Issue 36
March 2010

AgScience

Inside

Genetic Modification Revisited

The New Zealand Institute of Agricultural & Horticultural Science Inc

Jon Hickford
President

Genetic Modification Revisited

This issue of AgScience contains papers and edited transcripts of presentations to the forum 'Genetic Modification Revisited', organised by the Canterbury Section and held at Lincoln University last year. Following the forum I attended the Agricultural Biotechnology International Conference (ABIC) 2009 in Bangkok, where a substantial quantity of GM science was presented. It is unlikely we lead the world in the volume of GM work being undertaken in New Zealand, doubtless reflecting matters other than the abilities of our scientists, but we do discuss the pros and cons of GM at a level rarely seen elsewhere. This is a good thing. What makes this country great is that those who are both strongly for and against GM can sit in the same room and maintain a quality dialogue on the topic. While I am reluctant to single out individuals for praise, over the years Jeanette Fitzsimons has always been prepared to front up for us and challenge the way we all think. I thank her for that.

This stated, it still surprises me that a small, yet vocal sector of the community wants to ban all GM research in New Zealand. It is the proverbial "country-mile" from undertaking scientific research, to having GM crops or animals in our paddocks providing food or products to the market. The banning of GM research would leave us the poorer and it would not stem the tide of GM products coming into the country. But if we don't have scientists who understand the science, then we will not be in a position to make any informed decisions as to the value of the GM being used by our trading partners, including that being undertaken by scientists in the apparently discerning and "clean and green" responsive markets of Europe.

At ABIC food quality and security underpinned many of the arguments on why we need GM. There was, for example, talk of the "need" to produce iron-fortified rice to address the issue of having at least 1 billion anaemic people on earth. This challenges us all to think again about the technology. That stated, several speakers at our forum cited GM as a way of feeding the worlds' population and – it seemed – to justify its use in New Zealand. I don't think this is useful, given the high value (and not volume) export markets we serve. Equally, whether there is currently a world food shortage is debateable – it is odd that as thousands die daily from starvation, we in New Zealand are in the throes of an obesity epidemic, courtesy of the extraordinary availability at little cost of calorie-rich, nutrient-poor "foods". The politics of food are complex.

But the proportion of consumer expenditure on food has fallen for many years in New Zealand. In 1920, 38% of household expense was on food and there is little doubt that the range of products available was somewhat lower. While we all grumble about food prices, the June 2009 median weekly household income was $1,234. In 1920 terms, we would be spending $470 per household per week on food. With the possible exception of my family (three growing boys), I doubt whether this is true.

In many of our primary industries, however, the income levels of producers is disconcertingly low, partly a result of the high value of the New Zealand dollar, but also reflecting the considerable power of supermarkets and their propensity to drive down what they pay farmers. Many of our producers may falter financially unless something changes soon. Food (GM or otherwise), farming and the science and technology that underpin them must gain more prominence in what we do in New Zealand.

POLITICS

We are more than one year into the term of a new government. I remain optimistic that for agricultural and horticultural scientists things are about to improve. They need to because a recently released survey of New Zealand scientists and technologists made for sorry reading. We are seeing the symptoms of over 20 years of systemic neglect, especially in agriculture and horticulture.

On the positive side, the CRI Taskforce report has been released. The recommendations are generally positive and should if implemented lead to considerable improvement in our science system. It would seem that CRI scientists will be in a better position to get on and do what they do best, and with greater funding security and less needless bureaucracy. Our major concern revolves around CRI governance. It is good that "at least one eminent scientist" will need to be on a CRI board, but why not three or four? Why is it still believed that lawyers, accountants and business people know how to run our CRIs, when you don't find many scientists on the boards of law firms, banks and companies? How do these non-scientists know what is achievable in science and what isn't?

The PGP fund remains in apparent limbo. It was reported recently in the farming media that $5 million had been allocated to the Pastoral Greenhouse Gas Research Consortium, and $2.18 million (approximately 30% of spend to date) had been allocated to cover the costs of the Investment Advisory Panel. This leaves $22.82 million unspent and with no guarantee it will be rolled-over to the next financial year. While, the fate of the Fast Forward Fund was sealed after the election, its replacement does not appear to have filled the gap.

The Institute remains vigilant on your behalf in targeting the political issues of the day, and I remain positive, although I am now looking for cause to sustain that optimism.

2010 FORUM

Finally, this issue announces our 2010 Forum. The date and venue are set: Lincoln University in early September to coincide with the 4th Australasian Dairy Symposium. The topic will be: "Where do we want our dairy industry to be in 20 years time?" I am now approaching a range of potential speakers, spanning Fonterra, the RSPCA, DairyNZ, conservation lobbies, Regional Councils, farmers, value-added industries, MAF, the rural banks, consumers and politicians. We all have good ideas of what the industry needs to do and this forum should provide a platform for creating a shared vision of the way forward.

By Prof Travis Glare
formerly GM Science Strategy, AgResearch
currently Professor of Entomology, Lincoln University

Is it time to proceed with less caution on GM?

GENETIC MODIFICATION HAS BEEN promoted as a way of overcoming many challenges in agriculture for several years. It has many supporters and many opponents. The Royal Commission, after looking at all the information and hearing all the arguments – recommended we "proceed with caution". What we must consider is whether it is time to reconsider that advice.

The world has an ever-increasing population of people who are going to need more food from a finite or reducing amount of cultivatable land. That land has been damaged by traditional farming practices and we have a changing climate, so it is going to be harder to produce enough food for the world.

New Zealand is an agricultural exporting nation, highly dependent on low-cost pastoral-based farming for the food it produces. But if we want to keep the sort of lifestyle we now enjoy, we must keep improving our productivity.

More than 50% of our export earnings are based on grass.

The following figures are somewhat outdated, but show dry matter production per hectare in the Waikato. The average Waikato farmer was producing about 12kg of dry matter per hectare, the best farmer was getting 18kg. We really need 24kg to be feeding animals to their potential.

Meanwhile there is a world-wide trend to increase the number of genetically modified crops commercially grown, although there are a limited number of types of modifications. Insect resistance and herbicide resistance account for over 90% of all the commercially grown crops. Soya bean, maize and cotton account for most of those crops.

On the back of this we have an increasing knowledge about genetics. Around 500 whole genomes (at a rough count) have been sequenced between prokaryotics and eukaryotics and the number is increasing exponentially. The technology is getting simpler and we know increasingly more about genes and genetics, whether from work in containment or in the field. There is cisgenics, transgenics and chloroplast transformation, and new targeting techniques are being developed all the time.

But GM work has become more complex, too, looking at trends beyond insect and herbicide resistance. It is becoming more agronomically and human health oriented, for example, to highlight the nutritional advantages in some plants, drought resistance, plants that will mitigate greenhouse gas emissions, larger biomass, and other characteristics that will help New Zealand.

But opposition to GM comes from people with differing objections: there are safety, environmental and human health issues as well as philosophical and religious objections (should man really be playing with nature; should man be playing God?). There are economic questions (does genetic modification add value?) and political ones, usually a combination of all of the above. Paradoxically, support comes for a range of reasons, too, including economic, environmental and human health.

New Zealand's choice accordingly is whether to allow genetically modified agriculture or not, and if so, with plants, animals or both. The worst thing would be to end up highly regulated, making the process so expensive and so difficult that we have a moratorium by stealth.

We want to look at our pastoral-based agriculture and some of our specialist crops, such as kiwifruit, but we are not likely to attract the necessary investment from companies required to go through our regulatory system. Research will need government support for exactly those reasons.

If we are not going to allow GM, what are we going to do? Conventional farming will still need productivity and sustainability increases and these call for technological innovations.

Organic production is often touted as the way New Zealand should go. But we must question whether we can earn enough revenue from organic food to sustain the country.

There is another question. Can traditional approaches to plant and animal improvement combat the changing climatic conditions while meeting the needs of rapidly changing export markets and the loss of productive land as increasing urbanisation obliges us to produce food on less land and less suitable land?

I am not proposing GM is the only thing we should do. There is plenty of non-GM research going on, such as marker-assisted selection which uses gene technologies. GM will never be the only solution.

But if we choose to say no to GM, would we remain GM-free? If we are serious about being GM- free we should have zero tolerance, which would mean destroying seed or not importing it because there is no way we can guarantee every import of seed is not transgenic. We have had incidents already of seed contamination.

Australia and South America meanwhile are growing GM and getting an economic advantage. These are exporting nations we compete with in the Northern Hemisphere, countries with similar climates and similar timing for their products. So how will we compete if we are not using the same technologies or developing superior ones?

If our major markets refuse to consume GM foods, on the other hand, does that mean we shouldn't be following this technology? This might be fine now but what happens when the world shifts, GM becomes acceptable and we haven't been doing any work? Where is the future-proofing? As a country we need to decide how much we will invest in something that may not be palatable now but could be in two years.

Another point we can't ignore is that the knowledge of GM technologies is expanding exponentially. We ignore this at our peril.

As to whether the technologies are safe, I would point to the ever-increasing numbers of crops grown around the world and transgenic animals held in containment. Few issues, if any, are apparent, although critics of the technology will always cite the occasional paper that suggests there is an issue.

Obviously I have nailed my colours to the wall and declared I am cautiously pro, but I am not suggesting GM will fix all ills and I think it has been over-sold as a technology in the past 30 years. It was highly seductive when it first came along. But it is a powerful technology, nevertheless, and it seems arbitrary to exclude GM technologies while using some aspects of genetic science to – for example – do markers-assisted selection.

The over-riding question perhaps is whether the drivers and the information that the Royal Commission looked at for so long have changed in the last eight years, and if so, in what way. We should also be making tough political and economic decisions about GM, rather than leaving it to a difficult regulatory regime which has been described as one of the toughest in the world.

The current situation and

Government policy on biotechnology generally and genetic modification in particular has not changed, essentially, since the Royal Commission on Genetic Modification released its report in 2001. Because some 64% of the country's exports come from the primary sector it has always been clear that biotechnology would be important for the country.

The first professor of biotechnology in the world was established in Palmerston North in the mid-1970s. In 1983 the DSIR looked at the sector in *Biotechnology in New Zealand: a discussion paper*, noting biotechnology's importance to New Zealand because of its potential global economic impact and potential to add value to our core business of agriculture. The report anticipated that biotechnology techniques would enable the country to boost the productivity of its agricultural plants and animals and develop new products from biomass. Despite under-estimating the effect of biotechnology on the global economy (the DSIR predicted a global market of $250 million in 20 years whereas the market actually crossed $US2 billion), the report still looks prescient today.

A key milestone in biotechnology was the introduction of the HSNO Act in 1996, which came into force in July 1998. Until then hazardous substances and new organisms had been regulated by a confusing mixture of *ad hoc* committees and outdated regulations. The legislation was developed partly in response to a growing groundswell of public concern internationally and in this country over GM. The groundswell became a wave that affected the New Zealand political landscape in the 1999 and subsequent elections and led to the establishment of the Royal Commission on Genetic Modification in 2000.

The report set clear directions. Key themes were the need to preserve opportunities for New Zealand as the benefits became clear in terms of premiums for GE-free products and product growth through application of GM technologies. The commission endorsed the basic suitability of HSNO to regulate GM technologies. It said New Zealand needed to ensure it kept ahead of developing technologies and called for a comprehensive biotechnology strategy.

In 2003 MoRST released the New Zealand Biotechnology Strategy with the tag line *A Framework for development with care.* In well modulated bureaucrat-speak it envisaged a vibrant and responsible biotechnology sector contributing to the country's enhanced wealth, health and environment.

To achieve this, the strategy laid out three goals:

1. Build understanding about biotechnology and constructive engagement between people in the community and biotechnology sector.
2. Grow New Zealand's biotechnology to enhance economic and community benefits.
3. Manage the development and introduction of new biotechnologies with a regulatory system that provides robust safeguards and allows innovation.

MoRST has been working towards these goals since then and will continue to do so.

MoRST has undertaken a variety of community activities, including the Biotechnology Roadshow, the Future Farming Roadshow and the Future of Food Roadshow. The Biotech Roadshow, stopping in supermarket carparks and agricultural shows over a summer, had more than 58,000 visitors. The Future of Food was seen by more than 130,000 people in 2008. We also launched the biotech learning hub *www.biotechlearn.org.nz*, an on-line resource for New Zealand students and teachers to lean about biotech and New Zealanders' involvement in it.

We have a continuing programme to improve understanding of New Zealand's biotechnology regulations. We have developed the Biotech Regulatory Wayfinder, *www.morst.govt.nz/wayfinder*, an interactive on-line resource to help people understand and engage with the New Zealand regulations. We also monitor biotech regulations to ensure they do allow innovation while addressing risk in a robust fashion. We are developing a monitoring and benchmarking framework so we can improve the regulations and see how they match the effectiveness of international regulation.

This is a fine balance between the interests of groups with entrenched positions and often much at stake. GM regulation is one of the most contentious issues and I am tempted to apply what I call the Potter Principle – if everybody hates you, then you must be doing something right.

GM as a basic science tool is now well established and New Zealand has world-class and in some cases world-leading scientists in the field. The regulations for the use of "low-risk" GM in the laboratory and full containment appear to be working well. Some issues around an understanding of the regulations could be improved but researchers generally find the regulators approachable and helpful.

But very few agricultural or horticultural-related GM trials are under way. Different sector groups have different opinions about whether this is a measure of success or failure of government policy. If the New Zealand economy is to benefit from GM, however, then these trials will have to be conducted at some point.

Some research groups have taken their GM trials offshore. A number of groups feel that the New Zealand regulations are too expensive or onerous and they are better able to conduct their trials overseas, particularly in Australia and the United States. Disruption of trials by the public is also a factor in trials being conducted offshore. Again, opinions differ on whether this is a good thing. Public concern has also been raised by recent issues around approved trials – although much less than I had anticipated – which will not help ease the burden of the application of regulation.

No applications for full release of GM plants or animals have been made and New Zealand primary production is still effectively GE free. This is driven by the fact that no one has yet seen sufficient potential benefit from a GM product in New Zealand for them to take on the costs of the regulation and the effects of public opinion.

WILL THIS SERVE US IN THE FUTURE?

MoRST runs a Futurewatch programme to look over the time horizon for issues in science and technology that will affect New Zealand policy development. One key area for monitoring is the changing nature of farming systems. Looking at the trends, we see an increase in concerns around areas where GM plants and

By Dr George Slim
Director Emerging Technologies
Ministry of Research, Science & Technology

a future perspective

animals could have impacts, both positive and negative, including increasing demand for food, climate change, carbon emissions, involvement of multinationals and supermarkets in the food value chain, the rise of new pests and diseases, increases in salinity from irrigation, equitable resource management and ethical concerns over animal management.

We also see developments in technology that will enable a greater range of GM to be used – improved DNA sequencing and data handling, the merging of bio- and nano-technologies and a better understanding of the physiological effects of modifications. The increasing use of robotic harvest and processing may call for changes in growth patterns of our crops.

New economic opportunities are also arising that will be impacted on by GM. New crops for biofuels are the most obvious example, but also production systems are changing to call for less oil. There is increasing demand for 'clean technologies' which could be met by GM.

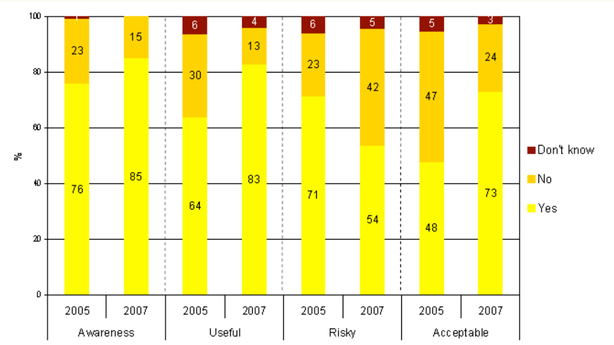


Figure 1. Australian public attitudes to GM Crops.

If we look at changing attitudes to GM crops in Australia *Figure 1* we see that in just two years, from 2005 to 2007, public perceptions of the risk of GM crops dropped sharply and perceptions of their usefulness and acceptability rose. What happened in those years? Drought. The public saw potential for a direct benefit from GM crops in addressing production issues in the "Big Dry" and their attitudes changed.

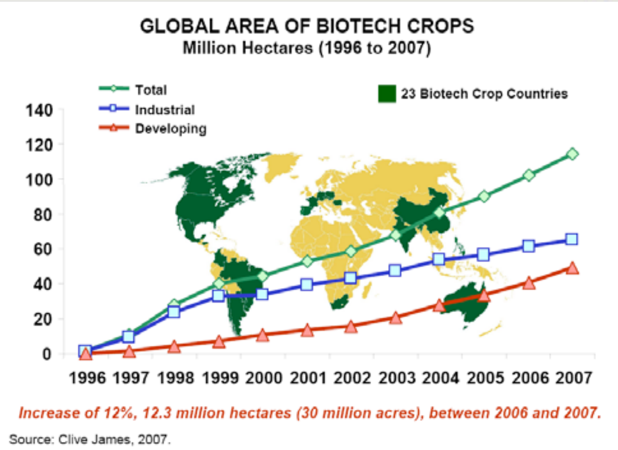


Figure 2.

Internationally we continue to see an increase in plantings of GM Crops *Figure 2*. This chart comes from the International Service for the Acquisition of Agri-biotech Applications (ISAAA), a lobby group for the uptake of GM crops. It has been disputed by the Friends of the Earth, among others, but their main issue was with the figures for Europe. The developing world figures have not been questioned and there is no dispute that the area of GM crops is increasing in developing nations, the USA, Canada and Australia. Despite all the discussions about the benefits or otherwise of GM crops, farmers in the developing world continue to buy them. In Australia, the US and Canada farmer groups are also claiming gains from the use of the technology and predicting increasing planting of existing GM varieties and introduction of new ones.

In its *Report on the Bioeconomy to 2030*, the OECD predicted that a number of GM products have a high probability of reaching the world market by 2030. These include GM plants with improved characteristics for biofuel production, plants and animals modified to produce pharmaceuticals and crops modified to produce higher levels of nutrients. Work on all of these areas is being conducted in New Zealand.

The OECD report also notes a mismatch between global research efforts and the likely economic benefits of the area of application. Table 1 shows that most of the global research effort

	Share of OECD Business Expenditure on R&D 2003	Share of Gross Added Value 2030
Health	87%	25%
Primary production	4%	36%
Industry	2%	39%
Other	7%	-
	100%	100%

Table 1. Global business expenditure on R&D vs. predicted share of gross added value due to biotech

goes into the medical area which is expected to give around a quarter of the expected benefit from biotechnology in 2030. The primary production and industrial production (including energy) areas which are expected to account for the remaining three quarters of the additional value from biotech are getting only 6% of the total investment in research.

This is not the case in New Zealand. While we don't have directly comparable figures for business expenditure in biotech R&D, around one third of the total government expenditure in biotech R&D is in the health area and around half in the primary production sector. Industrial biotech gets relatively little attention in New Zealand. Given the importance of primary production to our economy MoRST expects to maintain its importance in biotech research spending. This Government has show its commitment to innovation in the sector by its investment in the Primary Growth Partnership over the next four years.

In the end the adoption of GM technologies will be down to

consumer acceptance. If people are prepared to spend money on the technology, then the incentives are there to have it go through the regulatory process and be brought to market. Predicting consumer trends is fraught with difficulty and subject to vested interest. However, clear signals are coming from the international investment community that the GM technologies to invest in are bioenegy production, non-food crops and non-food products from bio mass.

In New Zealand there is considerable research into GM development of the forage that underpins our agricultural production systems. As New Zealand slips from being the world's low-cost producer will there be increasing demand from farmers to use these products?

From these signals we draw the following conclusions:

- The RS&T system will continue to fund research involving GM so long as it complies with the regulations.
- GM products are more likely to be accepted if they provide recognisable benefits to the public.
- The increasing range of modifications being made and public concern around issues such as climate change, the growing international demand for food and changes in farming systems means that this is increasingly likely. A change in market focus from GM conscious Europe to price conscious Asia may also drive change.
- New Zealand researchers are close to needing to apply for release of GM organisms to commercialise their products and we expect to see applications to ERMA soon.
- New Zealand-developed GM plants are progressing through regulatory systems offshore and could be available in overseas markets in the next few years.
- As GM plants are released into the environment, co-existence will become a more pressing concern.
- This all means the New Zealand legislation will be tested soon but until that happens it is hard to make a case for change.

As I said at the outset, the Government's overall policy on GM is the same as it was in 2001 and we have not seen signs of change. MORST will continue to try to make the policy work. GM offers the potential for considerable benefits to New Zealand, particularly in agriculture and horticulture but also poses considerable risks. As a government agency we will continue to preserve opportunities and go forward with care.

The HSNO Act and surrounding regulations – with their underlying principles to assess the risks, benefits and costs of introducing new organisms into New Zealand by allowing prior assessment of effects and risks to people, property and the environment before problems arise and to enable public and Maori input into the decision-making process – will continue to regulate GM in New Zealand – MoRST will continue to implement the New Zealand Biotechnology Strategy, by working across government to ensure that the regulations provide assurance while allowing innovation, encouraging the sector to grow and ensuring that the community is connected to the sector.

REFERENCES

Visit www.agscience.org.nz for the full version of this article including the references.

Obituary – Professor Sir James Stewart

Emeritus Professor Sir James Stewart was – successively – a student, lecturer, professor and principal at Lincoln University in the days when it was Canterbury Agricultural College, then Lincoln College.

Sir James completed his Diploma in Valuation and Farm Management, the college's flagship qualification at the time, in 1949 and joined the Department of Agriculture as an economist. But at the urging of his college principal, Professor Eric Hudson, he took up an assistant lecturership in farm management.

That began a career which resulted in his becoming the doyen of farm management education and research in New Zealand. In 1965 he was appointed New Zealand's first Professor of Farm Management and he became principal at the college in 1974.

Popular with students at all levels, he developed the case study approach to farm management as a lecturer and always went on field trips to enhance student learning. Today this is more likely to be referred to as experiential learning.

As a researcher, Sir James had a long and significant research association with Ashley Dene Farm, south of Lincoln, where he conducted pioneering work on light land pastoral farming, particularly the use of lucerne. His more significant work included a comparative examination of profitability on irrigated and non-irrigated sheep and cattle farms.

In the late 1950s he collaborated on a major research project examining the inter-relationships between investment and output in New Zealand agriculture and forged a close partnership with Bryan Philpott, foundation Professor of Agricultural Economics at Lincoln College, which led to the establishment of the influential Agricultural (now Agribusiness) and Economics Research Unit,

Late in the 1960s, he was one of the founders of the NZ Society of Farm Management, now the NZ Institute of Primary Industry Management.

He had a long association with South America, particularly Uruguay, and carried out consultancies in the Middle East, Indonesia, Eastern Europe and other countries for the World Bank, the UN Development Plan and the UN Food and Agricultural Organisation.

He was awarded the Bledisloe Medal by Lincoln College for distinguished contributions to advancing New Zealand's land-based interests in 1976 and was knighted in 1983, the year he retired from the college, for his services to agriculture and education. Subsequently he was became foundation chair of the NZ Qualifications Authority.

Both in this country and overseas he was a champion of access to education and life-long learning opportunities as a means of ensuring social justice and equity.

– Prof Roger Field, vice-chancellor, Lincoln University

By Dr William Rolleston
Chair, Life Sciences Network

An industry viewpoint –
why it's time to relax the regulations

Dr William Rolleston gives an update on global developments in genetic modification, then focuses on the New Zealand scene. Rather than try to debunk the myths he hopes the figures will speak for themselves.

The Royal Commission on Genetic Modification rejected a GE-free New Zealand. Its report said there was a future for genetic modification, subject to appropriate care. It said our regulatory system was robust and that we needed to proceed on a case-by-case basis. Finally, it said we should go for co-existence and that co-existence was possible.

The biggest issue facing the planet is the world's population of about 6 billion people. This is projected to climb to about 9 billion by 2050. To feed those people we are going to need to increase agricultural production.

But the availability of productive land since 1961 has dropped considerably. By 2050 it will have dropped even further.

We have a number of choices. We can curtail the population, improve productivity or just get more farmland.

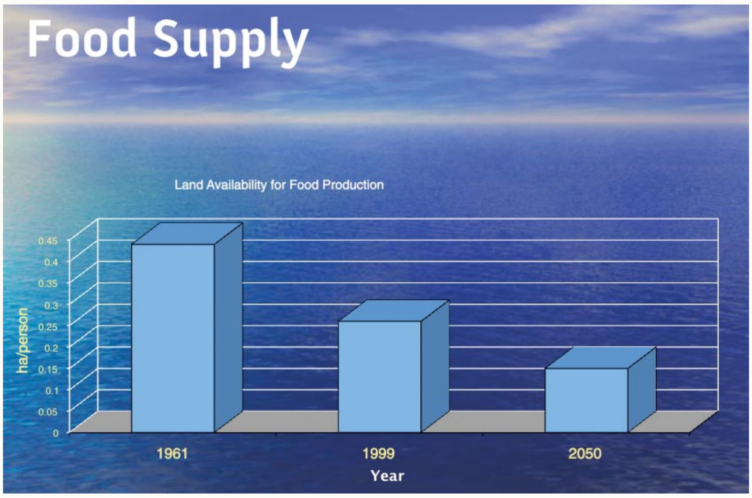
Genetically modified crops arrived in 1996 and are starting to spread around the globe. Seven European and three African countries are among those growing biotech crops. Australia has GM cotton and most states have approved the production of GM Canola.

It took seven years to plant the first billion acres of GM crops. The second billion acres took three years to produce. The growth is accelerating more in the developing countries than in the developed ones, which means they are catching up, mainly driven out of China and India.

The main GM crops are soya bean, maize, cotton and canola, none of which are grown – at least not significantly – in New Zealand (we do grow a bit of maize).

Herbicide-tolerance has been the most popular trait, but there is a trend now to put more than one trait into a plant.

In 2006 the first plant to produce a GM vaccine was approved. In that year – according to the American Bio website – more than 200 therapeutics using GM had been approved and 400 more were in clinical trials. Last year the first animal-produced therapeutic, developed by GTC Therapeutics, was approved.



The average wage in biosciences in the US is around 69% higher than the average wage across the country, so biotechnology is making a significant contribution in terms of adding wealth.

Looking at the private-sector jobs it is creating in the US, there was a bit of a dip after the .com crash but the growth is starting to pick up. Many of those jobs are in research and drugs but about 8% are in agricultural feedstocks and chemicals.

In terms of investment and leadership around the world, countries are taking biotechnology extremely seriously. India is spending more than $300 million. China has invested $3.5 billion, and that's just to produce or develop 15 biotech crops over the next 12 years. Brazil is spending a similar sum and it is worth noting significant levels of investment by the European Commission, even though we often think of Europe as being GM-adverse. But GM crops can play an important part in mitigating the effects of the global food crisis.

New Zealand spent about $US140 million on all our biotechnology. We have a long way to go.

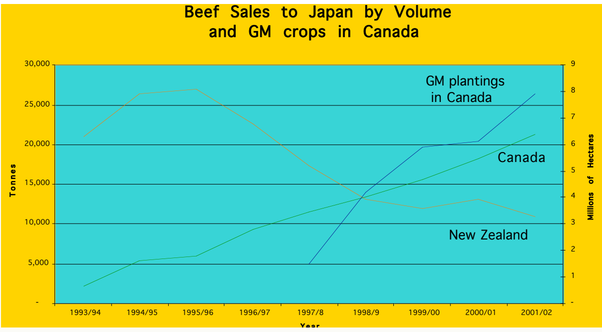
A number of studies give an idea of the benefits from biotech crops over the last decade. Principally, they show that yields have improved, that pesticide use has reduced and that income and profitability has increased. These studies are looking particularly at small farmers in the developing countries. The National Centre for Food and Agriculture Policy showed that in the USA biotech crops have increased production by 1.8 million tonnes, cut pesticide use by 20,000 tonnes and boosted farm incomes by US$1.5 billion. So the same benefits are being recorded wherever these crops are used.

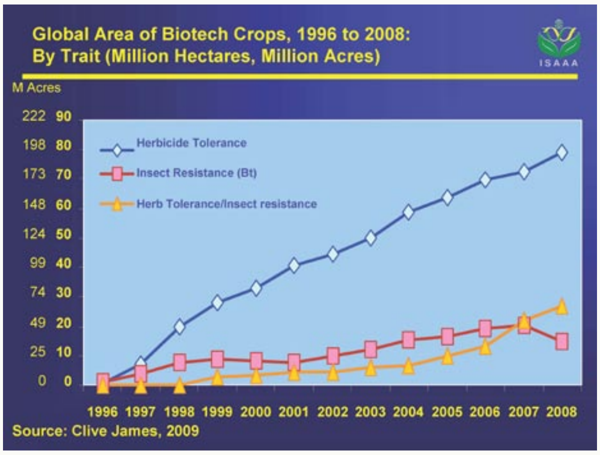
The great promise of biotech crops is food security and affordability by bringing down production costs. They could contribute, too, to the conserving of biodiversity. When you are producing more efficiently you don't need so much farmland to produce crops and therefore you are not draining wetlands, cutting down forests and so on to produce food for the world.

Biotechnology can reduce the environmental footprint of agriculture by improving nitrogen uptake, reducing the need for water and reducing the need for space. Biotechnology offers a tool we can use to help mitigate climate change and greenhouse gases and to produce cost-effective biofuels. It can improve

food safety and people's health, too. In China the number of poisonings from the application of agricultural chemicals has dropped significantly among farmers using biotech crops.

Adverse trade effects have been raised as an issue for New Zealand. The Australian Government's economic research bureau, Abare, undertook an in-depth study of the trade effects of biotech crops. Despite the perceptions of consumer resistance, it found, GM-producing countries dominated the world in the particular products they were producing. Canada did lose market share in Europe, due to the strict EU regulations, but picked up trade elsewhere. Europe is a huge importer of GM animal feed and when the EU passed its GM regulations, it made exceptions for products it was actually using, such as GM feed for animal production, and GM enzymes for cheese and beer production. Australia's advantage from supplying GM-free Canola will be limited as Europe eases its ban.





There are price premiums for GM-free foods, but they are offered in small niche markets.

Abare noted Canadian meat exports had grown strongly since the introduction of GM grains and oilseeds in the US and Canada. The effect on the Canadian milk trade was not so clear but Canada had a very small share of the world market and other issues were a factor.

During the debate on GM, I had a look at what was happening to Canada because there was a lot of talk about Canada suffering. The volume of GM plantings increased steadily from 1997 onwards. But despite Japan's GM-sensitivity, its imports of Canadian beef – most of it fed on GM crops – steadily increased too. The supply of New Zealand beef to Japan, curiously, has been steadily declining.

But as soon as BSE hit Canada, their exports to Japan dropped to just about zero. So in terms of real risk, BSE is a real threat but production of GM produce perhaps is not.

John Knight, in Dunedin, undertook a study just out of Cromwell where he was selling cherries. He sold organic cherries, GM spray-free cherries and conventional cherries and he looked at different price points at which people would buy or not buy. All the cherries happened to be the same and as soon as people walked out of the shop they had to be told this was an experiment and they weren't actually getting what they paid for. What was noticeable – and what wasn't put in the study – was that of about 300-500 people who went through, only one person refused to buy anything because there was GM produce in there.

The study did show that if Knight kept the prices the same, the organic bio-grow-certified product outsold the others. But you only needed about a 15% price differential to start changing people's buying habits. So price is a strong driver of what people will buy.

In Europe, meantime, consumer acceptability of biotechnology is starting to pick up.

Doug Powell of Geulph University in Canada, conducted an experiment in association with a local farmer Farmer Jeff . They grew corn under conventional and GM conditions and then had a roadside stall where Farmer Jeff explained exactly what he was doing. The GM product outsold the conventional by three to two.

But organics is a legitimate farming practice and a major issue is whether it can co-exist in New Zealand with GM. To address this question I looked at the organics industry in the USA – a strong user of GM technology. The acreage planted in organics was constant in the early 1990s at around one million. Since the introduction of GM in 1996 it has steadily increased, quadrupling to four million acres by 2005. A clear sign of GM's unpopularity one could conclude. However to put that into perspective, in the same time, GM crop acrage has grown from nothing to 120 million acres. These figures reinforce the popularity of GM crops but also show that organics can co-exist even when farmers are using GM in large numbers.

Horse influenza vaccine, a genetically modified live vaccine, has obtained approval for conditional release in this country. But the regulations have been subject to politicking. By 2008, the Labour/Green co-operation agreement was starting to make some inroads in slowing GM development. In that year there was regulation change governing what ERMA had to look at with releases and conditional releases of crops and further insidious rules were proposed about the time of the election. Most concerning was that under these proposals the Minister for the Environment could direct ERMA in terms of what it had to do, undermining the agency's independence and quasi-judicial role. ERMA's decisions would be subject to the whim of the government of the day. Fortunately we had the election and those plans have disappeared off the radar.

Last year we had a case of Plant & Food non-compliance and we have had the High Court judgement on AgResearch's GM application (which the CRI has appealed). In Northland, local authorities are looking at liability and are planning to introduce

another layer of regulation around GM crops.

The Northland Regional Council, significantly, has pulled out of that group so rifts are starting to show.

A big issue in New Zealand is the extent of the difference between our regulatory system compared with other overseas countries, especially with regard to low-risk laboratories. Significant costs are incurred in setting up a laboratory in this country and getting approval because of the need for a containment facility, regular audits, registers and an onerus reporting regime. Australia's low-risk regulations essentially say no approval is needed for using low-risk GM organisms, but you must not deliberately release them. The Australians have based that on the risk profile of particular organisms that have been dealt with in laboratories. For the last 20 or more years we had a similar regime here. But when ERMA was established, the reporting registers and the bureaucracy around setting up laboratories were introduced. There is a much greater emphasis on public hearings for GM development here, while Australia is much more focussed on the risk of a particular application.

It is important therefore that we look at our regulations and do some international benchmarking to compare what we are doing with what the rest of the world is doing and to determine what risks have actually been exposed around the rest of the world that indicate they are not doing it right but we are. I have seen nothing that would persuade me that Australia – for example – is taking a cavalier approach to GM in the low-risk areas.

But the regulations here do erode our capability in science. We are seeing projects being done overseas that are being hampered here. Our scientists are bound to leave for the countries where this is happening. Obviously this is reducing New Zealand's competitiveness, if other countries are taking up GM and – where there is a choice to use GM – farmers increasingly are using it. We also miss an opportunity to increase our productivity and competitiveness, although the Govnerment is focussed on improving productivity and competitiveness.

Several years ago I drew up a raft of opportunities that could be opened with GM. It hasn't changed much and focuses on pest control and animal feed production. Possum control using immunocontraception is still on the agenda, but a new way of tackling this problem could be through the use of meiotic drive to produce just male offspring and therefore drive a species to local extinction.

Also on the list is the use of fodder crops to produce more palatable plants that use less water – in Canterbury water is a big issue. If we can produce plants that will require less water, then more water can be kept in our rivers. Plants that use less fertiliser will also help, not only economically but enivornmentally in terms of leaching of nitrogen. Pest resistance, of course, is another opportunity which has been used abroad.

It is certainly important to note that the sorts of pests that afflict the main industrial crops overseas are not pests we have had here. That is another reason why those technologies haven't come to New Zealand – because we haven't had the same sort of pest pressure. It is clear though that pests such as the clover root weevil are costing the New Zealand economy hundreds of millions of dollars. Adaptation of GM technologies to deal with our local issues would be required and that is why we need local expertise.

Other opportunities lie in vaccines for diseases like Johnes disease and Tb, reducing greenhouse gases and our risk in terms of Kyoto. We should also be looking at biopharmaceuticals, biofuels and biodegradable plastics – these are all ways that can enable New Zealand to produce higher-value products from our agricultural base. Work is under way already to reduce spray use in onions.

The things we are unlikely to do are genetically modifying our animals, particularly deer, cattle and sheep, and crops like kiwifruit. We are more likely to modify fodder crops, the things those animals will be eating. And as we can learn from Canada, this will not have adverse trade implications.

To sum up, the biotechnology revolution is continuing apace around the world and there is a high uptake of GM in agriculture where farmers have the choice. The trade risks with GM are overstated and New Zealand regulation of GM is a barrier to our competitive development. We should relax the regulations to exploit the opportunities for GM to benefit not just our economy but the health of our people and our environment.

By Dr Geoff Ridley
Science Manager for New Organisms
ERMA New Zealand

Tweeting about ERMA, HSNO and GM

In our technological world where a huge amount of "information"' passes across our desks and computer screens, it is great to see the world embracing the succinct form of micro-blogging known as the tweet. A tweet is a communication made in 140 characters or less. This paper on GMO in New Zealand is an attempt to present some data and factoids, to make some observations, and to ask some questions in the form of tweets.

The term factoid was coined by Norman Mailer and refers to "facts which have no existence before appearing in a magazine or newspaper". Here it is extended to include the internet.

ERMA New Zealand is a regulatory agency and not a policy agency. It is our role to implement the law (Hazardous Substances and New Organisms (HSNO) Act).

In the 11 years of the HSNO Act nine approved field tests have been completed, and five either ceased before completion or were never started. Currently there is one active outdoor development and one field test, and one further field test approved but not started.

Only one GMO, in a vaccine, has been approved for release in New Zealand but has never been used. The current GMO situation in New Zealand could be described as 'a few cows standing in a paddock'.

Quotes from the media: "It is time to euthanase … current GE cattle, not add a macabre zoo to their unnatural and unwanted experiment" and "Sad for everyone, but why kill the tiger? It did nothing wrong". Why do they want the cattle killed but lament the death of the tiger when tigers have killed or injured more people in New Zealand then GM cows?

A factoid from the internet: "GM sheep die in New Zealand too. Thousands of sheep and goats died in New Zealand after grazing on GM cotton leaves and pods left in fields after harvesting. Deaths began after seven days continuous grazing." Cotton is not grown in New Zealand and there is no approval to grow GM cotton in New Zealand. This factoid has been on the internet for two years and is an example how long incorrect information can persist.

Quote from the media: "poorly managed field trials of ERMA-approved projects showed Government authorities were getting it wrong". Since 1998 there have been nine breaches of containment or non-compliance at GM field sites. Six were break-ins, and three were non-compliance with controls. No GMOs have escaped from outdoor containment in New Zealand.

With respect to the decisions made for GMOs over the last 11 years ERMA New Zealand has been taken to court five times. Three of these actions were dismissed and two were upheld. Those that were upheld were on procedural points and not on the decisions themselves.

The purpose of the HSNO Act is to protect the environment. In 11 years the HSNO Act has accumulated a plethora of amendments and regulations not all of which are compatible with each other and as a result is there a demand for irrelevant information?

Do our narrow regulatory approvals stifle innovation and serendipity? Is New Zealand being scooped? Is our transparent regulatory system a catalogue of research ideas for overseas workers?

Is the field testing of GM plants over-regulated because of perceived rather than real risk from gene flow? Any breach of a flowering control is a significant failure of compliance but is it a significant risk to the environment? Has horizontal gene transfer been blown out of all proportion?

It is claimed that the presence of a GM field test or herd of GM animals will have significant negative effect on our "clean green image" and therefore on our economy. Why is there no evidence or research to support or dismiss these claims?

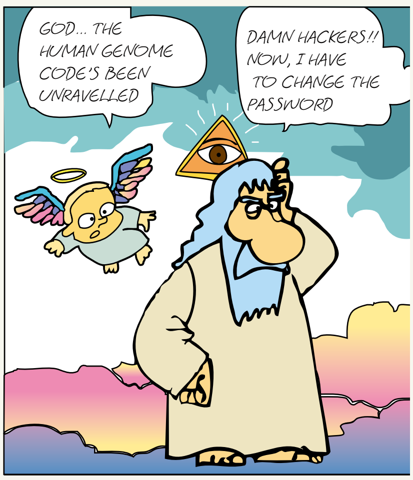
Quote from the media: "With the serious risks of genetic engineering, …are being reckless and damaging to New Zealand primary production, tourism and manufacturing's best value trading brands – clean and green and 100% Pure." Why is there no serious research done around the economic value of these concepts?

Should we regulate GM products under the HSNO Act? Is a jersey made from wool sheared from a GM sheep a GM product and does the jersey have an adverse environmental effect? Does pasteurised milk for human consumption from GM cows have adverse environmental effect? Does a highly refined compound that is a component of a medicine, derived from the infertile eggs of a GM chicken have an adverse environmental effect?

Are the products of transgenics, cisgenics and epigenics all equal? If not, which should and shouldn't be regulated and why?

Co-existence between non-GM and GM crops is critical if there are to be commercial GM production. However is coexistence achievable if a threshold or tolerance is not accepted and implemented?

Is it possible to conditionally release a GM crop for field research when it is too early to demonstrate any significant benefits to offset any risks and the field research is required to establish the benefits? Catch-22?



Why is it that New Zealand regulates low-risk research at a level that no other jurisdiction does? For example what is the environmental risk from a GM toad cell line?

ERMA New Zealand is the regulator and as such it is not its role to answer the many questions proposed above. Rather it is important to point out these questions and challenge the research and production sectors to find the answers.

By Dr Alan Stewart & Dr Derek Woodfield
PGG Wrightson Seeds

A plant breeder's view of genetic modification

New Zealand's primary industries generate around $18 billion in export earnings a year from animal products produced on grazed pastures. Our cheap, and yet high-quality, temperate pastures have enabled us to be internationally competitive but we are coming under increasing pressure from South America and Australia. The ongoing debate about the role of genetic modification in the species that underpin our economy is important.

On one side of the argument, we risk being followers rather than leaders in our uptake of genetically modified forages that could improve our competitiveness; on the other, we risk some markets using GM forages as a non-tariff trade barrier. The use of GM in forage species appears to be a safe and viable way of improving pastures and hence New Zealand's economic returns, particularly if the cisgenic approach is used: grass genes in grass, clover genes in clover. The public seems to find this as acceptable as GM-based medicines and the GM cotton that we all wear. Internationally GM fodder such maize, canola, cotton seed and soybeans are already widely used. Furthermore, GM research is integrally linked to the enormous expansion of biological knowledge driven by public funds and so essential to our scientific understanding.

Improvements in animal performance on farms can be achieved in several ways. First and most important, increased production can be achieved through changes to the farm system (eg optimal fertilisers, stocking rate, irrigation, and grazing management). However improvements can also be made through the introduction of new species, new symbionts such as endophyte, or through genetic improvements that overcome limitations (eg drought tolerance or pest and disease resistance) or increase the production potential of existing species.

Conventional plant breeding continues to provide many new cultivars with small but real incremental genetic improvement over time. Conventional breeding achieves this through the full range of methodologies available such as new germplasm (combined with new endophytes), recurrent selection, interspecific hybridisation, mutagenesis and polyploidisation, to mention a few tools in the breeder's toolbox. All these traditional methodologies can be supplemented by the use of molecular markers to track or introgress any desirable traits into cultivars, although this technology is only beginning to be successfully applied in forages.

Stable and heritable genetic variation for any given trait is a prerequisite to any breeding programme. Selection among this variation will result in higher expression of this trait over time. The rate of genetic improvement depends on the number of genes controlling each trait and the number of traits for which the breeder is selecting. In most plant breeding programmes multiple traits are required to develop successful cultivars. These programmes differ from GM programmes where the initial focus and expense is on one trait.

Breeders mostly are developing cultivars from the primary gene pools of elite material which usually include the best cultivars available. Further genetic variation can often be found in secondary gene pools of those difficult-to-cross wild relatives, however, and at times introgression of traits from these is necessary.

It is necessary to explore a genetic modification approach using genes and/or promoters from the same (cisgenic) or different organism (transgenic) only when genetic variation for a trait is either exhausted and/or cannot be obtained from the secondary pool.

There is no public funding in New Zealand for conventional breeding, despite a long track record for success, and there is an increasing dependence on commercial companies to fund this work. But there is some funding for germplasm exploration, endophytic fungi and scientific methodologies underpinning the science of plant relevance to breeding.

Conventional breeding is predominantly funded by commercial seed companies from the royalties earned on about $100 million of seed sales. Seed companies in New Zealand invest up to 10% of their turnover in R&D, a higher proportion than is normal across the country's industry.

This small investment in conventional breeding is the driver that underpins $18 billion of exports. New Zealand has a highly effective seed industry for delivery of traits to farmers but seed sales cannot capture the returns necessary for large scale R&D investments and it is unlikely the high cost of genetic modification could ever be met by the seed industry alone.

Biotechnology, on the other hand, is almost entirely financed from public funds and has been highly funded since the mid-1980s despite little contribution to cultivar development and no delivery of cultivars to date. To be fair, however, a lot of scientific knowledge has been

generated by biotechnology although the anti-GM environment in New Zealand and in some key markets has prevented some potential products being commercialised. Molecular maps have been developed of our major forage species and genetic markers have been developed and are beginning to be implemented for selection purposes. It has also allowed phylogenetic relationships of species, cultivars and germplasm groups to be more fully understood. Increasingly new technologies are being explored, such as tilling, which may also be valuable in the future.

A large part of the lack of delivery of cultivars has been due to "unforeseen complexities" but also because funding to take these innovations from the crucial proof-of-concept stage through the "Valley of Death" to commercialisation is absent. This is particularly apparent in terms of support to get these new technologies through the regulatory process, a process which no plant cultivar has gone through yet.

A widely touted claim by many laboratory-based scientists, at least in the early years, was that genetic modification would speed up breeding and eliminate the requirement for conventional breeding. This is plainly incorrect for forage species, because genetic modification does not reduce the requirement for conventional breeding to achieve a marketable product. A hemizygous founder plant with good expression of a novel trait is only a starting point of a backcrossing programme to the most elite germplasm possible. At times this founder plant will also have a selectable marker which has to be crossed out of the final cultivar, and – potentially – it may also have multiple gene inserts at different loci to complicate expression and backcrossing.

The timeline from a founder plant to a commercial cultivar is surprisingly long. It will require one or more backcrosses simply to eliminate potential inbreeding depression from the single founder plant. The founder plant effect could be significant and requires identification of elite performing plants rather than one chosen at random from a leading cultivar.

The backcrosses will have to be taken to the F2 generation in order to select plants homozygous for the gene of interest. These plants or their progeny will still need to be selected for field performance in a similar manner to traditional breeding programmes. This will require a two-year cycle at one or more locations before seed increase, plus the normal cultivar testing programme at multiple locations. This whole process would take at least six to eight years, depending on progress made and technical performance. Furthermore, regulatory requirements are highly likely to cause delays, particularly if crosses and evaluations must be done in artificial containment. This will further delay field breeding.

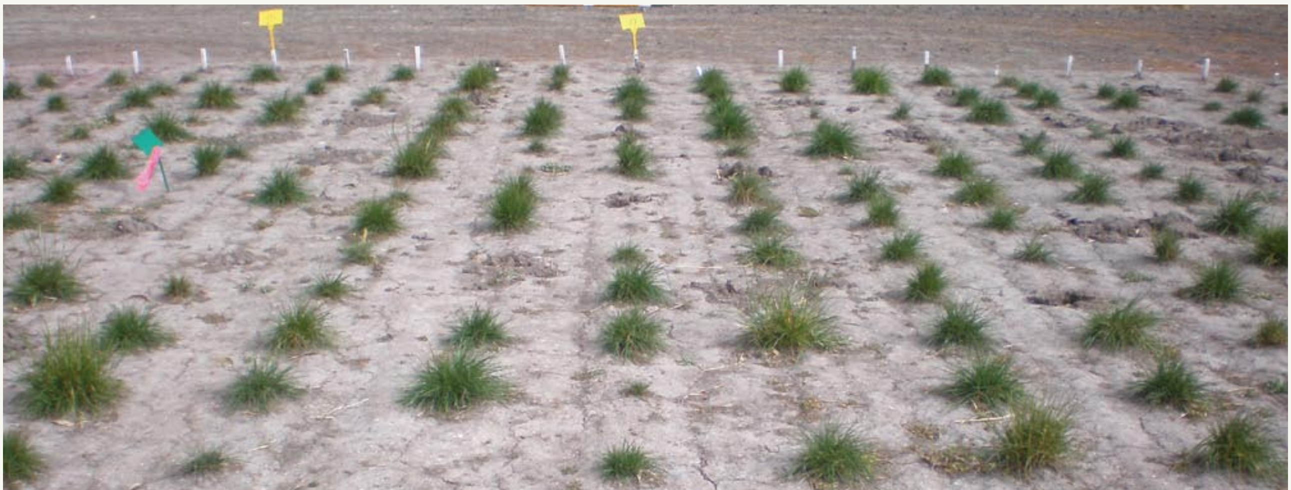
The GM debate in New Zealand has created a stringent regulatory environment that is a huge barrier to innovation. Although regulations are required, the current regulations are particularly punitive where low-risk genes are used from the species concerned, sometimes referred to as the cisgenic approach. In these situations the rearrangements of the genome may be less severe than those caused by mutagenesis or interspecific hybridisation methodologies that are unregulated.

These situations were not foreseen when the regulations were developed and need to be interpreted more leniently by regulatory bodies. This is particularly true when some gene constructs of this type could have large effects on forage production and hence animal product exports and our New Zealand economy.

The HSNO Act has also placed severe limitations on the flow and availability of new germplasm and organisms into the country. This has already had the detrimental effects of making some wild crop relatives almost impossible to use by plant breeders. This is particularly true when most introductions are of unknown value until studied. Where a species has a known value it is possible to make a viable case for import, although it is apparent this is not happening. New species introduced over the past 150 years have provided the foundation of New Zealand agriculture and the wider wealth of the country. Continued access to wild relatives is essential.

The stringent GM regulatory boundaries almost certainly mean that new GM biotech products will be field tested and commercialised overseas first. There has been much greater freedom to field-test GM plants overseas, although in many countries, such as the USA, the release of GM forage products has been difficult. Commercialisation of GM forage species is most likely to occur initially in South America, Australia or possibly China. New Zealand risks being a follower rather than having products that can improve our international competitiveness. Conversely, the risks of GM forages being used as non-tariff trade barriers to exclude New Zealand agricultural products must be taken seriously. In many situations this would be hard to justify, however, because many GM products and by-products are already widely used as forage throughout the world.

Because almost half our economy is based on pastures, New Zealand is in a unique position in the world. Therefore a production advantage is likely to lead to an economic advantage for all New Zealanders. It would be remiss of us not to attempt to use the best scientific knowledge to improve pastures, including GM technology.



Over 10 years ago Wrightson invested in gene discovery with Genesis, resulting in an EST database, numerous gene sequences and patents, and the search for a suitable biotech partner who could use these genes to develop GM cultivars for improved pasture quality. This resulted in the joint venture company Gramina based in Australia. Despite large corporate changes for Wrightson, this project has continued to focus on developing ryegrass cultivars for Australian conditions with higher expression of fructans and tall fescue cultivars for South America with reduced expression of lignin. Potential founder plants are now being field-tested in Australia.

Although they are likely to be commercialised and proven in Australia or South America before New Zealand, the benefits of both technologies could be greater in this country. It is also likely that uptake of such technology could be rapid if it provides real benefits, perhaps in a similar way to the rapid uptake of AR1 endophyte technology.

SO WHAT LESSONS HAVE WE LEARNED FROM OUR PARTNERSHIPS IN THIS AREA?

First, it is essential to have a partnership between industry and research. GM-based projects are expensive and require industry support.

There are genes and traits (often within the species) that can provide enhanced environmental and animal performance, some also offering human health benefits.

Many forage molecular biologists have been overly simplistic and optimistic. Their predictions have been unreal and we can go back and quote many instances where cultivars have yet to be delivered. For example, the enrichment of sulphur amino acids in forage to promote wool growth was not successful and the development of rust-resistant ryegrasses using somaclonal variation. Pest resistance using Bt genes has been proven in brassicas and other crops but has not succeeded in clover. Roundup Ready herbicide-tolerant lucerne has been successfully developed in the USA but so far has been blocked from delivery to the market. GM crops nevertheless are enormously successful in the world.

Many plant breeders have not made an effort to understand the technology and hence the technology has usually been driven by scientists with little understanding of the cultivar development and field requirements. These scientists also have a limited understanding of the farming systems in which their GM products will be used.

Genetic modification does not reduce the need for strong conventional breeding programmes. In most instances GM technology will deliver a founder plant that requires more breeding input than conventional breeding programmes. The successful delivery of GM cultivars will require an integrated programme of GM science and conventional breeding.

With the benefit of hindsight, it is clear that many GM projects have turned out to be more complex, slower, and more expensive than anticipated at the beginning. At times, furthermore, the regulatory requirements have been more constraining than anticipated.

The combined technology and regulatory costs mean that this form of biotechnology is limited to large-volume species and markets. This itself has many unintended effects on cultivar diversity, breeding programmes and germplasm development.

Much of the opposition to genetic modification is based around the existing products and large agribusiness approaches to agriculture. This is not a consequence of the regulated GM process but more a consequence of the traits used, many of which would have the same consequences if they were developed using non-GM means.

WHAT ARE THE BIG OPPORTUNITIES FOR NEW ZEALAND AGRICULTURE?

Despite criticism of the techniques, scientists and regulatory situation, New Zealand has an opportunity to develop forage plants using genetically modified and similar precise biotechnology techniques. The focus must be on high-impact traits that cannot be achieved through conventional breeding – traits which can reduce environmental impacts of agriculture including those that help mitigate climate-change effects through greenhouse gases or environmental nitrogen losses. Traits such as fructans, lipids, and condensed tannins are all potentially helpful in this regard. Value-added traits which can improve the product value of meat or milk would be immensely valuable as for example, any lipid trait that can alter the proportion of unsaturated fats in the product. Lastly, large increases in animal productivity on-farm are immensely valuable to our economy. These may relate to large increases in forage yield *per se* or traits such as drought or pest tolerance which may improve productivity during critical period.

CONCLUSION

Forage plant improvement offers New Zealand large economic benefits. Genetic modification and other newer, often unregulated, biotechnology techniques have a role within the overall plant breeding framework. To date conventional plant breeding has delivered all of the forage cultivars for New Zealand agriculture and yet it lacks any substantial Government support. The science of biotechnology has been highly funded by Government and although it has resulted in scientific publications it is yet to deliver a cultivar. Sadly, some of this investment has been at the expense of conventional breeding. To this extent better integration is required between the two areas. However, while funding and regulations are targeted largely at technique and the science employed rather than the outcome, this may be difficult.

REFERENCES

Visit www.agscience.org.nz for the full version of this article including the references.

Why GM – in containment –

Dr Zac Hanley has been working in the field (and the lab) for nearly two decades and says "I am working for the country's benefit when I do this work." His brief was to discuss plants and the genetic modification of them.

At a conference in Cork, Ireland last year Professor Denis Murphy lamented that the industry has promised to deliver gains from genetic modification (GM) to people "in 10 years time" for the last 10 years. I believe we can speed up the process with events such as the NZIAHS forum on genetic modification.

Pictures of a glorious far-future GM utopia, with plentiful food and Elvish tree-house lifestyles, have been painted for years. Meanwhile, critics have predicted a genetic apocalypse that would arrive on the same schedule, with harvests dead in the ground or killer plants stalking the streets. Neither happened, nor are they going to happen. Nothing even like them is going to be true. We inevitably and unfortunately make systematic errors in predicting the future. It turns out that the best way to find out what is going to happen in ten years time is to wait ten years.

One of the errors of prediction is what futurist Alex Pang has called the Nunberg error, after the man who first spotted it. This happens when we assume that only the technological change we are interested in will affect the future, and nothing else. In 1950, *Popular Mechanics* magazine published an article predicting the future, saying that by the year 2000 everything in our homes could be waterproof and so the "housewife can do her daily cleaning with a hose". Their Nunbergian vision of 2000 was really 1950 with waterproof sofas, not 2000 at all. This same flawed foresight has been used to tell us what GM will bring. Whether the pictures painted are good or bad, it is all hype and it is all wrong. We make the Nunberg error when we predict that the future is the same as today but with Golden Rice, or the same as today but with all food grown organically.

The opposite of the Nunberg error is to predict that everything changes when one technological change occurs. We see this in the GM debate too. For example, there has never been a claim for genetic apocalypse that is scarier or has less credibility than the purported genetic modification that could "destroy all terrestrial plant life", which was documented and discredited in the detail of the Royal Commission on Genetic Modification report (p166).

MUNDANE MODIFICATIONS

What some genetic scientists working in New Zealand are trying to do is provide stronger foundations for our existing agricultural production systems. While our systems are good, they are neither perfect nor sustainable in the long term. We can keep building on the strengths of our system by enhancing its biological underpinnings. While others may claim GM techniques could do some wonderful things and build a heaven on earth, I am only interested in something as mundane as making sure that the system we have got works better. Tomorrow's farms should look like today's ones – only better, more efficient and more effective.

GM technologies are available in more varieties than is commonly understood. GM's successes to date have been where genes have been moved from one species into another. The possibilities are huge and the range of options enormous thanks to the large volumes of gene information gathered in the last decade. At times it has seemed that humans could turn their imagination to just about anything – another example of over-prediction. Great expense is involved, and at times some multinational or trans-national corporation can end up in charge. That's a problem for some people and has led them to dismiss the technology as merely a tool of the corporations. Anyway, things can be done differently – we have learnt a lot in the past few years.

CURRENT AND FUTURE SUCCESS

So what is the status of GM in plants around the world that have been bred using this approach? The world area planted with GM crops increased by 11.3 million hectares between 2007 and 2008 (the North Island – by way of comparison – is 10.7 million hectares). That is an increase of around 10% and means that more than 100 million hectares of GM crops have been planted every year since 2006. And yet some people claim genetic modification of plants is not successful!

Success must be measured in more than just hectares. There are plenty of detailed reports supporting both sides of the debate

By Dr Zac Hanley
Chief Scientist, Pastoral Genomics
ViaLactia Biosciences NZ Ltd

deserves a second look

whether agriculture has been improved by the first wave of GM plants. It is important to read more than just the summaries, which might, for example, make strong statements about how GM crops have "failed to yield", but if you read on you learn that even the anti-GM authors are compelled by the science and the data to admit the successes (*Failure To Yield*, Union of Concerned Scientists, 2009).

Brookes and Barfoot (2009) strike a more impartial note, going into detail on a country-by-country basis. They identify where there were "failures to yield" and "successes to yield". Failure to increase yield, however, often represented real gains for farmers because they adopted lower impact farming practices that preserved land, required less expensive inputs and were more sustainable.

Roundup Resistance and the issues around it prompt headlines, mostly negative or even apocalyptic. These plants have been around since 1996 and continue to be very successful at increasing yields, or maintaining them with less management, and decreasing overall chemical usage. The other headline favourite, the insecticide produced from the Bt gene (and its variants), was proven effective by the organics industry over the long term, for which inspiration genetic engineers are grateful. Bt cotton in India is an unequivocal and resounding success: pesticide use has halved, yields are up and farmers have voted with their wallets, making Bt cotton uptake one of the fastest rates of adoption anywhere in the world. Authors of reports on GM, whether for or against, admit these facts. It is unfortunate that, while the successes and economic gains are spread over many farms around the world, the most prominent successes and profits land with large multinationals – this is discomforting for some but should not be the only factor when determining the benefits of GM technology.

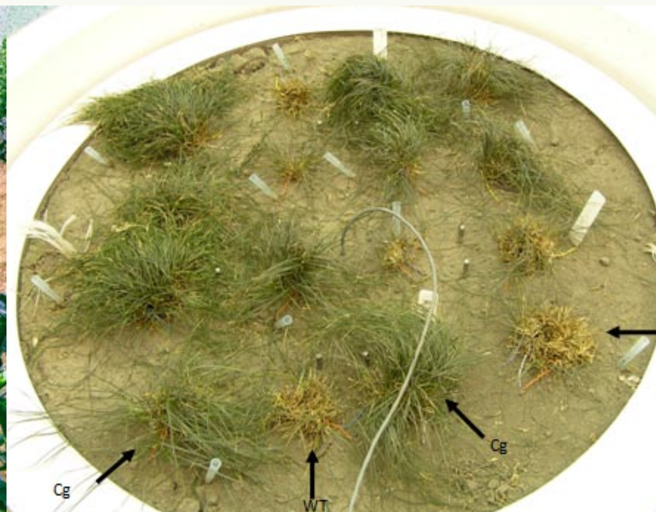
MANY KINDS OF GENETIC IMPROVEMENT

Genetic changes are continuing, natural, random and sometimes dramatic. Teosinte, an unimpressive little plant from Mexico, crossed naturally with some other species and then underwent dozens of generations of breeding and selection. From this humble beginning came maize. At each stage 30,000 genes from one plant were mixed with 30,000 genes from another. This means millions of genetic combinations were tried out and tested without long-term planning or regulatory oversight. That was an enormous and enormously successful genetic experiment far larger than any of the limited and carefully planned studies of single-gene changes the scientific community is undertaking today.

Ryegrass, of course, was introduced to New Zealand over a century ago, but a genetically doubled-up version (a tetraploid) was not available naturally in this country. With chemical treatment, it is possible to artificially double the chromosomes in ryegrass and go from 30,000 genes to 60,000 genes. Should we regulate such a drastic change? We didn't. This was first carried out years ago and is now a major contributor to farm production, is available in seed stores and garden centres, is wholly unregulated and has been allowed to spread up and down the country. This unregulated genetic experiment held right here in New Zealand has also been wonderfully successful.

Then there is the famous Flavr Savr tomato, where one single gene change was made, using a tomato gene in tomato. I would argue that the possible outcomes of this particular change are much less than the doubling of chromosomes in ryegrass or the sweeping changes that took teosinte to maize, yet a GM tomato is viewed with much more trepidation by some. The problem with Flavr Savr is not that it is genetically modified but that it is a lousy-tasting tomato. It seems inconsistent to me that we spend so many hours, headlines and legislative efforts on such changes while the breeders, in the time since Flavr Savr, have made many more (and admittedly tastier) changes by "conventional" means.

For some, using intragenics or cisgenics is an upgrade over the transgenic technologies that have been so successful. It provides another string to the genetic engineering bow. Genes from within the species are used, rather than choosing genes that confer beneficial traits from anywhere in the kingdom of life. The possibilities are therefore more limited. Tree genes can only provide traits to intragenic trees that trees already possess; maize genes can only help maize do things it already does. This rules out new abilities such as herbicide resistance or insecticidal proteins but not growth or drought-tolerance. Trait precision is higher, not necessarily as a virtue of the technology but more likely because we have learned a lot more while working on this in the past 10-15 years. I favour this approach.




ANNA SMYTH

Genetic modification

A STRENGTH WE HAVE in New Zealand is that we can discuss issues like genetic modification and typically have a sensible conversation. Hence, while the scientists who use GM technologies are strongly opposed by people who see no benefit in it, the two sides can typically enter and maintain a reasonable dialogue. This is a decided benefit, especially when it comes to understanding the complex issues surrounding the genetic modification of animals. However, in a recent case involving the Crown Research Institute (CRI) AgResearch, the Environmental Risk Management Authority (ERMA) and GE-Free New Zealand, the dialogue broke down and GM finished up in the courts. The outcome was that both AgResearch and ERMA were reprimanded by the High Court as they upheld action brought by GE-free New Zealand and struck out AgResearch's applications to import genetically modified material and undertake GM trials in New Zealand on several species of animals1. I believe this defines a low point in how we manage GM research in New Zealand.

AgResearch had made four applications for research described as a "veritable zoo of genetic engineering", in that they wanted to develop or import GM cows, buffalo, sheep, pigs, goats, llamas, alpacas and horses. According to press reports, Dr Jim Suttie, the manager of the project at AgResearch, said "we believe this is necessary to secure for New Zealand the opportunity to do this type of research and provide options for the pastoral industry." I can't dispute that statement. We do need access to this technology.

On the other hand John Carapiet, from GE-free New Zealand, said the Royal Commission into GE in 2001 and subsequent Governments did not want an "anything, anywhere, anytime" approach to GM research. They wanted a case-by-case careful assessment of the risk and the opportunities. He is correct, too. The Royal Commission's report certainly reflected the absence of public will for scientists to be able to do whatever they want, whenever they like, and the High Court was therefore unlikely to give *carte blanche* to AgResearch on such a wide front.

So where does that leave us? I think as confused as ever, because the law doesn't really assist us in discussing and deciding what we do with GM animals in New Zealand. In effect the basic tensions remain between those who want to use GM and who argue about its benefits and those who don't want a bar of it, and I see little prospect of change in this. What is more, trying to litigate GM research is fraught. To understand why I say this we need to know more about the history of animal GM in New Zealand.

Internationally we have had transgenic organisms for about 40 years and transgenic animals; the first ones were mice, for about 30 years. The technology is no longer that new, although in animals it is not that well developed either.

One of the key methods for creating GM animals remains the injection of foreign DNA through a fine needle into the male pro-nucleus of a fertilised egg. If you are lucky (the success rate is about 1%) the egg takes up the foreign DNA and can be implanted into a recipient animal. This may produce genetically modified or transgenic offspring. Animal scientists certainly don't have the same assortment of technologies as those working with plants, where far greater GM developments have been made, but this technique works and it can be used to put foreign genetic material into animals.

Using this technique, New Zealand's first GM sheep were produced at Lincoln University in 1993. This work preceded ERMA and in fact much of the modern outcry about GM. That stated, the research ceased more than 10 years ago and the sheep are gone. These GM sheep did produce marginally more wool as hoggets, but if you know anything about the value of wool now, you will understand the economic benefit wasn't great.

GM research involving animals is now being undertaken at other universities, at the Malaghan Institute of Medical Research in Wellington and obviously at AgResearch. Various types of experimentation are being undertaken, ranging from the importation and creation of genetically modified lines of immortalised animal and human cells, through the creation of transgenic mice to modified large animals such as was historically undertaken at Lincoln and as occurs now at AgResearch. Mice are probably the most commonly genetically modified animal in this country (by type of experiment and not by number) and typically they are produced as model organisms for understanding human disease and biochemistry. Cattle, sheep, salmon, fruit flies and blowflies are among other animal GM that ERMA has approved.

In approving this work ERMA will ask why a research project is being done. Responses vary, but as an example, the University of Otago and collaborators at the Malaghan Institute and Auckland University sought approval to import into containment 35 strains of genetically modified in-bred mice. The purpose of the importation is to conduct research into several areas of experimental immunology and disease treatment. The mice are to be used in experiments to "model different types of disease such as cancer and multiple sclerosis", while also more generally being used "to help our understanding of biological and immune responses". This probably summarises where the majority of our animal GM work has been occurring historically. It is all

By Assoc Prof Jon Hickford
Department of Agricultural Science
Lincoln University

# of animals in New Zealand revisited

undertaken "within containment", which for larger animals is fairly easy to ensure because a missing cow will soon be found. That stated, the containment of blowflies and fruit flies is more difficult and some levels of containment perhaps aren't as watertight as we would like to think.

In the last few years, ERMA has become aware of the compliance costs it imposes bureaucratically on scientists in New Zealand in approving this work and has suggested applications be amalgamated or clustered into larger applications. There are certainly efficiencies in processing a large number of projects in one large application. That would be why the Otago University application covered 35 strains of mice and why 35 individual benefits, each of them the same, are listed in the records. The approach of bringing several projects together into one big application therefore probably underlies AgResearch's plans to apply for a "zoo of animals" to be experimented on genetically.

To get a better perspective on what is being done in New Zealand, we also need to contrast our relatively small investment in GM animals with overseas efforts. There are many examples. For better or worse, zebra fish genetically modified to glow are coming to pet stores around the world. The University of Guelph in Canada believes its pigs will be the first genetically modified animals to enter the food chain (and chances are the bacon you had for breakfast was from Canadian pigs, not home-grown ones). That could mean that in a few years we are asked to accept GM pork from Canada. In the US, Department of Agriculture researchers have used gene-transfer technologies to produce dairy cows that resist mastitis. Mastitis ranks about number two as an animal health issue in the New Zealand dairy industry after lameness, so this may well be of benefit to us, but will we ever accept the use of the technology?

From a New Zealand agricultural perspective, applicants to ERMA for animal GM approvals inevitably argue there will be future benefits to our pastoral economy. They are quite enthusiastic about this at times. However, offsetting those pleadings are a raft of public concerns: concerns about animal escape and environmental contamination, the loss of our perceived "clean-green" image and export markets, the perceived risk of GM animals entering the food chain and the impact on public health and animal welfare of GM, the lack of transparency in the regulatory system and the perception of overseas corporate benefit and control of "our" farms and production systems. That stated, I believe there is a lot of water to go under the bridge before any GM animal development in this country gets anywhere near a non-contained paddock, let-alone your plate.

In this respect, ERMA currently has to deal with the same basic problem that confronted it when it was established. Under New Zealand law (the HSNO Act) genetic modification is essentially allowed and in the absence of quantifiable evidence that something is actually harmful, it will therefore be undertaken in this country. Given that it is impossible to prove that anything is absolutely safe, however, doubt will always exist in many minds about the safety of GM, or at least until it is so common as to be run-of-the-mill or clear evidence of danger emerges. It can therefore be argued that litigating GM in court is pointless, because the arguments sustained either for or against will be weak and uninformed. This – ironically – is one of the reasons why scientists do research, to get better information about phenomena, man-made or otherwise.

Jon Hickford

Jersey Cows, Uruguay

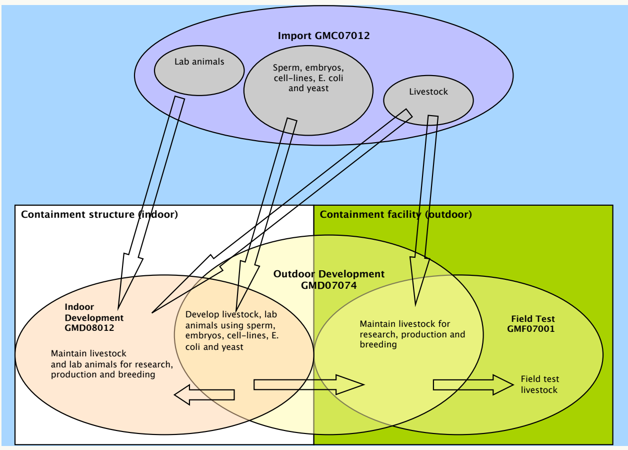
Charolais-cross cattle
Nimrod Downs, Mt Nessing

Robert and Jenny Hobson

Because the HSNO Act basically allows GM research, GE-free New Zealand and The Soil and Health Association will almost always be dissatisfied with ERMA and the processes they administer. After all, ERMA's activity is in many ways nothing short of a rubber-stamping exercise, albeit a convoluted and drawn out one. Cynics probably argue the only real role of the processes is to slow down the inevitable approval of GM applications, while giving the appearance of consulting and heeding public opinion. But at what cost?

A huge and arguably unpopular bureaucracy has been established and probably unnecessarily as we regulate GM, in the absence of any sound scientific argument as to why we should. Confidence in ERMA is accordingly undermined and it therefore falls foul of both the anti- and pro-GM lobby, the latter because of the direct cost it imposes on their research and because of its policing (through MAF) of the regulations.

AgResearch ERMA application flow chart



To illustrate the bureaucratic cost, my laboratory is visited every few months and inspected because we use what is internationally deemed to be a 'low-risk' GM technology and in a very strict containment. I am routinely asked among other things where I am storing my GM organisms. I routinely answer that we don't store GM organisms, but I don't think I am believed, even though the GM bacteria we produce are

disposed of by autoclaving within days of their creation. We use these bacteria as a way of engineering DNA for genetic analysis and not because we want to store them. Nevertheless, we still get put through the regulatory wringer.

Do we actually need GM animal research? The medical research case seems compelling and in my experience there seems to be little anxiety about what is being done. After all, mice probably don't rate highly when ethics are concerned, and the mention of cancer, heart disease, diabetes and so on play upon the public sentiment. Could we just ban research on GM livestock? This seems to be a popular idea in some quarters, including apparently among some members of the farming community. While it could be claimed that they don't know the potential of the technology, I would not want to question the scientific literacy of our farming community. That stated, their argument seems to be based primarily around how the use of GM livestock "may" affect our markets and not any scientific argument as to it relative safety. I will come back to this argument shortly.

Banning some forms of animal GM (such as livestock modification) and not others would probably require legislative change. Once again in the context of a dearth of scientific evidence of harm accruing from large animal GM, the legislation would have to be rationalised on opinion (that is, we don't want to do it to livestock) and not fact (that there is something fundamentally wrong with doing it). I also suspect we would be left wondering if we are just burying our heads in the sand on this issue, and whether we are missing an opportunity (such as better ways of controlling mastitis in dairy cows as described above). Certainly it would put us at odds with developments elsewhere in the world, including with some of our major trading partners. We would also run the risk of losing scientists who work in this area, although the anti-GM lobby would probably argue this is a good thing.

So for now, AgResearch has failed itself and primarily because it put up the applications without highlighting explicitly the benefits that would flow from what it was planning to do. Regardless of the arguments mounted, any appeal will be costly and it is inevitable that precious science dollars will be spent on the litigation. In the process, I feel science and scientists will be further marginalised in the public eye, something we can ill afford given the importance of science in a developed economy.

I also believe we need to be less enthusiastic (some might say evangelical) about the technology. It has in some respect been sold as the panacea for everything. It isn't, and I believe it has been massively over-hyped, especially with regard to its benefits in animal production. AgResearch admits as much. In a scientific paper authored by an AgResearch staff member it is stated that "While various transgenic concepts for genetic improvement in livestock animals for agriculture are being evaluated the integration of this technology into practical farming systems remains some distance in the future." It is my belief, that it will be some time before we see these things producing better lamb chops!

I shall end with a cautionary tale, explicitly about why the counter argument of maintaining a GM-Free status and therefore a supposedly better market position with our livestock industries may be fraught. In 2007/08 the sheep farmers I work with were getting around $50-$55 for a lamb. They weren't happy. In 2008/09 lambs fetched $90-$120 and some people were getting up to $150 at the works. This has been driven by a number of factors including reduced competition for our meat, increasing demand in Europe and by a favourable change in the exchange rate. Despite some people placing great faith in it, our "clean-green" image did not radically change for the better in that time. I therefore think we need to be very cautious when we claim that a clean-green image or for that matter being GM-free will be the reason why people buy New Zealand lamb. This is unknown territory in the market so it could be dangerous to underpin the future profitability of our lamb industry on the GM-free claim. Equally, if that GM-free claim gave us a market advantage, but no tangible evidence could be provided of why being GM-free was a benefit to the consumer, then our competitors and their regulatory watchdogs may see fit to question the validity of our apparent marketing edge, while also looking more closely at other things in our production system that might be embarrassing to us.

Let's not lose sight of the fact that GM research may provide benefits. We certainly should contemplate this when researching how to control such things as rumen methane production and nitrogen metabolism in livestock. These are major problems in our livestock industries and things for which we must find solutions. The path forward will not be easy, whether we have GM research or not.


David Hollander


Hereford Bulls, Uruguay
Jon Hickford

As of January 26 2010 AgResearch plans to challenge that decision in the Court of Appeal.

By Dr Karen Cronin
Science Leader (IRIS)
Environmental Science & Research

New Zealand attitudes to genetic modification revisited: how to influence the psychology of risk

Social research in New Zealand and internationally has given us a clear understanding about attitudes to genetic modification. Public attitudes to GM in this country are consistent with those around the world; they have largely stayed the same over the last two decades and they incline towards risk aversion. However, the level of risk aversion will depend on what kind of biotechnology is involved, its application and social purpose.

Risk attitudes to GM are similar to risk attitudes to new technologies generally, so there is nothing remarkable about the public reaction to GM; in fact it is possible for social scientists to anticipate public responses to emerging new technologies based on their risk characteristics.

When the GM discussion was at its height 10 years ago it was often seen as a 'pro' or 'anti' debate – people either whole-heartedly supported GM because it was brilliant and would save the world, or there was outright hostility because GM was evil and must be stopped. The spectrum of views is actually quite wide, and it is worth delving into opinions in between the extremes. It was also assumed that scientists and the public held totally opposing views about GM. My research and that of other social scientists in New Zealand has shown that the public are more concerned about some GM applications than others, and this is much the same for scientists.

So what can we learn 10 years on? For communication to the public about GM to be effective, it should not simply be about persuading the public with technical facts. It requires a deeper understanding of the drivers of risk perception and risk acceptance. The same applies to understanding farmers' perceptions, or regulators' perceptions, or industries' perceptions, or scientists' perceptions. We need to dig deeper to understand what is driving the discussion on all sides. My key message today, therefore, is that successful communication requires listening as well as talking. There are ways of doing this, even with difficult science issues, by using the principles of dialogue.

Let us go back to the beginning of the GM debate. The GM issue triggered widespread outrage, internationally and in New Zealand. People went marching on the streets, opinion polls showed that the general public were concerned, and government intervention became necessary to moderate what had become a conflicted social debate. Since then we have moved into an era where scientists are showing greater interest in engaging with people. This is an improvement on the past, when the issues were mostly played out in forums such as regulatory hearings and the courts. If society is to celebrate scientists, and see their work as doing good, much more effective and sophisticated communication is needed. So how can we do this and create more constructive public debate when technologies come on stream, such as GM?

Scientists need to be more aware of the approach they are taking in relation to society. When we want to develop a new area of science, what kind of communication strategy do we use? Do we just press ahead with a new technology, arrogantly assuming the public won't notice because they already have too much to worry about – their mortgages and so on? Some people advocate this strategy. Others think we should carefully move forward in stages, and bit by bit the public will become accustomed to a new development and won't make a fuss. Many scientists believe we should aim for an education approach, targeting the public with facts and data to try to raise their understanding of the topic. But should we assume that education will alter the public's concerns, and should we assume the response is simply based on fear?

When scientists and experts find they are not making much progress with the facts, the next step is often to identify how the public believes its interests could be served and people could be better off as a result of a new technology. So we start looking for benefits to be attributed to the proposal, particularly personal benefits so there is an immediate payback. This happens in marketing approaches to science communication, especially in the food area – the emphasis goes on a personal payback for customers, rather than generic public health issues such as diabetes or obesity. More recently, communication strategies have aimed to promote public benefit in terms of environmental outcomes.

These strategies have all been used in the past for influencing the public's response to new technologies, but I doubt if any of them will change public perceptions of GM because they under-estimate the drivers of risk perception. They are not delving deeply enough into what the debate is about and the underlying issues.

When we examine people's responses to technology proposals in detail, some key factors become apparent. Different technologies and different proposals raise different risk issues: some technologies may raise economic or social questions, or challenges about how we run our agriculture or manufacturing systems. Some technologies may raise ethical questions. Any technology carries a raft of attributes and risk characteristics – and so it not simply a technical matter, it also has a social dimension. Many responses to new technologies come down to a few well understood dynamics, which can be understood from the psychology of risk.

People will be averse to a technology if they have a sense that they lack any personal control over it or feel something is being imposed on them. Risk aversion will be much higher if the technology is unfamiliar and never before experienced in a community. Risk aversion will be higher if the technology is similar to or evokes memories of something we do know about and which went terribly wrong, such as thalidomide or the Bhopal disaster. Risk aversion will be higher, too, where there is uncertainty about a technical process and its immediate outcomes or what will happen in another generation; what will happen in the immediate locale and what will happen in the wider population or eco-system, and so on. The greater the uncertainty, the greater will be the risk aversion.

Moral dimensions and issues of trust will increase risk aversion too. If you have a reputation for honesty and you make a mistake, but admit it and clean up the mess, people will believe you. If your reputation is blemished and public trust in you is undermined, it can take decades for your credibility to be restored. Trust is a highly valuable commodity.

When non-technical dimensions are involved in the public

debate over a technology, it is hard to subject the technology to a standard technical risk assessment. That is the problem that people have had with ERMA and with the HSNO Act. We are trying to use a regulatory formula approach to deal with issues that are not amenable to a classic technical-scientific risk assessment. People have found that the non-technical arguments they bring into the domain of an ERMA hearing don't fit there. The question then becomes where should those conversations be held?

Effective risk communication is not simply a matter of transferring technical information and expertise to the lay public. It is about communicating with the public about risks in an array of dimensions, from different points of view. This is the difference between one-way communication and two-way communication or dialogue.

One-way communication is basically the flow of information from the expert source to the non-expert recipient. It is common around many areas of science. It is fine for helping people to understand something to improve their safety – wearing a seat belt, eating fresh vegetables, or giving up cigarettes. But when we are looking at a technology that raises issues for many different stakeholders, the science and expert view is only one dimension. It is important, but it should be put in a wider context that includes the environmental, economic, legal, ethical, cultural and political dimensions.

Two-way communication requires us to both provide and receive information: it is a communication exchange that involves others in the discussion. This is likely to be the best way of increasing public interest and reducing resistance to complex technologies. People will take part if the scientist is willing to listen and show respect for what they know from their experience in everyday life. You are then likely to get a more moderated response and a more useful conversation. These approaches to public engagement in science and in technology have been found to be productive in many parts of the world.

There are other benefits from two-way communication. Scientists can test ideas, or get new information and new angles because they talked with someone outside the laboratory. External stakeholders often have their own valuable expertise. This can give rise to different ways of thinking and different strategies for the science or its application. Scientists can achieve buy-in and acceptance for solutions that emerge from stakeholder discussion; this can reduce costs in pursuing options that might be commercially or socially unacceptable, including the costs of litigation. This results in both improved technical outcomes and reduced social costs. Dialogue communication is not a panacea for all issues, but it can be effective and I think it needs to be used more widely.

It is worth looking at why a gap can open up between an expert's view of a new technology and the public's view. The gap is inevitable when one side is focused on technical facts, but the other side is concerned about questions such as who is this technology for, in whose interest was it developed, and is it morally right? A gap is likely if the discussion is focused solely on economic issues without considering social or other concerns, or focused only on how something can be done rather than why it should be done, the benefit or the social purpose. You get gaps when there is a short-term focus on localised effects, rather than on wider systemic effects, especially in the absence of testing from the past or effective monitoring and reliable testing for the future. These gaps in perception apply to all technologies.

The key point for scientists is to ask yourself what kind of technology you have and whether it raises anything other than technical issues. If there are commonly recognised benefits, and no ethical issues have been identified, a one-way communication technique would usually be fine. But if there are wider issues, two-way communication is likely to be more successful.

Experts, scientists and technology developers have been gradually learning about the kind of communication strategy that works best, over several decades. Social scientists like me who study 'science and society' relations have found that expert communication has gone through four phases. In the first phase, experts tended to build a wall around themselves, saying they knew what the technology was all about, and outsiders did not. Outsiders were unimportant and ill-informed, and experts should not have to bother with their opinions. The experts knew what they were doing; the public therefore should not interfere. It was a 'stone-walling' approach.

The next communication style or strategy has been described as the 'missionary' approach. The experts have information about a great proposal and they are going to take the 'good word' out to people. They will give the public the facts and the data, and the public will be so impressed they will want the proposal put into effect. Sometimes the technique works, but often it doesn't. The proposal might not just be about technical issues.

The next phase is dialogue. The experts realise they have information to impart but they need feedback and hence want to listen to what people say. Different points of view and different forms of knowledge are opened up. There might be dimensions that some experts don't relate to, but the two sides can have an interesting and useful conversation with greater understanding. It still might leave a question about what happens next.

The fourth phase is called organisational change. This is where feedback from dialogue is taken inside the organisation and used to support future strategy. In the management literature we talk about resilient organisations or learning organisations. This is where I think we are starting to go with GM and science organisations in New Zealand. A learning organisation knows it must understand the context in which it is operating in order to implement its business plan. What is happening with our stakeholders and customers? What can we pick up and use in our decision-making to ensure we are on track with our strategy, our responsiveness, our resilience?

It is worth asking where you think we are in our communication approach, 10 years on from the introduction of GM technologies in New Zealand. Are we at phase 1, 2, 3 or 4 in terms of science and society engagement? In my view, we are certainly around stage 3 and in some places we are moving into stage 4 towards organisational change. I think this is a good sign and will be an improvement on the kind of debate we had in the past. If we put greater emphasis on dialogue communication and organisational learning, the public will find that scientists are people too, who just want to do useful work; and scientists will find that citizens are often quite well informed and have some useful ideas.

By Jeanette Fitzsimons
Former Green Party MP

A genetic modification critic revisits the technology – and remains unconverted

I am starting with basic principles and with simple questions: what is the purpose of agricultural and horticultural science and how does genetic modification fit with that purpose? I can see two related purposes for the science of food production.

First, from an international perspective, it's to produce enough quality food for the world's growing population in a way that is reliable, affordable, protects the ecosystem services that sustain it and protects human health.

Second, from a New Zealand point of view, it is to enable our country to prosper through producing surplus food to trade and using our natural advantages of climate, soils, water, and knowledge to do so sustainably.

If no-one has a problem with that statement of goals, we need to look at the best ways to ensure food quantity, nutritional quality, safety; to sustain soil, water, biodiversity and crop genetic diversity; and to develop resilience to factors like accelerated climate change.

We also need to avoid creating market resistance or undercutting food production in less developed countries; and consider the role of intellectual property, the regulatory system and opportunity costs.

On the way through we should be assessing the extent to which genetic modification can help us meet those goals.

A major international study investigating very similar questions was initiated at the 2002 World Summit on Sustainable Development, backed by the UN and the World Bank. Over three years some 400 authors systematically reviewed the science of food production and addressed the very questions I have just asked, so I will draw on its conclusions. It was peer reviewed twice and reported in 2008 as the *International Assessment of Agricultural Knowledge, Science and Technology for Development.*

That report asked whether we would have an agroecosystem in 2050 that could feed the world then and not exhaust itself in the process. It found we do not have that system now, and we will not ever have it if we continue along present approaches both in biotechnology and policy.

FOOD QUANTITY

We have a growing population wanting to eat better food despite limited cultivable land, water, oil and fertiliser. So, predictably, one promise of GM is to increase yields. But no-one is starving today because too little food is being produced. In fact, even during the world's most famous famines, those countries were exporting food.

People are malnourished because they lack the income to buy food or the land on which to grow it; they are starved of markets for their surplus production, starved by explicit cash subsidies to farmers in some countries and subtle subsidies such as artificially low fossil fuel costs and attendant mechanisation in others.

It is commonly held that intensive use of water, pesticides and fertilisers are needed to raise yields above what can be achieved with agroecological, including organic, agriculture, and that genetic modification can raise them further. Several studies have examined those claims. To quote from what is probably the largest meta-analysis on conventional and agroecological agriculture ever conducted:

> Model estimates indicate that organic methods could produce enough food on a global per capita basis to sustain the current human population and potentially an even larger population, without increasing the agricultural land base.

A recent empirical study completed by the UN found that in Kenya, conversion from conventional to organic production increased yields up to 179% and more than doubled yields in most of the 24 countries across Africa in which the study was conducted.

There are many organic techniques to increase yields by preserving soil moisture, improving fertility through rotations and natural fertilisers and controlling pests without poisons. A study in Africa by the International Water Management Institute and Earthscan found that in the same water-stressed conditions, improving the yield of the low-yield farms to 80% of the yield of high yield farms was enough to close the food gap.

I have personally seen, some 20 years ago, a 60-acre plot in the Mackenzie Country, surrounded by bare earth and hieracium, support metre-high vegetation and grazing by cattle without irrigation, just by growing the right plants in the right way.

Organic methods have a reputation in some circles for poor yields. This is explained by the fact that comparisons are frequently made between established chemical-based systems and land only recently converted to organics. It is typical of these conversions that yields initially drop and then return and surpass as the new methods bear fruit.

What, then, can GM crops add to this? Almost all commercially released GM crops have been designed to increase resistance to either pests or herbicides. Any increase in yield would be a side effect resulting from easier management at massive scales, and not the purpose of the GM trait.

There is anecdotal evidence of both increased and lowered yields in GM crops in practice, and it is pretty obvious that it depends on environmental and management conditions and how the measurements are made. While the evidence has tended towards positive for cotton, it tends towards negative for soy beans and maize. A 2003 study published in *Science* found that:

> For insect resistant maize in the United States and herbicide tolerant soybeans in the US and Argentina average yield effects are negligible and in some cases even slightly negative.

The most recent and advanced study on cotton in the American state of Georgia has found lower profits and yields for farmers using GM varieties. These results would not justify the higher cost of seed and licensing, let alone potential market resistance.

The International Assessment found that yield gains were variable and unpredictable and declines too frequent to endorse claims of enhanced yields from commercial GM crops.

FOOD QUALITY

Food is not just bulk to fill the stomach, but nutrients to support health. The only GM crop ever designed to improve human nutrition – the so-called golden rice – is a technological solution for a policy problem. It raises some issues of principle that are typical of the GM debate – vitamin A deficiency is normally addressed by eating green leafy vegetables which are easy to grow. Why engineer one grain to provide all nutritional requirements – which it can't do anyway – when those considerable resources could have been devoted to arranging a more balanced diet in a locally resilient agroecosystem?

But there are practical issues too. Philanthropic agencies exploiting years of public-sector research developed the rice, but not without stepping on the intellectual property claims of many different companies including the agrochemical giant Syngenta. In a symbolic gesture Syngenta donated its IP (but only in developing countries that would not otherwise recognise Syngenta's claims, making it not seem so generous after all). But the interlocking IP ownership in the industry meant that just the gene transfer process required some 40 patented or proprietary processes or materials owned by over a dozen entities and the wider research needed 70 product or process patents held by 32 universities or corporations. This seriously slowed down the research and increased its costs.

GM, then, has not achieved anything much to improve nutrition. Moreover, it is unlikely to. The technology is designed for, and encourages, large monocultures and intensive systems where soils often become depleted of micronutrients because fertiliser regimes are confined to NPK. It is certainly not designed for small mixed farms which use composts and a wide range of soil conditioners to maintain micronutrients. It has been estimated that more than half the micronutrients in intensively managed soils under large-scale farming are not replaced by fertilisers and what isn't there in the soil will not be there in the food.

SAFETY

Another aspect of food quality is safety, and it is here that arguments about GM have raged most fiercely.

It is often claimed that glyphosate or glufosinate tolerance enables farmers to avoid the use of more toxic herbicides in favour of less toxic ones. Yet because they are deliberately sprayed directly on the crop much greater quantities will be ingested. While they are less toxic than some herbicides the story is not that simple. In normal commercial formulations which also contain other ingredients they have been found to kill human umbilical, placental and embryonic cells. These toxic effects of commercial formulations have only recently come to light so we cannot rely on past studies to assure us of the safety of glyphosate herbicides, such as Roundup. They also have other effects on non-target organisms such as soil microbial communities.

> The toxicity exerted by glufosinate induced shifts in the microbial community structure with apparently long lasting significant effects. Changes in soil microbial populations can also affect soil functionality, thereby influencing nutrient turnover and the restoration process of the soil.

If it is true that these herbicides are much more benign than their alternatives, then we should be very concerned that the evolution of multiply herbicide resistant weeds will deny us their use in future, leading to a return to the more toxic herbicides in non-GM crops.

Turning to Bt crops, we need to look at the effects of the various cry proteins in the food itself. Many people have been relaxed about possible health effects as the proteins are found naturally in soils with populations of Bacillus thuringiensis. Soil is ingested with food in various ways and inhaled as dust – in quantities of tens to hundreds of mg. However to equal the dietary exposure from various commercial varieties of Bt corn a typical US consumer would have to eat between 14kg and 600 tonnes of soil.

The claim is often made that GM foods are the most tested of any, and that no evidence of harm has ever been found. What is more, there is no obvious sign of human illness resulting from eating GM foods.

You don't have to be an epidemiologist to know that science rarely finds what it doesn't look for. Human ill health is rife everywhere. There are countless allergies and many metabolic disorders that are not well diagnosed but which undoubtedly have many causes. There is no way of knowing who has eaten GM foods and which ones, so no epidemiological work can be done. Nor could there ever be a matched control. On the question of whether GM food is making people sick, we simply have no idea, and few are trying to find out.

The next best proxy is animal feeding trials, of which there are alarmingly few, and most tests have been on the protein of interest, not the whole food. That assumes there is no possible risk from disruption of the genetic and physiological function of the plant, from the antibiotic markers that are used, or from multiple insertions of the target gene. It assumes the location of the gene is of no significance. If a protein is acutely toxic to humans such tests might discover that, but I take no comfort at all from claims of lack of harm when there have been so few tests of whole GM foods.

These risks and others, which have never been satisfactorily addressed in published peer-reviewed studies, are explored in a new online, free-to-the-public resource for citizens, regulators, journalists and scientists called the Biosafety Assessment Tool. The five year international cooperation was led by Norway and the University of Canterbury.

Only recently have long-term and reproductive animal tests been published using the whole food. I find it a terrible indictment on the industry, sufficient to destroy all credibility in their ethics, that they have pushed these crops at farmers and these foods on the market for over a decade without doing basic safety testing. It is also an indictment on the regulatory authorities who have allowed them to.

Pryme and Lembcke in 2003 could find only nine animal feeding studies of whole GM foods and of these, the industry studies found no health effects but the independent studies found significant effects that merited further study. Yet no further research had been done to confirm or refute them. There is always a problem funding safety tests that are not required by authorities and not in the interests of the owners of the IP. It can even lead to difficulties in obtaining accurately characterised samples of GMOs for independent testing.

Since then, and in fact just in the last two years, we have four more studies which indicate all is not well.

The 2007 re-analysis by Seralini and others of Monsanto's data

on Bt corn MON 863 found toxic effects on the livers and kidneys of rats. Seralini's work was supported by a local Environmental Science and Research (ESR) internal evaluation ignored by the New Zealand Food Safety Authority. It matters who funds the safety research.

Kilic and Akay last year in Turkey found granular degeneration of the livers of rats fed Bt corn over three generations.
Last July Austrian researchers studied the effects of a Bt corn combining MON 810 and NK603 on breeding mice and found effects on the kidneys and "time related negative reproductive effects of the GM maize".

Finally, just last November Italian scientists concluded from their study that:

> The consumption of MON810 maize ...induced alterations in intestinal and peripheral immune response of weaning and old mice.

This is not a picture of thorough testing of GM foods with no evidence of harm. It is not surprising that so many European countries have banned BT corn MON 810 – Austria, France, Luxembourg, Greece, Hungary and most recently Germany.

SECURITY

Factors like yield, accessibility and affordability of seeds and technology, reliability, and resilience are sometimes put together in a measure of food security for the poor. FAO statistics, measuring two different levels of under-nourishment in the US showed that food security has not improved in the decade of commercialisation of GM foods. In Argentina and Paraguay, where over 60% of arable land is in GM, food security has decreased since the mid- nineties when GM crops were first widely commercialised.

SUSTAINABILITY/RESILIENCE

The International Assessment saw the sustainability of agricultural systems as a key challenge to food security. Its co-chair Dr. Hans Herren said:

> Agriculture is at the centre of the multiple looming crises of water, soil degradation, energy costs, biodiversity loss, climate change, population growth, dwindling natural resources and increasing inequities.

With regard to biodiversity, there have been too few long-term, properly controlled studies of the effects of GM crops to make much comment. However, Bt corn was found in a 2007 study to increase mortality and reduce growth of ecologically important stream insects.

Water is the key limiting factor in much of the world and even in parts of New Zealand. Last year I visited farms in Hawke's Bay which had just come out of its third serious drought in three years. Many of those farms had no grass on their hills. One of the great promises of GM technology for the last 25 years has been to develop drought- and salt-tolerant plants, so I looked for evidence of how they were getting on. It seems that in the US alone more than 1,000 applications have been received to field test such plants but not one has ever been commercialised. The contribution of GM to overcoming adverse environmental conditions – after 25 years – is zero.

In the meantime, the World Bank has noted significant yield gains through disease resistance and drought tolerance from selective breeding despite too little funding in comparison to GM. New maize varieties and hybrids are yielding 20 percent more on average under drought conditions. Significant gains have also been made in breeding wheat for drought and heat- stressed environments, and rice that survives flooding. Such advances will be especially important in adapting to climate change.

If we get our priorities straight, we could do this better and faster.

Sustaining agricultural production into the long-term future requires access to a wide range of germplasm, both across and within species. Changing climatic conditions will require selective breeding to adapt. GM crops are not available for selective breeding and when they are grown in large monocultures they crowd out other varieties. GM patents are a major obstacle to seed saving and local adaptive breeding. Just five companies control more than 95% of gene transfer patents.

MARKETS

So the record and the prospects of GM crops increasing food yields, security, safety or sustainability are rather poor. But let's face it: that's not the motivation of most people involved with them anyway. In New Zealand we do not grow crops to feed the hungry – they can't afford to pay enough for them. We grow to feed the discriminating, high end of the market that can pay good prices. In that case the first lesson is to grow what the market wants. Our markets are consumer-led – we should have learned that lesson from fat lambs in the sixties.

The EU and Japan are primary markets for our food exports and both have strong consumer resistance to GM foods. While their governments may allow tolerances of minor contamination at the border, the consumer and therefore those who supply them don't. Even a barely measurable GM contaminant in a corn pizza topping led to its rejection in Japan. If such rejections become more frequent it will damage our brand overall.

While I would argue that our so-called "clean green" brand is largely undeserved, it is certainly an important marketing image and has been valued at around a billion dollars. The benefits of GM organisms of any kind would have to be overwhelming for us to even contemplate damaging that image. And the benefits are far from overwhelming.

Overseas experience is that contamination of non-GM crops is inevitable if GM crops are grown nearby. It isn't just the pollen drift – it's the mix ups in the seed store or in the field, the contamination of harvesting machinery, and the brand contamination of it being known that we grow GM crops.

Back in the late nineties partnerships between apple and kiwifruit growers and research institutes were developing GM varieties in containment. A surge of consumer resistance led to firm statements from those industries that they would discontinue all such developments. Both industries have done well, especially their organic variants, and have never looked back.

FULL VERSION

A complete version of this paper with references can be found at *www.agscience.org.nz*

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THE NEW ZEALAND INSTITUTE OF AGRICULTURAL & HORTICULTURAL SCIENCE INC

National Secretariat
P O Box 121 063 Henderson, Waitakere City
Phone 09 812 8506 Fax 09 812 8503
secretariat@agscience.org.nz

Contributions to the Editor
Phone and fax 04-237-8074
bob.edlin@paradise.net.nz

www.agscience.org.nz

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ISSN 1175-3927