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Aspects of biotechnology and genetically modified crops in South Africa

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1. Introduction

South Africa has a proud and solid biotechnology research and development (R&D) history. Some of this R&D have lead to the establishment of one of the largest breweries in the world, production of world class wines, the creation of new animal breeds and plant varieties that are used all over the world and also lead to the establishment of competitive domestic dairy and yeast industries (DACST, 2001). However, South Africa, relative to developed and some developing countries, has failed to benefit from the most recent advances in biotechnology, particularly over the last 25 years, with the emergence of genetics and genomic sciences. Ofir (1994) attributes this lag in development of beneficial second and third generation biotechnology products partly to the attitude the pre-democratic government had in the 1960s and 70s regarding biotechnology. In contrast to the chemical, energy and military sectors, biotechnology was not seen as essential for the survival and self-sufficiency of the Republic of South Africa.

Only in the early eighties were more effort made to develop expertise in molecular biology - mainly by academic and government research institutions. The National Research Foundation (NRF) formerly known as the Foundation for Research and Development (FRD) established a biotechnology and molecular biology training programme and new research focus areas were founded in molecular and cell biology, microbial genetics and mineral biotechnology by the FDR, and parastatals - Medical Research Council (MRC), the Agricultural Research Council (ARC), the Council for Science and Industrial Research (CSIR) and the Council for Minerals Technology (Mintek). Various governmental departments also established their own centres to develop modern molecular genetics in agriculture (Ofir, 1994).

Over the last twenty-five years scientists in South Africa have been developing genetic

engineering techniques and capacity but only a small number of products have been developed despite the fact that over 600 biotechnology research projects are underway. A 1998 NRF financed survey of biotech R&D found that an estimated 55 biotechnology companies spent in excess of R100 million on research and development annually (www.africabio.com). An estimated 50% was spent on medical research, 40% on plant biotechnology and the rest on environmental and industrial biotechnology research.

The reasons why relatively few marketable biotechnology products and techniques have been developed to date and the possible solutions as proposed and partly implemented by Government will be discussed in detail in section 3 of this paper, but first the performance and socio-economic impacts of the commercially released genetically modified crops in South Africa are discussed in section 2. Section 4 identifies some institutional challenges for commercial dissemination and section 5 sheds light on the development and challenges of the South African biosafety regulatory system. Section 6 concludes with some policy challenges.

History of agricultural biotechnology and genetically modified crops in South Africa

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. The application came from the US seed company Delta and Pine Land (D&PL), which used South Africa as an over-wintering haven for field trials. The application was reviewed and approved by the South African Committee for Genetic Experimentation (SAGENE) and the Department of Agriculture issued a permit. D&PL's involvement in SA increased and in 1995, after approval, multiplication of Bt seed to be sold in the US was conducted on South African shores for the first time.

In 1997 South Africa became the first country in Africa to commercially produce transgenic crops. To date the commercial release of insect-resistant (Bt) cotton and maize as well as herbicide-tolerant (RR) soya-beans, cotton and maize have been approved. Cotton with the "stacked gene" (Bt and RR) was in May 2005 still being evaluated. Farmers started adopting insect resistant (Bt) cotton varieties in the 1997/1998 season and insect resistant (Bt) yellow maize in the 1998/1999 season. Herbicide tolerant cotton was made available for commercial production in the 2001/2002 season and a limited quantity of herbicide tolerant soya-bean seed was also released. Bt white maize was introduced in the 2001/2002 season and 2002/2003 saw the first season of large-scale Bt white maize production. A limited quantity of herbicide tolerant maize seed was commercially released for the 2003/2004 season. Table 1 summarises the areas

planted under transgenic crops in South Africa for the most recent seasons.

Table 1: Percentage and estimated areas planted to transgenic crops in South Africa (hectares)

Crop	*1999/2000*	*2000/2001*	*2001/2002*	*2002/2003*	*2003/2004*
% Bt Cotton	50%	<40%	70%	70%	81%
Bt Cotton area	13 200	12 000	25 000	18 000	30 000
% RR Cotton	0	0	<10%	12%	7%
RR Cotton area	0	0	1 500	3 500	2 500
% Bt Yellow Maize	3%	5%	14%	20%	27%
Bt Yellow Maize area	50 000	75 000	160 000	197 000	250 000
% Bt White Maize	0	0	0.4%	2.8%	8%
Bt White Maize area	0	0	6 000	55 000	175 000
% RR Soya-beans	0	0	5%	10.9%	35%
RR Soya-beans	0	0	6 000	11 000	47 000

Source: Percentages - CottonSA and SANSOR
Area – author's own estimations

The US cotton seed company, Delta and Pine Land (D&PL), has the sole use of Monsanto's Bt cotton gene in their cotton seed in South Africa. In 1997/1998 D&PL introduced two Bt varieties – NuCOTN 35B and NuCOTN 37B. These two varieties were based on D&PL's older Acala 90 variety and were not initially adopted with great enthusiasm, as the newer Delta Opal, a conventional variety, was D&PL's more popular variety at the time. In 1998/1999 D&PL's cotton seed market share was estimated around 10% with Clark Cotton (also a cotton ginning company) selling most of the cotton seed in South Africa. 1999/2000 saw D&PL's market share increase to close to 20% and when NuOpal (Opal with Bt) was introduced for the 2000/2001 season D&PL's market share soared to over 80%. With the release of herbicide-tolerant cotton in 2001/2002 D&PL's market share increased to over 95% (Gouse et al, 2005)

The initial spread of Bt yellow maize was quite slow. In 2000/2001, after two years of experience with Bt yellow maize, farmers planted less than 3% of the total maize area under Bt maize. Farmers and seed companies suggested three reasons for the slow spread of Bt maize. First, the Bt hybrids that were on the market were not well adapted to the local South African consumer markets or to local agricultural production conditions. White maize is usually planted on 45-60% of the maize area, but Bt white maize was not for sale to farmers until the 2001/2002 production

season. The Bt yellow maize varieties that were available were not the ideal hybrids for the region. A second reason for slow adoption was that many farmers did not see a big productivity increased from the use of Bt maize seed. The main target insects of Bt maize in SA are the African maize stalk borer (*Busseola fusca*) and the Chilo borer (*Chilo partellus*). Many farmers feel that if they manage to plant at the recommended time, so as not to correlate with the moth flight times, they will have limited damage whether they plant Bt or conventional varieties. In addition many farmers felt that the increased yield from Bt maize was not enough to pay for the additional technology fee. Especially not when being compared to newer better adapted conventional hybrids. Thus, at first Bt was most likely mainly adopted in those areas where stem borers were a particularly difficult problem. The third reason for the initial slow spread of Bt maize was farmer's concern that they might not be able to sell their crops because of consumer concerns about GM food.

By 2000 and 2001 seed companies in SA had been able to cross the Bt gene into newer and more appropriate local yellow maize hybrids and in 2001 the first Bt white maize hybrids were released. Farmer's perception of low profitability with Bt maize also changed in 2001/2002 due to a substantial stalk borer infestation in a number of major maize production areas. Many farmers suffered high rates of damage and yield losses on their conventional maize and Bt maize rendered significant yield benefits due to more effective borer control. The final adoption constraint – farmers' concern regarding demand and consumer acceptance – has not become a significant reality in SA thus far. In the majority of cases farmers have had no problem in selling their GM maize and there currently exist no price premium on non-GM maize in SA. Exports of non-GM maize to niche markets in mainly Asia have been limited and in cases where it happened the profits were captured by the commodity trading companies and not by the producers.

2. Socio-economic Impacts – Evidence to date

South Africa is marked by a dualistic agricultural system, with a relatively small number of large-scale, commercial farmers producing more than enough agricultural products needed for national food security and a relatively large number of small-scale farmers producing on a subsistence level. It is thus important to take both small- and large-scale farmers into consideration when new agricultural technologies are introduced.

Comprehensive independent studies supplying information on the socio-economic impacts of the introduction and adoption of GM crops in South Africa are rather limited. A Rockefeller

Foundation supported study by the University of Pretoria assessed and compared the on-farm effects of Bt cotton and Bt yellow maize amongst small- and large-scale farmers. A Department for International Development (DFID) funded project by the University of Reading in the UK focussed on small-scale Bt cotton and a number of papers were published making use of the findings from both these studies. The French research institute *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD) in collaboration with the University of Pretoria are also actively involved with research on Bt cotton in South Africa and have produced a number of working papers. From 2001 to 2004 the University of Pretoria conducted a study on the socio-economic effects of Bt white maize amongst especially small-scale farmers in SA and a current Rockefeller Foundation supported study aims to measure labour effects of Bt maize and to make some ex ante labour estimations regarding herbicide-tolerant maize adoption by small-scale farmers. Little independent research has been done on RR soya-beans in SA but the impressive adoption rate (Table 1) suggests that farmers are benefiting from the new technology.

Insect resistant cotton

Studies on the impact of Bt cotton adoption amongst small-scale farmers in SA focussed on the Makhatini Flats in northern KwaZulu Natal. This is because the Makhatini Flats is the larger of only two areas in SA where smallholders have fairly continuously produced cotton over the last two decades. Depending on credit availability, the price of seed cotton and pre-season rain indications, between 2,500 and 10,000 ha of cotton is planted on the Flats annually. Bt cotton was first introduced on the Makhatini Flats in 1997 when 4 farmers planted demonstration trials on their plots. According to Monsanto the results where impressive and in 1998/1999 75 small-scale farmers planted Bt cotton on approximately 200 hectares. In 1999/2000 the number of Bt adopters rose to 411 farmers on about 700 hectares and in 2000/2001 to 1184 adopters on about 1900 hectares (Bennett, 2002). The impressive adoption rate of Bt cotton on the Makhathini Flats can partly be attributed to the success of the farmers who first adopted. Currently close to 95% of the cotton on the Flats are genetically modified but the total area planted by small-scale farmers has declined dramatically due to a lack of production credit and the low seed cotton price.

The yield benefits found with the use of Bt cotton in South Africa compares well with that reported to be found in Argentina (Qaim, Cap & De Janvry, 2003; Qaim & De Janvry, 2005). Yield increases due to more effective control of the bollworm complex in South Africa, like in Argentina, differs between large-scale commercial and small-scale farmers, mainly due to different pest control practises. Gouse et al (2003) found an 18.5% yield increase for large-scale

irrigation farmers for the 2000/2001 season, which compares well with a 16.8% increase measured on field trials at the Clark Cotton experimental farm in Mpumalanga. Large-scale dryland farmers enjoyed a 14% yield increase while small-scale dry land farmers enjoyed an increase in access of 40% in the wet 1999/2000 season (Gouse et al, 2003). These figures compare well with the findings in Argentina where large-scale commercial farmers were reported to enjoy 19% yield increases and small-scale farmers 41% yield increases. Like Qaim et al (2003) the South African researchers attribute the difference between the Bt yield advantages of small and large-scale farmers to the financial and human capital constraints that cause small-holders to invest in chemical pest control. By the time a small-scale farmers in SA has noticed bollworms, bought pesticides with a limited amount of cash or credit and started to spray, severe damages has already been done. Shankar and Thirtle (2005) showed that the average insecticide application level of small-scale farmers on the Flats is lower than 50% of the optimal level. Many small-scale farmers indicated that they were not even able to apply pesticides on their whole field due to a lack of time, knapsack sprayers, labour, and the cost of pesticide. With a low education level causing problems with the mixing of pesticides and the calibration of knapsack spraying nozzles, the efficacy and efficiency of insecticide applications is questionable for a large number of small-scale farmers.

Large and small-scale farmers in SA however still need to apply chemical insecticides for sucking insects like Jassids and Aphids and from time to time for insects like stinkbugs that were in the past all killed in the crossfire aimed at bollworms. Even though Bt adoption has significantly reduced farmer expenditure on insecticides, in most seasons the saving on chemicals alone have not been enough to offset the increased seed cost due to the additional technology fee levied by the Bt gene owner. The yield advantage with Bt cotton compared to conventional cotton is thus very important in the cotton seed decision. Preliminary results from a study by CIRAD in collaboration with the University of Pretoria (Hofs, Fok & Gouse, 2005) found no significant yield difference between Bt and conventional varieties on the Makhathini Flats in the dry 2003/2004 season. This can mainly be attributed to a low bollworm pressure and farmers who purchased Bt seed where thus in all probability worse off than farmers who planted conventional varieties as they had to spend more on seed. The dilemma in South Africa is however that, for most seasons, it is very difficult to predict the bollworm pressure for the season at planting time.

In the first couple of seasons since the introduction of Bt cotton in SA, small-scale farmers paid a substantially lower technology fee than large-scale commercial farmers. The lower technology fee for small-scale farmers can be explained by a combination of possible factors including

willingness to pay, an effort towards poverty alleviation by the multinational technology innovator, but more likely an endeavour to establish a market for transgenic cotton among small-scale producers as the small-holder farming conditions in South Africa are more applicable to the rest of Africa than that of South African large-scale farmers. The more agriculturally related reason is that large-scale dryland cotton farmers plant between 5.3 and 8 kg of seed per hectare while according to Vunisa (former cotton gin and input supplier on the Flats) many small-scale farmers are known to plant closer to 18 kilograms of seed per hectare.

Gouse, Pray and Schimmelpfennig (2005) showed in a static calculation using cotton production budgets by Gouse, Kirsten and Jenkins (2003) that despite facing a monopolist as a seed supplier and monopolist as a gene supplier South African cotton, farmers in 1999/2000 and 2000/2001 captured the lion's share of the additional welfare created by the introduction of the Bt technology in the South African cotton sector (Table 2). Even though D&PL's share of the additional profit seems small, they were able to, through their agreement with Monsanto, secure most of the South African cotton seed market. The technology supplier captures its share through the technology fee and farmers benefit through increased yield and saving on insecticide chemicals. Other benefits indicated by farmers included peace of mind, managerial freedom, saving on spraying water, labour and machinery but was not quantified or included in the calculation. Calculations show that, based on the 1999/2000 technology fees and if a small-scale farmer had to pay the same technology fee as large-scale farmers, small-scale farmers' share of the benefit will decrease to approximately 46% (from 69%) with 52% (increasing from 28%) accruing to Monsanto. Currently all farmers are paying the same techno fee based on whether cotton is produced on dryland or irrigation.

Table 2: Distribution of additional benefit according to farmer group
(Amounts in Rand at a Rand/US$ exchange rate of 8)

	Small-scale dryland farmers	Large-scale dryland farmers	Large-scale irrigation farmers
Seed company: D&PL	32 500 3%	54 600 2%	74 200 1%
Technology supplier: Monsanto	299 400 28%	1 309 800 52%	1 779 700 20%
Farmer	1 038 600 69%	1 323 500 45%	5 988 100 79%
Primary Consumer: Ginning company	0%	0%	0%
Insecticide companies	-90 600	-777 700	-1 086 400

SA is a net importer of cotton from mainly Zimbabwe, Zambia and Malawi and of late, importers were in many instances able to import seed cotton or ginned cotton from these countries for less than what they pay domestically. South African cotton gins would like to support cotton farmers in South Africa (especially irrigation farmers) so as to be relatively sure of a fixed, lower risk quantity of seed cotton that can be purchased and ginned to cover fixed cost. However, South African cotton farmers cannot compete with farmers in large cotton producing countries that enjoy subsidies nor with the small-scale farmers in other Southern African countries were labour costs are minimal and cotton producing climatic conditions ideal. In SA, cotton competes with mainly maize for area under irrigation and with maize and sunflower on dryland. In the 1999/2000 season an estimated 51 000 hectares of cotton were planted, showing a decline of more than 50% from the previous season's 99 000 hectares. The 2002/2003 harvest was estimated to be around 31 000 hectares and the current estimation for 2004/2005 is a mere 21 200 hectares. South African cotton farmers are dependent on, or rather exposed to a deflated cotton world price and a fluctuating Rand / US $ exchange rate. Large-scale commercial farmers can in most instances convert to a different crop or farming system, but for small-scale farmers in dry areas like the Makhathini Flats cotton used to be the difference between subsistence and poverty.

Bt maize

In South Africa and other Southern African countries the losses sustained in maize crops due to damage caused by the African maize stem borer (*Busseola fusca*), are estimated to be between 5 and 75% and it is generally accepted that *B. fusca* reduces the South African maize crop by an

average of 10% annually (Annecke and Moran, 1982). Accordingly, *Busseola fusca* and the *Chilo* stem borer (*Chilo partellus*) are the most harmful pests of maize and grain sorghum in South Africa (Kfir, 1997). A conservative estimation of 10% for damage caused by both *B. fusca* and *C. partellus* means an average annual loss of just under a million tons of maize with a approximate value of a US$ 100 million. Both *B. fusca* and *C. partellus* can be controlled to a satisfactory level with the use of the Bt gene currently used in South African Bt varieties, Cry1Ac.

Monsanto not only sells its Bt gene in its own hybrids but also licences this gene to other maize seed companies in South Africa like Pioneer Hi-Bred and Pannar, for use in their hybrids. In 2003 the biosafety committee of SA approved Syngenta's Bt maize, breaking Monsanto's monopoly on Bt genes in SA. Table 3 indicates the GM maize sources of genes and hybrids.

Table 3: GM maize sources of genes and hybrids

Crop	Source of gene	Source of hybrids	Year gene approved for commercial use	First planting year
Bt Yellow maize	Monsanto	Monsanto	1998	1998
	Monsanto	Pioneer	1998	1999
	Monsanto	Pannar	1998	1999
	Syngenta	Syngenta	2003	2003
	Dow	Pioneer	future	future
RR Yellow maize	Monsanto	Monsanto	2003	2003
Bt White maize	Monsanto	Monsanto	1998	2001
	Monsanto	Pioneer	1998	2001
	Monsanto	Pannar	1998	2004
RR White maize	Monsanto	Monsanto	2003	2003

Source: Gouse, Pray, Kirsten & Schimmelpfennig (2005)

Gouse et al (2005) found that large-scale commercial maize farmers benefit economically from the use of insect resistant yellow maize. Despite paying more for seeds, farmers who adopted Bt yellow maize enjoyed increased income on Bt maize compared to conventional maize through savings on pesticides and increased yield due to better pest control. Data from a total sample of 33 farmers, producing maize under dryland and irrigation conditions were collected for the 1999/2000 and 2000/2001 seasons. Table 4 summarises the yield advantages enjoyed by large-scale yellow maize farmers who adopted Bt maize. It is important to note that the differences in

mean yields of Bt and conventional hybrids were statistically significant (at a 95% confidence level) only in the total irrigation and the total dry land calculations. Farmers did not report a high level of stem borer infestation in either season or survey region. It is important to note that these yield benefits can be expected to vary between regions and farmers and seasons according to the stalk borer pressure in the particular season, the conventional variety the Bt variety is compared with, and the pest control practises of the particular farmer.

Table 4: Average maize yields for Bt and conventional hybrids 1999/2000 and 2000/2001

Province	Production condition	Yield with Bt maize (kg)	Yield with Conventional maize (kg)	% Yield advantage
Mpumalanga	Irrigation	11 280	10 500	7%
Northern Cape	Irrigation	12 160	10 860	12%
Total	Irrigation	12 081	10 881	11%*
Mpumalanga	Dryland	5 000	4500	11%
North West	Dryland	3 130	2 920	7%
Total	Dryland	3 398	3 072	10.6%*

Note: * Statistically different at 95% confidence level
Source: Gouse et al, 2005

Contrary to what was found by Marra, Pardey and Alston (2002) in the US, the level of damage caused by stalk borers in South African in most seasons and maize production areas necessitates application of chemical insecticides. Depending on the seasonal stalk borer infestation level, saving on insecticides has been found to be significant with Bt maize.

In 2003/2004 the University of Pretoria conducted a new survey of 40 large-scale farmers producing white maize on mainly dryland in Mpumalanga and the Eastern Free State. More than 50% of the farmers indicated that stalk borers on conventional maize are only a problem when they are forced by rain to plant late or early, while 44% of the farmers indicated that stalk borers are a problem every season. 32% of farmers indicated that they spray conventional maize for stalk borers every season as a precaution while 24% indicated that precautionary spraying for stalk borers is done only in some seasons – when planting late or early.

Despite the fact that almost all the farmers indicated that Bt maize seed was too expensive due to the additional technology fee, 34 farmers (87%) indicated that they are planning to plant Bt maize again next season and 3 farmers will not be planting maize at all in the following season due to

the low grain price. Only 20% of farmers indicated a yield increase to be the most important benefit, 31% of farmers indicated a decrease in expenditure on chemical insecticides and application as the most important benefit, while 34% indicated peace of mind about stalk borers and easier crop management as the most important benefits. Almost all the farmers agreed that the stalk borer pressure on conventional maize in 2003/2004 was lower than normal.

Of the 40 surveyed farmers only 21 were able to make a yield comparison between the yields of Bt and conventional maize as produced under dryland conditions. Of the 21 farmers 12 farmers thought there was no substantial difference between the yield of Bt maize (no insecticide) compared to that of conventional maize that was sprayed with insecticides. Farmers attribute the small yield difference to a low stalk borer pressure in 2003/2004. On irrigation schemes, where farmers produce maize intensively year after year, stalk borers are a more regular and serious problem. Chemical control is expensive and even though these farmers can apply insecticides through the irrigation system (pivots), it interferes with the irrigation program and high plant density decreases effectiveness of chemical applications. According to an extension agent in the Douglas irrigation scheme area (Northern Cape), farmers in this area have seen yield increases of approximately 2 tons (about 12%) with Bt maize when stalk borer pressure is high (Coetzee, 2004).

The fact that South African large-scale maize farmers benefit from the Bt technology is not really surprising as the farming practises and managerial skills of South African large-scale farmers compare well with that of farmers in developed countries where the Bt technology was developed. Due to the innate insect control ability of Bt maize, one would expect that this technology could also appeal to small-scale farmers.

In 2001/2002 Monsanto introduced Bt white maize to small-scale farmers through workshops in nine areas in four provinces in South Africa. Farmers who wished to try out the new seeds received two small bags of white maize seed. One of the bags contained 250grams of CRN 4549 seed, also known as Yieldgard, insect-resistant or Bt maize seed, while the other bag contained 250grams of the isoline conventional variety (CRN 3549 that is genetically identical to CRN 4549 except that it does not contain the Bt gene). As Monsanto supplied only a small quantity of seed to each farmer, farmers still had to buy and plant their own seed of choice, or use their own saved maize seeds. In the second season (2002/2003) small-scale farmers had to, as usual, buy maize seed based on their experience of the previous season.

The University of Pretoria studied the first three seasons of Bt white maize production by small-scale farmers in South Africa (Gouse & Kirsten, 2004). The first season rendered some interesting results with 175 small-scale farmers across 6 sites reporting yield increases between 21 and 62 percent and an average of 32% with Bt maize above the conventional isoline. It is however thought that these findings might have been influenced by some preconceived yield increase perceptions by small-scale farmers due to the workshops and free seed samples. Unfortunately for the study and unfortunately for many small-scale farmers, only a limited number of farmers were able to buy Bt seed for the 2002/2003 season due to a limited seed supply and an increased demand for Bt seed by large-scale farmers. The 2002/2003 season saw an impressive demand for Bt seed from various sites (Transkei for instance ordered 4,5 tons of Bt seed), but in only two sites in KwaZulu Natal (KZN) were a significant number of subsistence farmers able to purchase Bt white maize seed. Despite a lower than normal rainfall and stalk borer pressure in 2002/2003, small-scale farmers in KwaZulu Natal enjoyed a statistically significant yield increase of 16% due to better stalk borer control with Bt maize. Bt maize adopting farmers were better off than farmers who planted conventional hybrids, despite the additional technology fee. In 2003/2004 no significant difference between the yields of Bt and conventional maize seed could be found due to drought, a very low stalk borer infestation level as well as damage to maize ears caused by late rain, which complicated measuring and comparing yields.

Based on the findings of thee years of research it was concluded that small-scale subsistence farmers in South Africa can benefit from the use of genetically modified insect resistant white maize. Like with large-scale farmers, due to the nature of the technology, small-scale farmers can only benefit from the use of Bt maize seed if stalk borers are present in that particular season. Even though farmer perception suggest otherwise, saving on insecticides were not found to be substantial due to a low level of chemical insecticide application, linked to the low stalk borer pressure the last couple of seasons. In the third season, which was also the fourth drier than usual consecutive season in the research area, the stalk borer infestation level was very low and farmers who planted Bt maize enjoyed similar yields as farmers who planted conventional hybrids and were thus in all likelihood marginally worse off due to the additional technology fee. It seems as if small-scale farmers have realised this to a certain extent, not only for Bt maize seed but also for expensive conventional hybrids, as a large number farmers in KwaZulu Natal in 2003/2004 and also in the current 2004/2005 season, bought Bt and conventional hybrids but decided not to plant it after a very dry pre-season. In order to minimise financial risk they planted some traditional seed or less expensive open-pollinated varieties without fertiliser and plan to plant the Bt and

conventional hybrids with fertiliser next season that they hope and pray will be a wetter more maize production friendly season.

Trade effects of Bt cotton and maize adoption

With South Africa producing yellow maize mainly for animal feed and white maize for predominantly human consumption, the maize sector has for years been geared to separate white and yellow maize and partly because of the previous government's emphasis on self-sufficiency, South Africa has ample silo storage facilities for grain. Infrastructure and a history of control on what goes where has made it possible to separate GM and non-GM maize if necessary and to a acceptable level. South Africa is a net exporter of maize to countries like Japan, Zimbabwe, Zambia, Malawi, Mauritius, Kenya and Mozambique and if there is a demand is able to supply non-GM maize. Where non-GM maize is required, farmers have to declare whether they are delivering GM or non-GM maize, the maize is tested using an Elisa test kit and the maize is deliver into specific silos. It has also become more common for companies or exporters that require non-GM maize to contract specific farmers to produce the maize for them. South Africa has made the decision to not separate GM and non-GM white maize that is milled for human consumption. However, a couple of companies that produce and export products like maize starches and glucose have, most likely for precautionary reasons, made the decision to only purchase non-GM maize for the time being. A large quantity of yellow maize is also exported to cattle feedlots in Namibia and according to their export contracts with the European Union, Namibian feedlots are not allowed to feed their cattle GM maize. So even though, up to now, earning a premium on non-GM grain has been more the exception than the rule, there does exist a demand for non-GM maize and the South African maize sector has been able to manage maize grain deliveries so as to be able to supply in the demand for GM and non-GM maize. With South Africa being a net importer of cotton from surrounding countries that only plant non-GM cotton and with cotton being an industrial crop (non-food), there has been no trade concerns.

3. Institutional challenges for R & D

In a 2003 National Biotechnology Survey it was found that 622 research groups are engaged in 911 research projects relevant to biotechnology in South Africa. The survey identified 106 companies active in modern biotechnology in South Africa. Biotechnology is the main business focus for 47 of these companies (core biotechnology) and the rest were non-core biotechnology - just utilising biotechnology. Of the core biotechnology companies, 39% were in human health

and 13% supplied support services; 26% of the non-core biotechnology companies are in the plant sector and the human health and industrial sector made up 15% each. The number of core biotechnology companies has increased since 1984 from 4 to 47 in 2003 but growth in the non-core biotechnology companies has been slow. Less than 20% of South Africa biotechnology firms have an annual revenue above R10 million. Of the core biotechnology companies 33% are new start-ups and 37% spun off from research groups. The majority of research groups are small and engage 10 or fewer researchers. Biotechnology research projects are spread over a number of sectors including human and animal health, plant, food and beverage, industrial, environmental and others. The human health sector has the most projects with the plant sector in the second place. The survey identified 30 plant biotechnology and 22 food and beverage companies. It is estimated that only 10% of biotechnology companies are conducting innovative cutting edge research and development, with the majority involved in new applications of low-tech modern biotechnology (DST, 2004).

In 2001 the Department of Arts, Culture, Science and Technology (DACST) made some rough estimations regarding the financial extent of investment in biotechnology R&D in South Africa:

- ARC - US$ 2 million
- Mintek - < US$ 0.17 million
- CSIR - US$ 4 million
- Universities and technikons - US$ 10 million
- Private sector – US$ 2 million

Some current and former plant biotechnology projects in South Africa include:

1. The Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria has, since establishment in 1997, been actively involved in goal directed biotechnology research focussed on the agricultural and forestry sectors and is currently shaping to become a world leader in specifically biotechnology R&D aimed at the forestry sector.
2. The Department of Molecular and Cell Biology at the University of Cape Town are developing maize resistant to the African maize streak virus and maize that are tolerant of drought and other abiotic stresses. They are also investigating the use of tobacco plants to produce vaccines for human use.
3. The South African Sugar Experimental Station has been able to develop herbicide tolerant sugarcane. This project is currently in the field trail stage.

4 The Council for Scientific and Industrial Research (CSIR) has genetically engineered maize with a gene isolated from beans to develop resistance to the fungal pathogen, *Stenocarpella maydis*. This project is currently at he field trail stage. The CSIR has also, in collaboration with overseas partners, been able to introduce four antifungal genes into maize to confer resistance to *Fusarium moniliforme*. Pearl millet has also been engineered to render the crop resistant to *Sclerospora graminicola*, which causes downy mildew (Thomson, 2004)

5 The Agricultural Research Council (ARC), fruit research institute, Infruitec. One of their main projects saw the development of an herbicide resistant strawberry. Results were extremely good but the project was shelved because it was too expensive for the private chemical company involved to licence the use of the specific herbicide on strawberries in South Africa.

Eleven of the thirteen Institutes of the ARC are involved with biotechnology research but only three are conducting research on transgenic crops. These include the Vegetable and Ornamental Plant Institute, the Grain Crops Institute and the Infruitec-Nietvoorbij Institute. These institutes have and are developing transgenic applications in potatoes, tomatoes, maize, lupins, soyabeans, tobacco, melons, pears, apples, apricots, plums, strawberries and groundnuts. The ARC has conducted field trails on their own research material as well as on contract for private companies testing maize, cotton, tomatoes, potatoes and strawberries.

Despite the existence of several centres of excellence in South Africa, where research is driven by well-trained and experienced staff, there is generally a lack of adequate expertise and skilled personnel. This is a major constraint on the development of biotechnology in South Africa and the constraint is not restricted to biotechnology only (DACST, 2001). Statistics from the 1997/1998 National R&D Survey indicated that South Africa numbered 7 researchers per 10 000 labour force, compared to the USA with 59 and Korea with 64 per 10 000. South Africa is also lagging behind its peers when it comes to the commercialisation of technology. According to the Human Development Report of 2001, South Korea registered 779 patents per million residents in 1998 and Australia 75. In comparison South Africa only registered 2.5 technology patents in 2001 (Katsnelson, 2004).

Despite high quality biotechnology research projects to be found in different sectors and organisations, the system is fragmented and up to now has delivered very little marketable outputs. Wolson (2005) suggests several reasons for this. Institutional arrangements has not been

conducive to promoting sufficient effective linkages between researchers in different disciplines and/or organisations, as well as between researchers, industry and government and have encouraged a linear approach to R&D. Human resource considerations include the generally low percentage of researchers in the labour force, brought about by limited employment opportunities in the local biotechnology industry for graduates (exacerbated by much better opportunities overseas – in SA an average post-doctoral income is estimated to be but 40% of the amount an good post-doc fellow could earn abroad (DACST, 2001)). Better opportunities abroad has led to a "brain drain" leaving limited numbers of skilled people for entrepreneurship in biotechnology. Limited R&D funding from both public and private sources handicaps the R&D system as a whole and the sector is characterised by particularly low private R&D engagement. Public funding programmes tend to be uncoordinated and in many cases not necessarily focussed on appropriate outputs. A relatively risk averse venture capital sector has not displayed much interest in investing in biotechnology and the general environment for commercialisation of biotechnology has not been conducive for establishment of private biotechnology firms.

In "The White Paper on Science and Technology" the South African government indicated that government considers science and technology as central to creating wealth and improving the quality of life in contemporary society. The South African government recognised its responsibility for creating and enabling an environment for innovation, specifically as a means of achieving the national imperatives of reducing the impact of HIV/AIDS, job creation, rural development, urban renewal, crime prevention, human resource development and regional integration. It is believed that biotechnology can play a major role in addressing these imperatives (DACST, 1996).

Realising that South Africa has failed to extract value from the more recent advances in biotechnology the South African government, through the Department of Arts, Culture, Science and Technology (DACST) released a "National Biotechnology Strategy for South Africa" in June 2001. In the document the South African government again identified biotechnology as a key technology platform and announced a series of policy initiatives to stimulate the development of an active and productive South African biotechnology industry. The South African government has committed an initial R450 million (US$75 million) from 2004 to 2007 to biotechnology development and the establishment of a biotechnology development conducive institutional, regulative and economical environment. In order to increase specific focus the DACST was divided into the Department of Science and Technology (DST) and the Department of Acts and Culture in August 2002.

In the National Biotechnology Strategy (2001) a number of objectives were formulated and strategic interventions suggested. Stemming from these objectives and interventions and supported by the funds made available by government a number of institutions or bodies had arose to date: Three Biotechnology Regional Innovation Centres (BRICs) and one National Innovation Centre have been established. The BRICs acts as nuclei for the development of biotechnology platforms from which a range of businesses and companies offering new products can be developed. These centres facilitate sharing of capital, equipment and specialised expertise; they disburse funding to existing research programmes at R&D organisations and industry and attract regional anchor investors (Wolson, 2005). The current existing BRICs are:

1. BioPAD – Biotechnology Partnerships for Africa's Development. Situated at "The Innovation Hub" in Pretoria and focuses on animal health, industry, mining and environmental related biotechnology (www.biopad.co.za). BioPAD also supports Bioresource Centres (BRC), which include regional breeding programmes, seed collections, insect collections, fungi collections and gene libraries at various institutes, to make them accessible for research and commercial purposes. These BRCs together with BioPAD have to ensure that the natural heritage of South Africa is protected and used on a manner that complies with national and international frameworks.
2. Cape Biotech – Cape Biotechnology Initiative is situated in Cape Town and focuses on human health and bioprocessing and acts as a biotechnology cluster development initiative as well as a funding body (www.capebiotech.co.za). Some of the current projects include: investment in the existing mircoarray facility situated at the University of Cape Town, investment in the Biovac institute to create a facility to produce clinical trail doses of developmental biotechnology products, Shimoda Biotech (Pty) Ltd a biopharmaceutical discovery company, Synexa Life Sciences (Pty) Ltd which manufactures high-value microbial secondary metabolites for the life science and pharmaceutical industries, SunBio a wine yeast project in conjuncture with the University of Stellenbosch and Genecare Molecular Genetics (Pty) Ltd who develops molecular assays and test guidelines for genetic diagnostics in routine clinical practise.
3. EcoBio – East Coast Biotechnology. Situated in Durban, this BRIC operates under the trade name LIFElab. LIFElab supports projects that stimulate the bioprocessing sector and projects that focus on infectious diseases like TB and HIV/AIDS as well as on Malaria (www.lifelab.co.za).

The National Innovation Centre for Plant Biotechnology (PlantBio) is situated in Pietermaritzburg in KwaZulu Natal and focuses on all aspects of plant biotechnology in South

Africa and plant biotechnology projects in the Southern African Development Community (SADC) are also considered for support (www.plantbio.co.za).

In early 2003 the programme on the "Public Understanding of Biotechnology" (PUB), was launched through the South African Agency of Science and Technology Advancement (SAASTA), which is part of the National Research Foundation (NRF). The PUB programme is funded by the DST. The overall aim of the PUB is to promote a clear understanding of the potential of biotechnology and to ensure a broad public awareness, to stimulate dialogue and debate on biotechnology's current and potential future applications, including genetic modification. The target audience includes all facets of society with emphasis on consumers, educators and learners (www.pub.ac.za). In a recently released study commissioned by PUB it was found that South Africa's knowledge and understanding about biotechnology is limited. In reply to the question "What do you think when you hear the word biotechnology?" 82% of 7000 respondents indicated that they did not know what they thought (HSRC, 2005).

Another initiative, the National Bioinformatics Network (NBN) has been created to develop capacity in bioinformatics in South Africa, especially among disadvantaged groups, and to perform rigorous bioinformatics research. The vision of the NBN is to place South Africa within ten years in the mainstream of bioinformatics, then being in a leading position amongst developing nations (www.nbn.ac.za).

In 2003 a biotechnology incubation institute, eGoli BIO Life Sciences Incubator was launched. This incubator is closely affiliated with the BioPAD BRIC and is a joint initiative between the CSIR Bio/Chemtek unit, the Innovation Hub and AfricaBio and is financially supported by the DST, the Department of Trade and Industry and the European Union. The aim of the incubator is to serve as a development conduit for the commercialisation of life sciences research, products, services and technology platforms by supplying business infrastructure, strategic guidance, financial and legal advice and creating an environment of learning and sharing in which information, experience and ideas are freely exchanged (www.egolibio.co.za). A number of new companies have made use of this initiative and there are currently four tenant companies present.

Property rights

South Africa has well developed and implemented legislation on intellectual property rights, patent rights and plant breeders rights and has a respected legal and judiciary system to enforce compliance. South Africa has ratified a number of international property right treaties and

conventions that apply to biotechnology. Some of these include TRIPS, CITES, IUGRFA and the Cartagena Protocol on Biosafety. There are however also a number of National Acts that apply to biotechnology in South Africa. The National Biotechnology Strategy points out that in order to create a favourable biotechnology innovation environment, some of these Acts need to be amended and that some of the Acts are not consistent with one another. For instance, various Acts only address the phenotypic characteristics of an organism and would need to be amended to take into account the genetic characteristics that biotechnology deals with to control the movement of genetic material, intellectual property rights and the exchange of information (DACST, 2001). Government is currently drafting legislation for a revised intellectual property rights framework. It has been proposed that the new legislation will roughly follow the US Bayh-Dole Act in which research institutions are granted ownership of inventions developed with government funds, but would also have to take into account South Africa's small size and young biotechnology sector (Paterson, 2004).

4. Institutional challenges for commercial dissemination

South Africa has a well-developed seed sector, with local and international players and with an annual turnover close to R1 000 million (US$ 160 million). Seed for maize and wheat account for 66% of the seed market, vegetable seed is second with 18%, pasture/forage accounts for 13% and flowers 3% (Kirsten & Gouse, 2002). On the South African variety list of October 2004 there were more than 400 registered white and yellow maize hybrids available for commercial production. These hybrids are marketed by 18 companies or institutions and there are also a number of high lysine and open pollinated varieties available. Four companies dominate the maize seed market. The South African company PANNAR owns 44% of the hybrids on the variety list, Monsanto 23%, Pioneer Hi-bred 18% and Syngenta 16%. The number of hybrids not necessarily equates to quantity of seed sold but PANNAR is the leading maize seed company in South Africa. Monsanto, through its acquisition of two South African seed companies (CARNIA and SENSAKO) in 1999/2000, has been able to capture a major share of the maize seed market and also owns 48% of the wheat hybrids on the variety list. All these companies' germplasm R&D has mainly focussed on developing high yielding varieties for commercial farmers using plenty of fertiliser. Only the ARC with a number of open pollinated varieties and PANNAR have really purposefully invested in development and marketing of maize varieties more conducive for subsistence farming. Syngenta with its partnership with Seedco in Zimbabwe might also be heading in this direction.

The truth is that constraints for commercial dissemination of genetically modified crops in South Africa have been few. With plant breeder's rights, intellectual property rights, a well-developed seed sector, and the biosafety regulatory system in place, the introduction and commercialisation of genetically modified crops in South Africa have been rather smooth and straightforward. Consumer tumult has been limited to mainly small usually well-off, expensive organic products and free-range chicken purchasing consumer groups and a couple of anti or provisionally anti-GMO groups like Biowatch and the South African freeze alliance on genetically engineering (SAFeAGE). It seems as if these groups have been able to delay the "stacked gene" decision in some way or another and Biowatch has recently been able to, through verdict in a court case, marginally increase the amount and accuracy of information the biosafety regulatory authority has to publicly release regarding permit applications. Even though delay of release of a technology has financial implications for biotechnology companies and more importantly potentially for farmers, these anti-GMO groups play a necessary, yet mostly unappreciated, watchdog role in keeping the regulatory system and seed and biotechnology companies honest.

South Africa's commercial farmers are hungry for technology that can increase efficiency and they are operating in an environment were production credit and information is available. The major challenge for commercial dissemination of GM crops in South Africa would be and is how to make these technologies accessible to the small-scale farmers whom can greatly benefit but struggle to afford the technology and some inputs that accompany it. Results have shown that small-scale farmers benefit form the use of insect resistant maize and in many instances small-scale farmers in South Africa have benefited more from the use of insect resistant crops than large-scale farmers. It is thought that herbicide tolerant maize could also greatly benefit small-scale farmers, as it would reduce the need for weeding labour. South African small-scale, subsistence farmers make use of mainly family labour for weeding. In a country where an increasing number of rural households are run by elders and children because a significant percentage of the economically active family members are either working in the city, sick and weak with HIV/AIDS or have already passed away due to HIV/AIDS, labour is becoming expensive and inefficient. Making use of conservation tillage, controlling weeds with chemical herbicides and using herbicide tolerant varieties farmers should be able to decrease the need for expensive mechanised land cultivation (many small-scale farmers currently make use of contractors) and decrease the need for weeding labour.

For a crop like cotton, where the harvest can be used as collateral for credit, expensive inputs can be sold on credit and that is also part of the reason why adoption of Bt cotton on the Makhatini

Flats has been so rapid. With credit available through the ginning company farmers were able to buy the more expensive seed and were in fact encouraged to do so as the ginning company, observing the increased yields with Bt cotton, wished to decrease their own credit risk. For food crops like maize there are however no production credit available to small-scale, subsistence farmers as these crops are produced to be consumed by the household. Land cannot serve as collateral either as the vast majority of small-scale farmers do not own the land they live and farm on. The land belongs to the local tribe and farmers merely have permission to occupy.

The Makhatini Flats GM cotton story can serve as a good example for developing countries who are still pondering the possible release of GM cotton. In the first couple of years after commercial release farmers on the Flats farmers were benefiting from Bt cotton through mainly increased yields and fewer pesticide applications. The ginning company (Vunisa) in partnership with the Land Bank of South Africa was supplying production credit and in 1998/1999 there was a loan recovery rate of close to 90%. Then in 2001/2002 a new ginning company erected a new gin on the Flats. A substantial number of farmers, who took production credit from Vunisa, avoided repaying their loans by selling their cotton to the new gin. Having suffered substantial losses Vunisa and the Land Bank no longer offered loans in 2002/2003 and in the 2004/2005 production season there was still no credit available to small-scale cotton farmers on the Makhatini Flats. Exacerbated by the low cotton price, area planted under cotton on the Flats decreased drastically. The Makhatini Flats cotton story emphasises that without good governance and institutional structure the potential gains of GM crops will not be realised (Gouse et al, 2005).

Adoption of genetically modified maize hybrids could expand if companies are willing to segment the seed market and charge lower prices to small-scale farmers than large-scale commercial farmers. PANNAR currently has such a programme with some of their conventional hybrid seed. PANNAR produces some less expensive (to produce) double-cross hybrids or open pollinated varieties and sell them at lower prices to small-scale farmers. At the same time PANNAR produces high cost (single cross) hybrids and sell them at a premium to commercial farmers. This pricing strategy may however not be possible if the biosafety regulation process is structured so that it is more expensive to provide new technology to small-scale farmers than it is to large-scale farmers. Under the current system every farmer who buys Bt or RR seed has to sign a contract with the company who sells the GM seed to ensure that the farmer plants the seed where he says he will plant it and abides by the stated refuge requirements. This is relatively easy when dealing with large-scale farmers but when thousands of small-scale farmers have to sign contracts it can very easily become an expensive administrative nightmare and could very well

lead to a decision of not marketing GM seed amongst smaller subsistence farmers at all (Gouse, 2005).

An increasing percentage of small-scale farmers in South Africa are planting hybrids, and make use of chemical fertiliser and herbicides. The adoption level is especially high in regions of KwaZulu Natal and Mpumalanga where PANNAR has actively marketed hybrids through extension officers. However in many poorer parts of South Africa and especially in the former homeland areas hybrid adoption is still minimal. Even though most small-scale farmers know about hybrids and chemical fertiliser some just cannot afford such a capital investment and others are not willing to invest in expensive inputs for a risky endeavour like dryland maize production. It can be expected that adoption of genetically modified maize seed in areas that has not even adopted hybrid seed yet, will be limited.

5. Institutional challenges for regulation

In 1978 the South African Committee for Genetic Experimentation (SAGENE) was formed to be responsible for promotion of all aspects of recombinant DNA, providing guidelines and approving and classifying research centres and projects. SAGENE consisted out of members from the research councils, National Departments, Committee of University Principals, the Southern African Institute of Ecologists and Environmental Scientists and the Industrial Biotechnology Association of South Africa. The committee dealt with all requests for permission to carry out laboratory, glasshouse or field trials with genetically modified organisms (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 (Thomson, 2002).

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 to promote the responsible development, production, use and application of genetically modified organisms in South Africa was only implemented in

December 1999. 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.

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

1. The Executive Council. This is the 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 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 replaced SAGENE and advises 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)

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). In the period 2000 to 2004 more than 900 permits for glasshouse and field trials, contained use, commodity clearance, imports and exports were reviewed and granted. The applications for commercial release of insect resistant cotton and maize and herbicide tolerant cotton, maize and soya-beans were reviewed and approved in, what has been regarded as a scientifically responsible yet efficient manner and South African farmers have been able to benefit economically due to timely access and utilisation of a new agricultural production technology. The enthusiastically awaited commercial release of cotton with the "stacked gene" (Bt and RR combined), has however been met with more regulatory resistance. Application for commercial release were submitted in 2001and in May 2005 the decision was still pending. This is strange as both Bt and RR had already been approved and cotton with a stacked gene can be produced using conventional breeding methods. Reasons for the holdup are unclear but it does seem as if anti-GM lobby groups have been able to influence the Registrar in one way or another.

Ratification of the Cartagena Protocol by South Africa in August 2003, impacted on the regulatory system and mainly necessitated some minor changes to application forms for, in particular, import and export permits.

5. Policy challenges and conclusion

The South African government has recognised the role biotechnology can play in agriculture, food security, rural development and poverty elevation and has stressed the importance of the creation of a knowledge based "bioeconomy" for South Africa as an international player and a leader in Africa. The South Africa government faces the considerable challenge of creating a policy, legislative and R&D environment where large-scale commercial farmers can produce affordable food for the increasingly urbanised South African population and the famine prone SADC region and where small-scale and emerging previously disadvantaged farmers can produce agricultural products of value in a sustainable manner and where subsistence farmers can increase their food security. At the same time South African farmers should be able to produce agricultural products for the international market and niche markets where a premium can be earned.

South African agriculture is battling to transform and to bring previously disadvantaged farmers into the mainstream of the agricultural economy. A land redistribution programme is underway and important policy changes, related to improving the support framework to new and smaller scale farmers to assist them into becoming truly independent farm entrepreneurs, are being contemplated. A new finance scheme for small-scale farmers and an improved extension and support system are taking shape.

Despite an impressive biotechnology research history, there is currently great concern about the capacity and ability of the ARC, to deliver and continue with sound and effective research in this field. In the last couple of years a lack of funding, human resources and capacity as well as poor management has plagued this organisation and have affected the whole agricultural research system. A redesigned institutional and funding framework is urgently needed to ensure that this organisation can continue its vital role as leading agricultural research provider in South Africa.

The incentives and initiatives created through the "National Biotechnology Strategy" are certainly positive and a step in the right direction. While the R450 million (US$ 75 million) made available by government to implement the "National Biotechnology Strategy" is substantial in African terms, it remains small by international standards (Wolson, 2005). More funds are needed to stimulate development and commercial dissemination. Sharing of R&D investment risk through a tax concession might serve as ample initiative for private companies.

South Africa has a vast biodiversity that presents to biotechnological entrepreneurs immeasurable

possibilities and opportunities. It is therefore extremely important that South Africa ensure that the correct legislation and institutions are in place to protect and utilise this resource to the benefit of the environment and South Africans.

The Makhatini Flats', technological triumph but institutional failure story emphasises the importance of governance and institutional structures and cooperation for successful adoption and dissemination of GM crops. It also serves as a reminder that in most cases scientific advances really are easier than establishing the social and economic conditions necessary for progress to occur.

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