biosafety, biopiracy and biopolitics series

biotechnology, seed and agrochemicals

global and south african industry structure and trends

african centre for biosafety

booklet 11

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ISBN: 978-0-620-42912-2

www.biosafetyafrica.net

PO Box 29170, Melville 2109 South Africa
Tel and Fax: +27 (0)11 482 8915

The African Centre for Biosafety (ACB) is a non-profit organisation, based in Johannesburg, South Africa. It provides authoritative, credible, relevant and current information, research and policy analysis on genetic engineering, biosafety, biopiracy, agrofuels and the Green Revolution push in Africa.

Design and layout: Adam Rumball, Sharkbuoys Designs

Printed by: PressPrint

Acknowledgements
This publication has been made possible as a result of the generous support of EED, HIVOS and Swedbio.

Contents

Acronyms

ACDASA	Agricultural Chemical Distribution Association of South Africa
ARC	Agricultural Research Council
BRICs	biotechnology regional innovation centres
Bt	*bacillus thuringiensis*, a naturally-occurring soil bacteria used as an insecticide
CEO	Chief Executive Officer
CMCS	Chemical Marketing and Consulting Services
CSIR	Council for Scientific and Industrial Research
D&PL	Delta & Pine Land Cotton Company
DAP	diammonium phosphate
DST	National Department of Science and Technology
DTI	National Department of Trade and Industry
ECoBio	East Coast Biotechnology Consortium
EU	European Union
FABI	Forestry and Agricultural Biotechnology Institute at University of Pretoria
FAO	Food and Agriculture Organisation of the United Nations
GM	genetic modification
GURTs	Genetic Use Restriction Technologies
HESA	Higher Education South Africa
IDC	Industrial Development Corporation
IPR	intellectual property rights
IT	information technology
MAP	mono-ammonium phosphate
NRF	National Research Foundation
OPVs	open pollinated varieties
PVP	plant variety protection
R&D	research and development
rBGH	recombinant bovine growth hormone
rBST	recombinant Bovine Somatotropin
RR	Roundup Ready
SANBI	South African National Bioinformatics Institute
Sansor	South African National Seed Organisation
Seda	Small Enterprise Development Agency
THRIP	Technology and Human Resources for Industry Programme (DTI)
TSP	Technology Station Programme (DST)
US	United States of America

"the essential purpose of food, which is to nourish people, has been subordinated to the economic aims of a handful of multinational corporations that monopolize all aspects of food production, from seeds to major distribution chains, and they have been the prime beneficiaries of the world crisis."

Miguel d'Escoto Brockmann, President of the UN General Assembly, 25 September 2008, United Nations, New York[1]

1. http://appablog.wordpress.com/2008/09/26/opening-remarks-by-h-e-m-miguel-d%E2%80%99escoto-brockmann-president-of-the-general-assembly-at-the-high-level-event-on-the-millennium-development-goals-25-september-2008-united-nations-new-york/

executive summary

Global context

The commercial introduction of agro-biotechnology demands that corporations have three assets under their control: biotechnological know-how; strong intellectual property rights (IPR); and a broad proprietary base of high quality germplasm. Biotechnological know-how was mainly located in universities and public sector institutions, which carried out the basic research and development (R&D). IPR on living organisms was a new field and undeveloped. The seed industry was mainly decentralised in a large number of independent, mainly regionally-based seed companies.

In 1980 the US Supreme Court made a decision that living organisms were patentable. This sparked the growth of commercial biotech in the US. Support to biotech start-ups was based on high levels of speculation, which seldom paid off in the short term. Other countries followed later, including China (a mainly public biotech sector), Canada, the EU and Japan. Over time, consolidation in the sector led to domination by a few very large companies. Especially after 2000, the big pharmaceutical companies began purchasing biotech companies that had products near commercialisation. By 2007, the top 10 biotech companies accounted for two-thirds of the sector's total revenues. Biotechnology became the engine of innovation in the drug industry.

In comparison to the healthcare industry, agricultural biotech (agbiotech) played a relatively minor role in the development of the sector. Most research and development (R&D) was conducted by the major agrochemical and seed companies, and it was these companies that began investing in agbiotech. Changes in the agbiotech industry structure were largely driven by the desire to control the three assets: biotech knowledge, IPR and quality germplasm. If IPRs are well-defined and transaction costs are low, contracting and licensing arrangements are favoured. Where IPRs are not well-defined, companies might

2. Vertical integration is the process in which several steps in the production and/or distribution of a product or service are controlled by a single company or entity, in order to increase that company's or entity's power in the marketplace.

prefer to buy out seed companies rather than license to them. Vertical integration[2] was also favoured where products are complementary or where greater value could be gained from outright ownership of seed companies.

The seed-agrochemicals industries saw a rapid increase in both vertical and horizontal concentration in the mid- to late-1990s in particular. When the dust settled, six multinationals dominated the biotech, seed and agrochemicals sector: Monsanto, Syngenta, Dow, DuPont/Pioneer Hi-Bred, Bayer and BASF. These corporations had their roots in the pharmaceutical and/or chemical sectors. Each of them is in the top 10 biggest companies globally in the seed and/or pesticides sectors. Monsanto and DuPont/Pioneer are focusing their investments in seed and biotech R&D; while Bayer, Syngenta, BASF and Dow are focusing on chemical crop protection R&D. Agricultural biotech is growing rapidly in both China and India, with the latter focusing more on animal health than crops.

Market concentration can be based on the share of the output market, but can also be measured on the basis of innovation competition. IPR and patent control over germplasm and plant variety protection including genetic modification (GM) techniques constitute key nodes in the value chain, and exhibits a high level of concentration globally. Seed company acquisition has led to a growing correspondence between a company's share of plant variety protection (PVP) certificates and GM patents, and its share of the commercial seed market. Monsanto, Syngenta, Bayer and DuPont/Pioneer dominate ownership of PVPs and GM patents. Monsanto was also amongst the top 10 publicly-traded biotechnology companies in 2007.

In agrobiotechnology, as with other sectors of the economy, the state is forced to fall in line with the agenda of big business. The push for patents on genetic materials forces the state to develop the expertise to be able to identify whether a gene sequence exhibits novelty and non-obviousness; criteria required to qualify for a patent. The state is either required to divert resources towards an appropriately capacitated regulatory authority, or to allow big business to 'self regulate'. Either way, the public loses: in the first instance, through diversion of public resources away from other needs; in the second instance, permitting corporations to do what they want without any checks or balances. Another way that private business expropriates public goods is through the research process. A few decades ago, university researchers used to conduct basic research funded by public sources, and then publish the results for public use. But with the decline in public sector funding for universities – a process taking place across the world as part of the neoliberal project – the private sector increasingly uses the universities as their own research laboratories, through private agreements with researchers.

Corporations insist that premiums are critical incentives for biotech and risk taking. Many products do not make it to commercialisation, and the biotech company aims not only to recover those costs through increasing their profits on products that do make it onto the market, but also to capture as much of the value as possible on those products. The central way in which these premiums are realised is through extensive supply chain control, which includes vertical integration, licensing, restrictive contracts, technology fees, and bundling[3]. Cross-licensing between the major multinationals is common and reveals cartel-like behaviour. In the process of securing profits from GM technology, the multinationals have criminalised farmers for saving seed, and forced those who disagree with their terms into bankruptcy.

Biotechnology and the agricultural input supply chains in South Africa

Biotechnology in South Africa is a very small industry at present, valued at just R1bn in 2007. Human health is by far the largest sector, followed by industrial applications and only then by plant biotech. The South African government has identified biotechnology as a key growth area for the economy. A key part of the strategy is the creation of biotechnology regional innovation centres (BRICs) to act as the core of the development of biotechnology platforms. These are now organised under the Technology Innovation Agency. Public-private-academic partnerships are core to the vision. The strategic focus is to stimulate the development and application of third generation (recombinant DNA) technologies.

Private sector investment in biotechnology remains low in South Africa, and it has been left to the public sector to drive the development of the sector. When the National Biotechnology Strategy was released, the private sector was only contributing around 10% of R&D expenditure in biotechnology. One small venture fund, Bioventures, was established in 2002. Funding is mainly from the National Department of Science and Technology (DST), the National Research Foundation (NRF), the Innovation Fund, the Industrial Development Corporation (IDC) and the National Department of Trade and Industry (DTI). The Council for Scientific and Industrial Research (CSIR) and the Agricultural Research Council (ARC) also have

3. The practice of joining related products together for the purpose of selling them as a single unit. Often these are made more appealing to consumers as a package by making it cheaper to buy the bundle rather than buying each product separately.

funds for biotechnology research, which they sometimes undertake in partnership with other entities. Mintek, a parastatal that receives about 35% of its funding from government, has a biotechnology division which carries out biotech R&D for the mining sector.

The agbiotech sector is a small component of the overall biotech sector in South Africa. R&D is driven by the seed companies and the ARC in particular. The use of genetically modified seed has grown rapidly in South African agriculture. The country was ranked as the eighth largest in terms of hectares under GM crops in 2008. However, these are all imported technologies that are licensed for use in South Africa. In 2007 the National Biotechnology Audit reported that 58% of the 1,542 biotech products under development by South African biotech companies were agricultural products. The UN Food and Agriculture Organisation (FAO) indicated that 39 out of 89 (i.e. 44%) of biotech applications in South Africa were for genetic modifications.

A number of multinationals see South Africa as a springboard into Africa for launching the Green Revolution for Africa. The continent has not been integrated into the global seed and agrochemicals markets, and it is seen as a potential new market, although one fraught with difficulties – not least institutional and infrastructural. To date the continent is the least significant user of fertilisers, pesticides, hybrid or GM seed, and is only minimally connected to global markets in these products.

The South African commercial agricultural input supply sector is large in relation to Africa but small in relation to the rest of the world. It is around 20th in the global seed market, but a significant developing country in the planting of GM seed (eighth largest area under GM crops in the world) – though still very small compared with the US, Argentina and Brazil. Information on market shares in the South African seed industry is very difficult to come by. However, just 10 companies/institutions control around two-thirds of commercial seed varieties. The largest companies are Pannar, Monsanto, Sakata, Hygrotech, Syngenta, Pioneer Hi-Bred, Agricol, Afgri and Klein Karoo Seed Holdings. The ARC is a major breeder and holder of cultivar rights, but has not carried this into commercial activity. ARC is a public entity and therefore these rights are held in the public domain. Four of the top 10 are multinationals from elsewhere and are also amongst the top 10 seed companies globally. Monsanto occupies second position primarily through acquisitions, and had a 50% share in the important maize market in 2009. Between them Monsanto, Pannar and Pioneer had an estimated 90% market share of agronomic seeds (maize, wheat and sorghum) in 2002.

Private IPR protection is generally considered to be the only incentive for innovation. The flipside of that argument is that exclusive plant breeders' rights limit innovation by closing off the likelihood of others developing and improving on privately-held seed. New varieties rely on existing ones. If ownership of varieties is concentrated, and access to these varieties for further research is difficult, follow-on innovations by other institutions and researchers are likely to be discouraged.

A large number of non-GM varieties exist for the crops for which there are also GM varieties available. This means that demand elasticity appears to still be quite high i.e. farmers can still choose to switch to alternatives if prices for GM escalate. The percentage of GM varieties varied from 17% (white maize) to 30% (yellow maize) of total registered varieties available in South Africa in 2008. Three companies hold rights/licenses for most GM traits: Pannar, Monsanto and Pioneer Hi-Bred. Afgri, Link Seed and Syngenta also hold a few licences/rights. In 2008 GM white maize constituted 56% of the total area planted; GM yellow maize constituted 72% of total area planted to yellow maize; 96% of the area planted to cotton is under GM varieties (83% stacked trait, 9% herbicide tolerant and 7% Bt cultivars), and 88% of area to soyabeans is under GM soya. Monsanto is the only producer of GM cotton seed.

Generally speaking, fertilisers and pesticides are two separate markets at the production node. Unsurprisingly, however, they tend to be distributed through similar channels, given that the end user market (farmers) is the same. The chains have two main nodes: manufacturing and distribution. Manufacturers usually supply to more than one distributor, and distribution agreements are not dominant.

The South African fertiliser industry is relatively small, with the retail fertiliser market valued at around R3.5bn/year in 2005. In the 1990s the sector was rationalised following deregulation and liberalisation. Local production capacity was closed down and South Africa became a net importer of fertiliser for the first time around 2000. The sector is dominated by three corporations: Sasol Nitro, Yara and Omnia, with Foskor a significant input provider. Given the link to the mining industry, and the domination of foreign corporations in the pesticides sector, the fertiliser and pesticides industries are not integrated.

An estimated 70% of agrochemicals (both fertilisers and pesticides) used in South Africa are imported. Eight of the ten largest pesticide multinationals in the world operate in the South African market. Plaaskem is the biggest local producer of pesticides. The pesticide distribution market consists of local companies who distribute on behalf of the pesticide producers. The most significant distributors are Qwemico, Wenkem, Laeveld Agrochem and Technichem. They are neither integrated with pesticide producers nor with seed companies. There is some vertical integration amongst smaller distributors, including UAP (Plaaskem), Afgri and Ububele.

The presence of the multinationals, especially Monsanto, Syngenta and DuPont/ Pioneer Hi-Bred increases the vertical integration of the local input supply sector within South Africa. A couple of local companies, in particular Afgri and Pannar are also vertically integrated to some extent. The other 3 of the 'Big 6' multinationals – BASF, Bayer and Dow – have a strong presence in the pesticides sector but not much in seeds. This is related to their emphasis on the agrochemicals node at a global level. Overall, vertical integration is not really the major issue in South Africa at the moment. A bigger issue is multinational domination in the seed and agrochemicals nodes.

This is especially so when one considers how profitability is determined. Two examples will suffice. First, South Africa had a local fertiliser industry until liberalisation when economic borders were opened and multinationals acquired local producers. Because sourcing from other countries might make more economic sense to these multinationals, they closed down local capacity. Another example is Monsanto with soya and wheat. First they bought local seed companies, and then discontinued seed cultivar development either because the market was too small (while they retained the lucrative maize market) or because they could make bigger profits elsewhere. The companies come in, essentially strip assets and restructure businesses to absorb the most profitable parts, and dispose of the rest or allow it to decay. The basis of these decisions has little to do with the real possibility of producing fertiliser, wheat or soya seed profitably in South Africa. It has to do with the broader profit-driven and expansionary logic of multinational companies. The impact it has, however, is the dismembering of local industrial and productive capacity and cherry-picking of the most profitable parts of the industry. Theoretically consumers benefit from lower prices from competitive global markets in the short term - though even that has proven to be questionable when these markets suddenly collapse. But in the long-term the country loses control over decisions about what to produce, when and for whom; suffers from greater unemployment and becomes increasingly dependent on imports.

introduction

Third generation biotechnology – the use of recombinant DNA techniques – is rooted in the pharmaceutical industry, where its application has stimulated the development of new medical drugs. It has functioned as a commercial industry for at least three decades now, although it really took off as a profitable sector in the 1990s. The US has been a leader in the technology, although China, the EU and Japan also have established biotech sectors. Agricultural biotechnology – the genetic modification of seed – was a spin-off from the broader industry. It only really found its feet in the 1990s when the first commercial genetically-modified (GM) seeds were brought to market.

GM seed fed into the growing industrialisation of agriculture. Development of the technology was very expensive, and only very large entities had the resources not only to develop the technology, but also to commercialise it successfully. The potential profitability of the technology stimulated horizontal integration (for economies of scale) and vertical integration (for synergies between different nodes in the value chain) between biotech research and development (R&D) and seed companies.

Horizontal integration is the same as concentration in one node in the chain. For example, If a seed company buys other seed companies, this is horizontal integration. Companies integrate horizontally to increase their market share, and to realise economies of scale. This means a reduction in per unit costs of production, resulting in greater profits.

Vertical integration occurs when a company buys another company in a different node in the value chain, for example when a seed company buys a chemical company (or vice versa). This gives the company greater control over the supply chain. In many cases, it opens up new business possibilities that are not possible if the company is only located on one node in the chain. For example, a biotech company can licence its technology to a seed company for royalties. But if it owns the seed company, this opens up possibilities for doing additional experimental work on the seed that is not yet commercially profitable. Vertical integration also allows the company to capture that share of the profits that the seed company was keeping for itself.

The first commercial applications of the technology were for herbicide tolerance, and this enhanced the link between the seed and agrochemical companies. Commercial success sparked major processes of restructuring in the biotech-pharmaceutical-chemical-seed industries, especially after 1997. Huge multinationals were absorbed into others or merged together, and different units were spun-off and reformed under different names. After the dust had settled, there was a clear distinction between the pharmaceutical multinationals ('big pharma') and the integrated agricultural multinationals. Most, though not all, the chemical giants had spun off their agricultural interests into stand-alone companies. Some, like DuPont and Bayer, retained agricultural interests as subsidiaries. Some of the spinoff companies, like Syngenta, became so large that they swallowed their parents. Each of them was a vertically integrated biotech-seed-agrochemicals behemoth, albeit with different emphases and with their bases in different segments of the chain.

structure of booklet

This study is organised into two sections. The first section provides an overview of global trends in the biotechnology, seed and agrochemicals sectors. This context frames South Africa's prioritisation of biotechnology as a lead sector for development, as well as the country's commercial adoption of genetically modified seed. It provides information on the major multinationals also active in the South African agricultural input supply sector. It helps us to understand the possibilities for South Africa's emergence as a biotechnology player at the global level, especially in agbiotech, as well as the character of the dominant corporations. The second section considers the current situation with regard to biotechnology development in South Africa, and trends in the relationship between biotechnology and the agricultural input value chain.

the global biotechnology and agricultural input industries

R&D, intellectual property rights and vertical integration

The commercial introduction of agro-biotechnology demands that corporations have three assets under their control: biotechnological know-how; strong intellectual property rights (IPR); and a broad proprietary base of high quality germplasm. When biotechnology started growing as a commercial activity in the US in particular in the early 1980s, these assets were owned by separate types of institutions. Biotechnological know-how was mainly located in universities and public sector institutions, which carried out the basic R&D. IPR on living organisms was a new field and undeveloped, but generally linked to those conducting the R&D. The breakthrough for the private sector came in 1980 when the US Supreme Court ruled that new life forms fell under the jurisdiction of federal patent laws. This decision opened the doors for the private sector to secure ownership rights over biotechnological innovations. Venture capital to the industry in the US rose rapidly after the ruling, with equity investment rising from US$50m in 1978 to over US$800m in 1981 (Biotechstocksite, 2003). At the time of the ruling the seed industry was decentralised in a large number of independent, mainly regionally-based seed companies. There were some larger entities, but they were not overwhelmingly dominant.

A flurry of biotech companies were formed in the 1980s following the Supreme Court decision. However, investors did not realise how long it would take to convert promising research into a marketable product. The sector consequently rose and fell on the tides of investment, which were linked to contingent events, such as the announcement of plans to map the human genome, the subsequent announcement by the US and UK governments that the map should not be privatised, and general stock market bubbles and crashes. Like the information technology (IT) sector, biotechnology was seen as a lead technology for the 'post-industrial economy', but support to both was based on high levels of speculation, which seldom paid off in the short term. However unlike the IT sector, biotech required significant material infrastructure, and it was very costly to do biotech R&D. This meant barriers to entry based on finance and, later, size.

Over time, consolidation in the sector led to domination by a few very large companies. By 2007, the top 10 biotech companies accounted for two-thirds of the sector's total revenues (ETC Group, 2008:28). At that time, Amgen and Genentech were the largest publicly-traded biotech companies in the world. They both originated at the start of the commercial biotech sector in the early 1980s. This consolidation was actually a very recent occurrence. As the biotech companies started getting products closer to approval, the large pharmaceutical companies ('big pharma') started taking more interest. Especially after 2000, they began purchasing biotech companies that had products near commercialisation. While big pharma significantly outspent the biotech companies on R&D, the latter secured more product approvals than their big pharma counterparts since the mid-2000s (Ernst & Young, 2007:1).

Biotechnology has become the engine of innovation in the drug industry. This has made biotech companies a very attractive investment for the drug companies. Between 2005 and 2007, there were 66 pharma/biotech mergers (ETC Group, 2008:26). In recent years, big pharma has acquired some of the biggest biotech companies, such as Novartis acquisition of Chiron in 2006, Merck's purchase of Serono and AstraZeneca's purchase of MedImmune in 2007 (ETC Group, 2008:28). In 2009 Roche, the fourth largest pharmaceutical company in the world acquired the 44% of Genentech (the second largest biotech company) that it didn't already own. Amgen and others are also likely to be the target of acquisitions by big pharma in the near future. The biotech sector is tiny compared with the pharmaceuticals industry, with revenues of US$78bn in 2007, compared with US$504bn in revenues for the top 10 pharma corporations (ETC Group, 2008:26,28).

In recent years, expectations of marketable products and regulatory approvals drove rapid growth in the industry, not only in the US, but globally. However, in the US an estimated 50% of the roughly 380 publicly-traded biotech companies had less than one year of cash remaining at the start of 2009 (Levisohn, 2009). This suggests consolidation in the years ahead, including further mergers into the large pharmaceutical corporations. The latest economic crisis has caused a decline in the sector, but less so than in other sectors of the economy. As new products come to the market, biotech companies will require support for marketing, and this is likely to drive mergers and acquisitions, or at least strategic alliances between them and the larger companies who have marketing expertise (Ernst & Young, 2007:10). Generally, the biotech companies have expertise in R&D, but don't often have a good idea or the resources, marketing know-how or distribution networks to successfully commercialise their products. They therefore rely on the big agribusiness already having presence and clout in the market to carry the product through to launch.

The US has dominated the biotech sector to date. In 2006, the US accounted for 75% of all revenues derived from publicly-traded biotech companies. R&D expenditure in the US was also far higher than other regions or countries, constituting 82% of all R&D spend by publicly-traded companies in 2006. Europe was the next largest, with Canada and Asia-Pacific of similar size after that (Ernst & Young, 2007:7). Almost three-quarters of biotechnology patents were held in four countries: the US, Japan, Germany and the UK. The US on its own accounted for 43.3% of all biotech patents. China, India, Korea and Russia had the fastest growth in patent applications, although starting from a low base (Ernst & Young, 2007:6). This is one signifier of a far larger shift in the balance of power towards the East, including in other nodes of the agricultural value chain, as we will see below.

The medical and healthcare sectors drove the growth of biotechnology. In comparison, agricultural biotech played a relatively minor role in the development of the sector. Early agbiotech companies such as Mycogen, Ecogen, Calgene and Plant Genetics Inc trailed behind medical biotechnology in product development, profitability and investor interest (Feder, 1991). Most R&D was conducted by the major agrochemical and seed companies, and it was these companies that began investing in agbiotech. **Apart from Calgene's GM Flavr Savr tomato, which was launched in 1994 but then withdrawn after a few years because of unsustainable costs, the first sustained commercial releases of GM products were Monsanto's glyphosate tolerant and insect resistant modifications in 1997. This was a result of Monsanto buying up a number of biotech companies in the 1990s, including Calgene, Plant Breeding International and others.**

Changes in the agbiotech industry structure were largely driven by the desire to control the three assets: biotech knowledge, IPR and quality germplasm. IPR is important for companies so that returns on costly R&D investments are secured. But IPR ownership and the technological know-how can only be converted into profit if they are attached to the seed as a carrier of the technology. Seed companies can choose which technologies they want to incorporate into their product lines, and without control over this part of the value chain, there is no guarantee that the agbiotech company will successfully bring its product to the market (Bergeron and Chan, 2004:101).

The three assets can be co-ordinated either through contracts, joint ventures, or ownership of all three types of assets (Kalaitzandonakes and Hayenga, 2000:222). If IPRs are well-defined and transaction costs are low, it is more likely that contracting and licensing arrangements will be pursued (Shi, 2006:3-4). Contracting and licensing arrangements were, and remain, common in the biotech industry. One reason for this is that the biotech companies had expertise in R&D, but had very little knowledge about how to enter the market and had no market base at all. This made out-licensing of products they had ownership over the best option, where they would generate royalties from the use of their patented product.

Where IPRs are not well-defined, companies might buy out seed companies rather than license to them (Shi, 2006:3-4). Early contestation over patent rights resulted in the legal questionability of IPR. On the one hand, not everybody agreed that patents should be allowed on life, and this was an important pillar in the growing global opposition to genetic modification, and third generation biotechnology more generally. On the other hand, the companies fought amongst themselves to secure the right to patents. A struggle commenced to gain exclusive control over aspects of the technology, including procedures and tools for genetic modification as well as the products of these processes – the traits and seeds. The large corporations flooded patent offices with applications, including some very speculative ones that had the potential to appropriate the R&D efforts of others a decade or more down the line. It led to a series of claims and counterclaims and court cases between the corporations that controlled the technology. It also ultimately drove vertical integration as corporations realised that it would be cheaper to buy the firms that produced the technology than to have to battle it out in court for a number of years at great expense to secure IPR.

But it was not only weaknesses in the IPR regime that spurred vertical integration. Companies faced high transaction costs in their contract and licensing agreements, which led them to favour outright acquisition and vertical integration (Kalaitzandonakes and Hayenga, 2000:225). Where products are complementary or where greater value can be gained from outright ownership of seed companies, vertical integration allows the full value of the innovation to flow back to the life sciences firm that took the greatest risk and made the greatest investment. Supply chain control is also preferable for the company because it cannot use the biotech assets for other purposes and therefore has a keen interest in the successful use of the product (Goldsmith, 2001:1307). Integration between seed companies and agrochemical companies also made economic sense because the technology used to produce GM seed may also be used in making complementary goods like herbicides (Goldsmith, 2001:1316). In turn, concentration through horizontal integration (i.e. integration with companies in the same node of the value chain) also made economic sense in some circumstances, linked as it is to R&D costs, economies of scale and scope, and regulatory costs (Fulton and Giannakas, 2002).

The 'Big 6' biotech, seed and agrochemical companies

The seed-agrochemicals industries saw a rapid increase in both types of concentration in the mid- to late-1990s in particular. Huge companies were being merged and their names changed, but it gradually settled down in the early 2000s with the 'Big 6' dominating the integrated biotech, seed and agrochemicals sector: Monsanto, Syngenta, Dow, DuPont/Pioneer Hi-Bred, Bayer and BASF. These corporations had their roots in the pharmaceutical and/or chemical sectors. BASF, Bayer, Dow and DuPont continue to be involved in other chemical sectors well beyond agriculture. BASF and Dow were the two largest chemical companies in the world by sales in 2007. DuPont was the eighth largest (ETC Group, 2008:42). In their current incarnations, Syngenta and Monsanto are specialist integrated agricultural input companies.

In 2007, Monsanto, DuPont (of which Pioneer Hi-Bred is a fully-owned subsidiary) and Syngenta were the three largest seed companies in the world, with a combined market share of 47% of the global proprietary seed market. This included an estimated 65% of the proprietary maize seed market and over half the proprietary soya bean seed market (ETC Group, 2008:11&12).

Monsanto and DuPont/Pioneer are focusing their investments in seed and biotech R&D, while Bayer, Syngenta, BASF and Dow are focusing on chemical crop protection R&D (Phillips MacDougall, 2008:42). Between 1990 and 2007, Bayer introduced the most products to the market (41), followed by Dow (26), Syngenta (24) and BASF (22). Japanese companies released 68 products in the same period, with Sumitomo releasing the most (18). Japanese companies had 20 products in the pipeline, compared with 20 for the Big 6, indicating growth for the Japanese companies and a decline in expected future product releases for the Big 6 (Phillips MacDougall, 2008:43). In China, the state has sponsored biotechnology research since the early 1980s, and it is one of the few countries apart from the US that has produced its own GM seed technology. Agricultural biotech is a key growth area, and accounts for 42% of government expenditure on biotechnology and 37% of biotech market value. India is also growing rapidly as an agricultural biotech centre, although its focus is more on animal health products (Teh, 2007:3,4).

Control over biotechnology: patents and IPR

Market concentration can be based on the share of the output market, but can also be measured on the basis of innovation competition. IPR and patent control over germplasm and GM techniques and tools constitutes a key node in the value chain, and exhibits a high level of concentration globally. Seed company acquisition has led to a growing correspondence between a company's share of plant variety protection (PVP) certificates and GM patents, and its share of the commercial seed market (Srinivasan, 2003:531). Ownership of IPR in biotechnology processes and research tools is even more concentrated than in PVP certificates. In 2000, Monsanto was either the first or the second largest holder of PVP rights in wheat, maize, soyabean and oilseed rape. The vast majority of Monsanto's maize, wheat and soyabean PVP certificates came from acquisitions of other seed companies (Srinivasan, 2003:525,531). In 2003, six major industrial groups[4] controlled most of the technology (Srinivasan, 2003:538). Subsequently there was further consolidation. Monsanto acquired Asgrow/Seminis, Novartis and AstraZeneca (including Mogen) merged and spun-off their agricultural units to form Syngenta, which also acquired Advanta. Bayer acquired AgrEvo and PGS. Therefore, where there were six groups in 2003, this was reduced to four by 2008: Monsanto, Syngenta, Bayer and DuPont/Pioneer.

Monsanto is the only one of the Big 6 that also makes it into the top 10 publicly-traded biotechnology companies. It was the third largest such company in the world in 2007 (ETC Group, 2008:28). In 2008, it owned three stand-alone biotech companies: Calgene, Agracetus and PBIC. More recently it purchased Israel-based company Evogene, where R&D is being conducted to identify and develop genes related to yield, environmental stress and fertiliser utilisation (Orelli, 2008). In 2004 DuPont acquired Verdia, a US biotech/seed company. DuPont also owns Protein Tech International.

In agrobiotechnology, as with other sectors of the economy, the state is forced to fall in line with the agenda of big business. The push for patents on genetic

4. The groups were (1) Agrevo/Plant Genetic Systems (PGS) (2) ELM/DNAP/Asgrow/Seminis (3) DuPont/Pioneer (4) Monsanto/Calgene/Delkalb/Agracetus/PBI/Hybritech/Delta and Pine Land (5) Novartis (6) Zeneca/Mogen/Advanta.

materials forces the state to develop the expertise to be able to identify whether a gene sequence exhibits novelty and non-obviousness, criteria required to qualify for a patent (McDonald, 1999). Some companies submit thousands of sequences at a time, and the state is either required to divert resources towards an appropriately capacitated regulatory authority, or to allow big business to 'self regulate'. Either way, the public loses: in the first instance, through diversion of public resources away from other needs; in the second instance, permitting corporations to do what they want without any checks or balances.

Another way that private business expropriates public goods is through the research process. A few decades ago, university researchers used to conduct basic research funded by public sources, and then publish the results for public use. But with the decline in public sector funding for universities - a process taking place across the world as part of the neoliberal project - the private sector increasingly uses the universities as their own research laboratories, through private agreements with researchers. In exchange for funding research at these institutions, the companies can observe the work of staff of entire departments, and have the right to negotiate licenses and patentable discoveries from the laboratories (McDonald, 1999).

Seed

The global commercial seed market was valued at between US$26.7bn and US$36.5bn in 2007. Proprietary seed (brand-named seed under exclusive monopoly) constituted 82% of the market (ETC Group, 2008:11). A combination of cheap and fast transportation, development of hybrid varieties and faster breeding and commercial processes have driven growth in international seed trade since 1985 (Bruins, 2008:18). The US, China, France and Japan (in order of size) occupy almost half the global seed market between them. In 2000 China passed a law permitting the private sector to produce seed, and the market is expected to grow rapidly as a result (Agrow, 2006a). Depending on whose figures you use, GM seed constitutes a third (Phillips MacDougall, 2008:2) or one fifth of the commercial market (Bruins, 2008:27). By one estimation, all growth in the commercial market since 1998 has been through the expansion of GM seed (Phillips MacDougall, 2008:2). The commercial seed market excludes farm-saved seed, which was valued at around $15bn in 2007 [International Seed Association figure, which estimates the higher value for the total seed market] (Bruins, 2008:5).

Since the first commercialisation of GM crops in 1996, the number of countries planting GM crops commercially has risen from 6 to 25 in 2008 (information in this and the following paragraphs from James, 2008 unless otherwise specified). This rapid growth should not hide the fact that **92% of all GM crops are grown in just five countries: the US, Argentina, Brazil, India and Canada.** The US is by far the largest producer of GM crops, with 62.5 mill ha in 2008, three times as much as the next largest producer, Argentina (on 21mill ha). In the US, 85% of the 35.3mill ha national maize crop was of GM varieties, and 78% of these were double or triple-stacked varieties. 90% of the US cotton crop was under GM, with double-stacked traits constituting 75% of this. Herbicide tolerant soya occupied 88% of total area planted to soya in the US in 2006 (Carlson, 2007:31).

Brazil, India, Canada, China, Paraguay and South Africa all have more than 1mill ha under GM crops. Soya is the dominant GM crop by area planted (53% of total area planted to GM crops in 2008), followed by maize (30%), cotton (12%) and canola (5%). Seventeen of the twenty-five countries produce GM maize, although 10 of these are on an area of less than 100,000 ha. Ten of the countries produce GM soyabean, and ten produce GM cotton. Just four countries produce GM canola. A handful of countries are also involved with a range of GM crops: the US has GM squash, alfalfa, papaya and sugarbeet; China has GM tomato, poplar, petunia, papaya and sweet pepper; Canada has GM sugarbeet; and Australia and Colombia have GM carnations.

The most well-known GM brands in commercial production are Roundup Ready, Yieldgard and Bollgard (Monsanto), AgriSure (Syngenta), Herculex (DuPont), Liberty Link (Bayer), Widestrike (Dow) and Clearfield (BASF/Dow). The major traits are herbicide tolerance (with glyphosate and glufosinate tolerance dominant) and insect resistance (with Bt the dominant one). The basic difference between these two is that the insect resistant seed substitutes for insecticide use, while the herbicide tolerant seed complements the use of particular herbicides. Therefore, the use of these seeds should see a decline in the insecticide market and a growth in the herbicide market. Herbicide tolerant traits are dominant, constituting 63% of area planted to GM crops in 2008. Stacked traits (usually combining herbicide tolerance and insect resistance in the same seed) have surpassed insect resistant seed, and now constitute 22% of area planted to GM crops (James, 2008).

Access to the market is critical for the success of biotech products. If a company has the patents but can't bring the products to the market on their own, they lose some of the value to others. Therefore extensive dealer networks are a key component for the realisation of profit. The 'Big 6' have therefore invested heavily in distribution networks. Some of this is through existing seed companies with their own distribution channels. Some is through the purchase of companies that specialise in distribution. For example, Monsanto's purchase of Holden's gave it ownership of Corn States International, a company specialising in international distribution of seed.

In 2007 Monsanto was the world's largest seed company, with 23% of the global proprietary seed market. Monsanto's biotech seeds and traits (licensed to over 250 companies worldwide) accounted for 87% of all GM plantings in 2007 (ETC Group, 2008:13). DuPont was the second largest seed company in the world in 2007 with a market share of 15%, followed by Syngenta at third (9%) and Bayer at seventh (ETC Group, 2008:11). Dow has a fairly extensive network of seed companies, but small in comparison to the top three.

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In 2008, Monsanto either fully or partially owned 83 seed companies around the world, mostly in the corn and oilseed sectors, including those purchased under its holding company called American Seeds Inc (Howard, 2009a, Organization for Competitive Markets, 2008). In 2006 Delta & Pine Land (D&PL) acquired Syngenta's cotton seed business, and Monsanto made another offer on the company after its 1998 bid failed after 18 months of anti-trust proceedings. In 2007 the merger was successful, combining Monsanto, with 95% of the cotton traits market, and D&PL, with 50% of the US cotton seed market and 30 subsidiaries around the world including South Africa (Moss, 2006:2). The acquisition allowed Monsanto to establish a cotton platform for traits, germplasm and seeds, as it had earlier done with corn and soyabeans (Moss, 2006:4). Monsanto's targeting of D&PL is seen as a way for the company to eliminate potential competition to its own GM traits. In the years just before the acquisition, D&PL had been working with both Syngenta and DuPont to introduce alternative herbicide tolerance and insect resistance traits in cotton (Moss, 2006:9). On acquisition of D&PL, there would be no reason for Monsanto to pursue these partnerships, since they would result in it losing market share, both in GM cotton seed and in herbicides (glyphosate). In 2008 Monsanto announced its intention to enter into the sugar cane sector with its purchase of Brazilian sugar cane breeders CanaVialis and Alellyx (Monsanto, 2008a).

DuPont purchased Pioneer Hi-Bred in 1997, which became a wholly-owned subsidiary of DuPont, but continued to trade under its own name. Apart from Pioneer, DuPont had interests in two other smaller seed companies. Pioneer gave it access to a significant network of seed producers. Pioneer sells hybrid maize seed in over 70 countries. In 2007, some 70% of Pioneer's hybrid maize seed had at least one GM trait, with double stacks making up 25% of sales and triple stacks another 10% (Agrow, 2006b). The contribution of seeds to Syngenta's revenue remains below that of agrochemicals, but is rising as a proportion of total revenues. The company is expanding into the seed sector, with the purchase of Garst and Golden Harvest seed companies in 2004 boosting its seed sales by 45% (Agrow, 2006b). In 2008 the company fully or partially controlled 23 seed companies (Howard, 2009a). Syngenta's main areas are maize, soyabean, flower and vegetable seed. Bayer concentrates on vegetable seed, canola, cotton and rice. It recently sold its maize and soyabean seed companies in the US and Brazil (Agrow, 2006b). However, it had accumulated some stake in 33 seed companies by 2008, mainly a result of its partial ownership of Aventis, which in turn fully owned AgrEvo, which has a network of seed companies, including partial ownership of KWS (Howard, 2009a), which was the sixth largest seed company in the world in 2007 (ETC Group, 2008:11).

The drive to produce seeds with stacked traits is a product of the ability of the seed companies to make bigger profits from these seeds than those with fewer traits. For example, Monsanto uses its market power to force farmers into purchasing stacked varieties they don't need and might not even want. In the US, triple stack maize varieties are expected to have 65% penetration in 2009, and will constitute 75% of Monsanto's maize seed sales (Taylor, 2008). Farmers purchase these varieties because Monsanto has withdrawn its single and even double stack varieties so that they do not compete with the more expensive triple stack - whether it's really needed or not (Dillon, 2008). If farmers even just want a Roundup Ready (RR) seed, they are forced to take stacked varieties with traits they might not want. First, open pollinated varieties (OPVs) were replaced with hybrids. Then hybrids were replaced with GM seed. Now seeds with fewer traits are being replaced by those with more. Monsanto and Dow have an agreement to launch SmartStax, an eight trait seed that includes Dow's Herculex I and Herculex RW technologies; Monsanto's YieldGard VT Rootworm/Roundup Ready 2 and YieldGard VT PRO technologies; and Roundup Ready 2 and Liberty Link tolerance. The technology is expected to be on the market by 2010. Given the concentration of the seed industry - especially ownership of traits - farmers have fewer and fewer choices, and have to keep upgrading at an externally-driven pace based on an agenda that is not always in their own best interests.

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Monsanto withdraws its single and even double stack varieties so they do not compete with the more expensive triple stack - whether it is really needed or not.

R&D on other input traits, such as fertiliser utilisation, nitrogen utilisation or drought tolerance, means that the price of inputs is shifting from other inputs to seeds. The seed becomes the technology that prescribes a range of farming practices, from soil management, the use of water, and the application of insecticides and pesticides. Consequently, farmers become locked into a particular type of technology and production model with limited options. That model is large-scale, uniform and monocultural, with seed companies securing most of the surplus value and retaining control over the technology. Production decisions are increasingly made by the multinational companies, who provide the farmer with a ready-made package of inputs that must just be applied according to instruction. This is the beginning of a process of deskilling of the farmer, with a greater reliance on large-scale, capital-intensive corporations where barriers to entry are now almost impossible to surmount, except by even larger entities. This has the long-term impact of allowing those corporations to shape the agricultural production process in their own interests, which is precisely what is happening through the introduction of eight stack varieties.

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There is some commercialisation of output traits, for example Monsanto's Processor Preferred, Improved Feed, and VISTIVE Low-Linolenic Acid traits (to replace trans-fats in deep frying and processed foods); Dow's High Oleic Acid and Nexera brands and Bayer's FiberMax cotton. Most of these are targeted at consumer concerns in the capitalist core economies. Drought tolerance is a key output trait in R&D, as well as others for improving fertiliser and nitrogen use. The 'Big 6' accounted for 79% of 55 'patent families' submitted on 'climate ready' genes in patent offices around the world (ETC Group, 2008:14). Other output traits in R&D include improved oil content, improved feed and ethanol use, and improved functionality and flavour (Phillips MacDougall, 2008-38). There is a strong connection between the growth of GM crops and growth in agrofuels. In the US, an estimated 29% of the area planted to maize was used for ethanol production in 2008, and 7% of GM soyabean plantings were used for biodiesel production (James, 2008).

Agrochemicals

The agrochemicals market is divided into plant nutrition (fertilisers) and plant protection (pesticides). In this booklet, the term fertilisers will be used for plant nutrition products, and pesticides will be used for plant protection products (insecticides, herbicides, fungicides and adjuvants[5]).

Fertiliser is made from a combination of potash, phosphate rock, ammonia, urea, sulphur and diammonium phosphate (DAP). Phosphate rock and sulphur are naturally occurring. Morocco and then China have the largest phosphate reserves. Potash occurs naturally but can also be manufactured. The largest reserves are found in Canada, followed by Russia. Ammonia and urea are derived from coal or other hydrocarbons. More than 90% of urea and 80% of ammonia produced globally is used for fertiliser (http://en.wikipedia.org/). DAP is produced through a reaction between ammonia and phosphoric acid.

China is the largest producer and consumer of fertiliser in the world. China, the US, Canada and Russia are the major countries producing raw materials for fertilisers. From a trade point of view, Canada and Russia are major exporters and the US and China are major importers (International Fertiliser Industry Association, 2009). The biggest global companies are PotashCorp of Canada, Yara of Norway and Mosaic (55% owned by Cargill) of the US (ETC Group, 2008:17). Unlike the high levels of vertical integration between the agbiotech, seed/germplasm and agrochemicals sectors, there is not a high degree of integration within the fertiliser sector. It is quite possible that this is related to the location of mineral inputs, which shape the geographies of production. In contrast, pesticides can be manufactured anywhere there is an infrastructural base. The raw materials can be sourced and transported far more easily than fertiliser raw materials. Vertical integration in the fertiliser industry is therefore more likely to occur upstream i.e. between the mining and the manufacturing industries. As shown below, the biotech-seed-pesticide link forms a separate chain altogether. The fertiliser-pesticide chains only coincide at the level of distribution of the final product to farmers, and there is not enough synergy between the chains to justify integration at the production stage.

Bayer and Syngenta were the largest pesticide companies in the world in 2007, with a market share of 19% each. Syngenta, formed in a merger between Novartis (itself a merger of CibaGeigy and Sandoz) and AstraZeneca in 2000, has its roots in the pharmaceutical/chemical industries. Through full ownership of Aventis, Bayer

5. An adjuvant is a substance added to a pesticide to enhance its' performance, for example decreasing water tension to ensure a more even spread of the pesticide.

also took control of Rhône Poulenc, Schering and Hoechst - all pharmaceutical-chemical-life sciences companies (Howard, 2009a). BASF was the third largest pesticide company (11% market share), followed by Dow (10%), Monsanto (9%) and DuPont (6%) (ETC Group, 2008:15). That gives the top six corporations 74% of the global market between them, with a high degree of vertical integration between the global seed and pesticide companies.

The top six corporations controlling the world pesticide market are Bayer, Syngenta, BASF, Dow, Monsanto and DuPont.

Herbicides are the largest pesticide sector globally, valued at around US$16bn in 2007. It is followed by insecticides and fungicides, each of which are about half its size. GM seed is rapidly rising in importance as a crop protection product, and is close to the size of the insecticide and fungicide markets (Phillips MacDougall, 2008:5). Glyphosate – launched by Monsanto in 1976 with a 25 year patent - is by far the dominant active pesticide ingredient used globally, amongst both generic and patented pesticides. Sales of glyphosate were larger than sales of the next 12 generics combined in 2005, with an estimated US$5bn in sales in that year (Agrow, 2005b). Even after the patent expired in 2001, Monsanto maintained its dominance of the glyphosate market. In 2007 Monsanto accounted for 30% of global production of glyphosate (PRLog, 2009). Monsanto generates the majority of its sales from active ingredients that have lost their patent protection. It is the largest producer of generic pesticides in the world, with annual generics sales valued at $3.18bn in 2004. This is larger than the total sales of the next four biggest pesticide generics companies[6] (Agrow, 2005a). Of the 'Big 6', Monsanto is the only one that generates significant sales from generics. Despite its dominance in the pesticide market, by 2005 Monsanto was getting more revenue from seeds and traits than it was from agrochemicals. Seeds and genomics[7] are expected to constitute 80% of its gross profits by 2012 (African Agriculture, 2009). In the insecticide market imidacloprid, developed by Bayer, is the largest selling insecticide active ingredient in the world, with global sales of US$1bn in 2004. Imidacloprid is no longer patent protected. In the generics industry, Bayer has formed a joint venture with Mitsu Industries called Bilag Industries, which has the 18th largest sales of pesticide generics (Agrow, 2005a). However, with sales of $85m in 2004, this is small compared to Monsanto's generics sales.

A number of trends are apparent in the pesticide industry. The introduction of new pesticide active ingredients into the market is slowing down, and patent

6. Makhteshim-Agan (Israel), Nufarm (Australia), Cheminova (Denmark) and Griffin (US)
7. The study of an organism's genome, including efforts to map the entire DNA sequence of an organism

protection is running out. This means the generics industry is growing faster than the R&D-based pesticide industry. The share of sales held by generics in the pesticide industry rose from 10% in 1996 to 20-30% in 2005 (Agrow, 2005b). Generics tend to be used in developing countries rather than developed countries, partly because they are cheaper and partly because of tightening of regulations, in the US and the EU in particular, around the use of generic pesticides. Attempts to harmonise pesticide registration systems globally are likely to benefit larger generic companies with international sales networks, as well as multinational R&D-based pesticide companies (Agrow, 2005c).

The centre of gravity in the production of generics is shifting to Asia. Already in 2005, 53% of the top 100 companies by sales were from China and India, and another 12 were from elsewhere in Southeast Asia and Australia (Agrow, 2005a). China is the biggest glyphosate producing country in the world, with an expected annual yield of 600,000 tons in 2010, two-thirds of the global market. This is mainly for export (PRLog, 2009). Consolidation is already beginning in India, and is gradually starting in China. Competitive prices from China and India are forcing consolidation in western countries too.

Marketing tactics: licensing, contracts, technology fees and bundling

Corporations insist that premiums are critical incentives for biotech and risk taking. Many products do not make it to commercialisation, and the biotech company aims to recover those costs through increasing their profits on products that do make it onto the market. The main way these premiums are realised is through extensive supply chain control, which includes vertical integration, licensing, restrictive contracts, technology fees, and bundling (Goldsmith, 2001:1303).

Licensing the use of patents by others is an important source of income for the ‘Big 6’. Monsanto, for example, has licensing agreements with some 250 companies around the world. Since they control most of the technology, they are able to charge high license fees and set the terms. Given the growth of GM seed, especially in the US, independent seed companies are under pressure to accept the terms.

Cross-licensing is a key trend in the input industry at present. The ‘Big 6’ all have cross-licensing agreements with one another, with Monsanto at the centre (Howard, 2009b). Just some examples of cross-licensing between the ‘Big 6’ are shown here, but the companies have many other licensing agreements with other smaller (and not so small) companies. In 2007, Monsanto and Dow announced a cross-licensing agreement to produce the eight stack SmartStax. Monsanto is in control of third party licensing through Holden's/Corn States. Both companies have the right to add additional traits to the stack. In the same agreement, the companies have a deal to share germplasm (Moore, 2007). In 2007 Syngenta Seeds and Pioneer Hi-Bred International formed a US joint venture, Greenleaf Genetics, to license maize and soybean germplasm to third parties in the US and Canada. As part of the terms of its 2007 acquisition of Delta & Pine Land, Monsanto provided germplasm to Syngenta with VIPCot trait technology. This allowed Syngenta to continue its development of the technology even while Monsanto had joint control of the germplasm (Monsanto, 2006). In 2008 Monsanto entered into an agreement with Pioneer Hi-Bred on maize herbicide tolerance and insect control technologies that would see US$725m being transferred to Monsanto over 8 years. Later in the same year, Monsanto and Syngenta entered into a Roundup Ready II Yield Soybean Licence Agreement, which would cost Syngenta at least US$81m over nine years (Guebert, 2008).

In 2009, Monsanto and Bayer cross-licensed their herbicide tolerance traits in canola (Roundup Ready and Liberty Link) (Marketwire, 2009). Also in 2009, Dow and Syngenta signed a cross-licensing agreement to access each other's maize traits. Syngenta will get global nonexclusive licenses with stacking rights to Dow's Herculex branded traits. In exchange, Dow will get similar rights to Syngenta's AgriSure brands. Sharing of seed treatment technologies are part of the deal (Moore, 2009). An earlier cross-licensing agreement between the two corporations saw the formation of Greenleaf Genetics, a joint venture to share maize and soybean traits (Daghlian, 2009). Another cross-licensing agreement in 2009 was between Bayer and DuPont/Pioneer. Bayer will provide Pioneer with rights to its Liberty Link technology, glufosinate tolerance technology in soybeans and Dual Bt patents, as well as rights to herbicide formulations (Bayer CropScience, 2009).

Bundling refers to the sale of a package of seed and chemicals (e.g. glyphosate resistant GM seeds with Roundup herbicide). It ties clients more closely to the supplying firm, especially as the firm develops a wider range of complementary services and products (Goldsmith, 2001:1316). Granting of patents and copyrights encourages the practice of earning economic rents (returns larger than needed to cover the costs of production and ordinary profits). Charging high prices is not enough to put competition authorities on the alert. Only if a monopoly engages in predatory or exclusionary behaviour does this become an issue for the authorities (Goldsmith, 2001:1304). Syngenta and Monsanto are both involved in R&D on

Genetic Use Restriction Technologies (GURTs) which prevent farmers from saving seed by genetically sterilising seed from the GM plant. After a public outcry, Monsanto promised in 1999 not to commercialise the technology. But R&D continues, especially into a variation of the technology that renders a seed sterile until it receives an application of a proprietary chemical, produced no doubt by the same company that owns the seed technology (Peterson, 2009). In 2000 Syngenta held 36 of 71 GURT patents (Corporate Watch, 2003:7).

Restrictive contracts with farmers and the imposition of technology fees form the basis for further profit-taking and liability limitation by the corporation at the expense of farmers. The terms of Monsanto's Technology/Stewardship Agreement, which all users must sign, include: barring farmers from saving seed or providing seed to others from the GM batch; granting Monsanto the right to examine and copy their records and receipts; the farmer assumes all responsibility for keeping GM crops out of markets or grain elevators that do not allow GM crops; farmers agree to be bound by the terms of the agreement simply by opening a bag of Monsanto's GM seed; and the only remedy farmers have for any liability, dissatisfaction or damage is reimbursement of the price paid for the seed or replacement of the seed itself. There is no right to negotiate the contract (Monsanto, 2008b, RAFI-USA, 2008). These stringent requirements function both to secure the IPR of the corporation and limit the liability of the corporation. If farmers do not follow the instructions to the letter, they are liable for any damages or losses. In this way, a process of deskilling of farmers is under way.

Table 1: Components of the price of GM seed

Crop	Genetic seed	Seed treatment	Technology fee	Total	Tech fee as % of total
Sugar beet	100	55	105	260	40.4%
Maize	70	20	30	120	25%
Maize - double stack	70	20	45	135	33.3%
Cotton - Bt	45	15	74	134	55.2%
Cotton - double stack	100	25	263	388	67.8%
Maize	145	35	54	234	23.1%
Maize - double stack	145	35	108	288	37.5%
Maize - triple stack	90	20	115	225	51.1%
Soybean	15	4	13	32	40.6%

(Source: Bruins, 2008:28)

In addition to the terms of the contract, farmers also pay a premium on GM seed, called a ‘technology fee’. In the US, prices for Roundup Ready seed reportedly increased by 230% between 2002 and 2006 (Moss, 2006:10). In years when agricultural commodity prices are high, farmers may be prepared to pay the additional costs. But in times of economic downturn, when demand for agricultural commodities is lower, prices will drop and farmers will carry the risk. Table 1 (above) shows that the technology fee constituted between a quarter (maize) and two-thirds (double stack cotton) of what the farmer paid for the seed.

In order to secure this source of income, the multinationals have taken farmers to court to force them to pay. Monsanto has an entire department dedicated to enforcing its seed patents and licensing agreements. A number of legal cases have been entered into in the US where Monsanto has attempted to penalise licensees for selling non-Monsanto traits or other competing products (Moss, 2006:10-11). By 2003 more than 400 farmers in the US had received threats of legal action over alleged patent infringement. US farmer, Homan McFarling, was fined US$1.7m and sentenced to eight months in jail for various offences that began with a Monsanto lawsuit (Beingessner, 2003). Monsanto has also gone on the offensive to defend the profits from its modifications. In 2007 it sued Kleinpeter Dairy, a small US dairy company that had placed a label on its milk stating it was produced by cows not on recombinant bovine growth hormone (rBGH). Milks sales rose sharply. rBGH - also known as recombinant Bovine Somatotropin (rBST) – increases milk production in cows but there are fears that it has negative effects on the cows over time from being forced to produce milk at unnatural rates. There are also questions about its health related effects both on people and the cows. Monsanto, which at the time produced Posilac, the leading recombinant bovine growth hormone (rBGH), claimed the dairy's label was hurting its' business. Monsanto tried to argue that the dairy was making negative claims about the safety of rBGH, even though there was no such claim. Monsanto's case was thrown out, but that has not prevented it from pursuing similar tactics in other states against dairy companies (Bartlett and Steele, 2008). These tactics indicate that the multinational is prepared to force farmers and small businesses into bankruptcy to secure its own profits.

biotechnology and the agricultural input value chain in south africa

Overview of biotechnology R&D in South Africa

Biotechnology in South Africa is a very small industry at present, valued at just R1bn in 2007. Human health is by far the largest sector, followed by industrial applications and only then by plant biotech (Pouris, 2008:60). The sector is guided by a series of international protocols and conventions, as well as numerous national laws. The latter include the National Environmental Management Act of 1998, the Genetically Modified Organisms Act of 1997, the Human Tissue Act of 1983 and the Patents Act of 1978. From about 2000, the South African government identified biotech as a key growth area for the economy. In 2001 the government released the National Biotechnology Strategy (Department of Science and Technology, 2001) as a framework to create incentives in the biotech sector. The Department of Science and Technology (DST) is the lead department, with the Department of Trade and Industry (DTI) concentrating on innovation and commercialisation. A key part of the strategy is the creation of biotechnology regional innovation centres (BRICs) to act as the core of the development of biotechnology platforms. Public-private-academic partnerships are also core to the vision. The strategic focus is to stimulate the development and application of third generation (recombinant DNA) technologies.

South Africa's economy is heavily reliant on first generation biotechnologies (fermentation, plant and animal breeding and clonal propagation of plants). But historically it has been far weaker on second (use of pure cell or tissue culture) and third generation technologies. The strategy is based on the creation of new intellectual property, and government will assist in the process of securing IP protection globally. The strategy proposed an initial budget of R182m, mainly to fund the BRICs and associated R&D programmes. The expense involved in registering foreign patents has put the brakes on the growth of private sector biotechnology in South Africa (Cloete, et al., 2006:557). This is coupled with a tendency in South

Africa for academics to focus on publishing papers and not producing commercial products. The result is that a quick search of the US Patent Office database[8] for South Africa and biotechnology reveals only 24 patents registered there by South African inventors between 1976 and 2009. In 2007, there were 24 product patents and 26 process patents at the Company and Intellectual Property Registration Office (Cipro) for the biotechnology sector (Pouris, 2008:81).

Government makes a distinction between active and core biotechnology companies. A biotech active company is one that either conducts R&D in biotech, or sells biotech products. Core firms are those that use at least one biotech-related activity and whose main activity is biotechnology. The core firms are a subset of the active firms. In 2007, 78 companies were identified as being active in biotech in South Africa, and of these, 38 were core (Department of Science and Technology, 2007). Private sector investment in biotechnology remains low in South Africa, and it has been left to the public sector to drive the development of the sector. When the National Biotechnology Strategy was released, the private sector was only contributing around 10% of R&D expenditure in biotechnology (Department of Science and Technology, 2001:25). Weak links between the private sector and academia resulted in most private sector R&D being outsourced internationally.

The R&D pipeline can be divided into four phases: fundamental research; applied research; product development; and commercialisation and market release. Different entities provide support at these different phases (see Figure 1 below). 'Angel' investment refers to high risk, early stage investments made by wealthy individuals or groups. Similarly, seed funding is high risk capital for new ventures nearing the stage of commercialisation. Venture capital is later stage funding usually managed on behalf of investors by a specialised venture capital firm. Their money is usually made by selling shares once a product has successfully reached the market (Medical Research Council, 2009).

8. http://patft.uspto.gov/

Figure 1: Funding for commercialisation of biotech research

Fundamental research Curiosity driven	**Applied research** Needs/market driven	**Product development** Market driven	**Commercialisation& market release** Wealth creation
NRF Core Grant			
Donor Funding			
Private Funding			
	THRIP		
	Innovation Fund		
		'Angel' Investment	
		Seed Funding	
		BRICs	
		Venture Capital	

(Source: Medical Research Council, 2009)

Government has established a network of biotechnology development agencies, organised under the umbrella of the Technology Innovation Agency, a newly formed entity that incorporates the BRICs that were mostly set up in 2002. The BRICs, sponsored by the DST, are the Cape Biotech Trust, BioPAD, the East Coast Biotechnology Consortium (ECoBio) and PlantBio. The Cape Biotech Trust manages public funds for investing in five focus areas: bioprospecting; diagnostics; drug delivery; nutraceuticals and vaccines. The Trust also supports capacity development. It currently manages investments in 12 companies in the Cape (www.capebiotech.co.za). BioPAD, based in Gauteng, has investments in nine companies, most of which are in early R&D stage. Eleven products in which it has invested, are in various stages of commercialisation (www.biopad.org.za). ECoBio, which trades under the name of Life Lab, is the BRIC for the Eastern Cape and KwaZulu-Natal. It works in the areas of human health and bioprocessing, supporting six and four companies respectively. Bioprocessing investments were made in companies developing pathogen control for citrus fruits, pectin production from citrus, and Bt-based biopesticides (www.lifelab.co.za). The latter is through a company called Biological Control Products that produces a range of other bio-pesticides, insecticides, fungicides and fertilisers (www.biocontrol.co.za).

PlantBio was established in 2004 and is dedicated to R&D and commercialisation of plant biotechnology products. It funds four companies and is involved in its own research (alone or in consortia) on 23 projects ranging from algal biodiesel to feasibility studies on open pollinated seed varieties.

There are also a number of incubators, which support the R&D and commercialisation efforts of private biotech companies. The main sponsor of the incubators is the Small Enterprise Development Agency (Seda), which used to be called Godisa Trust but is now the Seda Technology Programme following a merger with the National Technology Transfer Centre and the Technology Advisory Centre. In 2008 one of these incubators, Acorn Technologies, merged with the Cape Biotech Trust. Another incubator is eGoliBio, which is currently, or has in the past, supported 19 biotech companies (www.egolibio.co.za). The form of support is mainly assisting companies to develop their business case and providing support to carry it through (IP, legal, financial management, fund raising etc); a more 'hands-on' approach than the strategy adopted by the Innovation Fund or the BRICs. Chemin is a chemical sector incubator that partners with Sasol, CSIR and Chemical Marketing and Consulting Services (CMCS) (www.chemin.co.za). The South African National Bioinformatics Institute (SANBI) at the University of the Western Cape and the National Bioinformatics Network were established to develop expertise around bioinformatics (the use of information technology to assist with the management and analysis of biological data). But the high cost and generally low speed of communications infrastructure in South Africa have inhibited the pace of their development to date.

Funding is mainly from DST, the National Research Foundation (NRF), the Innovation Fund, the Industrial Development Corporation (IDC) and the DTI. The DTI provides support through the Technology and Human Resources for Industry Programme (THRIP) as well as a number of other programmes and funds to support innovation and competitiveness in industry. THRIP is a partnership between government and the private sector and is based on matching funding for R&D in higher education. These are all public sector/parastatal institutions. Industrial biotech received 35% of THRIP funds in 2006 and 2007, and plant biotech received 28%. The total funding amount over the two years was R78m (Pouris, 2008:67-68). Twenty out of 70 NRF chairs in 2006 were related to biotechnology, with funding of R50m/year (Pouris, 2008:69).

The Council for Scientific and Industrial Research (CSIR) and the Agricultural Research Council (ARC) also have funds for biotechnology research, which they sometimes do in partnership with other entities. Mintek, a parastatal that receives about 35% of its funding from government, has a biotechnology division which carries out biotech R&D for the mining sector. Tshumisano Trust was established as the implementation agency for the DST's Technology Station Programme (TSP) to accelerate interaction between Universities of Technology and SMMEs. It is a partnership between DST, GTZ and Higher Education South Africa (HESA), the body for the heads of tertiary education institutions (Tshumisano Trust, 2005:1). An estimated R2bn a year is brought in from outside the country to fund clinical trials on biotechnology products, mainly in the health field (Pouris, 2008:51). Table 2 below shows that the science councils were responsible for just under half of the R20m expenditure on genetic engineering R&D in 2005/06. The remainder was split more or less evenly between the private sector and higher education institutions.

The BRICs and the Innovation Fund (both public agencies) contributed 55% of funds to core companies in 2007 (Department of Science and Technology, 2007:5). Bioventures, the first private sector biotech and life sciences venture capital fund, started operations in 2002. It is a joint venture between Gensec Bank and Real Africa Holdings. It currently has investments in eight biotech companies whose activities range from bioinformatics to the extraction of carotenoids from algae (www.bioventures.co.za). Other dedicated venture funds for biotech do not seem to be in existence anymore, including Catalyst Innovations and Chrysalis Biotechnology Holdings.

Table 2: R&D expenditure in Rands by sector and biotech-related discipline, 2005-06

Field	Business enterprises	Government	Higher education	Not-for-profit	Science councils	Total Expenditure
Biochemistry	11,355,550		15,599,187		30,172,600	57,127,337
Genetics and molecular biology	81,556,900	566,380	15,965,844	788,600	66,148,348	165,026,072
Microbiology	14,773,650	772,000	24,800,647		29,521,290	69,867,587
Genetic engineering	5,781,400		5,155,869		9,051,780	19,989,049
Biotechnology	39,783,350		25,099,998		65,396,220	130,279,568
Total	153,250,850	1,338,380	86,621,545	788,600	200,290,238	442,289,613

(Source: Pouris, 2008:26)

Agricultural biotechnology in South Africa

Government explicitly sees its role as providing an example for the adoption and acceptance of biotech crops in Africa and globally (Department of Science and Technology, 2007:6). A claim is made that public opinion supports biotech crops based on a 2003 survey of respondents mainly in urban areas of South Africa. The results, however, are highly questionable. Only 34% of respondents said they had confidence in the scientific community. Sixty-six percent of respondents were not familiar with the term biotechnology. Seventy-four percent were not sure if GM organisms were sold in South Africa, or were firmly of the opinion they were not. Fifty-nine percent of people wanted to know about science in their daily life. Forty-five percent of respondents said government should regulate the production of GM foods more than other foods (and 40% didn't know what to answer). Seventy-one percent of respondents felt that GM foods should be specially and clearly labelled. Only between 45% and 53% of respondents would definitely buy or eat GM foods even if it had no negative effects (Pouris, 2003). Another more comprehensive survey conducted in 2005 found that two-thirds of respondents had never heard of biotechnology before, and 80% had little or no knowledge about it at all (Wolson, 2007:186).

Part of the biotechnology strategy is a programme ostensibly designed to enhance the public understanding of biotechnology. This takes the form of materials for distribution to the public that explain what biotechnology is and how it can benefit society. It is certainly the responsibility of government to deepen the public's understanding of biotech, especially where it is actively being promoted as a key growth area. However, one-sided information extolling the virtues of the technology is inadequate to really deepen understanding. In essence, government is sponsoring one side of one part of a debate (in favour of the science of agricultural biotechnology) that has many facets - not only scientific and technical, but also political, social, economic and spiritual. It would be beneficial - including to the participants in the currently polarised debate - for government to open the discussion up, to allow many different sides to be heard, so that citizens can make up their minds in an informed way.

The use of genetically modified seed has grown rapidly in South African agriculture. The country was ranked as the eighth largest in terms of hectares under GM crops in 2008. However, these are all imported technologies. The main agbiotech work happening in South Africa is through the parastatal research councils - mainly the Agricultural Research Council and its branches, and the Centre for Scientific and Industrial Research (CSIR) and universities. Both are currently working on major crops: the ARC on GM potato, and CSIR on GM sorghum with funding from the Gates Foundation. A handful of private companies are involved, including Monsanto, Syngenta and Pioneer Hi-Bred. The UN Food and Agriculture Organisation (FAO) reports some 89 agbiotech applications currently underway in South Africa. Appendix 1 provides a breakdown of these. Thirty-nine of these (44%) were on genetic modification. Fifty-eight percent of the 1,542 biotech products under development by South African biotech companies were agricultural products in 2007, according to the National Biotechnology Audit.

Overview of commercial seed and agrochemical use in Africa

A number of multinationals see South Africa as a springboard into Africa for launching the Green Revolution for Africa. The continent has not been integrated into the global seed and agrochemicals markets, and it is seen as a potential new market, although one fraught with difficulties - not least institutional and infrastructural. Africa and the Middle East constituted just 2.7% of the global commercial seed market in 2007 (Phillips MacDougall, 2008:28). Because the majority of African farmers are resource poor, they can not afford to purchase hybrid seeds, and rely on saved seed using OPVs. Hybrid seed is up to 20% more expensive than OPVs, and constitutes less than 30% of the regional seed market (excluding South Africa) (Langyintuo, 2005:3,6). The formal seed system contributes about half of seed requirements in Southern Africa, but taking South Africa out of the picture indicates that other countries in the region generally rely on farmer-saved seed (Langyintuo, 2005:16).

Africa is a net exporter of the raw materials required to make fertiliser, with Morocco and Egypt the only two countries involved in the export of fertilisers and raw materials (phosphate rock) in any significant quantity. Apart from phosphate rock, generally speaking the trade in fertiliser and raw materials bypasses the African continent entirely (International Fertiliser Industry Association, 2009). Sub-Saharan Africa's per hectare use of fertiliser is very much lower than anywhere else in the world, at 8kg/ha in 2002/03. This can be compared with 61kg/ha in South Africa, 98kg/ha in North America and 202kg/ha in East Asia (Pitse, 2007:4).

Africa and the Middle East constituted just 4-7% of the US$30-32bn global pesticide market in 2007 (Agrow, 2007). The market on most of the continent was seen to be in decline, with only a few countries (including South Africa) showing slow growth (Phillips MacDougall, 2008:10). Agrochemicals are a commodity and large economies of scale are required to make investment in manufacturing infrastructure an attractive proposition. This is even more relevant as China ramps up production of agrochemicals on a massive scale. Arysta, the Japanese-based multinational which holds a 50% stake in Volcano, is not shy to describe its expansionary ambitions. “We have a strong commitment to Africa and aim to be the largest agrochemical company in the continent”, says Arysta CEO, Chris Richards. According to Richards, Arysta is the only company amongst the big pesticide producers that has production facilities in Africa. Elsewhere he describes the company’s strategy as “identify[ing] niches – geographic areas and crop segments - where competition is less intense. It then develops a range of products for the niche and co-ordinates its resources with an aim to grab a sizeable market share”. Investment in agrochemicals in South Africa is also driven by the belief that sugar cane will increasingly be used as a fuelstock for ethanol production, not only in South Africa but also Tanzania, Malawi and potentially Zimbabwe (Agrow, 2008).

CEO of Arysta, a Japanese-based multinational, is not shy to describe its expansionary ambitions. “We have a strong commitment to Africa and aim to be the largest agrochemical company in the continent.”

The commercial seed sector in South Africa

South Africa, by contrast with the rest of Africa, was a beneficiary of the Green Revolution. Commercial agriculture was built on the base of exclusion of the majority, and a high level of concentration in ownership of land, water and other resources required for agriculture. In this context, the state provided ongoing support to the creation of a capital intensive farming sector. In 2007 the commercial seed market in South Africa was estimated to be valued at US$300m, making it the joint 19th largest market in the world with Taiwan, Hungary, Netherlands and the Czech Republic (Bruins, 2008:14). Grain crops constitute almost three quarters of the domestic seed market, followed by vegetables at 16% (Sansor, 2009:11). The market for OPVs remains vigorous despite the rapid uptake of GM seed. In 2008/09 hybrid seed was the most favoured seed type in the maize sector. Hybrids were also favoured for sunflower and grain sorghum, but for all other crops, OPVs were the dominant seed type (Sansor, 2009:17). In 2007 South Africa exported US$48m of seeds, making it the 22nd largest seed exporter in the world.

The global export market in 2007 was valued at US$6.4bn, giving South Africa a 0.75% share (Bruins, 2008:16). At the same time, South Africa imported US$75m in seeds, mostly vegetable seed (88%). This placed the country as the 20th largest importer of seed globally (Bruins, 2008:17).

Despite the rapid uptake of GM seed in South Africa, in 2008/09 hybrid seed was the most favoured seed type in the maize sector. Open pollinated varieties of seeds are favoured for all crops except maize, sunflower and grain sorghum where hybrid seed is preferred.

The South African National Seed Organisation (Sansor) had 97 corporate members in 2009. Not all members are seed producers themselves; some companies are stakeholders in the seed industry, such as agrochemical companies not involved in the seed sector. While it is not a statutory requirement to be a member, all of the significant companies are, and the membership list gives a sense of who is involved in the industry. The seed production process starts with the R&D to improve varieties. This stage includes any biotech R&D. Once the R&D is completed, the seed is planted out to produce foundation seed. Foundation seed is used as the genetic base to produce certified seed for sale. Most seed companies source foundation seed from the breeders, although some of them are breeders themselves. The bulk production of certified seed is generally outsourced to farmers, since seed companies often do not have access to the land required to produce enough seed on their own. In Southern Africa, large-scale commercial farmers are usually contracted to produce hybrids, and small-scale farmers are contracted to produce OPVs (Langyintuo, 2005:5). After bulk production, seed is cleaned/conditioned and then packaged and distributed. Conditioning is the process of removing trash, standardising the shape, weight and size of the seed, hulling and scarifying where necessary, and applying chemical treatments to control pathogens. Table 3 below shows the number of Sansor members involved in different parts of the seed production process. Breeders are the smallest group. Most of the biggest companies (see table 4 below) are involved in most parts of the production process except as seed agents, since they produce and distribute their own seed.

Table 3: Sansor members by function

Function	No. of companies	No. of top 10 companies
Breeder	26	7
Grower/producer	50	7
Conditioner	53	8
Broker/agents	32	4
Importer	33	8
Exporter	37	8
Wholesaler	47	9
Retailer	59	8

(Source: derived from Sansor, 2009)

Information on market shares in the seed industry is very difficult to come by. However, table 4 below shows the number of cultivars owned or locally distributed by different companies in South Africa. Although this should not necessarily be taken as an accurate reflection of market share, it can be used as a proxy for the importance of the various companies in the South African seed market, either in ownership or distribution of seed. As we saw in the global context above, there is also a growing correspondence between ownership of plant varieties and share of the seed market. Between them the top 10 companies have rights over almost two-thirds of registered varieties. While the table does not indicate the many smaller companies that operate in the seed industry without ownership or distribution rights, it is probably a fairly accurate reflection of the major companies, since all the large companies are certain to have at least some of these rights as part of their commercial assets. Three of the global 'Big 6' are amongst the most important seed companies in South Africa: Monsanto (#2), Syngenta (#6) and DuPont/Pioneer Hi-Bred (#7). In addition, Sakata Seed (#4 in South Africa) was the eighth largest seed company in the world in 2007.

Six seed companies control the South African non-GM seed market: Pannar, Monsanto, Syngenta, Du Pont/ Pioneer Hi Bred, and Sakata Seed, with Pannar being the top dog.

At the top of the list is Pannar, a South African company which incorporates Pannar Seeds and Starke Ayres. Pannar Seeds is the holder or distributor of a wide number of varieties across all sub-sectors, while Starke Ayres specialises in vegetable and flower seeds. Pannar operates globally, including in 19 other African countries, the US, Argentina, China and elsewhere. In 2005 Pannar purchased Pau Seeds in the US from Bayer. Another subsidiary in the group, Pidelta, is a farming operation that produces the seeds for Pannar. The group holds the most varieties in the summer grain, oilseed and vegetable sub-sectors. Pannar, Hygrotech and Afgri are South African companies that have extended into markets outside the country - in Southern Africa, but also beyond.

Monsanto occupies second position primarily through acquisitions. In 1999 and 2000 it purchased two of South Africa's largest seed companies, Sensako and Carnia. These were partially absorbed into Monsanto's De Kalb brand, with some varieties remaining under the names of Sensako and Carnia. This gave it a dominant position in the maize and wheat seed sectors. By its' own accounts, Monsanto had a 50% share in the maize market in 2009. The international acquisitions of D&PL, Seminis, De Ruiters and Mahyco further increased the number of cultivars it could claim ownership over in South Africa, especially in the cotton and vegetable sub-sectors. Between them Monsanto, Pannar and Pioneer had a 90% market share of agronomic seeds (maize, wheat and sorghum) in 2002 (Kirsten and Gouse, 2003:244).

In 2007 Monsanto suggested that it might withdraw from the wheat seed market. It had already decided to discontinue producing soya seed because the small market affected its profitability (Blom, 2007). Monsanto's wheat threat followed intense opposition globally to the introduction of RR wheat, especially from European countries. In South Africa, Monsanto took aim at farm-saved seed, a practice that is as old as agriculture itself (Blom, 2007). Sixty-two percent of all wheat planted in South Africa is derived from farm-saved seed (den Hartigh, 2007). The multinational argued that by saving seed on the farm for sowing in the next year, farmers were reducing the incentive for Monsanto to invest in R&D for improved varieties. Most maize seed in commercial use is hybridised, which means that the high yields bred into them will only last for one planting. This provides built-in protection for the IPR that companies who invest in R&D assert, because farmers will return each year to buy more seed. But all wheat varieties in South Africa are open pollinated, which means that farmers can save the seed for use the next year without losing quality, and without having to pay again for the seed. Monsanto wants to stamp this practice out, and is supported by Sansor. It is clear that the only condition under which the corporations will do any R&D is if they make a profit from it, regardless of how important the improvement of varieties might be for the public at large. In a survey conducted by Monsanto, almost every farmer agreed that wheat varieties needed to be improved. But 54% stated that government should bear the cost of this (since ultimately it is a public benefit), while 23% said seed companies should pay (Blom, 2007).

That farmers should be in favour of government-funded R&D is very significant, especially in light of the strong position of the parastatal, the ARC, on the list of holders of plant breeder's rights. ARC is the only one of the major players in the seed sector that has ownership or distribution rights across all crop types. It holds the most rights of any institution in the fodder and grass sub-sector, and is the only one with rights in the tobacco sector. But it also carries reasonable plant breeding weight across the other sub-sectors. The institution is purely involved in breeding, and does not participate in any other processes associated with the seed production system.

Table 4: Holder/local distributors of seed varieties as at April 2008

	Company	Vegetables	Summer grain	Winter grain	Oilseeds	Fodder & grass	Cotton	Tobacco	Total	% of all registered cultivars
1	Pannar Group	165	168	18	42	25			418	18.9
	- Pannar Seeds	62	168	18	42	25			315	14.2
	- Starke Ayres	103							103	4.7
2	Monsanto	153	49	50	10	6	20		288	13.0
	- Monsanto SA	139	41	6	8	2	7		196	8.9
	- Monsanto Agriculture	1	8	44	2	4	13		51	2.3
	- Mahyco	12							27	1.2
	- D&PL SA	1							13	0.6
	- Seminis Vegetable Seeds								1	0.0
3	Agricultural Research Council	41	28	28	21	60	1	11	190	8.6
4	Sakata Seed SA	139				3			142	6.4
5	Hygrotech Seed	103				10			113	5.1
6	Syngenta SA	67	24		10				101	4.6
7	Pioneer Hi-Bred (DuPont)	2	57		7				66	3.0
8	Agricol		3	4	17	28			52	2.3
9	Afgri Seeds	2	36	2		4	1		45	2.0
10	Klein Karoo Seed Holdings	1	15		13	16			45	2.0
	TOTAL								1,460	65.9

(Derived from National Department of Agriculture, 2008)

ARC is a public entity and therefore these rights are held in the public domain. Private IPR protection is generally considered to be the only incentive for innovation. The flipside of that argument is that exclusive plant breeders' rights limit innovation by closing off the likelihood of others developing and improving on privately-held seed. New varieties rely on existing ones. If ownership of varieties is concentrated, and access to these varieties for further research is difficult, follow-on innovations by other institutions and researchers are likely to be discouraged (Srinivasan, 2003:532-533). Varieties could be made available for all who want to work on them, on condition that what they produce is added to the commons for further enhancement and innovation – much like open source software. Monsanto explicitly rejects this precisely because it will not have IPR over the resulting product (Blom, 2007). The second important point about the ARC's significant position is that it also engaged in R&D on genetic modification. It is an institution doing plant breeding in the public interest, but with the potential to use technologies on that pool of common resources that are contentious, to say the least. This raises age-old ethical and political questions about the role of science in society, how new technologies are developed and used, and what processes for public engagement there are.

A large number of non-GM varieties exist for the crops for which there are also GM varieties available, which means demand elasticity is still high i.e. farmers can still choose to switch to alternatives if prices go too high. The percentage of GM varieties varied from 17% (white maize) to 30% (yellow maize) of total registered varieties available in South Africa in 2008. The companies in table 5 have plant breeders' rights over GM varieties. The South African company Pannar has the most GM varieties on the market. Most of these are licensed from Monsanto.

Table 5: Number of GM varieties available in South Africa, 2008

Company	Yellow maize	White maize	Soya bean	Cotton	Total
Pannar	25	18	8	-	51
Monsanto	13	7	3	9*	32
Pioneer Hi-Bred	12	6	2	-	20
Afgri	9	-	-	-	9
Link Seed	-	2	5	-	7
Syngenta	2	-	-	-	2
Total	61	33	18	9	121

*Delta & Pine Land, owned by Monsanto
(Source: National Department of Agriculture, 2008)

GM cultivars were introduced commercially in South Africa in 1998. In 2008 GM white maize constituted 56% of the total area planted; GM yellow maize constituted 72% of the total area to yellow maize; 96% of the area planted to cotton is under GM varieties (83% stacked trait, 9% herbicide tolerant and 7% Bt cultivars), and 88% of the area to soyabeans is under GM soya (Nel, 2009, Sansor, 2009:11).

Table 6: GM traits available in South Africa, 2008

Trait	Yellow maize	White maize	Soya bean	Cotton	Total
Bt	38	26	-	1	65
Roundup Ready	16	3	18	3	40
Stacked	7	4	-	5	16
Total	61	33	18	9	121

(Source: National Department of Agriculture, 2008)

As shown in table 5 above, Monsanto is the only producer of GM cotton seed, which constitutes 90% of the total area to cotton in South Africa. Double-stacked traits constitute 19% of GM cotton varieties used in South Africa (James, 2008). This monopolisation of the sector has meant that any company wishing to access the technologies must go to Monsanto; adaptation of Bt cotton to local conditions must be done in collaboration with Monsanto, varietal development and adaptation has been undertaken through a subsidiary of which Monsanto has a controlling interest, and a technology fee valued at several times the seed's cost is charged over and above the basic seed price (Srinivasan, 2003:538). The ability of Monsanto to sustain this price premium is directly related to the absence of competing suppliers and to its ability to prevent the unauthorised reproduction of the genetic material (Srinivasan, 2003:539).

The agrochemicals sector in South Africa

Generally speaking, fertilisers and pesticides are two separate markets at the production node. Unsurprisingly, however, they tend to be distributed through similar channels, given that the end user market (farmers) is the same. The chains have two main nodes: manufacturing and distribution. Manufacturers usually supply to more than one distributor, and distribution agreements are not dominant. It is only recently that vertical integration between manufacturing and distribution has started in South Africa.

Fertilisers

The South African fertiliser industry is relatively small. It emerged as a by-product of the mining industry in the early 1900s. In the 1950s Foskor, a parastatal, was established to exploit phosphate resources near Phalaborwa, and facilities for nitrogen and phosphate production were later set up. Sasol, which previously was only a supplier of raw materials to other fertiliser companies, established its own company (Sasol Fertilisers) and started marketing to farmers directly in 1984 (van der Linde and Pitse, 2006:2). The fertiliser industry grew as part of the state-protected agricultural sector until the 1980s. After the deregulation of agriculture, which started in the early 1980s, the industry was unable to sustain itself. South Africa became a net importer of fertiliser for the first time around 2000 (Food and Agriculture Organisation, 2005:19). South Africa now exports phosphoric acid as a raw material through Foskor's Richard's Bay terminal run by subsidiary, Indian Ocean Fertilisers, 90% of which goes to India (Le Roux, 2009).

As the industry faced the pressure of deregulation and liberalisation, rationalisation took place. Currently, Sasol supplies most of the locally produced nitrogen, with ArcelorMittal SA providing some. When Norsk Hydro purchased Kynoch (now Yara SA), it closed down the urea producing factories in

Modderfontein and Milnerton, resulting in all urea being imported. LAN (limestone ammonium nitrate) is manufactured locally by Sasol and Omnia, and ammonium sulphate is produced by Sasol and ArcelorMittal. Foskor supplies phosphates to local and international markets, which producers then convert into phosphoric acid and di-ammonia phosphate (DAP). The corporation had a market share of more than 50% for the key fertiliser ingredients, mono-ammonium phosphate (MAP) and DAP. Foskor is also a major producer of granulated fertilisers. Its main shareholders are the Industrial Development Corporation (IDC) and Indian-based company Coromandel, which has a 15% share. Sulphuric acid is imported with some produced locally by Sasol.

Sasol Agri, Omnia and Yara are the dominant suppliers of intermediate and final products to the market (van der Linde and Pitse, 2006:3). They produce bulk blending products that are then processed further by other companies such as Atlas Organic Fertilisers, Nitrophoska, Plaaslike Boeredienste and Nitrochem. In 2009 the Competition Tribunal found Sasol, Omnia and Yara/Kynoch guilty of cartel conduct in the supply of nitrogenous fertiliser, and Sasol and Foskor guilty of cartel conduct in the supply of phosphoric acid. Sasol had to pay a fine of R250m (Competition Tribunal, 2009).

Fertiliser prices are shaped by four main factors: the price of oil, the exchange rate, cereal prices (an estimated 65% of fertiliser in South Africa is applied to maize, wheat and sugar cane), and the growth of the biofuel industry (which will increase demand for fertiliser, so driving prices up). Prices consequently rose extremely sharply during the commodities boom until mid-2008. The South African retail fertiliser market was valued at around R3.5bn/year in 2005 (Food and Agriculture Organisation, 2005). Around 760,000 tons of minerals are required to meet local demand. All potash is imported, and 40-60% of nitrogen is imported to produce fertiliser, while South Africa produces about 90% of its own phosphate requirements (Food and Agriculture Organisation, 2005:20, Pitse, 2007:2). Manure is an important source of plant nutrition, with a nutrient equivalent of around 30,000 tons being applied as fertiliser in the mid 1980s, a situation that is not likely to have changed much since then, according to FAO.

Pesticide production

As with seed, information on market shares in the pesticide sector is extremely difficult to come by, since it is often not publicly available or is not disaggregated. In any case, market share fluctuates from season to season because pesticide use is partly related to sporadic pest occurrences and insect resistance. Different crops also form sub-markets where there is a greater or lesser degree of concentration in market share (Competition Tribunal, 2002:4).

However, pesticide distribution agents are required by law to register with the Agricultural Chemical Distribution Association of South Africa (ACDASA), and all pesticides must be registered with the Registrar in accordance with the Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act 36 of 1947. The data from ACDASA enables us to identify the number and location of agents attached to particular pesticide dealerships. This can give us a good sense of the relative scope and size of each dealership. For example, a dealership that has 60 agents spread across nine provinces is certainly more significant than a dealership that employs five agents in one province. The data from the Registrar enables us to ascertain either the number of registered active ingredients or the number of marketed pesticides, and their categories (e.g. herbicide or insecticide). Again, companies with 150 registered/marketed products across all pesticide categories can certainly be understood to be more significant in the market than those with two products in one category. Using these two measures as a proxy for size, we can also begin to identify processes of vertical integration between production and distribution in the pesticide sector by seeing which companies are active in both nodes.

An estimated 70% of agrochemicals used in South Africa are imported (Computus, 2008:3). It is no surprise then that the large agrochemical multinationals dominate the South African market. As a proxy indication of the importance of the companies, this table does not necessarily translate directly into market share. For example, although Efekto has more registered active ingredients than Monsanto, the former mainly produces pesticides for home garden use, while Monsanto dominates the glyphosate market in South Africa. Glyphosate is one of the most widely used herbicides in agriculture and Monsanto holds a 60% share of the market. So the table really just gives an indication of some of the important companies in the production sector.

70% of agrochemicals used in South Africa are imported.

There are 180 companies with registered/marketed pesticides in South Africa. Half of these only have one or two registered products. Foreign companies dominate the South African pesticide production sector. We can immediately note that the ‘Big 6’ are all represented amongst the bigger companies in the table. In addition to that, Arysta LifeScience, the tenth largest agrochemicals company in the world in 2007, purchased a 50% stake in Volcano (#3) in 2004. It also holds a few additional registered ingredients under the name of Tomen, which was a previous entity that merged with Nichimen in 2001 to form Arysta (Agrow, 2007).

The Israeli company Makhteshim-Agan (#4) was the seventh largest agrochemicals company in the world in 2007 (ETC Group, 2008:15). Nufarm (Australia) and Sumitomo (Japan) are another two of the top 10 global agrochemical companies that have a foot in the door in South Africa. Sumitomo has pesticides registered in its own name, as well as a larger number registered through Philagro SA, of which it is a 51% shareholder. Therefore the top 10 pesticide companies in the world are all represented in South Africa. Sipcam South Africa is the local subsidiary of the Italian multinational, the Sipcam-Oxon Group. Sipcam-Oxon was ranked 17th largest agrochemicals company in the world in 2006 (Agrow, 2007). The South African subsidiary mainly assists with registration of their pesticides at present. Universal Crop Protection is a UK-based agrochemicals company.

Table 7: Important pesticide companies operating in South Africa, December 2007

	Company	No of registered active ingredients				
		Insecticides	Fungicides	Herbicides*	Adjuvants	Total
1	Bayer SA	78	51	19	1	149
2	Dow Agroscience SA	40	34	46	3	123
3	Volcano Agrosciences	14	7	65	3	89
4	Makhteshim-Agan SA	24	31	33	-	88
5	Syngenta South Africa	19	33	33	2	87
6	Universal Crop Protection	36	17	29	5	87
7	BASF South Africa	32	19	17	3	71
8	Plaaskem (Gouws & Scheepers)	18	13	8	17	56
9	Efekto (Agro-Serve/Pannar)	39	10	4	1	54
10	Villa Crop Protection	21	9	22	2	54
11	Meridian Agrochemical Co.	2	6	23	-	31
12	Monsanto	-	1	28	-	29
13	Kombat	20	3	5	-	28
14	Ag-Chem Africa	5	9	1	11	26
15	DuPont SA	5	8	12	-	25
16	Sipcam South Africa	5	15	2	-	22
17	Crompton Chemicals	8	12	-	-	20
18	RT Chemicals (Erintrade)	10	1	6	3	20
19	Tsunami Crop Care	-	-	20	-	20
20	Klub M5	7	1	8	3	19

*Figures for herbicides are for the number of marketed products in South Africa
(Derived from Department of Agriculture Forestry and Fisheries, 2007)

In 1997 Dow Chemicals acquired Sentrachem, a South African company whose subsidiary Sanachem had a 20% market share in the local agrochemicals sector, and which at the time was planning to become a major glyphosate producer (Crop Protection Monthly, 1997). Sanachem had two subsidiaries: Agricura and Efekto. Agricura, which was Dow's ultimate target, was renamed as Agrihold after the acquisition, and then converted into Dow AgroSciences. The acquisition allowed Dow to enter the South African agrochemicals market where it had not had a presence up to that time. Efekto was subsequently sold to Pannar. Kombat, a significant player in the pesticide production node, is another subsidiary of the Pannar Group, the largest seed company in South Africa.

Volcano Agrosciences is a joint venture between Arysta LifeScience (mentioned above) and Strand Agroscience Investment Holdings, which started out as a BHP Billiton special purpose investment vehicle, but no longer appears to be so. Plaaskem is the biggest of the local companies on the list. It is the agricultural chemicals subsidiary of Chemical Services Ltd (Chemserve) which is controlled by AECI, a publicly-listed South African company.

Pesticide distribution

The retail pesticide market is valued at around US$240m (herbicides US$90m, insecticides US$80m, fungicides US$55m and adjuvants US$15m), or just below R2bn a year at current rates (Villa Crop Protection, 2009a). Pesticide distribution has historically been regionally based, but a number of companies have expanded to a national level in recent times. There are 34 registered pesticide dealerships in total, with one third of them having three or fewer agents. Five companies can be considered to be national in scope (operating in six or more provinces): Qwemico, Wenkem, Laeveld Agrochem, Technichem and Tsunami Crop Care. Another eleven fairly significant companies are regionally based (see table 8 below).

Table 8: Important pesticide distributors in South Africa

Dealership	No. of registered agents	No. of provinces operating in	Main provinces
Qwemico	71	7	Free State, Mpumalanga, North West, Limpopo
Wenkem	66	9	West Cape, East Cape
Laeveld Agrochem	55	6	Limpopo, Free State, Mpumalanga
Terason	48	3	West Cape
NexusAG	44	2	West Cape
Farmers Agri-Care	40	2	KwaZulu-Natal
Avello	33	4	Limpopo
Technichem	33	6	Free State
Viking	30	3	West Cape
NRC	23	4	Limpopo
Tsunami Plant Protection	18	6	Free State, Limpopo
UAP	17	3	West Cape, KwaZulu-Natal
BayAgro-Central	15	2	Free State, North Cape
AAPI	14	3	Mpumalanga

(Derived from Agricultural Chemical Distribution Association of South Africa, 2009)

The distributors generally act on behalf of the main suppliers. Villa Crop Protection was established in 1998 from the growth of a network of dealers across South Africa. The company's model is based on a shareholding arrangement between producers of off-patent generics and pesticide distributors. Exportos, a company set up in 1989 to supply off-patent products into the South African market, sources the pesticides and supplies them to Villa. Villa then supplies its shareholder members (17 distributors in South Africa and Cropserve in the Southern African region) with the pesticides, which in turn sell them for a commission. Exportos also purchases products from Villa and sells them to non-shareholder dealers. According to Villa, its products have a 20% share of the market, and dealers working with Villa hold 65% of the market at farmer level (including selling products of other companies too) (Villa Crop Protection, 2009b).

There is some vertical integration taking place between producers and distributors. Plaaskem is a leader in the integration of production and distribution, since it is a significant player in both nodes. In 2004 Plaaskem acquired UAP Agrochemicals in KwaZulu-Natal and UAP Crop Care in the Cape (Competition Tribunal, 2004). At the time of acquisition, UAP was owned by Lager, a subsidiary of US multinational ConAgra. Prior to the acquisition AstraZeneca sold its share of UAP Crop Care to Plaaskem. BASF used UAP as its exclusive agent before Plaaskem acquired the latter, but from 2005 BASF also started supplying Viking.

Afgri (formerly Oos-Transvaal Ko-op, privatised in the mid-1990s) is a very large agricultural services company that is integrated well beyond seed and agrochemicals, including in financial services, trading and logistics, R&D, producer services and others. It is involved in the seed sector (including GM seed) through Afgri Seed. It produces and distributes pesticides through Tsunami Crop Care and Tsunami Plant Protection, in which it has an 82.5% shareholding. And it sources and distributes fertiliser through Afgri Fertiliser. Afgri subsidiary Scinetic has a 100% ownership of Labworld (Pty) Ltd that produces lab equipment, and a 50% ownership in Afgritech which aims to establish IP around animal feed technology, seed technology and development and agrochemicals.

Ububele Holdings, through Ububele Chemical Group, has a 50.1% share in pesticide producer RT Chemicals (aka Erintrade) and has 100% ownership of pesticide distribution company WTP Novon, which is active in the North West and Northern Cape provinces. It also owns Alfa Agro Chemicals, a regional pesticide producer in the Northern Cape and Free State. So it is becoming a regional-level vertically-integrated entity. Farmers Agri-Care is mainly a distributor in KwaZulu-Natal, but has some herbicide products under its own name. Wenkem also has a couple of active ingredients registered in its own name. Hygrotech, which is mainly a seed company, also has some agrochemicals in its name.

Most of the big multinationals supply their products through a number of distribution agents, and there is no apparent integration between them and local distribution agents. For example, Monsanto uses Qwemico, Wenkem and Technichem as three of its major outlets. However, in 2006 the Indian-based company United Phosphorous, ranked as the 13th largest agrochemicals company in the world (Agrow, 2007), acquired the Southern African pesticide distributor, Cropserve, for US$3 million. Cropserve serves the Southern African region under the Villa Crop Protection umbrella. As part of the deal, United Phosphorous also purchased a 4% stake in Villa, which it later increased to 11%. This is the first indication of multinational interest in making acquisitions in the pesticide distribution node.

Table 9: Summary of major companies in the South African agricultural input supply industry

Company/institution	Seed cultivars	GM seed	Fertilisers	Pesticide production	Pesticide distribution
Pannar	#	#		#	
Monsanto	#	#		+	
Syngenta	#	+		#	
DuPont/Pioneer Hi-Bred	+	#		+	
Afgri	+	+		+	+
Plaaskem				#	+
Hygrotech	#			+	
Ububele Holdings				+	+
Agricultural Research Council	#				
Sakata Seed	#				
Sasol			#		
Omnia			#		
Yara			#		
Foskor			#		
Bayer				#	
Dow Agroscience				#	
Volcano Agrosciences*				#	
Makhteshim-Agan				#	
Universal Crop Protection				#	
BASF				#	
Villa Crop Protection				#	
Qwemico					#
Wenkem					#
Laeveld Agrichem					#

Company/institution	Seed cultivars	GM seed	Fertilisers	Pesticide production	Pesticide distribution
Agricol	+				
Link Seed		+			
Terason					+
NexusAG					+
Farmers Agri-Care					+
Avello					+
Technichem					+
Viking					+

major actor; + secondary actor; * joint venture
italics - non-South African multinationals

conclusion

At a global level, the integration between biotech, seed and agrochemicals is increasingly close, and dominated by a small group of very large, powerful multinationals. The major multinationals also operate in South Africa. However, most of the technology they bring is developed outside South Africa, whether GM traits or pesticide active ingredients. However, seed must be adapted to local conditions and for this reason the local seed industry remains important as a way of introducing GM traits into the country. For this purpose, Monsanto, the main holder of GM traits, has both acquired South African seed companies, and licensed GM technology to local companies - in particular to Pannar, the largest seed company in the country.

Government aims to make the South African biotech industry amongst the top three in emerging countries by 2018. In agbiotech it is pinning its hopes on developing traits (e.g. drought tolerance, climate change ready, biofuels) and working on crops (e.g. sorghum, potato) that are more relevant to developing countries. As is the case globally, the emphasis of biotech in South Africa is on healthcare. However, agbiotech is being carried out by a combination of multinationals and public institutions. In South Africa, agbiotech is mainly licensed from these multinationals, in particular Monsanto in the three crops it dominates in - maize, soya and cotton. The ARC is the strongest public sector institution working on biotech. It limits itself to the R&D side of things, and will most likely enter into licensing agreements for the commercialisation of what it produces. The biotech and seed nodes are integrated with one another, especially through the largest seed companies who both produce and distribute their own seed.

In the agrochemicals production industry, there is also a heavy reliance on imported products, with multinationals playing a very big role. Monsanto is not as dominant here from a product point of view, but its' glyphosate products occupy an important share of the market. This is bound to increase if and when the GM crop area expands. There is some South African production, but also cherry-picking by the multinationals (e.g. Kynoch, Sanachem). The result has been the downscaling of local industry in favour of imports. In the distribution node, by its nature locally rooted, the production companies generally prefer to utilise a local distribution network without feeling the need to own that network. However, there are some signs of vertical integration with agrochemical producers acquiring distribution networks.

The presence of the multinationals, especially Monsanto, Syngenta and DuPont/ Pioneer Hi-Bred increases the vertical integration of the local input supply sector within South Africa. A couple of local companies, in particular Afgri and Pannar are also vertically integrated to some extent. The other 'Big 6' multinationals – BASF, Bayer and Dow – have a strong presence in the pesticides sector but not much in seeds. This is related to their emphasis on the agrochemicals node at a global level. Overall, vertical integration is not really the major issue in South Africa at the moment. A bigger issue is multinational domination in the seed and agrochemicals nodes.

This is especially so when one considers how profitability is determined. Two examples will suffice. First, South Africa had a local fertiliser industry until liberalisation when economic borders were opened and multinationals acquired local producers. Because sourcing from other countries might make more economic sense to these multinationals, they closed down local capacity. Another example is Monsanto with soya and wheat. First they bought local seed companies, and then discontinued seed cultivar development either because the market was too small (while they retained the lucrative maize market) or because they could make bigger profits somewhere else. The companies come in, essentially strip assets and restructure businesses to absorb the most profitable parts, and dispose of the rest or allow it to decay. The basis of these decisions has little to do with the real possibility of producing fertiliser, and wheat or soya seed profitably in South Africa. It has to do with the broader profit-driven and expansionary logic of the multinationals. The impact it has, however, is the dismembering of local industrial and productive capacity and cherry-picking of the most profitable parts of the industry. Theoretically consumers benefit from lower prices from competitive global markets in the short term - though even that has proven to be questionable when these markets suddenly collapse. But in the long-term the country loses control over decisions about what to produce, when and for whom; suffers from greater unemployment and becomes increasingly dependent on imports.

appendix 1: biotechnology applications in south africa

Species	No. of applications (no. of GM)	Traits/techniques	Status of GM applications	Organisations involved
Acacia	2 (0)	Micropropagation, biofertilisers		Forestry and Agricultural Biotechnology Institute (FABI) at University of Pretoria
Banana	4 (0)	Micropropagation, design-delivery biocontrol agents, cell biology		FABI
Canola	2 (2)	Glufosinate tolerance, phosphinothricin (glufosinate)	Field trials (2)	
Cassava	2 (0)	Micropropagation, PCR		ARC
Cattle	7 (0)	Genotyping, PCR, DNA sequencing, DNA markers		
Coffee	1 (0)	Micropropagation		
Cotton	9 (9)	Multiple resistance, Lepidoptera (insect resistance), imidazoline (fungicide), bromoxynil (herbicide tolerance)	Field trials (6), commercialisation (3)	Monsanto
Encephalartos (cycad)	1 (0)	Micropropagation		
Eucalyptus	9 (1)	Micropropagation, gene expression, sequencing, DNA based, microsatellites, SSRs, cryopreservation, glyphosate tolerance	Field trials (1)	FABI
Eucalyptus globulus	2 (0)	AFLP		FABI

Species	No. of applications (no. of GM)	Traits/techniques	Status of GM applications	Organisations involved
Eucalyptus grandis	4 (0)	AFLP, DNA chip, marker assisted selection (MAS)		FABI
Eucalyptus spp	1 (0)	Gene expression		FABI
Maize	21 (15)	AFLP, virus resistance, fungus resistance, multiple resistance, insect resistance (Lepidoptera), glyphosate tolerance, PCR, cell biology, RFLP, ELISA, phosphinothricin	Experimental (3), field trials (6), commercialisation (6)	Pioneer Hi-Bred, Monsanto, Syngenta, FABI, CSIR
Picea (spruce)	1 (0)	Micropropagation		FABI
Pinus (pine)	6 (0)	Micropropagation, SSR/ microsatellites, DNA based, cryopreservation		FABI, Rhodes University, University of Natal
Potato	3 (3)	Virus resistance, insect resistance (Lepidoptera)	Experimental (1), field trials (2)	ARC, First Potato Dynamics
Sceletium tortuosum (kanna herb)	2 (0)	Micropropagation, marker assisted selection (MAS)		Stellenbosch University
Sorghum	1 (1)	Biofortification	Experimental (1)	CSIR
Soyabean	2 (2)	Glyphosate tolerance	Field trials (1), commercialisation (1)	Monsanto
Strawberry	2 (2)	Glufosinate tolerance, fungi resistance	Field trials (2)	
Sugar cane	4 (3)	Design-delivery biocontrol agents, multiple resistance, glufosinate tolerance, starch composition	Field trials (3)	South African Sugar Research Institute, University of Natal
Xanthamonas campestris pv campestris	1 (1)	Protein content	Field trials (1)	Durban University of Technology

(Source: Food and Agriculture Organisation, 2009)
Note: Techniques: PCR – Polymerase Chain Reaction; AFLP – Amplified Fragment Length Polymorphisms; RFLP – Restriction Fragment Length Polymorphisms; ELISA – Enzyme Linked Immunosorbent Assay; SSRs – Single Sequence Repeats

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