTION

Crop yields in South Africa, when compared to other countries, are exceedingly low due to the harsh environmental conditions. Forecasts of the impact of climate change suggest that should South Africa continue to utilise its current crop species and varieties, its competitiveness will be reduced.

Agricultural biodiversity provides genetic resources that are essential for increasing crop yields. The intrinsic intra-specific genetic variability of species has allowed many rural communities and plant breeders to improve crop yields. Agricultural biotechnology can play an important role in improving crop production, resulting in increased yields.

KEY ACTIONS:

- Increasing yields through the use of drought- and salt-tolerant crops
- Increasing the diversity of crops and varieties grown in the field (e.g. the use of alternative staple crops)
- Producing insect and pathogen resistant plants to reduce the chemical impact on the environment and improve yields
- Characterising genetic variance in order to introduce material from other species or genera
- Producing diagnostic tools for early and accurate pathogen and pest detection
- Ensuring the continuous availability of improved disease-free planting material
- Development of DNA-based selection systems

3.2 IMPROVEMENT OF THE NUTRITIONAL VALUE OF FOOD

In addition to improving yields, agricultural biodiversity (agro-biodiversity) provides the material and information essential for good nutrition. Biotechnology can therefore be utilised to improve the nutritional value of food through the introduction of plants that contain key vitamins and amino acids that are low in the diets of many poor South Africans. Biotechnology can, in this regard, be utilised to fortify diets.

KEY ACTIONS:

- Altering gene expression to effect the production of endogenous metabolites or to achieve the synthesis of metabolites not traditionally produced by specific plant species (e.g. increased folic acid synthesis, or vitamin A etc.). This is often called the bio-fortification of plants that can be achieved through proteomics or functional genomics and metabolomics of plants.
- Characterising and identifying indigenous crop species with high nutritional qualities.
- Introducing genetic material from other species or genera to improve the concentration of nutrients.

3.3 IMPROVEMENT OF ANIMAL HEALTH AND PRODUCTION

Farm animals are an integral component of South Africa's agricultural system. They are important for food security, nutrition, biodiversity, economic growth and culture. Animal production includes a wide variety of activities from large-scale extensive beef, wool, mutton and mohair production, to intensive dairy, sheep, goat, pig and poultry systems, as well as a growing game ranching and aquaculture sector. It is a rapidly changing industry with new technologies that improve production efficiency.

A large portion of animal agriculture in South Africa is dependent on natural veld or planted pastures. Veld and pastures are, in turn, dependent on the environmental elements such as soil and water resources. Obtaining optimal and sustainable use of the animals and other natural resources requires biotechnology utilisation in conjunction with good agricultural practices as articulated in the Animal Improvement Policy.

To obtain the objectives of the Animal Improvement Policy, which are increased production and better health (e.g. disease resistance), would require the use of agricultural biotechnology in research and development. Therefore, agricultural biotechnology needs to focus on the following target areas:

KEY ACTIONS:

- Vaccine development for diseases of economic and social importance to South Africa (e.g. foot -and -mouth disease, Newcastle disease etc)
- Pedigree determination, based on DNA fingerprinting and similar technologies
- The development of disease detection methods such as the use of molecular markers (particularly the development of portable, but highly sensitive diagnostic kits for the early detection of highly infectious diseases such as foot -and -mouth, African swine fever etc.)
- Improved breeding techniques that encompass agro-biodiversity
- Improved characterisation and analysis of breeding material
- Characterisation of indigenous and locally adapted animal genetic resources
- Improved farm animal production methods

3.4 IMPROVEMENT/SUPPORT OF INDUSTRIAL DEVELOPMENT:

Although South Africa has a large diversity of natural resources, it lacks the ability to preserve and utilise them in a sustainable manner. Biotechnology could be utilised to harness natural resources, particularly agricultural outputs, in an efficient and sustainable manner. This would lead to improved competitiveness and economic growth.

KEY ACTIONS:

- Development of competitive bio- processing techniques to utilise plant, animal and other sources of biological material for the production of chemical and other products
- Processing of agricultural products in order to improve characteristics such as nutritional content, reduced toxicity, flavour, taste etc

- Developing biotechnology techniques that decrease the costs of inputs in agriculture and industry, or increase beneficiation
- Harvesting of agricultural outputs (crops, horticultural plants, fruits, animals etc). These are sometimes referred to as bio-farming
- Characterising indigenous genetic resources for industrial production

3.5 PROMOTION OF ENVIRONMENTAL SUSTAINABILITY

As noted earlier, technological developments of the green revolution in the 1960s enhanced agricultural productivity through the widespread availability of chemicals such as synthetic insecticides, herbicides and fungicides, as well as elite cultivars (often called hybrids), making it possible to realize increased agricultural production, but with consequences upon the environment. Conversely, biotechnology can, and should be utilised to mitigate the adverse impacts of agriculture on the environment. In order to replace the green revolution paradigm of maintaining pressure on the ecosystem with one of sustainable agriculture, it is essential to focus on a multi-pronged (or multi-disciplinary) approach

KEY ACTIONS:

- Improving upon current integrated pest management systems towards an agro-ecological approach to farming
- Identifying, characterising and conserving plant and animal genetic resources to enhance biodiversity
- Facilitating sustainable use of genetic resources in agriculture
- Determining the ecological impacts of agriculture
- Developing and implementing mitigating tools for environmental damage
- Developing and implementing efficient and environmentally sound biological control systems
- Improving biosafety systems

3.6 HUMAN RESOURCE MANAGEMENT AND DEVELOPMENT

The National Biotechnology Strategy identified several constraints with regard to human resources and suggested a particular solution. The suggested solution aims to develop and retain appropriate human resources for biotechnology. Through the National Biotechnology Strategy, it is recognised that biotechnologists need to be multi-skilled in areas such as bioinformatics, information communication technology, engineering, statistics, genetic epidemiology, business management, product development and legal issues skills, to mention but a few. These skills and others (e.g. plant breeding, farming, genomics, conservation etc) are essential for agricultural biotechnology; the same interventions mentioned in that strategy would thus be recommended, namely:

- Establishing career opportunities
- Fast-tracking the human resources needs of regional innovation centres
- Improving the current post-doctoral fellowship system
- Promoting curriculum development

Another strategic objective for the success of agricultural biotechnology is the sustainable supply of human resources, their development, management and existence at a critical mass level. In order to address the identified human resource constraints , a capacity building plan is essential. The capacity building plan should focus upon the following:

KEY ACTIONS:

- **Strategic planning** by institutions and government on agricultural biotechnology that:
  - Identifies all skills necessary for sustainable success, taking into consideration when they will be required in the life of a project and how they relate to institutional objectives
  - Identifies and develops the appropriate skills for technology transfer
  - Initiates a process to identify auditing skills already present and what is required to change them in order to reach the strategic objectives
  - Merges the total resource management of people, equipment, consumables and financing into the institution's comprehensive plan
- **Assessing national human resource needs**
- **Analysis of personnel (staff) capacity** in public and private institutions to determine the degree levels of agricultural biotechnology researchers and the ratios of researchers to technical support staff and managers
- **Planning for human resource development,** primarily for addressing current and historical imbalances, taking cognisance of the need for effective and efficient use of human resources. The plan should aim at producing highly skilled, demographically balanced, more satisfied and competent personnel at all levels
- **Research teams** should be recognised for their potential to reduce the time towards project completion, improved range of knowledge management and skills development. Therefore, building research teams through the developmental stages of a project in the agricultural community should be one of the strategic interventions of human resource management and development

3.7 MANAGEMENT OF INTELLECTUAL PROPERTY RIGHTS

South Africa, like many developing countries, continues to face the challenge of Intellectual Property Rights (IPR), which is assuming increasing significance to agricultural research, particularly when the research is conducted by public institutes. It is important to note that IPR are part of the exploitable capital of any research institute. In some instances, research may depend on securing permission to use the IPR of others. Third, where there is a research team, there will be visitors and institute members, and there will be the difficult question of identifying ownership of any intellectual property that is generated.

There are management challenges with regard to the use of IPR, such as ways of disclosing intellectual property, questions of ownership, remuneration, forms of intellectual property exploitation, and the question of who should manage intellectual property rights as well as the growth and developmental challenges of a country like SA.

Currently, SA invests about 0.7% of its Gross Domestic Product (GDP) in research. Although this amount is currently small in comparison to other countries, government's contribution, particularly in agricultural research, is significantly larger than that of individual private sector entities. These investments require research institutes, public or private, to be accountable for the intellectual property that they generate. Therefore, a new discipline for the management of their intellectual property needs to emerge, starting with ownership. Public research institutes should be allowed ownership of intellectual property as a public good. Similarly, private sector entities should also be allowed ownership of intellectual property in order to serve as incentive for encouraging investment in research, leading to further innovation and development.

Public research institutes should own intellectual property in order to promote national interests in growth and development. This can be achieved through the promotion of further innovation by the research entity in the public interest. Such ownership will assist the public research institutes by:

<u>KEY ACTIONS:</u>

- Protecting the institute's integrity and welfare, providing a resource for the industry and community it serves
- Allowing institutes to obtain the appropriate return for the use of facilities, resources, and services provided by them
- Encouraging growth, progress and success of the research institute through ventures with industry
- Seeking commercial returns to provide fair and reasonable rewards (and incentives) to staff, students and other participants (including communities) who apply their intellectual activity
- Increasing the acumen and accountability for management and use of public funds and fostering the identity of the research institute

To achieve the objectives of ownership, research institutes should manage their intellectual property. Research institutes will need to provide a central point for the management of intellectual property. Other objectives for the management of intellectual property would be to confront the complexities of the legal protection of IPR and commercial arrangements needed to acquire and exploit these rights.

SA is a developing country with its own set of developmental challenges in which agriculture plays a central role. Therefore, it is imperative to develop and implement a national policy on intellectual property rights that focuses on the sustainable use of agricultural biotechnology. Such policy will need to be in alignment with the current Indigenous Knowledge Policy, SA's obligations to international agreements (e.g. the World Trade Organisation's TRIPS agreement, World Intellectual Property Organisation, etc) and other national laws. Target areas for the policy should be the following:

a) Eliminating the skewed ownership of Plant Breeders' Rights relating to holders and their nationality
b) Accommodating the contribution of local biodiversity and indigenous knowledge to agricultural biotechnology
c) Providing protection of new animal breeds
d) Benefit-sharing mechanisms for access and use of germplasm (e.g. material transfer agreements etc)
e) Protecting landraces from possible adverse impacts of new technologies
f) Management of knowledge and innovation in agricultural biotechnology
g) Facilitating and creating commercial enterprises

The National Biotechnology Strategy identified a strategic objective of creating an enabling legislative framework for the development and commercialisation of biotechnology. Several interventions are listed to achieve such an objective.

3.8 INTERNATIONAL COLLABORATION

The National Research and Development Strategy acknowledges the global nature of science and the need, therefore, to encourage and maintain international collaboration. Similarly, innovation in agricultural biotechnology could be expedited through intentional collaboration. Another reason would be access to international human and financial resources to address South African priority needs. The National Biotechnology Strategy suggests, in this regard, international collaboration. Such international collaboration could be through:

KEY ACTIONS

- Strategic partnerships where there are strong linkages with equivalent institutions, as the platform for innovation and research. This approach could be utilised within the New Partnership for African Development (NEPAD) to achieve common goals of national and regional growth
- Programme partnerships in which government and the private sector develop joint projects to address specific priority needs and stimulate innovation in agricultural biotechnology
- Bilateral agreements on projects of common interest between countries, industry and communities
- Establishment of regional centres of excellence in agricultural biotechnology, where interaction and research between South Africans and other Africans could be encouraged and maintained

3.9 PUBLIC AWARENESS

Although South Africa has been engaged in the application of a broad spectrum of biotechnologies, much of the public remains unaware or uninformed about such developments. Broad public appreciation of investments in agricultural biotechnology research is, in this regard, difficult to determine. In the absence of public awareness, South Africa also faces the potential rejection of important scientific developments, which may adversely impact upon the attainment of its national priorities.

KEY ACTIONS:

- Articulating a single vision for agricultural biotechnology
- Promoting public education programmes on agricultural biotechnology
- Facilitating access to products of agricultural biotechnology
- Ensuring ethical engagement with agricultural biotechnology
- Providing accurate information on agricultural biotechnology

4 IMPLEMENTATION OF THE STRATEGY: KEY INITIATIVES

4.1 STRATEGIC ALIGNMENT

Before implementing the strategy outlined in this document, the Department of Agriculture (DoA) will ensure that the requisite buy-in from all stakeholders is achieved. In developing this document, the DoA consulted informally with, and requested inputs from a number of stakeholders. The next step would be the soliciting of more formal and focused inputs from a wide range of stakeholders. The feedback will be incorporated into the final document.

The Department will be responsible for rolling out the strategy and communicating its purpose. It is important to explain why the strategy was developed and what its objectives are. Key stakeholders will include agribusiness, academics, industry experts, agricultural associations, science councils and non-governmental organisations. The key role of the stakeholders will be to participate actively, give inputs and comments, and display commitment. As the strategy implementation progresses, specific roles will be clarified. Communication workshops, presentations to industry and academics and policymaking will be undertaken.

At the stage, the DoA will provide leadership, co-ordination and sponsorship of the process using the integrated strategic framework shown in Appendix B. The strategy development is a process that will be conducted in phases.

The desired outcome of this alignment and consultation process is to reach a common understanding of the strategic direction that is proposed in this document. A shared vision will result in commitment that will enhance effective implementation of the strategy.

4.2 AUDIT OF AGRICULTURAL BIOTECHNOLOGY IN SOUTH AFRICA

As stated earlier, a national biotechnology survey of the biotechnology industry in South Africa was completed and published towards the end of 2003. This audit gives an overall picture of biotechnology in different sectors in South Africa. However, the audit did not provide a detailed account of the status of the agricultural sector. Therefore, before deciding on the development programmes, a realistic, in-depth appraisal is essential.

The output of the audit will provide a profile of the present situation. One of the main objectives of the audit will be to uncover opportunities from the technology base. The audit will identify areas of particular strengths and weaknesses. A key activity will be to evaluate the technological capital in relation to demands placed upon it to meet future objectives.

The technological gap will be highlighted, and will be an indication of the changes that are required to satisfy the chosen strategies.

4.3 AGRICULTURAL BIOTECHNOLOGY ROAD-MAPPING

To translate this strategy into action, a biotechnology road-mapping exercise will be embarked upon. Technology road-mapping is a planning tool and is a highly effective means of facilitating the forecasting of critical new technology development requirements; it is also a valuable technique for decision-making. This process will be applied to prioritise the development of the agricultural biotechnology programmes.

The purpose of this exercise will be to identify existing strengths and pinpoint technology gaps or impediments. A working group comprised of experts, academics and government representatives will be tasked with examining the areas of importance in South Africa. The government will provide the required resources and facilitate the road-mapping exercise. The road-mapping process will be oriented towards taking advantage of market and social needs. The end result is to ensure that the resources and capabilities are utilised in a sustainable manner.

The main benefit of the road-mapping exercise is that it will provide the required information to make better decisions for technology investment. Furthermore, it provides a framework to help plan and coordinate development within the entire industry.

4.4 FUNDING SUPPORT FOR IMPLEMENTATION OF THE STRATEGY

The Agricultural Biotechnology Strategy is one of the outputs suggested by the National Biotechnology Strategy. It is imperative in this regard, that implementation of the Agricultural Biotechnology Strategy be aligned with the broader, national one. This helps in avoiding duplication of projects, and ensures the best and most efficient utilisation of resources.

Successful implementation of the strategy will require considerable resources. The following are some of the funding options and opportunities that will be considered:

Option 1*: *Inter-governmental collaboration

It is proposed that the Department of Agriculture facilitates access to funds that need to be specifically allocated for the projects identified in the strategy of the Department of Science and Technology. In the current MTEF cycle, the Department of Science and Technology has been allocated approximately R400 million for biotechnology. Some of the money has been utilised during the current financial year, but additional money could be sought for the forthcoming year. The primary recipient for such money would be the Agricultural Research Council as a scientific institution mandated to deliver research outputs on behalf of the agricultural sector and the Department.

Option 2: Participation in existing programmes

This is necessary to encourage the Agricultural Research Council and other institutions with relevant expertise, and to compete for the funding of research projects as identified in this strategy. The Department of Science and Technology would, in this regard, be requested to utilise the list of priority areas as identified in the strategy for agricultural biotechnology in its decision making for funding.

Option 3: Additional government support

The Department of Agriculture will request additional funding within the options of the MTEF to focus attention on resources and research at the Agricultural Research Council, and possibly other agricultural institutions. The performance and capacity building objectives of the ARC would, in this regard, be addressed, while encouraging collaboration with other institutions. Therefore, not all the monies need be allocated to the ARC, but a substantial portion thereof. The initial amount of approximately R186 million could be allocated over a period of 3 years and increased by 50% each year, depending on the outputs and needs. Projects would need to focus on the identified focal areas, with specific objectives and outputs outlined. The Onderstepoort Biological Products (OBP) is uniquely placed to push the frontiers of biotechnology in South and Southern Africa. An assessment of current facilities and production constraints for OBP indicates a funding shortfall of R700 million to enable the OBP to participate fully in the biotechnology industry within the framework of an agriculture biotechnology strategy.

Option 4 : ***International Collaboration***

It is suggested that additional funding for the implementation of the Agricultural Biotechnology Strategy be obtained from international sources through collaboration and/or competitive requests. Examples of sources of such funding could be common projects with the CGIAR, ICGEB, OECD, UNECA and FAO to name but a few. In all instances, it is recommended that such funding should address the priority interests of South Africa, even though some of the funding may be linked to NEPAD. Departments of Agriculture as well as Science and Technology could facilitate access to such funds, based on South Africa's membership of and participation in many international organisations. It is also possible to explore access to such funds in the context of supplementing national investment into research and development, and facilitating the acceleration of biotechnology development. Clear criteria for accepting and utilising such funds would need to be developed, including ownership of outputs as well as intellectual property rights issues.

Option 5 Incentive scheme to support Innovation in Agricultural Biotechnology

To support the implementation of the strategy, the DoA will consider the possibility of introducing a dedicated fund for agricultural biotechnology.

The mandate of the fund will be to promote technology development and encourage the commercialisation of innovations. The fund could be in the form of matching grants or partnership schemes, and industry participation will be encouraged. To encourage innovation, the proposed innovations should demonstrate a significant technological advance and commercialisation potential.

5. APPENDIX A: CASE STUDIES FROM OTHER COUNTRIES

As a developing country, it is important to run a comparative analysis of a few countries. Such comparative analysis provides lessons on how others have tackled various problems associated with agriculture and technology development. In this section, a few case studies ranging from least to highly (technologically) developed countries are analysed with regard to agricultural biotechnology. South Africa, as one of the few countries that tend to be in the middle with regard to development, but more on the developing side, could learn from errors and solutions observed in other countries.

In this Appendix, a few case studies from both developing and developed countries are discussed.

5.1 CASE STUDY I: CUBA

When the Soviet Union collapsed in 1990, Cuba began to experience major economic hardships that required significant shifts in the orientation and management of its economy and agricultural production. For example, during this period, the Cuban agricultural sector experienced a drop of more than 80 per cent in its fertiliser and pesticide supplies, while the rest of the economy had to manage with only half of the petroleum formerly available. Obviously, this led to major food shortages, and Cuba began to experience food insecurity.

To overcome food insecurity and dependence on food imports, the Cuban government launched a *National Food Programme* (NFP) in 1989. The main focus of this programme was to rapidly increase the production of vegetables, plantains, roots and tubers by *Low-External Input and Sustainable Agriculture* (LEISA). The main pillars of LEISA include Integrated Pest Management (IPM), intercropping and rational use of water. Biotechnology played an important role in this shift as it provided measures to substitute petroleum-based fertilisers and pesticides with biological means. Consequently, several Cuban products entered their agricultural system:

- Bio-fertilisers: Nitrogen-fixing micro-organisms such as *Azospirillum rhizobium* are used for legumes and *Azotobacter* for non-symbiotic nitrogen fixation in sugar cane and other grasses
- Biological pest control (Bio-control): Insect pests are controlled by other insects or micro-organisms such as *Bacillus thuringiensis* (Bt). Bio-pesticides are produced countrywide in about 200 centres on an artisan scale as well as in brewer's yeast factories, using large-scale fermentation technologies.

In order to overcome its world market position as a mere provider of commodities, Cuba took a strategic decision to promote knowledge-intensive, advanced technologies such as biotechnology. To transform the economy, the country invested US$ 50 million annually in biotechnology during the period 1990 to 1996. By 1995 it was employing 1612 researchers and 1121 technicians per million inhabitants. (During this time, Argentina, as the second largest research nation in Latin America, employed only one-third of that number). In 1998, the annual budget of the biotechnology sector was stepped up to approximately US$ 60 million. Although most of the expenditure was in the medical field, a focal point of six institutions was also created under the leadership of the *Centro de Ingenieria Genetica y Biotecnologia* (Centre for Genetic Engineering and Biotechnology – CIGB) to specialise in agricultural biotechnology.

Cuba's agricultural biotechnology programme is based on its diverse agricultural needs that are focused on:

a) Increasing cash crop production, mainly sugar cane
b) Increased food production

To achieve this, the country has targeted tropical crops and traits relevant to its specific agro-ecological circumstances, such as the following research priorities:

- Micro-propagation for high quality seeds: Bio-factories with the capacity to produce 60 million plantlets *in vitro* and artificial seeds annually were created to become independent of seed imports. The other objective was to produce disease-free propagation material and to minimise external inputs like fertilisers and herbicides, and also energy for greenhouses and sterilisation laboratory material. For example, *in vitro* production of potato plantlets has reduced seed imports by approximately 20 per cent per year.
- Detection of plant diseases and characterisation of pests: The country has developed and produced molecular diagnostic kits to detect plant diseases in sugar cane, tomato, potato, banana, pineapple and citrus crops. Recently, Cuba proposed a project to collaborate with South Africa on the development of recombinant vaccines for the control of Rhipicephalus and Amblyoma tick infestations. Amblyoma tick infestations are a major problem in South Africa. The goal in this particular project is to develop a vaccine against ticks that would form part of an integrated pest management system that reduces dependency on expensive and environmentally unsound chemical tick control
- Transgenic plants: Cuba is currently conducting research on nearly all important crop plants to produce transgenic varieties (GMOs). In this case, projects focus on resistance to insects, viruses and fungi, and tolerance to the herbicide *gluphosate*. In view of market interests, Cuba has delayed the commercial release of transgenic sugar cane. However, should market perceptions change, particularly in Europe, which is Cuba's largest market, the country is likely to release the variety

As noted in the national biotechnology strategy, Cuba's significant investment in biotechnology has resulted in a variety of biomedical and agricultural products. For example, in the biomedical field, the country has successfully produced the world's only anti-meningococcal vaccine, which is patented worldwide. Other successful vaccines include those for hepatitis B and cholera. It is important to note that Cuba's biotechnology industry is interlinked and integrated between biomedical, agricultural and environmental needs.

5.2 CASE STUDY II: ZAMBIA

Zambia is a tropical country with a population of about 10 million, and 42 million hectares of arable land, of which only 6 per cent is cropped annually. Its annual rainfall averages 600 mm. The country has a highly differentiated agricultural sector of approximately 1,5 million farming families, scattered over nearly 740 000 square kilometres of African savannah. This farming community ranges from large-scale commercial farmers, who traditionally produce for export, to small-scale resource-poor farmers, who produce more than 80 per cent of the country's staple food crop, maize. In spite of its diverse and rich natural resources, Zambia's crop production, particularly maize, has been declining annually for the past 10 years. Its production can no longer meet the national demand, and this forces the government to import maize from South Africa, Canada, Argentina and the USA. These are countries where genetically modified crops have already been commercialised.

In order to deal with the food insecurity of Zambia, efforts were made to increase crop productivity. The majority of Zambian farmers grow Open Pollinated Varieties (OPVs), and cannot afford to buy inputs such as fertilisers and pesticides that are normally required to grow hybrid varieties. In that regard, farmer-saved seed resources are very important. The United Nations Food and Agriculture Organisation (FAO) has supported this OPV breeding programme.

Crop improvement research programmes have focused upon conventional plant breeding for insect pest and disease resistance, as well as higher yields. Much of the research is conducted at Mount Makulu Agricultural Research Station and Golden Valley Agricultural Research Trust (a private initiative). To date, these have produced new maize, sorghum and millet hybrids that have been approved by the Seed Control and Certification Institute. Local seed companies, with the support of the Swedish International Development Agency, now produce the majority of the seed hybrids.

As a country, Zambia does not have a strategy for dealing with food security and biotechnology. Similarly, there is no commitment towards improving research in agricultural biotechnology. In addition, there is a lack of institutional capacity or framework to deal with the unfolding political and scientific issues concerning biotechnology, even for the biomedical field. To date, there appear to be efforts by some individuals at the National Institute for Scientific and Industrial Research to draft a national biotechnology and bio-safety policy, primarily with a view towards protecting the country's biodiversity.

5.3 CASE STUDY III: THE EUROPEAN UNION (EU)

The European Union (EU) comprises a group of 15 member countries, all with a broad range of agricultural and technological development, but generally not extremely divergent from each other. Traditionally, the EU, along with the United States of America (USA), has been the leader in technology innovation, research, development and adaptation, particularly for health and agriculture. However, events with regard to the development of genetically engineered products seemed to have surpassed the EU some time during the 1990s. Combined with a series of health and bio-safety failures due to poor regulatory systems, the EU public lost confidence in its governance system. This led to an EU moratorium in 1999 that prohibited the deliberate release of any genetically modified agricultural products in the market. Subsequently, the EU has been involved in a number of initiatives aimed at transforming its regulatory system in such a manner that the member countries and the community at large are able to reclaim their leadership role in the realm of biotechnology. Therefore, in January 2002, the Commission of the EU Communities released a strategy for Europe on life sciences and biotechnology.

It is important to note the contents of the strategy because they provide an important insight with regard to how the EU views biotechnology, as well as possible future actions within this field. The strategy begins by highlighting the challenges that Europe is faced with, regarding life sciences and biotechnology. One such challenge can be quoted in the following manner:

> "Europe is faced with a major policy choice: either accept a passive and re-active role, and bear the implications of the development of these technologies elsewhere, or develop pro-active policies to exploit them in a responsible manner, consistent with European values and standards. The longer Europe hesitates, the less realistic this second option will be".

Although recognising the wide range and significant impacts of biotechnology and the need for a policy response, Europe appears to be hesitating as indicated by the following statement in the strategy:

> "A revolution is taking place in the knowledge base of life sciences and biotechnology, opening up new applications in health care, agriculture and food production, environmental protection, as well as new scientific discoveries. This is happening globally. The common knowledge base relating to living organisms and ecosystems is producing new scientific disciplines such as genomics and bioinformatics and novel applications, such as gene testing and regeneration of human organs or tissues. These in turn, offer the prospect of applications with profound impacts throughout our societies and economies, far beyond uses such as genetically modified plant crops.
>
> "The expansion of the knowledge base is accompanied by unprecedented speed in the transformation of frontier scientific inventions into practical

use and products and thus, also, represents a potential for new wealth creation: old industries are being regenerated and new enterprises are emerging, offering the kind of skill-based jobs that sustain knowledge-based economies. As probably the most promising of the frontier technologies, life sciences and biotechnology can provide a major contribution to achievement of the European Community's Lisbon Summit objective of becoming a leading knowledge-based economy. The European Council in Stockholm in March 2001 confirmed this and invited the Commission, together with the Council, *to examine measures required to utilise the full potential of biotechnology and strengthen the European biotechnology sector's competitiveness in order to match leading competitors, while ensuring that those developments occur in a manner which is healthy and safe for consumers and the environment, and are consistent with common fundamental values and ethical principles.*

"Europe's current performance in life sciences and biotechnology is not facilitating the achievement of that objective.

"In Europe and elsewhere, intensive public debate has emerged. While the public debate has contributed to awareness and concrete improvements on important issues, it has also focused narrowly on genetically modified organisms (GMOs) and specific ethical questions, on which public opinion has become polarised. In the Community, like in other regions and countries, the scientific and technological progress in these areas raises difficult policy issues and complex regulatory challenges. Uncertainty about societal acceptance has contributed to detracting attention in Europe from the factors that determine our capacity for innovation and technology development and uptake. This has stifled our competitive position, weakened our research capability and could limit our policy options in the longer term.

"Europe is currently at a crossroads: we need to actively develop responsible policies in a forward-looking and global perspective, or we will be confronted by policies shaped by others, in Europe and globally. The technology and its applications are developing rapidly – the Commission believes that Europe's policy choice is, therefore, not whether, but how to deal with the challenges posed by the new knowledge and its applications."

The document continues to identify strategic priorities for Europe to develop sustainable and responsible policies to address the following three broad questions:

- Opportunities: "How can Europe best attract the human, industrial and financial resources to develop and apply these technologies to meet society's needs and increase competitiveness?"

- Broad Public Support: "How can Europe deliver effective, credible and responsible policies, which enjoy the confidence and support of its citizens?"
- Globalisation a reality: "How can Europe best respond to the global challenges, develop its domestic policies with a clear international perspective and act internationally to pursue its interests?"

In terms of solutions to existing problems in the world, the strategy noted the following:

> "Biotechnology already enables cheaper, safer and more ethical production of a growing number of traditional as well as new drugs and medical services (e.g. human growth hormone without risk of Creutzfeldt-Jacobs Disease, treatment for haemophiliacs with unlimited sources of coagulation factors free from AIDS and hepatitis C virus, human insulin and vaccines against hepatitis B and rabies)".

Specific to agriculture and food, the document notes the following:

> "Biotechnology has the potential to deliver improved food quality and environmental benefits through agronomically improved crops. Since 1998, the area cultivated with genetically modified (GM) crops worldwide has nearly doubled to reach some 50 million hectares in 2001 (in comparison with about 12 000 hectares in Europe). Food and feed quality may be linked to disease prevention and reduced health risks. Foods with enhanced qualities ("functional foods") are likely to become increasingly important as part of life-style and nutritional benefits. Plant genome analysis, [sic], has already led to the genetic improvements of a traditional European cereal crop (called Spelt) with an increased protein yield (18%), which may be used as an alternative source of protein for animal feed. Considerable reductions in pesticide uses have been recorded in crops with modified resistance. The enhancement of natural resistance to disease or stress in plants and animals can lead to reduced use of chemical pesticides, fertilisers and drugs, and increased use of conservation tillage – and hence, more sustainable agricultural practices, that would reduce soil erosion and benefit the environment. Life sciences and biotechnology are likely to be one of the important tools in fighting hunger and malnutrition and feeding an increasing human population on the currently cultivated land area, with reduced environmental impact."

A selection of case studies have been identified and examined within the National Biotechnology Strategy. It is imperative that when reading this report, reference be made to the following country case studies: Brazil, Nigeria, Australia and the USA. In view of the developments in both developing and developed nations, it is clear that South Africa's commitment to biotechnology, though laudable, remains lacking.

In light of the observations cited above, it is clear that agricultural biotechnology has significant contributions to make towards South Africa's economic development. In order to sustain and enhance agricultural productivity, South Africa needs to invest in activities that encourage innovation. As noted by the EU Commission, we are in the knowledge-based era that requires innovation that in turn, involves new science-based products and processes to contribute reliable methods for increasing productivity and environmental sustainability. Clearly, effective development and safe deployment of new agricultural products, particularly those derived from biotechnology, will require decisions on priorities and resource allocations. This will also mean that policymakers, research managers and scientists need to address new responsibilities, such as trade, public awareness and dialogue, bio-safety, trans-boundary movement of genetically modified organisms, intellectual property rights, food safety and consumer choice, as well as public research and investment.

5.4 CASE STUDY IV : INDIA

For a developing country, the emergence of the biotechnology industry in India is instructive; South Africa can learn a lot from their experience. India is a very populous and poor country, but it offers an excellent example of government policy intervention that has led to significant progress in biotechnology. To stimulate biotechnology, the Indian government established a Department of Biotechnology with the following mission:

> *"Attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – specially for the welfare of the poor."*

Since it was established, the focus has been on basic and application oriented new biology and biotechnology covering agriculture and plants, genomics, molecular medicine, bioinstrumentation, bioinformatics, biofuels, biofertilisers, biopesticides, human resource development and biodiversity. Biosafety protocols and guidelines regarding ethical issues have been developed. Partnership with the industry for commercialisation of technology and marketing of bioproducts has been encouraged, and has led to some successes.

The following are a few examples where significant progress, that is relevant to the South Africa, has been achieved. This section is summarised from the report, Biotechnology in India, and is publicly available on their website·

Crop Biotechnology: Transgenic research has been carried out on a number of crops to increase nutritional value, introduce disease resistance and achieve better shelf life in certain plant species. These achievements have been made possible through genetic modification, which allowed for the introduction of new traits to target plants such as wheat, rice and potatoes.

Plant Tissue Culture: By using tissue culture, different crosses have been developed in a variety of orchids. At present, field demonstration trials are being conducted for tissue culture propagated coffee, pepper and tea. Complete regeneration systems are now available for 20 different plant species.

Animal Biotechnology: The expression of foreign proteins in transgenic mice and other genes has been achieved. A buffalo chromosome probe for sex determination of an embryo is being applied in this field. An interesting development is the use of cell culture to produce rabies vaccine. This development is being validated before commercialisation.

Biological Pest Control: Technology transfer to industry has been achieved for the mass production of candidate biocontrol agents, baculovirus, parasites, predators, antagonists, fungi and bacteria for economically important crops. The important crops include coffee, cotton, oilseeds, pulses, spices, sugarcane, tea and vegetables. Fermentation-based technologies of three fungal biocontrol agents have been transferred to industry.

Human Resource Development: India places a lot of emphasis on human resource development to develop a critical mass of scientists and technologists. India has 62 biotechnology teaching programmes in various universities and institutions. Approximately 1600 students have been trained in two years in special programmes such as Neurosciences. National and overseas associateships are awarded annually to about 45 scientists, resulting in the development of the required expertise. National Bioscience Awards for Career Development and National Women's Bioscience Awards are conferred annually to recognise the outstanding contributions of biotechnologists in various fields. An increased number of scholarships are given to encourage school leaving students to pursue careers in biotechnology.

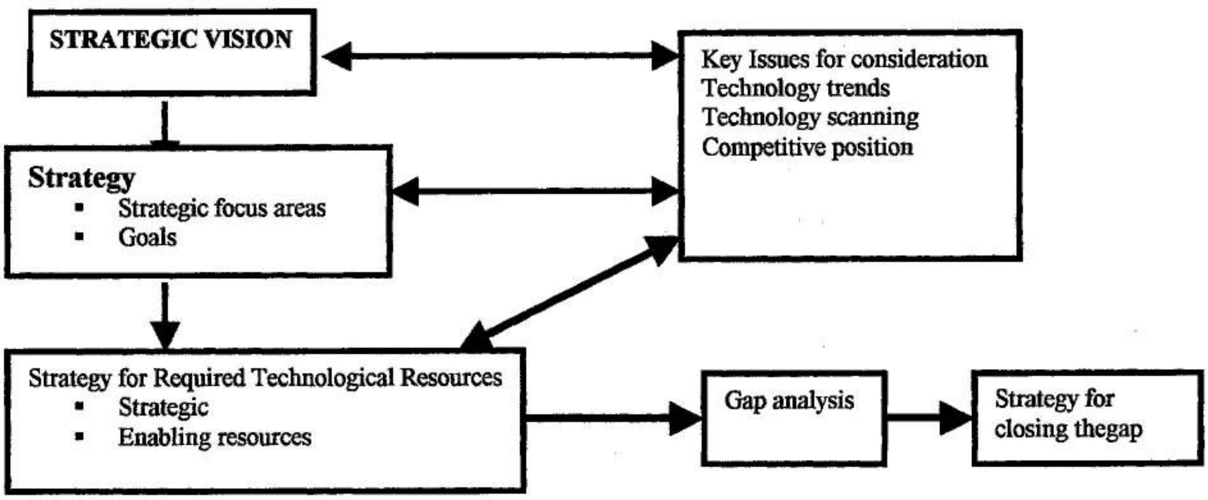
Food Biotechnology: In this area, low cost nutritious food supplements for school going children have been developed. This includes large-scale production of Betalains (food colorant) and optimisation of oyster mushroom. Processes for the preparation of clarified fruit juices with aroma retention and food flavours and diagnostic kits for rapid detection of food borne pathogens have been developed

Biotechnology for Societal Development: Training and knowledge transfer forms an integral part of the Indian strategy. The training includes large-scale demonstration and cooperative marketing activities in the areas of food processing, leafy vegetable and mushroom cultivation, organic farming, orchids, ornamental plants, and the conservation of rare species. From this initiative, endangered herbal medicinal plant species have benefited this target group significantly. A Women's Biotechnology Park with many industrial modules is one of the success stories.

Biovillage: A Biovillage at Mocha village, Porbandar for the extension of technologies which are pro-poor, pro-women and pro-nature to grassroots level, has been a model for rural development. In this area, farmers of target villages have been trained in the production and use of bio-fertilisers, bio-pesticides, modern farming practices and the cultivation of marine algae seaweeds. Furthermore, the cultivation of medicinal and economically important plant species is taking place in the wasteland of the village.

Repositories and biotech facilities: Infrastructure facilities and repositories have been established, as well as different institutions to facilitate advanced research. These include a repository on Drosophila, a national containment facility, and a national facility for Virus Diagnosis and Quality Control in Tissue Culture,, with Planting Materials having been set up at Indian Agriculture.

APPENDIX B: INTEGRATED STRATEGY DEVELOPMENT FRAMEWORK



Printed by and obtainable from the Government Printer, Bosman Street, Private Bag X85, Pretoria, 0001
Publications: Tel: (012) 334-4508, 334-4509, 334-4510
Advertisements: Tel: (012) 334-4673, 334-4674, 334-4504
Subscriptions: Tel: (012) 334-4735, 334-4736, 334-4737
Cape Town Branch: Tel: (021) 465-7531

Gedruk deur en verkrygbaar by die Staatsdrukker, Bosmanstraat, Privaatsak X85, Pretoria, 0001
Publikasies: Tel: (012) 334-4508, 334-4509, 334-4510
Advertensies: Tel: (012) 334-4673, 334-4674, 334-4504
Subskripsies: Tel: (012) 334-4735, 334-4736, 334-4737
Kaapstad-tak: Tel: (021) 465-7531