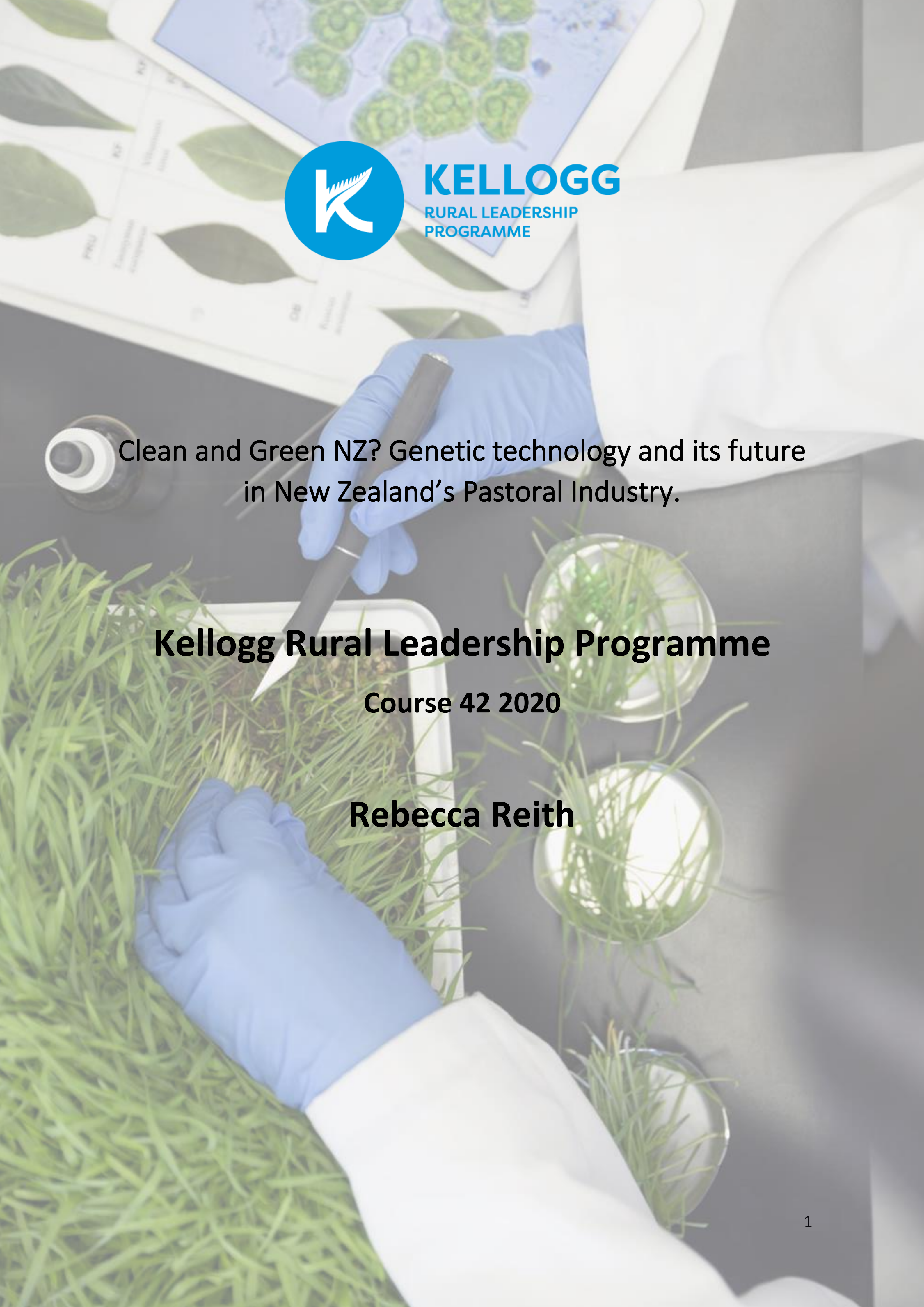

Clean and Green NZ? Genetic technology and its future in New Zealand's Pastoral Industry.

Kellogg Rural Leadership Programme

Course 42 2020

Rebecca Reith

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Limitations

This study must be seen in the light of some limitations, and further study is needed on many fronts. Genetic technology's future in the pastoral industry will need to be looked at from a financial, economic, international, social, and industrial perspective to understand better how it could work.

Executive Summary

Pastoral farming is the most dominant and natural land use in New Zealand today and is one of the main contributors to New Zealand's 'Clean green' image. The pastoral industry is under increasing domestic, social, and political pressure to reduce its environmental footprint whilst maintaining New Zealand's pasture feed products in the market and ensuring prosperous farming communities. New Zealand's pastoral industry is not the only one facing these issues but many countries worldwide including Europe, USA, and Australia. Some of these countries however have relieved some of the pressures surrounding environmental footprint of pastoral farming through new genetic technologies being integrated into plant breeding cycles causing lesser reliance on water, herbicides, and insecticides to name a few.

New Zealand pastoral industry is underpinned by plant breeders and the modern ryegrass plant. On average it takes 12-15 years to test, multiply and commercialise a new ryegrass meaning a large breeding programme with multiple scenarios predicted ensures there will be a cultivar for future situations. The purpose of this report is therefore to understand the current plant breeding technologies and compare them to the controversial genetic technologies which have recently become available to New Zealand. My research details past, current, and future plant breeding methods, from cross and hybrid breeding, chemical and radiation breeding to new breeding technologies such as Genomic selection, Marker-assisted selection, Genetic modification, and Gene editing.

The Genetic technologies available to plant breeders allow multiple forms of enhancement and a ryegrasses ability to withstand, herbicides, insects, and extreme weather events, whilst increasing the rate of genetic gain. Of these technologies available worldwide but not in New Zealand is Genetic editing (GE) or genetic modification (GM). GM has been a controversial topic in New Zealand for over 20 years which has been heavily debated especially around its use in the agricultural industry and the possibility of it single handily able to tarnish our 'clean green image'.

The methodology used in this report was literature reviews which was used to quantify themes which were gathered through a series of informal interviews from leading industry professionals in New Zealand's pastoral industry.

The misconception and lack of understanding around past and present technologies associated with ryegrass breeding are significant worldwide. This is linked back to several factors like the growing presence of social media, lack of engagement from the science community around consistent relevant information to the public, but also higher up, in governments and regulatory paperwork worldwide. From the Cartagena Protocol to the Food Standards Australia and New Zealand (FSANZ), each country has their own stance and even definition of what GMO or GE stands for.

Ethical and social considerations were one of the most prominent themes to come out of my research. The lack of monetary value on morals and cultural beliefs makes genetic technologies statistically hard to quantify its effects. Excluding such values has led to a lack of trust in both scientists and politicians. However, the true misconception lies around indigenous cultural values which underpins New Zealand. Literature suggests Māori are not against biotechnology but were more concerned about how it affected whakapapa (genealogy), mana, mauri (life essence), and kaitiakitanga (guardianship) and what forms of biotechnology could be a positive addition to their communities not to just those who can afford it.

Therefore, the recommendations from the research undertaken are:

Collaboration of industry bodies within the pastoral sector to.

- *re define* the pathway of the pastoral sector and how it could look with and without new biotechnologies such a Genetic editing or Genetic modification. The stance of the collaborative response will be communicated to the wider industry followed by consultation then to the wider public.

- *re define* what 'clean green' image means to New Zealand. How do we link our cultural aspirations with the reality of economics in the pastoral sector? '

Commitment to Engage with New Zealanders about genetic technologies through the re-establishment of a bioethics committee. The non-political committee will have a multitude of respected and knowledgeable professionals from agricultural, biotech, science, communication, environment as well as social and cultural organisations.

This groups main responsibility will be to engage with their wider communities about their opinions, thoughts, and concerns. This will be at the forefront of the committee's priorities.

Approving specific acronyms and definitions for the biotechnology sector worldwide. Scientists use many technical and non-technical acronyms throughout their work however the use of these outside of the industry is contributing to the fragmentation of trust in science. An approved list of acronyms with their responding definitions to be implemented under a protocol such as the Cartagena protocol to ensure correct depiction and understanding of biotechnologies by the public.

The approved language is then to be enforced by individual governments across industries to ensure miscommunication is minimised.

Regulating a technology not by the final product or outcome. Define the technologies by assessing the risk the outcome or product has to the pastoral industry across all areas.

1. Introduction

21st-century agriculture is becoming under increasing pressure. The global population is set to increase to over 10 billion by 2050, which results in agricultural food production worldwide needing to be increased by 70% (Friedrichs, et al., 2019). Other challenges associated with the increase in food production from the agricultural sector are the dwindling commodities such as artificial fertilisers and synthetic pesticides, land area reductions which is stemming from urbanisation and the biggest elephant in the room climate change, which in New Zealand is leading to hotter longer droughts to unpredictable cold wet weather. The biggest concern is that all the above is leading to less and less tools for farmers to use to reach productivity goals and feed the world.

New Zealand has an enviable reputation for the efficient and arguably most natural production of food for the size of our population. This is reputation has been built over many years and has led to New Zealand being branded as 'clean & green' or '100% pure'. Ironically, the origins of the brand 'clean green' is linked back to the Rainbow warrior incident in 1985 and New Zealand's "stance against nuclear energy and genetically modified organisms". 'Clean and green' has economic significance as well as being commonly understood by everyone. It is the connection and sense of belonging in Aotearoa New Zealand (Florian, 2016) .

The pastoral sector has had a huge part to play in the New Zealand 'clean green' image. An opinion piece by (Dixon, 2019) states our pristine lakes and rivers which are the jewel in our country's crown and are the backbone of our ability to portray an authentic clean, healthy, vibrant image to the world, is largely being destroyed by intensive pastoral farming (Dairy, Sheep and Beef).

Pastoral farming in New Zealand is undoubtedly one of the most dynamic and unpredictable business's driven by operating variables such as climate, markets, and regulations. Recently environmental regulatory targets and international markets are putting a considerable amount of strain on New Zealand's largest export earner. 7-8 million of New Zealand 27 million hectares is improved pasture, with sheep and beef dominating the land use at 69% followed by dairy at 12% (MPI (Ministry for Primary Industries), 2012).

Perennial ryegrass is the most dominant pasture species grown here in New Zealand due to its easy establishment and persistence under a range of climatic and management systems (Hunt & Easton , 1989). In 2021 perennial ryegrass is under far more pressure than it was 80 years ago in New Zealand. The strong climatic variations alongside regulations restricting the use of herbicides, pesticides and fertilisers means the pastoral sector is becoming infinitely harder.

Plant breeders in New Zealand have been breeding and researching ryegrass since the 1920's (Hunt & Easton , 1989) however it takes roughly 12-15 years to produce a ryegrass from first selections through to commercialisation. In a changing world where regulations, restrictions and environmental events can happen in less than a year plant breeder may struggle to ensure New Zealand's pastoral industry remains competitive as well as remain a part of the 'clean and green' image.

One of the most controversial plant breeding tools available to New Zealand but highly regulated and banned, is in the form of genetic technology. Arguably one of the most significant additions to the modern biotechnology toolbox bringing both profoundly challenging and enabling opportunities across multiple industries. This brings me to my research question, genetic technologies, and their future in New Zealand's pastoral industry. The Genetic Editing (GE) and Genetic Modification (GM) debate has been happening for close to 20 years in New Zealand and has not gained much traction.

In my report I aim to delve into genetic technologies and what their future looks like in the current time in the pastoral industry. This report investigates, through multiple literature reviews, conventional plant breeding through to the new breeding genetic technologies available for use. An investigation into the laws and regulations in New Zealand and worldwide is followed by contexts in which these technologies sit and the ethical and social implications of genetic technologies across the globe.

Methodology

Throughout this report, literature reviews were the primary tool to quantify themes. The themes for this project were gathered from informal conversations with industry leaders and professionals. I choose 7 people to interview based on their experience in the pastoral industry as well as understanding of genetic technology and the current debate as it stands in New Zealand. Unfortunately, I believe the 4 respondents interviewed are not a fair representation of the debate as time restrictions hindered my ability to talk to non-government organisations (NGO's) and politicians.

I analysed the conversations had with respondents through a thematic qualitive analysis which allowed me to find common themes across the interviews and group these into categories and subcategories. These themes lead to some of the key recommendations in my report.

Domestic and international literature was reviewed with the focus being on pastoral agriculture; however, due to the nature of genetic editing and modification technology and its recent addition to the biotechnology sector, some evidence could only be found in the health sector.

2. The present

Plant Breeding of ryegrass has been occurring in New Zealand since the 1920's. Despite the common phrase 'traditional' or 'conventional' plant breeding being used, there are several techniques that are less transparent to the wider public. These original methods are important in understanding the process of plant breeding up until genetic editing and modification.

2.1 Conventional Plant Breeding

Perennial ryegrass breeding involves cycles of seed generation evaluation and selection. Genetic gain is accumulated through these cycles; however, it is 0.25 – 0.6% in DM production per annum in a ryegrass, whereas a significant cereal crop can average 1.6% per annum for genetic gain. (Faville, et al., 2020) Plant breeding depends on genetic gain and new variation is fundamentally vital for introducing new traits into breeding programmes.

Typically, conventional plant breeding involves evaluating for 12 -15 years from identifying a new target trait through developing an experimental cultivar to be tested. The process usually begins with raw materials such as plants collected from old pastures, seed imported from overseas or recently completed crosses (Easton , Stewart , & Kerr, 2011).

Conventional Plant Breeding achieves improved characteristics by crossing together plants with relevant phenotypic characteristics and selecting their offspring with the desired combination of characteristics because of the genes inherited from the two parents.

Most food crops consumers encounter in their local supermarket are generally the product of conventional breeding. Varieties such as seedless watermelons, apriums, and tangelos that are often mistakenly thought to be a product of modern genetic engineering are conventional breeding practices. (Kaiser, et al., 2020)

Plant breeding methods have evolved as technology has become more advanced and readily available and the underlying knowledge and mechanisms of creating superior plants and organisms.

Mutation events are generally rare, but when thinking about the large number of plants in a field plus the number of genes in a singular plant, mutations are frequent in a population. (Hartl & Clark , 2007) Mutations in a field had more favourable genotypes and therefore had a selective advantage, becoming a predominant type through human selection. The accumulation of mutants protected and rescued by ancient farmers from competition is a major cause of 'domestication syndrome', a set of characteristics that have made many species dependent on humans for their survival. (Breseghello & Guedes Coelho, 2013)

Therefore, most domesticated plants' molecular variability tends to be smaller than in related wild species because of domestication. By selecting favourable phenotypic plants, most of the variation present in wild populations was lost. It is now clear that many valuable genes, especially those related to resistance to pests, were left out of this gene pool. (Zamir, 2001)

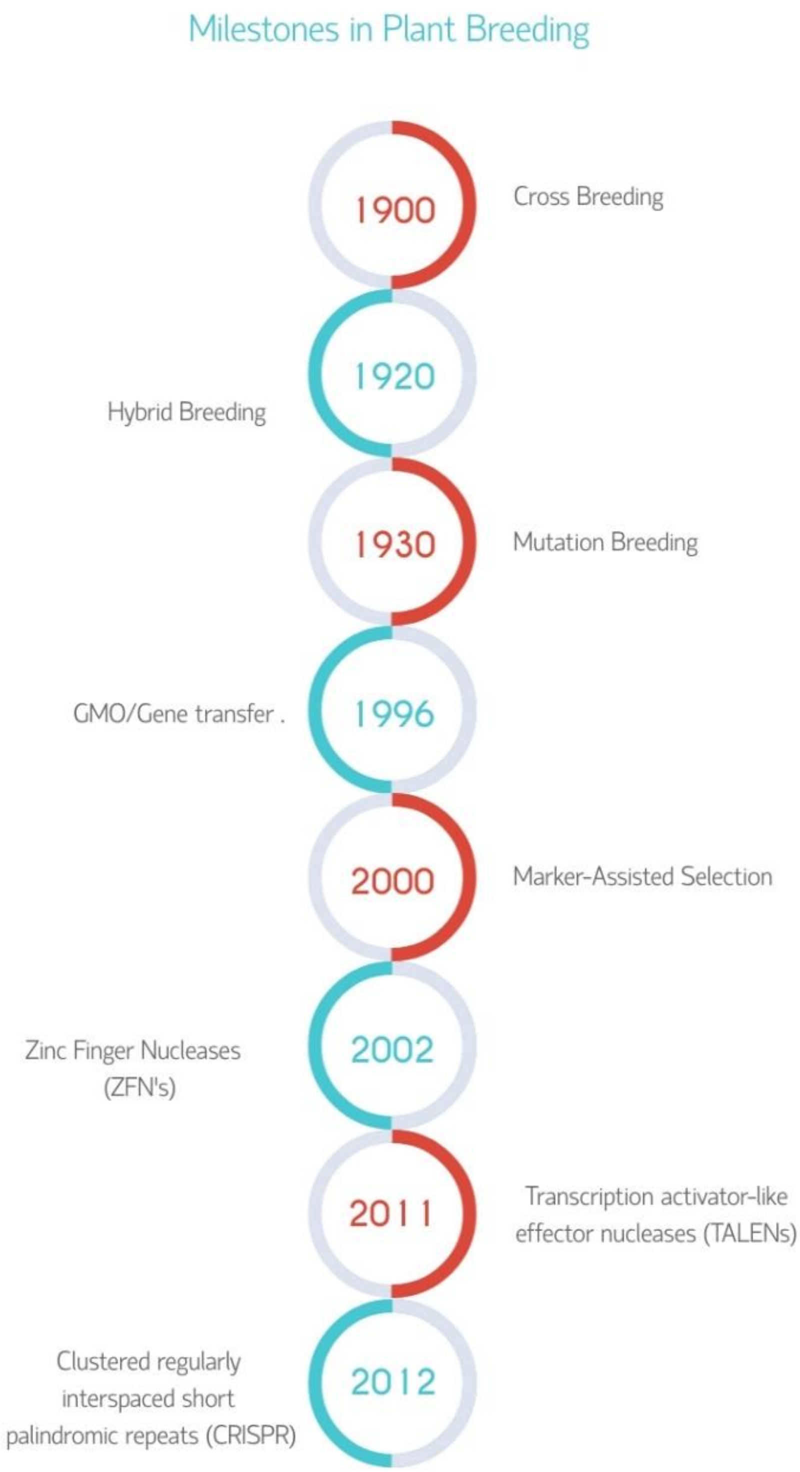

Figure 1: Milestones in Genetic technologies in plant breeding

“Landraces” are populations of plants that have been cultivated for many generations in a specific region, being shaped by both abiotic and biotic stresses. They are dynamic as they are continuously changing due to intentional or unintentional selection (Breseghello & Guedes Coelho, 2013). These populations have a high level of genetic diversity within populations characterised by limited variations between individuals with certain traits that make the “landrace” identifiable.

Despite the diversity found in landraces, simply applying selection on a pre-existing diversity is an eroding process that eventually comes to a limit. (Breseghello & Guedes Coelho, 2013) The highest capability of plant breeding comes from recombination for mixing favourable alleles. Crossing two parents results in a multitude of possible genotypes. Especially in ryegrass, where genetic gains per annum are roughly 0.25% (Faville, et al., 2020). The limitation of genetic gain is also in the breeding programme which to get the best results has to be large and its ability to screen plants from crosses.

2.2 Mutagenesis

Since the 1920s, scientists have used chemical mutagenesis to change or mutate heritable genomes to introduce new traits into species through radiation and chemical treatments. Mutagens identified for use include the following radiation sources: X-ray, gamma rays, beta and ultraviolet irradiation and neurons. A wide range of chemical mutagens was identified and included alkylating ethyl methanesulfonate agents (EMS). Target tissue such as seed and pollen were used, and axillary buds and stem cutting for a sexually propagated species. (Songstad, Petolino, Voytas, & Reichert, 2017) S

More than 3,200 varieties in 214 plant species of plants have been bred and released through mutagenesis like Rio Red Grapefruit. Which was bred through X rays and thermal neutrons (Hensz, 1991). The incorporation of molecular markers in mutant identification and selection shows that 60% of mutants were generated within the last 25 years versus the previous 50 plus years. (Songstad, Petolino, Voytas, & Reichert, 2017)

Mutagenesis through chemical and radiation therapies was **random** and **non-directed,** and there are limited ways to select and screen for mutants. It is essential to choose a suitable form of mutagen. Each one could generate different types of mutagenesis; for example, treatment with gamma rays induced a majority of base deletions, creating random and large deletions of genes that ended up missing to all progenies following. (Songstad, Petolino, Voytas, & Reichert, 2017)

2.3 Hybrids

Heterosis refers to the superior increase in a hybrid's phenotypic qualities over its parents, both genetically diverse. According to (Moll, Lonnquist, Velez - Fortuno, & Johnson, 1965) the more divergent the parents, the higher the offspring's heterosis. Heterosis in ryegrass has demonstrated yield increases of 25% in F1 hybrids (Pembelton, et al., 2015); however, heterosis can only be maintained for one generation in hybrid varieties.

The harnessing of hybrid vigour is arguably the most significant practical contribution plant breeding has made to agriculture. It is used in various economic species, including some trees, legumes, small grains, maize, and oilseeds. (Barrett, Turner, Lyons, Rolston, & Easton, 2010)

The most successful development of hybrid varieties has been in maize due to its male flowers (tassels) and female flowers (incipient ears) being easy to handle.

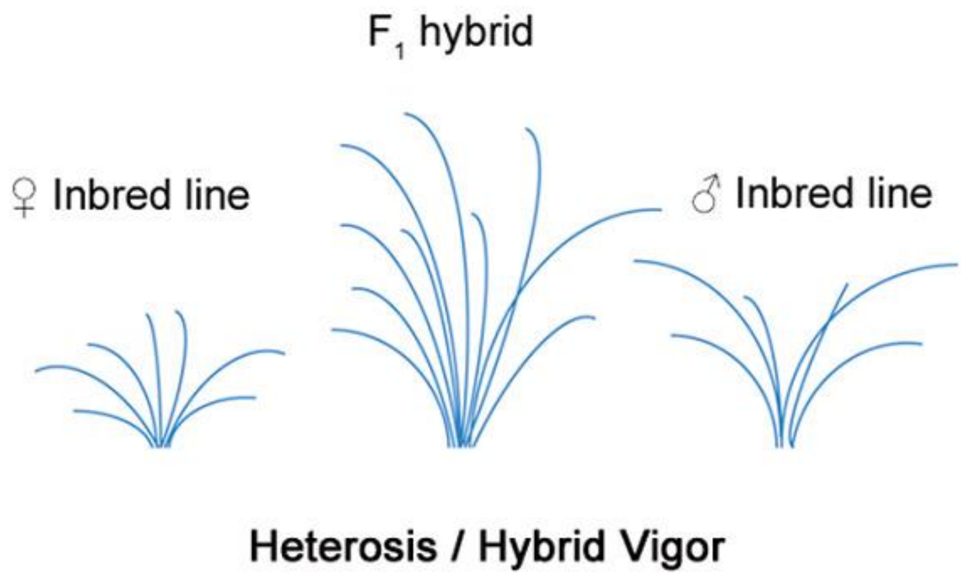

Figure 2: Heterosis in ryegrass (Lio, Li, Zhang, Wei, & Huang, 2019).

2.4 Marker-assisted selection (MAS)

Some traits like flower colour may be controlled only by one gene. Many genes may influence other more complex characteristics like crop yield or starch content. Traditionally plant breeders have selected plants based on visible and measurable traits called phenotypes. This process can be slow, heavily influenced by the environment and expensive. (International Service for the Acquisition of Agri-biotech Applications (ISAAA) , 2006). With marker-assisted Selection (MAS), once the marker-trait association is correctly established, the gene- or QTL markers can be used to select plants carrying those desirable traits. Though MAS has promise, statistical associations are still heavily influenced by several factors such as trait heritability, phenotyping methods, and marker density, to name a few that may lead to false positives (Kadirvel, Senthilvel, Geethanjali, Sujantha, & Varaprasad, 2015).

MAS's application is designed to improve the selection for traits that are usually targeted as problematic or complex and expensive to phenotype. This consequently accelerates the selection and breeding process (Williams , Easton , & Jones , 2007). Although markers can be used at any stage during a plant breeding programme, MAS's biggest advantage is on early generations and single plants because undesirable gene combinations can be eliminated early whilst single plants can be genotyped without the unreliability of environmental factors (Bertrand, Collard , & Mackill , 2007).

2.5 Genomic Selection (GS)

Genomic selection (GS) is a process in where a breeding value for a trait may be cost-effectively predicted for selection candidates using genome-wide markers—initially proposed by (Meuwissen, Hayes , & Goddard, 2001) for animal breeding. A training population combining both genotypic and phenotypic information is used to develop a model that can predict genomic estimated breeding values (GEBVs) for individuals in a population that have been genotyped already. GS can accelerate genetic gain, especially for complex traits controlled by multiple genes, which may only have a negligible effect on traits. (Arojju, Cao, Jahufer, Barrett, & Faville, 2020). Genomic selection is currently successfully used in New Zealand and Australian ryegrass breeding, especially when looking for traits around Nutritive value impacts on animal nutrition.

3. Creation of genetic technologies

Early DNA modification methods were developed in the 1970s, and by the 1980s, gene delivery systems such as *Agrobacterium* enabled the transfer of novel genes into plants. The ability to target a specific gene, however, remained difficult (Royal Society , 2019).

3.1 Genetic Modification (GM)

There are three different main types of genetic modification that are currently used. **Cisgenics**, **Transgenics** and **Intrangenics**. All three methods use the same transformation technique, e.g., Agrobacterium-mediated transformation following the isolation of genes from the host, which the gene(s) are then introduced into an organism (Kaushik, 2017). Worldwide despite their differences, Cisgenics and transgenics are both regulated under GMO laws.

Cisgenics was first called this by (Schouten , Krens F, & Jacobsen , 2006), who defined a Cisgenic plant as "a crop plant that has been genetically modified with one or more genes isolated from a crossable donor plant" (Hongwei, Neslihan, & Zhen-Xiang, 2014). The European Food Safety Authority (EFSA) describes Cisgenic as specific alleles/genes in the breeder's gene pool which is introduced into new varieties without the accompanying linkage drag (co transfer of DNA sequences linked to the gene of interest), which occurs in conventional breeding. (European Food Saftey Authority (EFSA), 2012). The introduction of this cisgene(s) will not alter the gene pool or provide the recipient species' additional traits as it has been present in the species or a sexually compatible relative for centuries (Schouten, Krens, & Jacobsen, 2006).

One of the critical purposes of Cisgenics is to transfer disease resistance genes to susceptible varieties in a timely matter. Cisgenesis can significantly speed up the breeding process, particularly in self-incompatible vegetative crops such as potato and apple. In these crops, a new variety could be developed in approximately five years using Cisgenics (if the gene(s) of interest have been isolated), whereas this might take 25 years or more using conventional plant breeding (Advisory Committee on Releases to the Environment (ACRE)).

Currently, Cisgenic crops are still at the research stage, with some field trials being conducted. An example of this is in the Potato family (*Solanaceae*), which is highly susceptible to multiple pests and diseases. One of the most prominent globally being late blight caused by the fungal pathogen (*Phytophthora infestans*) has been identified as the cause of the potato famine in Europe dating back to the 1800s. It is the most destructive pathogen of potatoes and is estimated to cause annual losses of 15% of global potato production. The British potato industry approximately uses $87 million annually in crop protection products in a typical blight pressure season. (Potatoes Australia, 2018).

Currently, to control late blight, potatoes heavily rely on the use of fungicides associated with substantial economic and environmental costs. In addition, residues left on produce that is then deemed acceptable for human consumption are an issue in which public concern in the EU has increased. (De Stur, Van Loo , Maes , Gheysen , & Verbeke, 2019). Traditional breeding methods have resulted in some resistant cultivars that are not widely adopted as they do not offer a competitive yield and optimal consumption qualities. (Cooke , et al., 2011)

The development and deployment of cultivars with genetic resistance are the most economical and eco-friendly approaches for reducing yield losses due to late blight. Wild potato species are a valuable genetic pool, and high levels of resistance (R genes) were found in several Mexican wild species including, *Solanum demissum* and *Solanum pinnatisecum.* (Yang , et al., 2017) Eleven R genes were identified, however once introduced into commercial varieties; they were unfortunately not durable to withstand commercial-scale production, which saw new virulence's emergence in *P. infestans* (Van Der Vossen, et al., 2003)

Professor Jonathon Jones of the Sainsbury Laboratory in Norwich, United Kingdom, has therefore introduced into field trials a stack of 3 different resistant R genes that confer resistance to late blight in the UK's most grown variety, Maris Piper. Together in one plant, this should make it much harder for pathogens to evolve and overcome the plant's defences (John Innes Center , 2016).

In contrast, **intragenic** is a gene comprising functional elements such as the coding part, promoter and terminator originating from different genes from the plant itself or a naturally crossable species. Therefore, all gene elements belong to the traditional breeder's gene pool however it differs from cisgenics as an intragenic is an artificial genetic construct so has been reorganised before insertion (Whelan & Lema, 2015).

Transgenics has been used as a plant breeding method for the last 40 years (Hudson, et al., 2019). It involves removing one or more preferred genes from one organism or non-plant organism and randomly introducing it into another organism of an entirely different species. These two organisms are naturally sexually incompatible. Transgenics can extend the gene pool of the recipient species. It could provide the target plant with a new trait that could not be introduced through traditional breeding methods (Schouten, Krens, & Jacobsen, 2006).

An example of a genetically modified food source using transgenics would be Bananas—Banana Xanthomonas wilt (BXW) or, more scientifically, the bacterium *Xanthomonas campestris* PV. *Musacerum* was first discovered in Ethiopia but rapidly spread to across the great lakes region in Africa in 2001, which causes roughly half a billion dollars in damage each year (Nordling , 2010).The damaged caused by BXW is significant to an important food and cash crop, which constitutes more than 30% (rising to 60%) of the daily capita calorie intake in Uganda, Rwanda and Burundi (Abele, Twine, & Legg, 2007). There are only a few banana varieties in the world due to it not being able to produce fertile seeds, therefore not reproducing sexually. This also means they are sterile and cannot be improved through conventional breeding methods. Therefore, no varieties are resistant to BXW.

Scientists identified the *Hrap* (hypersensitivity response assisting protein) gene from sweet pepper (*capsicum annuum*). This gene is one of the most crucial hypersensitive cell deaths (HCD) associated genes that can be utilised to protect plants from bacterial pathogen attack (Chen, Lin, Ger, Chow, & Feng, 2000).

Six out of the eight transgenic bananas with the *Hrap* gene when exposed to *Xanthomonas campestris* PV. *Musacerum* did not show any infection symptoms after artificial inoculation in glass houses, whereas the non-transgenic plants showed severe symptoms (Tripathi, Mwaka, Tripathi, & Tushemereirwe, 2010).

Many plant species, including major crops such as rice, soybean, maize, cotton, canola, potato, squash, papaya, and other numerous fruits and vegetables, have foreign genes inserted into their genomes. (Hongwei, Neslihan, & Zhen-Xiang, 2014) GM crops' most common trait is herbicide resistance (representing 59% of all GM crops). They were followed by the combined or stacked traits of herbicide tolerance and insect resistance (26%) and insect resistance (15 %) (Agricultural Biotechnology Council of Australia).

3.2 Gene Editing

Gene editing is a process that has evolved from the use of chemical and physical mutagenic agents. These agents can alter DNA sequences to biological tools such as **sequence-specific nucleases** (SSN) to produce **knock out** (KO) or **knock-in** (KI) edits (Songstad, Petolino, Voytas, & Reichert, 2017). Where specific changes are made enabling targeted genetic modification in various organisms. SSN tools including Zinc-finger nucleases (ZFNs), transcription activator-like effector nucleases (TALEN's) and the Clustered Regularly interspaced short palindromic repeats (CRISPR) – Cas system. (Yin, Gao , & Qiu, 2017).

3.2.1 Gene Editing Technologies

CRISPR – Cas 9

Clustered regularly interspaces short palindromic repeats (CRISPR). This name refers to the unique organisation of short partially palindromic repeated DNA sequences found in the genomes of bacteria and other microorganisms. (Barrangou & Doudna, 2016)

CRISPRs were first discovered in archaea and later in bacteria by Francisco Mojica in 1993, whereby 2005 it was found that CRISPR is an adaptive immune system. (Broad Institute - Feng Zhang , n.d.)

CRISPR Cas 9 essentially enables us to edit parts of the genome by removing, adding, or altering the DNA sequence sections.

- An enzyme called Cas 9 acts like a pair of precise molecular scissors that can make double-stranded DNA breaks at any site in any organism.
- A Cas 9 protein is introduced along with guide RNA, which has a specific sequence that will direct where the Cas 9 protein will cut the DNA.
- Cas 9 protein binds to the guide RNA and scans the cells DNA looking for a particular recognition sequence.
- Once the sequence is found, Cas9 opens the double helix to check that the adjacent sequence is complementary to the guide RNA. If all the DNA bases match the guide RNA's targeting sequence, Cas 9 will cut both strands of the DNA.

After the above mechanisms, there are two options.

1. The DNA strands can repair themselves by sticking the two cut ends together, which often results in mutations at the cut site, which is formally known as Gene disruption or repair.

2. Cells will generally try and fix the damaged DNA without causing mutations by finding matching sequences. Scientists can therefore introduce into the cell matching sequences, which also includes desired genetic alterations. By inducing the cell, scientists can incorporate any desired change into its genome.

As seen above, CRISPR beyond applications encompassing bacterial immune defences, can make **precise** changes in organisms' genes. A change in the sequence of even one gene can significantly affect the biology of the cell and may affect an organism's health. CRISPR techniques allow scientist to modify specific genes while sparing others, thus clarifying the association between a given gene and its consequence to the organism. (Harvey, 2015)

The impact of CRISPR gene editing and gene drives is likely to be huge. There are many potential applications in various fields, including disease control, crop and livestock management, germline research, human therapy, pharmaceuticals, and invasive species control.

ZFNs

Zinc Finger Nucleases (ZFNs) is a site-directed nuclease tool designed to produce a mutation at a predetermined position in the plant genome (Holme, Gregersen, & Brinch - Pedersen, 2019). One of 3 methods that change the genome with engineered nucleases.

Many restriction enzymes exist in prokaryotes, with a catalogue of many enzymes available. Most restrictive enzymes cannot be readily adapted or modified to cleave new sequences. Example: An enzyme that can cut sequence X cannot be persuaded to cut enzyme Y, and if it does, it will do it very weakly. (Gupta & Musunuru, 2014)

Zinc finger nucleases (ZFNs) are chimeric fusions between a zinc finger protein (ZFP – a class of engineered DNA binding proteins) and the nuclease domain Folk I.

ZFNs consist of two functional domains,

a.) the DNA binding domain, which comprises two-finger modules that each recognise a unique six base pair sequence of DNA. The two-finger modules are stitched together to form a Zinc finger protein, each with a specificity of 24 base pairs.

b.) A DNA cleaving domain which comprises of the nuclease domain of Folk I

When the DNA binding and DNA Cleaving domains are fused together, a highly specific pair of genomic scissors are created.

Double-stranded breaks are essential for site-specific mutagenesis in that they stimulate the cells natural DNA repair process (homologous recombination and non-homologous end joining)

ZFN mediated targeted genome editing occurs when the ZFN pair is delivered into the cell, recognise the target site, and make a double-stranded break in the DNA. When no repair template is co transferred with the ZFN pair, this results in non-homologous end joining and gene deletion. When a repair template is transferred with the ZFN pair, this results in homologous recombination - Gene integration.

Double-stranded breaks are essential for site-specific mutagenesis in that they stimulate the cells natural DNA repair process (homologous recombination and non-homologous end joining)

The benefits of ZFNs are.

- Rapid disruption
- Mutations made are permanent and heritable.

(Merck, n.d.)

TALENs

Transcription activator-like effector nucleases (TALENs) are similar to ZFNs (Joung & Dander, 2013). However, TALENS exhibit better specificity and efficiency than ZFNs (Li, et al., 2020). TALENs discovered back in 2009 (Malzahn, Lowder, & Qi, 2017) are proteins made and used by plant pathogenic bacteria to control plant genes during infection. TALENs are protein combinations composed of two parts: the TALE that targets the protein to a specific DNA sequence. These proteins are found in plant pathogenic bacteria of the genus *Xanthomonas.* This transcriptor, like factor genes, and their role in *Xanthomonas* activate specific host plant genes to support Xanthomonas ability to cause damage to the host. They have a straightforward code that is easy to mutate and adapt. If the host plant changes the sequence of a promoter, the essential host genes to stop *Xanthomona*s infecting them can quickly change the tail protein sequence. (West , 2020) Moreover, the "N" is a nuclease that cuts the DNA. TALENS are extremely precise and have additional capabilities, such as targeting any DNA sequence discriminating between methylated and unmethylated DNA targets and modifying DNA within organelles such as mitochondria.

The three families of gene editors (first year of report)	**Zinc finger nucleases (2003)**	**TALENs (2010)**	**CRISPR/Cas (2012)**
Production	Not very easy	Easy	Very easy
Cost of production	5000 Euro	1000 Euro	10 Euro
Time needed for an experiment	Months	Weeks	Days

Table 1: Gene editing technologies summary (Friedrichs, et al., 2019)

Gene editing has some critical differences from other techniques used to generate DNA mutations. Unlike the random mutations which can occur from Radiation based mutagenesis and Transgenesis**, gene editing** only targets precise location (s) in the genome, either amending an existing gene or insert a new gene expression.

4. Regulations and contexts

4.1 Cartagena Protocol

The Cartagena Protocol is a legally binding protocol on biosafety to the Convention on Biological Diversity (CBD). An international agreement that aims to ensure the safe handling, transport, and use of living modified organisms (LMOs) resulting from modern biotechnology. These LMO's may have adverse effects on biological diversity and risks to human health. It was adopted on 29th January 2000 and entered into force on 11 September 2003. (Convention on Biological Diversity , 2020) Out of the 195 countries in the world, there are 173 parties involved.

The protocol, however, does not cover:

- Products derived from LMOs (e.g., paper from GM trees)
- LMOs, which are pharmaceuticals for humans that are addressed by other relevant international agreements or organisations.

The protocol helps developing countries build their biotechnology capacity and creates an advanced information agreement (AIA) procedure that requires exporters to seek consent from importing countries.

Its primary mechanism, however, is the AIA requirement. It is a procedure that must be followed before the first intentional transboundary movement of an LMO into the importing country's environment.

The protocol defines an LMO as; *"Any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology".*

And Modern biotechnology as, The application of:

"In vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles or"

"The fusion of cells beyond the taxonomic family that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection".

(Internation Service for the Acquisition of Agri-biotech Applications (ISAAA) , 2004)

4.2 World

The International Service for the Acquisition of Agri biotech application (ISAAA) recorded 160 million ha of GM crops were grown worldwide in 2011. By 2015 179.7 million hectares, over 10% of the worlds arable land, seven times the UK's land area for context. (Royal Society, 2016)

Many GM crops are in 2015 were soybean (92.1 million ha), followed by maize (53.6 million ha), then cotton (24 million ha) and oilseed rape (canola) (8.5 million ha) (Figure 3). This represents 83% of the world production of soybean and 75% of production of cotton. GM crops made up 29% of the world's maize production and almost a quarter of the world's oilseed rape that year. (Royal Society, 2016)

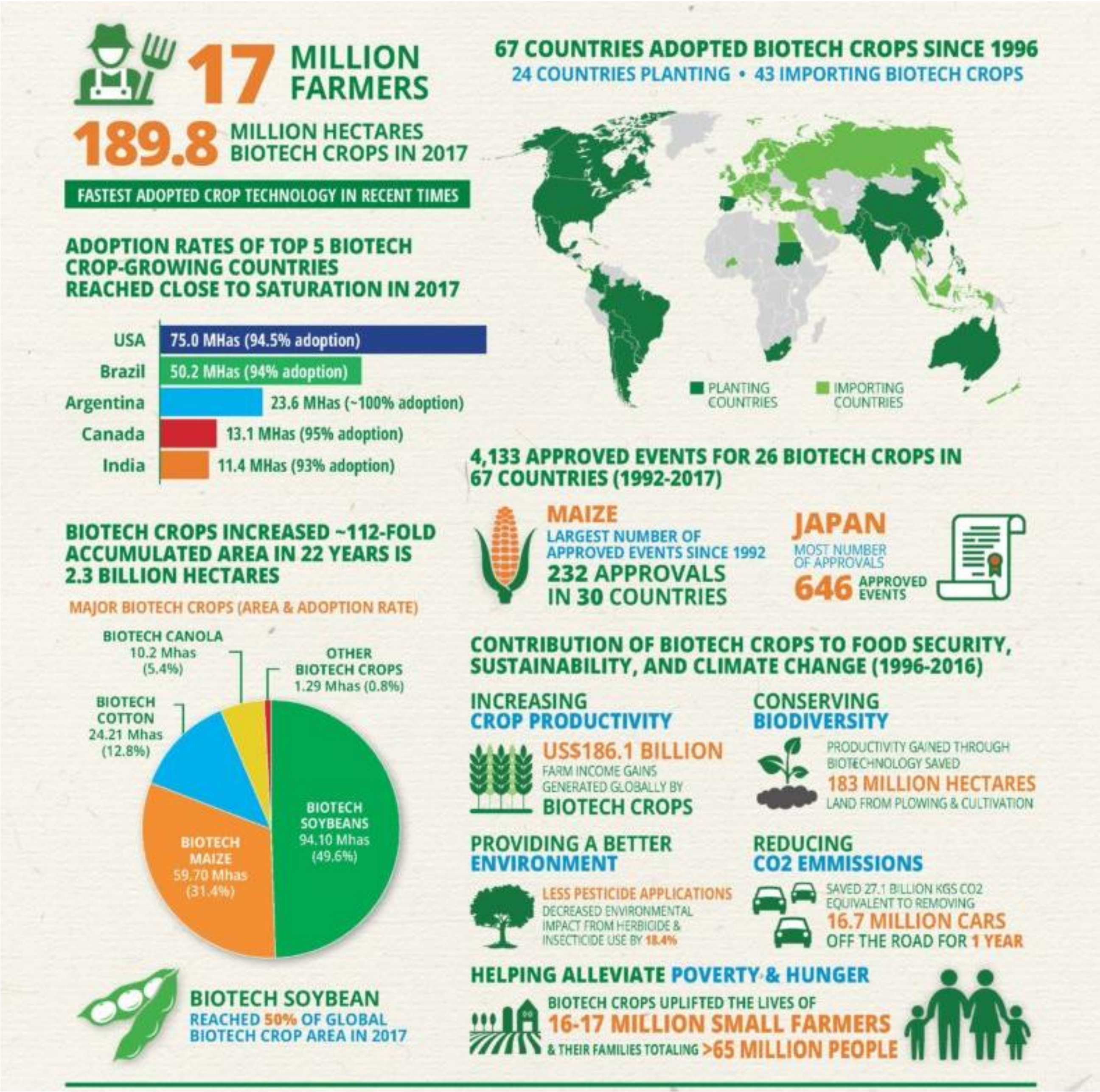

Figure 3: Commercial Biotechnology crops (Brookes & Barfoot, 2018)

4.3 New Zealand

In Aotearoa, New Zealand, genetically modified organisms have been regulated since the establishment of the Environmental Risk Management Authority (ERMA) Through the Hazardous Substances and New Organisms Act (1999) responsibilities which transitioned to the Environmental Protection Authority (EPA) (2011) (Hudson, et al., 2019)

In May 2014, the high court of New Zealand rendered the first judicial opinion in the world about the legal classification of gene-editing techniques. The court ruled that ZFN-1 and TALEs are genetic modification techniques and thus within the New Zealand statute and regulations governing genetically modified organisms. (Kershen, 2015) The HSNO (Hazardous substances and New Organisms) Act is the primary means of regulating genetically modified organisms in New Zealand. Its purpose is to protect the environment and the health and safety of people and communities. In the two decades since its enactment, there have only been minor amendments to the Act. (Royal Society Te APARANGI , 2019)

In New Zealand, the HSNO Act defines genetically modified organisms as: 'any organism in which any of the genes or other genetic material.

A.) Have been modified by in vitro (within a laboratory vessel) techniques; or

B.) Are inherited or otherwise derived, through any number of replications, from any genes or genetic material which has been modified by in vitro techniques (Royal Society , n.d.)

This definition of genetic modification in the HSNO act appear to no longer be fully; fit for purpose'.

For example:

- The use of gene-editing technologies such as CRISPR-Cas 9 are deemed genetic modification under current legislation, and the resulting organisms are, therefore, classed as new organisms. By contrast, those generated by random mutagenesis, which may result in many more gene alterations and the desired change, do not count as new organisms.

- CRISPR-Cas 9 can be applied using in vivo (within the body of an organism) techniques, thereby no longer fitting the legislative definition relying on the in vitro techniques.
  (Ministry for Primary Industries , 2020)

The Royal Society report (Royal Society Te APARANGI , 2019) states that the modern reality that organisms cannot be categorised as 'genetically modified' or 'not genetically modified. The report also stated the panel's concern around the complexity of regulations and the legislative use if gene editing were in NZ.

For example, if gene editing were to be used to develop and administer a gene drive to rid New Zealand's conservation estate of possums, it would require the navigation of multiple pieces of legislation with various regulatory authorities. As seen below in figure 2.

In New Zealand, early applications of gene technologies to create transgenic organisms were met with public outrage, leading to establishing a Royal Commission of Inquiry into genetic modification. The Commission considered over 10,000 public submissions to develop its report, which led to no genetically modified crops being grown in NZ. (Royal Commission on Genetic Modification, 2001)

Dr Hillary Sheppard, a senior lecturer for the school of biological sciences at the University of Auckland. comments on the (Royal Society Te Aparangi, 2019) report.

"Gene editing allows us to change gene sequences with unprecedented ease and specificity. It is a powerful tool that can significantly impact many sectors, including healthcare, agriculture, and conservation. The versatility of gene editing means that we need to think carefully, as a society, about the various and varied scenarios to which this tool can be applied and to decide if we find specific applications to be scientifically, ethically, and morally acceptable. As such, this report is timely. Historically gene modification has been an emotive and polarising issue. However, the benefits that gene editing can bring to society demand that we re-examine our position. We need to provide a legislative framework that allows for risk-tiered regulations to govern current and future biotechnological advances."

(Science Media Center NZ , 2019)

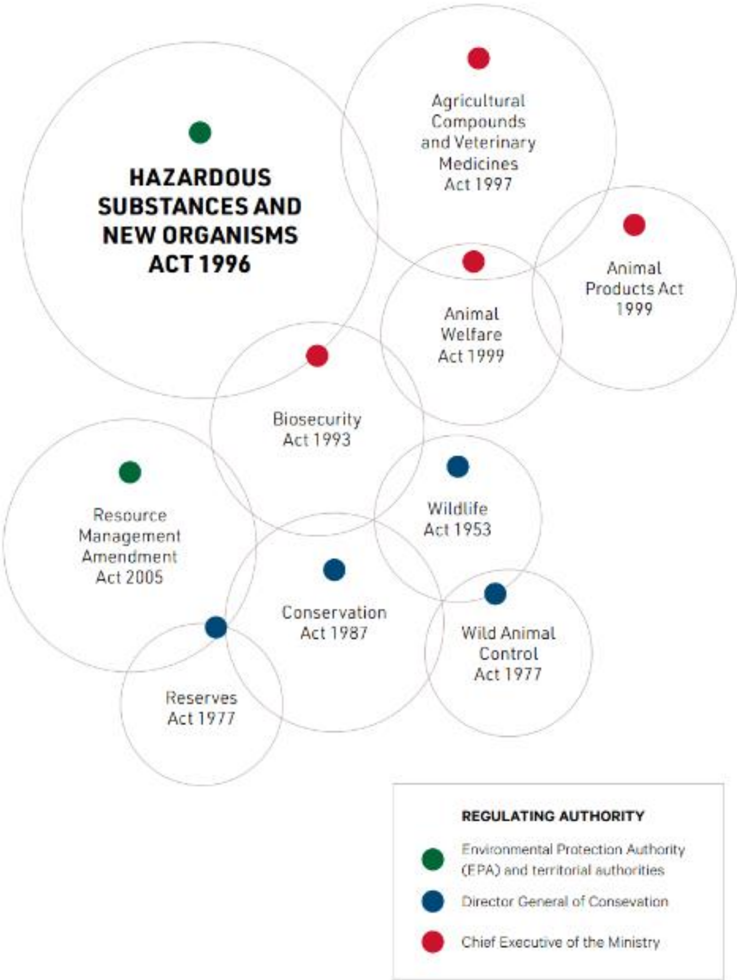

Figure 4: *Authorities involved in administering Gene drives to rid New Zealand's conservation estates of possums.* (Royal Society Te Aparangi, 2019)

One of the significant regulatory concerns is around the joint food regulatory system with Australia. Australia is currently producing GMO cotton and not being ratified to the Cartagena Protocol, which is explained below.

In 1983 a comprehensive trade agreement – the Australia New Zealand Closer Economic Relationship Free Trade Agreement (CER) – was signed by the New Zealand and Australian government.

The CER underpins several economic arrangements between the two countries, including.

- An agreement between the two countries concerning a joint food standards system (the Food Standards Treaty)
- The Trans-Tasman Mutual Recognition Arrangement (TTMRA)

The Food Standards Treaty was signed in 1995. Both countries committed to the development and implementation of a single set of food standards. The underlying aims of the join system consider the needs of both Australia and New Zealand to protect public health and reduce unnecessary barriers to trade (Ministry for Primary Industries , 2020)

Under this system, the food products of genetically modified organisms are regulated separately to the organisms themselves rather than the process. (Royal Society Te Aparangi, 2019)

4.3.1 Regions

Several councils in New Zealand have won their districts' rights to remain GE free only to crops that are defined as cereals, vegetables, and fruit, so not including grasses, trees, or livestock. The 3 District council areas are Whangarei, Auckland, and Hastings, which came into act in 2017.

4.3.2 Food

New Zealand currently imports more than fifty varieties of genetically modified food ingredients, including ingredients derived from GM crops such as corn and soybeans. (Food Standards Australia New Zealand , 2020)

To be sold in the country, each GM food or ingredient must be evaluated by Food Standards Australia New Zealand (FSANZ) and determined to be safe for consumption, then approved by the FSANZ Board and all Australian and New Zealand ministers responsible for food regulation.

A particular standard in the FSANZ code, Standard 1.5.2 – Food Produced Using Gene Technology, Animal feed containing genetically modified ingredients is not subject to the exact labelling requirements. Meat and dairy products from animals fed such feed also does not need to be labelled under the food regulations. (Ministry for the Environment , 2020)

In New Zealand, there is currently no

- fresh produce (fruit, vegetables, and meat) that is genetically modified.
- genetically modified crops (e.g., potatoes, sweet corn) growing commercially.

However, some processed foods may contain imported ingredients that have been genetically modified. (Ministry for the Environment , 2020)

In July 2008, NZFSA confirmed that it found rice and rice products containing the unauthorised genetic modification (GM) Bt63 in the New Zealand market. Because of this finding product was recalled. (Ministry for Primary Industries (MPI), 2013)

4.3.3 Medicines

Some medicines and vaccines are made in New Zealand using genetically modified bacteria as chemical factories to produce them. These medicines are known as recombinant DNA medicines and do not contain any genetically modified material. They are just products of a GM process. In most cases, the genetically engineered bacteria are grown in large fermentation vessels.

Currently, available medicines produced using this method 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 antiviral drug used for treating multiple sclerosis and cancer.
- Hepatitis vaccines, including a hepatitis B vaccine widely used in New Zealand.
- A vaccine for equine influenza containing live GMOs has been approved for conditional release in New Zealand by the Environmental Protection Authority (EPA). It can only be used in the event of an equine influenza outbreak in New Zealand and must comply with strict controls by the EPA.
- A GM live vaccinia virus has been approved for conditional release in New Zealand by the EPA. It is only approved for use in clinical trials for liver cancer patients. Strict controls have been put in place by the EPA that must be complied with.

(Ministry for the Environment , 2020)

4.3.4 Agricultural

Several New Zealand Crown Research Institutes (CRIs) have been involved in several programmes to sequence and improve our knowledge of the genomes in crop plants and domesticated animals to understand the importance to New Zealand Primary production systems (Royal Society , 2019)

In 2010 the ERMA approved with controls an application from Scicon to field test genetically modified radiata pine in outdoor containment. This trial could only occur in a 4-ha field over 25 years, with trees needing to be cut down at eight years of age when reproductive structures start to develop (New Zealand Forestry Owners Association , 2010). However, this trial was short-lived due to protests and damage done to the trees by anti-GE lobbyist groups.

Ag Research at its Palmerston North site developed a genetically modified High Metabolisable Energy ryegrass that could grow up to 50% faster than conventional ryegrass, store more energy for better animal growth, more resistant to drought and to produce 23% less methane. Since 2001 it is now progressing in the United States' Midwest, where GMOs can be field-tested outside the lab. Animal feeding trials are planned to take place in two years, which we will need regulatory approvals for, and the information we get over the next two years will help us with our application for those feeding trials.

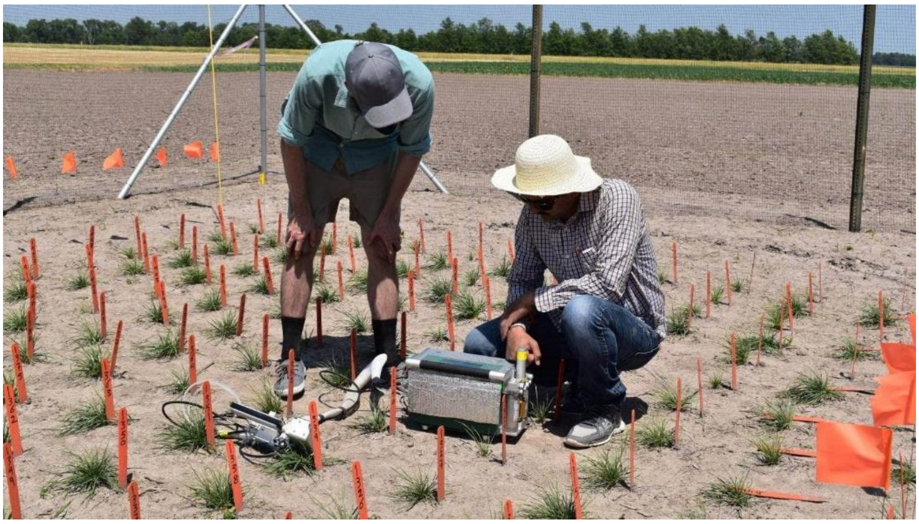

Figure 5: High Lipid ryegrass (GM) in trials in the USA (STUFF.co.nz, 2018)

Dairy NZ strategy and investment leader for new systems and competitiveness, Dr Bruce Thorrold, says the HME ryegrass is a science breakthrough and holds great potential for New Zealand farmers.

"HME ryegrass could help us achieve less nitrogen leaching and reduce greenhouse gas emissions, as well as improving pasture quality and productivity," says Dr Thorrold. "This research could be transformational in future, and so it is important we explore all promising avenues which could help dairy farmers respond to the challenges we face." (The New Zealand Insitute of Agricultural & Horticultural Science Inc - Bob Edlin , 2018)

4.4 Australia

Whom has not ratified the Cartagena protocol, after concluding alongside Phillip and Kerr (2000) (Espinosa, 2014), the Protocol seems to have much more to do with restricting and hampering trade in genetically modified products, for other reasons, than with protecting biodiversity (Productivity Commission, 2000).

In Australia, a national gene technology Act was introduced in 2000, the same year as the Cartagena Protocol. This, however, is a national scheme that regulated genetically modified organisms to protect the health and safety of the people and environment by identifying risks posed by or because of gene technology and managing those risks by regulating certain dealings with genetically modified organisms.

Reviews of the scheme are mandated every five years. Two have been undertaken in 2006 and 2011 to ensure that the Act remains up to date and flexible to the latest technologies or problems that have arisen in the previous five years.

Definition of a genetically modified organism is-

(a) an organism that has been modified by gene technology; or

(b) an organism that has inherited particular traits from an organism (the ***initial organism***), being traits that occurred in the initial organism because of gene technology; or

(c) anything declared by the regulations to be a genetically modified organism or that belongs to a class of things declared by the regulations to be genetically modified organisms.

Nevertheless, it does not include:

(d) a human being, if the human being is covered b only because the human being has undergone somatic cell gene therapy; or

(e) an organism declared by the regulations not to be a genetically modified organism or belongs to a class of organisms declared by the regulations not to be genetically modified organisms.

(Federal Register of Legislation , 2000)

In May 1999, the Australian government committed $17.5 million to develop a new biotechnology strategy to ensure that Australia captures the benefit of this emerging technology. (Wynen, 1999)

It has since become known that Australian gene regulators are consulting on deregulating CRISPR products, which would again affect the trans-Tasman FSANZ regulations.

Commercial Bt cotton has been grown in Australia since 1996, when 30,000 ha were grown. By 1998 this had risen to 85,000 ha (Wynen, 1999)– a 97% decrease in insecticide use (Cotton Australia, 2020). The International Service for the Acquisition of Agri biotech application (ISAAA) 160 million ha of GM crops were grown worldwide in 2011, with cotton taking up 15.4%.

In December 2001, Australia adopted new labelling laws for GM foods and ingredients. Standard 1.5.2 (food produced using gene technology) ensures that all GM crops, animals, and microorganisms must be assessed and approved by FSANZ as safe before being used for food or food processing. (Agricultural Biotechnology Council of Australia)

4.5 Canada & US

Unlike many other countries, the regulation of GMOs in the U.S is favourable to their development. This is because as they are an economically important component of the biotechnology industry, The US's 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. (Library of Congress) The US is one of few countries alongside Australia that are not signatories to the Cartagena Protocol.

A bit like New Zealand, there is no legal definition of GMO. However, it is the definition of Organic that genuinely matters. The U.S. Food and Drug Administration (FDA) use a stricter definition for a GMO: an animal or plant that has been created through genetic engineering.

"Genetic engineering is a term used to describe biotechnological methods used by scientists to manipulate an organism's genome directly. Under this definition, GMOs do not include plants or animals made by selective breeding or animals modified by being given hormone supplements or antibiotics".
(Powell, 2015)

First commercially introduced in 1996, adoption rates of GM technology rapidly increased, as seen in Figure 6. In 2021 of the 170.3 million ha of biotech crops globally, the United States accounted for 69.5 million (40%). For several crops grown in the US, genetically engineered varieties now make up the vast majority of the crop. In 2013 93% of soybeans, 90% of cotton and 90% of corn grown in the US were genetically engineered for either herbicide tolerance or insect resistance. (U.S. Department of Agriculture - Economic Research Service , 2020)

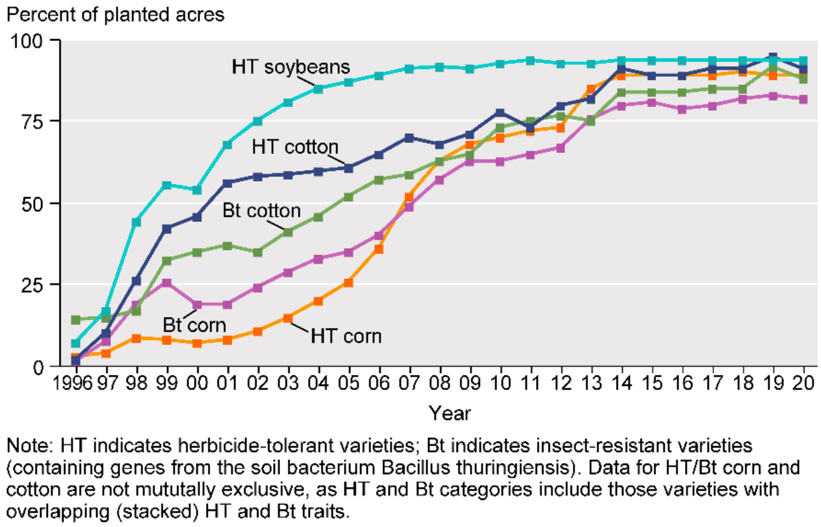

Figure 6: Adoption of GM crops grown in the United States. (U.S. Department of Agriculture - Economic Research Service , 2020)

In 2016, the US Department of Agriculture (USDA) decided that a mushroom editing using CRISPR to resist browning fell outside its regulatory oversight. Similarly, plants modified with ZFNs and TALENs are also escaping USDA GMO scrutiny.

In 2019, an American biotech company Calyxt announced the first commercial launch of a product derived from a gene-edited crop, its Calyno brand high oleic soybean oil. The oil is designed to be a heart-healthy product with increased heat stability, 80% oleic acid, 20% lower saturated fat and zero grams of trans fat per serving. The soybeans in this product were edited using TALEN gene editing.

4.6 Europe

GMO regulations in Europe were established in 2001 and were designed to strictly regulate DNA introduction from other species into animals and plants. These regulations do not cover mutagenesis techniques such as exposure to radiation. The process, not the product, also defines GMOs.

In 2016, the French government requested the current GMO directive reinterpreted after the arrival of new gene-editing techniques such as CRISPR. Michael Bobek, advocate general of the Court of Justice of the European Union (ECJ), released a statement with the proposed changes to the regulation stating,

"while the crops that have undergone gene editing should be considered GMOs, they could be exempted from strict regulation if no foreign DNA was inserted".

The resulting decision in 2018 was to apply stricter regulations to organisms that have undergone gene editing. In contrast to the European ruling in 2018, many other countries, including the US, Canada, and several South American and Asian countries, have decided to exempt gene-edited organisms from GMO regulations as long as they do not contain any foreign DNA. The court ruled that only techniques that have *"conventionally been used in several applications and have a long safety record"* should be exempt from GMO regulations. (Albert, 2020)

There are currently 49 authorised GMO for food and feed within the European Union. Mainly Cotton, Maize, Rape, soybean along with one potato and two micro-organisms (European Commission , 2013)

No distinction between Cisgenic and transgenic approaches is currently made within European GMO regulation, which has become a highly controversial issue.

5. Social, Cultural and Ethical Stance of gene technologies

Most research concerning indigenous people's responses to biotechnology establishes that they are positioned on the anti-GM end of the spectrum against commercialisation development. Many biotechnology projects are inconsistent with Māori values, impinge on Māori rights and sovereignty, and continue a process where indigenous cultures, values, knowledge systems and even lives are under marginalized and undervalued (Hudson, et al., 2019).

A distinction is needed between products or processes changed by gene technologies for commercial production, especially those with no clear cultural or environmental benefits than those that might provide direct community benefit (Fairweather & Roberts, 2004).

Throughout both (Hudson, et al., 2019) (Fairweather & Roberts, 2004) reports a lack of trust in scientific evidence due to scientists having differing views, uncertainties of longer-term effects on the environment, social license – how gene technologies should be used, the rationale, objectives and consequences were the common reoccurring themes which despite singling out the Māori and their cultural views is the same responses seen in general public surveys.

A considerable concern is also that technology benefits the wealth and tends to increase inequities through the commodification of resources (Hudson, et al., 2019).

Participants in (Hudson, et al., 2019) suggested that the effect of gene editing on Māori values is not always in a negative direction, and it was suggested that whakapapa (genealogy), mana, mauri (life essence), and kaitiakitanga (guardianship) might be enhanced using gene-editing technologies. These cultural values can be considered as a cultural scaffold when considering gene editing technologies and the value-based framework which comes from other gene-based technologies.

5.1 Ethics

Gene Editing has opened a pandora's box. The Nuffield Council on bioethics stated, "food production is one the necessities of sustaining human life and is also a matter of deep soil significance often rooted in cultural ethnic, religious and social practices such as fairness, freedom, harm/benefit and purity". Many of the resulting questions relating to genomic manipulation of food that we eat are common to both plants and animals and involve complex moral, political, and scientific considerations. (Royal Society , 2019)

New Zealand's bioethics council 'Toi te Taiao' was first established in 2002 after the (Royal Commission on Genetic Modification, 2001) reports recommendations. It was apparent that broad topics around biotechnology's ethics in New Zealand did not fall under an area of ministries or committees. In 2009 the government disestablished the committee. This committee was the link between the government and the public enhancing New Zealand's knowledge and understanding of biotechnology's cultural, ethical, and spiritual aspects. Since its disestablishment, nothing has replaced it.

A recent UK study on the potential uses of genetic technology (Van Mil, Hopkins, & Kinsella, 2017). The scenarios that moderated public acceptance of pursuing research into genetic technologies included applications to:

- Promote equitable access to genetic technologies as they are developed.
- Prioritise collective welfare.
- Enable the science to develop further and knowledge of future applications to be extended.
- Provide cheaper health interventions.
- Prioritise positive and reduce negative environmental impacts.
- Have benefits to society that outweigh risks to human health, animal welfare and the environment.
- Alleviate suffering.
- Use transparent processes.

Applications that were unacceptable to many were those which:

- Edit out difference and create a monoculture.
- Prioritise individual or corporate wealth.
- Drain currently over-stretched healthcare resources.
- Enable humans, plants, or animals to be weaponised.
- Are introduced with insufficient safety monitoring or measures.
- Restrict freedom to choose whether they should be applied or not, e.g., enforced genetic screening.
- Reduce biodiversity or harm the ecosystem and related food chains.
- Contaminate plants or animals not grown or reared using genetic technologies.
- Are not sufficiently regulated and equally are so over-regulated as to stifle scientific progress.

Gene-editing technology may cause reconsideration of the concept of 'GM-free'. For example, minor CRISPR-directed edits could produce outcomes both possible and indistinguishable from those achieved with conventional breeding (albeit faster and more cheaply).

6.0 Findings and Discussion

6.1 Summarising Gene Technologies

Genetically modified organisms, a product that has been modified through Cisgenesis, arguably have the same properties as that of a traditionally bred plant. This is due to using genes that have come from a sexually crossable donor plant. The advantages of Cisgenics are that it speeds up the breeding process and introduces genes that could be traditionally breed into the organism over a long period of time. Controversially, Cisgenics are regulated worldwide under the same laws as Transgenics which is, in contrast inserting genes from a foreign and not sexually compatible species. Transgenics is the type of GMO that the public is aware of and against. However, with Cisgenics being categorised under the same GMO umbrella as transgenics despite being adversely distinct, clarity around the difference is not communicated well enough.

Gene editing, as mentioned in this project with SSNs, is precise, site-specific, modifying the organism's genetic outcomes by inserting, deleting, or altering base-pair arrangements within the genome. Therefore, no foreign genetic material is inserted into the genome of the organism. However, the addition of a protein or agrobacterium is a foreign body to the gene. The agrobacterium is not able to cause a change in the genotype of the product.

When comparing traditional/ conventional plant breeding methods to the new breeding technologies (NBT's) mentioned above, it suggests that the likes of Cisgenic and some forms of gene editing are far more favourable. Chemical and radiation mutagenesis in which random mutations occur, transgenics where foreign DNA is included from a different species, and at random with possible linkage drag of unwanted DNA.

New breeding processes such as MAS and genomic selection can revolutionise plant breeding in the current time. Understanding which genes control specific desirable phenotypes will allow for quick selections and better understanding; in this case, ryegrasses will be suitable for the future market where environmental outcomes alongside maintaining performance are critical.

These outcomes are due to the increase in understanding and capabilities of technology. These types of technology are indicative of the progress in breeding technologies. They could serve as an ethical and practical tool until New Zealand understands the ethical, social, and economic challenges of other controversial gene technologies on our pastoral sector.

6.2 Confusion and Communication

As anticipated, genetic modifications, an area of biotechnology that most are familiar with through media coverage or personal and professional interest (Fairweather & Roberts, 2004). The broad range of potential applications for gene editing has re-ignited the ethical debates first brought about by the earlier forms of gene technology, GMO's.

However, gene-editing technology is confused with GM due to the lack of continuity in information from scientists and media. As reported in (Cui & Shoemaker, 2018), only 23.2% trusted the government and scientists out of the Chinese study respondents. This is not surprising, especially in a global pandemic where multiple nation leaders are going against scientist's factual advice. If nations' leaders do not believe scientists or go against advice, where does that leave the public? The disconnect between the facts of science vs politics and the public is huge and rational fact-based critiques no longer matter.

In the 21st century, there is much more ability for the public to get information from multiple sources such as the internet. Suddenly, thousands of people in a community who have a shared common interest can connect. An example is the anti-vax community which has increased its following by at least 7.8 million people since 2019 due to social media movements such as Facebook. (Burki, 2020) .

An example of miss-communication in New Zealand was an article published by stuff.co.nz regarding Ag Research's GM ryegrass. 'GE Free NZ' states multiple times GM and GE in the same paragraph about a grass which is GM (The New Zealand Insitute of Agricultural & Horticultural Science Inc - Bob Edlin , 2018). GE Free New Zealand is a voluntary group of like-minded individuals who gather momentum, and articles like this can be very misleading due to the lack of continuity. What they are meaning is Genetically engineered, which categorises Genetic modification (GM) and Gene Editing (GE).

Given much discussion on gene editing remains to scientific meetings, conferences, and TED talks, a 2016 Pew Research Centre survey showed that 42% of Americans have heard "nothing at all" about the topic, compared with 48% "a little" a 9% "a lot". However, polls also showed that Americans hold consistent opinions and judgements about gene editing, even as they possess very little information about the complex subject, which is drawn on by their religious and cultural values.

Scientists are known to publicly ridicule the public if they disagree with science or research that has been undertaken not due to anger but frustration. This retaliation exacerbates issues and cause other like-minded individuals to seek support which causes the start of a community against scientific information. Although scientists hold a responsibility to engage the public about gene editing's social and ethical implications, a lot of science dialogue is heavily reliant on journalism.

In 2013 the New Zealand government announced new funding for the National Science Challenges (NSCs) to 'respond to the most important, national scale issues and opportunities identified by science stakeholders and the New Zealand public' (Department of Internal Affairs, 2013). A series of government surveys starting in 2002 with the latest in 2014 recorded public attitudes towards science in Aotearoa. The survey results showed that the science and technology sector is perceived to be necessary, with 62% of respondents feeling well informed about science and technology, 79% enjoy finding out about new ideas in science and technology; however, 62% think scientists need to listen more about what ordinary people think. (Ministry of Business, Innovation and Employment (MBIE) and Ministry of Education (MoE), 2014)

6.3 Insurance policy

One of the major themes of this report was about the Insurance policy of GE / GM products and processes. They were categorised under the below three headings.

a.) If GE or GM products and processes were in New Zealand, could we ever go back to completely GE or GM-free?

If New Zealand were to introduce GM or GE products into the pastoral industry at a commercial level, there would be no opportunity to go back. As mentioned below the ability to test GE products is little to none therefore If a decision is made to introduce gene technologies into New Zealand's pastoral sector that is a lifelong choice. Hence why our regulations are very precautious. An unnerving fact is that it is unclear what Gene-edited products using the CRISPR technique have left the walls of a lab. One of the biggest problems with CRISPR is it is not expensive, and there is no need for years of training to conduct experiments and result in potential products. Researchers often need to order only the RNA fragment; the other components can be bought off the shelf. Total cost can be as little as USD $30 (Ledford 2015).

b.) Can we have a multi-dimensional market where some farmers were GE/GM-free vs farms that choose to use GE/GM products?

Can New Zealand's pastoral industry have a multi-dimensional farming system where those that are certified Organic, those that are GE/GMO-free or those who have GE or GMO grasses growing on-farm can all continue farming without each other affecting the status of each other's choices? or can the government decide how Farmers are to farm their land for the continuity of New Zealand's agricultural sector?

Unfortunately, it is not as simple as a yes or no. After many discussions from varied industry professionals, the current thinking suggests an apparent 50:50 ratio to whether we can or cannot.

It is complex without integrating market demands and requirements due to the different plant species, how it reproduces and how it would be used in the farming system as pollen dispersal, contracting equipment as well as livestock movement and uncontrollable animals such as bees, birds, and insects. All these factors need to be taken into account when assessing a final product or outcome.

Testing over in the USA is already underway on New Zealand developed GM ryegrass species. This is allowing us to gather information that cannot be attained in glasshouses in New Zealand. Testing overseas allows us to become better aware and informed of opportunities, risks, and other consequences of these GMO/GE ryegrasses in a controlled open paddock situation.

However, we will come to a time when GMO/GE testing will have to happen appropriately in NZ. The experiments conducted in NZ that were shut down due to protests or slip up in management indicate that the public were not appropriately communicated with about the trials' safety. The rigorous protocol they were under was not expressed significantly enough or controlled.

c.) How can we guarantee a GM/GE Free status?

New Zealand is one of very few major countries that are entirely GE/GM-free, which is currently a market advantage. Multiple scientific papers have pointed to conventional GM's techniques creating modifications in the genome that could not occur naturally; therefore, most organisms and products can be identified. However, NBT's such as genome editing can introduce a single nucleotide without integrating foreign DNA and can potentially be indistinguishable from naturally occurring or conventionally bred counterparts. Therefore, detecting GE organisms and products is much more complicated than that of a product or organism that has been processed using GMO or conventional techniques. This suggests that New Zealand can claim to be GMO-free but claiming GE free will be hard to quantify unless a test is established.

It is so complex without integrating market demands and requirements due to the different plant species, how it reproduces and how it would be used in the farming system as pollen dispersal, contracting equipment, and livestock movement uncontrolled animals such as bees, birds and insects. All of these factors need to be taken into account when assessing a final product or outcome.

Testing over in the USA is already underway on a couple of New Zealand ryegrass species. This is allowing us to gather information that cannot be attained in glasshouses in New Zealand. Testing overseas allows us to become better aware and informed of opportunities, risks and other consequences of these GMO/GE ryegrasses in a controlled open paddock situation.

However, we will come to a time when GMO/GE testing will have to happen appropriately in NZ. The experiments conducted in NZ that were shut down due to protests or slip up in management indicate that the public were not appropriately communicated with about the trials' safety. The rigorous protocol they were under was not expressed significantly enough or controlled.

6.4 Ethics

If we allowed GE or GM technology or products to be used in New Zealand, where is the line between ethical and not?

Many scientists have developed biotechnology to help not hurt humanity; however, the "Risk of unintended consequences" is high (Hudson, et al., 2019). International agreements will become harder to agree upon and enforce; there is a high risk of misuse – bio or agro terrorism, human treatments, and unintended health risks. The most challenging, most critical part of the ethical challenge is doing it not to go down a dark path of improvements to humanity.

Much discussion around 'where to draw the line' is surrounding human genome editing, which can lead down the slippery slope of non-therapeutic and enhancements "humanity plus"; however, in the agricultural industry, the ethical values "encompass value judgments that cover the production, processing, and distribution of food and agricultural products" (Food and Agriculture Organisation of the United Nations, 2001)

There are no ethical principles that will be sufficient to encompass every religion and beliefs worldwide to build a more equitable and ethical food and agricultural system; however, co-existence across societies. Without a clearer understanding of ethics in each community, it will be hard to understand the information needed and deal with different opinions.

6.5 Clean and Green NZ

Clean and Green NZ, or **100% pure** as we know it is a brand that was developed to promote New Zealand's natural environment and our stewardship of that to international markets. In 2001 a report was conducted by (Ministry for the Environment , 2001) to investigate the 'price on paradise' for 3 of our primary sectors, two being agriculturally based, Dairy and Organics. Organics is one of our smallest export earners, exporting certified products to over 90 countries internationally, earning $450 million and a market sector value of $700m (Organic Exporters Association of New Zealand , 2020). Compared to Dairy, which exported NZD $19.7 billion of dairy products in 2020 (Dairy Companies Association of New Zealand , 2020).

The report describes if our environment is valuable to New Zealand in a global context. The surveys from several of New Zealand's key export customers indicate that our clean green image has a significant export value – our environmental image is a crucial driver of the value of goods and services in the international marketplace. This quantitative evidence backs up other evidence on the environmental contribution to export value:

- The export sectors recognise the need to promote New Zealand's image as a producer of food in a natural environment and develop appropriate environmental standards for production, processing, packaging, and storage.
- Many consumers are buying organic produce because of concerns about food safety (Ministry for the Environment , 2001)

Several scenarios were given to the customers, one being if the Dairy industry were seen to be degrading New Zealand's environment, would they still purchase NZ dairy products.

"the consumers surveyed would purchase 54% less dairy products.

The actual loss in revenue would depend on how much of the lost product could be redirected to products and markets where environmental image plays a less critical role so that the potential annual loss would vary between:

- *$241 million (all lost product redirected), and*
- *$569 million (none of the lost product redirected)."*

The organics scenario looked at two major UK wholesalers. They were asked how their buying would be affected by two possible genetic modification policy scenarios in New Zealand:

(i) allowing limited field test of genetically modified (GM) crops for research purposes; and

(ii) allowing the uncontrolled release of GM crops in New Zealand.

The focus was on fresh organic produce because currently, it accounts for 80% of New Zealand organic exports.

In the short-term, New Zealand's organic sector would not be affected by allowing field tests of GM crops for research, although, in the long-term, buyers would probably shift to other sources. Adopting an uncontrolled policy would see New Zealand almost certainly suffer immediate losses, with buyers either stopping or substantially decreasing purchases. (Ministry for the Environment , 2001)

This brings us to the multiple global agreements we have ratified or are a party too as a country to deal with climate change alongside many other countries worldwide.

- The United Nations Framework Convention on Climate Change was signed in 1992 (Ministry for Foreign Affairs and Trade (MFAT) , 2020).

New Zealand and other parties produce regular reports to track progress towards our climate commitments which are a mandatory requirement to United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol.

In 2016, under the Paris Agreement, New Zealand committed to reducing emissions by 30 per cent below 2005 levels by 2030. The Government since introduced the Zero Carbon Bill to Parliament. The Bill recognises the various impacts of greenhouse gases, with a separate target for biogenic methane emissions – a reduction of 10 per cent compared with 2017 levels by 2030 and a reduction of 24–47 per cent by 2050. In contrast, carbon dioxide and nitrous oxide emissions must get to net-zero by 2050.

Biological emissions from agriculture make up 48 per cent of New Zealand's reported emissions – 92 per cent of which are methane and nitrous oxide emissions from pastoral livestock and approximately 6 per cent from nitrogen fertiliser. (Ministry for the Environment , 2019).

Here the question lies; whilst working towards net-zero carbon dioxide and nitrous oxide emissions by 2050, as well as a sustainable, profitable agricultural sector, do we discriminate against biotechnological tools which could significantly contribute to our goals?

or

Do we allow biotechnological tools that have been appropriately tested, spoken about in detail with iwi and the public to gage ethical and social implications to help protect our ecosystem and sustain New Zealand's agricultural industry for future generations?

7.0 Conclusions

The backbone of New Zealand's agricultural industry is pastoral farming, it is also one of the main sectors connected to the 'Clean green' image that is marketed worldwide.

The pastoral sector in New Zealand is hugely at risk of climate change. I believe areas of pastoral farming will reduce significantly due to environmental and economic viability which will cause flow on effects associated with overstocking, even more intensified farming systems and significant economic losses let alone international and domestic opinions on the ethics of pastoral farming in such intensity.

The lack of tools and technologies being turned away from plant breeders in New Zealand restricts their ability to redefine what the pastoral sector looks like and how this can be carried out. GS and MAS are two tools that are being heavily invested in and will be a steppingstone for the New Zealand pastoral industry until other genetic technologies challenges have undergone rigorous scrutiny.

The lack of understanding around Genetic technology is a huge problem not only here in New Zealand but globally. Gene editing and the technologies associated with it are revolutionary and to many, scary. By knowing which genes control water use efficiency in ryegrass, sugar levels and persistence could revolutionise New Zealand's pastoral industry and make our environmental targets not only achievable but sustainable. The biggest elephant in the room with genetic technology is where do we draw the line of helping the people and land of New Zealand vs meddling and creating a super world or race, or as some like to put it, "playing God."

People used to talk about the urban-rural divide. However, the real divide is between politicians, scientists, and the public. The lack of engagement and communication within each community is causing individuals with like concerns and beliefs to join and form other communities, which does not allow for any practical or sensible steps to be made.

The gene technology discussion needs to take a fresh collaborative approach. Communication and clarity to the public about the different technologies is the biggest hand brake on this discussion moving forward in the agricultural industry. New Zealand has a raft of goals that are needing to be met environmentally, socially, and economically and reality is we are lacking in tools to help us on all fronts. There is a risk we are already falling behind the rest of the world, why would New Zealand a leading agricultural nation want to restrict itself from any technological advancements? Genetic technologies will be no silver bullet for any of New Zealand's challenges but could be one of the most controversially exciting and innovative tools in the toolbox going forward.

8.0 Recommendations

From my research I have compiled 4 main recommendations which will address the most basic of issues related to new genetic technologies and their potential introduction into New Zealand. These recommendations will allow better input from the general New Zealander as well as a greater understanding.

Collaboration of industry bodies within the pastoral sector to;

- *re define* the pathway of the pastoral sector and how it could look with and without new biotechnologies such a Genetic editing or Genetic modification. The stance of the collaborative response will be communicated to the wider industry followed by consultation then to the wider public.

- *re define* what 'clean green' image means to New Zealand. How do we link our cultural aspirations with the reality of economics in the pastoral sector? '

Commitment to Engage with New Zealanders about genetic technologies through the re-establishment of a bioethics committee. The non-political committee will have a multitude of respected and knowledgeable professionals from agricultural, biotech, science, communication, environment as well as social and cultural organisations.

This groups main responsibility will be to engage with their wider communities about their opinions, thoughts, and concerns. This will be at the forefront of the committee's priorities.

Approving specific acronyms and definitions for the biotechnology sector worldwide. Scientists use many technical and non-technical acronyms throughout their work however the use of these outside of the industry is contributing to the fragmentation of trust in science. An approved list of acronyms with their responding definitions to be implemented under a protocol such as the Cartagena protocol to ensure correct depiction and understanding of biotechnologies by the public.

The approved language is then to be enforced by individual governments across industries to ensure miscommunication is minimised.

Regulating a technology not by the final product or outcome. Define the technologies by assessing the risk the outcome or product has to the pastoral industry across all areas.

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