IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of a further submission on the proposed Waikato District Plan by the New Zealand Forest Research Institute Limited

EVIDENCE OF ELSPETH MACRAE

18th December 2019

<u>TOPIC: GENETIC ENGINEERING AND GENETICALLY MODIFIED ORGANISMS - Hearing 8B</u>

1 My full name is Elspeth Ann MacRae. My qualifications and experience are as follows:

(a) A PhD in Plant Physiology from Otago University

(b) A BSc (Hons) in Botany from Otago University.

2 I have worked in science for over 30 years and have extensive scientific experience across food, plant and microbial sciences, 'omics' technologies, industrial biotechnology, bio-based product development, bio-refinery and bio-energy developments. This includes consumer and market assessments, plant biochemistry, molecular biology, gene structure-function studies, enzyme regulation, plant and fruit physiology and food interactions with human perceptions.

3 I have extensive experience in kiwifruit research at the DSIR and HortResearch including work on proteases in kiwifruit and mucilages and polysaccharide polymers (fibres) and allergens in kiwifruit and other plants. I was involved in discovering the key enzymatic pathway and enzymes and genes that result in ascorbate in kiwifruit.

4 I have had 11 years as a General Manager of Manufacturing and Bioproducts at the New Zealand Forest Research Institute ("Scion"). I am currently the Chief Innovation and Science Officer at Scion.

5 I have led the applications for GMO trials to the EPA for Scion field trials and also the pan-NZ application for Arabidopsis (non-field trial).

6 I am the author of 110 peer reviewed journal papers, 5 books or book chapters and an inventor of 3 patents (2 of which attained registration in NZ and the USA) and 4 plant variety rights. The peer Reviewed Publications include those attached in the Appendix to this evidence.

7 I have been responsible for registering the following patents and plant variety rights

Patents

Alpha amylase

Alpha Farnesene synthase,

Multifunctional Germacrene D synthase

Plant Variety Rights

Hortgem Tahi,

Hortgem Rua,

Hortgem Toru,

Hortgem Wha.

8. I am a participant in European Cost Action CA18111, a multi-party project funded by the European Union to evaluate plant genome editing techniques and their products to design a research and policy roadmap for the use of these biotechnologies in meeting Europe's and the world's environmental, social and economic challenges.

9. I am a 2019 member of the EPA Hazardous Substances Modernisation programmes Stakeholder Reference Group.

10. I am a current member of the IBISA-EU virtual biotech pilot plant advisory board.

11. I am New Zealand's representative and co-chair of the International Bioeconomy Forum Forest bioeconomy.

12. I am an international reviewer for Helmholtz Forschungszentrum Julich in the Bioeconomy research field

13. I am a member of the European Plant Science Organisation agritech working group

14. My earlier professional distinctions and memberships include:

2013-2014	Advisory Board EcoChem
2012	Strategic Advisory Group for the high value manufacturing portfolio, MBIE Organising Committee 2012
	Marsden Panel: Evolution, Ecology and Behaviour
	Advisory Panel for two EU programmes on bioproduct standardisation
2011	Organising committee for COST-ESF-IUFRO funded conference on Forest biomass for bioenergy, November 2011, Austria
	Reviewer for Star Colibri, an EU roadmap to 2030 for biorefineries
	Strategic Advisory Group for the biological industries portfolio, MBIE
	Member delegation of primary industry CRIs to Brazil, MFAT June 2011
2011-2013	Member of BRMAC advisory group to the EPA
2010-2014	IUFRO Deputy Coordinator Bioenergy
2010	MoRST/MSI/MBIE International KBBE Forum twinning activity; theme leader for biobased industrial products; led NZ delegation on biorefineries and biobased materials, 2010 Canada
2010-2011	COST EU Forest products and services foresight strategic steering group
	COST representative; EU Forest Products and Services Domain Committee
	Materials Accelerator Industry Advisory Board
2008-2019	NZ representative for plant-based CRIs on the European Plan Sciences Organisation
2008	Marsden Panel: Relocation Funds
2007	OECD contract; Industrial Biotechnology Scenarios 2030, Bioeconomy

	NZ Ministerial Delegation to the EU
2007-2019	IEA Bioenergy Executive Committee
2007-2019	2006-2013 Board of Biopolymer Network, Deputy Chair 2012, 2013
2006-2009	Marsden Panel: Evolution, Ecology and Behaviour
2005-2011	Futurewatch (Ministry of Science) team
2005	NZ Delegation to the EU "Fork to Farm"
2004-2019	NZBio membership
2002-2003	HortResearch strategic planning group (4 leaders); responsible for leading Health and Food; contributed to Genomics
2002	NZ Government Innovative Foods Strategic Planning Group
1987-2019	Australian Society of Plant Scientists membership
1992-2005	Leadership of multiple scientific grants, including a Marsden grant (2002-); Ministry grants between $250,000/pa and $6M/pa; offshore travel grants; and incorporation into successful EU grants

15. I have been provided with a copy of the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Note. I have read and agree to comply with that Code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scion

16. I am currently employed as the Chief Innovation and Science Officer in the Executive team at Scion, a Crown Research Institute also known as the New Zealand Forest Research Institute.

17. Scion is a Crown Research Institute established under the Crown Research Institutes Act 1992.

18. Under sections 4 and 5 of the Crown Research Institutes Act, Scion has a statutory obligation to conduct research for the benefit of New Zealand. We are obliged to consider the future and to ensure, through creating options, that New Zealand is well placed to continue to do well in that future.

19. Scion will make no private gain from participation in this hearings process or its outcomes. Scion is participating in this process in order to meet its statutory duty to benefit New Zealand.

20. Crown Research Institutes are aligned with specific industry sectors or research areas. In Scion's case we are the designated Crown Research Institute for the forest, forest products biomaterials and bioenergy industries and related research.

21. Our strategy 2030 is to enable New Zealand to transition to a circular bioeconomy based on prosperity from trees. Our responsibilities are not limited to the growing of trees or to solid wood products. Our research includes protection of forests and trees from pest and disease, tree breeding, genetics and improvement, biomaterials, packaging, bioplastics, fibre and chemicals derived from wood, value chain, forestry practices, wood processing, land use, climate change, ecosystems services and use of trees and wood as a source of biomass to substitute for industrial chemicals, fuels and other products that are currently manufactured in an unsustainable manner. Virtually all of our research is directed to environmentally and sustainable science and technology. We have a bioeconomy of the future focus and we have a responsibility to ensure future opportunities are available for NZ uptake. We are the leader of several Government programmes including biofuels and Kauri die-back

22. Scion provides fee for service science services to industry but also conducts central government research programmes and technology development. Scion has a firm focus on sustainability and conservation of the environment and is independently certified through the Enviro-Mark Programme for this.

23. Further, by way of example, in addition to our work certifying the sustainability of forests, conducting life cycle analyses and developing decision making tools regarding sustainable land and resource use, our current suite of technologies include:

- Biofuels from softwoods - liquid fuels from renewable biomass to substitute fossil fuels;

- Wood-polymer composites – reinforced polymers to replace glass fibre in plastics enabling lightweighting of various products The research currently also involves using recycled polymers and biopolymers such as polylactic acid and polyhydroxylalkanoate – plastics generated from biological sources) as substitutes for petrochemically manufactured (and imported) plastics to a produce a 100% green product that can be used in place of fossil and synthetic products in appliances, vehicles, hardware items and building materials;

- Municipal and industrial solid organic waste destruction, preventing landfilling of harmful, voluminous and leachable waste while converting toxic and pathogen carrying waste into clean and valuable chemical feedstocks;

- Bioadhesives – substitutes for formaldehyde containing resins used in wood panel production but made entirely from wood extracts and agricultural waste products;

- New carbon fibre products using a wood biopolymer instead of the petrochemical derived polymer that is currently in global use.

24. These goals and technologies are not just economically driven. They are green sustainable technologies that are, in our opinion, necessary to mitigate the harm that the environment is currently experiencing. It is my firm belief that Scion has not only well established environmental credentials in the way it operates but also is a national leader in the development of environmentally friendly technologies and practices and Scion has applied these practices over an extended period of time.

25. Because social licence is a significant factor in the adoption of genetic technologies, Scion this year sponsored market research run by Colmar Brunton and ConsumerLink surveying 4000 people on New Zealander's views on genetic technologies and then further surveyed them on genetic technologies in the context of trees and specific scenarios. I have attached a copy of the preliminary findings to this evidence. It shows varying levels of awareness of different GM technologies, relatively low levels of being informed about these technologies, high levels (68-82%) of acceptance of use of genetic technologies for conservation applications and a perception that other New Zealanders will be less accepting of genetic technologies.

WHAT ARE GMOs?

26. Some people with limited familiarity of GMOs, when thinking about GMO leap to thoughts of Frankenstein-like organisms. This is not the reality. Modern Genetic modification techniques make very minor modifications to an organisms' genetic material and usually effect only one or a small number of that organism's traits. The changes to gene sequences are generally lesser than those made by conventional breeding techniques and unregulated mutagenesis techniques. GM cotton looks like cotton, GM wheat looks like wheat, GM potatoes look like potatoes.

27. The photo below was taken in our containment facility – one tray contains young non-GM pine trees, the other tray young GM pine trees. These are the sorts of plants that are subject to the weighty requirements of the HSNO Act and any other additional regulation that may be put in place.

GMO Products in New Zealand

28. There are a multitude of items on our supermarket shelves with ingredients that came from imported GMO food. We use GMO enzymes in our washing powder and GMO yeast in our beer, we wear GMO products in the form of cotton clothing and our homes and workplaces have GMO materials such as cotton fibres. We have GMO vaccines for animals and people. Diabetics use GM insulin. Many of the fruit, vegetable and herb varieties grown commercially and domestically in New Zealand have been developed by forms of chemical mutagenesis or irradiation that cause modification in DNA that until recently were considered GMOs. So we already grow, live with, use and consume GM products on a daily basis.

DEFINITION OF GMO

29. In discussing Genetically Modified Organisms, a key starting point is the definition of the term – what is in and what is out – because in scientific terms there is often no clear boundary of what is a GMO and what isn't.

30. While the term GMO is used in legislation, in the media and by scientists, it is not a scientific term insofar as it is not used to describe a specific scientific technique or methodology and it cannot be used to define an organism by specific characteristics.

31. Rather it is a generic and somewhat amorphous term that covers a wide but non-continuous and non-comprehensive range of 20th and 21st century breeding techniques and the resulting organisms.

32. Because of it having no clear technical meaning and because there are new processes invented on a continuing basis almost every person will have a different definition. Should it be defined by transgenics (organisms with genes from other organisms)?. If so, how do we deal with transgenics in the natural world? Transgenic organisms are not unusual in the natural world– A recent study from St Petersburg State University has shown that at least 5% of flowering plants are naturally transgenic incorporating genetic material from Agrobacterium; humans have co-opted genetic material from microbes so we are ourselves transgenic, a number of kumara species have been shown to be naturally transgenic, as has tea, bananas, peanuts, yams, some cranberries and cherries and hops.

33. Are the various forms of mutagenesis included or excluded? Under the HSNO Act regulations some forms of mutagenesis are included and some are excluded with the key defining feature being the date of development, not the nature of the process or resulting organism. Is mutagenesis by the various forms of gene editing included when only infinitesimal changes are made but no foreign genetic material is introduced? What about other forms of gene editing where foreign genes are introduced?, The closest thing to a common feature is that they are made in-vitro but there are also a number of exceptions to this. There is general agreement that transgenic organisms (organisms where genes from other species are inserted) developed by in vitro techniques are considered to be GMOs, but beyond that there would be no clear global consensus as to what is a GMO and what isn't. GMOs and non-GMOs may be completely indistinguishable from each

other. The reality is that there are a range of different breeding techniques that have been developed over different times and have different levels of certainty of outcome. GMOs generally include most of the 1990s technologies, some of the 2010s technologies and some of the 1950s technologies. GM technologies are a largely random selection of technologies along the breeding continuum determined more by the politics of a particular period in time than by risk, precision, commonality of techniques or organism traits.

34. Almost every country has different and sometimes multiple definitions. In New Zealand the HSNO Act has one definition dictated not by science but by legislative expedience largely defined by a random date – before which organisms are deemed not to be GMOs even if they are genetically modified, and after which they are included even if they are indistinguishable from non-GM organisms.

35. The Royal Society presented another definition and many scientists and non-scientists have their own opinions on what is and what isn't GM or a GMO.

36. For anyone, attempting to regulate, the first issue is always "what is GM and how are GMOs defined? What is included and what is excluded?". The next question is how do we effectively regulate such a wide range of organisms and processes with such a wide range of different aspects and properties that are used in such a wide range of industries and applications from medicines to agriculture to manufacturing?

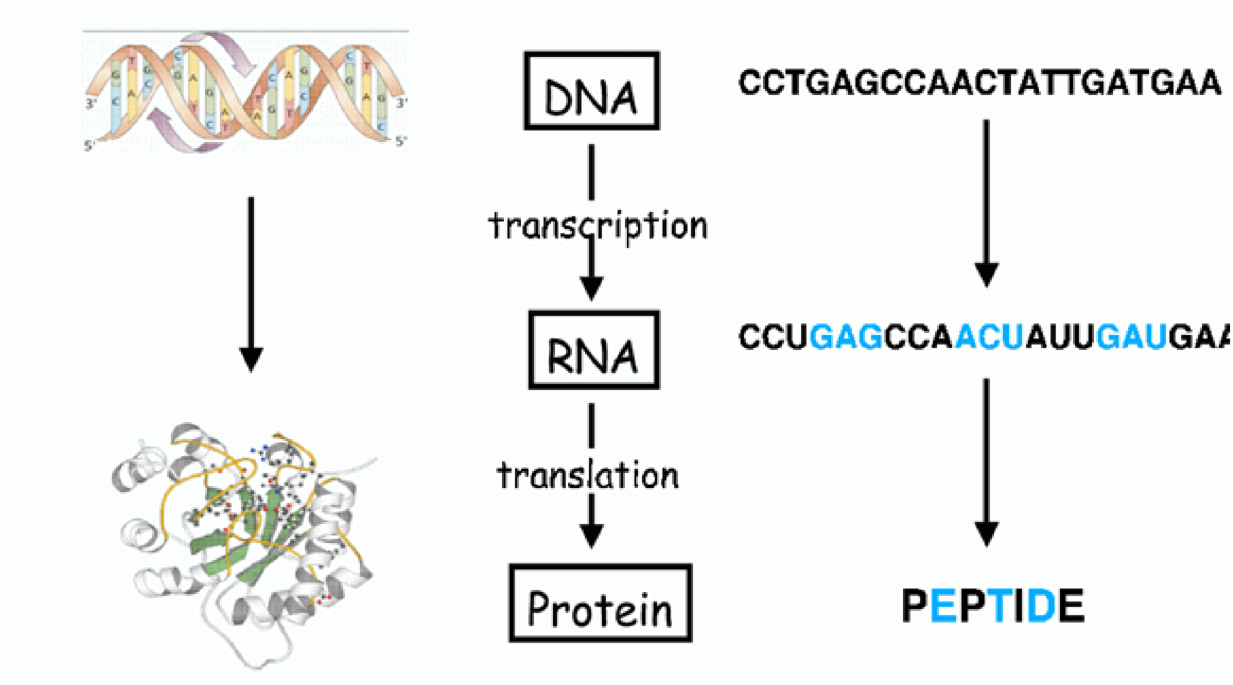
37. Science can inform but cannot provide a conclusive answer to what is the correct definition of even if the term "genetically modified organism" is fit for purpose in a regulatory context.

38. It is of interest that in Europe the terminology has changed. In place of "GMOs", "New Plant Breeding Technologies" of "NPBT" is now the language commonly used, particularly in the regulatory and legislative environment, to describe the range of biotechnology breeding processes.

GENETICS AND GMO BACKGROUND INFORMATION -

39. In simple terms genes consist of long sequences of four common nucleic acids arranged on a chromosome with other genes. They serve as a template for the manufacture of the proteins that are the building blocks of living organisms and the tools by which metabolic functions are driven. Genetic material exists in virtually every cell of every living organism – it is in our bodies, in our food, in the plants and animals and in the microbes that live in and around us.

40. The following diagram illustrates how genes are transcribed into proteins.



41 Breeding technologies whether conventional or modern change the physical characteristics or phenotype of an organism by modifying the genes of an organism. This modification may be by breeding to add or eliminate genes in a population, by increasing or decreasing the number or activity levels of those genes or by creating mutants with new combinations or activities of genes. But whatever the change the genes are still arranged in pairs on chromosomes and made of long sequences of the same four nucleic acid bases, with or without methylation.

42 Some breeding techniques rely primarily on unpredictable and random effects, some are targeted and some are precise making changes to only a few or even one base pair in a sequence.

43 Transgenic organisms which are one subset of GMOs (and are often considered the most controversial) are created by way of identifying the trait caused by a gene sequence or combination of gene sequences in a first organism. This sequence is replicated in a lab and implanted into the target organism. There is no direct transplant from one organism to another, but through lab techniques the second organism is made to mimic the first organism in relation to the specified gene sequence. The new organism now has a sequence that provides a template for a protein that it could not previously produce or it may be stopped from producing a protein that it previously produced. The chromosomes of the new organisms are still made with the same four nucleic acid bases but there is now a section that has a new sequence or arrangement of these. The DNA or RNA itself has the same composition as the DNA or RNA but the subject organism has a trait that is new, or accentuated, or suppressed.

44 The definition in New Zealand, of what constitutes a Genetically Modified Organism ("GMO") and what does not, is based on a generic description of the processes used to generate the organism, rather than the genetic composition itself or a risk assessment of the characteristics of the resulting organism.

GM more precise than traditional breeding methods?

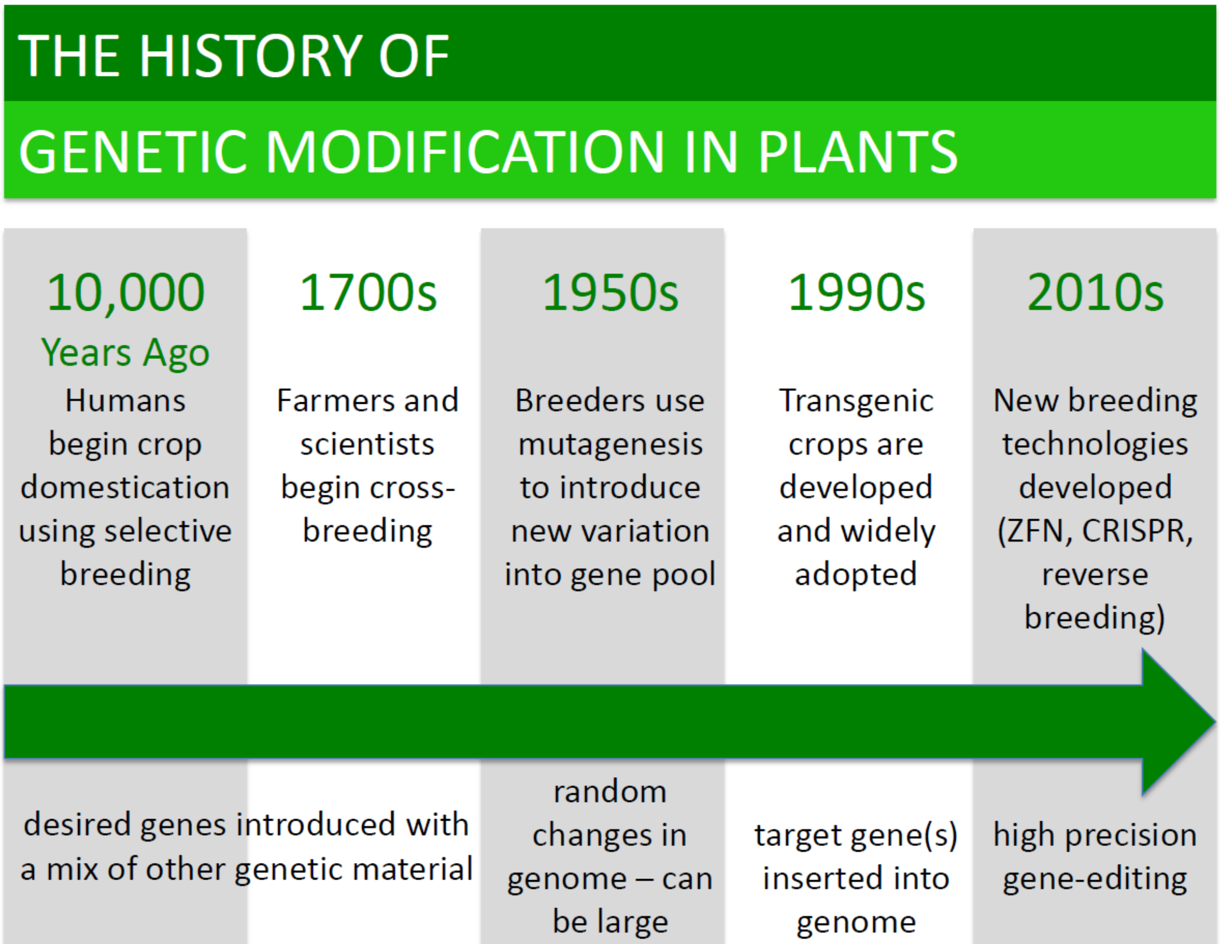
45 GM is not an easy science where genetic material is modified or mixed on a whim in a few minutes. Rather it is a lengthy and rigorous process that involves screening enormous numbers of genes, identifying or attempting to identify their function, assessing candidate genes, modifying cells to try to introduce a trait by adding or increasing the expression of a gene or by reducing expression or silencing an existing gene followed by lengthy testing and trialling. It is a complex and time consuming and lengthy process that is carried out in a rigorous and controlled scientific manner.

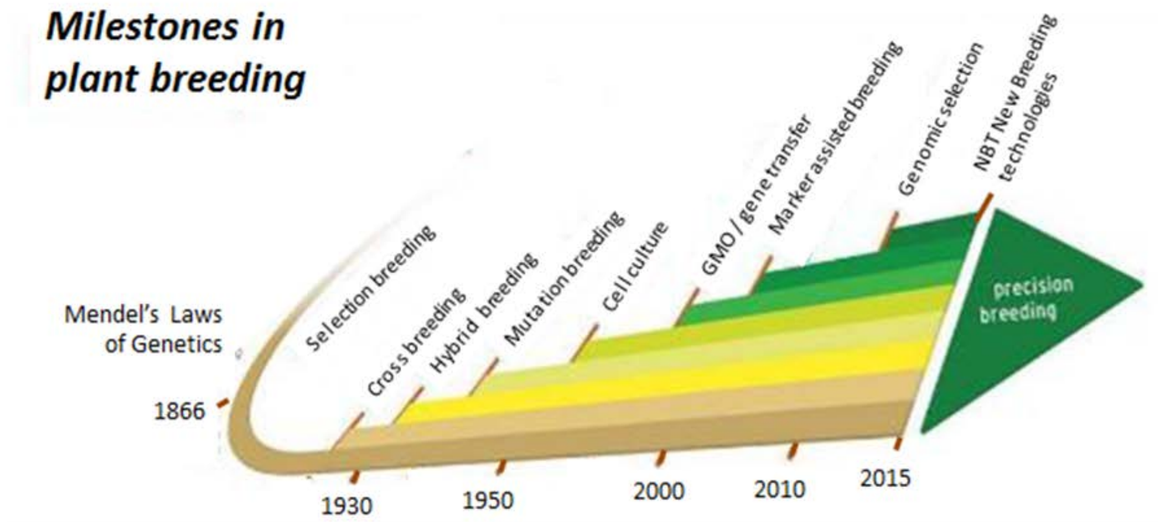
46 There is considerable scientific literature suggesting that the changes in gene expression (and changes in the proteins and metabolites produced by these genes) are greater in plants produced using traditional crossing (non-GM) techniques than those produced using the GM methods.

47 Modern molecular analysis techniques allow the expression of a substantial number of genes (10s of thousands) to be measured simultaneously in an organism. Using these methods scientists have compared the gene expression patterns of plants created using either traditional breeding or GM methods. The changes found in the GMO's were far fewer than those in comparable plants produced by traditional crossing (Ricroch et al. 2011, Gao et al. 2013, Ricroch 2013, Venkatesh et al. 2015).

48 Examples where conventional breeding has been shown to produce greater changes than GM methods include maize (Venkatesh et al. 2015), rice (Gao et al. 2013), soybean, and barley(Kogel et al. 2010). These results are not surprising since GM methods usually introduce a few (1-3) genes whilst crossing involves the mixing and segregation of the total set of each of the parent's genes. Organisms generated by methods not regarded as GM generally introduce greater and more random changes to the plant genome than GM methods.

48B Plants derived by cell fusion (including protoplast fusion) are also not considered to be GMOs under the HSNO regulations. Cell fusion allows the genomes of two different species to be fused to create a new organism. Protoplast fusion technologies, using in-vitro techniques, allow species that cannot breed naturally to be fused to create new organisms unknown in nature. Such hybrid organisms have genome components from both species and as such, have genome modifications that are much greater in extent that the changes produced by the transgenic techniques and are defined by the HSNO Act as GMOs.

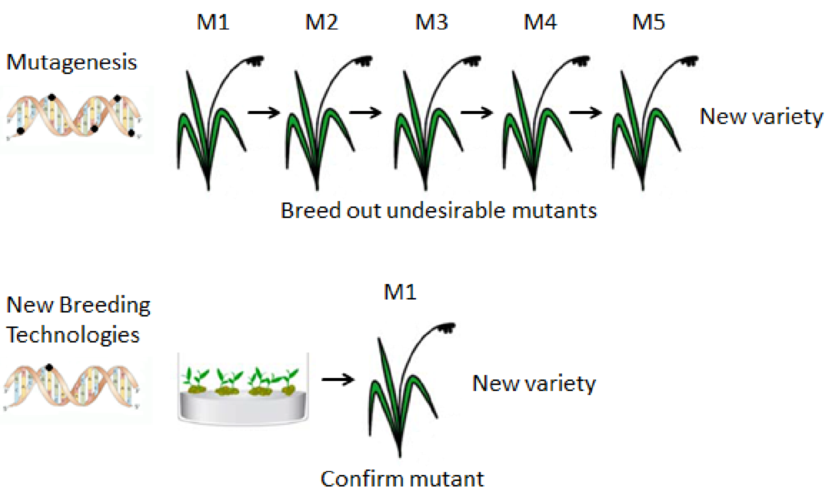




49 The above diagrams are of course simplifications of reality. There are numerous additional breeding technologies and variations on breeding technologies including new GM and non-GM technologies.

50 The below diagram provides an example of how GMOs may be more precise with lower risk of off-target mutations than non-GM processes. It illustrates the routes taken to reach equivalent organisms using a non-GM mutagenesis technique. This

technique requires multiple generations of subsequent breeding to breed out undesirable genes and traits. This is compared to a GM gene editing technology that makes only small and precise changes to a gene to realise the new variety hopefully without off-target effects.



THE SCIENTIFIC CONSENSUS

51. There is a consensus in the science world that GMOs under current international regulatory regimes are "safe" and that there are no significant risks inherent in the technologies. This assessment is based on products that have been developed and tested in labs and grown commercially at scale. This is not to say that the tools that are described as GM could not be used to intentionally develop a harmful organism – but such research and organisms would never get research approvals, release approvals, would not comply with food safety regulations or medicine approvals, would be discovered in trialling and testing and would not be accepted in the market etc in any regard. Persons with this intention would need to be operating outside of the system so be unaffected by whatever form regulation may take.

52. In science, consensus does not mean that 100% of scientists agree but that the vast majority of suitably expert scientists agree and that the evidential basis for this agreement is overwhelming. There are outliers, but the majority of the outliers present no evidence but rather theory or opinion contrary to the consensus without any real world or experimental evidence.

53 GM is no longer a new technology and an increasing body of evidence supports its safety. The peer reviewed scientific literature contains a wealth of evidence attesting to the lack of damage to either human health or the environment resulting from the worldwide growth of GM crops.

54 Worldwide, approximately 3 trillion transgenic-GM meals have been eaten over the past decade with no evidence of harm. The number of meals comprising plants developed via mutagenesis is innumerable.

55. One of the few to present experimental data was the French scientist Seralini, however, both Seralini and his experimental results have been discredited and his papers withdrawn from all reputable scientific publications.

56. I will discuss the main opposition to the consensus then review analyses of the scientific record and the findings of major reputable and international organisations.

Seralini

57. The most commonly cited scientific paper in opposition to genetic modification is a paper by French scientist Gilles-Eric Seralini that concluded that genetically modified maize caused cancer in rats. What is commonly not understood is that the rats were lab rats bred to get cancer for the testing of therapies. Seralini fed GM foods to the rats and manipulated the data to give the impression that the cancer rate in the GM-fed rats was higher when the statistics didn’t support this. Seralini also distributed lurid photos and (prior to publication) required reporters sign confidentiality agreements that prevented them from getting an independent science review before they published their media articles reporting a (false) link between GMOs and cancer.

58. Seralini’s paper was published but subsequently withdrawn by the publishers. It has also been discredited by the European Food and Safety Authority, Food Standards Australia and New Zealand and numerous other credible regulatory bodies, scientific sources, science commentators.

59. Peer reviewed publications (such as that the European Society of Toxicologic Pathology - Schorsch F. Et. Al. Food and Chemical Toxicology 53 (2013) 465-466) have described the Seralini study as pseudoscience and damaging to the credibility of science.

60. Since publication of Seralini’s paper, and the data presented in it, it has been extensively reviewed by a number of independent national regulatory authorities concerned with food safety as well as by world-leading food and toxicology experts. All of the independent national food safety regulatory authorities that have reviewed this study have concluded that the results presented do not support the conclusions made in the publication i.e., they have found that no credible evidence that GM maize is associated with tumours is presented. These include:

Food standards Australia and New Zealand (FRANZ) (http://www.foodstandards.gov.au/consumer/gmfood/seralini/pages/default.aspx)

“On the basis of the many scientific deficiencies identified in the study, FSANZ does not accept the conclusions made by the authors and has therefore found no justification to reconsider the safety of NK603 corn, originally approved in 2002.”

The European Food standards Agency (ERSA)
(http://www.efsa.europa.eu/en/press/news/121128.htm)

"Serious defects in the design and methodology of a paper by Séralini et al. mean it does not meet acceptable scientific standards and there is no need to re-examine previous safety evaluations of genetically modified maize NK603. These are the conclusions of separate and independent assessments carried out by the European Food Safety Authority (EFSA) and six EU Member States following publication of the paper in the journal Food and Chemical Toxicology on 19 September 2012".

Health Canada

(http://www.hc-sc.gc.ca/fn-an/gmf-agm/seralini-eng.php)

"Based on Health Canada and CFIA's review of this information, the authors' conclusions concerning the long term safety of NK603 corn and glyphosate are not supported."

The German National Academy of Sciences have called for legislation to reflect that genetic technologies including transgenics have been used widely for 30 years with no risks inherent to the technology being evident for humans, nature of the environment (Towards a scientifically justified, differentiated regulation of genome edited plants in the EU, 2019).

The German federal Institute for Risk Assessment (BfR)

(http://www.bfr.bund.de/en/press_information/2012/29/a_study_of_the_university_of_caen_neither_constitutes_a_reason_for_a_re_evaluation_of_genetically_modified_nk603_maize_nor_does_it_affect_the_renewal_of_the_glyphosate_approval-131739.html)

'The study shows both shortcomings in study design and in the presentation of the collected data. This means that the conclusions drawn by the authors are not supported by the available data"

SAFETY OF GM TECHNIQUES

61. The Italian Ministry of Agriculture and University of Perugia reviewed nearly 2000 scientific papers are produced the following review concluding that there was no inherent risk in GM technologies (full paper attached):

"An overview of the last 10 years of genetically engineered crop safety research

Critical Reviews in Biotechnology", March 2014, Vol. 34, No. 1 , Pages 77-88

Alessandro Nicolia, Alberto Manzo, Fabio Veronesi, and Daniele Rosellini

62. This Italian study found

> "The technology to produce genetically engineered (GE) plants is celebrating its 30th anniversary and one of the major achievements has been the development of GE crops. The safety of GE crops is crucial for their adoption and has been the object of intense research work often ignored in the public debate. We have reviewed the scientific literature on GE crop safety during the last 10 years, built a classified and manageable list of scientific papers, and analyzed the distribution and composition of the published literature. We selected original research papers, reviews, relevant opinions and reports addressing all the major issues that emerged in the debate on GE crops, trying to catch the scientific consensus that has matured since GE plants became widely cultivated worldwide. The scientific research conducted so far has not detected any significant hazards directly connected with the use of GE crops; however, the debate is still intense. An improvement in the efficacy of scientific communication could have a significant impact on the future of agricultural GE. Our collection of scientific records is available to researchers, communicators and teachers at all levels to help create an informed, balanced public perception on the important issue of GE use in agriculture."

63. The UK Select Committee via the Chair of the UK Science and Technology Select Committee in a report (attached) released in February 2016 stated:

> "Opposition to genetically modified crops in many European countries is based on values and politics, not science. The scientific evidence is clear that crops developed using genetic modification pose no more risk to humans, animals or the environment than equivalent crops developed using more 'conventional' techniques.
>
> Unfortunately, the way the EU's regulatory system works means that countries opposed to genetically modified crops can block their growth in other countries. This has driven research activity out of the EU and put at risk the UK's ability to be a global player in advancing agricultural technology.
>
> Regulatory reform is no longer merely an option, it is a necessity. To meet the huge challenge of feeding a burgeoning global population, using fewer resources, as our climate becomes increasingly unstable, we will need to use all of the tools at our disposal, be they social, political, economic or technological."

64. The Chief Scientist of the European Union and professor of microbiology at Aberdeen University, Anne Glover has stated:

> "The main conclusion to be drawn from the efforts of more than 130 research projects covering a period of more than 25 years, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se more risky that e.g. conventional plant breeding technologies"

and

> "There is no validated evidence that GM crops have greater adverse impact on health and the environment that any other technology used in plant breeding. There is compelling evidence that GM crops can contribute to sustainable development goals with benefits to farmers, consumers, the environment and the economy."

65. Ms Glover's statements caused political controversy in Europe. In response to this controversy her position was backed by the European Academies Science Advisory Council.

66. Professor Sir David Baulcombe, University of Cambridge with the agreement of The Society of Biology has stated we can now

"be confident that the risk associated with GM crops is negligible."

67. The (UK) Society for Biology has stated:

"Worldwide, over 175 million hectares are dedicated to GM crop cultivation, accounting for 12 percent of arable land, and no inherent risks have so far been identified to human or animal health from this consumption or to the environment from their cultivation."

68. The European Academies Science Advisory Council (known as the collective voice of European science) stated in 2013 stated the scientific literature shows no compelling evidence

" linking genetically modified crops "with risks to the environment or with safety hazards for food and animal feed greater than might be expected from conventionally bred varieties of the same crop."

69. The (UK) Royal Society has stated:

"no evidence exists that GM methods, as defined in current legislation, are intrinsically more dangerous than other less regulated approaches."

70. Professor Joe Perry, European Food Safety Authority (EFSA), stated that the GMOs that had received a positive opinion from European Food Safety Authority were

"as safe as their conventional counterparts"

71. Professor Ottoline Leyser of the UK Royal Society has stated:

"The idea that [genetic modification] is inherently more risky compared with what we now know about all the conventional approaches that we use is not tenable based on the current science. I am not saying that it is risk free, but nor is conventional breeding"

and

"If one takes herbicide tolerance, for example, and all the issues about weed resistance and so on and so forth, there are non-GM, single gene, herbicide-tolerant crops out there. [...] They have exactly the same, or possibly slightly worse, issues associated with them. This is exactly the point. If one is concerned about particular environmental issues, such as the spread of herbicide tolerance, campaigning against GM is the wrong way to go, because it is not caused by GM. It is caused by herbicide resistance. If your concerns are those environmental issues, you should be campaigning against herbicide resistance, however it is introduced."

72. Food Standards Australian New Zealand (http://www.foodstandards.govt.nz/consumer/gmfood/gmoverview/Pages/default.aspx) makes the following statement:

All genetically modified (GM) foods intended for sale in Australia and New Zealand must undergo a safety evaluation by Food Standards Australia New Zealand (FSANZ). FSANZ will not approve a GM food unless it is safe to eat.

73. The American Association for the Advancement of Science has stated:

"The World Health Organization, the American Medical Association, the U.S. National Academy of Sciences, the British Royal Society, and every other respected organization that has examined the evidence has come to the same conclusion: consuming foods containing ingredients derived from GM crops is no riskier than consuming the same foods containing ingredients from crop plants modified by conventional plant improvement techniques."

74. In addition to the science literature, over 190 million hectares of the world's arable land is sown with GM crops with no demonstrable harm or risk and the world has eaten billions of meals of or including GM food with no evidence of harm.

75 By comparison there are a tiny number of scientists presenting an opposing opinion such as Seralini. Seralini is by far the most cited as his is a rare case where data and experimental results are reported as opposed to opinions unsupported by data.

76. There are also a number of older papers such as one indicating Bt maize harms larvae of monarch butterflies but further research has disproven these.

77. There are also a number of other scientists with expertise in unrelated fields , dentists and medical general practitioners who also publish opinion pieces in opposition to GMOs. But it would be incorrect to say there is not scientific consensus on the safety and benefits of GM technologies.

How does the government regulate GM foods?

78. In New Zealand, the Environmental Protection Authority, under the Hazardous Substances and New Organisms (HSNO) Act 1996 regulate GM research and product releases. Research must be approved via an open process and controls in protections put in place around that research. The EPA must be satisfied that any risks posed can be managed in such a way as to protect the health and safety of people and to protect the environment. If the GM organism will be used to produce food, FSANZ will also determine if that food is safe for people to eat.

79. GM foods are regulated under Standard 1.5.2 – Food produced using Gene Technology, contained in the Australia New Zealand Food Standards Code (the Code). The standard (an enforceable regulation) has two provisions – mandatory pre-market approval (including a food safety assessment) and mandatory labelling requirements. This standard ensures that only assessed and approved GM foods enter the food supply. Anyone seeking to amend the Code to include a new GM food under Standard 1.5.2 should refer to the Application Handbook."

80. These regulations are in addition to general regulations that apply to products of the same type as GM products.

81. By contrast, the United States which has millions of hectares of GM crops takes a different approach. The United States does not have any federal legislation that is specific to genetically modified organisms (GMOs). State law generally plays little role in the regulation of GMOs in the US. The federal pre-emption doctrine, which bars conflicting state regulation when Congress intends federal regulation to occupy a particular field, precludes many aspects of state regulation of GMOs . GMOs are regulated pursuant to health, safety, and environmental legislation governing conventional products. The US approach to regulating GMOs is premised on the assumption that regulation should focus on the nature of the products, rather than the process in which they were produced. The Food and

Drug Administration administers GMO foods, the Animal and Plant Health Inspection Service administers new plants and animals, the Environmental Protection Agency administers pesticides and microorganisms. The organisms are governed by the same health and safety and environmental regimes as apply to non-GM products. (Pew Initiative on Food and Biotechnology, Guide to U.S. Regulation of Genetically Modified Food and Agricultural Biotechnology Products 6 (Sept. 2001))

GMOs CURRENTLY GROWN IN NEW ZEALAND

82 It is generally recognised that New Zealand has in place one of the strictest regulatory regimes for GMOs in the world for NZ developed GMOs and although a number of field trials have taken place, including several by Scion, there has been no approvals for unconditional releases (commercial planting) in the country for GMO plants developed in New Zealand under the HSNO/EPA regime.

83. However, contrary to the occasional statements seen in the media, New Zealand is by no means GM-free. They are GMOs in New Zealand that have pre-dated or avoided the regulations, there are GMOs used in containment and field trials, there are probably GMOs that no-one knows are GMOs, and many GMO products.

84. Prior to the introduction of the GMO provisions in the HSNO Act, a large number of horticultural crops were and continue to be used in New Zealand that had been developed by a range of mutagenesis techniques such as EMS mutagenesis. These have been grown at scale in New Zealand for many years. These are genetically modified organisms according to most definitions including the HSNO Act (until recently).

85. An amendment made three years ago to the Hazardous Substances and New Organisms (Organisms Not Genetically Modified) Regulations 1998 have deemed these older GMOs to be "excluded" from the definition of GMOs for the purposes of the HSNO Act. but the organisms themselves are still GMOs by most definitions and still present in New Zealand and are the basis for a significant part of our horticultural sector.

86. There is a high likelihood that a number of ornamental plants have also been developed by such non-transgenic techniques.

87. Many current crops have been developed by chemical mutagenesis. Many of these are available on the FAO/IAEA mutant database (http://mvd.iaea.org/) and have been developed from as early as 1966 and are still being added this century. Many are new disease resistant varieties. Most have been developed in Asia and Asia has the highest number of releases (Pathirana 2011 attached). However at least 10 new cultivars developed this way have been released in Australia and the Pacific. However not all varieties developed through chemical mutagenesis are available on this database. We are aware that there are 3211 mutant varieties registered internationally in more than 170 different plant species most of which are food plants. They include varieties of: pea, eggplant, bean, apple, rice, soybean, rape, tomato, green pepper, lettuce, spinach, wheat, maize, barley, brassicas, citrus, dahlia, carnation, mint, grape, tomato.etc.

88. Well-known New Zealand developed examples are forage brassicas, for example the herbicide resistant turnips, rape and swede developed in New Zealand (Dumbleton et al 2012 attached) through seed mutagenesis allowing a re-emergence herbicide application that produced significantly more total dry matter per hectare than the untreated controls.

89. In the early 2000s, petunia seeds were imported over several years into New Zealand and sold through garden centres in New Zealand and around the world without being identified as transgenic GMOs. After a Finnish researcher noticed them in the environment in Europe, MPI investigated and found seeds had been imported and sold in New Zealand. There was a recall from garden centres but not from gardens. The US, Finland and New Zealand did partial recalls. Most other countries ignored the issues presumably because they were just orange, red and purple petunias and posed no environmental risk.

90. Any Council deciding whether or not to regulate GMOs under the Resource Management Act will need to decide whether their regulations and rules will extend to regulating a large section of the current horticulture sector and backyard flower gardens.

GMO PRODUCTS USED IN NEW ZEALAND

91. GMO products used in New Zealand include over 80 different food ingredients and other products.

92 Common GM ingredients and products used in New Zealand include most of the staple crops (corn, wheat etc), cotton, yeast, clothes washing powder, medicines including insulin, vaccines and many others. Many processed foods sold in New Zealand supermarkets include GM ingredients. Most cheeses manufactured at scale are manufactured using GM rennet.

93 There is an existing approval (GMR07001) to release genetically modified vaccines (Proteqflu and Proteqflu Te) developed to protect horses against Equine Influenza. This approval is to conditionally release a GM canarypox virus based vaccine in the event of an outbreak of equine influenza in New Zealand.

94 There are a number of human therapeutic agents produced using GM technologies that are widely used. These are produced by fermentation with GMO bacteria and include insulin for diabetics, growth hormone for individuals with pituitary dwarfism, tissue plasminogen activator (a substance that dissolves blood clots for heart attack victims), interferon (an anti-viral drug used for treating multiple sclerosis and cancer) and numerous vaccines. Progress in global research harnessing the power of GM technologies suggests that the list of beneficial agricultural, veterinary and medical uses available to New Zealand will increase sharply over the next few years.

95 GM food ingredients are common in products available in New Zealand. These primarily consist of corn, canola and soy ingredients. GM enzymes are the basis for our washing powder and almost all cotton is GM.

96 As previously mentioned a significant component of the commercial fruit and vegetable and wine industries in New Zealand are GMO although recently deemed not to be by recent regulation amendments and the products of these industries are common.

GMOs GROWN AND USED ELSEWHERE IN THE WORLD (EXCLUDING FRUIT/VEGETABLES/HERBS AND ORNAMENTALS DEVELOPED BY MUTAGENESIS OR GENE EDITING)

97. The area planted in biotech crops continues to increase globally. In 2018, 191.7 million hectares of biotech crops were grown globally in 26 countries, with growth continuing every year after more than 20 years of commercialisation (http://www.isaaa.org/). 18 countries grow more than 50,000 hectares of biotech crops. ISAAA calculated the accumulated biocrop area over the 23 years of commercial cultivation as 2.5 billion hectares.

98. ISAA that shows that GMO crops have been so successful in early adopting countries that nearly all farmers in those countries growing those crops now use the GMO varieties. For soy, maize and canola the numbers are US 93%, Brazil 93%, Argentina almost 100%, Canada 92%, India 95%.

99. Australia is a significant grower of GM products but an interesting case because the states of South Australia and Tasmania originally decided to ban GMOs by way of moratoriums. On 4 December 2019 it was reported that South Australia's Marshall Liberal Government has now introduced legislation to lift the GM Crop ban so that from 2020 South Australian farmers can use GM crops. According to South Australian newspaper reports, this change is the result of a study that showed South Australian farmers had lost at least $AU33 million since 2004 because of the ban, because the promised "GE-free premium" failed to eventuate, and to enable farmers to use improved crop varieties to help overcome the effects of drought and climate change.

100. In Japan, despite surveys showing a significant percentage of the public having reservations about eating gene edited food, Japan's Ministry of Health, Labor and Welfare has decided to allow gene edited food on the market from 2019.

101. There are now numerous plant species with GM varieties that have been approved for commercial release and growth. These include alfalfa, apple, Argentinian canola, bean, carnation, chicory, cotton, creeping bentgrass, eggplant, eucalyptus, flax, maize, melon, papaya, petunia, plum, polish canola, poplar, potato, rice, rose, salmon, soybean, squash, sugar beet, sugarcane, sweet pepper, tobacco, tomato, wheat. There are many, many more that are in the pipeline in different countries.

102 China grows GM forests and driven by their need to feed 1.4 billion people, is investing billions of dollars in R&D directed gene editing of food crops (such as high temperature resistant soybeans) and in the purchase of international biotech companies and agribusinesses such as Syngenta. China is a major importer of GM products such as soy from the US and Brazil.

103 In Europe and North America, gene editing is being developed and used in a range of human therapies. For instance, in the US, in trials, patients have been successfully treated using gene editing techniques for sickle cell disease and beta-thalassemia.

104. Seventy countries have approved GMO materials for release or use. These include our major trading partners – US, China, Japan, Korea, Australia, EU, Malaysia and India.

105 The European Union has GMO regulations (particularly relating to food) as strict or almost as strict as New Zealand's GMO regulations but there is a major shift occurring in Europe. Despite their regulations the European Union is the second largest importer of certain GMO products such as soybean and 58 different GMOs have been authorised for consumption as food or feed in the EU with a number of others awaiting. Member countries such as Spain and Portugal that are GMO growers have forced through changes enabling them to make independent decisions regarding the growing of GMO plants. A European Court decision that confirmed that gene editing was GMO under European law has sparked major science projects (EPSO) and policy reviews recommending a shift to evidence based law and policy. 14 European countries (Netherlands, Estonia, Belgium, Cyprus, Finland, France Germany, Greece, Italy, Portugal, Slovenia, Spain, Sweden and the UK) have called for the EU's laws that regulate new plant breeding technologies to be updated.

106. Key commercial traits modified in plants and approved for release are abiotic stress tolerance, altered growth or yield, disease resistance, herbicide tolerance, insect resistance, modified product quality and pollination control systems.

107. By 2017 thirty five different GM traits have been approved for release including anti-allergy, altered lignin, delayed fruit softening or ripening, enhanced photosynthesis, sterility, drought tolerance, flower colour, mannose and amino acid metabolism, modified starch or fatty acid composition and metabolism, reduced browning, reduced acrylamide, wood increase, pest and disease resistance. These are a large array of traits of benefit and there are a very large number more in the pipeline.

108. There has been a concerted effort in engineering plants for human health benefit (deSteur et al 2015; Wamboga 2011).

109. Consumer studies have been carried out in a wide range of countries and concluded:

> **"Whereas consumers often demand a discount when it comes to first generation GM foods, the premiums they are prepared to pay for transgenic biofortified crops are relatively high, from 20% to 70%, regardless of the targeted crop, micronutrient and country "**

110. Golden rice is often used as the classical case study on benefit. Rice does not contain the compound pro-vitamin A (β-carotene). A daffodil gene was transferred by genetic modification into some rice strains. The health problem being addressed is the one third of children and many women who are Vitamin A deficient and suffer blindness and worse. Clinical trials have shown that one bowl a day of Golden rice can compensate for the deficiency. Now the same compound is being engineered and field trialled in banana, cassava, corn and wheat.

111. In Uganda bananas modified to contain significant levels of pro-Vitamin A, iron and disease resistance have been field trialled. This would have been impossible without genetic engineering as the commercial Cavendish banana cannot breed.

112. Another well-known example is folate (vitamin B9)-enhanced rice. Here, transgenes from Arabidopsis were overexpressed in rice endosperm, which resulted in a 100-fold increase in folate content. Again, conventional breeding was not an option because of the low folate content and low natural variation of this compound in rice kernels.

113. The recent release of a GMO Eucalyptus in Brazil is the first really significant release of a GMO tree with valuable economic benefit (attached). It predicts an increase in wood from the same area of 15%, 13% less land area to meet the same commercial demand, and a 12% increase in the amount of CO2 captured per year. Small growers are expected to improve their profit by 28%. In addition benefits are expected in keeping people in the regions and an improvement of 20% in the productivity of the Brazilian forest industry compared to countries like New Zealand.

114. GM Atlantic Salmon is now on sale in restaurants in the USA.

115 New Gene editing techniques has seen a boom in the development of gene edited products in a wide range of applications such as cacao that is resistant to climate change, corn with starches ideal for bioadhesives etc. In most countries these are not subject to GMO regulation.

116. A company called Calyxt became the first to commercially debut a gene-edited soybean oil with reduced or no trans-fats.

RISKS AND BENEFITS

RISKS

117. Because GMOs are essentially the original organism and its large number of inherent traits with a new trait or traits introduced by genetic modification, the risks and benefits of a GMO are dependent on the combination of inherent and introduced traits. Any risks that the GMO poses should be considered in context. It should be remembered that the traits of naturally occuring organisms are not risk free. If they were there would be no toxic plants, no disease, no invasive species etc.

118. While GM is just a tool and could be used to develop a harmful product such as a food product with increased toxicity, release of that product would never be approved, it would not meet food safety regulations or drug approval requirements, farmers wouldn’t grow it, shops wouldn’t sell it and in New Zealand the research would never be approved by the EPA.

119 GM processes while becoming increasingly precise will never be perfect. Off-target modifications occur meaning the resulting GMO may have different genetic sequences than intended and, if the organism, if viable, this may carry in unintended traits. Indeed, an unintended genetic modification occurred recently in the US when a start-up company in collaboration with the University of California modified dairy cattle to suppress horn growth but also introduced additional bacterial DNA to one bull that potentially could introduce an anti-microbial trait. This unintended addition was discovered by FDA testing. The bull had 17 offspring. Some have been euthanised, others await their fate while awaiting an application from the University to sell the meat for use in hamburgers.

120 The trials required by regulatory bodies such as the EPA in New Zealand serve to identify unintended traits prior to the release process. The possibility that an organism could go through the process with unintended traits is very small in New Zealand but could possibly happen.

121 This risk should also be considered in the context that other breeding techniques result in greater changes to organisms but are unregulated. The risk should also be weighed in the context of the global challenges we face such as population growth, climate change, resource limitations etc.

122. The greatest potential risk of GMOs is probably environmental - if an introduced trait gives the organism a significant competitive advantage in the environment and so enables it to become a weed. However, this risk needs to be put into perspective – a GM pinus radiata pine tree developed under the EPA process is never going to be a wilding risk comparable to non-GM Pinus Contorta. A GM Petunia that has been modified to be a different colour poses no greater risk that a non-GM petunia. And weeds can be killed by spraying or being pulled out of the ground. GM modification can also be used to modify important commercial crops to make them less fertile or less invasive.

123. The real world evidence of millions of hectares of arable land being used to grow GMOs without any significant episodes of effects beyond those seen when using conventional crops illustrates the low risk levels of approved GMO releases.

124. The international production of GMO microbe produced products at scale such as medicines, cheese ingredients, washing powder, yeast etc. without incident also demonstrates the risks are low or manageable.

The BENEFITS

125 The benefits of GM can broadly be broken down into those already proven by real world use of GMOs and future potential benefits that might use biotechnology to create new products, replace industrial and non-renewable processes with biological processes.

126 Transgenic genetically modified (GM) crops were first grown commercially in 1996. By 2018 the area planted in GM crops had increased 100-fold, from 1.7 million hectares in 1996 to 191 million hectares in 2012. It continues to grow and also to diversify. This rapid uptake is testament to the huge benefits delivered by the technology that have made GM planting attractive to the 17.3 million farmers worldwide who planted GM crops in 2012. Crops bred in-vitro using various forms of mutagenesis have been grown since the 1950s or 1960s and continue to be bred at used to the present day. A large proportion of the world's and New Zealand's commercial and domestic horticultural crops are the product of mutagenesis.

127 From 1996 to 2011, transgenic GM crops contributed to food security, sustainability, and climate change by: increasing crop production valued at US$98.2 billion; providing a better environment by saving 473 million kg (active ingredient) of pesticides; in 2011 alone reducing CO2 emissions by 23 billion kg, equivalent to taking 10.2 million cars off the road; conserving biodiversity by saving 108.7 million hectares of land; and helped alleviate poverty by helping >15.0 million small farmers and their families totalling >50 million people who are some of the poorest people in the world.

128. Productivity and reduction in agri-chemical use - Metaanalyses are scientific studies that collate large numbers of individual scientific studies and trials and are useful for providing a comprehensive overview of research areas. Several metanalyses are now appearing which take advantage of the long period of commercial cultivation for some early GMOs. In an analysis of the economic benefits of GM pesticide and herbicide resistant plants (Klumper and Qaim 2014), 147 studies of soybean, maize and cotton were compared. There was an overall 37% reduction in chemical pesticide use, and increase in crop yields of 22% and increased farmer profits of 68%.

129 To date the vast majority of commercially planted transgenic GM crops have been improved to be either resistant to insect pests or tolerant to relatively benign herbicides or provide drought resistance for a number of stable crops (Corn, wheat, soy). The principal advantages of both being increased yields with lower chemical inputs.

130. In a further analysis on the impacts of GMO feedstocks on livestock populations (Van Eenennaam and Young 2014), it was found that there was no impact on the >100 billion animals fed these feedstocks in the US (95% of all livestock are fed GMO food), no short or long term nutritional impacts were observed and no impact was observed on the humans eating the >1 Trillion meals.

THE USE OF GM FOR THE PRESERVATION OF AGRICULTURAL/FORESTRY SYSTEMS

131 In addition to their well-documented role in increasing yield and reducing chemical inputs, the use of GMOs may represent the only viable solution to prevent crop destruction by pests or disease and may be pivotal in preserving conservation, agricultural and forestry opportunities.

132 A good illustration of this is the Hawaiian Papaya industry and the damage caused by Papaya ring spot virus (PRSV) that has been reversed using GM trees resistant to the virus. Prior to the 1950's Florida and Hawaii had thriving Papaya export industries. However, increasing spread of PRSV, which leads to dwarfing in young plants and poor quality fruit in mature trees, led to the collapse of the industry in Florida. News articles such as those in the Hawaii Tribune Herals document the destruction and recovery of the Hawaian papaya industry (http://hawaiitribune-herald.com/sections/news/local-news/papaya-gmo-success-story.html).

133 Hawaii had some initial success in resisting the disease due to the island's geographical isolation and tough biosecurity measures. However, by 1995 the largest virus free growing region in Hawaii had become infected, and the industry was in crisis. Work initiated in the 1980's to breed resistance by conventional means has had only limited success. Some tolerant (but not resistant) varieties have been developed but these still produce poor quality fruit when the plant is infected and act as a reservoir for the virus accelerating its spread. In response to this, work to produce a GM plant resistant to PRSV was undertaken and the first trees successfully field trialled in 1991. After regulatory assessment and testing the tree was rapidly adopted by growers such that by 2 years after its release in 1998 more than half of fruit bearing papayas were GM varieties and yields had recovered to near pre-infection (1992) levels. The industry is now recovering and exporting to Canada, China and Hong Kong. In 2011 GM papayas, after extensive safety testing, were cleared for export to Japan, the most economically attractive market for premium quality fruit, where they went on sale in 2012.

134 A faster growing modified salmon has been approved for aquaculture relieving overfishing pressures on wild populations of Atlantic salmon.

135 Production of enzymes and chemical by GMO microbes means we have products that cannot be produced in the quantities that the world demands by other means. GMOs mean diabetics can live through production of insulin, and cheese can be manufactured with GM rennet rather than being extracted from calves' stomachs.

FUTURE BENEFITS

136 From a scientists perspective, the benefits and especially the future benefits of GMOs must be viewed in the context of the global challenges that we face, the solutions that we need and that most of the most likely solutions are likely to be biotechnology based.

137 In a world threatened by overpopulations, resource scarcity and climate change there is a desperate need for green technologies that enable a circular economy and replace non-renewable and polluting industrial production and enable crops to be grown on land that ceases to become viable.

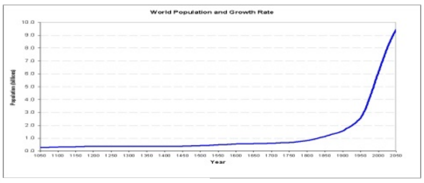
Global Challenges

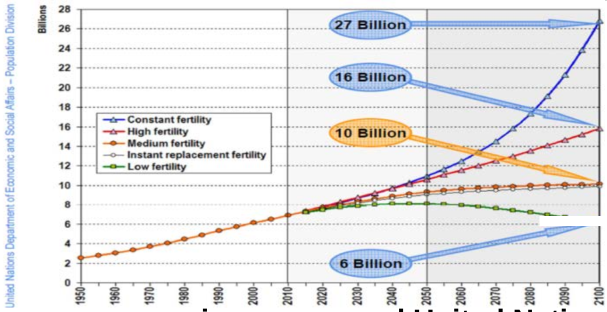
138. The world is currently facing a raft of serious challenges. These include:

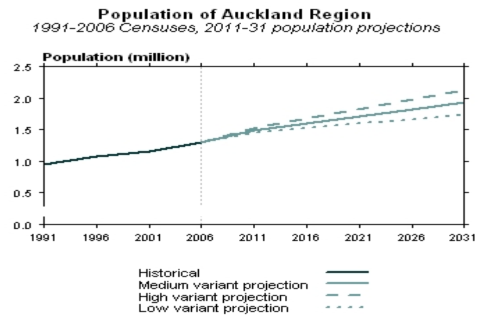
- Population density increases and urbanisation,
- ageing populations,
- water scarcity, droughts and loss due to irrigation,
- increased fire, wind and storm risks,
- eutrophication and land and soil fertility,
- temperature, greenhouse gas emission increases and reduction targets,
- need to supply 70% more food and over 300% more fibre (trees and agricultural waste streams) by 2050 than is currently possible with greater productivity gains than in the past needed. By 2030, food demand is predicted to increase by 50%
- Roughly 30% of the food produced worldwide – about 1.3 billion tons - is lost or wasted every year
- Producing 1 kilo of rice, for example, requires about 3,500 litres of water, 1 kilo of beef some 15,000 litres, and a cup of coffee about 140 litres.
- Increased pest and disease spread as global travel and trade increases.

139. These are graphs of the world's population showing the industrial age's unabated population explosion. Over the past 2 centuries the world's population has grown

sevenfold (Federoff 2015), at least a further 2-3 Billion will be added this century to reach ~10 Billion, predominantly in Africa.

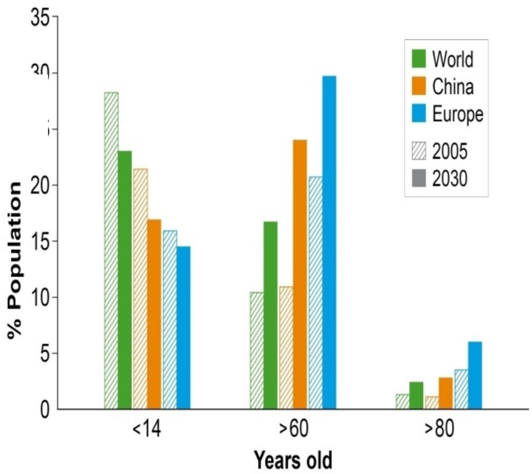






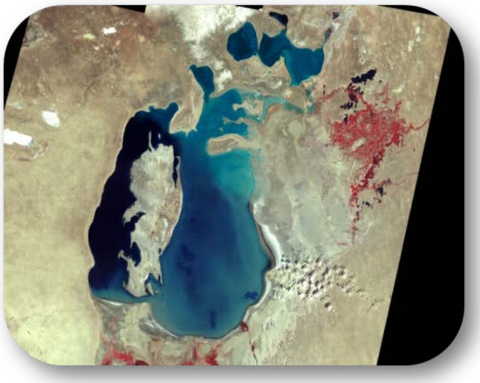
sources: zmescience.com and United Nation **Z**

140. In addition to the overall increase in population, all populations are aging – it is not just a western phenomenon. (Source: United Nations Department of Economic and Social Affairs).



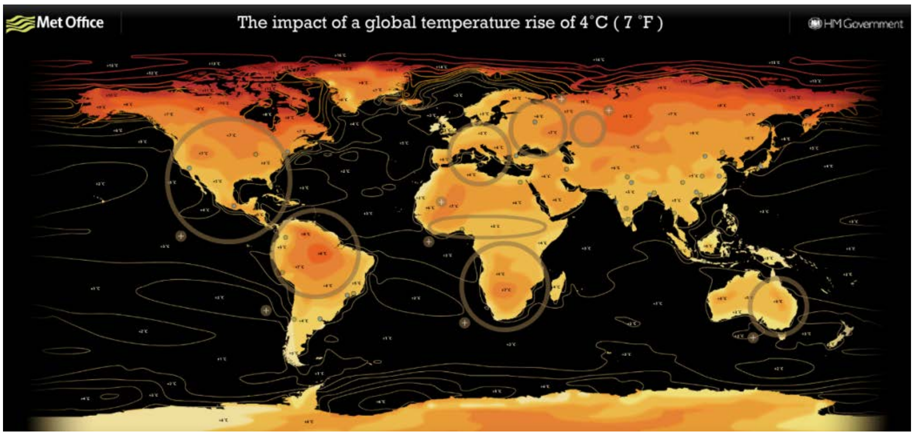
141. With population increase, clean and fresh water becomes a valuable and increasingly rare resource. Droughts have a greater impact and increased agriculture and urban needs use more water. The satellite photos below show the loss of water from the Aral Sea due to irrigation requirements. This effect is mirrored in New Zealand in Canterbury with recent drought and irrigation increases.

Aral Sea 1973

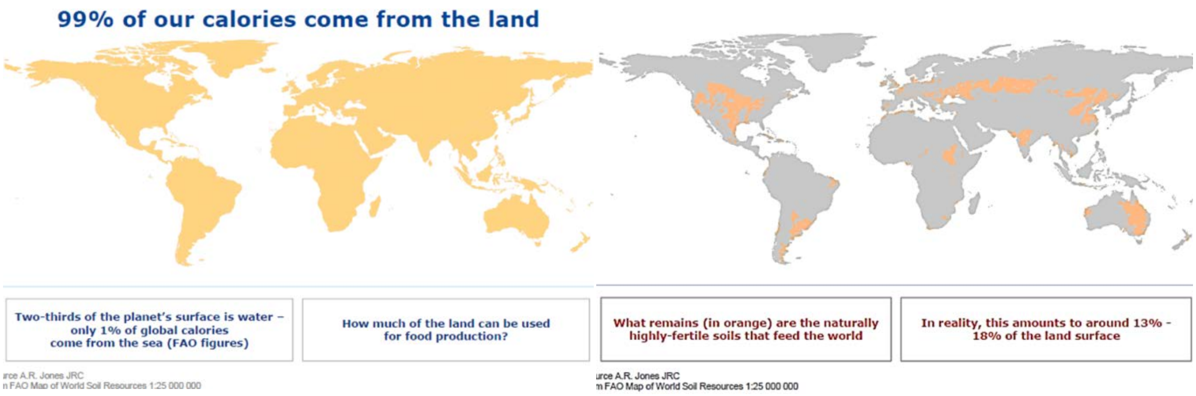


Aral Sea 2012

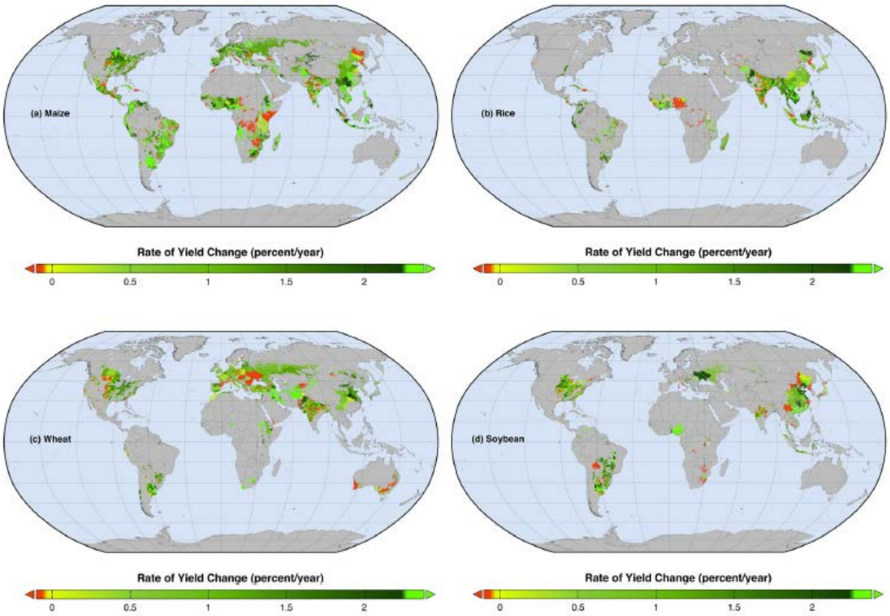
142. Increased "weather events" such as fire (UK Met Office below), have increased and are predicted to increase further alongside droughts and changing weather patterns. Parts of the world that are currently productive for food and fibre will be affected. This can already be seen in the increased fires in Eastern Australia and western US, and in New Zealand we have seen a 3-4 fold increase in the numbers of fires compared to 20 years ago, although the areas have declined.



143. Land and soil fertility is also predicted to become a problem in a very short space of time. Ironically this is exacerbated by fertiliser applications that impacts water availability due to eutrophication. Several parts of the world that have historically been naturally fertile are now predicted to be insufficient to support current crop production, let alone met increased production needs. (FAO Map of World Soil Resources)



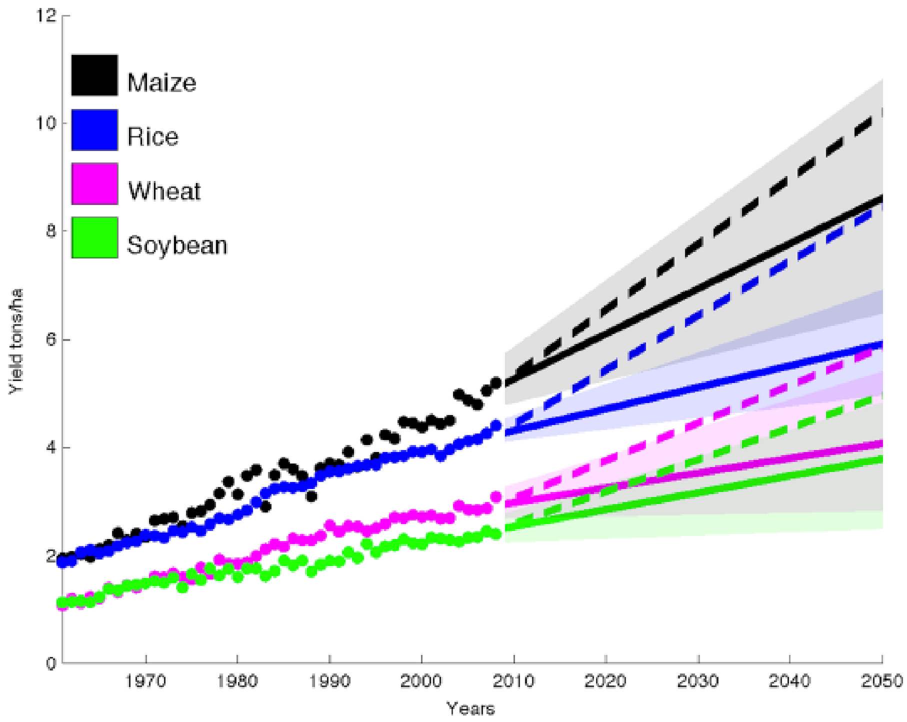
144. The Figures below represent the predicted ability of land to sustain the needed increased yields of each of the four global staple crops through to 2050. Red indicates an inability to provide yield increases and fluorescent green indicates where the needed increased yields can be achieved (Ray, Mueller, West and Foley 2013).



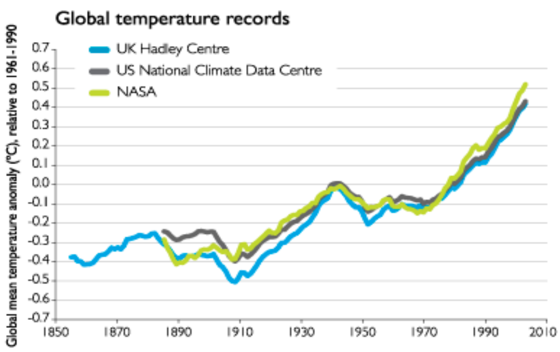
145. Providing sufficient food and fibre for the increased global population by 2050 is expected to be a greater challenge than in the past and to require a significant increase in the rate of productivity improvements compared to today.

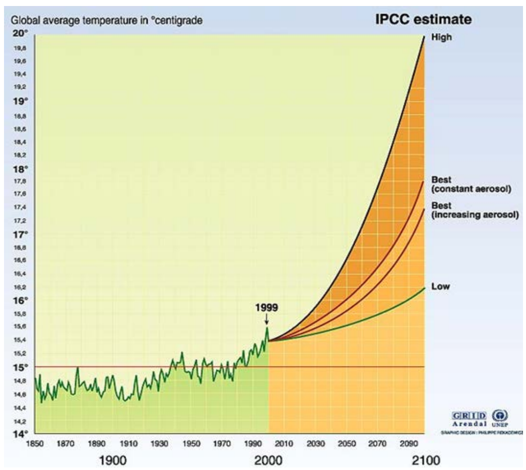
146. The Figure below explains how a continued improvement in productivity of the four major crops at the same rate as that of recent years cannot provide the required sustenance for the world of 2050. It shows the required increase in productivity improvements over the current increases. The dashed lines show the required rates, the solid line that of continuing to improve at current rates. The dotted lines show historical improvement rates (Ray, Mueller, West and Foley 2013). In addition, it has estimated that there is an urgent need for plantation forests and afforestation to cover the >300% increase in fibre predicted to be

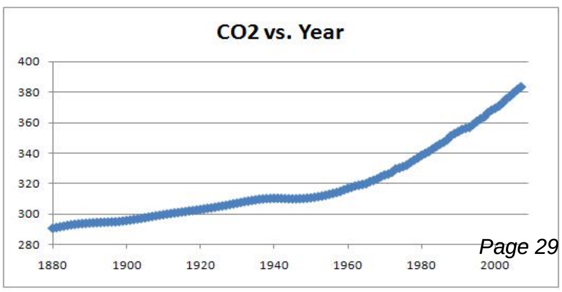
needed (WWF 2012). This suggests a real need for new and multiple approaches and techniques to achieve these gains effectively and efficiently without further environmental erosion and reduction in water availability.



147. Many countries, including New Zealand, have agreed to ensure a reduction in greenhouse gas emissions by 2030 with another target of 2050. New Zealand has recently agreed to a reduction 30% below 2005 figures by 2030. This is expected to impact global temperatures by reducing the predicted rise in temperature, such as that experienced in NZ over the past decade (see Figure below). New Zealand has a challenge ahead of itself (see below) to ensure NZ reaches its obligations. These obligations may be fulfilled by either reduction of gross carbon emissions or may be offset by increased carbon capture such as that stored by plants. Hence an increase in the areas of plants that can capture carbon efficiently and effectively, perhaps while also providing food and fibre, appears the most viable option.







148. An increasing global problem is the ease of movement of pests and diseases. This is due to greater tourism and also greater global trade exchanges. An example of the impact that such pests can have is the mountain pine beetle. It has destroyed 16 million of the 55 million hectares of lodgepole and ponderosa pine forest in British Columbia. It has also moved to Colorado and Alberta. A key reason for such severity and movement of the insect into areas where it had minimal previous impact, has been concluded to be climate change – warm winters and hot summers which have also led to a longer breeding season. Not only has the infestation caused major commercial loss, but it has also caused a loss of amenity value for activities such as hiking and cycling and camping.

148B In 2019, these issues have manifest themselves in a close to catastrophic way. Drought and pests have rendered multiple tree species in Europe vulnerable and bark beetles have laid waste to forests in Germany both natural and planted. Dramatic tree deaths are visible to anyone visiting the areas and German experts have reported that Germany's forests are on the verge of collapse.

149. New Zealand has already been experiencing significant new forest pest and disease challenges. New arrivals are seen increasingly often. A disease called red needle cast has appeared in New Zealand and is affecting pine trees in many areas of New Zealand. The disease is impacting the commercial viability of current pine forests. The current impact of this is estimated to be NZ$37 million per year in lost production (Watt et al 2012). It has been estimated that a new pest or disease could reduce the net present value of NZ forestry revenue by US$34 million to US$612 through reduced log exports and an additional phytosanitary measure would reduce revenues by at least US$1,200 million (Turner et al 2007).

150. The harm is not limited to reductions in productivity. New disease can and have resulted in the complete destructions of forestry plantations and extinction of native/wild species. The American Chestnut used to occupy a significant place in US native forests of the north-eastern coast and mid-east. A new fungus – Chestnut blight was introduced by accident early last century, and within a few decades had killed a few billion trees. Efforts to rescue the species have included introducing a resistant species from China and backcrossing many generations to try to bring back the original American Chestnut. So far the best chance after decades of breeding is a plant with 98% American chestnut DNA and 2% Chinese chestnut DNA. A more speedy approach has been recently to use GMO technology to introduce only the resistance gene to the American Chestnut – insertion of a specific wheat gene into the genome has resulted in a tree that can resist the blight. Efforts are being made to release the GM tree back into the wild.

151. In New Zealand the iconic and significant Kauri tree has also recently become infected with a new disease - Kauri dieback. This is following a pattern very similar to that of the American chestnut. To save this tree may require a similar multipronged approach to that of the American Chestnut.

152 Much of the current research is directed at developing GMOs to meet these global challenges. For example

153. Examples of GM products developed to meet some of these challenges include biofortified foods include high anthocyanin tomatoes, crops with improved stress tolerance for resistance to cold, heat, drought, low soil nutrient availability, high salt environments, enhanced Vitamin E and C.

154 The US Dept of Agriculture and Cold Spring Harbor Laboratory have this year developed a modified sorghum with double the normal yield via a modification that diverts the plant's energy away from flower production and towards grain development.

155 Golden rice is a variety of rice genetically engineered to produce nutritionally relevant enhanced levels of Vitamin A to prevent blindness caused by vitamin deficiency in poor countries by a not-for-profit consortium. Rice has very low levels of vitamin A and in some developing nations where rice is the staple crop, vitamin A deficiency is a major health issue and cause of blindness. UNICEF estimates that the number of child deaths precipitated worldwide by vitamin A deficiency is 1.15 million per year with many more suffering less serious consequences. Extensive research has demonstrated Golden Rice's health benefits and safety but the crop still faces strong opposition from anti-globalisation activists. When it becomes available bio-fortified Golden rice has the potential to prevent death and alleviate suffering amongst some of the poorest sections of society.

156. A non-browning apple was released recently and commercially – expected to compete with New Zealand's crops - to reduce browning in cut apples (http://www.arcticapples.com/) and a low acrylamide potato in response to people's concerns regarding high acrylamide levels in potato fries (**http://www.rsc.org/chemistryworld/2014/11/low-acrylamide-gm-potato-approved-simplot**). Reduction in food wastage has the potentially to significantly impact on land use efficiencies.

157. There are currently over 700 Field trials for GM trees globally. These include a wide range of traits; traits of value to allow better growth, less weediness, and improved

product quality, including better carbon capture and offset for greenhouse gas emissions and reduced environmental impacts (see attached).

158. The European Union has field trials of various GM trees sited in Belgium, Poland, Sweden and Finland. One EU company, Swetree has screened over 1000 genes and have 35 top candidates in field trials of Eucalyptus and poplar in Sweden, Brazil and China. The successful GMOs will confer benefit to New Zealand's competitors.

159 Argentina will commercially release of a virus resistant potato in 2020 which is projected to provide farmers with a 10% cost saving and reduction in use of insecticides.

FUTURE BENEFITS FROM NEW ZEALAND TREES

BIOFUELS

160. The use of fossil fuels is a universally recognised environmental challenge with sequestered carbon being mined, refined then combusted into greenhouse gases.

161. Techno-economic analyses show that replacing fossil fuels with first generation biofuels (i.e. biofuels from food crops) would compromise food supply and biodiversity. For many developed countries this would also require use of more arable land than those countries have.

162. As a result second generation biofuels (i.e. biofuels from lignocellulosic biomass – trees, shrubs, grasses) have been identified as the most viable solution for substitution of liquid fossil fuels. And assessment of fossil fuel options is provided in the paper: "Production of first and second generation biofuels: A comprehensive review" by Naik, S,N, et. al , Renewable and Sustainable Energy Reviews 14 (2010) 578-597 (copy attached).

163. Scion is the leader of the New Zealand Biofuels research programme.

164. Biofuels have an economic disadvantage compared to fossil fuels as fossil fuels externalise cost elements via pollution and climate change.

165. Second Generation Biofuel processes must therefore be highly efficient to compete and this efficiency cannot be achieved without feedstocks (ie plants) designed (i.e. modified) for easier refining and digestion.

166. As leader of the New Zealand Lignocellulosic Bioethanol Initiative, Scion has developed a highly efficient process for converting (non-GM) NZ softwood into biofuel and developed accompanying techno-economic models.

167. Benchmarking against commercial fuel and sugar prices, modelling of the Scion process resulted in a price per litre that was still several 10s of cents above a competitive price even when fossil fuel prices were at record levels.

168. Vital factors for commercial viability were identified that included enzyme improvement, developing large scale markets for process by-products, advanced pre-treatments and feedstock modification.

169. Counter-intuitively, (based on the impression people get from the names) soft wood species that grow quickly in NZ like Pinus radiata are more difficult to refine

and convert that are slower growing hardwoods. Economic viability depends on being able to reduce costs of refining.

170. Scion has developed and is trialling modified pines tree directed to better pulping properties that may make refining of the wood considerably more energy efficient saving substantial operating and capital costs. This would not be possible by non-GMO processes. Under the current controls Scion cannot grow these trees to maturity so cannot produce feedstock for fuel conversion processes so we don't have data on the price per litre that would result.

171. This trait should also reduce the use of chemical digesting agents by pulp and paper mills and reduce their waste discharges.

172. It is not Scion's opinion that Biotechnology is the sole solution. Technologies such as fuel efficient, fuel cell and electic vehicles are also important. However, making cars 20% more fuel efficient has no sum benefit when there are 20% more cars on the road. The only permanent solution involves also addressing the fuel source.

DISEASE RESISTANCE IN COMMERCIAL AND POSSIBLY NATIVE CROPS

173. Research and real life New Zealand experiences confirm that our forests (and other primary industries) are under ever increasing threat from pests and diseases as a result of a combination of human mobility, trade and climate change.

174. A recent paper in the prestigious Science Magazine entitled "Planted forest health: The need for a global strategy", Wingfield et.al. 21 August 2015 Vol 349 Issue 6250 (copy attached) outlines the increasing threat to forests of pests and pathogens and outlines their spread and identifies biotechnology including genetic engineering as key tools in the fight against these increasing threats.

175. These increasing threats are not just theoretical but are already manifest in New Zealand in the form of Red Needle Cast in pine trees, Kauri Die Back in Kauri, Myrtle Rust in Manuka and Pohutukawa, Swiss Needle cast for Douglas Fir and Crown Rot in apples.

176. Pine Bark Canker is spreading in pine plantations internationally.

177. Douglas Fir (one of our three major plantation forest species) is not planted or grown in northern parts of New Zealand because of Swiss Needle Cast.

KAURI DIE BACK

178. After the discovery of Kauri dieback, the Department of Conservation and Councils implemented countermeasures in the form of foot baths and boardwalks with the aim of slowing the spread of the Phytopthera pathogen.

179. Central Government recognised this approach was inadequate insofar as it would only slow the loss Kauri.

180. The pathogen is soil borne and it is unlikely to be viable to treat thousands of square kilometres and billions of tonnes of soil so the most viable solutions are to treat the tree not the pathogen. Long term the goal is to re-establish the forest with resistant individuals or to develop resistant individuals.

181. Kauri is a relatively small population of large and slow growing, long lifecycle organisms living in a limited range of environments and climates. Because of this Kauri has lower populations, lower genetic diversity than many species and very slow evolutionary and adaptation rates .

182. Even if resistant individuals are found, a breeding programme to generate resistant stock would take many years.

183. There is a distinct possibility that genetic modification may prove to be the only means of introducing sufficient resistance into Kauri. Scion is aware that there are cultural sensitivities involved particularly when dealing with indigenous and taonga species so such initiatives would require the approval of the mana whenua.

184. Other NZ native species such as Manuka are subject to similar threats in the form of diseases such as Myrtle Rust that is now present in New Zealand.

RED NEEDLE CAST

185. A defoliating disease known as Red Needle Cast is currently causing significant reductions of productivity of pine forests particularly on the East Coast of the North Island and in Northland. The pathogen appears to have been introduced to New Zealand relatively recently and the evidence indicates it originates from Oregon, USA where it has been identified and recorded but does not cause identifiable harm.

186. Scion has identified individuals in the pine population that have some degree of tolerance to the pathogen so there is hope of developing resistant or at least more highly tolerant plants by conventional breeding within 20 or 30 years. Because selective breeding is an imprecise tool, breeding for needle cast tolerance may result in loss of other beneficial traits that have taken decades to develop such as growth rate. Although genetic modification may not be necessary to produce tolerance in this case, it would still be useful in order to retain produce high performing trees with needle cast tolerance.

187. Pine plantations are also under threat from more devastating diseases such as Pine Bark Canker which has destroyed pine plantations and wild pine in other parts of the world.

188 There will inevitably be other pathogens that have not yet arrived in NZ or mutated into a virulent form yet that New Zealand will have to address in the future.

189 American Chestnut is a tree indigenous to North America. In the case of American Chestnut a pre-disease wild population estimated to be about 4 billion trees was reduced to a few isolated stands of adult trees by the fungus that causes Chestnut blight.

190 A restoration programme has embraced both conventional breeding and GM techniques in an attempt to save the species since there is little natural resistance in the American Chestnut population. Conventional breeding has involved crossing the American Chestnut with a related Chinese species whilst the GMO programme has introduced resistance genes sourced from both the Chinese Chestnut and other species.

191 Currently, trees obtained by both means are being field trialled to assess their resistance and a reintroduction plan is in development to save the species. This is likely to involve trees produced by conventional and GM methods.

192 Interestingly, the GM derived tree has few non-American Chestnut genes added whilst the tree produced by hybridising two different species will still derive 2% of its genes from the Chinese species even after multiple rounds of crossing. In other words, the non-GM tree will have greater modification to its genetic composition that the GM tree.

193 Lessons learned from ongoing attempts to save the American Chestnut are likely to be important for the conservation of the increasing numbers of species being threatened by the effects of climate change including species in New Zealand.

WILDINGS/WEEDS

194. Wilding pines (mostly Pinus contorta and Douglas Fir) are a significant problem in New Zealand.

195. The Ministry of Primary Industries has made a conservative calculation that wildings will cost New Zealand $1.2 billion over the next 20 years in the form of loss of farming productivity, loss of land access, loss of biodiversity and loss in usable surface water.

196. In addition to this cost New Zealand spends $6.5 million per year to reduce encroachment but there is still a 6% increase in area per annum.

197. The most likely effective solution to the wilding problem is sterility or lowered fertility by genetic modification.

New Horticultural Products

198 New Zealand has had commercial successes via the development through conventional breeding or apples and kiwifruit in particular. Gene editing provides a powerful platform for producing new fruit varieties. New Zealand is at a competitive disadvantage compared to other countries which do not heavily regulate gene editing so may lose competitiveness over time in the horticultural sector if access to modern breeding techniques is excessively limited.

OTHER

199. There are numerous other future benefits including growth rate and high value chemical yields that may enable to use it tree resource as feedstocks for biorefineries producing a range of high value products and allow New Zealand to break away from producing logs and solid wood for export.

CONCLUSIONS

200 Defining GMOs is not an easy task.

201 New Zealand is not GM or GE free.

202 There is scientific consensus that there are the modification technologies carry no inherent risks.

203 Genetic Modification is just a set of modern breeding tools. The traits in the resulting organisms are more important than the process by which they are bred.

204 The benefits of GM are significant. In light of the global challenges we face biotechnology including GMOs could be viewed as essential from a global perspective.

205 Risks associated with released products internationally have been shown to be negligible and any risk need to be viewed in context of the risks that the environment is currently subject to. The EPA process means only organisms of low and negligible risk will be in the Waikato.

206 GM is an established technology with approved GMOs having an extensive history of benefit.

207. Biotechnology is a key tool (and part of the natural progression of knowledge and technology). It is a necessary tool to cope with the global challenges facing the planet and New Zealand. We are not immune by dint of our relative isolation! Our survival and economy continues to be built on our primary industry base which is about growing things and making money out of the products. It is also in many cases the only viable tool to defend from the increased pest and disease threat to our primary industries that are consequences of human mobility and climate change.