CHAPTER 2

AGRICULTURAL BIOTECHNOLOGY: A LITERATURE REVIEW

2.1. INTRODUCTION

The year 1998 was the 200th anniversary of the publication of Reverend Thomas Malthus's well known, "*Essay on the Principal of Population*". According to Malthus the blind biological urges of mankind would cause the population to increase in a geometrical fashion and quickly exhaust the finite resources of the earth. Malthus stated that "The power of population is indefinitely greater than the power in the earth to produce subsistence for man" (Malthus, 1798). But according to Petersen (1990), Malthus in a later work gave the answer to this dooming prospect himself: "..under the right circumstances and within appropriate institutional structures, impending scarcity could stimulate creative responses to mitigate or curtail resource depletion" .

Malthus was neither the only nor the first scholar of nature who observed that the crop production practices of the seventeenth century were going to lead the earth's population to food security problems. Jonathan Swift, author of *Gulliver's Travels*, expressed in 1727 through the mouth of the King of the Brobdingnag: "....whoever could make two Ears of Corn, or two blades of Grass to grow upon a Spot of Ground where only one grew before, would deserve better of Mankind, and do more essential Service to his Country than the whole Race of Politicians put together." (As seen in Prakash, 2001). Biotechnology - like innovation in irrigating, tilling, fertilising and those associated with the "Green Revolution" is a response to mitigate the dooming resource depletion.

The purpose of this chapter is to provide a brief summary of the history and development of agricultural biotechnology, to highlight the dominant issues in the controversial biotech debate and to shed light on the developing biotech industry in South Africa.

2.2 BACKGROUND AND BRIEF HISTORY OF BIOTECHNOLOGY

Biotechnology is not new. Man has been manipulating living things to solve problems and improve his way of living for millennia. Early agriculture concentrated on food production and animals, and plants were selectively bred according to preferred traits and nutritional value. Micro-organisms through yeast and fermentation were used to make wine, beer, bread and cheese. According to the United States Department of Agriculture (USDA), biotechnology can be described as a range of scientific techniques, including genetic engineering, that are used to create, improve, or modify plants, animals, and micro organisms for the benefit of humans (http://www.usda.gov/news/bioqa.htm).

The late eighteenth century and the beginning of the nineteenth century saw the advent of vaccinations, crop rotation involving leguminous crops, and animal drawn machinery. The end of the nineteenth century was a milestone for biotechnology. Microorganisms were (formally) discovered, Mendel's work on genetics was accomplished and institutes for investigating fermentation and other microbial processes were established by Koch, Pasteur and Lister.

Biotechnology at the beginning of the twentieth century began to bring industry and agriculture together. During World War I, fermentation processes were developed that produced acetone from starch and paint solvents for the rapidly growing automotive industry. World War II brought the manufacture of penicillin and the biotechnological focus moved to pharmaceuticals. The cold war years were dominated by work with microorganisms in preparation for biological warfare, as well as antibiotics and fermentation processes (Murphy and Perrella, 1993).

Biotechnology as we know it today consists of three historical types of coexisting biotechnological undertakings (Nef, 1998):

The "first generation", traditional mode (7000 BC to 1940s), is characterised by empiricism and a minimal input of science and engineering. It includes the conventional use of yeasts and fermentation for the production of food, beverages and energy.

The "second generation", or intermediate biotechnology (1940s to 1980s) was characterised by significant scientific and engineering inputs on an industrial scale, including industrial microbiology, biochemistry and industrial engineering. It utilised fermentation, bio-conversion and bio-catalysis to manufacture pharmaceuticals, produce chemicals and fuels, and to process residues.

The "third generation" or modern biotechnology (from the 1980s) is characterised by "new genetic combinations". It is based on molecular biology and the utilisation of genetic engineering techniques (such as recombinant DNA). Potentially the applications of the modern biotechnology encompass all biological processes, leading to new products and operations.

There are numerous current and potential applications of biotechnology in agriculture to produce genetically modified food, crops and fibre. The first wave of agricultural biotechnology has benefited farmers and producers by providing input or agronomic traits that make production easier and more effective. Most of the food in the market today that is referred to as genetically modified, is food that is produced through field crops that are either herbicide tolerant or has a genetically engineered resistance against certain insects, viruses or fungi. The second wave of agricultural biotechnology will be focussed more on output or quality traits and will benefit mainly the consumer through food with enhanced nutritional components and healthier oils. It is envisaged that the agricultural biotechnology industry will evolve into a third generation in which even more bio-industrial applications will emerge in industry, manufacturing and in the pharmaceutical sector.

2.3 THE ADOPTION OF GENETICALLY MODIFIED CROPS

According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA) the global area under genetically modified crops exceeded 50 million hectares for the first time in 2001. It is estimated that 52.6 million hectares of GM crops were planted in 13 countries by 5.5 million farmers. In 2002 up to 6 million farmers in 17 countries planted 58.7 million hectares of genetically modified crops. The area under GM crops increased 19% (8.4 million hectares) between 2000 and 2001, with a further 12% increase (6.1 million hectares) between 2001 and 2002.

Since the international introduction of GM crops in 1996 the global area planted has increased more than 30-fold. (Figure 2.1.)

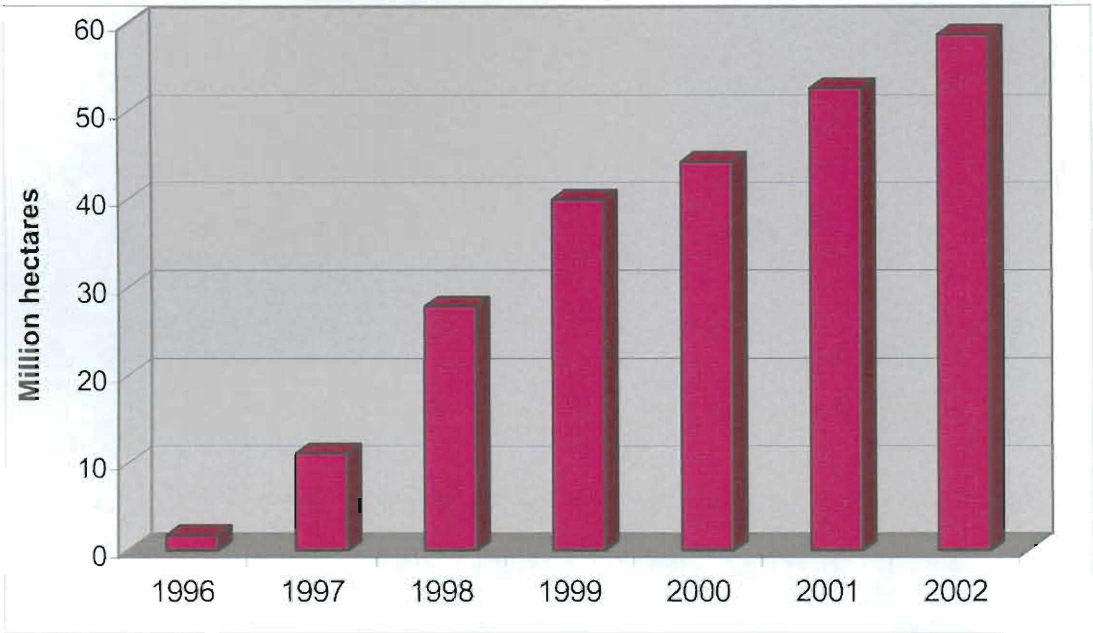

Figure 2.1: Global area under GM crops, 1996 to 2001

Source: www.isaaa.org

Table 2.1 shows that four countries had more than 99% of the total GM crop area. In 2002 more than 16 million hectares or 27% of global transgenic crop area was in developing countries, but the absolute growth in GM crop area between 2000 and 2001 was twice as high in industrial countries (5,6 million ha) than in developing countries (2,8 million ha). The percentage growth was higher in the developing countries of the South (26%) than in the industrial countries of the North (17%). Despite resistance, 2002 was the first year that more than half of the world's population lived in countries where genetically modified crops were produced.

Table 2.1: Areas planted to GM crops for 2000, 2001 and 2002

<table>
<tr><th>Country</th><th>Hectare (mil) 2000</th><th>Hectare (mil) 2001</th><th>Hectare (mil) 2002</th><th>Crops</th></tr>
<tr><td>USA</td><td>30.3</td><td>35.7</td><td>39.0</td><td>Soya beans, Cotton, Canola, Maize, Chicory, Potato, Rice, Squash, Sugar Beet, Tomato</td></tr>
<tr><td>Argentina</td><td>10</td><td>11.8</td><td>13.5</td><td>Soya beans, Maize, Cotton</td></tr>
<tr><td>Canada</td><td>3.0</td><td>3.2</td><td>3.5</td><td>Sugar Beet, Canola, Squash, Soya beans, Cotton, Linseed, Tomato, Potato, Wheat, Maize</td></tr>
<tr><td>China</td><td>0.3</td><td>1.5</td><td>2.1</td><td>Cotton</td></tr>
<tr><td>South Africa</td><td>0.2</td><td rowspan="14">0.4 **</td><td rowspan="14">0.6**</td><td>Cotton, Maize, Soya beans</td></tr>
<tr><td>Australia</td><td>0.2</td><td>Canola, Cotton, Carnation, Soya beans, Maize</td></tr>
<tr><td>Romania</td><td><0.1</td><td>Soya beans, Potatoes</td></tr>
<tr><td>Mexico</td><td><0.1</td><td>Soya beans, Cotton, Tomatoes</td></tr>
<tr><td>Bulgaria</td><td><0.1</td><td>Maize</td></tr>
<tr><td>Spain</td><td><0.1</td><td>Maize</td></tr>
<tr><td>Germany</td><td><0.1</td><td>Maize</td></tr>
<tr><td>France</td><td><0.1</td><td>Maize</td></tr>
<tr><td>Uruguay</td><td><0.1</td><td>Soya beans</td></tr>
<tr><td>Indonesia</td><td><0.1</td><td>Cotton</td></tr>
<tr><td>India</td><td><0.1</td><td>Cotton</td></tr>
<tr><td>Honduras</td><td><0.1</td><td>Maize</td></tr>
<tr><td>Colombia</td><td><0.1</td><td>Cotton</td></tr>
</table>

** Estimated figure as total for remaining countries.

Source: Compiled from data on the ISAAA website and the Agbios Essential Biosafety CD.

According to a Reuters publication (2002, Feb 4), even though the number of European biotechnology companies outnumber American companies by 1570 to 1273, the American firms boast three times the stock market value and generate three times the revenue, as 28 percent of them are publicly listed versus only six percent of those in Europe. The publicly listed US biotechnology companies boast an estimated market capitalisation of $353 billion and a turnover of $22 billion per annum.

2.4 THE AGRICULTURAL BIOTECHNOLOGY DEBATE

Although the GMO debate is highly publicised, comprehensive objective literature on the issues is rather limited. Anti-GMO activists tend to stress issues like the Monarch butterfly and StarLink corn debacles. The full stories of these two issues are widely published on the World Wide Web. Scientists, developers and supporters of biotechnology on the other hand tend to focus rigorously on scientific proofs, ignoring the perceptions of consumers. Perceptions can sometimes be influenced by miscommunication from scientists, misinterpretation by sensation seeking media and false prior beliefs of "anti-something" advocacy groups. In the GMO debate people or institutes are portrayed to be either pro- or anti- GM with nothing in between.

It is not the aim of this chapter to enter into the intense and often emotion driven debate about the creation, production and consumption of genetically modified organisms. Only a brief overview of the ideologies and certain issues that have played a major role in the debate as well as some reasons why perspectives differ will be given. In the following chapters more comprehensive literature concerning issues like adoption, costs and benefits will be summarised.

2.4.1 THE ISSUES THAT DRIVE THE DEBATE

According to Gerald C. Nelson (2001) the GMO debate can usefully be defined in terms of three main issues, namely:

- Costs and benefits of the technology and its products.
- Regulatory strategies and human and environmental safety.
- Legal institutions and intellectual property.

Each genetically modified product has certain economic, social and ethical benefits and costs associated with it. Potential benefits include a more abundant food supply, plants which enhanced health characteristics as well as reduced chemical inputs resulting in a healthier environment. Possible costs include environmental and food safety hazards, as well as adverse distributional effects - if the technology were to favour only large-scale farmers or multinational corporations. The ethical concerns, according to Nelson (2001), arise from the notion that genetic engineering methods extend the intrusion of humans into natural processes far beyond that of normal plant breeding. The other side of the coin is that there are ethical considerations involved in repressing a technology that provides humanitarian benefits to the most needy.

The second set of issues regard the regulatory responsibility. Certain questions arise that need to be answered by governments and regulatory bodies responsible for product approval and releases. Questions like: "Have governments adequately assessed the possible health and environmental effects of GMOs or has the process of adoption been rushed as a result of commercial pressures by companies responsible for the technologies?", "Should one wait until long-term studies of the effects of GMOs on the environment and in the diet can be concluded, or is it enough to deduce from short term scientific studies what the impact will be?" Another set of questions concerns how regulatory responsibilities change as countries try to establish a bio-safety regime to suite trade regimes as established in the WTO (Nelson, 2001).

The third issue surrounds the legal and effective ownership of genetic material. The cost of developing GM crops, patent laws, intellectual property rights, genetic markers and the potential for genetic and biological enforcement of legal rights has shifted control of biotechnologies towards multinational biotech and seed companies. There is growing concern that the nature of global agriculture and the relationship between farmers and other parts of the food system is undergoing drastic change (Nelson, 2001).

With biotechnology, like with all technological innovation, the development, adoption and benefits of new technologies need to be communicated to the public in truthful, understandable ways. Many other innovations that are now common in our lives were met with scepticism and opposition when first introduced. Such fear of technology was and is especially pronounced in food-related innovations like pasteurisation, canning, freezing and the microwave oven. However, once consumers recognise that the new innovations can enhance their quality of life and once they understand that risks are either minimal or manageable, such technologies may enjoy widespread public acceptance (Prakash, 2001).

In a US State Department publication Calestous Juma (2003) mentions the case of the introduction of coffee. In the 1500s the Catholic bishops tried to have coffee banned from the Christian world for competing with wine and representing "new cultural as well as religious values". In public smear campaigns, similar to those currently directed at biotech products, coffee was rumoured to cause impotence and other ills and was either outlawed or its use restricted by leaders in Mecca, Cairo, Istanbul, England, Germany and Sweden. In a 1674 effort to defend the consumption of wine, French doctors claimed that when one drinks coffee: The body becomes a mere shadow of its former self; it goes into a decline and dwindles away. The heart and guts are so weakened that the drinker suffers delusions, and the body receives such as shock that it is thought to be bewitched (Juma, 2003).

Analysis of public reaction to agricultural biotechnology has rightfully focused on social, cultural, economic, and political issues as determinants of public attitudes. Some of these analyses have discounted the importance of personal and societal knowledge as factors shaping perceptions and public attitudes towards agricultural biotechnology, in part because of the failure of scientific arguments to sway attitudes and public policy decisions (Wolt & Peterson, 2000)

2.4.2 DIFFERENT IDEOLOGIES

In a "Concept note for a regional policy dialogue" prepared by the Food, Agriculture and Natural Resources Policy Analysis Network (FARNRPAN) and the International Food Policy Research Institute (IFPRI, 2002) the uncertainties and controversies surrounding the role of biotechnology in agriculture were explained in the following manner:

"In most cases these uncertainties and controversies appear to have two dimensions. One dimension applies to relatively well-informed stakeholders, the other to relatively un-informed stakeholders. Because the relatively un-informed, either by design or by default rely on the relatively well-informed for guidance, understanding the foundations of differences among informed stakeholders are crucial."

The foundations for these differences are discussed in three sub-sections on biophysical and social sciences, modernism and post-modernism, and north and south political myths.

A) Conflicting Disciplinary Perspectives: Biophysical Sciences vs. Social Sciences vs. Humanities

Many of the differences in perceptions of informed stakeholders in the debate surrounding agricultural biotechnology stem in part from the contrasting disciplinary approaches and methodologies in knowledge generation. Biophysical sciences make use of tight, narrow, experiment-based hypothesis-testing approaches while social sciences use looser, broader, collective behavioral hypotheses in which both theory and data provide ambiguous guidance on casual relationships. "This particular divide can be bridged through the increased use of experimentation in the social sciences but it reinforces another divide between the social sciences and the humanities. The reductionism that drives model building and hypothesis-testing in the sciences is negated in the humanities, where explanation is often built on narrative depictions of dialectic tensions between individual agency and social determinism" (FANRPAN & IFPRI, 2003).

B) Competing Paradigms: Modernism and Post-Modernism

"The deep divergences defined by alternative disciplinary perspectives are further accentuated by a more fundamental paradigmatic clash based on differences surrounding the role of science and technology in human development - the clash between the modernists and the post-modernists." Modernists believe that science and the technological innovations brought about by science are predominantly positive and advantageous, and that under scientific and technological advance, human progress and development are good and inevitable. For post-modernists, reality is constructed, knowledge is subjective, and thus interpretation is everything. Progress and development is far from being outcomes of scientific and technological advance or of human history. Rather the only sure outcome of science and technology, and of passage of time is change. According to this ideology science and technology have had their chance, but failed to deliver (FANRPAN & IFPRI, 2003).

C) Divergent Political Myths: South vs. North

A third disruptive force in the agricultural biotechnology debate relates to political myth-making, in other words, the different myths about the nature of the global political order dominant in the South versus those dominant the North. "In the South a significant thread of political myth-making springs from centuries of technology-driven domination by the North. In the North, despite efforts toward greater inclusion and participation of "Southern" voices in development policy formulation, elements of the famous "White Man's Dilemma" persist" (FANRPAN & IFPRI, 2003).

Key elements of these clashes in disciplinary, paradigmatic, and political perspectives can be found in almost every public utterance on the role of biotechnology in agriculture.

In a paper entitled "Rich and poor country perspectives on biotechnology", Pinstrup-Andersen (2001) discusses various reasons why the perspectives and perceptions of people in developed and developing countries regarding the use and adoption of GMOs might differ. According to Pinstrup-Andersen one can also expect that perspectives would differ within a country between the poor and the non-poor. Albeit a rather gross generalisation, it is revealing to consider how countries' and people's perspectives on agricultural biotechnology and GMOs are influenced by their disposable income. The following couple of paragraphs quote and summarise some of the reasons and discussions as indicated by Pinstrup-Andersen.

The utilisation of modern biotechnology in agriculture and food production may lead to increased productivity and thus a reduction in unit cost. This will lead to a combination of higher incomes to producers and reduced prices for consumers. Consumers spending a large share of their budget on food thus would tend to view the use of biotechnology in agriculture more favourably. Consumers in developing countries often spend 50-80% of their total disposable income on food in contrast with Europeans, Americans and Australians who spend on average 10-15%. The cost of the physical food commodity also occupies a much bigger portion of the consumer price among the poor. The cost of marketing and processing tend to dominate in food consumed by the rich. Unit cost savings in the production of food thus will have a larger price reduction in the consumer price paid by the poor (Pinstrup-Andersen, 2001).

In low-income countries a large percentage of the population depends on agriculture for their livelihood. More than 70 percent of the world's population reside in rural areas and between 50 and 80 percent of low-income country's population depends directly or indirectly on agriculture. On the other hand only between 2 and 5 percent of the population of industrialised countries depend on agriculture. Linking to this aspect is the importance of the agricultural sector in generating broad-based economic growth in society as a whole. Agricultural growth is essential to promote growth within as well as outside agriculture in low-income countries while it may be of very little importance in industrialised countries (Pinstrup-Andersen, 2001).

Historically, political logrolling by farmers in developed countries has earned them large farm subsidies, supported in part by fiscal resources and in part by artificially high consumer prices. However, the market power of the farmers in industrialised countries has gradually deteriorated as consumers have gained a greater say in the market for food. Thus while European farmers continue to receive their subsidies by exercising political power, they are unable to exercise similar power over the government regarding genetically modified food. The European consumers, who now have the political power over agriculture, in general do not look favourably on GMOs. The opposition is partly driven by a perceived lack of consumer benefits, ethical concerns, uncertainty about personal health and environmental effects as well as the perception that large corporations will be the primary beneficiaries. Despite their position of power, consumers still agree to pay large subsidies to agriculture through taxes as well as through inflated food prices even though it can be argued that the adoption of modern biotechnology could reduce the need for farm subsidies. It thus seems that European consumers are willing to pay European producers to not produce genetically modified food. Farmers in the United States are also enjoying vast agricultural subsidies, but up to now they have not yet met the same level of consumer and governmental resistance against genetically modified food. Farmers in developing countries possess very little political power and are taxed rather than subsidised. In contrast with consumers in industrial countries, developing country consumers cannot influence government due to lack of purchasing power (Pinstrup-Andersen, 2001). It is sometimes forgotten that in many cases in lower income countries, the producers are the consumers.

It would be wrong to suggest that all "rich countries" are against biotechnology and that all "poor countries" support it. Countries like Australia, Canada and the United States have supported biotechnological development but they strongly support agriculture overall. The simple reason for this could be the importance of agricultural exports to their economies. The negative or tentative attitude of the European countries and Japan, who substantially rely on food and feed imports, can be partially explained by perceived health risks. Notwithstanding the fact that consumers' health perceptions of genetically modified crops are based on very limited knowledge of basic biology, Europe has had some very real food scares in the not so recent past. "Mad cow disease" and the sad picture of thousands of possibly food-and-mouth disease infected cattle burning for days has left a bad taste in the mouth of the European consumer, but this had very little to do with genetic engineering.

Certain anti-GMO civil society groups with substantial political power have had a considerable influence on the GM debate and on government and consumer attitudes towards genetically modified food in Europe. These advocacy groups are also gaining power in developing countries to the regret of most food and agricultural decision-makers. This is one of the reasons why it would be wrong to say that all "poor countries" are supportive of biotechnology in agriculture. Decision-making in a country like the Philippines has been hugely influenced by advocacy groups with strong links to international groups like Greenpeace and British Christian Aid. Another reason why perspectives on biotechnology differ between developing countries is that a coalition of decision-makers in non-poor developing countries, and governments and other decision makers in high-income countries may be possible. Such a coalition might establish policies and standards that could be detrimental to the majority of the people in the country who are poor (Pinstrup-Andersen & Cohen, 2001).

The 2002/2003 food crisis in Southern Africa and the decision by governments of amongst others Zimbabwe, Zambia and Malawi to refuse relief food consisting of Bt maize is an example of how decision makers are influenced by outside advocacy groups to make policy decisions harmful to their own people. It is believed that before attending the World Summit On Sustainable Development in South Africa advocacy groups paid a brief yet influential visit to decision makers in these Southern African countries (www.consumerfrccdom.com).

Through globalisation, policies on issues like the current food safety levels preferred by the rich can be imposed on the poor at the expense of food security of the latter. Poorer people would tend to place a higher premium on quantity and very basic food safety until basic nutritional requirements are met. European, Australian and American consumers however are prepared to pay a premium for even small increases in food safety and reduced uncertainty (Pinstrup-Andersen & Cohen, 2001).

Proponents envision biotechnology as providing additional food, fibre and medical resources without increasing, and possibly decreasing, human demands on land and plant habitats. Opponents believe that biotechnology will increase the already excessive demands upon the world's resources by increasing human populations and consumer demands for food, clothes and other materialistic goods. Proponents view human populations and demands as positive opportunities for biotechnology (Kershen, 1999).

Even though there may shortly be scientific proofs of the economic, health and environmental benefits of genetically modified crops, it is unfortunate on the one hand but reassuring on the other to perceive that as Kershen (1999) suggests, the acceptance or rejection of biotechnology will not be based on information or understanding but biotechnology will stand or fall on the ideological belief and the cultural values adopted by individual human beings who, in turn, will shape social belief and values. This could mean that if farmers in developing countries, despite possibly not understanding the scientific concept of GMOs, perceive GM crops to render advantages to them as farmers and as consumers, then adoption and acceptance will take place.

2.5 AGRICULTURAL BIOTECHNOLOGY IN SOUTH AFRICA

According to the pro-biotechnology non-governmental organisation (NGO), AfricaBio, South Africa has been involved with biotechnology research and development for more than 25 years. There are more than 500 biotechnology projects spread over seven sectors in South Africa. There are approximately 110 groups, both academic and research institutions, involved in more than 160 plant biotechnology projects and it is estimated that more than 45 companies are using biotechnology in food, feed and fibre applications. The medical and pharmaceutical sector attracts the most funding with the plant sector being the second largest in terms of funding. Interesting to note is that despite the 25 years of research and development few local products have been developed and all sectors are heavily dependent on imported biotechnology applications that are driving commercialisation and industrial growth.

2.5.1 POLICY AND LEGISLATION

An application to the South African Department of Agriculture in 1989 to perform field trails with genetically modified cotton kick-started the South African biosafety process and initiated the first trials with transgenic crops on the African continent (Koch, 2000). The application came from the US seed company Delta and Pineland who in those years used South Africa as an over wintering haven for field trials and seed multiplication.

The South African Committee for Genetic Experimentation (SAGENE) was established in the early 1970s when international genetic engineering first began. The initial task of this committee was to develop guidelines for the safe use of GM bacteria in laboratories, and more recently for work with all GMOs (Thomson, 2002). The committee consisted of representatives from a number of bodies namely: the Agricultural Research Council, Council for Scientific and Industrial Research, Foundation for Research Development, Medical Research Council, Council of National Health and Population Development, Department of Environmental Affairs and Tourism, Committee for University Principals, the South African Institute of Ecologists and Environmental Scientists and the Industrial Biotechnology Association of South Africa. According to Thomson (2002) the committee for many years dealt with all requests for permission to carry out laboratory, glasshouse or field trials with GMOs. When the volume of work increased, members of SAGENE in collaboration with outside experts handled requests through ad hoc sub-committees. SAGENE was only an advisory body and thus had no legislative power to enforce compliance with their guidelines. Dealing mainly with plant material, SAGENE advised the National

Department of Agriculture regarding the merits of each application. It was the work of the Department to enforce and monitor conditions under which trials were conducted. This period in which SAGENE established procedures and guidelines and where the Department of Agriculture issued permits for GMO work under the Pest Control Act of 1983, in theory, came to an end on 23 May 1997 when Parliament passed the Genetically Modified Organisms Act (Act 15 of 1997). The GMO Act was only implemented in December 1999, 31 months after it was passed. According to Koch (2000) the belated implementation can be ascribed to the efficiency and the cost effectiveness of the interim procedure, but also to lack of capacity in the public service to implement the Act. During the interim period 1990 to 1999 over 150 applications where reviewed covering 13 plant types and several medical and industrial microorganisms (Figure 2.2).

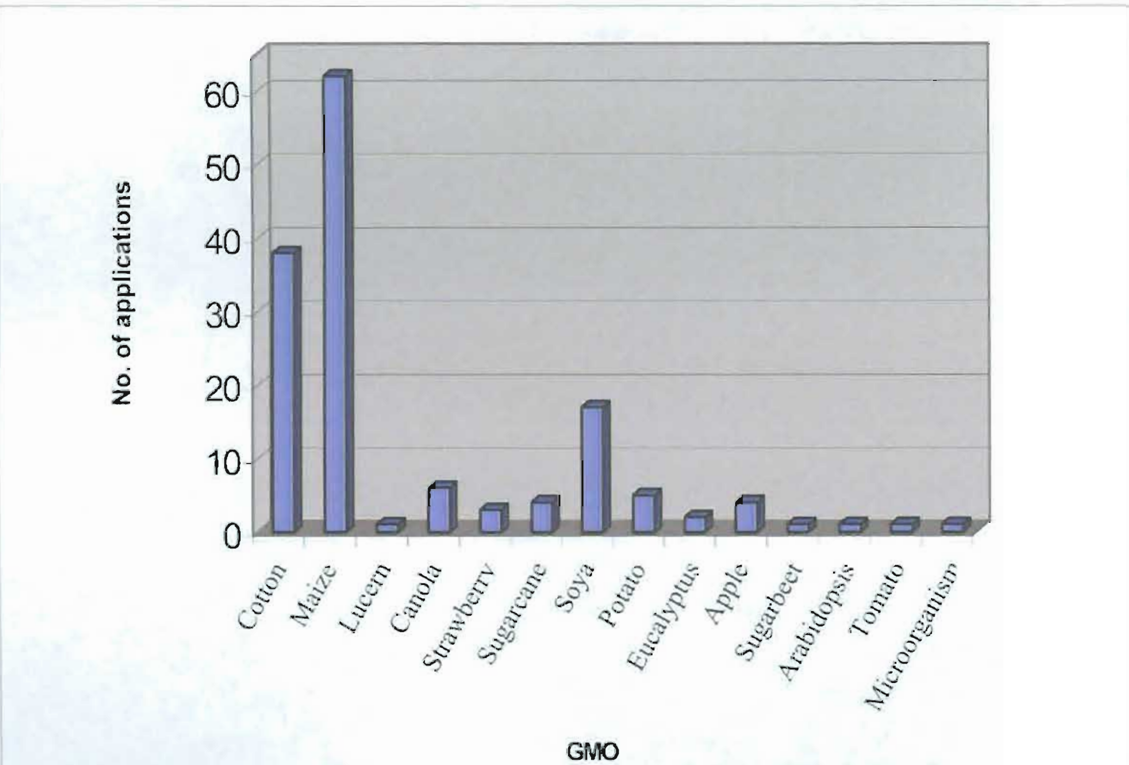

Figure 2.2: Applications for GMO permits in South Africa (1990-1999)
Source: Muffy Koch, 2000

Once the GMO Act of 1997 was implemented the following three biosafety structures were established to regulate all aspects of GMOs in South Africa.

1. The Executive Council. This is a national, independent decision making structure responsible for making decisions on all applications for work with GMOs. The council is comprised of representatives from 6 government departments (Agriculture, Environmental Affairs and Tourism, Health, Trade and Industry, Labour and Art, Culture, Science and Technology). The council also includes a scientific advisor who is the Chairperson of the Scientific Advisory Committee. The powers and duties of the Executive Council include:
   - Deciding on the issue of permits to undertake glasshouse and field trails or commercial releases of GM crops and other GMOs.
   - Overseeing the office of the Registrar.
   - Liaison with other countries.
   - Advising the Minister of Agriculture.
   - Ensuring law enforcement according to the GMO Act.

2. The Scientific Advisory Committee. This structure replaces SAGENE and will advise the Executive Council on human and environmental safety of applications submitted for permits. This committee consists of scientific experts approved by the Executive council and appointed by the Minister. The main functions of this committee is to:
   - Advise the Minister of Agriculture and the Executive Council on environmental impacts related to the introduction of GMOs.
   - Consider all matters pertaining to the contained use, import and export of GMOs.

3. The Registrar and Inspectorate. The Registrar administers the GMO Act on behalf of the Minister of Agriculture and the Inspectorate is used to monitor local work with GMOs. The duties of the Registrar include:
   - Administration of the Act.
   - Issuing permits.
   - Being pro-active in terms of any contravention of the Act.
   - Appointing inspectors to monitor field trails.
   - Ensuring compliance with the conditions of permits.

(Thomson, 2002) (Koch, 2000) (AfricaBio Website, 2002)

According to Thomson (2002) the process that is set in motion as soon as the Registrar receives an application can be summarised as follows:

- The Registrar appoints a member of the Advisory Committee to act as chair for the review.
- The Review Chair appoints a sub-committee of three reviewers who are not members of the Advisory Committee.
- The Review Chair receives reports from the sub-committee and compiles a report for the Registrar.
- The Registrar submits this report to all the members of the Advisory Committee for comment.
- The Advisory Committee reaches a decision and informs the Registrar.
- The Registrar presents a letter of recommendation to the Executive Council, which finally approves or rejects the application.

GMO regulations stipulate that this process should not take longer than 90 days for a decision on field trails and 180 days for a decision on general release applications (Thomson, 2002).

2.5.2 BIOTECHNOLOGY RESEARCH IN SOUTH AFRICA

In agricultural biotechnology the current major biotechnology companies are Monsanto, Pioneer Hi-bred International, Syngenta and Aventis. Almost all of these multinational companies have links with South African companies and research institutions. The major South African governmental or parastatal institutions that promote and conduct public agricultural biotechnology research are the Agricultural Research Council (ARC) and the Council for Scientific and Industrial Research (CSIR). Universities like the University of Cape Town, University of Natal and the University of Pretoria through amongst others the Forestry and Biotechnology Institute (FABI), also contribute to biotechnology research.

Following the compilation of the National Biotechnology Strategy by the Department of Arts, Culture, Science and Technology (DACST) in June 2001 certain bodies and partnerships have been organised to, in their own words “rapidly assemble the necessary teams and projects to place South Africa among the world leaders in the application of biotechnology to both regional and global issues" (www.biopad.org.za/mission). There exist three "BRICs" or Biotechnology Regional Innovation Centres that were established under the auspices of DACST and in partnership with a range of players, including the CSIR as lead organisation. The BRIC in Gauteng is known as BioPAD (Biotechnology for Africa's Development) and focuses on animal health and industry / environmental related biotechnology. Ecobio in KwaZulu-Natal focuses on human health, bioprocessing and plant biotechnology, while the Cape Biotech Initiative in the Western Cape concentrates on human health and bioprocessing (www.dst.gov.za).

Monsanto is the only company in South Africa that currently has genetically modified crops on the market for commercial production. Herbicide tolerant cotton and soya-beans, and insect-resistant maize and cotton currently being produced in South Africa, have been developed by and are licensed to others by Monsanto. Companies like Delta & Pineland with cotton, and Pioneer with maize buy the right from Monsanto to use specific traits in their own varieties. Syngenta that was formed in late 2000 through a merger between Novartis Agribusiness and Zeneca Agrochemicals has recently applied for permission to sell genetically modified maize seed in SA. Monsanto may soon lose its position as monopolist supplier of insect-resistant maize seed.

Over the last twenty years scientists in South Africa have been developing genetic engineering techniques and capacity. These techniques and technology are only now being used and commercialised. Only a small number of products have been developed despite the fact that over 600 biotechnology research projects are currently underway. According to a 1998 National Research Foundation financed survey of biotech research, an estimated 55 biotech companies are spending more than R100 million on research and development annually (AfricaBio, 2002). An estimated 50% was spent on medical research, 40% on plant biotechnology and the rest on environmental and industrial biotechnology research. Currently the total expenditure on biotech research and development is about $24 million (AfricaBio,2002).

Table 2.2: Summary of some of the past and current agricultural biotechnology research projects conducted by academic and parastatal institutions in SA.

Institution	Summary of main research programmes
ARC-OVI (Onderstepoort Veterinary Institute)	• Identification, cloning and expression of relevant genes, and preparation of prototype viral-vectored and genetic vaccines for African horse sickness, Newcastle disease, bovine ephemeral fever and Rift valley fever as well as lumpy skin disease.
ARC-Infruitec Division for Plant biotechnology and Pathology	• Development of efficient adventitious shoot regeneration from single cells of in vitro grown leaves of apple, pear, apricot and strawberry varieties • Transformation of and regeneration of transgenic plants • Generation of unique DNA fingerprints for 17 pear, 15 plum, 13 peach and 16 wine grape cultivars.
ARC-Roodeplaat Biotechnology Division	• In-house genetic transformation protocols for melon, potato and tomato • Three potato cultivars have been transformed with genes, which confer resistance to potato leaf-roll virus and potato virus Y. • A gene transfer system for some species of indigenous flowering bulbs
ARC - Institute for Tropical and Sub-Tropical Crops	• Biotechnology and tissue culture techniques used in breeding programs for papaya, guava, ginger, pineapple, coffee and avocado
ARC- Grain Crops Research Institute	• Embryo rescue techniques in order to expedite sunflower breeding and create interspecific crosses in dry beans • Meristem culture techniques to produce disease free dry bean seed • Plant regeneration from tissues in order to create transgenic plants after ballistic bombardment in groundnuts. • Cultivar identification at DNA level in groundnuts, sunflowers and soya beans. • Incorporation of alien genes in order to enhance herbicide resistance in lupins and drought resistance in groundnut. • Marker assisted selection for nematode resistance in soya bean. • Breeding of maize cultivars for disease resistance to ear rot and maize streak disease. • Maize breeding for insect resistance to stem borers (Busseola fusca)
CSIR (Foodtek /Bio-chemtek)	• Genetic engineering of cereals – successfully transforming and regenerating a laboratory strain of maize (Hi-II). • Maize was genetically engineered to combat maize cob rot caused by one of the most serious fungal pathogens of maize. • Genetic enhancement of the protein quality of sorghum • Genetic enhancement of maize to improve food safety through the introduction of four plant anti-fungal genes to combat contamination by the post harvest pathogen Fusarium moniliform which produces mycotoxins which are toxic to humans and animals.
SA Sugar Experiment Station (SASEX)	• Production of transgenic sugarcane in which desirable characteristics have been added. Varieties containing genes for herbicide resistance. • Developing transgenic sugarcane resistant to sugarcane mosaic virus.
University of Pretoria (Forestry and Agricultural Biotechnology Institute)	• Improvement of disease resistance and the general quality of widely planted forest trees such as *Eucalyptus spp.*and *Pinus spp.* • Improvement of wheat resistance to Russian wheat aphid, leaf rust, strip rust and stem rust.

University of Stellenbosch (Institute for Wine Biotechnology and Instiute of Plant Biotechnology)	• The establishment of efficient transformation and regeneration systems for grapevine cultivars. • The construction of genomic and cDNA libraries of grapevine cultivars. • The cloning and characterization of the PGIP encoding gene in grapevine. • The identification of grape cultivars using genetic marker technology. • Genetic manipulation of carbon flow in sugarcane and grapes. • Characterisation of carbon flux in non-photosynthetic plant systems with special reference to sugarcane and grapes. • Isolation and characterisation of plant movers.
University of Cape Town	• Collaboration with PANNAR to develop techniques for the reliable regeneration and transformation of local maize varieties. • Engineering of transgenic resistance in maize to maize streak virus. • Investigation of desiccation tolerance in plants.
University of the North	• Micro-propagation of indigenous trees – Marula
University of the Free State	• Vaccines for diseases in the poultry industry

Sources: Rybicki (1999)

Some other current biotechnology research and development projects include:

- Development of AIDS and TB treatments,
- Functional genomic and gene mining of South African plant resources.

A number of private South African companies are also involved in biotechnology research in South Africa. The most notable are Pannar (grain and vegetable seed) and Mondi (tree improvement). Pannar initiated its hybrid maize-breeding program in 1960 and began developing its own improved cultivars, specifically adapted to meet the demands of farmers in South Africa. A few years later, it became the first private seed company in South Africa to register a maize hybrid for the local market. Over the years many more PAN hybrids followed with demand exceeding all expectations and lately Pannar has added some genetically engineered varieties to its research programme with company field trials on genetically engineered maize rapidly increasing from 2 trials in 1995/96 to 105 in the 1998/99 season to 112 during the 1999/2000 season. Pannar uses Bt technology from Monsanto in their own cultivar lines and hybrids.

Following Monsanto's acquisition of Sensako and Carnia (two major South African seed companies) in 1999/2000, a joint research team was formed to cut costs on research investments. It is estimated that Monsanto currently spends about R40 million on research and development in South Africa annually (Green, 2002). The major share of Monsanto's research is done by institutions outside of the company on a contract basis. Institutions like the Agricultural Research Council (ARC) through their Grain Crops Institute in Potchefstroom and the Institute for Industrial Crops in Rustenburg, and the Council for Scientific and Industrial Research (CSIR) in Pretoria as well as smaller consultancy companies have been contracted to do research for Monsanto.

2.5.3 GENETICALLY MODIFIED CROPS IN SOUTH AFRICA

At present no genetically modified fresh produce is available in South Africa. The fresh produce varieties currently available on the shelf have been genetically enhanced by using only traditional breeding programs. The only genetically modified crops that have been approved for commercial production in South Africa up to now are herbicide-tolerant soya-beans, cotton and maize and insect-resistant cotton and maize. Bt cotton has been produced since the 1997/1998 season and Bt yellow maize since the 1998/1999 season. Herbicide tolerant cotton has been made available for commercial production in the 2001/2002 season while only a limited quantity of herbicide tolerant soya-bean seed has been released. Bt white maize was introduced in the 2001/2002 season and the 2002/2003 season will see the first season of large-scale production. A limited quantity of herbicide tolerant maize seed will be commercially released for the 2003/2004 season. Cotton seed containing the Roundup Ready – Bt combination has not commercially been released yet.

2.6 CONCLUSION

This chapter supplied a brief overview of the history, development, adoption and debate surrounding agricultural biotechnology and genetically modified crops. With a capable and informed albeit ad hoc regulatory system in place, South Africa was able to react to the availability of GM crops. Now with a well-established and accredited regulatory system, South African farmers will be able to make best use of new biotechnological innovations. Questions however remain whether South African farmers actually benefit by adopting genetically modified crops and if they do benefit, in what way and to what extent do they benefit. Chapter 3 will focus on farmers in South African who have adopted GM crops as well as the reasons why they have adopted.