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TE APĀRANGI

# GENETICALLY MODIFIED FORAGES

## Emerging Issues

**Summary**

The past decade has seen both global growth of the use of genetically modified (GM) technologies in agriculture and increasing concern over the ability to maintain adequate food production.

New Zealand research into genetically modified forages has led to plants with traits that, when grown in containment, offer improved performance over traditionally-bred lines. Improved forage performance can be delivered by both transgenic (using genes from other species) and cisgenic (using genes from the original species) methods. Cisgenic transformation may be more socially acceptable, but many believe that the benefits and risks depend more upon the traits themselves, not upon the sources of the genes that deliver the traits.

The use of genetically modified forage could increase farm productivity, drought resistance, and reduce greenhouse gas emissions intensity. However, the release of genetically modified organisms is at variance with identities and values that many New Zealanders hold dear.

In overseas markets, some consumers retain a preference for non-GM products but such opposition is decreasing. However, research on social and market acceptance is largely limited to the European market. These issues are seen as less of a concern for animal feed than for human food.

The scope of this paper covers the technologies and drivers associated with the development and use of genetically transformed forages that are of interest to New Zealand's pasture-based industries. The pastoral sector is an area where New Zealand research is world-leading. The intent of this document is not to make recommendations, but to inform discussion on the benefits, risks, and acceptability of the use of these technologies.

**Changing drivers for genetic modification in agriculture**

Fifteen years ago, intense public interest about the management of genetic technologies led to the creation of the Independent Biotechnology Advisory Council in 1999, followed by the Royal Commission on Genetic Modification report in 2001. The Commission recommended that New Zealand "should proceed carefully, minimising and managing risk".[1] That finding contributed to a period of continuing but less intense concern around genetic modification.

Since then, issues of food production and food security have grown in significance internationally.[2,3] For this country a number of factors have arisen that may influence opinion about the release of genetically modified forages.

These include:

- Ongoing intensification of pastoral farming and the need to transform the sustainability of agriculture
- Increasing costs of farm inputs, e.g. fertiliser and fuel, and the corresponding concerns about the potential limits of 'business as usual' agriculture
- Mitigating agricultural greenhouse gas emissions
- Adapting to climate change, e.g. more frequent and intense droughts
- Growing competition from low cost producers overseas
- Increasing animal welfare concerns, particularly the nutrition of pasture-fed animals
- Improving precision of GM techniques

1 "Report of the Royal Commission on Genetic Modification", 2001
2 "Reaping the benefits: Science and the sustainable intensification of global agriculture", The Royal Society of London, October 2009
3 "Agriculture at a Crossroads", International Assessment of Agricultural Knowledge, Science and Technology for Development, 2008

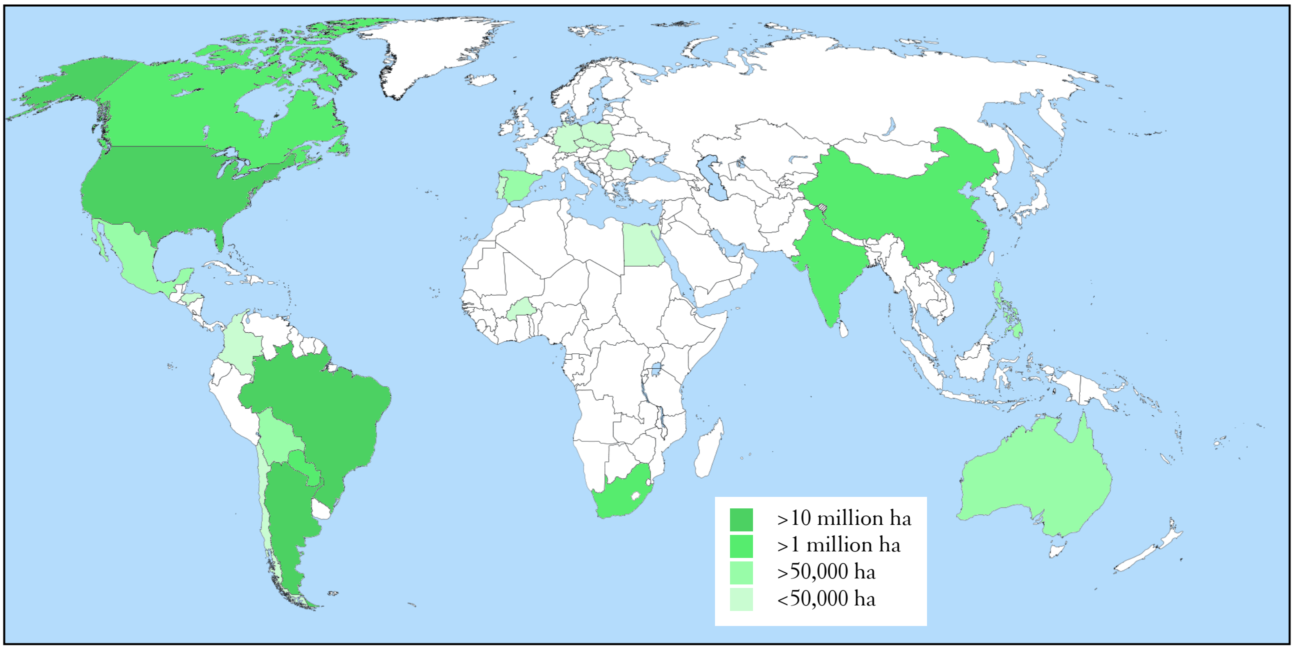


Figure 1: Nations using genetically modified crops. The majority of GM crops are grown in the US, Argentina and Brazil.[4]

**Many researchers believe that traits influence risks and benefits more than the techniques used to deliver the trait**
A trait is a distinct variant of the observable characteristics of an organism. An example of this is blue or brown eyes. Commonly used traits in commercial crops that have been manipulated by genetic modification are those for herbicide tolerance and insect resistance.[4]

In brief, consideration of genetic modification[5] broadly has three components: (i) the nature of the *trait* being introduced and how it is expressed, (ii) the *technique* being used to introduce the DNA encoding the trait into a host's genome and (iii) the *source* of the introduced trait-related genes. Many regulators and members of the public have focused on the techniques used to introduce new traits into plants and any resulting effects upon food products, rather than the traits themselves. This being the case, it is also necessary to recognise that 'conventional' plant breeding can be expedited via the use of mutagens to alter a plant's DNA to create new base-pair combinations that, by chance, may create a useful trait. This approach is seen by some to be more acceptable than the precise insertion of trait-coding genes into a DNA sequence.

Given the above, the question can be asked whether it is the trait that matters, rather than how it is arrived at. Many of our contributors believe that risk management should lean more towards understanding a new trait's functions and implications rather than the method of modification. Focusing on the technique used, instead of the trait, could create its own risks around incomplete understanding of a trait's impacts.

Regulation based on traits rather than techniques is already in use in Canada with the USA taking a similarly safety-based approach, although these countries show differing degrees of precaution. New Zealand legislation differentiates between GM and non-GM methods of modification prior to assessing the effect of new traits.

**Many believe trait evaluation should be carried out on a case-by-case basis**
When new traits are introduced, they enter dynamic and complex systems. These systems range from the biochemistry and physiology of the plant, the ecosystem of the soil and pasture, through to the wider local environment, the farm business system and ultimately, the national economy. Impacts must be evaluated across all of these levels. This multi-faceted evaluation raises a number of questions including:

- How much system-level understanding is there available?
- How well can outcomes (and risk profiles) for ecosystems, individual agricultural businesses and the sectors be predicted?
- How well understood are the likely impacts on social and cultural responses and New Zealand's market position?

Extrapolation based on prior experience with currently-used traits does not provide full information on the possible effects of newly introduced traits. Each new trait may have widely different impacts, and should therefore be considered as a new and separate effect interacting with existing components.

When considering new traits, researchers can sometimes use conventionally bred analogues grown under field conditions to partially assess impacts in place of releasing

4 James, C. "Brief 39 – Global Status of Commercialized Biotech/GM Crops: 2008", International Service for the Acquisition of Agri-biotech Applications, 2008

5 Defined here as recombinant techniques as regulated by the Hazardous Substances and New Organisms Act

| Categories | Source of new genes | Potentially achievable with conventional breeding? | Genetic distance |
|---|---|---|---|
| Cisgenic | From species genome | Yes | Low |
| Famigenic | Species in the same family | Maybe | |
| Transgenic | Unrelated species | No | |
| Xenogenic | Synthetic genes | No | High |

Table 1: Definitions of genetically modified organisms based upon sources for modified genes[11]

genetically modified organisms.[6] Such preliminary assessment of a trait's likely effects can aid subsequent field investigation using the modified organisms themselves. There are limits to the extent non-genetic modification approaches can replicate the traits delivered by genetic modification so these approaches will remain useful, but incomplete, ways to assess the impacts of new traits.

**Increasing offshore experience with genetically modified crops**

Up to fifteen years have elapsed since the US and other nations began intensive cultivation of genetically modified crops, particularly soya bean, maize, and cotton. The area sown reached 125 million hectares in 2008.[4] Such use of genetically modified technology has been associated with reduced pesticide use and increased farm income from insect resistant maize in parts of the EU[7] and from various other crops globally.[8]

No evidence has been found of harm to human health[2] or permanent ecological damage.[9] This is often taken as evidence in favour of the use of genetically modified crops. However, as has been noted in the consideration of traits, it is necessary to recognise that if one type of modification or group of modifications has been safely and successfully used, that does not automatically mean that all genetically modified crops are safe. By the same token, it cannot be assumed that the products of conventional breeding are inherently safe. A modification for one purpose may not in any way resemble another modification, be it functionally, biologically, or ecologically. For example, most experience with genetically modified crops has been with annual crops that are modified for pest resistance. This contrasts with the prospects of persistent inter-seasonal perennial forages with other introduced traits.[10] Thus all modifications should be considered on a case-by-case basis.

**Sources of genes: cisgenic versus transgenic modification**

In general, barriers between multi-cellular species prevent interbreeding and functional gene transfer. This is seen by many as part of the "natural order". Genetic manipulation crosses these barriers.

There is a continuum of sources of potential genes that may be used in genetic modifications. For example, genes may be acquired from within a species, or from species of increasing genetic distance from the transformed species. Alternatively, genes may be created entirely synthetically by assembling new combinations of base pairs.

The process of *cisgenetic* (or *intragenic*) modification involves manipulating genetic material only from the species being transformed. When genes are sourced from a different species, the process is known as *transgenic*.

The implications of cisgenics and transgenics are sometimes viewed differently amongst scientists, regulators, and the general public. Cisgenic transformation may appear to conform more to the "natural order" of species isolation and therefore may be more acceptable for that reason to the New Zealand public.

6 An example of this approach is the work being carried out by Dr Anthony Parsons under the FRST contract "Novel Trait-based Assessment". Earlier work has been published as:
Parsons, T., Rasmussen, S., Newton, P., Bergelson, J. "A basis for developing a priori assessments of the risks and benefits of novel organisms" AgResearch Internal Report, 2003

7 Brookes, G. "The impact of using GM insect resistant maize in Europe since 1998", International journal of Biotechnology, 10 (2/3); pp 148-166, 2008
Gómez-Barbero, M, Berbel, J., Rodriguez-Cerezo, E. "Bt corn in Spain – the performance of the EU's first GM crop", Nature Biotechnology correspondence, 26 (4); pp 384-386, 2008

8 Brookes, G., Barfoot, P. "Global impact of Biotech Crops: Socio-Economic and Environmental Effects, 1996-2006", AgBioForum, 11 (1); pp 21-38, 2008

9 Department of Environment Food and Rural Affairs "Farm Scale Evaluations of herbicide tolerant GM crops", 2005

10 For example, alfalfa is perennial, insect-pollinated, regrows quickly, is drought and cold tolerant, and produces dormant seeds. These characteristics aid gene flow in wild populations. GM alfalfa has been approved for unconfined release in Canada.
Bagavathiannan, M.V. Van Acker, R.C. "The Biology and Ecology of Feral Alfalfa (Medicago sativa L.) and Its Implications for Novel Trait Confinement in North America", Critical Reviews in Plant Sciences, 28 (1&2); pp 69 – 87, 2009
Bagavathiannan, M.V., Van Acker, R.C. "The Feral Nature and Implications for The Co-Existence of Genetically Modified and Non-GM Alfalfa", Department of Plant Science, University of Manitoba, 2009

11 Adapted from Nielsen, K.M. "Transgenic organisms – time for conceptual diversification?", Nature Biotechnology, 21; pp227-228, March 2003

**Demonstrated and potential benefits of genetically modified forages**

The Royal Commission referred to the "exciting promise" of genetic modification. Such promise is no longer speculative. Forage research now has made demonstrable progress towards the discovery and incorporation of useful traits. For example, those in ryegrass and clover plants (in containment) now include:

- Drought resistance and improved performance under moisture stress that will increasingly arise from climate change
- Improved balance of soluble carbohydrate and protein levels for increased available energy, higher productivity, and better nitrogen use efficiency
- Higher levels of condensed tannins for the elimination of bloat and optimal protein uptake leading to less nitrogenous waste and possibly less methane production
- Changed lipid content leading to higher available energy and reduced methane production

Other traits under development include:

- Reduced lignin for more digestibility and improved nitrogen efficiency
- Improved efficiency in the plant's use of water and nutrients
- Encapsulated lipids to increase the level of omega 3 unsaturated fats in the grazing animal, with potential human health benefits
- Improved growth at lower temperatures for increased production outside of the peak growth period

If these benefits are realised in production systems, then they should lead to improved feed production and conversion, increased tolerance to droughts, reduced greenhouse gas emissions, reduced nitrogen intensity, and improved animal nutrition. Overall, the effect on farms should be to increase productivity while providing more options to manage the environmental effects of intensification.

However, the possible impacts of genetically modified forages on farm income and profitability have not yet been modelled in detail. Definitive work has yet to be done that clearly links farm productivity improvement to the uptake of new forage technologies, and also links farm profitability to the response of international markets to increased production. Potential reductions in greenhouse gas emissions and nitrogen leaching will also need to be factored in as their reduction will increasingly offer economic as well as environmental value. Some preliminary modelling has shown potential economic benefit,[12] whereas other substantial work predicts that strategies to simply increase market demand will have a more profitable impact.[13] Both approaches may be necessary, but the impact of the use of genetically modified technology on demand for New Zealand products will always rest with consumers.

**Potential adverse effects of genetically modified forages**

Ryegrass is perennial and produces wind-blown pollen. Unlike, previous field trials of GM pine trees, it would not be possible to guarantee that there will be no movement of genetic material. Flowering cannot be avoided if proper agronomic evaluations are to be made of large areas of forages. Whilst the vast majority of ryegrass pollen is deposited a few metres from the source,[14] viable pollen has been shown to move at least three kilometres.[15] Seed dispersal will also be a concern, with limited information available about possible role of birds and mammals.[14]

Enhanced traits may create potential for more weediness where those traits deliver plant persistence and vigour. Conversely, many traits under development promote nutritional value to livestock rather than likely adaptive fitness. Such transformed plants often generate new proteins which could incur an increased metabolic cost, reducing overall fitness and thus survival in the wild.

The exclusive use of cisgenics limits the potential changes made to an organism, purely because the range of usable genes is limited to those already present within the species. This reduces the range of available traits but similarly, may limit the risks and the potential for unexpected consequences.[16] This limitation has led to the assumption that the greater the genetic difference between the host plant and a gene donor species, the greater the risk of unpredicted consequences. Conversely, within a plant's genome there is a range of unused genes; use of them may incur risks equivalent to the use of foreign genes. For this reason, some argue that the use of cisgenic plants does not differ materially in risk from transgenic plants. Again, there is a view that risk depends more on the impacts of the trait used than the source of the genes for that trait.[17] This point remains subject to debate.

There are no indigenous ryegrass (*Lolium*) or white clover (*Trifolium*) species in New Zealand and thus modified

12 Simon Harris, Harris Consulting, personal communication AgResearch modelling reported in Harrigan, J. "Switching on to grass", Country-Wide 31 (9); pg57, Sept 2009

13 Kaye-Blake, W.H., Saunders, C.M., Cagatay, S. "Genetic modification technology and producer returns: the impact of productivity, preferences, and technology uptake", Review of Agricultural Economics, 3 (4); 692-710, 2008
Saunders, C., Kaye-Blake, W., Cagatay, S. "Economic impacts on New Zealand of GM crops: Result from partial equilibrium modelling", Agricultural Economics Research Unit, Lincoln University, Research Report No 261, August 2003

14 "The Biology of Lolium multiforum Lam. (Italian ryegrass), Lolium perenne L. (perennial ryegrass) and lolium arundinaceum (Schreb.) Darbysg (tall fescue)", Office of the Gene Technology Regulator, Australian Government, May 2008

15 Busi, R.; Yu, Q.; Barrett-Lennard, R.; Powles, S. "Long distance pollen-mediated flow of herbicide resistance genes in Lolium rigidum" Theoretical and Applied Genetics 117; pp 1281-1290, 2008

16 As reported in Francois, F. "Regulatory Issues Concerning Emerging GM Techniques", Ministry for the Environment, Presented at the Ninth International Symposium on Biosafety of Genetically Modified Organisms, September 2006

forages do not directly threaten to hybridise with endemic species. However, UK research on insect resistant crops suggests that the major conservation impact comes not from genetic modification itself, but from changed farm practises enabled by that modification[9] and from the spread of forages into off-farm ecosystems. This suggests that the conservation effects as well should be assessed on a trait by trait and ecosystem by ecosystem basis.

Horizontal gene transfer needs to be considered as part of the risk assessment for the introduction of genetically modified forages. This involves the uptake, integration, and expression of genetic material from one species to another without interbreeding. Horizontal gene transfer has always played an important role in the evolution of bacteria. In terms of higher plants and animals, horizontal gene transfer has been the subject of thorough and extensive investigation which has produced sparse evidence of such activity.[18] To date there is no evidence of transfer of genes from plants to vertebrate genomes.

**Social acceptance is driven by personal and national identity**

Much of New Zealanders' personal and national identity, and sense of place is linked to concepts about nature. This is expressed as both the concept of New Zealand's clean, green image and Maori concepts of whakapapa and mauri. Such values provide a standpoint from which to consider biotechnology and genetic modification and, for many, justify the rejection of field releases of genetically modified organisms.[19]

The social acceptability of new technologies is influenced by people's identities and values, the trust they place in authorities, and a natural desire to preserve options in the face of uncertainty.[20] Other factors influencing acceptability include: fear of negative environmental impacts, threats to food safety, dislike of corporate ownership of food production systems, and ethical beliefs around modifying the natural state.

Within this framework, acceptance of new biotechnologies depends upon the perceived risk and benefit to the individual or to their environment. When perceived benefit compensates for risk, then acceptance is more common.[21] Such risk and benefit analyses are often considered on a case-by-case basis. For example, New Zealand focus groups considered a hypothetical rot-resistant GM potato to be less acceptable than a GM bacterial strain for removing pesticide contamination from soil.[22]

The first generation of genetically modified crops were seen to benefit producers and corporate owners of intellectual property, rather than the consumers who bore any risk. This led to their widespread public rejection in many nations. More recent justification for genetically modified organisms now focuses more on reducing environmental impacts, such as lowered greenhouse gas emissions or nitrogenous run-off. Such offerings stand to benefit the human population and the environment as a whole and may therefore be more acceptable. However, even then, environmental benefits are diffuse and lagged and therefore may still not be seen as adequate compensation for perceived risk.

**Social and market opposition to GM food is decreasing**

The question of market acceptability of genetically modified biological material in some parts of the world is unresolved and evolving, whereas in other countries (e.g. the USA & China), the issue is much less contentious.

Reviews of consumer attitudes are showing a gradual reduction in concern over genetically-modified organisms as anxiety over climate change, security of food supply, and other environmental problems grow. However, around a fifth of Europeans continue to see GMOs in agriculture as a significant environmental threat.[23] Conversely, the effect on consumer buying patterns is less pronounced. In many situations consumers do not actively avoid GM-foods and, while labelling of GM status is stated as desirable by consumers, few consumers apparently use the information presented on the labels.[24]

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17 For examples of this debate, see:
Russel, A.W., Sparrow, R. "The case for regulating intragenic GMOs", Journal of Agricultural and Environmental Ethics, 21; pp 153-181, 2008
Jacobsen, E., Schouten, H.J., "Cisgenesis, a New Tool for Traditional Plant Breeding, Should be Exempted from the Regulation on Genetically Modified Organisms in a Step by Step Approach", Potato Research, 51(1); pp 75-88, 2008
One commentary on the evidence in the cis/trans debate can be found at:
"Cisgenic Plants: Just Schouten from the Hip?", Bioscience Resource Project, 23rd February, 2007

18 van den Eede, et.al. "The relevance of gene transfer to the safety of food and feed derived from genetically modified (GM) plants", Food and Chemical Toxicology, 42; pp 1127-1156, 2004

19 Fairweather, J., Campbell, H., Hunt, L., Cook, A. "Why do some of the public reject novel scientific technologies? A synthesis of results from the Fate of Biotechnology Research Programme", AERU Research Report No 295, Lincoln University, June 2007

20 A useful summary of the research from the "Socially and Culturally Sustainable Biotechnology" project can be found in the workshop proceedings "Working across boundaries: science industry in society", Royal Society of New Zealand, 2007
Also relevant is Frewer, L., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., Berdal, K.G. "Societal aspects of genetically modified foods", Food and Chemical Toxicology, 42; pp 1181-1193, 2004

21 Knight, J.G., Mather, D.W., Holdsworth, D.K, "Consumer benefits and acceptance of genetically modified food", Journal of Public Affairs, 5 (3-4); pp 226 – 235, 2005

22 Hunt, L.M., Fairweather, J.R., Coyle, F.J. "Public Understandings of Biotechnology in New Zealand: Factors Affecting Acceptability Rankings of Five Selected Biotechnologies", Agribusiness and Economics Research Unit, Lincoln University, Research Report No. 266, December 2003

23 "Attitudes of European citizens towards the environment", Eurobarometer 295, 2008
"Opposition decreasing or acceptance increasing? An overview of European consumer polls on attitudes to GMOs", GMO Compass, April 16, 2009

**Consumer acceptance of animals fed on GM feeds is poorly researched**

There are differences in market acceptability between genetically modified food products and food products from non-genetically modified animals that have been fed on genetically modified feeds. Some surveys show that many consumers believe that food products from a non-GM animal fed on GM feed should be considered as genetically modified. However, food products from animals fed on transgenic soya bean products (amongst others) are widely purchased and generally not labelled as containing GM material.[25] Few trade restrictions are placed on the products.

There has been little research done to investigate consumer attitudes to products from non-GM animals fed on GM feeds, especially in markets beyond the EU. The ABARE review *GM stockfeed in Australia* is one of the few relevant summaries of this limited research; their key recommendation is further market analysis. Despite this, their conclusion is that livestock producers using GM feed are unlikely to be disadvantaged in the market or suffer market access problems.[26]

**The effect on market value of GM-fed animals**

Questions remain around the size of any price differentials for genetically unmodified products obtained from a nation that also supports production systems using genetically modified crops.[27] More specifically, how would this apply to New Zealand and to the use of GM forages, not GM food? It is important to determine whether this country's trading status would be compromised should genetically modified crops be introduced commercially. It appears that European consumer concern about GM technology is apparently linked to the products themselves rather than GM use in the countries of origin. The limited domestic research on this suggests that co-existence of non-GM food production and GM forages for non-food use has little impact on consumer perceptions of country-of-origin image.[28] Similar work looking at the Chinese market suggests that current ambivalence about GM products may change if GM products deliver consumer benefits or price advantages. There is little suggestion that Chinese buyers would discriminate against non-GM products from countries also growing GM crops.[29]

Linked to this is the question of whether the presence of low but measurable levels of cisgenic or transgenic material in food would, in the eyes of the market, mean that NZ forage systems would be considered as genetically modified or not. In the EU there are tolerated levels of GM co-mixing in GM free products. Up to now separation distances and control of seed mixing has enabled the New Zealand seed industry to produce proprietary seeds of certified quality. These methodologies are widely accepted as sufficient to minimise genetic contamination between non-GM lines. The same practises may also be suitable for maintaining mandated separation between GM and non-GM seed lines.

**Further Reading**

"Reaping the benefits: Science and the sustainable intensification of global agriculture", The Royal Society of London, October 2009

Ansell, E., McGinn, E. "GM stockfeed in Australia", Australian Bureau of Agricultural and Resource Economics, prepared for the Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, 2009

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24 European Commission CONSUMERCHOICE project, "Do European consumers buy GM foods? – Final report", 2008

25 One recent New Zealand government finding is that some products have been mislabelled, with chickens that had been fed GM soya labelled as containing no GM ingredients. "Inghams warned over GM free chicken claims", Commerce Commission, Release no 50, November 18th, 2009

26 Ansell, E., McGinn, E. "GM stockfeed in Australia", Australian Bureau of Agricultural and Resource Economics, prepared for the Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, 2009

27 This issue has been a continuing feature of the NZ debate around the use of genetic modification. For a previous example of the discussion, see: "Economic Implications of a First Release of Genetically Modified Organisms in New Zealand", Independent Biotechnology Advisory Council, December 1999

28 Knight, J.G., Mather, D.W., Holdsworth, D.K. "Impact of genetic modification on country image of imported food products in European markets: Perceptions of channel members", Food Policy 30; pp 385-398, 2005

29 Knight, J.G, Gao, H. "Chinese gatekeeper perceptions of genetically modified food", British Food Journal, 111 (1); pp 56-59, 2009