GM SUGARCANE FOR SA - A SWEET IDEA?

Cedric Mboyisa

Brazil – the largest sugarcane, sugar and ethanol producer in the world – has just been given the green light for the commercial use of the insect resistant genetically modified (GM) sugarcane in that country.

The keynote address at the 90th SASTA Congress zooms in on and dissects the issue of GM sugarcane. Dr Hennie Groenewald, Executive Manager of Biosafety South Africa, will deliver a presentation titled "GM sugarcane: Super Pain or Super Cane?"

"The desirability of GM sugarcane for the SA industry can only be determined by the industry itself. From my outside perspective I can see a clear, potential advantage in insect resistant GM cane for SA to manage Eldana based on the ex ante viability studies done by SASRI (South African Sugarcane Research Institute). However, generally speaking, the sustainability of a GM product is impacted by various other factors, which all should be analysed critically, as the industry is doing currently, before making a final decision on the matter," says Dr Groenewald. He has more than 25 years of experience in biotechnology research and development, teaching, biosafety risk analysis and governance, science communication, business development and innovation management in the public, private and academic sectors.

Dr Groenewald's paper will, among others, highlight the opportunities and benefits associated with the use of GM technology, discuss the non-technical issues that may impact on the successful deployment of GM sugarcane cultivars… highlighting the whole spectrum of interventions required to ensure sustainability.

The *SA Sugar Journal* (SASJ) spoke to SASRI Principal Scientist Dr Sandy Snyman (Biotechnology, Crop Biology Resource Unit) to unpack what GM sugarcane is all about:

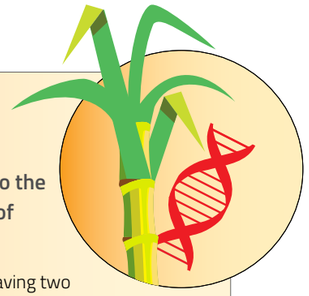
SASJ: Please explain the science behind GM sugarcane

Dr Snyman: Breeding, whether in humans or plants, is a process where genetic recombination occurs in the offspring and a 'mixing' of characteristics from the male and female parent is expected. So we are all literally 'genetically modified'! However, the specific biotechnology term genetic modification or GM refers to the introduction of a certain genetic element, not possible by conventional breeding, to an organism which is then termed a 'genetically modified organism or GMO'. There is specific legislation around the release and deployment of these GM plants, vaccines and use in medicine etc. GM technology where we introduce specific genes into plants, in part, relates to how difficult conventional breeding is, especially in sugarcane. Conventional breeding or crossing to improve sugarcane for commercial production first started in Java by Dutch breeders in the late 1890s. In order to create new hybrids, sugarcane has to flower and produce fertile pollen. It is a sub-tropical plant and flowering requires long day lengths and warm night-time temperatures. In South Africa, these ideal environmental conditions don't occur regularly, so SASRI has specially constructed glasshouses where flowering of parental lines is facilitated

Dr Sandy Snyman, Principal Scientist: Biotechnology, Crop Biology Resource Unit, SASRI

and fertile pollen is produced. To select for desirable traits (such as high sucrose and pest and disease resistance), breeders have to select parents that contain the good genes and the characteristics should be manifested in the progeny. However, sugarcane is a genetically complex polyploid with a variable chromosome number (80-120), so inheritance is complicated! From a single cross, there are thousands of offspring – and each of these have to be planted out and assessed in the field for their particular set of characteristics.

A single trait can be introduced via GM technology, for example protection against the insect borer, eldana, by means of a single gene isolated from a soil bacterium. The bacterium that contains this insecticidal property is called *Bacillus thuringiensis* and it has been formulated as a crop spray for more than 50 years. The insecticidal gene which produces a protein that binds to the gut of the insect and causes paralysis, is cut out of the bacterial nucleus and is placed in a genetic construct with a promoter (an 'on switch') and this element is introduced into the sugarcane nucleus and DNA.



Ploidy Level

Ploidy level refers to the numbers of copies of the genome.

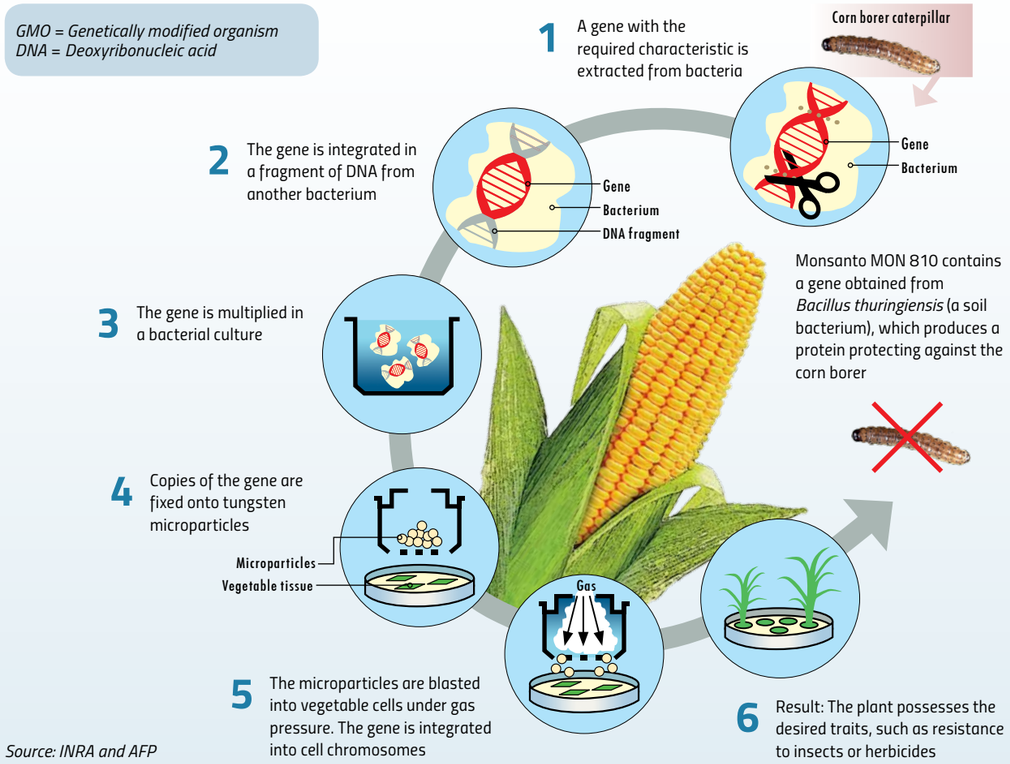
Diploid: humans having two copies of the genome – one from Mom and one from Dad with a total chromosome no. of 46 (23 pairs).

Tetraploid: wheat with four copies of the genome.

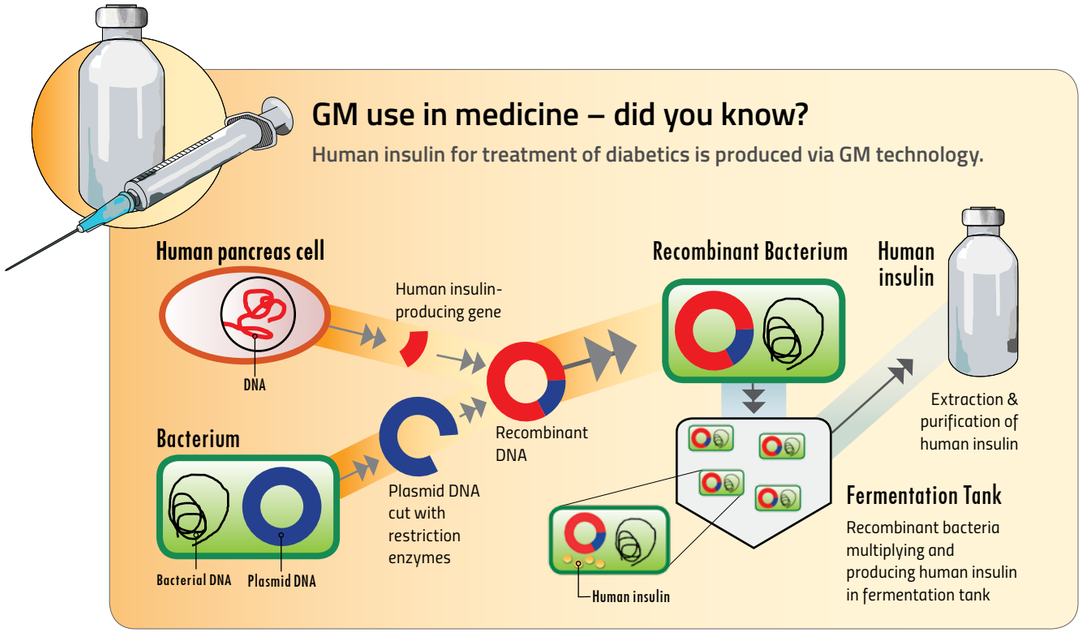
Polyploid: Sugarcane is a polyploid with 8-10 copies of the genome and chromosome number that varies from 80-120.

HOW CORN IS GENETICALLY MODIFIED

GENES THAT INTRODUCE A NEW FUNCTION ARE SPLICED INTO THE PLANT'S DNA



Source: INRA and AFP



SASJ: What are the advantages and disadvantages of GM sugarcane?

Dr Snyman: Advantages

- We can insert specific genes/traits/characteristics not possible by conventional breeding.
- We can potentially decrease amounts of herbicide and pesticide used in commercial production if the traits are herbicide tolerance and insect resistance.

Disadvantages

- The release of a GM crop is a highly regulated process that may take even longer than conventional breeding to get a new cultivar out to growers.
- Export market and consumer acceptance is unknown.

SASJ: What are the benefits of genetic modification in crop plants?

Dr Snyman: *(Source DAFF website)*

- Plants can be modified to increase their resistance to insects, diseases and other pests that are capable of destroying or seriously damaging crops.
- This not only results in increases in these crops' yields, but also reduces the need for using pesticides.
- Reduced pesticide use implies decreased pollution and an increased safety for farm workers and those living nearby, as well as less harm to animal life.
- Food quality is improved because there is less fungal infection, insect damage and residual pesticide.

SASRI glasshouses where temperature and daylength is manipulated to produce flowers with fertile pollen for conventional breeding.

- In addition, less time and energy is spent in crop production.
- Plants can also be modified to have stress-tolerance qualities, improved taste and appearances and better processing characteristics.
- Improvements can be made to nutritional qualities such as vitamin A, which can play an important role in combating deficiency diseases in millions of people (see example of Golden Rice in box).
- Eliminating nutritional deficiency helps in promoting a healthy population and productivity.

SASJ: What is the global status of GM sugarcane? Which countries (including African ones) in the world produce GM sugarcane?

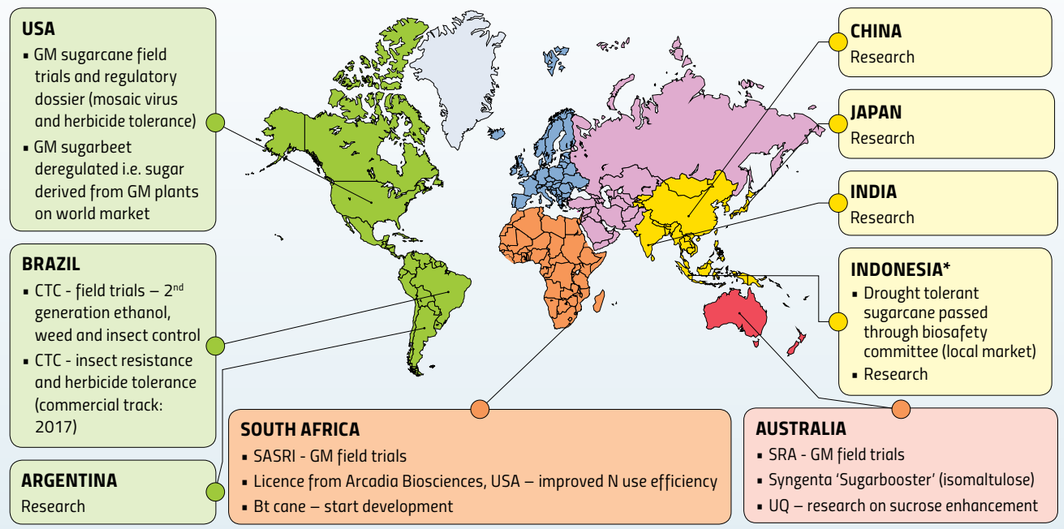
Dr Snyman: Indonesia has released drought-tolerant GM sugarcane for commercial cultivation. All of their sugar derived from GM cane is for local use. Recently (in June), Brazil approved an insect resistant GM sugarcane. All of the other sugarcane growing countries are involved in research and development of GM cane and many have conducted field trials on various GM lines.

Story of Golden rice

Golden rice is genetically modified to contain a higher content of Vitamin A in the Philippines. Golden Rice is a potential component of the broad strategy against vitamin A deficiency in developing countries. Rice is the staple food of more than half of the world's population. Rice grains are rich in carbohydrates and comprise a good source of energy but lack many essential nutrients, such as vitamins and minerals. For people who barely eat more than a portion of rice a day, those deficiencies can result in serious health problems. Tackling poverty, the lack of infrastructure and inadequate education are the greatest challenges. In attaining these goals the fortification of staple food crops in developing countries can comprise a sustainable way of adding additional nutrients to people's diets. The development of Golden Rice is an example of this. This rice contains provitamin A, a substance that the body converts into vitamin A. Efforts must continue to be made in combating global poverty and promoting a varied diet. But, for as long as vitamin A deficiency remains a public health problem in several countries, Golden Rice can be of added value.

Text source: https://www.isaaa.org/kc/inforesources/biotechcrops/The_Golden_Rice_Technology.htm
Image source: International Rice Research Institute (IRRI) - http://www.flickr.com/photos/ricephotos/5516789000/in/set-72157626241604366

INTERNATIONAL GM SUGARCANE LANDSCAPE

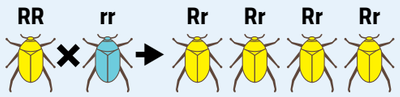


REFUGIA PLANTINGS
= NON-GM PLANTINGS IN GM FIELDS

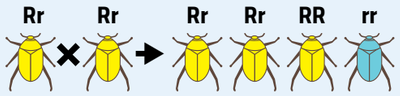
Is there any way that we can slow the spread of resistant genes? Evolutionary theory points to an answer: we can provide havens for non-resistant insects (and their non-resistant genes). These havens are called refugia — they are fields without pesticides (sprayed or plant-produced) located near fields planted with pesticide-producing crops. The diagram below illustrates how refugia slow down the evolution of pesticide-resistant pests by allowing non-resistant pest strains to survive.

Refugia slow the evolution of widespread Bt resistance by providing havens in which the non-resistant insects survive. The allele for Bt resistance happens to be recessive — that means that the resistant allele can be masked by the dominant non-resistant allele.

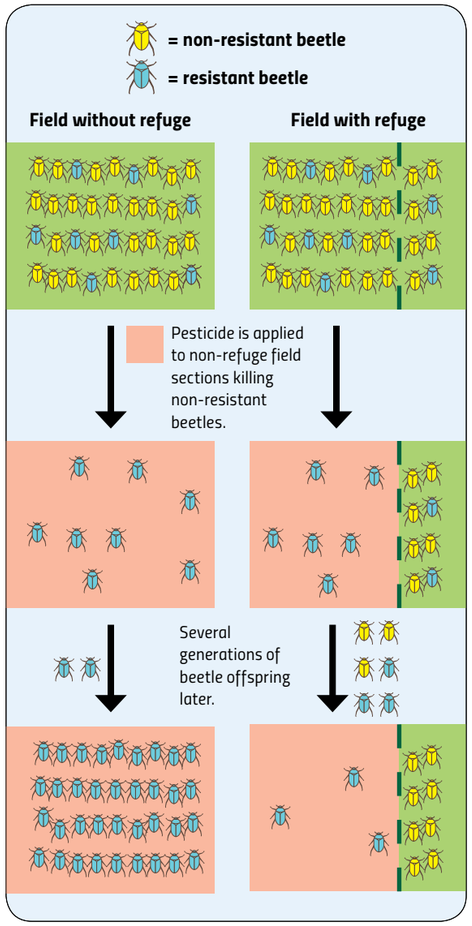
So if a resistant insect (rr) surviving in the Bt-producing field mates with a non-resistant insect (RR) surviving in the refuge, all of their offspring will be non-resistant (Rr).



When two heterozygous pests mate (Rr x Rr), only one in four offspring (on average) will be homozygous recessive (rr) and therefore resistant to the pesticide.



By keeping refuges for the non-resistant alleles, we can prevent many of the resistant alleles from being expressed. More insects will be vulnerable to Bt and the spread of the resistant allele will slow.



SASJ: What is the GM sugarcane status in South Africa?

Dr Snyman: SASRI has been conducting research on GM sugarcane since the 1990s. We have established all of the laboratory technologies required to get a foreign gene into the sugarcane genome and we have checked that it works as expected in the field (this is called Proof of Concept). The SRASA Committee, which comprises stakeholders from both grower and miller cohorts, has scrutinised a business case including return on investment calculations for Bt cane (eldana resistant). Based on this analysis, SASRI has been given the green light to proceed along a commercial track for GM sugarcane. Release is likely to take as long as it would for a conventional 'N' variety i.e. 10-12 years from now.

SASRI scientists have been working on aspects of GM technology since the late 1990s. This includes mastering cell and tissue culture techniques, figuring out how to track the inserted gene once it is in the sugarcane and checking out how the GM plants perform in the field. They have written scientific papers and presented their results at congresses all over the world. They also collaborate widely in the scientific community and belong to an International Consortium for Sugarcane Biotechnology, which conducts research on aspects of GM technology, sugarcane breeding, gene discovery and genome sequencing.

Once GM technology is in the hand of the growers, we need to be sure that we use an integrated approach to manage pests and weeds. We must prevent, at all costs, the emergence of resistant insects. We can do this by:

- Planting non-GM refugia
- Avoiding overuse of a single pesticide
- Implementing other aspects of the recommended IPM programme.

If we don't do the above, then it is possible for insects to evolve resistance against the Bt gene and we will have one less thing that is effective against eldana.

> **SASRI scientists have been working on aspects of GM technology since the late 1990s.**

SASJ: Is there an interest or appetite from the industry to try GM sugarcane?

Dr Snyman: Given that eldana causes a loss (both direct – due to insect damage and indirect – due to shorter cutting cycles implemented to manage the pest) of R900 million per annum, there is considerable interest in insect resistant GM cane. Other lepidopteran insect borers such as sesamia and chilo (the latter is a problem in Mozambique and has not yet been recorded in SA, but it is considered a biosecurity threat), this is a good trait to engineer into cane. Less insect damage means higher yields for the growers and more cane delivered to the mill – so both parties stand to benefit from the technology.

SASJ: What is the legislative process pertaining to GM plants and sugarcane?

International: The Cartagena Protocol on Biosafety, which is an international agreement that aims to ensure an adequate level of protection in the field for the safe transfer, handling and use of living modified organisms (LMOs) resulting from modern biotechnology, was established under the Convention of Biological Diversity. South Africa acceded to the Cartagena Protocol on Biosafety in August 14, 2003. In terms of the Protocol, the Department of Agriculture Forestry and Fisheries (Directorate Genetic Resources) is the recognised Competent National Authority for South Africa and is responsible for ensuring that all provisions and obligations relating to the Protocol are met.

In SA: The Genetically Modified Organisms Act, 1997 (Act No.15 of 1997) was implemented in 1999 and aims to ensure that all activities involving genetically modified organisms are carried out in such a way as to limit the possible harmful consequences to human and animal health and the environment. The Act makes provision for a Registrar; two regulatory bodies viz. Advisory Committee and the Executive Council, as well as inspectors. The objectives of the Act are as follows:

- Provide measures to promote responsible development, production, use, application, import and export of GMOs
- Ensure that all activities involving GMOs are conducted in such a manner as to limit possible harmful consequences to the environment, human and animal health

- Ensures effective waste management
- Stipulates requirements and criteria for risk assessment
- Ensure that GMOs are appropriate and do not present a hazard to the environment
- Establish appropriate procedures for the notification of specific activities involving GMO.

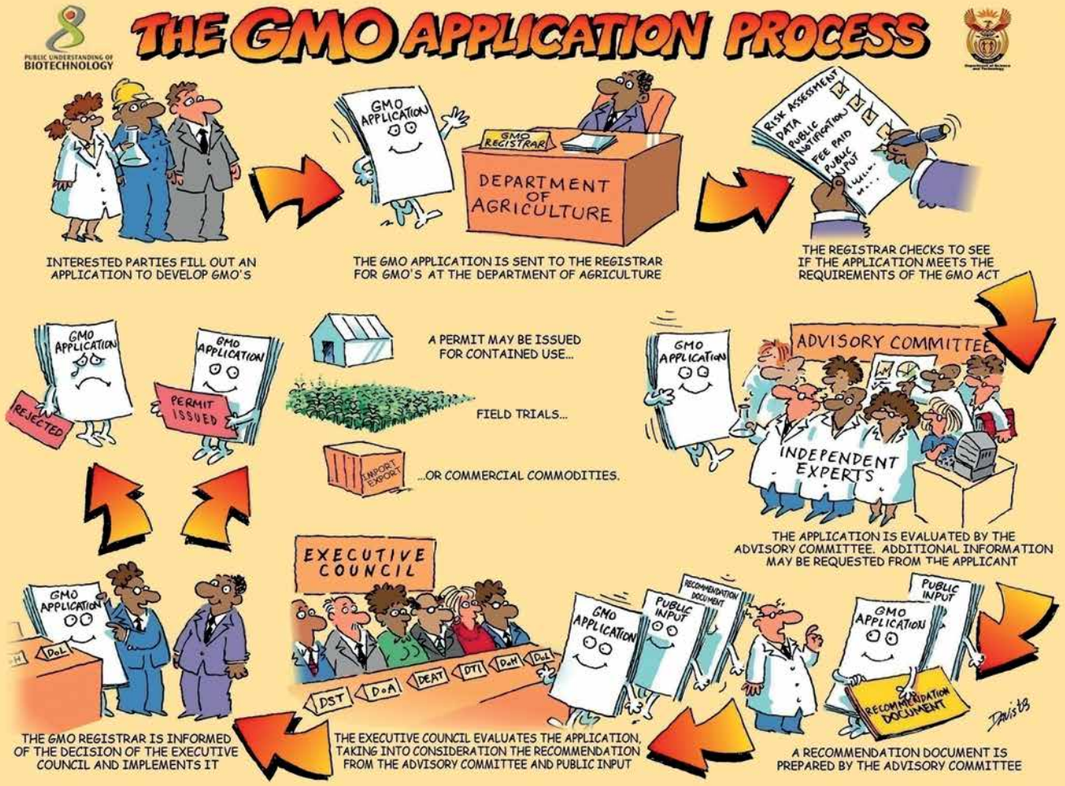
(source of info for above - http://www.daff.gov.za/daffweb3/Branches/Agricultural-Production-Health-Food-Safety/Genetic-Resources/Biosafety)

How does this affect us at SASRI? Once the SASRI scientists have a GM sugarcane line that has been thoroughly tested and they are ready to release it to the industry, an application needs to be made to the GMO Registrar who will consider aspects relating to food and feed safety, effect on the environment, socio-economic benefits etc. before a decision is made to grant approval for commercial cultivation.

Note that along the route of GM sugarcane development, permits need to be obtained from the Registrar to conduct any field testing. Several SASRI facilities are registered to conduct GMO work – the Biotechnology laboratory and containment glasshouse, and the Quarantine Facility.

SASJ: Is GM sugarcane the future or will conventional sugarcane stand the test of time?

Dr Snyman: We need both! Once a GM sugarcane plant has been approved for commercial cultivation, it will be used as a parent in the plant breeding process and conventional breeding techniques will be used to transfer the novel trait to new progeny.



SASJ: Are there any health concerns or hazards regarding sugar from GM sugarcane?

Dr Snyman: No, for the following reasons:

1. Unexpected and unintended effects can be seen with all methods of breeding. Traditional breeders observe such 'off-types' regularly; they methodically eliminate these individuals during the evaluation process, long before preparations are made for commercial release. An unexpected or unintended effect does not imply a health hazard, although clearly a plant expressing novel and unexpected characteristics warrants closer inspection prior to commercial release – see kiwi fruit story.

2. Sugar is a highly processed product and no plant material remains in the final product which is sucrose or sugar.

3. The inherent properties of sugarcane will remain unchanged by the genetic modification and this concept is referred to as 'substantive equivalence'. The GM plant is compared with a control non-GM plant and the sucrose content, growth characteristics, pest and disease resistance needs to be the same. The only thing that will be different is the new GM characteristic.

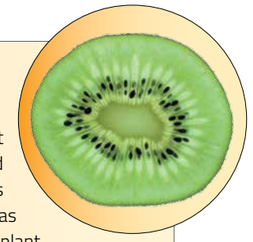
4. Some sugarcane is used as chewing cane, so the new GM protein needs to be assessed for safety. This is done using standard toxicology methods, by conducting mouse or rat feeding studies (see infographic box for maize feeding studies). Scientists can also predict the amount of new protein that humans and livestock will be exposed to should they eat sugarcane. Based on a principal called 'no observable effect level' (**NOEL**), one can assess the risk of exposure and therefore the toxicity of any substance.

5. A thorough risk analysis is conducted and things like the production of new toxins and potential allergenicity can be predicted using a genetic comparison with databases of known allergens and toxins.

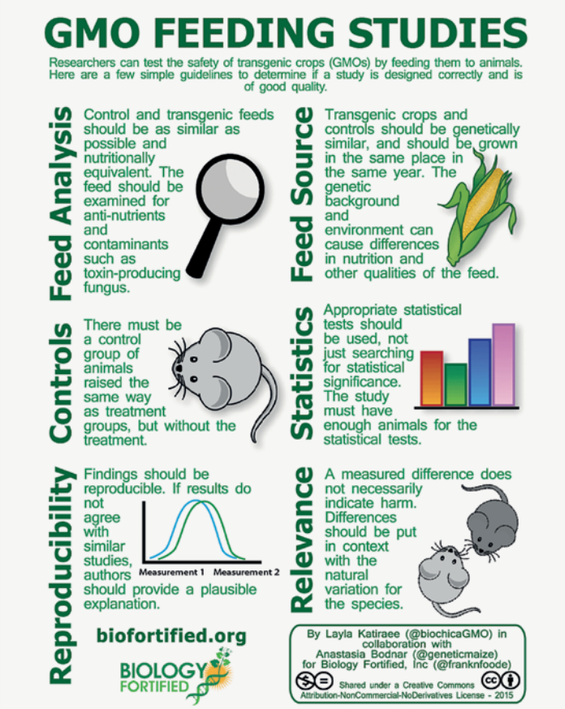
NOEL

Greatest concentration or amount of a substance, found by experiment or observation, which causes **no** detectable adverse alteration of morphology, functional capacity, growth, development, or life span of the target organism under defined conditions of exposure.

Kiwi fruit



In recent history, the closest example of a new food produced by traditional breeding is the kiwi fruit. Originally, it was an edible, but unpalatable plant producing small, hard berries, native to China. Breeders in New Zealand developed what we now know as kiwi fruit (*Actinidia deliciosa*) during the 20th century. It was commercialised in the USA during the 1960s. However, it appears that there is no official record of a pre-market safety analysis of the fruit. Consequently, some people who were not previously exposed to kiwi fruit developed allergic reactions. Recently, well after commercial release, the responsible allergenic protein (actinidin) was isolated and characterised.



Infographic showing maize feeding studies.

SASJ: What other crops in SA are genetically modified?

Dr Snyman: South Africa for many years was the only country on the African continent that had biosafety legislation governing the release of GM plants, vaccines etc. Internationally, SA is the 10th largest grower of GM crops.

The percentage of South African crops that are genetically modified and grown commercially are:

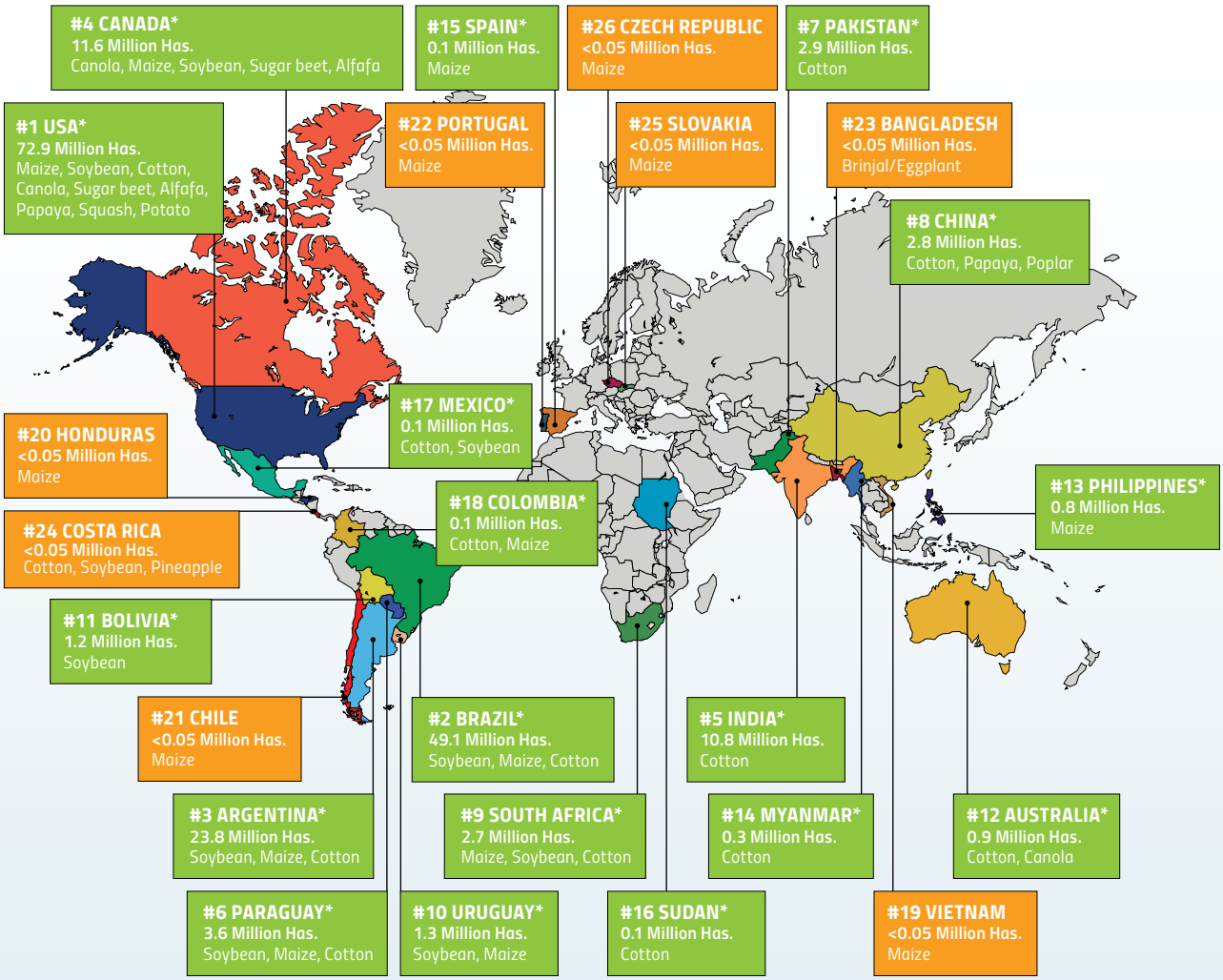
- 80 % white maize
- 55 % yellow maize
- 85 % soya
- 98 % cotton.

There are no GM fruit or vegetables grown or on the market in South Africa. Many research institutions are doing research and conducting small scale field trials with GM crops.

Imports of GM maize and soybean from USA are allowed for food, feed and processing purposes. These are well regulated under the GMO Registrar and a Commodity Clearance application, where food and feed safety is assessed and a permit is required. For example, in the last season where there was a drought and a severe maize shortage, we imported GM maize from the USA.

Other countries in Africa such as Sudan and Burkino Faso grow Bt cotton. A total of 70% of their cotton crop is GM which has increased their yield by 20% over non-GM cotton.

MAP OF COUNTRIES GROWING GM CROPS IN 2016



*Eighteen biotech mega-countries growing 50,000 hectares, or more, of biotech crops.

Source: ISAAA, 2016