Peddling for profits:

Pioneer Hi Bred's redundant rootworm-resistant GM maize coming soon to South Africa

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The African Centre for Biosafety (ACB) is a non-profit organisation, based in Johannesburg, South Africa. It was established to protect Africa's biodiversity, traditional knowledge, food production systems, culture and diversity, from the threats posed by genetic engineering in food and agriculture. It, has in addition to its work in the field of genetic engineering, also opposed biopiracy, agrofuels and the Green Revolution push in Africa, as it strongly supports social justice, equity and ecological sustainability.

The ACB has a respected record of evidence-based work and can play a vital role in the agro-ecological movement by striving towards seed sovereignty, built upon the values of equal access to and use of resources.

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Acronyms

ACB	African Centre for Biosafety
ARC	Agricultural Research Council
Bt	Bacillus thuringiensis
CRW	Corn Root Worm
EFSA	European Food Safety Authority
EPA	Environmental Protection Agency (USA)
EU	European Union
GMO	Genetically Modified Organism
IPM	Integrated Pest Management
NAMC	National Agricultural Marketing Council
PBR	Plant Breeder's Rights
PTM	Potato tuber moth
USA	United States of America

Key findings

- Pioneer Hi-Bred is in the fifth year of field trials for its genetically modified (GM) maize variety, 59122, containing the Cry34Ab1 and Cry35Ab1 proteins from *Bacillus thuringiensis* (Bt), which confers resistance to certain beetle (*Coleopteran*) pests, including the Western corn rootworm (*Diabrotica virgifera virgifera*).
- The Western corn rootworm (CRW) is not present in South Africa. Though climate models have predicted it could eventually migrate here, this migration "could take 100 years" according to one local expert.
- In the United States of America (USA) CRW populations have developed resistance to CRW-targeting Bt maize in 13 states across the maize belt. Studies have found that, on average, CRW resistance took little over three and a half years to develop.
- Low refuge requirements (due to pressure from the seed companies) has been cited as one reason, but more fundamental is the fact that the Bt maize that targets CRW leaves roughly 2.6% of exposed CRW populations alive. This is 260 times the survival rate used by the US Environmental Protection Agency (EPA) in its guidelines on "high-dosage" events.
- Pioneer has gained regulatory acceptance for this particular variety with ease in contrast to the Agricultural Research Council's application for Bt potato, which was rejected partly on the grounds that it was not deemed a necessary technology. This points to biosafety considerations being applied preferentially to multinational seed companies operating in South Africa over public research institutions. Given that CRW is not present in South Africa, it could be argued that Pioneer's Bt maize variety 59122 is also not a necessary technology.
- Pioneer Hi-Bred has long played second fiddle to Monsanto on a local and global level. Despite its prolific in-house conventional maize breeding capacity, and the acquisition of Pannar Seed (between them they account for over 60% of all registered maize varieties in South Africa), Pioneer needs regulatory approval of its own GM "traits" to ease its reliance on licensing agreements with Monsanto.
- The likely result of this is the increasing proliferation of more complex and costly "stacked" GM varieties in South Africa, and concomitant increases in maize seed prices. Maize seed prices virtually doubled (in nominal terms) between 2008 and 2014.
- This strategy is symptomatic of the efforts of the biotechnology industry (and the research agenda it has so much influence over) to define agronomic issues, their solutions, and to squeeze as much profit out of proprietary technologies as possible, no matter their efficacy or appropriateness.

Introduction

Pioneer Hi-Bred, owned by USA chemical giant DuPont, is currently in its fifth year of conducting field trials in South Africa with its GM maize variety, 59122. This variety expresses the Cry34Ab1 and Cry35Ab1 proteins from Bt, which confers resistance to certain beetle (*Coleopteran*) pests, including the Western corn rootworm (*Diabrotica virgifera virgifera*) (CRW). It is also tolerant to the application of herbicides based on glufosinate-ammonium. Pioneer's latest field trial application states that Pioneer intends to apply for general release after "evaluation of trial data"'. Given that it usually takes six to seven years of field trials in South Africa before a full commercial release is applied for, Pioneer could be in a position to apply for a general release in 2015 or 2016.

These are extremely worrying developments from both a biosafety and agricultural point of view, and do not appear to be guided by any form of logic, for the CRW, the major target pest for this variety, is not present in South Africa. Seeking some clarity on the issue, the African Centre for Biosafety (ACB) contacted Pioneer Hi-Bred, and were requested to direct any questions we had via the Genetically Modified Organism (GMO) Registrar at the Department of Agriculture, Forestry and Fisheries. However, the answers we received (a regurgitation of Pioneer's field trial application) did little to dispel our sense of confusion over this. A number of other people contacted, including farmers, agricultural economist and entomologists, were equally baffled as to the

intentions of these field trials.

Presently, variety 59122 has only been authorised for full commercial release (cultivation) in the USA, Canada and Japan (where no GM maize is grown of any description). Countries that have permitted the import of maize grain shipments containing 59122 include Australia, China, Columbia, the European Union (EU), Japan, Mexico, New Zealand, the Philippines, South Africa, South Korea, Taiwan and Turkey.[1]

The Corn rootworm, pest management and Bt maize

The Western CRW is among the most serious of maize pests in the USA, and is estimated to cost the USA maize industry over $1 billion a year in damages. The majority of crop losses from this pest are the result of larval feeding on maize roots. The first GM maize varieties resistant to Western CRW (containing Cry3Bb1) were commercialised in 2003, constituting 45% of the maize crop in the USA by 2009.[2]

In 2009, the EPA approved Bt maize with a pyramid of two Bt toxins targeting the Western CRW, including Cry3Bb1 with Cry34/35Ab1 and mCry3A with Cry34/35Ab1. The refuge requirements (see box) for these new varieties were reduced to 5% as a result of this.[3] At present, Monsanto, Syngenta and Pioneer Hi-Bred/Dow all have CRW Bt maize approved in the USA.[4]

By 2008, farmers in Nebraska were already noting severe damage on Cry3Bb1 maize[5], and subsequent laboratory analysis revealed resistance to Cry3Bb1 to be the cause of the resistance. Research in some of those fields identified as containing resistant CRW populations found no difference in survival rates of CRW between non-Bt and Bt maize. Resistance spread throughout 2010 and by 2011 the first incidences of cross-resistance between different Bt toxins (Cry3Bb1 and mCry3A) were detected[6] (see box).

http://www.extension.iastate.edu/CropNews/2012/0824gassmannhodgson.htm

Bt, pyramids and refugia

Bacillus thuringiensis, or Bt for short, is a soil dwelling bacterium that is toxic to many agricultural insect pests. Before the advent of genetic engineering, it had been used as a natural pesticide for many years before being formally registered in the USA in 1961. Processes of genetic engineering have allowed the transfer of genes from Bt into a maize plant, meaning the maize plant will continually produce the Bt toxins (alternatively referred to as proteins or genes). Along with herbicide tolerance, Bt (or 'insect resistance') is the most commonly grown GM crop trait worldwide. Different Bt genes target different organisms. For example, Monsanto's MON810 GM maize variety, until recently widely grown in South Africa, produces the Cry1Ab gene, which targets certain species of moths and butterflies (*Lepidoptera*). The Western CRW, on the other hand, is part of the *Coleoptera* order of insects, commonly known as beetles. In the USA, GM crops containing the Cry3Bb1, Cry34/35Ab1 and mCry3A genes target *Coleoptera*.

Continual exposure to these toxins increases the likelihood that some, and later many more, insect populations will start developing resistance to these toxins (the same is also true of weed populations developing resistance to the herbicides

used with GM herbicide-tolerant crops). Resistance is a natural mechanism and thus not exclusively a problem of GM crops. However, there is little doubt now, after more than 15 years of commercial cultivation, that GM crops have severely exacerbated the problem of resistance, in both insect and weed populations.

In the early years of Bt crop cultivation it was assumed that planting a refuge of non-Bt maize would slow down the spread of resistance; insects being exposed to Bt would mate with insects in the refuge area, and therefore prevent (or at least slow) the passing down of Bt resistance. Another strategy has been to develop GM crops with more than 1 Bt gene; some of these multiple Bt varieties are referred to as "pyramids", though not all of them. The theory is that even if insects develop resistance to one Bt gene, they will not survive exposure to the other one. Both of these strategies are underpinned by two assumptions: that the dose of Bt each insect receives will be sufficiently high to kill them, and the gene that confers resistance is recessive and therefore not easily passed on.

In South Africa, where the first published reports of insect resistance to MON810 occurred as early as 2007, neither of these assumptions has been borne out. As a result, Monsanto has withdrawn its MON810 GM maize variety, based upon the Cry1Ab gene, and replaced it with variety MON89034, based upon the Cry1A.105 and Cry2Ab genes. Though combining two Bt genes together may work in the short term, evidence has emerged, in population of beetles and caterpillars, that, far from delaying resistance, in some instances pyramiding actually speeds up the process. (For more details on the case of MON810 resistance in South Africa, see the ACB's publication *Africa bullied to grow defective Bt maize: The failure of Monsanto's MON810 in South Africa*[7]).

Widespread and rapid resistance in the USA

As stated above, resistance to Cry3Bb1 was first reported in Nebraska in 2008, followed by reports from Minnesota and Iowa in 2009. By 2013 incidences of resistance had been recorded in a total of 13 states across the USA's maize belt. On average, fields where resistance was reported had been growing CRW Bt maize for just over three and a half years[8], indicative of non-recessive inheritance of resistance.[9] The underlying causes of this rapid spread of resistance have been identified as the low doses of Bt toxin that GM maize targeting CRW produce, and inadequate refuge requirements. The USA's Environmental Protection Agency's (EPA) guidelines for Bt GM crops calls for a "high-dose" strategy; the crop should produce a strong enough dose of the Bt toxin to kill at least 99.99% of target insect pests. However, several studies have found the survival rate of CRW on Bt maize expressing Cry3Bb1 to be around 2.6%, or 260 times the maximum 0.01% survival rate that defines high-dose Bt events. Similar studies on Bt maize expressing Cry34/35Ab1 and MCry3A found survival rates of 4.2% and 3.6% respectively.[10]

With such high survival rates of CRW, in 2002 a clear majority (11 of 14 members) of the EPA's scientific advisory panel recommended a minimum refuge of 50% non-Bt maize. Perhaps unsurprisingly, the EPA failed to heed this advice and instead sided with Monsanto, which had requested a 20% refuge. When the first pyramid Bt maize varieties targeting CRW were released in 2009 (Cry3Bb1 + Cyr34/Cry35Ab1 and mCRY3A + Cyr34/Cry35Ab1) the refuge area was reduced further, to just 5%. Coupled with this has been a marked decline in the availability of high-quality, non-Bt maize, as the latest high-yield potential maize varieties produced through conventional breeding are all destined to be released as Bt varieties.[11]

This large outbreak of resistance has been accompanied by increased pesticide use among maize farmers in affected areas. A survey conducted by University of Illinois

entomologist Michael Gray revealed that 50% of Illinois maize farmers expected to use both Rootworm-resistant Bt maize and chemical insecticides during the 2013 cropping season. In Minnesota 50% of farmers who did not practice crop rotation expected to supplement their Bt maize with insecticidal use. Between 25 and 30% of farmers practicing crop rotation, with no threat of resistance, were expecting to use insecticides. University of Minnesota entomologist Ken Ostlie concluded "I suspect final percentages of both were somewhat higher".[12]

It is clear that this technology has been an abject failure in the United States, yet Pioneer seems intent on releasing this here. South Africa should not be a passive recipient of failed technologies, no matter who is trying to peddle them. It is disconcerting to note that our GMO regulators clearly see no such issues, either with the efficacy or appropriateness of this GM maize variety, and this is symptomatic of a regulatory system designed to facilitate the commercial release of GM crops rather than promote robust biosafety research.

Pioneer's risk assessment dossier

The ACB has submitted over 40 scientific comments on various GM crop applications over the last decade. Though this document is not a formal objection, the ACB wishes to place on record some of the shortcomings in Pioneer's latest field trial application:

- A description of the molecular characterisation of 59122 based on southern blot and sequence analysis is provided, though the original southern blot upon which this is based is missing, preventing independent verification.
- Reference is made to previous field trials in which Cry34Ab1 and Cry35Ab1 conferred "resistance to certain *coleopteran* pests, thus resulting in improved crop yields and reduced pesticide usage as compared to conventional pest management practices". No further information is given, for example on specific *Coleopteran* pests targeted or data on crop yield or pesticide use.
- No information is given as to the expected (or actual) Bt dose delivered to target organisms. This is of particular significance given the performance of CRW targeting Cry genes in the USA.
- It is claimed that the Cry34Ab1 and Cry35Ab1 proteins expressed in 59122 target certain *Coleopteran* insect pests, consequently "there is negligible likelihood for adverse effects on other organisms arising from the proposed release"; however, the European Food Safety Authority (EFSA)'s GMO panel has found that the combination of Bt toxins produced by 59122 presents a potential hazard to *Lepidoptera* and that this "was not expected based on the known spectrum activity of these binary proteins".[13]

Why in South Africa?

Given the fact that South Africa does not need this technology, and its abject performance in the USA where CRW *is present*, what could be the possible rationale for Pioneer seeking an eventual commercial release of GM maize variety 59122 (or field trials with several other stacked varieties containing 59122)?

The potential spread of corn rootworm to South Africa?

The Western CRW is thought to be native to the high-elevation regions of tropical or sub-tropical Mexico (the centre of origin of the maize plant) and that it spread into North America following the rapid expansion of maize production in the USA and Canada from the mid-20th century.[14] In 1992 the Western CRW was first detected in Europe, close to Belgrade airport in Serbia. By 2007 it had been found in 20 European countries and is now considered a major agricultural pest.[15]

Generally speaking insect pests will migrate to where their favoured crops are cultivated, but there are no hard or fast rules as to the pace of this spread. A recent paper has posited a risk of the spread of CRW to several maize-producing

countries, including South Africa.[16] Professor Johnnie van den Berg at the University of the North West cautioned that, while this is likely in the long term, it could take "another 100 years", and other crops (and their pest species) are more likely to arrive in South Africa before CRW.[17]

Rather than addressing any immediate risk, Pioneer's application should be rather interpreted as a "pre-emptive strike", in the event CRW spreads to South Africa. However, this "preventative strategy" has been described as the "worst IPM [integrated pest management strategy] to follow".[18] Further, crop rotation has shown itself to be a far more effective IPM strategy to combat rootworm in both Europe and the USA than the GM route.[19]

Pioneer's business strategy

At the time of its take-over by DuPont in 1999, Pioneer Hi-Bred was the world's largest seed company. Though it remains a significant player, Pioneer has more recently been playing catch-up with market leader Monsanto. Pioneer has been present in South Africa since 1968[20], but significantly strengthened its position in the South African market with the acquisition of Pannar Seed, South Africa's largest remaining seed company, in 2012.[21] In addition to gaining control of Pannar's vast maize germplasm collection, Pioneer will also benefit from Pannar's extensive footprint on the African continent, which includes research stations in five southern African countries and a presence in 23 African countries (excluding South Africa).[22]

With Pannar in its stable, Pioneer now accounts for 62% of all maize varieties registered with plant breeder's rights (PBRs) in South Africa, and 70.5% of all GM maize varieties registered.[23] Over the period 2007 to 2013 the two companies received 33% of all PBRs granted in South Africa.[24] However, despite a spate of field trials in recent years (see annex), Pioneer has only one GM maize variety of its own currently authorised for commercial cultivation in South Africa, a GM maize variety (TC1507) tolerant to glufosinate-based herbicides and resistant to certain *Lepidoptera* (from the Cry1F Bt protein).

A perusal of the latest available online maize seed catalogues from both Pioneer and Pannar indicate that many of the varieties they sell contain Monsanto's Bt "Yieldguard" traits, sold under license (Pannar also sells some Bt maize varieties that contain Syngenta's Bt11 trait). The more of its own GM traits Pioneer has on the market (regardless of how appropriate they are for local conditions), the more scope for it to "stack" these together into varieties with multiple traits, and pocket the technology fee rather than pay royalties to rival companies.

In the USA single trait GM varieties have long been replaced by double and triple stacks or higher. In 2010, Monsanto and Dow Agro-chemicals released a GM maize variety containing eight genes.[25] Since 2007 Monsanto has only sold GM maize targeting the CRW as part of stacked varieties that also target *Lepidoptera* and/or infer tolerance to herbicides. There are also reports that GM maize containing CRW targeting genes is being used in areas where the CRW is not present, as more (costly) combinations of genes are being incorporated into the best available maize germplasm. As a consequence, not only are seed prices rising, but the availability of high quality non-GM maize seed is diminishing significantly.[26]

In South Africa, single gene GM varieties are also being replaced by stacked varieties. In 2007/08 stacked varieties accounted for just 8% of the GM maize area.[27] By 2012/13 this had risen to 49%.[28] The proportion of GM maize containing more than one gene is likely to be higher however, as Monsanto's MON89034 variety, expressing two Bt genes, was released in 2010[29]. Pioneer Hi-Bred have been conducting field trials with a number of stacked varieties in recent years, some of which include the 59122 variety.

Pioneer Hi-Bred stacked GM maize varieties (including 59122) under field trials

Event	Other traits	Last date of approval
TC1507 x 59122 x MON810 x NK603	HT[1] (glufosinate and glyphosate); IR[2] (Lepidoptera)	2011
TC1507 x 59122 x NK603	HT (glufosinate and glyphosate); IR (Lepidoptera)	2011
TC1507 x 59122	HT (glufosinate); IR (Lepidoptera)	2013

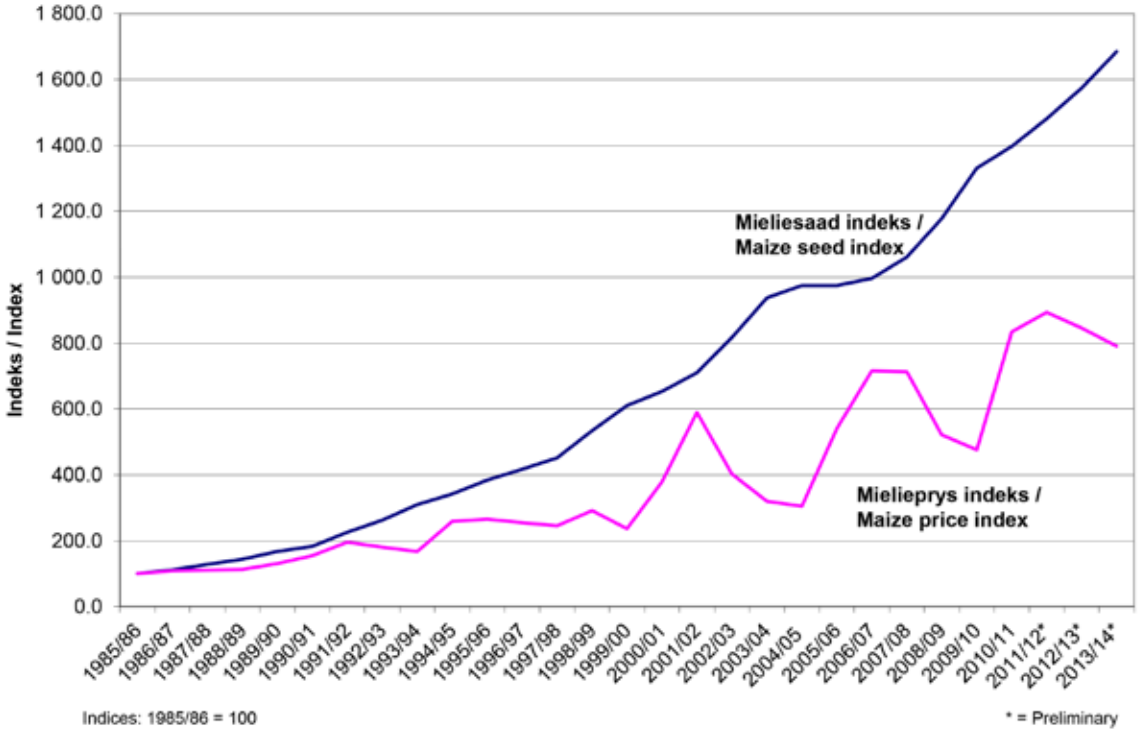
[1] HT – herbicide tolerance
[2] IR – insect resistance

It is clear that maize seed prices in South Africa, and GM maize seed in particular, have been on the rise in recent years. In 2004/05 it was estimated that (on average) seed accounted for 6% of a maize farmer's costs. By 2010/11 this had risen to 13%.[30] This trend appears to be continuing. The table below indicates the average price (based on the list price) of GM maize seed sold by Monsanto, Pioneer and Pannar Seed.[31] A word of caution, these are nominal prices (not adjusted for inflation) so direct comparison is difficult, but comparing the increase in the price of seed to the increase in the price of super maize meal[32] over the period is illuminating. This is further supported in the graph below.

Average GM maize seed prices versus super maize meal prices in South Africa, 2008 – 2014 (ZAR per bag*)

	2008	2012	2014	Change, 2008 – 2014 (%)
White GM maize seed	R1 543	R2 690	R3 010	95.1
Yellow GM maize seed	R1 418	R2 600	R2 885	103.4
5kg super maize meal (rural)	R27.57[34]	-	R33.37[35]	21
5kg super maize meal (urban)	R23.38[36]	-	R30.37[37]	29.9

Source: GRAIN SA; National Agricultural Marketing Council (NAMC)
*1 bag contains 80 000 maize kernels



Source: GRAIN SA

http://www.ent.iastate.edu/imagegal/coleoptera/rw/3936.69wcrw.html

It is difficult to imagine maize farmers paying even higher prices for non-essential traits, unless, as has been the case in the USA, this trait is stacked with other GM maize varieties (and sold at correspondingly higher prices). Pioneer has also been conducting field trials with its stacked GM maize variety TC1507 x 59122 since 2011,[33] indicating their intention to release this variety on the South African maize seed market within the next few years.

GM crops, innovation pathways and lock-in

This application appears to be yet another example of a failed, or at least inappropriate, GM trait being placed on the market to ensure the continuing profitability of GM crops for their developers, the major seed companies. This has echoes of the Agricultural Research Council (ARC)'s application to release an insect resistant Bt potato variety that targeted the potato tuber moth (PTM), a pest that was not prevalent in the region of South Africa where release was intended.[38] Similarly, despite the widespread failure of Monsanto's MON810 in South Africa, Monsanto now has ambitions to sell this product to small-scale farmers throughout Africa.[39]

In the USA, the pyramiding of genes to target the CRW is likely to have minimal effect in the long term if, as is the case now, more resources are not dedicated to IPM methodologies. The experience of GM herbicide-tolerant crops for weed management in the USA has been equally short sighted, with weed populations tolerant to glyphosate spreading across vast areas of USA farmland. As has the solutions put forward by the biotechnology industry such as the creation of new GM crops tolerant to mixtures of chemicals even older and more toxic than glyphosate, including glufosinate, dicamba and 2,4-D. In 2012, over 7 000 people, including 18 health professionals, signed a petition demanding the reversal of the South African Executive Council's decision to approve imports of a Dow Agro-chemical GM maize variety tolerant to 2,4-D based herbicides.[40]

This innovation pathway is inevitable in a system where the same companies that profit so handsomely from the introduction of GM crops have such undue influence over the research and policy space. What little autonomy remains in the public research space is put under enormous pressure to support "growth and national competitiveness" with a focus on results based (or applied) research, often in the form of public-private partnerships (which usually see fruits of the research transferred to the private sphere through complex intellectual property arrangements).[41] This is evident in South Africa, where the ARC now has to source approximately 36% of its income from non-governmental sources.[42] The University of Pretoria has a collaborative research programme on herbicide resistance with Monsanto,[43] one of the leading players in the South African herbicide market. It would be interesting to compare the research budget for this with other research into non-herbicide-based weed management systems.

In this paradigm, GM crops are seen as "radical" innovations and examples of scientific breakthrough, whereas other simpler forms of crop management (such as IPM) are seen as "incremental", even regressive. As an example, a simple key word search of the journals *Nature*, *Science* and the *Proceedings*

of the National Academy of Sciences reveals that genetic engineering features roughly 100 times more than agro-ecological engineering.[44] From the heavy focus on GM crops in the Department of Science and Technology's 2013 bio-economy strategy it would appear that, after 16 years of GM crops in South Africa in which only two traits (insect resistance and herbicide tolerance) have been released, GM crops still have a stranglehold over the policy and research space in South Africa. The opportunity costs of diverting scarce resources away from more diversified, locally appropriate agricultural research could be considerable.

Conclusion

Pioneer Hi-Bred has been conducting field trials of its GM maize variety, 59122, in South Africa since 2009. The variety contains the Cry34Ab1 and Cry35Ab1 (bt) genes that target certain species of *Coleopteran* pests, the western CRW – the major target of this variety in the USA. CRW is not present in South Africa. Further, the performance of GM maize targeting CRW in the USA has been fatally undermined by the extremely low doses of Bt toxins produced in the maize plant. Despite this, Pioneer is intent to release this variety in South Africa, which, if nothing else, will increase the company's scope for releasing its own GM traits and stacked varieties, thus increasing profit margins. The acquisition of Pannar Seed, its huge maize germplasm collection and seed marketing infrastructure, will give Pioneer ample opportunity to do this. The ready approval of this variety in South Africa, despite its inappropriateness given that CRW is not present in the country, indicates the skewed nature of the biosafety regulatory system, which gives preferential treatment to corporate interests above robust biosafety practice.

Annexure – Pioneer Hi-Bred GM maize varieties under field trials, 2013 – 2014

Variety	Trait	Year of approval
PHP34378	IR[1]	2014
PHP36827	IR	2014
PHP36682	IR x HT[2]	2013
TC1507 X NK603	IR x HT	2013
TC1507 x MON810	IR x HT	2013
TC1507 x MON810 x NK603	IR x HT	2013
PHP37046	IR x HT	2013
PHP37050	IR x HT	2013
PHP27118	IR	2013
PHP36676	IR x HT	2013

[1] IR – insect resistance

[2] HT – herbicide tolerance

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