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RURAL LEADERSHIP PROGRAMME

Genetic Technologies & the Effect on New Zealand's Dairy Farmers

Kellogg Rural Leadership Programme

Course 50 2023

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I wish to thank the Kellogg Rural Leadership Programme Investing Partners for their continued support.

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Executive Summary

New Zealand's dairy industry is strategically important to New Zealand. Dairy generates $25.7b in exports, or 1 in every 4 dollars which has grown by $7.9b since 2019. It is a cornerstone employer in many regions, with 55,000 employees' nationally, considerable wage growth, and is a top 10 purchaser across dozens of industries. (Stats NZ – Sense Partners 2023).

Despite dairy farming's economic importance, New Zealand has strict controls regarding the use and development of genetic technologies that are readily available around the globe, which could further advance the industry.

The aims of this report are to:

- Outline the potential opportunities for genetic technologies for New Zealand's Dairy Farmers.
- Understand the potential risks or threats of genetic technology use in New Zealand.
- Help to inform dairy farmers on genetic technologies.

The methodology for this report was the joint analysis method. This included conducting a literature review and semi structured interviews to build knowledge on genetic technologies and what implications those could have on the end user – the farmer.

Genetic technology is a broad topic, covering transgenesis or genetic modification, as well as new breeding technologies which is targeted gene editing using site directed nucleases resulting in gene deletion, modification, or gene insertion. Application of these technologies are broad; however, this report serves to focus on plants for animal feed such as grasses, legumes, and brassicas.

The findings from the literature review and semi structured interviews identified the following recommendations that could help farmers improve across the board, including increased output and productivity, improved environmental outcomes, animal wellbeing and financial benefits.

- New Zealand needs a science based, consistent approach to regulating genetic technologies. This will need to evolve as the science develops and evolves.

- Risks need to be balanced against benefits and ensure adequate testing is undertaken before commercial use. This should include flow on effects and animal health monitoring for plant breeding.

- The right plant breeding programs need to be prioritised first.

- Incremental gains are powerful in the long run, but New Zealand needs to adopt genetic technologies now.

Due to the economic value of the dairy industry, if farmers prosper there can be an expectation that regional economies will be positively affected, median wages for dairy workers will rise, and local input purchasing will rise with this.

Acknowledgments

I would like to thank the New Zealand Rural Leadership Trust, for the opportunity & encouragement to complete the Kellogg Rural Leaders Programme. I came into the programme looking to improve my leadership skills and came out with a vastly improved network of passionate people about the Food and Fibre sector.

I would like to acknowledge my employer, Armer Group, for putting me through the programme and being patient with the commitments of this course.

To the speakers and my interviewees, thank you for your time spent on the course and my project.

To my wife Rebekah, thank you for your support and looking after our family while I was away and working on my project. I hope to return the favour one day.

Finally, Cohort 50, an incredible bunch of people that I have learned a lot from and look forward to staying in touch with.

1.0 Introduction

New Zealand's dairy industry is internationally recognised for its low cost pasture based farming system, large scale processing, innovations in new product development and farm production technology. The New Zealand dairy industry is integral to the country's economy and is world renowned for pioneering large scale dairy processing and production techniques. These have allowed it to take advantage of its abundance of quality farm land and pasture fed cows, to export high quality dairy products around the world.

Dairy products were New Zealand's largest export good in the year ended April 2023, accounting for approximately 35.3% of total goods exports and valued at NZ$25.7 billion (Sense Partners, 2023).

The New Zealand dairy industry upholds a reputation for premium quality, safe products, complying with rigorous industry health and safety standards.

New Zealand is the largest dairy exporter in the world, exporting approximately 90% of all its products by value and consequently accounting for approximately 35% of global dairy exports. (Sense Partners, 2023).

Dairy's growth has exceeded expectations. In 2020, the Ministry for Primary Industries published the 'Fit for A Better World Roadmap'. The report set a goal for dairy export revenues to reach $23.1 billion by 2030. The sector's 2023 export result of $25.7 billion bettered the 2030 target by $2.6 billion. In fact, the industry has enjoyed continual volume growth for a considerable period, sustaining a compounding annual growth rate of 5.5% from 1990 through to 2018. (Cameron Partners, 2019).

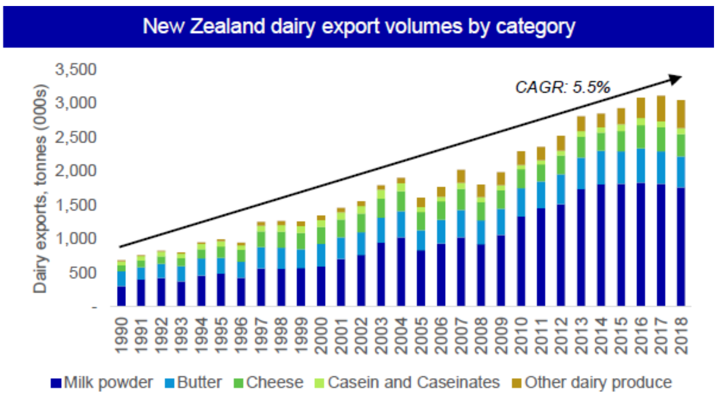


Figure 1: New Zealand export volumes by category. Cameron Partners Report 2019

Despite the importance of the dairy industry, there are genetic technologies driving productivity and environmental improvements around the globe that are heavily regulated in New Zealand, effectively completely restricting the potential advancements they could yield.

Genetic technologies encompass a broad range of methods and tools used to study, manipulate, and understand genetic information. These technologies allow scientists to explore the structure, function, and behaviour of genes, as well as their roles in various biological processes.

While this is a very broad topic, this report looks to focus in mainly on genetic editing and genetic modification. Technique's such as CRISPR-Cas9, which allows precise modification of DNA sequences within the genome of living organisms; and manipulation of an organism's genetic material using biotechnology to achieve specific traits or characteristics. This includes the insertion, deletion, or modification of genes.

Genetic technologies have seen the fastest adoption of any new agricultural technology. In 1996 global biotech crop area was less than 2 million ha, five years later it was 50 million ha. Ten years after introduction, biotech crops were being grown on more than 100 million ha. By 2016 global biotech crop area was 185 million ha. (ISAA Brief No 52, 2016). To put that in perspective, an area approximately 7 times the total area of New Zealand is cropped using genetically edited or modified crops, annually.

New Zealand stands out as one of the few countries that has gene edited plant or crop species fully regulated as genetically modified organism's (GMO's). For a country that is heavily reliant on export earnings from the agriculture sector, it is a firm stance.

Perennial rye grass is the most dominant pasture species grown in New Zealand due to its easy establishment and persistence under New Zealand's range of climatic conditions (Hunt & Easton ,1989). However, rye grasses, clovers, legumes, and brassicas are all under more pressure now, than ever before. The strong climatic variations alongside regulations restricting the use of herbicides, pesticides and fertilisers means the dairy sector is becoming more challenging.

50,000 hectares, or more	
1. USA	72.9 million
2. *Brazil**	49.1 million
3. *Argentina**	23.8 million
4. Canada	11.6 million
5. *India**	10.8 million
6. *Paraguay**	3.6 million
7. *Pakistan**	2.9 million
8. *China**	2.8 million
9. *South Africa**	2.7 million
10. *Uruguay**	1.3 million
11. *Bolivia**	1.2 million
12. Australia	0.9 million
13. *Philippines**	0.8 million
14. *Myanmar**	0.3 million
15. Spain	0.1 million
16. *Sudan**	0.1 million
17. *Mexico**	0.1 million
18. *Colombia**	0.1 million
Less than 50,000 hectares	
*Vietnam**	*Bangladesh**
*Honduras**	*Costa Rica**
*Chile**	Slovakia
Portugal	Czech Republic

Figure 2: Global status of Biotech/GM crops: 2016 ISAA Brief No 52

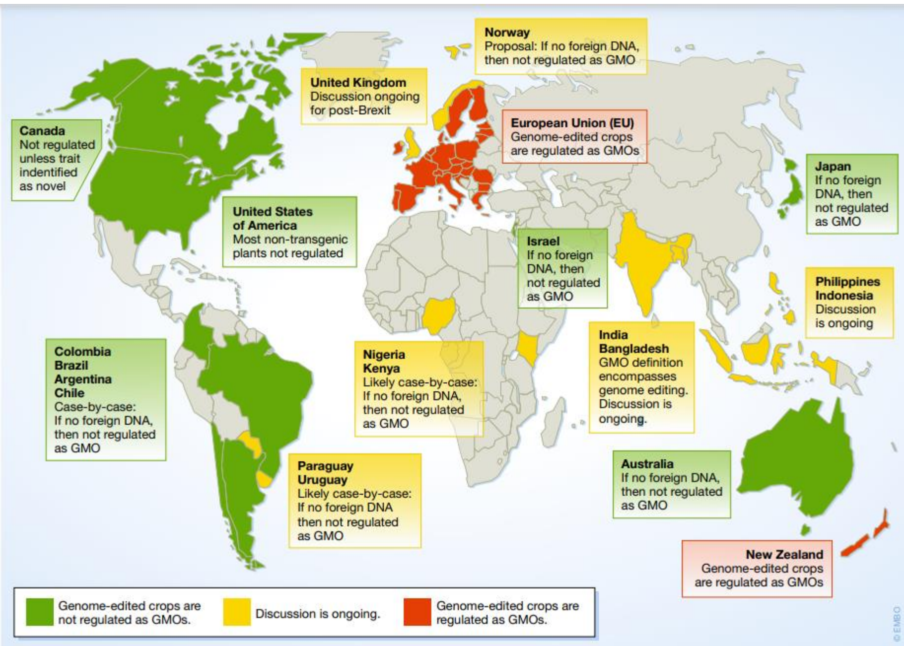


Figure 3: Current state of genome-editing legislation. Schmidt et al. 2020

2.0 Aims and Objectives

This report aims to understand the opportunities and risks, based on the scientific evidence on genetic technologies, and analyse how that could impact New Zealand dairy farmers.

The objectives of this report are to:

- Outline the potential opportunities for genetic technologies for New Zealand's dairy farmers.
- Understand the potential risks or threats of genetic technology use in New Zealand.
- Help to inform dairy farmers on genetic technologies.

The output of this research will provide insights into opportunities, risks and threats that genetic technologies could deliver and how they could affect New Zealand dairy farmers and regional economies. Looking through the lens of genetically edited organisms for animal feed, it will go into relevant broader topics to establish effects environmentally, socially, perceptions and trade. Importantly, this can be a useful guide for dairy farmers to understand what could be achieved if regulations were changed in New Zealand.

3.0 Methodology

The overall approach to this report was based on the joint analysis method. By conducting a literature review and semi-structured interviews to pull together the relevant information for this report.

Literature Review:
A review was undertaken to understand genetic technologies in the broader context of what they are and what they can or could potentially do. The aim was to understand the technologies and to be able to assess what impacts they could have on New Zealand dairy farmers if there was regulation change in New Zealand allowing them. Analysis was also required to be done on the New Zealand dairy industries value to regional economies and nationally to then be able to apply the knowledge gained back to the sector.

Semi Structured Interviews:
Semi structured interviews were conducted with nine individuals. Five of those were scientists and four were farmers. The aims of the questions were to establish:

- Views on New Zealand's current stance on genetic technologies.
- What risks, threats, or barriers there are for genetic technologies and how they could be managed.
- Whether there were trade-offs to consider for consumer's purchasing genetically edited foods.
- What economic benefits there could be to the farmer, and the economy, both regionally and nationally.

Key findings were then summarised by pulling together the information from the literature review and the semi structured interviews to come up with a conclusion and recommendation.

4.0 Limitations/Constraints

Several limitations were encountered throughout the process and therefore need to be considered:

- Genetic Technologies are constantly evolving: It is difficult to quantify potential benefits of something today that is on a pathway for continuous improvement and development.
- Genetically modified grasses: There is limited evidence of commercially grown grass species that have been genetically edited. Most of it has been done for crops as New Zealand (and Ireland) stand out with majority of animal feed being pasture based.
- Interviewees: Interviews were split between scientists and farmers. All of whom were already pro genetic technologies. None of those interviewed had strong ethical or cultural views on the matter, whereas if the net was cast wider then a more diverse set of views would have come through.
- Interviewees: Due to the technical nature of genetic technologies, the farmers interviewed knowledge base was considerably less than the scientists. This was to be expected, however their ability for practical thinking for cause and effect was demonstrable.
- Time Constraints: The topic is broad, with far reaching applications. Even narrowed down into the subparts this report focuses was challenging to truly cover the material.

5.0 Literature Review

5.1 Dairy Industry Overview:

The New Zealand dairy industry contributed $25.7 billion in export revenue for the year to April 23, more than meat, wood, fruit, wine and seafood combined (Sense Partners, 2023). It has seen considerable growth in exports, lifting by $7.9b from 2019-2023.

Figure 4: New Zealand Export Revenue for year ending April 2023. Stats NZ, Sense Partners 2023

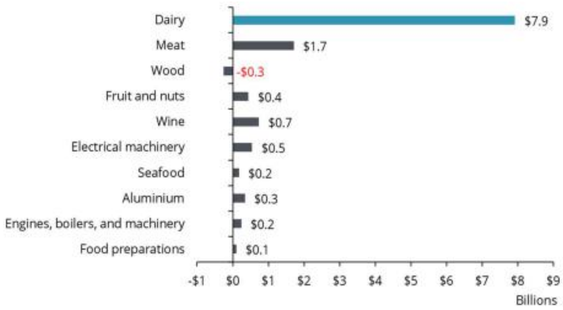


Figure 5: New Zealand Export Revenue Growth 2019-2023. Stats NZ, Sense Partners

As the sector has grown in value for export receipts, we have seen wage growth throughout the sector. The dairy sector paid $3.6 billion in wages across New Zealand in the year to March 2023. Of this, $1.4 billion came from dairy farming, up 20% since 2019. The remainder, $2.2 billion, came from processing, up 24% since 2019.

Dairy farming's median wage has now caught up to be the same median wage as the median for all sectors. The higher wage growth has amplified the importance of the sector in regional economies.

Over the past few years, job growth has declined on dairy farms. However, this is as much of an availability issue as opposed to a genuine decline. Federated Farmers have run an employment survey in the dairy farming sector with challenges in attracting and retaining employees being a key theme in the results. High labour costs mean that employers face tough choices between employing sufficient staff, at high cost, and paying themselves well. Over half of respondents were paying themselves less than staff, with 11% not paying themselves at all (Sense Partners, 2023).

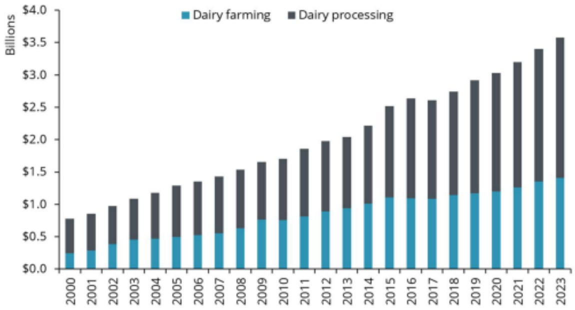


Figure 5: New Zealand dairy Sector wage growth. Stats NZ, Sense Partners 2023

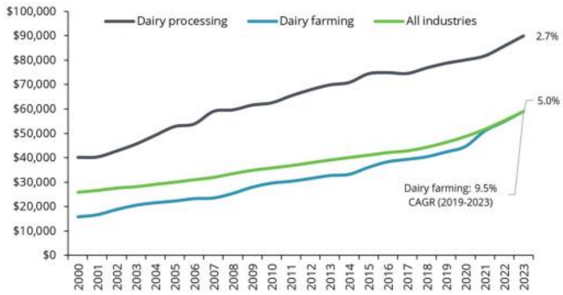


Figure 5: New Zealand dairy sector median wage growth. Stats NZ, Sense Partners 2023

Not only for direct employment, as a land-based activity, the sector is naturally spread out over the country. By contrast, sectors like manufacturing and services tend to be concentrated in larger cities. This means the dairy industry makes an important contribution to spreading economic activity across regional New Zealand. Dairy plays a prominent role in regions like Southland, where it represents 13.8% of regional GDP. The West Coast (14.4%) and Taranaki (12.0%) have similarly high shares of economic activity coming from the dairy sector. Even in regions with high GDP from other activities, dairy continues to play a prominent role. Of Waikato's GDP of $31.8bn, 9.3% came directly from dairy, while Canterbury drew 4.6% of its $42.4bn GDP from the sector.

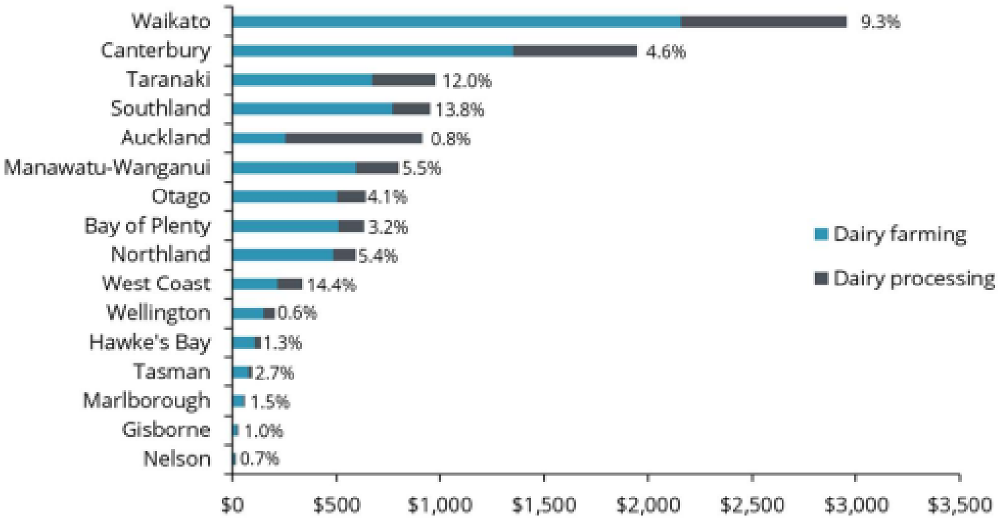


Figure 6: New Zealand dairy sector related GDP by region. Stats NZ, Sense Partners 2023

Finally, dairy also supports several New Zealand's other industries. Dairy farmers spent just over $15.7b on inputs in the year to March 2023, while the dairy processing sector purchased $5b beyond the farm gate. Dairy farming is a top 10 purchaser in 35 industries, while dairy processing is a top 10 purchaser in 25 different industries.

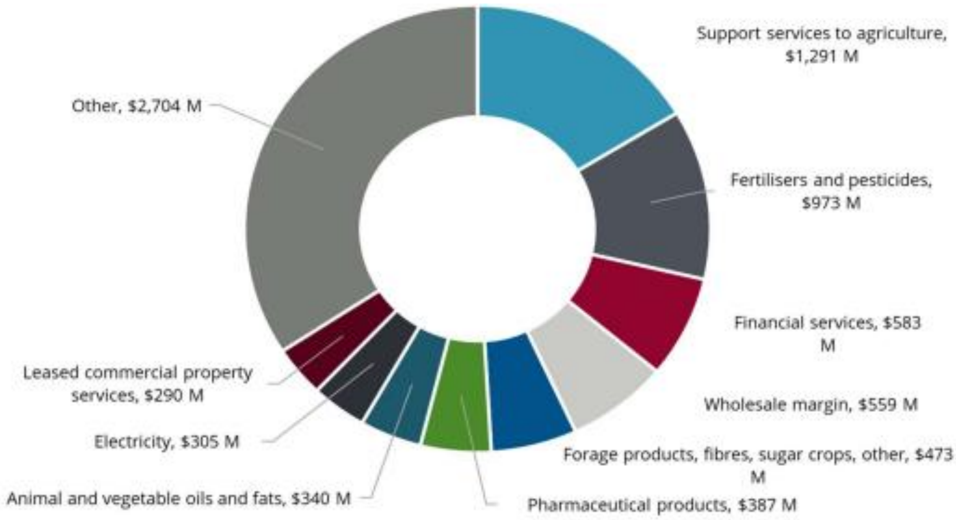


Figure 7: Dairy farming input purchasing by sector, year ending 2023. Stats NZ, Sense Partners 2023

5.2 Genetic Technology - History and Background:

Selective Breeding has been used by humans for 10,000 years by modifying or enhancing desirable traits and removing or reducing undesirable traits, through the selection of breeding pairs. Some examples of this are outcrossing, linebreeding and inbreeding.

This process has been used widely over plants and livestock, even pets. Well known examples of this are:

- The use of the wild mustard plant to create vegetables we know today such as, Brussel sprouts, cabbage, broccoli, cauliflower and kale.
- Livestock being bred from the best animals to improve milk production, udder shape, reproductive performance, calving ease for example.
- Wild wolves have also gone through the same process, which has created the variety of dogs we have today.

Mutagenesis:

Mutagenesis is a process by which an organism's DNA is altered by an induced mutation through chromosomes being broken apart.

Mutations are the primary source of all genetic variations in any organism, including humans. It is a natural process which occurs spontaneously and slowly – over generations – in people, plants, animals, and all other living beings. The natural process is driven by mistakes in the replication of DNA in cell division, through things such as radiation from the sun and infections by viruses.

In the 1920s, researchers figured out how to induce mutagenesis via chemicals and radiation, which breaks apart DNA, causing changes to the genome that result in random mutations.

Importantly, random mutagenesis does not offer much control over which DNA base is being changed or how it is changed.

New Breeding Techniques:
In the 1970's New Breeding Technique's (NBT's) were developed which allowed scientists to target specific traits within an organism which allowed changes to be made more quickly and precisely. There are three different main types of NBT's, known as genetic modifications (GM), that are currently used. Cisgenics, Transgenics and Intragenics.

Cisgenesis describes a process where DNA from the same, or a closely related species, is inserted into the organism's genetic information without changing the inserted DNA sequence or arrangement.

Transgenesis describes the process of introducing a transgene, or foreign gene, from a different species with the aim of the resulting organism exhibiting some new characteristic that could not be achieved through selective breeding due to a reproductive barrier.

Intragenesis is similar to cisgenesis, except the DNA to be inserted is changed from its original form, often to include additional pieces of DNA from the same or a closely related species, and/or rearranged in some way before being inserted in the genome.

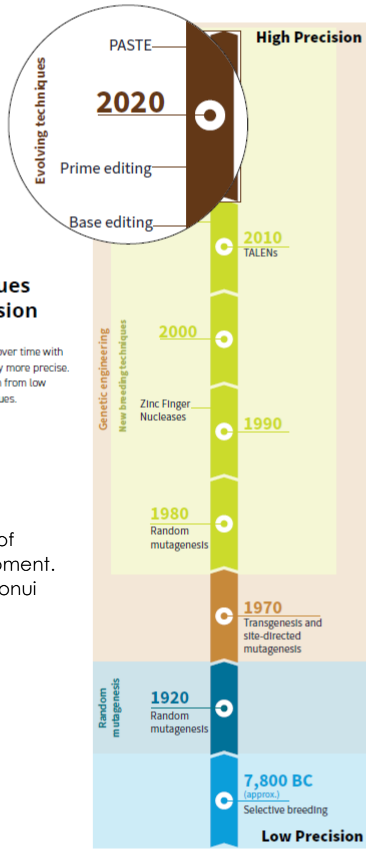


Figure 8: Timeline of breeding development. Te Puna Whakaaronui 2023

Transfer of a gene (cisgenesis) or combination of genes (intragenesis) between organisms of the same species, or from a cross-compatible species, is different from transgenesis in that it uses no foreign DNA. Cisgenesis may lead to a new organism that is indistinguishable from its wild relative and could feasibly be produced via selective breeding, intragenesis, on the other hand, may produce an organism that is not obtainable by selective breeding alone. (Te Puna Whakaaronui, 2023).

Genetic Editing (GE):
Refers to using directed nuclease technologies to modify DNA at one or more specific sites.

Site Directed Nucleases:
The site-directed nucleases (SDN) are a suite of techniques for modern site-directed mutagenesis that have been created since the 1990s.
This sub-group includes:
- Zinc-Finger Nucleases (ZFNs);
- Transcription Activator-Like Effector Nucleases (TALENs);
- Clustered Regularly Interspaced Short Palindromic Repeats CRISPR-associated protein 9 (CRISPR-Cas9); and, evolving technologies using elements of the CRISPR-Cas system.

These techniques are all artificially generated but are based on naturally occurring components, such as proteins occurring in animals, plants, fungi and algae. They represent advances in targeting that improves significantly through ZFN and TALENs, and then by an even larger increment with CRISPR (Te Puna Whakaaronui, 2023).

5.3 How do SDN's work?
Each SDN is used to create a double-stranded break (DSB) at a targeted site that is responsible for a particular characteristic. Three results are possible:

- The break is repaired by the host organism without further intervention. This can result in mutations that change the function of the gene, normally disabling it.
- A DNA template is provided to convert the gene to another version from the same or a different species.
- A DNA template is provided, and a new (trans)gene is inserted at the DSB site.

SDNs make it possible to modify a range of agriculturally important plants and animals relatively easily and cheaply, and without permanently introducing foreign DNA sequences.

5.4 What can these genetic technologies do?

ZFNs, TALENs, and CRISPR-Cas9 have been used to achieve similar goals in both plants and animals: productivity, resilience, lower inputs, and lower greenhouse gas emissions. A key feature of these techniques is their ability to produce new organisms at speed, meaning commercialisation can be completed in a relatively short time.

A literature review of two hundred and thirty-one studies by Menz et al. (2020) found that globally, between 1996 to 2020, 41 plants for commercial purposes were developed using ZFNs, TALENS and CRISPR-Cas9 and, 140 different applications of the techniques were identified; most for soil management and crop production purposes as well as food and feed quality, and organism stress tolerance (Te Puna Whakaaronui, 2023).

Specific SDN applications include:

ZFN has been used to genetically modify kale, cress, tobacco, maize, petunia, soybean, rapeseed, rice, apple, and fig. Some applications of the technique include the development of:

- Herbicide tolerant maize). This maize cultivar also reduces the amount of phytate which naturally accumulates in the plant. Phytate is a component of seeds which impairs the absorption of iron, zinc, and calcium in humans; and
- Transgenic cows which produce milk containing lysostaphin, which helps relieve mastitis. Due to different laws and regulations affecting GMO, these animals are only commercially available in a few regions.

TALENs has been applied across a variety of crops, for example, to create:

- Blight resistant rice – a bacterial disease that causes yield loss, in some cases up to 70% losses in environments favourable to the disease (the earlier the disease occurs, the higher the yield loss).
- Powdery mildew resistant wheat – a fungal infection that impact the health of plants and reduces their yields.
- Improved nutritional profile and shelf-life of crops (soybeans, tomatoes, and potatoes); and,
- Disease resistance in pigs (African Swine Fever) and cattle (*Mycoplasma bovis*).

CRISPR-Cas9 has become the most common tool for crop improvement due to its versatility. Some examples of CRISPR-Cas-9 uses are:

- Crop quality improvement: physical appearance, edible quality, shelf-life, fruit texture and nutritional value of key crops such as tomato, rice, wheat, and soybean.
- Development of nutrient-enriched fruit and vegetables such as: increased carotenoid content in banana, rice, and tomatoes.
- Increased y-Aminobutryic acid content in tomatoes and rice.
- Increased micronutrients such as selenium, zinc, iron, and iodine in rice.
- Improved fatty acid composition in soybean, rapeseed and camelina; and
- Reduced concentration of unwanted substances in rapeseed (phytic acid), wheat (gluten proteins), and rice (cadmium).

Globally, research activities employing genetic technology are continuing to increase, raising the number of plants, animals and micro-organisms created by genetic engineering to meet market and environmental demands (examples given from - Te Puna Whakaaronui, 2023).

5.5 Other risks or threats?

There is an interesting distinction when it comes to consumers and consumer behaviours due to the limited range of products the end consumer sees and get to choose from. Retail buyers, particularly from big conglomerates, essentially act as gatekeepers regarding product availability and the range for consumers to choose from.

Gate Keeper:

From the many numbers of new products presented to retail grocery buyers every year, only a small sub-set make it into stores due to limited shelf space. Consumers are therefore only able to choose from this very reduced set of manufacturer products (Hansen and Skytte, 1998; Heslop et al., 2004; Sullivan, 1997).

Furthermore, in regard to imported products, there are other layers of industrial buyers who play a gatekeeper role. Among these are importers and wholesale distributors, manufacturers of value-added products based on imported raw ingredients, and suppliers to the food service sector. The role that all these "shapers" of the marketplace play can be easily overlooked (Heslop et al., 2004), but the reality is that they greatly influence the range of options open to consumer buyers and patrons of hotels, restaurants, and other food service outlets.

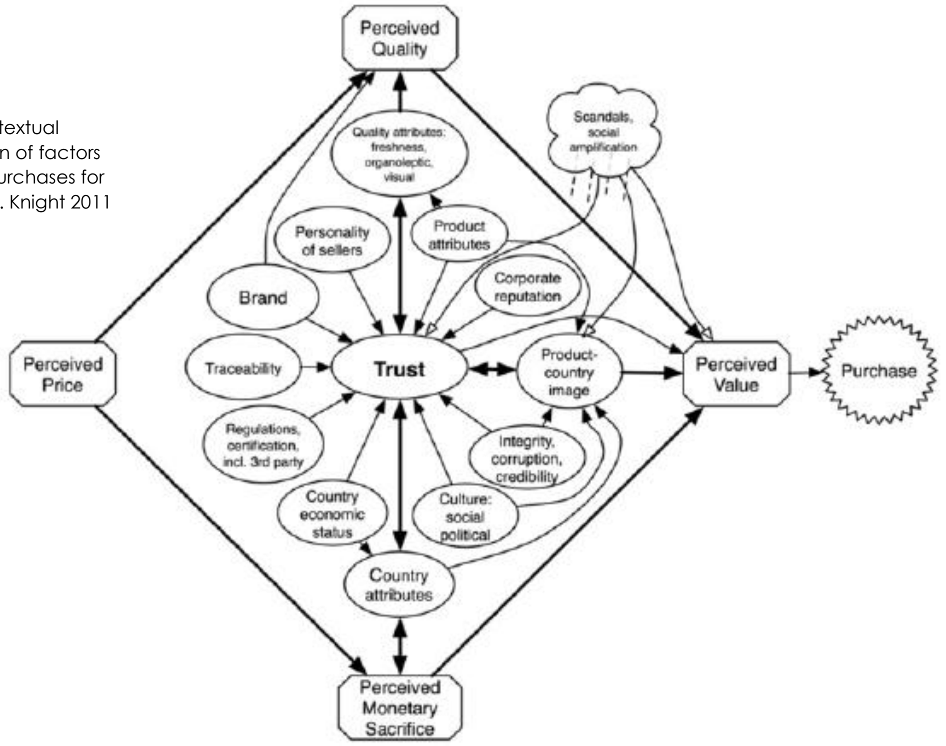
Interestingly, in 2002 there was a study conducted on some European 'gate keepers', otherwise known as retail buyers, who were overwhelmingly negative about GM pasture plants being used for animal meat and milk production. The view was clear, they would not buy the product. However, the interviewees did not appear to be aware that the European Union was already importing and/or growing GM soybeans for animal feed and had no system for separating GM varieties from non-GM varieties. (Knight et al).

Studies of gatekeepers in Germany, Italy, Greece, the Netherlands, the UK, China and India revealed no evidence that presence of GM crops in a country causes negative perceptions in general of food from that country (Knight, Mather and Holdsworth, 2005; Knight and Gao, 2009; Knight and Paradkar, 2008).

This issue was carefully explored in relation to perceptions of food products sourced from Spain, from the USA, from Argentina, and from Australia – all countries that had highly favourable reputations as suppliers of high-quality food products, and all of which were producers of GM crops. Even respondents who were themselves negatively disposed towards GM food could see no connection between food they were importing from a given country and whether there were GM crops grown in that country or not (Knight, Mather and Holdsworth, 2005b).

The below model shows a representation of the factors that go into purchasing decisions. Genetic technologies only influence, price, quality, quality attributes & product attributes. Where the model indicates there is a considerable amount more that influence a 'gate keeper'.

Figure 8: Contextual representation of factors influencing purchases for gate keepers. Knight 2011



Consumer:
Consumer sentiment on a product is complex and multi-layered.

Country Image:
Images that consumers have of particular countries have been widely regarded as having a major impact on consumer evaluations of products sourced from those countries and, by implication, on propensity to purchase products originating from those countries (Papadopoulos and Heslop, 2002).

The inference has been drawn that views of a country and its people influence consumer purchase behaviour through both cognitive (analytical) and affect-based (emotional) mechanisms (Laroche et al., 2005). Heslop and colleagues (2008) have proposed a model to explain the presumed impact of country image on consumer purchasing behaviour based on several inter-relationships including:

- Country-based beliefs affecting product evaluations (e.g. "French wines are high quality")
- Production-related beliefs about the capabilities or competence of the country and its people in producing desirable products (e.g. "Japan makes well-engineered reliable cars")
- Non-production-related qualities or character of a country and its people – what might be considered as the "personality" of a country (e.g. "Dutch business people are honest, reliable, likeable but highly price-conscious")
- Overall evaluations of the country-people composite (e.g. "Australia is un-crowded and sunny, the Australians are open, friendly, but keen on winning at all costs; and Australian goods are value-for-money, and generally of reasonable quality.") (Note: the stereotypic examples are added for clarification by John Knight (Knight 2011); they are not from Heslop et al).

What consumers say vs what consumers do:
One challenge that appears evident when surveys are conducted is that consumer responses to survey questions don't necessarily equate to what a consumers actual purchasing behaviours are. Willingness-to-pay research needs to be tempered by the large body of literature indicating that willingness-to-pay is overstated in hypothetical valuation questions as compared to when actual payment is required (Lusk, 2003). A European Commission study titled "Do European Consumers Buy GM Foods?" perceived a unique opportunity to conduct a fact-based survey on the sales of GM-labelled foodstuffs as they became available for the first time in ten Member States. Rather than concentrating on what consumers said they might do with respect to buying GM-foods, the study has explored as far as possible what in fact they did do in those countries where such foods were on sale – the report concluded that yes, Europeans do buy GM foods when given the opportunity (European Commission, 2008).

John Knights research (Knight et al 2007) using fruit stalls to get the stated preference vs the real (revealed) preference of consumers comes to a similar conclusion – that consumer purchasing behaviours differ between actual behaviours and what a consumer will say or potentially believe.

The results of the revealed preference and stated preference measurements were very different – there was a much lower stated willingness to buy the GM option than the revealed willingness that was apparent when people were making real choices, with their own money at risk.

		% Market Shares		
Price level		Organic "Biogrow" certified	Ordinary Low residue	Spray-free Genetically Modified
New Zealand:				
15% premium for organic,	RP	20	20	60
15% discount for spray-free GM	SP	38	32	30
Sweden:				
15% premium for organic,	RP	20	38	43
15% discount for spray-free GM	SP	39	30	31
Germany:				
15% premium for organic,	RP	33	31	36
15% discount for spray-free GM	SP	28	59	12

Table 1: *Comparison of revealed preference (RP) and stated preference (SP) market share simulation estimates with the scenario where organic is priced at a premium and a discount is offered for the GM option, in three countries. Knight, 2011*

Several researchers have estimated consumer willingness to pay for either GM or GM-free food in different countries. James and Burton (2003) conducted a choice modelling mail-out survey in Australia and concluded: "The results of the present study show that most consumers will require some form of discount if they are to purchase GM foods although the size of this discount would depend to some extent on any effects (e.g., chemical, environmental) of the new technology and on the age and sex of the consumers themselves."

Trade:
Typical rhetoric heard within New Zealand, are that GM or GE organisms being allowed to be used in New Zealand will harm the 'clean green' image of the country, and therefore do irreparable harm to our export markets for food products. It is further quoted by former Minister

of Agriculture Damian O'Connor "New Zealand does have an advantage in the marketplace being GMO free, so those who are selling our products have to weigh up what the introduction of genetic engineering in whatever form may mean to their marketing opportunities".

John Knight from the University of Otago completed a paper (Knight et al, 2011) reviewing multiple streams of evidence to enable policy makers within government to make an informed decision on potential regulatory change. The report concludes that it is highly unlikely that the introduction of GM pastures into New Zealand would have any long-term deleterious effect on perceptions in overseas markets. The report focused on Cisgenics, rather than transgenics and particularly on Europe given the Unions historic stance on GM regulation. There is evidence the great majority of animal derived food products in Europe are derived from animals raised on GM feed, as are the animals farmed within the EU itself. The EU has been importing large quantities of GM feed for many years, and growing GM maize since 1998. No system exists for keeping this GM feed separate from the rest of the animal feed supply of Europe.

The report also concludes that it is highly unlikely that New Zealand's image as a tourist destination would suffer if GM pasture was introduced. The surveys conducted at Auckland International Airport (515 first time visitors) provide unambiguous results, showing that introduction/presence of controversial technology (nuclear power, GMOs, factory farming) in a country that tourists themselves consider "most similar" to New Zealand has essentially no effect on intentions to visit that country in future. Furthermore, the prospect of potential introduction of any of these technologies into New Zealand has no significant effect on tourist ratings of their intentions to visit New Zealand in future.

Further evidence from Anderson et al, 2019 in her report on the South Australian GM Food Crop Moratorium. There has been a moratorium on GM crop production in and transportation of GM crop products through South Australia since 2003. The key objective of the moratorium following the approval in 2003 by Commonwealth authorities of commercial production of GM canola in Australia, has been to provide time to assess the risks that GM food crops might impose, in terms of access to markets and trade, for the state's conventional and organic growers and consumers/users of non-GM crop varieties.

In the fifteen years that have elapsed since the moratorium was first imposed, the policy has been re-considered and renewed three times (in 2008, 2014 and 2017). As currently legislated, the moratorium is to apply through to 2025. Meanwhile, all other mainland states have allowed their farmers to grow GM crops, most recently Western Australia in 2009.

Anderson's findings were that any price premium received for non-GM crops did not make up for the improved yield of the GM crops on a gross revenue basis. It was also noted that the findings ignored other benefits such as reduced weed control costs and easier establishment and yield of the following seasons crops.

What about our major trading partners?

New Zealand's top trading partners are China, Australia, the USA and Japan who collectively take 58% of New Zealand's exports (World Bank 2019). China, New Zealand's largest trading partner imports about $17 billion of goods, namely dairy, meat, wood and preparations cereals, flour, and starch (Ministry of Foreign Affairs and Trade [MFAT] 2022). In 2021, China imported 44% of dairy, 90% of logs and 41% of meat exported by New Zealand (Xinhua 2021). China is also Australia's major export market (Department of Foreign Affairs and Trade 2021) despite Australia permitting under regulation the production of some GM crops (Ishii and Araki 2017). While primarily these exports are ores and minerals (Trading Economics 2022), China is still a top market for Australian exports of meat, wine, wool, fruit and nuts, seafood, grains and dairy (Department of Foreign Affairs and Trade 2021),(Caradus, 2022).

China itself has the sixth highest area under commercial cultivation of GM crops among 28 countries known to grow GM crops (Ishii and Araki 2017). Additionally, China is the largest importer of soybean (97 million MT – over 6 times greater than the next highest importer the European Union) (Shahbandeh 2022) most of which will come from the USA and South America where soybean crops are largely GM varieties. In 2007, the Australian Department of Agriculture, Fisheries and Forestry (DAFF) declared that 'marketers of GM canola and of products from livestock fed on GM materials, including GM canola, are unlikely to be disadvantaged in the Australian and world markets' (DAFF 2007) (Caradus, 2022).

5.6 New Zealand's stance on GE/GM and how it compares globally:

Creation of new organisms in New Zealand is currently allowed using traditional techniques such as selective breeding, and random mutagenesis using chemical and radiative methods. The use of newer site directed genetic technologies is technically allowed but heavily regulated.

Organisms developed using new and more precise technologies such as site directed nucleases receive the same level of scrutiny as earlier GM techniques. This may result in organisms being regulated at a level that is not proportionate to the risk they pose and New Zealand missing out on the benefits they could provide. Anecdotal evidence suggests the high level of regulation is discouraging potential applicants from applying to the Environmental Protection Authority (EPA) for field trials in containment, or a release of a GMO, as the perception is, they are unlikely to be successful or it will take too much time, effort, and financial backing (Ministry for the Environment, 2018, Te Puna Whakaaronui, 2023). This was further noted by all 5 interview participants from the scientific community who all felt that the "regulation may as well be a total ban, as it was so prescriptive it was almost impossible to comply with". This led to more trial work being done overseas, instead of New Zealand.

While the breeding and release of new organisms is highly regulated, genetically modified food is allowed to be imported into New Zealand and sold once it has been approved by Food Safety Australia New Zealand (FSANZ). Once a GM crop has been approved by FSANZ, any ingredient made from that crop can be sold in New Zealand. (Food Standards Australia New Zealand, 2021). FSANZ does not consider that genetically modified crops carry any additional risk compared to conventional crops due to their genetic modification. (Food Standards Australia New Zealand, 2021). There presently are already several GM foods listed on the FSANZ website, all of them processed foods.

The rapid advancement of genetic technology over the last thirty years has prompted many nations to re-assess their GMO regulations head-on. We have seen how governments in the UK and EU are proactively considering existing regulatory regimes to bring them up to date. Both are proposing alternative settings to better balance perceived risks and benefits of modern gene editing techniques, and to improve the effectiveness and efficiency of implementation in achieving broader objectives. Whereas for example in most of the America's, unless there are novel traits/foreign traits then it is likely not regulated as a GMO.

	USA	Brazil	Canada	China	Singapore	Argentina	Australia	India	Chile	Japan	EU	UK	New Zealand
Process-based Regulations[1]									●	●	●	●	●
Trait-based Regulations[2]	●	●	●	●	●	●	●	●					
Hybrid approach[3]						●	●	●	●	●	○	○	

Notes:
1. Includes GMO products and those produced using GMOs in the process.
2. Regulates based on novel traits.
3. Transgenic GMOs regulated but products of NBTs exempt.

Key
Regulations in place ●
Regulations under consideration ○

Figure 9: International approaches to GMO regulation. Te Puna Whakaaronui, 2023

Over the last two decades New Zealand has, from time to time, also conducted formal reviews and investigations into how its own regulatory settings should be managed. There have been several studies, reviews, and critiques on New Zealand's GMO regulatory regime but the most in-depth and broad-based studies at a national level over the period are:

- The Royal Commission on Genetic Modification, *Report and Recommendations*, 2001;
- The Royal Society Te Apārangi, *Gene Editing in Aotearoa*, 2019;
- Prime Minister's Chief Science Advisor briefing on the Royal Society Te Apārangi gene editing report, 2019;
- The Productivity Commission, *New Zealand firms: Reaching for the frontier*, 2021; and
- Food Standards Australia and New Zealand, Proposal P1055 – *Definitions for gene technology and new breeding techniques,* 2021.

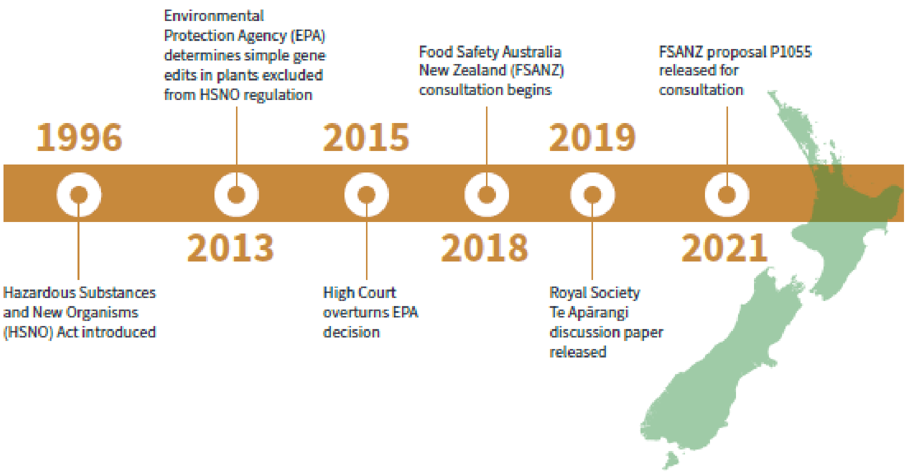


Figure 10: Gene Editing in New Zealand Te Puna Whakaaronui, 2023

Dr Hillary Sheppard, a senior lecturer for the school of biological sciences at the University of Auckland. commented 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."

However, to the dairy farmers interviewed, not a lot has changed over the years on the matter although it's noted the newly formed coalition government has put genetic technologies on the table for a discussion with the NZ public.

6.0 Analysis

As described in the methodology, semi structured interviews were conducted with famers and scientists to understand the possible effect of genetic technologies on New Zealand dairy farmers.
There was some challenge in this as the scientists interviewed then provided considerable studies for the writer to read which helped build the basis of this report. Unsurprisingly, the studies backed up the interviewees opinions which did shape the content of this report.

The below mind map using Miro was used break the interviewee's comments into subsections based on their views of genetic technologies.

- Regulation
- Trade
- Agriculture
- Consumer

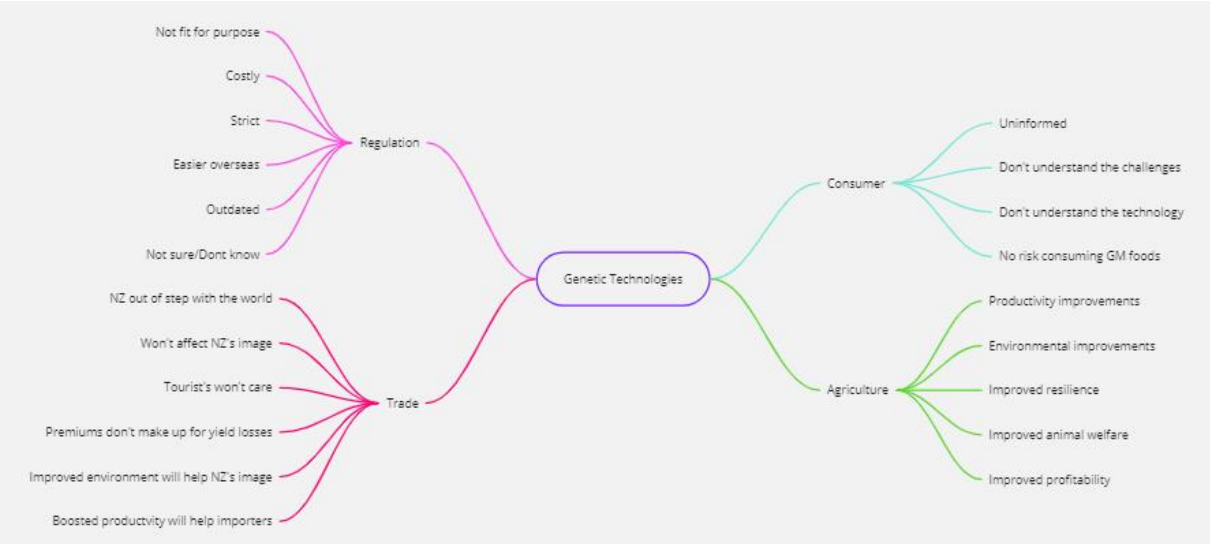


Figure 11: Mind map of interviewee's responses on genetic technologies for New Zealand dairy farmers

<u>Regulation:</u>
Most interviewed were strongly against New Zealand's stance on genetic technologies with nearly all saying it was out of step with the world and too difficult to work within the current regulatory framework.

- "New Zealand's largest crop is rye grass. We are choosing not to use the latest scientific tools to advance our largest industry".
- "Where are the politicians that will demand that NZ farmers deserve the best tools if they are to continue to provide the lion's share of our nation's income?"
- "It is too strict and too difficult to follow the regulatory pathway, it easier to do overseas".

Trade:
All interviewees did not believe trade would be negatively affected by adopting genetic technologies. Most struggled to understand why a tourist would care if GM plants were grown in New Zealand.

- "I've never researched whether a country grows GM crops before travelling there, why would tourists do that coming here."
- "It is the farmers that enable us to buy the flat screen TV's, computers, smart phones, petrol for our cars, and the cars, from overseas".

Consumer:
Most viewed consumers as both uninformed on genetic technologies and uninformed on how challenging farming can be to provide products for consumers.

- "There is no evidence that consuming products from animals that have eaten GM plants has any adverse health risks".
- "There is no human dietary risk".
- "All consumers care about is price and taste".
- "Consumers don't understand how tough it is on farm".
- "Both clover and ryegrass are fed to humans via the herbivore rumen. There is no risk."

Agriculture:
There was considerable enthusiasm for possible benefits of genetic technologies on agriculture with all agreeing it was a necessary next step for New Zealand.

- "If I could make it happen, I would modify our largest crop, ryegrass, so that it was resistant to the pasture pests that cost farmers way too much".
- "Clover root weevil has been decimating clover nitrogen fixation since its introduction in 1996 (the year that biotech cropping began). What do farmers do instead, buy purchased nitrogen".
- "New Zealand farmers grow 300,000 ha of forage brassicas. Weed control is difficult. Pest control is difficult. The biotech solutions are available off the shelf to breeders in USA, but not in New Zealand".

7.0 Findings and Discussion:

7.1 What application could Genetic Technologies have for New Zealand Dairy Farmers?

Opportunities from these technologies include greater farm productivity, better animal health and improved environmental results that may include reduced greenhouse gas emissions and less nitrogen loss that has the potential to contaminate waterways. Work is underway to understand the potential benefits of these technologies and to ensure that those benefits outweigh any potential risks.
While there are wide potential benefits to farmers in terms of livestock genetic improvement, control of pests, controlling wilding conifers this report aims to focus on feed grown for livestock purposes.
Some of the main and most exciting work being done by Agresearch presently cut to the immediate largest benefit options. Three key pieces of research being completed now are:

- Gene Edited Endophytes.
- High Metabolizable Energy Rye Grass
- High Condensed Tannin White Clover.

Gene Edited Endophytes:
The addition of selected fungi called Epichloë endophytes to ryegrass has saved New Zealand billions of dollars over the past 30 years (Agresearch, 2023), and now gene editing technology could provide even greater benefits through targeted changes to these endophytes.

To provide context, one non-edited commercialised endophyte alone, AR37, has been estimated to contribute $3.6 billion to the economy through the life of its patent (Agresearch, 2023).

These naturally occurring endophytes live inside ryegrass and form a mutually beneficial relationship with the grass. Natural substances released by the endophytes deter insect pests from eating the ryegrass and improve plant growth and persistence, which collectively results in a reduced need for chemical pesticides and increases efficiencies in milk and meat production. AR37 stands out as one of the rye grasses that has the strongest defences against the Argentine stem weevil, pasture mealy bug, black beetle, root aphid and Porina.
The challenge has always been that some endophytes that protect ryegrass against pests also produce toxins that can be harmful to the livestock which feed on the ryegrass, most commonly causing a disease called ryegrass staggers, which, if left untreated can be potentially fatal.

Over the past few decades scientists and the seed industries have successfully harnessed selected endophytes to add to ryegrass that have brought this benefit, but efforts have continued to identify other endophytes that may further maximise the benefits and minimise the negative effects. Agresearch, in an article written in 2018 also stated that farm pasture pests are costing dairy farmers alone $1.4b in loss productivity due to pasture damage and productivity losses (Agresearch, 2018).

Agresearch scientists have now identified targeted changes to the DNA of selected endophytes via gene editing, resulting in either greater plant protection or less harm to livestock.

Without intervention, the toxic effect of compounds from some endophytes for livestock is expected to worsen as a result of climate change (Agresearch, 2023).

Agresearch and its partners have launched field trials in Australia, where ryegrass containing these gene edited endophyte strains is being tested in the open. The trials will be in locations where the ryegrass is likely to come under pressure from insect that is similar to New Zealand conditions.

High Metobolisable Energy Rye Grass:
This is being done by adding and modifying two plant genes to increase lipid content in the leaf and enhance photosynthesis in the plant under some conditions.
The purpose is to increase the nutritional quality of ryegrass to drive greater productivity, but the research also suggests environmental benefits such as reduced nitrogen loss that can contribute to waterway contamination, and reduced emissions of greenhouse gases, methane and nitrous oxide.

Current research suggests that methane reductions of 10 to 15 per cent may be achievable but the animal feeding trials are still to be undertaken to definitively test this (Agresearch, 2023).

For nitrous oxide, the opportunity is the improved animal nutrition leading directly to a reduction in urinary nitrogen excretion, resulting in reduced emissions and lower nitrate leaching; as well as the potential for reductions due to the HME plants influencing composition of the soil microbes leading to benefits in the nitrogen cycle (Agresearch, 2023).

Growing of HME Ryegrass and the required research has taken place indoors in contained conditions in New Zealand, according to regulations in place around genetically modified organisms. However, it has also been grown in regulated outdoor growing trials in the United States.

Planning is now underway for a trial that is expected to start late 2024, in which lambs will be fed both the HME ryegrass and a control ryegrass. To enable this, work is now underway to grow enough of the ryegrass in contained glasshouses in New Zealand that can be ensiled (preserved) for feeding to the lambs when the trial begins.
Scientists expect the trial to provide insights on methane emissions and urinary nitrogen excretion. Further confirmation in cattle will need to be performed in outdoor trials, most likely in Australia at a later date.

Results from the feeding trial commencing next year will guide next steps for the development of the HME Ryegrass programme and inform the potential for future commercialisation.

High Condensed Tannin White Clover:
High Condensed Tannin (HiCT) white clover has been modified to boost the level of condensed tannins present. Condensed tannins occur naturally in the flowers of white clover and in other species such as grapes, tea, and many other components of the human diet.

In white clover they offer significant promise for reducing environment impacts from livestock farming while improving both animal health and production.

Agresearch scientists are working to genetically modify white clover — an important component of pastures in New Zealand — with a gene taken from another species of clover to enable expression of condensed tannins in the leaves of the white clover.

The modification increases the condensed tannins content to meaningful levels in white clover leaves.

The results seen to date in containment in New Zealand suggest reductions in methane emissions; and nitrogen leaching, in excess of 15 per cent are potentially achievable. (Agresearch, 2023).

Consumption of the white clover with increased condensed tannins is also expected to reduce the occurrence of a condition known as bloat that can be fatal for both dairy cows. It may also reduce the internal parasite burden for livestock.

In addition to the modified white clover bred and grown in contained conditions in New Zealand, three years of field trials have been completed in the United States where regulations controlling the testing of genetically modified plants differ to those in New Zealand.

The levels of condensed tannins expressed in the HiCT white clover grown in USA was consistent with what was seen in the plants grown in containment in New Zealand.
Subsequent cycles of breeding and growing in containment in New Zealand have demonstrated that modified HiCT white clover with commercially acceptable yield and persistence can be generated (Agresearch, 2023).

Permission has now been granted for further field trials in Victoria, Australia, for a period for up to four years, and the first field trial was recently planted.

Further steps will see selection of plants for seed multiplication in Australia, as the partners look ahead to animal feeding trials and the potential for commercialisation of the HiCT white clover in the next few years.

The below table provides a range of potential examples that could be done in New Zealand.

Table 2: Examples of genetical modified plant traits with the potential to provide benefit in managed grassland ecosystems. Caradus, 2023

Potential benefit	Trait	Exemplar	References
Biotic resistances			
Disease resistance	Expression of antifungal protein AFP from the mould Aspergillus giganteus	Provided protection against *Puccinia substriata* and *Sclerospora graminicola* in pearl millet (*Pennisetum glaucum*)	Girgi et al. 2006
Insect pest resistance	Bt Cry protein expression	30 pests controlled by Bt crops in Latin America	Blanco et al. 2016
	Expression of lectins, protease inhibitors; multiple resistance genes		Christou et al. 2006
Abiotic tolerances			
Drought tolerance	Improved water use efficiency	Event MON 87460 used to improve drought tolerance though improved water use efficiency	ISAAA 2016
	Expression of related cold shock proteins from bacteria promotes stress adaptation	Demonstrated in rice and maize	Castiglioni et al. 2008
Improved winter hardiness	Mn-superoxide dismutase targeted to the mitochondria or to the chloroplast	Alfalfa transformed with a Mn-superoxide dismutase had higher winter survival	McKersie et al. 1999
Salinity tolerance	Overexpression of stress responsive gene SNAC1	Enhances salinity tolerance in transgenic rice	Hu et al. 2006
Physiological benefits			
Improved digestibility	Reduced cellulose and lignin concentration	Downregulation of cinnamyl alcohol dehydrogenase and caffeic O-methyl transferase in tall fescue and ryegrass	Vogel and Jung 2001; Faville et al. 2010
Improved metabolizable energy levels	Co-expression of diacylglycerol O-acyltransferase and Cys-oleosin	Approx. 30% increase in fatty acid content of ryegrass	Beechey-Gradwell et al. 2022
N-fixation in non-legumes	Direct *nif*- gene transfer	Postulated transfer of *nifB, nifE, nifN, nifH, nifD* and *nifK* genes to the cereal genome	Curatti and Rubio 2014

Reduced methane emissions and urinary nitrogen	Condensed tannin expression in leaves of white clover using TaMYB14-1 transcription factor	15% reduction of methane production using *in vitro* test	Caradus et al. 2022
	Co-expression of diacylglycerol O-acyltransferase and Cys-oleosin	Lowered methane production in ryegrass using an *in vitro* test	Winichayakul,et al. 2020
Reproductive efficiency	I–CreI homing endonuclease from *Chlamydomonas reinhardti* to gene edit and provide male sterility for hybrid breeding systems	Used in maize hybrid breeding	Djukanovic et al. 2013

7.2 Interview Findings:
During the process of one interview the interviewee asked what the writer believed were the key causes of concern for dairy farmers in New Zealand, the list was the following:

- Lack of profitability
- Labour talent and availability, particularly in areas without towns nearby.
- Environmental concerns, particularly nitrogen leaching, phosphorus loss, sediment loss and greenhouse gas emissions.
- Climatic risks.

The scientist in question believed genetic technologies, if adopted in New Zealand, would go some way to improving each one of those concerns. After reviewing the literature, there is logic to the theory.

Lack of profitability:
Profitability would be improved by genetic technologies such as better control of pasture pests and higher metabolizable energy pastures. The sector exported $25.7b worth of products and Agresearch estimated in 2018 there was $1.3b of lost revenue from pasture pests alone, as we have seen the industry dollar value of exports has considerably grown since that article.

According to Dairy Base, the average operating profit percentage over the 2019/2020 and 2020/2021 season, dairy farms ran on average 33% operating profit margins, while the top 50% were 5% higher at 38%. Therefore, if an average dairy farm were able to increase its revenue by 10% through genetic technologies without any increase to operating expenses, we would see operating profit margins lift from 33% to 39%, an 18% change.

Other considerable opportunities exist with high yielding crops that are 'roundup ready' making them considerably easier to manage weeds while improving yields.

Labour talent and availability, particularly in areas without towns nearby:
If profitability lifts, then farmers can improve pay and other benefits to attract staff. This is well documented through the Sense Partners report that wage growth has risen rapidly (9.5% CAGR) along with the growth in the dairy industry. Further supported by regions and such as Southland and the West Coast which GDP and employment data indicates strategic importance of the industry to their regional economies.

Environmental concerns, particularly nitrogen leaching, phosphorus loss, sediment loss and greenhouse gas emissions:
Both high metabolizable energy rye grass and high condensed tannin white clover appears to have the ability to reduce methane emissions with Agresearch quoting 10-15% reductions with the rye grass and 15% or more for the white clover. It is further expected to reduce nitrate leaching and urinary nitrate excretion reducing nitrous oxide. While crop yield improvements should lead to reduced land areas required for intensive winter grazing to help reduce land exposed for phosphorus and sediment loss.

Climatic risks:
With the ever-changing climate and the higher frequency of extreme events, pasture persistence is more important than ever. Greater persistence in droughts is becoming more demanded and coastal lands are being more affected with salinity issues with sea level rise. Overexpression of stress responsive gene SNAC1 to improve salinity tolerance as well as improved water use efficiencies are options that could be looked at in New Zealand grassland areas to mitigate climatic risks.

Farmers:
Through the interview process it became clear the farmers, despite having less knowledge of genetic technologies, had a very good understanding of possible downstream effects once presented. It was notable there was less knowledge of genetic technologies however with some discussion around possible options that Agresearch were looking at as examples to stimulate conversation, the immediate concern went to animal welfare – perhaps due to farmers at the coalface seeing the results first hand of animal health issues such as bloat and grass staggers. However, there was a real confidence that issues have come up in the past and farmers have always found a way to solve them through science, knowledge, and proactive management on farm. One Bay of Plenty farmer noted their "bloat management used bloat oil through their dosatron on farm for the cows to drink, multiple (feed) breaks allocated through the day to prevent cows from gorging and a watchful eye in case more active management was required".

Risks:
The scientists and farmers interviewed in general had the same view that benefits greatly outweighed the risks and with a well written regulatory framework those risks could be well mitigated. One Waikato based scientist quipped there has been "2 billion hectares of biotech crop over the last 20 years and no problem".

Genetically modified crops, developed through transgenesis, gene stacking, targeted gene editing using site-directed nucleases resulting in gene deletion, modification or gene insertion have been used for over 25 years for both human food and animal feed with. There is considerable evidence to support that this is safe for both humans and animals to eat.

While the most common commercialised genetically modified traits have been glyphosate tolerance to improve weed control (ISAAA No.53, 2017) and those incorporating genes expressing insecticidal proteins from *Bacillus thuringiensis* (Barrows et al. 2014), an increasing number of other traits are being used including abiotic stress tolerances, disease resistance, modified product quality, and pollination control (ISAAA 2022).

There are still many more GM opportunities at an experimental/research phase and some of these have applicability to forage and grassland species. However, there are very few examples of GM technologies being used commercially in forage and grassland species (Stewart and Hayes 2011; Wang and Brummer 2012, Caradus 2023).

Tourism:
Tourism is often discussed in terms of New Zealand's clean green image the interviewees struggled with the logic of why that would be affected. The consensus from those interviewed was that whether a country grew GM crops didn't enter their decision making for whether that was an interesting country they would like to visit. The study completed by Knight et al confirmed this from new arrivals. Things such as safety were much greater valued.

We can also see that of the just shy of 10m people that have visited in New Zealand over the past five years ending November 2023. (Stats NZ, 2023). The Top two nations are Australia and the USA contributing over half of the arrivals – from countries that have genetically modified crops grown and consumed in their countries.

7. 3 Literature Review Findings:

Consumers:
On balance, consumers are willing to buy GM foods, but these decisions are based on the perceived benefits the consumer receives, foods that are: cheaper, healthier, no spray residues, more nutritious, and with positive biodiversity and environmental outcomes (Te Puna Whakaaronui, 2023).
If the benefits accrued solely to the grower, for example they were cheaper to grow or had a higher yield, then consumers are less willing to purchase GM foods.

Trade Premiums:
There is a premium over genetically modified products, but this declines in the presence of other product characteristics (e.g. product appearance, consumer benefits such as environmental and nutritional qualities and the genetically modified approach used to produce the product).

In addition, perceptions of value are very product specific – more caution should be used for commodity and ingredient-based products, as seen in the South Australia canola example where it found farmers incurred an opportunity cost by foregoing productivity benefits of growing GM canola crops allowed in other Australian States (Te Puna Whakaaronui, 2023).

New Zealand's clean green image:
When consumers are making purchasing decisions country of origin is only one factor within a broader decision-making framework specific to that market's characteristics: the product's price, perceived benefits and cultural influences within that market, weighed against the product's perceived risks. A survey of tourists entering New Zealand gave a clear 'no' response to the question (Knight et al).

Risks or limitations of genetic technologies using site directed nucleases:
While it is possible to affect a gene, other than the one targeted, using SDNs, evidence to date suggests these techniques have less unintended outcomes than traditional breeding and certainly no more (Te Puna Whakaaronui, 2023).

There are public perceptions of risk associated with plant, animal, and human health, however, there is no evidence that producing new organisms using gene editing is more likely to have unintended consequences than using selective breeding. While gene editing is much less likely to introduce unforeseen outcomes than the less precise mutagenesis technique, it is possible for cuts to occur in unexpected places. Even though off-target impacts happen much less than they do with non-direct mutagenesis, it is still an issue that needs to be monitored.

How informed is the New Zealand public on Genetic Technologies?

Scion commissioned Colmar Brunton to undertake a survey of New Zealanders' current opinions and understanding of genetic technologies in 2019. It surveyed over 4,000 New Zealanders between the ages of 18-69 years. It found that more people are aware of GMO (*transgenic*) gene modification technologies, 68%, than of gene editing (New Breeding Techniques), 41%. However, the study also found that although the majority of the population is aware, this does not translate to knowledge, with less than a third of the population overall saying they feel informed about some type of genetic technology and only a third of those who are actually aware of each technology feeling informed.

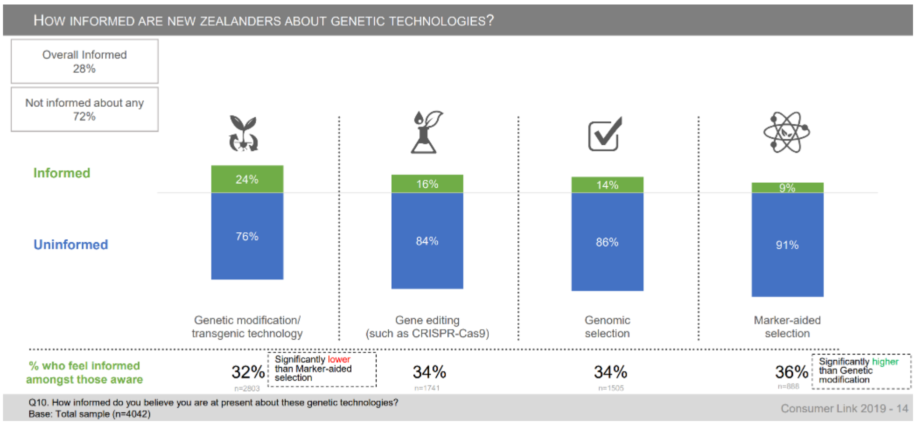


Figure 12: How informed are New Zealanders about genetic technologies. Scion 2019

Scion further then went into how informed the New Zealand population was about genetic technologies. The result is overwhelmingly that the New Zealand public is not informed (72%) about genetic technologies.

Consistent with these and several other studies which investigate the acceptance of genetic technologies, the level of acceptance goes up the more important the outcome is to the respondent (Te Puna Whakaaronui, 2023). In the Scion study 44% of all respondents believed that genetic technologies are important for New Zealand's future. The survey also canvased questions like how important conservation was to them personally, with 78% responding that it was either important or very important. A subsequent question asking about how accepting respondents would be of using genetic technology to save the Kauri tree, only 3% considered it not at all acceptable and overwhelmingly, 82% favoured to be either slightly or highly acceptable.

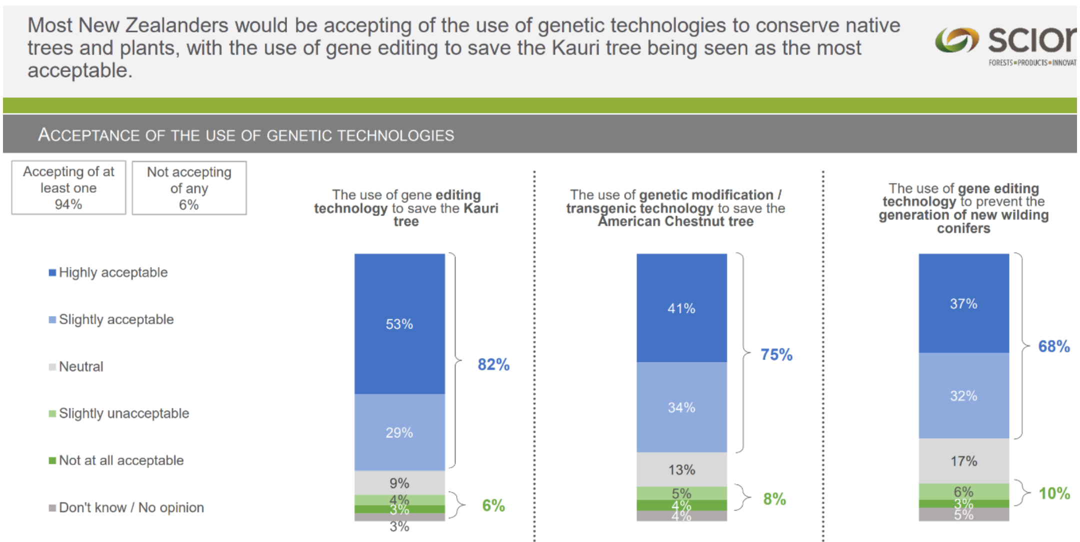


Figure 13: Acceptance of genetic technology use. Scion 2019

8.0 Conclusions

Inconsistent approaches to regulating GM plants across different jurisdictions and the situation where many countries allow the consumption of GM food but do not allow GM plants to be grown simply creates confusion.

Despite that, GM technologies have been extensively used in providing many benefits in crop plants but are yet to be fully exploited in forage and grassland species. Public concern over GM foods is focused on their impacts on human and animal health, environmental safety, labelling and consumer choice, intellectual property rights, ethics, food safety, poverty reduction and environmental conservation (Caradus 2022). GM feeds for animals however causes less concern with 70 to 90% of GM crop production being used for animal feed (Flachowsky et al. 2012), with the largest users being USA, China, and Europe (Shahbandeh 2022), which are some of New Zealand's largest trade partners.

However, there is still a need to balance risks against benefits and ensure adequate testing is undertaken before commercial use of GM feeds. This should include monitoring animal health, effects on non-target organisms, and an understanding of the impact of gene flow (Caradus, 2022).
New Zealand farmers will need to balance the benefits between themselves and the consumer desires to ensure they take both the consumer and the gate keepers along for the ride. This will need to form part of the marketing strategy for dairy processors to ensure the benefits of genetic technology is perceived adequately in the eyes of the customer, gatekeepers, and public.

If New Zealand can successfully implement genetic technologies, boosting productivity and profitability of the dairy industry, while simultaneously improving environmental and animal and human health outcomes we will continue to see the strength of the industry.
As New Zealand's number one export earner and cornerstone of many regional economies, the benefits will continue to flow via GDP and wages across the whole country allowing rural communities to prosper.
New Zealand's current account and the New Zealand dollar will continue to receive support from exports derived from the sector, helping to hold the value of the New Zealand dollar; in turn providing significant benefit to every day New Zealanders purchasing power for imported goods.

9.0 Recommendations

- New Zealand needs a science based, consistent approach to regulating genetic technologies. This will need to evolve as the science develops and evolves.

New Zealand's approach to regulating genetic technologies is outdated, not fit for purpose, and holding back the agriculture industry without clear evidence for why the stance is maintained. There are clear opportunities that could lift productivity, environmental and animal health outcomes, while lifting profitability for the dairy industry. As the industry plays a pivotal role to the New Zealand and regional economies this could be a shot in the arm for many regions prosperity. There has been a lack of evidence to show why genetic technologies should not be adopted in New Zealand given the benefits considerably outweigh the risks.

- Risks need to be balanced against benefits and ensure adequate testing is undertaken before commercial use. This should include flow on effects and animal health monitoring for plant breeding.

There needs to be a process of checks and balances that lead right through to the animal to ensure that genetically edited species are improving outcomes as expected of them. This should be pivotal for any new regulatory approach to ensure unintended outcomes are limited.

- The right plant breeding programs need to be prioritised first.

As strongly discussed with one interviewee, there is no point creating highly metabolizable and palatable pastures if we can't control the pasture pests that will destroy them. The right programs need to be prioritised to achieve the desired productivity gains. This stands the same as for the animal health testing above, higher metabolizable pastures allowing a cow to eat more rye grass won't help if grass staggers become an uncontrollable problem.

- Incremental gains are powerful in the long run, but New Zealand needs to adopt genetic technologies now.

No one thing in this paper is a catch all fix everything solution. However, this paper outlines how genetic editing can provide benefits across almost every aspect of a dairy farmers biggest concerns as discussed in the analysis section. Excitingly, there is the potential for scientists and farmers to continue innovating and building on this, but the later New Zealand starts, the longer it takes for farmers to have the tools to improve.

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Appendices

Research Question: Discuss the impact of gene technologies on New Zealand's dairy farming sector.

Interview Questions:

1. What are your views on New Zealand's current biotech policy?
2. Where do you see the main opportunities for gene editing in New Zealand?
    - *Agriculture*
    - *Conservation/Environment*
    - *Healthcare*
    - *Other*
3. Where do you see the risks?
4. How could these risks be managed in order to negate any negative effects?
5. What barriers, if any, could there be to the adoption of GE/GM in NZ that are not regulatory?
6. What considerations or trade-offs do consumers need to think about before consuming genetically edited foods? E.g.
    - *Reduced pesticide use*
    - *Price*
    - *Impact on the environment*
    - *Impact on human & animal health*
    - *Cultural beliefs*
7. What economic benefits could genetic technologies deliver to the pastoral farming sector? (broken into 3 sub parts)
    - *Individual farmers*
    - *Rural Communities*
    - *New Zealand Economy*
8. Any further comments?

(Note – comments in italics were not sent, they were there to provide discussion prompts for the interviewer in case of a lull).