THE WEED SOCIETY
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Seminar Papers

NEW ADVANCES IN HERBICIDE USE

Wednesday

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Vibe Hotel, Milsons Point

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THE WEED SOCIETY
OF NEW SOUTH WALES Inc.
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Edited by
Warwick Felton and Bob McKillop

Seminar Program

8.30 – 9.15	**Registration Tea/Coffee**	
9.30 – 11	**Session 1 – Setting the Scene**	
	Chairman: Dr Rex Stanton	
9.30 – 9.45	**Dr Rex Stanton**	***Welcome and Background to the Seminar***
9.45 – 10.30	**Professor Julian Cribb**	***Tackling the Global Food Crisis***
10.30 - 11	**Jonathan Benyei**	***Regulation of GM Crops in Australia Identifying and Managing Risks***
11 – 11.25	**Morning Tea**	
11.30 – 1	**Session 2 - Managing GM Crops**	
	Chairman: Warwick Felton	
11.30 – 12.10	**Dr Suzanne Warwick**	***Lessons for Australia: GM Crops in Agriculture***
12.10 – 12.35	**Max Foster**	***Economics of GM Grain Crops***
12.35 - 1	**Murray Scholz**	***Integrated Weed Management and the Implications of Herbicide Tolerant Crops***
1 – 1.55	**Lunch**	
2 – 3.30	**Session 3 – Meeting the Challenge**	
	Chairman and Moderator: Neil Inall	
2 – 2.25	**Clare Hughes**	***Understanding Consumers' Concerns About GM Foods***
2.25 – 3.30	**Panel Discussion and Audience Participation. The speakers plus representatives from industry and concerned farmers**	
3.30	**Summation and Resolutions – Neil Inall**	

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Keynote Speaker

Julian Cribb

SPECIALIST COMMUNICATION IN SCIENCE,
AGRICULTURE, MINING, ENERGY & THE ENVIRONMENT:

Julian Cribb is Adjunct Professor in Science Communication at the University of Technology Sydney and a fellow of the Australian Academy of Technological Sciences and Engineering.

From 1996-2002 he was Director, National Awareness, for CSIRO.

A journalist since 1969, he was editor of the “National Farmer” and “Sunday Independent” newspapers, editor-in-chief of the “Australian Rural Times”, and chief of the Australian Agricultural News Bureau. For ten years he was agriculture correspondent, science and technology correspondent and scientific editor for “The Australian” and still writes a regular column for the national daily. He edits Australian R&D Review and ScienceAlert.com.au, the nation’s leading scientific news site.

He has received 32 awards for journalism including the Order of Australia Association Media Prize, the inaugural Eureka Prize for environmental journalism, the inaugural AUSTRADE award for international business journalism, the Dalgety Award for rural journalism, two MBF Awards for medical journalism and five Michael Daley Awards for science journalism.

He was national foundation president of the Australian Science Communicators (ASC), president of the National Rural and Resources Press Club, a member of CSIRO advisory committees for agriculture, fisheries and entomology. He has served as a Director of the Australian Centre for International Agricultural Research (ACIAR), the Crawford Fund, the Secretariat for International Landcare, CSIRO Publishing, the Australian Minerals and Energy Environment Foundation, the National Science and Technology Centre (Questacon) and the Council of the Academy of technological Sciences & Engineering.

His published work includes more than 7,000 print articles, 1000 broadcasts, 500 media releases and 300 speeches as well as “The Forgotten Country”, six editions of “Australian Agriculture”, and “The White Death”. His most recent book is “Sharing Knowledge”, a manual for effective science communication. He teaches science communication at ANU.

Keynote Speaker

Dr. Suzanne I. Warwick

Principal Research Scientist
Agriculture and Agri-Food Canada – Ottawa

Suzanne Warwick received her PhD in Experimental Plant Taxonomy from Cambridge University, UK in 1977. In her subsequent 31-yr career as a Research Scientist with Agriculture and Agr-Food Canada, her research has focused on weed and crop evolution. She has published over 155 scientific papers on the population biology and genetics of herbicide resistant weed biotypes, invasive alien weed species, and the role of hybridization and introgression in weed evolution. Since the early 1990's, she has specialised on the phylogeny and biodiversity of the Crucifer plant family (Brassicaceae, canola, mustards etc), and has currently been studying the environmental impact of commercially released GM modified canola crops.

Dr Warwick is a member of the Canadian Botanical and Weed Science Societies

From 2000-2008 she has been Associate Editor for: Biology of Canadian Weeds and Invasive Alien Plants in Canada Series in the Canadian Journal of Plant Science.

Her recent invited participation in national and international symposia and workshops include:

2006 Brassica Workshop, GMOs and Gene flow, Netherlands

2005 Biotechnology and Biological Sciences Research Council, UK, Scientific Advisor

2004 Norwegian Biotechnology Advisory Board, Scientific Advisor

2003 APEC Workshop - Mexico/Canada/United States, "Biotechnology of Crops in Centres of Origin, Canadian scientific advisor

2003 Canadian Food and Inspection Agency Workshop, Management of Herbicide Tolerant Crops , Ottawa, Invited paper on “Selection of imi- herbicide resistance in weeds.”

2003 European Science Foundation Conference, “Introgression from GMOs into Wild Relatives and their Consequences”, Amsterdam, Symposium paper.

In 2007 Dr Warwick received a Career Excellence in Weed Science from the Canadian Weed Science Society.

Her current projects include:

• Accurate identification, information and related training for scientific research and biodiversity protection.

• Assessing the impact of gene flow from genetically modified (GM) oilseed crops to non-GM oilseed crops and wild relatives by investigating the potential for out-crossing, the survival of hybrid plants in the field, and the inheritance of GM traits.

• Development of a pollination control system for the production of Brassica rapa hybrids: Genetic relatedness of parental lines.

• Plants: Develop new information on taxonomy, phylogeny, distribution and biology of plants including systematic research related to new and existing crop/bioproduct development, alien invasive species and impacts of genetically modified plants.

Dr Warwick’s trip to Australia to participate at this seminar

was supported by a travel grant from

the Council of Australasian Weed Societies (CAWS)

Invited Speakers

Jonathan Benyei – Office of the Gene Technology Regulator

Jonathan Benyei manages the Evaluation Branch of the Office of the Gene Technology Regulator in Canberra. Their responsibilities include the review and approval for the release of genetically modified crops in Australia. His role at the seminar is to provide a clear message as to what regulations are in place, and the processes that take place for these crops to be available for farmers to use in Australia.

Max Foster – Australian Bureau of Agricultural & Resource Economics

Max Foster is a Principal Economist in the Agriculture and Trade Branch of ABARE. He has extensive experience of economic analysis of mainstream and emerging agricultural industries in Australia.

Max has produced a number of ABARE research reports on issues to do with genetically modified (GM) crops, including: *Genetically Modified Grains: Market Implications for Australian Grain Growers* (2001); *GM Canola: What are its Economics Under Australian Conditions?* (2003); *Market Access Issues for GM Grains* (2003); *Cartagena Biosafety Protocol: Implications of the Documentation Regime* (2006); *GM Crops in Australia: Identity Preservation* (2006); and *Market Acceptance of GM Canola* (2007).

Murray Scholz – Farmer, Culcairn, southern NSW

Murray Scholz is a farmer from Culcairn, southern NSW. He is the manager of the 1600 ha family farm growing wheat, canola, and lupins. His family have been avid up-takers of new technology and they have been practicing no-till farming for approximately 25 years. They also have a shorthorn cattle operation.

In 2007 Murray was awarded a Nuffield Australia Scholarship to study the implications of herbicide tolerant genetically modified crops on weed management. He also looked at pesticide development and regulation together with organic methods of weed control. Murray's research has taken him to North America, Europe and South America. He also spoke at the 5th International Weed Control Congress in Vancouver Canada about a farmers experiences living with herbicide resistance.

Clare Hughes – Senior Food Policy Officer, CHOICE

Clare Hughes is the Senior Food Policy Officer at the CHOICE. CHOICE is Australia's largest consumer organisation and is the publisher of CHOICE magazine.

Clare has graduate and postgraduate qualifications in nutrition, public health and health administration. As Senior Food Policy Officer at CHOICE, Clare is responsible for ensuring that the interests of consumers are considered during the food policy and regulatory processes. Her areas of responsibility include nutrition, health and related claims, fortification, food labelling, the food regulatory system and standards development.

Clare currently sits on a number of Food Standard Australia New Zealand committees including the Standard Development Advisory Committee on Nutrition and Health Claims, the Consumer Liaison Committee, and the Standard Development Committee for the Poultry Meat Primary Production and Processing Standard. Ms Hughes also represents the CHOICE on the Standards Australia Committee on Organic and Biodynamic Products and is a member of the NHMRC Dietary Guidelines Working Committee.

Chairpersons

Dr Rex Stanton – Session 1

After completing a BSc (Hons) degree at the University of New England, Rex worked as a technical officer with NSW Agriculture at Cobar on woody weeds. He moved to Charles Sturt University, Wagga Wagga in 1997 to investigate glyphosate resistance in annual ryegrass. This led to his PhD project on the role of glyphosate in future southern Australian farming systems; completed in 2004.

He is now a post-doctoral fellow currently involved with management of the deep rooted, summer perennial weeds, silverleaf nightshade and prairie ground cherry. The project aims to study their biology and ecology, improve herbicide efficacy, develop competitive pasture options, and evaluate allelopathic compounds.

Rex is the current President of the Weed Society of New South Wales, a delegate to the Council of Australasian Weed Societies (CAWS), was CAWS secretary (2002-2004), a member of the organising committee for the 2004 14th Australian Weeds Conference, and chairman of the National Glyphosate Sustainability Working Group (2006-2008).

Warwick Felton – Session 2

Before retiring in 2004 Warwick was a Senior Research Scientist with the NSW DPI at Tamworth. His work for almost 40 years included weed management in both irrigated and dryland crops, no-tillage farming systems, and development of the weed detecting spray technology.

He received numerous awards in recognition of his work including AgQuip Land Inventor in 1991, Brownhill Cup in 1991 for contributions to Conservation Farming, Council of Australian Weed Science Society medalist in 1992, Excellence in Engineering Awards in 1992 and 1993, and a NSW Agriculture Staff Achievement Award in 1998.

Warwick has been a member of the Weed Society of New South Wales for over 30 years serving as President in 1987, 1988, 2005 and 2006. He is currently Vice –President, a delegate to the Council of Australasian Weed Society, and a member of the GM Seminar Organising Committee.

Neil Inall - Chairman and Moderator for Session 3

Neil was sacked from his first job at age 14 for talking too much. In the past 40 years though he has chaired forums in small outback towns and capital cities, as well as on national radio and television! He's perhaps best known for his involvement in television programs for the ABC like Outlook, Countrywide and Horizon-5, and for Cross Country on the Seven network.

He grew up on a small farm in the Hawkesbury Valley, was a jackeroo at Coonamble, a station hand at Canberra, and an agronomist with the NSW Department of Agriculture. He was co-founder of the rural affairs company Cox Inall Communications.

Neil Inall was a National President of the Australian Institute of Agricultural Science and is a Fulbright Fellow. He was a member of the GM Seminar Organising Committee.

Session 1 - Chairman Dr Rex Stanton

WELCOME AND BACKGROUND TO THE SEMINAR

Rex Stanton, President, Weed Society of New South Wales Inc.

It gives me great pleasure to welcome everyone to this seminar that is addressing some of the weed aspects of genetically modified crops. The Weed Society of New South Wales and the Australian Institute of Agricultural Science and Technology (AIAST) have collaborated, along with significant financial support from the Council of Australasian Weed Societies (CAWS), to bring this seminar day to fruition.

The Weed Society of New South Wales was formed in 1966 as Australia's first specialist society in this field. The Society is focused on providing a forum for networking between weeds workers to share information and experience.

The AIAST is the national professional organisation of agricultural scientists and technologists, which promotes professional standards and recognition, assists information flow from scientific and technological advancements, and provides products and services to help maintain Australia's agro-industries as world leaders in their fields.

The Council for Australasian Weed Societies (CAWS) has been a peak body in Australian weed management for some 30 years and serves as the national voice for the state bodies. Its objectives are to promote weed management and science, through education, awards, travel grants and publications. CAWS has provided significant financial support to allow a senior Canadian researcher, Dr Suzanne Warwick, Principal Research Scientist Agriculture and Agri-Food Canada, Ottawa, to attend this seminar as a keynote speaker.

Australian agriculture has responded to a series of historic technological or scientific advancements, such as the advent of fertilisers and pesticides, which have led to improvements in our agricultural systems and production levels. More recent advancements have occurred within our crop varieties via the availability of herbicide tolerance traits, allowing more diversity with crop chemical weed management. For instance, conventionally bred triazine tolerant canola proved to be a boon to Australian farmers, despite its yield penalties, as canola could be grown while still achieving control of related weeds such as wild radish. Imidazolinone tolerance traits soon followed in both canola and wheat, again as a result of conventional breeding methods, and found a niche in the marketplace.

The most recent advancement has been the introduction of genetically modified (GM) crops. The most common GM traits at present are insect resistance and tolerance to the non-selective herbicides, glyphosate and glufosinate. These traits allow these non-selective herbicides to be utilised in a selective manner within a crop and provide new opportunities on how we manage our weeds in cropping systems.

Herbicide resistance is a significant challenge facing Australian agriculture. Resistance to selective herbicides is steadily increasing, particularly in weeds such as annual ryegrass. While resistance to glyphosate, a herbicide heavily relied on in current minimum tillage systems for pre-season weed control, remains low, the potential to use non-selective herbicides such as glyphosate and glufosinate in a new role within a GM crop poses new risks, challenges and benefits for the long term sustainability of herbicide-based weed management.

It is in this context that I look forward to the presentations at this seminar. Your organising committee has brought together an impressive group of speakers covering the range of issues that are of concern to farmers, consumers and the general public regarding the use of GM crops, their risks and potential benefits. I thank the speakers for their time in preparing their papers and presentations.

Our aim is to present a balanced assessment of where the debate about GM crops is at and to establish an agreed position on where we should go from here. We have set aside time this afternoon for a panel discussion on 'Meeting the Challenge' in which we look forward to your contributions to the debate.

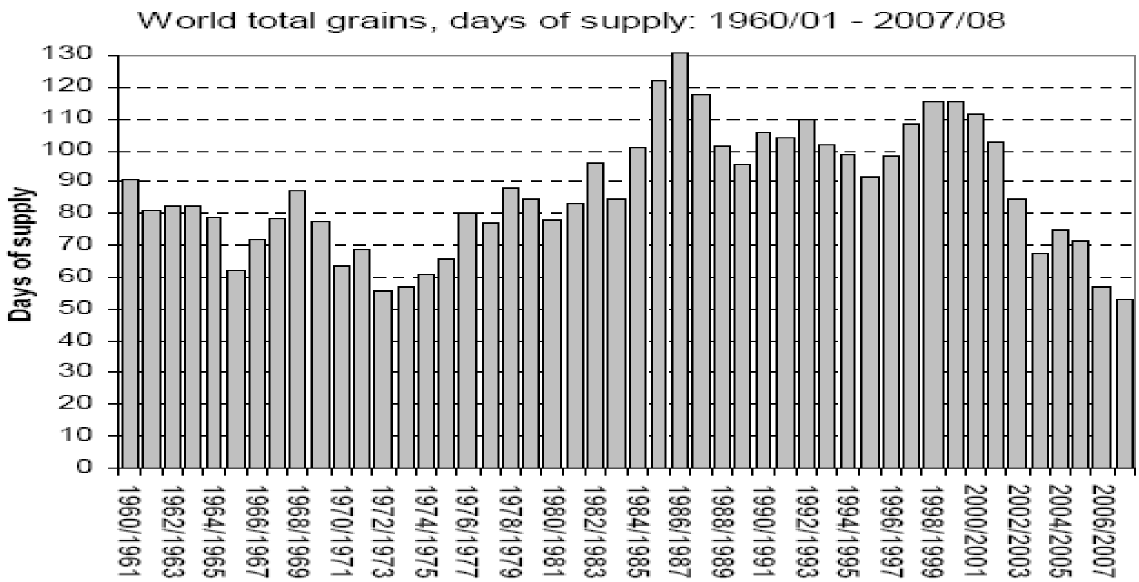
I trust you find the day challenging and rewarding.

TACKLING THE GLOBAL FOOD CRISIS

Professor Julian Cribb BA FTSE,
Julian Cribb & Associates

The world faces its gravest food crisis in half a century, due to a synergetic confluence of resource scarcity, underinvestment and changing climate. There is a high probability of regional food supply collapses, leading to conflict and refugee floods on a scale not before seen. There is an urgent need to redouble the global scientific enterprise in food production.

The context



Meeting over a mountain of caviar, sea urchin roe, Kyoto beef, milk-fed lamb, conger eels, truffles and champagne in Japan in July 2008, leaders of the G8 richest countries discussed spiralling grocery prices in the developed world and growing starvation in Africa, India and Asia. Between mouthfuls of an 18-course banquet prepared by 60 chefs, the world's eight most powerful men said they were 'deeply concerned'.

Four months earlier global food security wasn't even on the radar of world leaders. In their busy round of affairs it was an issue they rarely devoted a moment's thought to.

Yet, in each of the past seven years, the world had consumed more grain than its farmers had been able to grow. The warning signs have been plain to read for quite a while. Grain reserves are at their lowest level in half a century and have only begun to recover slightly with the northern harvest.

Like many people, the world leaders sounded puzzled at the sudden emergence of a food crisis. They blamed climate change, biofuels, oil prices and Chinese appetites—but there was little sign they fully grasped what was happening, down on the farm.

The present food crisis is but a forewarning of what the world can expect in the decades ahead as civilisation runs low on water, arable land, nutrients and technology, as marine catches collapse, as biofuels expand, energy costs soar and as droughts intensify under climate change. At the same time global demand for food is expected to double.

The reasons are straightforward:

1. The **human population** is growing, towards 9.1 billion in 2050—but demand for protein food, especially in China and India, is rising faster still. Total world food demand is forecast to grow by 110 per cent in the next 40 years. By 2050 we will be feeding the equivalent of 13 billion people at today's nutritional levels.

2. We are facing a **global water crisis**. Cities will soon take half of the world's fresh water—once mainly used to grow food. Groundwater levels are falling in every country in the world where it is used for agriculture. To meet projected food demand, we need to find at least 2000 cubic kilometres of new fresh water, possibly as much as 3800—whereas the global farm water supply is now contracting, per person and in absolute terms.

3. The world is facing **'peak land'**, meaning it has run out of good arable country. We have degraded a quarter of the global stock of productive land to the point where it is scarcely usable. We are building cities, golf courses and resorts on our best soils. We are locking them in conservation reserves. New land available in Brazil and Russia is not large enough to offset these losses.

4. We are **haemorrhaging nutrients**. The world passed peak Phosphorus in 1989—and there is no substitute for this vital input. Half the fertilisers applied on our farms are lost. Up to half the food between farm and fork is lost post-harvest or thrown in the garbage tip. Most of the nutrients in our urban waste systems are lost.

5. **Biofuels** are eating into food production areas, in the US and Brazil especially. By 2020 at present rate the world will be burning 400 million tonnes of grain a year—which is the same as burning the entire rice harvest.

6. There has been a 30-year real decline in **global scientific research** to lift farm production, in both developing and developed countries. This means farmers worldwide will soon hit a major technology pothole, where less new technology overall will be available to help them lift output.

7. There is heavy inflation in the **prices of fuel, fertiliser and chemicals** driven by the advancing proximity of **peak oil**. This is pricing these out of the reach of both poor and medium farmers in all countries. Indeed the entire system of high intensity agriculture is going to have to work out a way to wean itself off fossil energy within 20 years or so.

8. A third of the world's major **fisheries** are in decline. Some scientists forecast sea catches will collapse completely in the 2040s, throwing increased protein demand onto land-based farming. Aquaculture is facing pollution and feed supply problems.

9. **Politics and economics** are acting against agriculture. Globalisation of the supply chain is driving down prices to all farmers while the continued failure of trade talks is excluding them from markets. Domestic farm subsidies also continue to depress global prices.

10. The **climate is changing**. UK Hadley Centre modelling suggests up to half the Earth may be in regular drought by the end of this century, with the food bowl grain growing regions worst affected. 'Unnatural disasters', already at record levels, will become more common.

The challenge facing today's farmers is thus to double world farm output, using less land, far less water, fewer nutrients, and with the prospect of less technology to do so—in the teeth of increasing drought.

This is not a challenge susceptible of 'silver bullet' solutions, but will require action on a global scale and by every individual and government on Earth. What the world's leaders, indeed all governments including our own, have failed to grasp is that the food crisis is not caused by one or two of these factors—but by all of them acting in concert. It cannot be overcome by addressing one or two of them—only by tackling all of them together. While these obstacles to sustainable food production were building up, our leaders were asleep at the wheel.

This situation heralds the real likelihood of regional and global instability. It is already manifest in soaring food prices – last year rice prices alone rose from $400 to $1000 a tonne—and food riots in 37 countries, in some of which there is high risk of government failure.

Most conflicts round the world in the last 20 years have been driven, at their core, by disputes stemming from a scarcity of food, land or water. Dafour, Rwanda, the Balkans were triggered by arguments over these issues. While the media and governments see them as clashes of religion, culture or politics, in reality the tensions which ignite these wars come from food insecurity—the primal fear that one cannot feed one's children and must fight another group to obtain the means.

Food insecurity is a major driver of refugees and war. The British Defence Department, for example, in its most recent strategic trends document foresees significant risk of growing climatic instability, chronic water scarcity, the collapse of fish stocks, food price spikes resulting in further economic turbulence, development failure, mass movements of refugees in Asia, Africa and the Middle East and a heightened risk of conflict. Similar warnings have also been sounded by America's CIA and defence think-tanks.

The United Nations High Commissioner for refugees reported there were 67 million refugees at the start of this year, the highest number ever recorded, most of them displaced by conflict and famine. On top of this is surging immigrant pressure felt by all western countries as the educated or more affluent flee the gathering storm.

In the 1850s a quarter of the Irish population left the country due to famine. In the 1970s 10 million Bangladeshis fled into India to escape hunger. Imagine, for example, what the world will look like if a quarter of all Indians, Chinese or Indonesians were to flee in response to local famine.... the looming regional food shortages of the coming famine could precipitate refugee waves numbering in the tens or even hundreds of millions, leaving no nation on Earth untouched.

If we wish to avoid these wars, riots and refugee tsunamis, the only answer is to secure the world supply of food.

This—even more than climate change—is the most urgent issue of the early 21st century.

This is **not** to say climate change is unimportant. But merely to remind ourselves of the old Spanish proverb: *Civilisation and anarchy are only seven meals apart.*

The challenge for farmers

The recent World Bank IAASTD report makes it clear that farmers need support not only as the producers of the world's food and fibre, but also as the stewards of its fresh water and its biodiversity and the guardians of its soil carbon. They tend for 40 per cent of the earth's total land mass and three quarters of its fresh water. They desperately need help, knowledge, skills and technology to manage these more sustainably. You cannot just kick-start R&D after letting it run down for decades. It takes on average 15-20 years for a new piece of science and technology to be researched, developed and disseminated to millions of producers.

And we have let our agricultural knowledge and skills run down. Worldwide, funding for the science that built the Green Revolution has been flat-lining *since 1976*. When it comes to yields the world is about to hit a brick wall: gains in crop yields in many countries have receded dramatically, in some cases to close to zero. When it comes to increasing yields, the world is about to hit a brick wall. The total world investment in agricultural science and technology today is around $23 billion—in contrast with a world armaments spend of $1.2 trillion

In Australia we have been cutting support for research and extension in State agriculture departments for quarter of a century. CSIRO, after many cutbacks, recently announced a new round of cuts aimed almost exclusively at agriculture. Our universities have seen 20-40 per cent declines in enrolments in ag science. Many of our scientists are close to or past retirement age. Despite all that has gone on in the private sector and in biotechnology, agriculture worldwide is driving headlong towards a large technology pothole—all the science we have *not* done in the last 20 years that will be *un*available to farmers to use in the coming 50 years. We will not fully appreciate the danger of this lagged disinvestment in agricultural skills and technology for another decade, where there is real danger of millions starving as a consequence.

This is nevertheless a very dynamic time for farming. For the first time in over 40 years, the terms of trade are swinging somewhat in the farmer's favour. Costs are rising—but so too are commodity prices. There has never been a better time in the last two generations to be a farmer, a farm worker, technologist or an agricultural scientist. Once more, young agricultural professionals are being challenged to feed and clothe the world. Now governments are being forced, reluctantly, to pay attention to their needs.

A role for GM crops?

GM science has a vital role to play in all this. As we have seen, critical shortages are emerging in land, water, nutrients and energy along with increased climate instability. GM holds some—though not all—of the answers to these challenges. So far, it must be said, the evidence that GM has put more actual food on the world's table is thin and not very persuasive. This is about to change however.

For example, at CIMMYT in Mexico they have gone back to the original three—yes three—parent grasses which originally formed wheat and barley and are now seeking to recombine these to create new synthetic 'superwheats' capable of producing more grain with less water, nutrients and under more erratic conditions. Clearly, when you go as far back as this in the ancestry of wheat, you also pick up a lot of undesirable genes along with the valuable ones, and GM techniques will be vital in eliminating these and accelerating the development of the new superwheats.

In a parallel development at the International Rice Research Institute, scientists are probing the ancestry of rice to see if they can discover early traces of the C4 photosynthetic pathway. Rice, as you know, is a C3 plant but researchers believe that if they can 'supercharge' it by giving it a C4 pathway they will be able to dramatically improve the rate at which it converts sunlight and CO_2 into grain, using less water and nutrient. However, re-engineering the entire cellular machinery of a plant is no simple task. It will almost certainly require GM and it will probably be at least a generation before such crops are available to the world's farmers—which gives a clear idea of the long lead-times involved in such profound scientific challenges.

A third challenge that will almost certainly involve GM is to defeat Ug99, a devastating cereal rust which emerged a few years ago in Africa and is now ripping through the Middle East on its way to India. Ug99 has already shown it can obliterate entire crops, and that the one or two rust-resistance genes with which most wheats are endowed offer no protection against it. Ug99 has the potential to decimate the world's second most important food grain crop and bring starvation to millions. Probably the only way to stop it is through identifying and layering several defensive genes which, if it is not to take many years, will require GM.

Of course there are many other characters susceptible of GM which offer more immediate benefit and greater prospect of improving global food security in the short term—hybridisation, drought and waterlogging tolerance, disease and pest resistance, enhanced nutritional features to name but a few.

Acknowledging and managing risks

However for GM to achieve its potential, its proponents need to understand some rather brutal home truths about how they got themselves into their current mess, earned the suspicion and mistrust of the general public and a good many politicians, and set back their science by 20 years or more.

Most scientists accept that, for science to be of any use, you first have to gather data—to do research. Well this applies to the public communication of science also. Because the advocates of GM failed to carry out even the most shallow, elementary research into what the public wanted they failed to anticipate the perfectly natural and reasonable concerns which ordinary people have about this powerful new technology. Research carried out by the consumer associations in both Europe and Australia in the early 1990s found that consumers would be prepared to eat GM foods *provided they held benefits for consumers.*

By its initial choice of transgenes with exclusive benefit to corporate agribusiness, and some farmers, the biotechnology sector set itself up for public rejection.

The public has learned over 200 years—though scientists sometimes forget—that all major new technologies have downsides, and often lethal ones. In view of this, society has a right and an expectation of being consulted. By talking up the benefits of GM and not being open and honest about the risks, the industry automatically made itself a focus of suspicion. By ignoring publicly expressed concerns and serving vested interests first and not those of the public, as the public saw it, the biotech sector automatically courted rejection.

By insisting, as the sector did for many years, that large agribusiness corporations had a right to dictate to individuals what they put in their own mouths, and not to inform them of it, they undermined one of the fundamental liberties assumed in western democracies. GM was seen by many members of the public as not only a risky technology—but a deliberate affront to and infringement of their freedom of choice. In an age of increasing democratisation, this was unacceptable. It was a transfer of power away from ordinary citizens to largely foreign-owned corporations—and one that people in many societies were not prepared to stomach.

As a result, progress in GM has been retarded for 20 years in this and many other countries. Not, as is commonly misrepresented by industry spokesmen, because of the greenies, the media, the organic farmers, the politicians or the stupid bloody public—but because the industry itself did not carry out the most basic and simple research and so produced products that were out of step with the ethical and other expectations of society.

So, if it is to achieve its genuine potential for the future, the biotech sector must pay far more attention to the real market—the consumer—and what she or he wants and does not want, and design its products accordingly. When GM proponents engage in communication, they must learn to *listen* as well as simply evangelising their products. They must learn to address the public good and the public interest in every significant product or research undertaking, and they must learn to account for this. After all, much of their work is done using the public's money.

Defining the road forward

I have no doubt that GM has a powerful role to play, along with other branches of agricultural science, in addressing the deeply serious issue of global food security in the coming decades. I believe we need this technology badly to address some of the looming scarcities I have spoken of. This goal will not be served, however, by trying to shove it down the public's throat. People living in democracies have every right to reject a technology if they do not like it. We need to build a much more consensual approach to GM—one that is open about the risks, which listens to the community's wishes and concerns and which adapts its products to meet them. It needs to be an approach that seeks to earn the respect and public ownership of the many important and urgent tasks it is attempting, instead of trying to bulldoze people. In the coming era of food scarcity, we cannot afford to lose a tool as powerful as GM for feeding the world.

At the same time we cannot afford the kind of sterile and ideologically-driven arguments over what is the best system for producing food that have marked the last few decades. It is not a stark choice between GM etc and organic farming: the world will need both. The fossil energy on which farming depends for its chemicals, fertilisers, fuel and transport is running out and by 2030 will be unaffordable and probably unavailable; so low-input systems will be vitally needed. These can be delivered both by advanced forms of permaculture and by GM. Debates about which is the better system are a waste of breath and, in the meantime, 30,000 children die of hunger every day.

By 2050 with over 9 billion people wanting protein diets, the world will need to produce the equivalent of food for 13 billion at today's nutritional levels.

Speaking personally, I doubt the world can produce enough protein from conventional farming systems to feed this many people in mid-century, year-in year-out, especially if fish harvests stagnate or collapse, if we fail to get on top of land degradation and water loss, and the climate swings against the world grain belt.

To sustain the projected growth in meat demand alone will require us to produce the equivalent of 1.8-2.5 billion tonnes more grain—which means, in a nutshell, we need to discover two more North

Americas somewhere on the planet. I've looked on Google Earth and there don't seem to be many undiscovered continents left.

Another aspect is that to produce all this meat it will take 2 million more cubic kilometres of fresh water—which is almost as much as the entire world irrigation industry now uses—and we know the water too is running out or being stolen by the cities. So the world may well have to turn to other means besides agriculture to meet the rising demand for food.

The urban dimension

I therefore wish to highlight to two further challenges of fundamental importance in which biotechnology can play a key role. Both are based on the observation that, within 25 years or so, three quarters of the world's population will live in immense cities of up to 30 and 40 million people. Such is urban planning today, these cities will be almost completely without the means or the knowledge to feed themselves, meaning that in the event of even quite minor glitches in the food supply they will become death traps.

Most people have forgotten how many city people died of starvation following the last two world wars, or the great famines in Russia and China, and such events could very easily be a grim feature of the more heavily urbanised and food-insecure society of the C21st.

Cities, apart from growing next to no food, are also vast traps for water and nutrients, most of which they waste. To feed humanity, urban and rural, sustainably in the years to come I foresee a time when vegetables will play a very much larger role the global diet. Indeed some food analysts are already predicting protein rationing even in advanced societies. A person on vegetarian diet requires just 3 kilowatts of energy a day to sustain, whereas a person on a western mixed diet uses 12 kilowatts. Some re-balancing of this disparity will become essential as the oil runs out.

Now there are over 1000 indigenous vegetables most people have never even heard of still to be farmed. So we have an opportunity to create a new culinary and dietary paradigm for the 21st century in which a much higher percentage of our diet consists of vegetables. We need to develop these new crops and the intensive vegetable culture that will grow them in our cities where vast quantities of water and nutrients are already concentrated. This intensive urban vegetable culture will be an entirely new industry with a new professional, the 'urban farmer' who can grow food on the roofs and sides of buildings and by other novel methods to feed the mega-cities. I foresee a significant role for GM in maximising the productivity and checking pests in this new industry.

The second opportunity is to establish industrial-scale food production to feed these cities by converting recycled water and nutrients directly into plant cell, microbial or fungal biomass in bio-digesters to create a synthetic food source which can be nutritionally enhanced or 'value-added' as so much processed food today already is. I see a key role for biotechnology in identifying and developing the most suitable, productive and nutritious organisms for this more highly intensive and less environmentally-damaging food system.

Australia's role in meeting the challenge

The scientific challenges of the coming decade are clear. They include:

1. The world will need a 200 per cent increase in irrigation water use efficiency across all crops. Who will lead this revolution is not yet clear—but Australians are quickly learning about how to grow food with less water and GM is one of the technologies that can assist.
2. We also need a massive global effort to exploit still-poorly understood soil biology to achieve major yield increases—and here gene mapping will be vital.
3. We need to develop low-input farming systems that require far less energy, nutrients, chemicals and water and which replenish soil carbon. GM can help design the crops for them.
4. There must be a global effort to recycle and conserve all nutrients, on farm, in the food chain and at the sewage works. GM may be able to help in this nutrient harvest and recycling. It can also help design the algae for bio-diesel production.
5. There should be a worldwide campaign to raise vegetable production and consumption, which will also address the problems of obesity and malnutrition. GM can speed up the improvement of many of these new crops and help raise their yields.
6. There should be worldwide adoption of ‘green cities’ (urban horticulture) and vegetable protein biosynthesis using nutrients from recycled sewage and composted waste, to help feed the mega-cities.
7. We need urgently to develop farming and grazing systems that protect native vegetation and biodiversity, cleanse water and 're-carbonise' our soils, especially in the world’s arid rangelands.

These challenges are far from trivial.

With its current, run-down agricultural science and skills Australia is starting further behind the eight ball that it did half a century ago, when we rallied to the last great call to help feed the world. There needs to be a fundamental shift in understanding among our leaders and our society as a whole that food production still underpins our civilisation, and merits due attention and investment. That investment in food security is defence spending, as it protects us from war and tidal movements of refugees.

We need not to double but to triple, maybe even make a fourfold increase in our investment in the science of food production. Even then we will only be spending less than a tenth on raising food production than what the world spends today on weapons intended to kill people. It is already clear to many experts that if we do not do the former we will need the latter and that the wars of the 21st century will be over the most basic resources for human survival: food, land and water.

The present global food crisis mainly affects the poorest billion citizens on Earth. Yet it is a wake-up call to everyone, because of the risk of far greater famines for all people as the confluence of all these scarcities of land, water, nutrients, technology, energy and climate change begins to impact on the food supply everywhere.

We should all be aware of the position, and if possible, alarmed.

Then, we must act: as individuals, as communities, as industries, as countries and as a species.

Australia was a leader in the last Green Revolution and we need to rediscover that spirit and that determination to make a difference.

We need to replenish our science—and our generosity as a people.

The challenge that I wish to leave you with is to develop in Australia the science and the knowledge to address the Coming Famine—and share them with the world, so that together we may avert it.

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Julian Cribb & Associates
2 Stedman Place, Nicholls, ACT 2913
ph 02 6242 8770
mob 0418 639 245
email: julian.cribb (at) work.netspeed.com.au
website: http://www.sciencealert.com.au

REGULATION OF GM CROPS IN AUSTRALIA: IDENTIFYING AND MANAGING RISKS

Jonathan Benyei, Office of the Gene Technology Regulator

Summary

The current arrangement for the formal regulation of gene technology in Australia has been in operation since 2001. Over the past seven years the Office of Gene Technology Regulator (OGTR) has successfully implemented a robust regulatory system that has enabled the issuing of over 500 licences, the processing of over 2400 low risk (mainly proof-of-concept) dealings and the certification of over 2700 contained facilities throughout Australia.

The Australian regulatory system offers an internationally recognised model that applies scientific risk analysis in order to appropriately balance the protection of people and the environment with the needs of the research and commercial sectors to operate responsibly and with certainty.

Introduction

The *Gene Technology Act 2000* was developed in consultation with all Australian jurisdictions over a number of years to establish a nationally consistent regulatory system for gene technology.

The objective of the Act is 'to protect the health and safety of people, and the environment, by identifying risks posed by or as a result of gene technology, and by managing those risks through regulating certain dealings with genetically modified organisms (GMOs)'. The Act requires that this regulatory objective is achieved whilst maintaining a cautious approach, providing an efficient and effective system for gene technologies, and ensuring cooperation with other Commonwealth and State regulatory schemes.

The Australian Gene Technology Regulator (the Regulator) commenced operation in 2001 to provide independent evaluation and regulation of GM organisms in Australia, including GM crops. It has achieved the balance required under the Act through the development of a comprehensive *Risk Analysis Framework* which applies internationally accepted benchmarks for risk analysis to Australian conditions.

Risk Analysis

The *Risk Analysis Framework* explains the approach taken by the Regulator to risk analysis, and detailed Risk Assessment and Risk Management Plans are published for every field trial and commercial release of a GMO.

Scientific evidence-based comparative risk analysis is the primary decision-making tool in regulating activities with GMOs, with peer review of all GM crop risk assessments provided by an expert committee and through consultation with the public and government agencies. Although specific legislation may differ between Australia and other countries, we share many common protection goals to restrict harm to people and the environment from, for example, toxicity, allergenicity and weediness.

In Australia, every licence application is considered on a case-by-case basis and the response considers the chance of an adverse outcome, together with the causal pathway and consequences of such an adverse outcome (if any). In the process of questioning pathways, only credible risks are identified and subjected to further scrutiny, with risk management measures proposed to address any adverse outcomes.

Ongoing Development

The independent review of the *Gene Technology Act* undertaken in 2005-2006 concluded that the objects of the Act were being achieved and suggested a number of minor changes to improve the operation of the regulatory framework. These changes, implemented in 2007-2008, include the differentiation between field trials and commercial scale licence applications, and measures to reduce the administrative burden on low-risk often proof-of-concept work conducted in contained facilities. They seek to enable the resources of the Regulator to be focused on areas of greatest potential risk to people and/or the environment.

Around 60 field trails of a wide range of GM plants have been approved, but only GM cotton, canola and carnations have been approved for commercial release in Australia. A post-release monitoring framework for commercial GM crops in Australia has been extended and a protocol has been developed with other key stakeholders to assess weed risks, if any, associated with GM plants.

Conclusion

Risk assessment, risk management and risk monitoring of gene technology in Australia has provided effective regulation by focusing on scientific scrutiny and transparency of regulation through consultation with the public, jurisdictions and other regulators.

Contact details: E: ogtr@health.gov.au T: 1800 181 030 W: www.ogtr.gov.au

Jonathan Benyei manages the Evaluation Branch of the Office of the Gene Technology Regulator in Canberra.

Session 2 – Chairman Warwick Felton

LESSONS FROM CANADA: GM CROPS IN AGRICULTURE

Suzanne I. Warwick[1] and Hugh J. Beckie[2]

[1]Agriculture and Agri-Food Canada (AAFC), K.W. Neatby Building, Central Experimental Farm, Ottawa, Ontario, Canada K1A 0C6 [warwicks@agr.gc.ca]

[2] AAFC, 107 Science Place, Saskatoon, Saskatchewan, Canada S7N 0X2 [beckieh@agr.gc.ca]

Summary

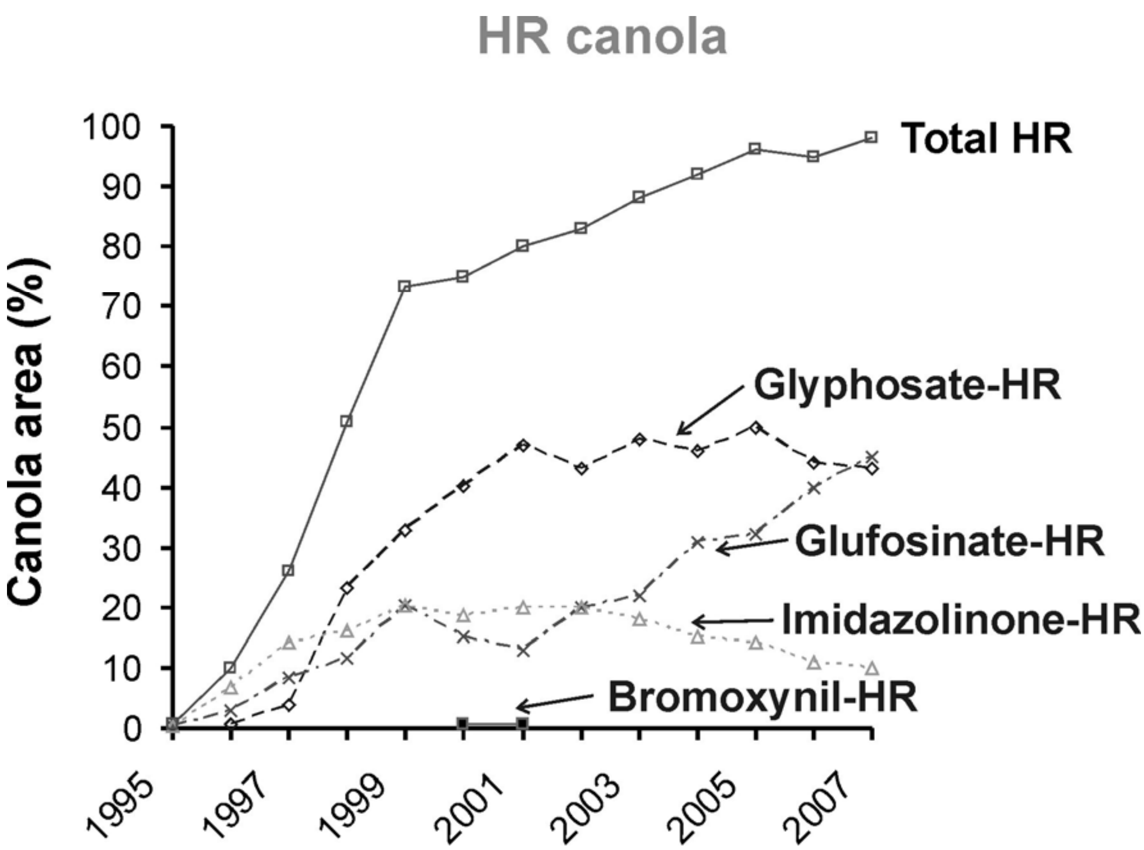
Approximately 88% of the canola grown in Canada is genetically-modified for herbicide resistance (glyphosate, glufosinate) and an additional 10% is imidazolinone-resistant (IMI-HR). Rapid adoption of herbicide-resistant (HR) canola has been driven primarily by easier and improved weed control or higher net returns to farmers. Large-scale use of HR canola provided an opportunity to estimate pollen and seed gene flow on a realistic field scale. Pollen-mediated gene flow (crop to crop crossing) in adjacent HR canola commercial fields was observed at distances up to 800 metres. Both pollen and seed were shown to be avenues for transgene movement and gene flow from HR canola volunteers (weedy/feral canola) was important in subsequent years. Consequences of gene flow include the presence of volunteers in agricultural fields (also roadsides) with multiple or stacked HR traits and adventitious presence (contamination or off-types) of pedigreed seed lots. Large seed losses occur in commercial fields (ca. 20 times the normal seeding rate), and canola can persist in the gene bank for a minimum of 4-5 years. Herbicides with alternative modes of action, such as metribuzin, 2,4-D, or MCPA are the dominant weed control tool for managing single- or multiple-HR canola volunteers. Interspecific hybridization, in contrast, is a less likely consequence of gene flow. Pollen flow from GM canola to Polish canola (*Brassica rapa*) and oriental mustard *(Brassica juncea*) fields have been documented up to 200 metres. Canola can potentially hybridize with four related weedy species in Canada: bird rape (*Brassica rapa*), wild radish (*Raphanus raphanistrum*), dog mustard (*Erucastrum gallicum*), and wild mustard (*Sinapis arvensis*), although field studies to date have only found evidence of hybridization with weedy *B. rapa*. Hybridization frequencies, both for GLY and GLU HR traits, averaged 10%, and transgenes can persist and even be stably incorporated (introgressed) into populations of *B. rapa*. There is no evidence of selection of HR biotypes in unrelated weed species or shifts in weed diversity towards more tolerant species, due to herbicide-use patterns associated with HR canola. Glyphosate–HR canola is associated, however, with large scale adoption of no–tillage agriculture systems in western Canada and with this system – there has been a shift to more perennial weed species. Recommendations include: adoption of a specific stewardship plan at the time of introduction of HR canola, monitoring and regulation of adventitious HR traits in premium and certified seed; long-term

studies on indirect effects on weed management, biodiversity, and/or selection of resistant biotypes and further research on the ecological effects of new 'fitness-enhancing' stress-tolerances GM traits in agricultural and non-agricultural habitats (now largely undocumented).

Introduction – adoption of herbicide resistant (HR) crops

First grown commercially in Canada in 1995, by 2007 the estimated global area of genetically modified (GM) crops reached 114.3 million hectares with production in over 23 countries (James 2008). Canada is currently the fourth largest producer of GM crops at 7.0 million ha. These include canola [*Brassica napus* L.], soybean [*Glycine max* (L.) Merr.], and maize [*Zea mays* L.], with herbicide resistance (HR) and insect resistance (Bt) traits dominating. HR canola will form the basis of this presentation as it has been the most comprehensively assessed of the GM crops. Canola was the first transgenic-HR crop, has a partially outcrossing breeding system and weedy attributes (e.g., volunteerism, seed shattering), and is cropped across a large area. About 98% of the canola grown in Canada is HR (Fig. 1). Approximately 88% is genetically modified (transgenic) for HR to either glyphosate (GLY) or glufosinate (GLU), while an additional 10% is resistant to the ALS-inhibiting imidazolinones (IMI) [non-GM as derived through mutagenesis but subject to same regulations as GM-HR canola in Canada].

Fig. 1. Adoption of HR canola in Canada. Adapted from Beckie and Owen 2008.



HR versus HR crop production

Rapid adoption of HR canola in Canada has been driven primarily by easier and improved weed control or higher net returns to farmers (reviewed in Beckie et al. 2006). Convenience in herbicide application to manage increasing farm size and concomitant time pressures was an important driver of HR crop adoption. Herbicides used in such crops can generally be applied over a wide range of crop growth stages with little potential injury. HR crops have facilitated the adoption of conservation-tillage systems (and vice versa) by use of postemergence-applied herbicides (e.g., glyphosate) vs. preemergence soil-incorporated herbicides, such as ethalfluralin, which are commonly used in some non-HR crops.

Net economic returns have been reported to be 13-30% higher for HR than non-HR canola production. Greater yields, less dockage, improved seed quality, reduced herbicide costs, and reduced tillage costs contributed to the improved net returns. HR cultivars yield the same or greater than non-HR cultivars and have equal quality. The greater yields of HR cultivars were attributed to higher yield potential and reduced weed competition. Results from experimental studies confirmed that yields of HR canola were greater when treated with GLY, GLU, or IMI than with herbicides typically used in non-HR canola, particularly where difficult-to-control weed populations were competing with the crop. Yields are often similar among GLY, GLU, and IMI-HR canola systems. A study by O'Donovan et al. (2006) reported higher net returns for herbicide regimes in GLY-HR canola than those traditionally used in non-HR canola. The farm income benefit of transgenic-HR canola relative to non-HR canola from 1996 to 2004 in Canada has been estimated at US$617 million (Brookes and Barfoot 2005).

HR canola has allowed farmers to plant earlier compared with a non-HR canola system using soil-incorporated herbicides, allowing better utilization of moisture from snow melt and reduced environmental stress during the flowering period and also incorporates operational diversity into cropping systems, thus diversifying weed management systems.

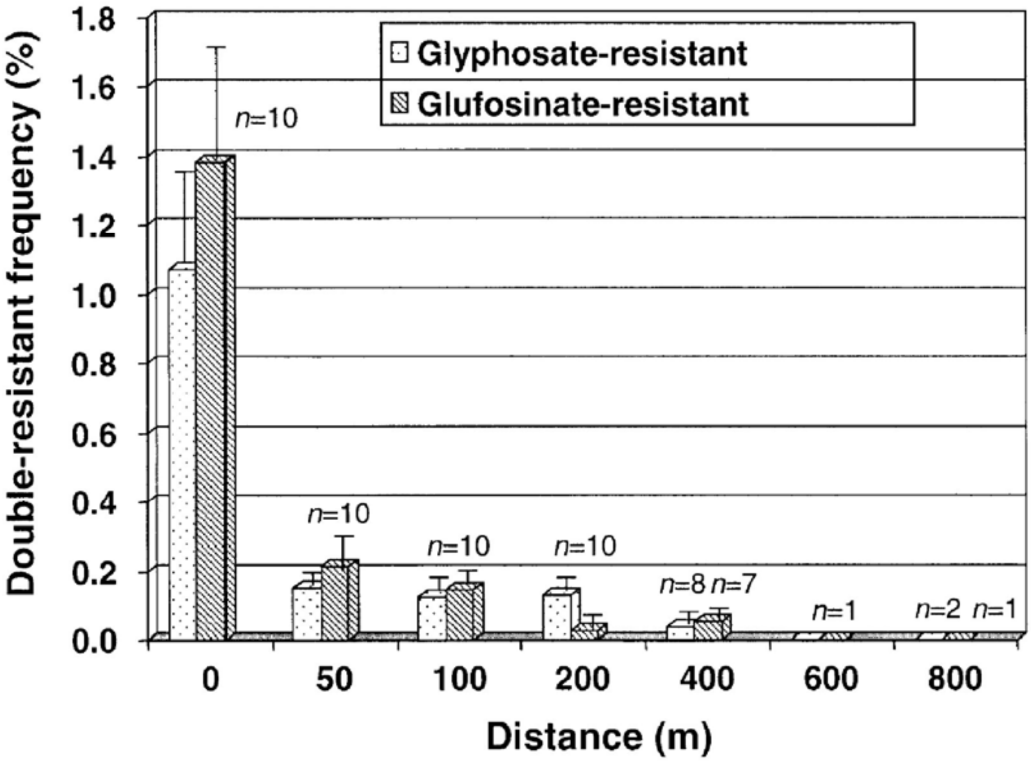
Gene flow and its consequences

The large-scale use of HR canola provided an opportunity to estimate pollen and seed gene flow on a realistic field scale. The HR marker, proved accurate, easy to monitor, and well suited for large-scale screening programs. Both pollen and seed were shown to be avenues for transgene movement and gene flow from HR canola volunteers (weedy/feral–self-perpetuating populations – canola) important in subsequent years. Pollen-mediated gene flow (crop to crop crossing) in adjacent HR canola commercial fields found pollen flow distances (up to 800m) to be comparable to that obtained in small-scale studies (Beckie et al. 2003), where gene flow ranged from 1.4% outcrossing at the border common to paired fields to 0.04% at 400m (Fig. 2). Thus, outcrossing distance was greater than the 100m isolation distance currently regulated for seed producers, and greater than the 175m buffer zone recommended to commercial canola producers. As a result, harvested seeds of canola grown in proximity to a different HR canola system may contain individuals with multiple herbicide resistance.

Intraspecific gene flow and adventitious presence

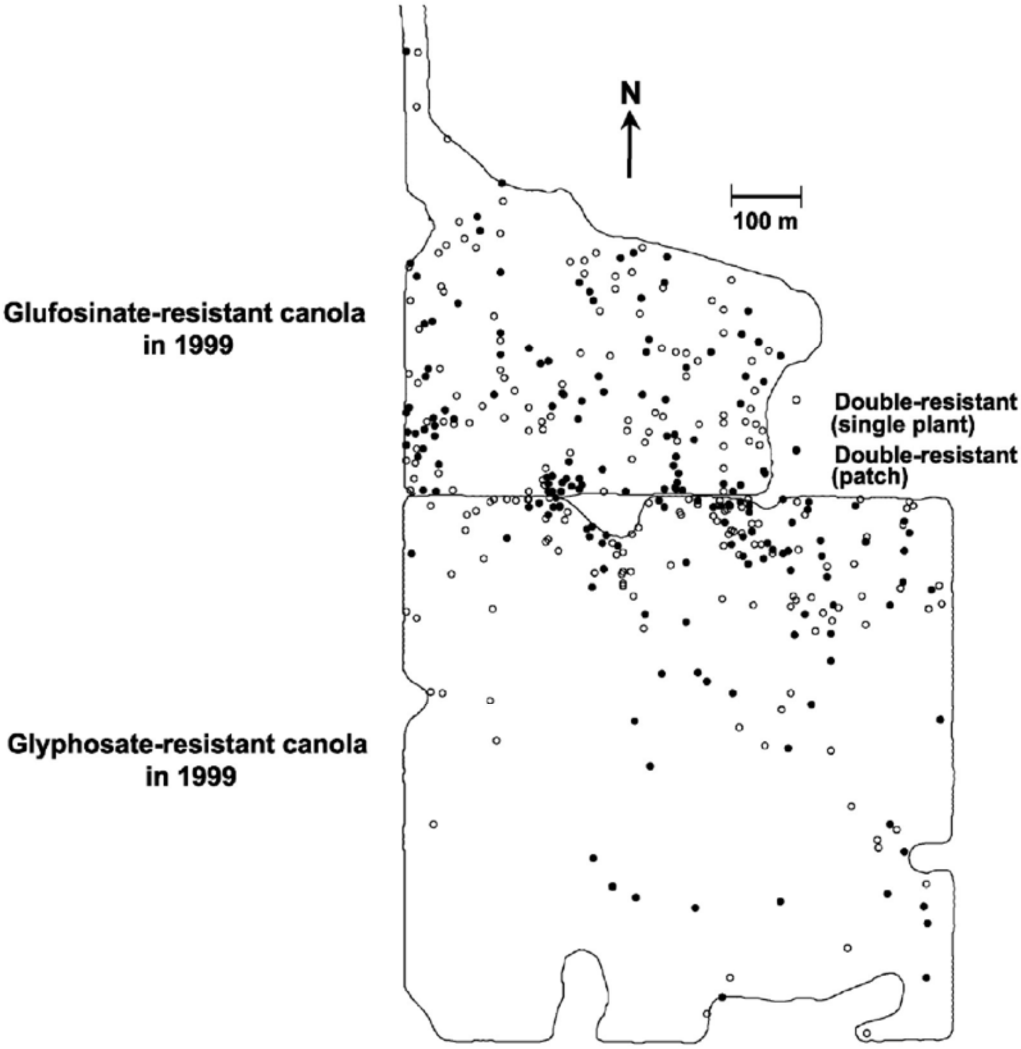
Consequences of gene flow for canola now include the presence of volunteers with multiple or stacked HR traits in agricultural fields (Hall et al. 2000; Beckie et al. 2003) and also in roadside populations (Knispel et al. 2007) and adventitious presence (AP; contamination or off-types) of pedigreed seed lots (Downey and Beckie 2002; Friesen et al. 2003; Demeke et al. 2006). Seed flow is the most important venue for trangene movement and special attention should be directed to seed suppliers and monitoring seed purity. Together, AP in pedigreed canola seedlots planted and pollen-mediated gene flow can result in large, unexpected populations of single- or multiple-HR canola, and canola volunteers in subsequent years.

Fig. 2. Outcrossing (+ SE) between adjacent GLY-HR and GLU-HR canola fields in Saskatchewan in 1999, based on frequency of occurrence of double herbicide-resistant plants as a function of distance from the common border (n = number of fields). Reproduced from Beckie et al. (2003).



An example of the spread and contribution of such seed contaminants in crop to crop gene flow is carefully documented in Beckie et al. (2003). This study found that in the year following canola (2000) when volunteers were mapped and characterised, gene flow as a result of pollen flow in 1999 was detected to 800m, the limit of the study areas (Fig. 3). Large variation in gene flow levels and patterns among sites was evident. The AP of double (GLY+GLU)-HR seed in GLY-HR seedlots planted at some of the sites in 1999 also contributed to the occurrence of double-HR canola volunteers in 2000. The results of the study suggest that HR gene stacking in canola volunteers in western Canada is common, and reflects pollen flow between different HR canola systems, AP in seedlots, and/or agronomic practices employed by Canadian farmers.

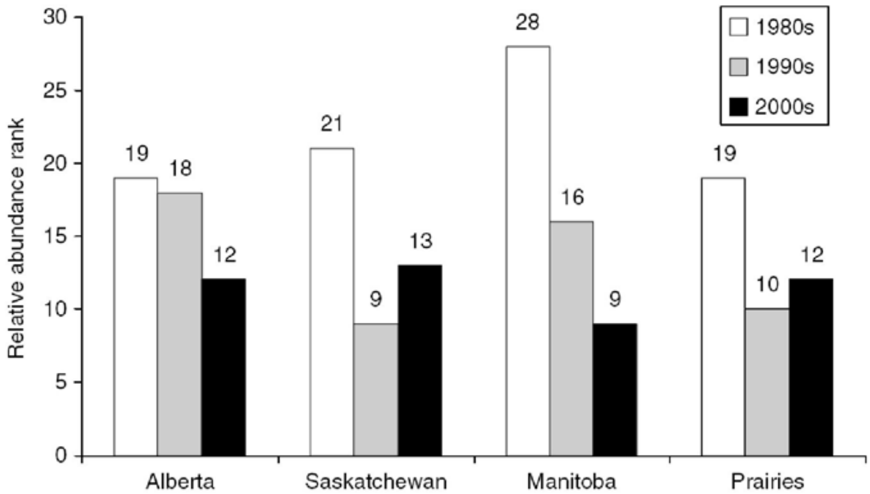
Fig. 3. The occurrence of double HR canola volunteers at a site in Saskatchewan, Canada in 2000 as a result of pollen flow the previous year. Reproduced from Beckie et al. (2003).



Managing single – or multiple-HR crop volunteers

Volunteer canola, is a frequent weed, ranking 12^{th} in relative abundance in weed surveys of the Canadian Prairies (Leeson et al. 2005); with no ranking change associated with HR trait adoption. Mean relative abundance ranking had declined from 10th position as determined from surveys conducted in the mid-1990s when canola was mainly non-HR (Fig. 4). In contrast, volunteer non-HR wheat increased in rank from 18th to 8th place from the 1990s to 2000s, suggesting that the HR trait is not a major factor influencing volunteer canola abundance. Canola produces large volunteer populations because of the quantity of seed lost before and at harvest. Research studies in commercial fields confirmed large seed losses, i.e. average 5.9% of crop yield, 300 viable seeds per m^{-2}, ca. 20 times the normal seeding rate) (Gulden et al. 2003a). Additionally, canola can have a persistent seed bank because of the potential for induction of secondary dormancy (Gulden et al. 2003b). Volunteers can occur for at least 4 to 5 years after production. Volunteer canola (seed escape) thus forms an important reservoir for extending the persistence of the transgene spatially and temporally in the environment. Results suggest that HR gene stacking in canola volunteers in western Canada is common and reflects pollen flow between different HR-trait canola, AP in seed lots and/or agronomic practices employed by Canadian growers (Beckie et al. 2003). Such volunteer weeds, can be controlled, but may require weed control methods in addition to herbicides (affecting use of environmental beneficial low tillage operations) and may impose restrictions on the choice of crops in the rotation in the future.

Fig. 4. Relative abundance rank of volunteer canola among weed species in the three prairie provinces in western Canada (J. Leeson and A. G. Thomas, unpublished data, used with permission).



Herbicides are the dominant weed control tool for managing single- or multiple-HR canola volunteers. In the year following HR canola, volunteers are best controlled in-crop (Harker et al. 2006) and at the four-leaf stage or earlier. All volunteers, whether non-HR, single-HR, or multiple-HR, can be controlled equally well by herbicides with alternative modes of action, such as metribuzin, 2,4-D, or MCPA (Beckie et al. 2004). There are over 30 registered herbicide treatments for control of single- or multiple-HR canola volunteers in cereals (Johnson et al. 2004), the most frequent crop type to follow canola in a typical 4-year rotation. A specific stewardship plan should be in place at the time of introduction of HR canola, which was not the case in Canada; this should help to alleviate reported cases of adverse impacts and make canola growers aware that volunteers may contain unexpected or multiple HR genes. Various cultural or mechanical practices are recommended to farmers to manage multiple – HR canola volunteers (Beckie et al 2006; Beckie and Owen 2007). These include: include: (1) leaving seeds on or near the soil surface as long as possible after harvest because a high percentage will germinate in the fall and be killed by frost, whereas seeds incorporated into the soil may develop secondary dormancy that will increase persistence; (2) silaging and green manuring crops to prevent seed set in volunteers; (3) isolating fields of canola with different HR traits to reduce outcrossing; (4) following canola with a cereal crop and not some annual legume crops such as lupin, lentil or chickpea or oilseed crops such as sunflower, because of few or no in-crop herbicide options; rotating canola in a 4-year diverse cropping sequence will deplete volunteers from the seed bank over time and facilitate use of herbicides with different modes of action; (5) scouting fields for volunteers not controlled by weed management treatments and preventing seed set; (6) using pedigreed seed to reduce the probability of AP; and (7) reducing seed loss during harvest by swathing at the correct crop development stage and properly adjusting combine settings.

HR crop volunteers in disturbed or natural ecosystems

HR volunteer canola is not considered invasive in natural (unmanaged) ecosystems. Feral/roadside HR canola populations are frequent, and these too have been found to have multiple HR resistance (Knispel et al. 2007; Yoshimura et al. 2006). Previous studies have shown little difference in fitness among non-HR, single-HR, or multiple-HR canola in the absence of herbicide selection, suggesting HR canola volunteers do not have any greater capacity than non-HR plants to invade disturbed or natural areas (e.g., Simard et al. 2005). Those findings and the results of Beckie et al. (2004) indicate that single- or multiple-HR canola volunteers are less weedy than non-HR plants in either disturbed sites where they can be controlled by herbicides of alternative modes of action or in natural ecosystems where enhanced fitness would only be evident if herbicide selection pressure were to be applied. However, the increasing use of glyphosate in North American cropping systems, spurred by increasing area and frequency in rotation of glyphosate-resistant crops, may require increased alternative herbicide use or other novel tactics to control glyphosate-resistant crop volunteers (Beckie and Owen 2007).

Gene flow to weedy/wild relatives

Interspecific hybridisation, on the other hand, is a less likely consequence of gene flow. Canola is the only commercial GM crop in Canada with both related crop and wild relatives. Studies on pollen flow between GM canola fields and related crops Polish canola [*Brassica rapa* L.] and oriental mustard [*Brassica juncea* (L.) Czern.] documented gene flow up to 200m. Canola can also potentially hybridize with four related weedy species in Canada bird rape [*Brassica rapa*], wild radish [*Raphanus raphanistrum* L.], dog mustard [*Erucastrum gallicum* (Willd.) O.E. Schulz], and wild mustard [*Sinapis arvensis* L.], although field studies to date have only found evidence of hybridisation with weedy *B. rapa* (Warwick et al. 2003; Simard et al. 2006).

The above species with the exception of *E. gallicum* also occur in Australia, as do other closely related compatible relatives (FitzJohn et al. 2007): including *B. adpressa* Boiss., *B. fruticulosa* Cirillo, and *B. tournefortii* Gouan (Hewson et al. 1982). Wild radish is likely the most important weedy relative in Australia but both French and Australian studies have indicated extremely low hybridisation frequencies (reviewed in Warwick et al. 2003). The

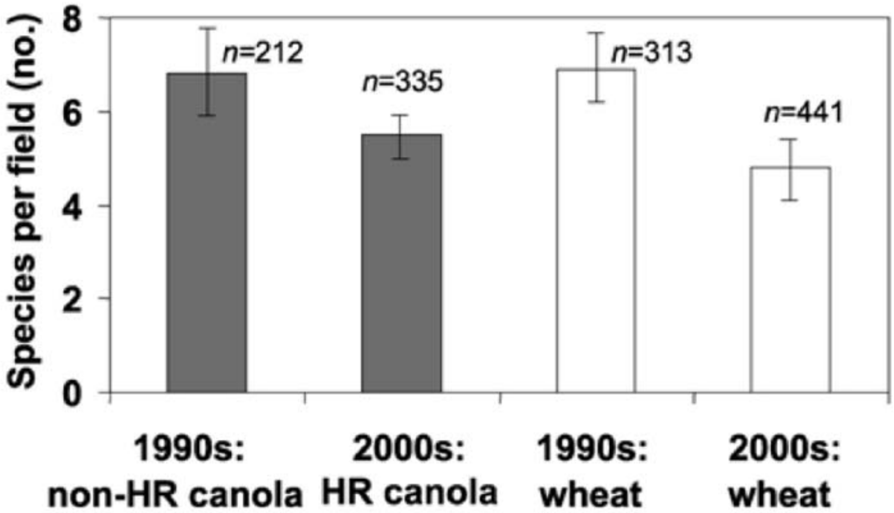
Canadian *B. rapa* sites were the first reports of transgene escape from commercial fields into natural weed populations. Hybridisation frequencies between *B. rapa* and canola are high, averaging 10% and both GLY- and GLU-HR hybrids were found. Hybridisation frequency is affected by recipient genotype and population densities (Simard et al. 2006). The GLY-HR transgene has been shown to persist in these populations over a 6 year period and results suggest stable incorporation (introgression) into the wild species (Warwick et al. 2008). Several studies have indicated an initial fitness cost of early hybridisation events between *B. rapa* and *B. napus*, regardless of the presence of a trangene. The environmental benefits/impact of the GLY- and GLU-HR trait in wild *B. rapa* populations is, however, expected to be restricted to the agro-ecosystem. The more important question will be the impact of true fitness enhancing GM traits such as stress tolerance traits.

HR crops and weed resistance/tolerance

Frequent use of HR crops in cropping systems, resulting in recurrent application of herbicides of the same mode of action, may select for new HR weed biotypes or augment the selection that has occurred previously. There is, to date, no evidence of selection of HR biotypes in unrelated weed species as a result of HR canola production in Canada, although ALS-HR weed biotypes selection is associated with ALS-HR crop use [as is the case in Australia]. Since 2000, evolution of three GLY-HR biotypes has been linked to GLY-HR cropping systems in the United States (Heap 2008): Canada fleabane/horseweed [*Conyza canadensis* (L.) Cronq.], common ragweed [*Ambrosia artemisiifolia* L.], and Palmer amaranth [*Amaranthus palmeri* S. Wats.]. The absence of glyphosate resistance in weeds in Canada can be largely attributed to the fact that RR canola is not monocropped, as is often the case for GLY-HR crops in the United States. If used improperly, glyphosate can create an intense selection pressure for weed resistance and jeopardise the future utility of this important herbicide. Used judiciously, the non-selective herbicides used in HR crops in Canada have been a powerful tool to proactively and reactively manage other HR weeds, such as those resistant to ACCase inhibitors and acetolactate synthase (ALS) inhibitors (Beckie 2006).

There is also no evidence for shifts in weed diversity towards more tolerant species, due to herbicide-use patterns associated with HR canola (reviewed in Beckie et al. 2006). The question of the impact on weed diversity, as a whole, was addressed through a comparison of field survey data conducted in the 1990s (pre-HR canola) and 2000s (post-HR canola) of residual weed species diversity. Weed species diversity (species richness) in non-HR wheat (not grown on canola stubble) in these two periods was used as a basis for comparison (Fig. 5). Differences in weed communities before and after the adoption of HR canola were found to be similar to those observed in wheat, suggesting that HR canola has not reduced weed diversity. GLY–HR canola is, however, associated with large scale adoption of no–tillage agriculture systems in western Canada and with this system – there has been a reduction in weed species richness and a shift to more perennial weed species.

Fig. 5. Weed species diversity in HR vs. non-HR canola relative to spring wheat, as assessed by number of species per field in surveys conducted in the 1990s (pre-HR canola) and 2000s (post-HR canola). (n = number of fields; J. Y. Leeson and A. G. Thomas, unpublished data, in Beckie et al. 2003).



Abiotic and biotic stress tolerance traits

The ecological effects of 2nd generation GM traits, such as abiotic and biotic stress tolerance traits to cold, drought, and salinity, and resistance to disease and insect and nematode pests are now largely undocumented. These are potentially 'fitness-enhancing traits' and could permit transgene spread to non-agricultural habitats. The role these traits may play in regulating both volunteer/feral canola populations and potential weed/wild relatives recipient populations requires further investigation.

Short comings in research on the impacts of GM crops

Based on the Canadian experience, recommendations include: adoption of a specific stewardship plan at the time of introduction of HR canola, and monitoring and regulation of adventitious HR traits in premium and certified seed. We also suggest incorporation of some type of gene containment strategy [i.e. physical distance and/or gene use restriction technologies (GURTs) (Hills et al. 2007)] to limit gene flow. While the environmental impact of the HR trait is generally understood, further research should be conducted on the ecological effects of new 'fitness-enhancing' stress-tolerances GM traits both as it affects increased competitiveness and range/niche potential of volunteer/feral canola populations as well as transgenic hybrid weed populations possessing these traits; potential consequences of transgene spread to non-agricultural habitats (now largely undocumented); and long-term monitoring of indirect effects on weed management, weed biodiversity, and/or selection of resistant biotypes.

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Dr. Suzanne I. Warwick is a Principal Research Scientist
Agriculture and Agri-Food Canada - Ottawa
Biodiversity Theme, Environmental Health National Program
K.W. Neatby Bldg., Central Experimental Farm,
Ottawa, ON, Canada K1A OC6
PH: (613) 759-1829; FAX: (613) 759-1701; Email: warwicks@.agr.gc.ca

ECONOMICS OF GM GRAIN CROPS

Max Foster, ABARE

Summary

Since the introduction of GM crops in 1996, the adoption of GM corn, canola, soybeans and cotton has been rapid throughout the world. Despite some consumer resistance to GM crops, particularly in Europe, GM crops now dominate world trade in grains.

The main drivers of the adoption of GM crops have been agronomic and environmental benefits. But another important driver has been the ability to patent plant innovations, a stronger form of intellectual property protection than the more traditional plant variety rights. Commercialising a new GM crop is a lengthy and costly process, meaning that virtually only the large multinational life sciences companies have the resources to undertake this commercialisation.

There are further GM crops innovations in the world research and development pipeline, particularly in the United States, that will increase competitive pressures on Australia in the near future in world grain markets.

Introduction

The ability to use modern gene technologies modify plants to have desirable agronomic, environmental and product qualities has already altered the landscape of world agriculture and has the potential to deliver further substantial productivity improvements with a range of crops. The progress of gene technology, however, has been complicated by resistance to GM products from a significant proportion of the consumer population. Consumer resistance, combined with the difficulty of keeping GM grains separate in marketing chains, due to cross pollination and mixing in the handling and storage system, has introduced important new dynamics into the economics of GM crops.

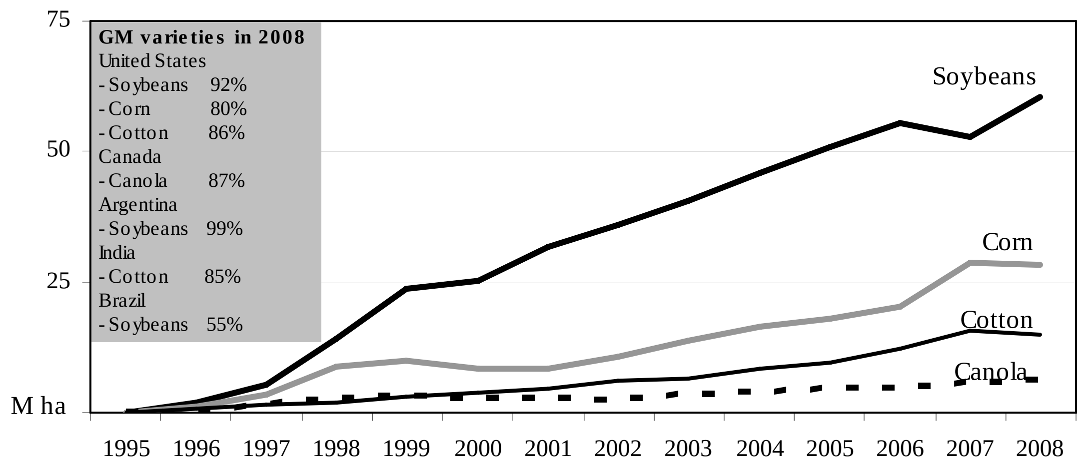
The aim with this paper is to broadly outline the key aspects of the economics of GM grain crops.

The progress of GM grains

There has been rapid adoption of GM crops throughout the world (Figure A). With GM food grain crops, the main adopters are the United States, Canada, Argentina and Brazil. With GM cotton, the main adopters are Australia, the United States, China and India. In 2008, GM varieties are estimated to make up 48 per cent of total world area harvested of cotton; 62 per cent of soybean area; 18 per cent of corn area; and 20 per cent of canola (or rapeseed) area. Commercial crops of GM sugar beet crops were planted in the United States for the first time in 2008, with GM varieties estimated to make up around half of total US sugar beet plantings in 2008-09.

To date, India and China have avoided commercialisation of GM food grain crops, though cottonseed is produced with GM cotton. The only foray by the European Union into GM grain production has been relatively small plantings of GM corn, mainly in Spain.

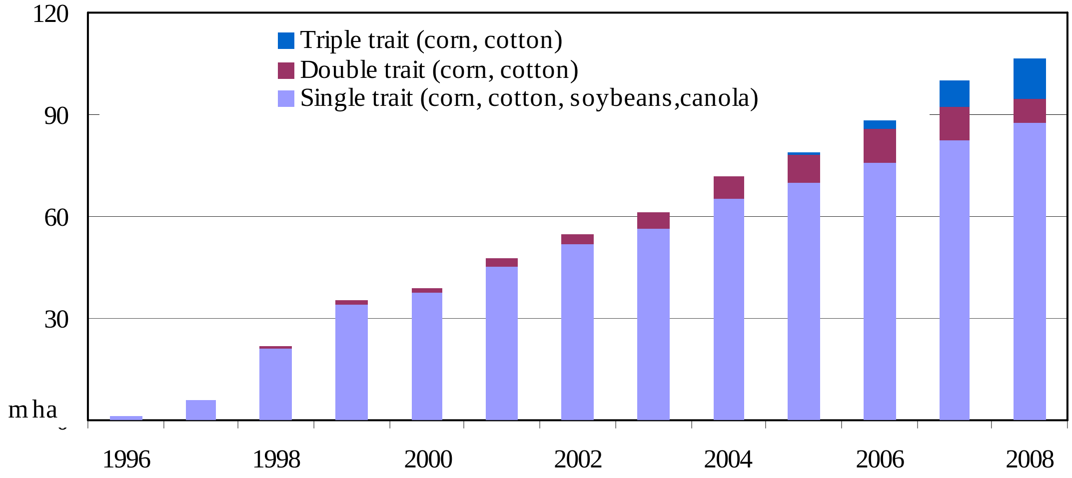
Figure A: World area harvested of GM crops



Source: ABARE estimates.

The main GM traits that have been commercialised are insect resistance and herbicide tolerance. GM traits owned by the life sciences company Monsanto are included in more than 90 per cent of the world's GM crops. GM crops started out with single altered traits but have evolved to have up to three traits (Figure B). The 'triple trait' corn varieties, available in the United States, have GM traits providing resistance to the corn borer and rootworm and tolerance of herbicide applications. The 'triple trait' cotton varieties have tolerance of herbicide and two separate inserted Bt genes providing insect resistance. The currently commercialised GM soybean and canola varieties provide only herbicide tolerance.

Figure B: Areas planted worldwide with Monsanto GM traits



Source: Based on data from Monsanto (2008a).

The rapid adoption rate of GM crops reflects that there significant agronomic and environmental benefits with these GM cultivars. Based on a survey of the available literature, Brookes and Barfoot (2008) estimated that the net economic benefits at the farm level of the currently commercialised GM crops were US$6.94 billion in 2006 and US$33.8 billion for the period 1996 to 2006. Brookes and Barfoot also estimated that the adoption of GM crops reduced herbicide and insecticide use by 15.4 per cent and reduced greenhouse emissions from cropping areas in 2006 by an amount equivalent to taking 6.6 million cars off the road.

All GM crops are subjected to extensive assessments by regulatory authorities before they are released commercially to ensure that they do not impose risks to the environment or human health. The conclusion of Sanvido, Stark, Romeis and Bigler (2006) who carried out an extensive review of the scientific knowledge of environmental impacts of GM crops derived from ten years of worldwide experimental research and commercial cultivation was that 'the data available so far provides no scientific evidence that the commercial cultivation of GM crops has caused environmental harm' (Sanvido et al 2006, p. vi).

Market acceptance

Many surveys of consumer attitudes suggest that there is widespread consumer resistance to GM products and a willingness to pay more to avoid GM products. A range of market access requirements at the country level have been erected in response to perceptions of consumer concerns and environmental issues.

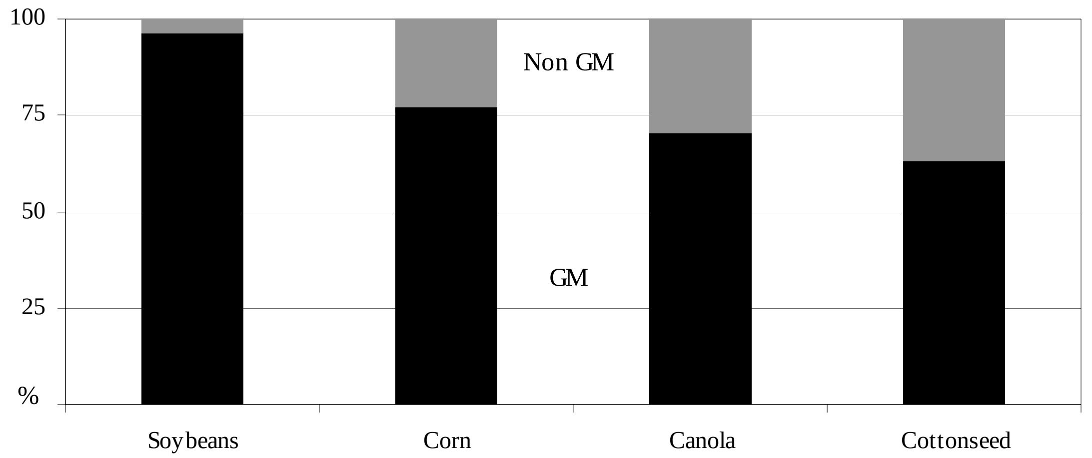
Prior to 1998, the European Union approved some GM varieties of soybeans, corn and canola for import but maintained a virtual moratorium on further approvals until the approval process was restarted in late 2004. It was only in April 2007, that the major varieties of GM canola were approved for importation into the European Union for animal feed and industrial purposes.

The other important form of market access requirement is mandatory labelling of products containing GM inputs that apply in most of the main grain importing countries. Recognising that it is difficult and prohibitively expensive to ensure complete absence of GM material, the mandatory labelling regimes usually have thresholds for unintended presence of GM materials. While there is a zero threshold in China, the thresholds are 0.9 per cent in the European Union and 5 per cent in Japan. Importantly, labelling regimes in most countries also do not require labelling if modified DNA is not detectable in the product. The key exceptions are China and the European Union. Only the European Union requires labelling of GM feedstuffs. No country mandates labelling of animals fed GM feedstuffs.

Despite these market access requirements, world trade in the grains and oilseeds for which there are GM varieties is dominated by countries that produce GM products (figure A). There are segments in world markets where there is a willingness to pay price premiums for non-GM grains, but these are very much niches. The main niche is with non-GM soybeans, accounting for an estimated 8 per cent of world soybean exports and paying price premiums of 2–9 per cent.

A recent ABARE analysis (Foster and French 2007) of canola prices paid by the key canola importing countries — Japan, Mexico, Pakistan and China — found no convincing evidence Australia's non-GM canola was earning significantly higher prices than Canada's GM canola in these markets. (While non-GM varieties make up 10-15 per cent of Canada's canola plantings, no segregation is undertaken so virtually all Canada's export canola is considered GM.) Canada accounts for more than 70% of world trade in canola, excluding intra-European Union trade, and its canola exports have more than doubled since the introduction of GM canola in that country.

***Figure* C: Shares of GM and no-GM producing countries in world grain trade**



a Three years to 2007-08. Excludes intra-EU trade.
Source: Based on US Department of Agriculture (2008) data.

A number of studies point to consumer acceptance issues with GM wheat (Sayler 2001; Wisener 2006), though this acceptance has never been tested in the market place. A herbicide tolerant wheat variety was submitted for regulatory approval in the United States in 2003 but the developer did not proceed to commercialisation because of concerns about consumer acceptance.

Key wheat marketers and industry organisations in Australia and North America have stated that they only support the introduction of GM wheat if there is widespread market acceptance, workable identity preservation arrangements and acceptable tolerances in world markets for unintended presence of GM wheat in non-GM wheat (Australian Wheat Board 2007; Canadian Wheat Board 2007; US Wheat Associates 2006).

Future generations of GM crops are likely to offer enhanced qualities, such as oilseeds with oil profiles altered to be healthier; consumer acceptance issues with these could be less than the current generation of GM crops that largely offer only agronomic benefits.

Identity preservation, segregation and coexistence

If premiums do exist for certified non-GM grains, it may be necessary to implement segregation or identity preservation arrangements aimed at preserving the non-GM status of the conventional grain. (Identity preservation is the process by which a crop is grown, handled, delivered and processed under controlled conditions to assure the customer that the crop has maintained its unique identity from seed producer to end user.) There is wide and successful experience in Australia of identity preservation with conventional grains like durum wheat and malting barley, though identity preservation with GM grains presents some new challenges.

Numerous overseas studies point to significant additional costs associated with segregation and identity preservation of grains. There is also the issue of who will bear the additional costs — GM or non-GM growers?

In Australia, ABARE estimates in Foster (2006) suggest that the cost of keeping GM and non-GM canola separate in the handling and storage process would average 4–6 per cent of the farm gate price for canola at ‘representative’ receival sites in four different regions of Western Australia.

It could be argued that the additional cost is not justified, given the lack of price premiums in world markets for non-GM canola reported by Foster and French (2007).

With future generations of GM crops, however, there are likely to be enhanced quality characteristics that earn price premiums, such as healthier oil profiles or pharmaceutical properties. This means that the emphasis of the identity preservation task is likely to shift to the GM varieties.

The grain industry in Australia has developed a set of guidelines aimed at enabling GM, conventional and organic industries to coexist. Concerns have been expressed over the impact on the Australian organic industry, a small but growing industry that earns significant price premiums for its produce. An ABARE analysis (Apted and Mazur 2007) concluded that commercialisation of GM canola in Australia is likely to have only negligible direct impacts on the organic canola, livestock and honey industries. It was acknowledged, however, that the introduction of GM varieties of other crops that are more extensively grown in Australia as certified organic may have a different impact.

Intellectual property protection

Intellectual property rights are an important influence on the rate of development of GM crops and the rate at which they diffuse through industry. Intellectual property protection enables technology developer to appropriate benefits from their innovations by giving them exclusive rights (market power) for a set period of time, usually twenty years in the case of patents. Utility patents — the devices that have traditionally applied to industrial innovations — have assumed heightened importance as drivers of technological progress in gene technology. With plants, they represent stronger property protection than the more traditional form of protection of plant variety rights.

Over the last twenty years, the large multinational life sciences companies have tended to enhance the ability to appropriate the benefits by buying up key intellectual property and seed companies as delivery vehicles for their technologies.

Intellectual property protection gives technology owners the ability to impose a technology fee. In setting this technology fee, at least part of technology benefit must be passed on to producers otherwise they will not adopt. Monsanto, for example, says its pricing model is to pass on 30–40 per cent the benefits to growers (Monsanto 2007). Competitive markets mean that the benefits provided to growers from productivity improving crop technologies also get passed on to consumers in the form of lower prices.

Intellectual property protection also has the advantage of providing incentives for technology owners to prolong the life of the technology, for example, making sure that users of the technology undertake practices (through Technology User Agreements) that minimise the development of resistance to the in-plant chemical or herbicide.

Some patents for key intellectual property related to GM crops are reaching the end of their protection period (Monsanto 2008). Monsanto’s insect protection traits, including *YieldGard* Corn Borer and *YieldGard* Corn Rootworm traits in corn seed and *Bollgard* Trait in cotton are protected by patents that extend to 2011. Having filed patents in 2001 and 2002 on the insect protection trait in cotton called *Bollgard II*, the patent protection is expected to extend through to 2022. Monsanto’s herbicide tolerant products (*Roundup Ready* traits in soybean, corn, canola and cotton) are protected by US patents that extend to at least 2014. Monsanto’s second generation trait for cotton, *Roundup Ready* Flex, is protected by US patents through 2025.

GM crops in the pipeline

There are numerous GM crops in the research and development pipeline throughout the world. Monsanto is the main provider of GM traits in crops, providing seed for more than 90 per cent of world plantings of GM crops. The main crop innovations in Monsanto's research and development pipeline are summarised in Table 1. A number of these crops are approaching commercialisation and appear to offer significant productivity advances. For example, Monsanto (2008b) claims that *Roundup Ready 2 Yield* soybeans that will be released in 2010 will provide yield increases of 7–11 per cent compared with its first generation *Roundup Ready* soybeans.

Table 1: Monsanto research and development pipeline

	Phase I **Proof of concept**	**Phase II** **Early product development**	**Phase III** **Advanced development**	**Phase IV** **Pre-launch**
Average probability of success	25 per cent	50 per cent	75 per cent	90 per cent
Average duration	12 to 24 months	12 to 24 months	12 to 24 months	12 to 36 months
Key activities	▪ Gene optimisation ▪ Crop transformation	▪ Trait development ▪ Pre-regulatory data ▪ Large scale transformation	▪ Trait integration ▪ Field testing ▪ Regulatory data generation	▪ Regulatory submission ▪ Seed bulk-up ▪ Pre-marketing
Corn	▪ *YieldGard* Rootworm III ▪ Second generation drought-tolerance ▪ Nitrogen utilisation	▪ Drought tolerant corn ▪ High yielding corn	▪ *SmartStax* corn	▪ *YieldGard* VT PRO ▪ Extrax corn processing system
Cotton	▪ Drought tolerance ▪ Dicamba (herbicide) tolerance ▪ Lygus (insect) control	▪ *BollGard III*		
Soybean	▪ Nematode resistance	▪ Dicamba (herbide) tolerance ▪ Insect protected ▪ High yielding ▪ High stearate ▪ *Vistive III* – altered oil profile	▪ *Vistive II* – altered oil profile ▪ Omega-3 ▪ High oil	▪ *Roundup RReady2Yield* ▪ Improved protein
Canola		▪ *Roundup RReady2Yield*		

Source: Adapted from Monsanto (2008b).

There are different forms of GM wheat at various stages of development throughout the world. The closest to commercialisation of these would appear to be a fungal disease (fusarium) tolerant variety that could be released in North America as early as 2010.

Getting regulatory approval for environmental release in the producing country and food release in the many different consuming countries is time consuming and costly. Monsanto puts the process of taking a GM crop from development to commercialisation as around ten years and the costs as around US$100 million a GM crop type. One implication of this is that the commercialising of GM crops has very much become the province of large multinational life sciences companies like Monsanto and Bayer CropScience.

Adoption of GM grains in Australia

Australia has commercialised GM cotton in 1996 and GM varieties are estimated to have made up 96 per cent of total Australian cotton plantings in 2007-08. There has been triple trait cotton varieties planted in Australia since 2007, containing two separate Bt genes conferring insect resistance and a gene conferring herbicide tolerance. GM canola has been approved for growing in New South Wales and Victoria for the first time in 2008, after being approved for environmental release by the Gene Technology Regulator in 2003.

ABARE has undertaken a number of analyses aimed at quantifying the economy wide impacts of adopting GM crops. The latest of these analyses are Acworth, Yainshet and Curtotti (2008) and Nossall, Abdalla, Curtotti, Tran and Brown (2008) who looked at the economic impacts of the adoption of GM wheat and oilseeds (canola and soybeans). It should be noted that these analyses assumed no consumer acceptance issues with GM crops (including GM wheat) and, hence, no price premiums for certified non-GM and no need to carry out costly segregation or identity preservation.

According to Nossal et al, estimated earnings from Australian oilseeds and wheat exports would increase by $912 million (in 2007 Australian dollars) by 2018, compared to what would be the case without adoption. Because GM wheat and oilseed areas would expand at the expense of other agricultural production alternatives, total agricultural exports would increase by only $747 million (in 2007 Australian dollars) by 2018.

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INTEGRATED WEED MANAGEMENT AND THE IMPLICATIONS OF HERBICIDE TOLERANT CROPS

Murray Scholz
2007 Nuffield Australia Scholar

Executive Summary

- Herbicides have changed the way farmers grow crops by allowing them to practice reduced tillage, but weeds have developed resistance to herbicides.
- It costs approximately $200 million and 10 years to develop a new herbicide, but the number of new herbicides coming to the market is decreasing because of reduced research, higher development costs and more stringent environmental standards. The last new mode of action was discovered in 1991.
- Genetically modified herbicide tolerant crops have been grown commercially in North America since 1996. Soybeans, canola, corn, cotton, alfalfa and sugar beets have been released.
- Positives of the technology have been simple and effective weed control, perceived to be easy to manage, has allowed an easy uptake of no-till cropping and higher end profits (but not always).
- Negatives have been weed shifts, weeds developing resistance to glyphosate, gene flow in the same species and between related species, and requires a strong degree of management to deal with issues like herbicide drift and volunteer weeds in following crops.
- Canada has been successful in using the technology to achieve higher profits and cleaner paddocks. The USA also has had some success, but the lack of crop rotation, and the continuous growing of HTGM crops is leading to major issues with glyphosate resistant weeds especially in cotton.
- HTGM crops are not the only context in which weeds are developing resistance to glyphosate. Fallow systems and use along roadsides are also developing resistant weeds.
- Australian farmers should be allowed to grow HTGM canola which is expected to provide improved weed control and yields than the triazine tolerant varieties that are now grow. There needs to be limits (possibly by regulation) to the amount of time between HTGM canola crops. Farmers also need to use integrated weed management techniques like pre-emergent herbicides, diverse rotations, rotation of knockdown herbicides and non herbicide methods.
- It is important that Australian industries get HTGM crops right. If we have weeds that develop resistance to glyphosate it could limit grower's ability to continue to use reduced tillage.

Herbicide tolerant genetically modified crops

Roundup and Roundup Ready genetically modified crops

Glyphosate is a particularly effective herbicide because most plants metabolically degrade it very slowly or not at all. Its relatively slow mode of action allows it to move throughout the plant before symptoms occur. It is also a "safe herbicide" with a reported acute oral toxicity of LD50 > 5000mg/kg in rats. It is a very popular herbicide in Australia, mostly being used in southern winter cropping agriculture as a knockdown herbicide before planting. It has been one of the main reasons that farmers have been able to take up no-till farming systems and even move towards zero till.

In 1996, Monsanto released to the North American market genetically modified crops that were tolerant to glyphosate marketed as Roundup Ready (RR). This enabled farmers to spray a growing crop with glyphosate and not hurt that crop while killing the weeds. RR soybeans and canola were introduced in 1996; RR cotton came in 1997l and corn in 1998. PR alfalfa (lucerne) was released in 2005, but is currently under a moratorium, while sugar beet had a release in 2006. Take up of crops like soybeans, canola and cotton was rapid and in North America today 90% of soybeans, 85% of cotton and 50% of the corn is Roundup Ready.

The take up of all GM crops around the world has been rapid. In 2006 102 million hectares of GM crops were grown (not all herbicide tolerant) an increase of 71% from 2002. There are 22 countries that grow GM crops with the largest being USA, Argentina, Brazil, Canada, China and India.

The reason that herbicide tolerant genetically modified (HTGM) crops have become so popular is because they have lots of positives such as:

- Simple and effective weed control
- Perceived to be easy to manage
- Have allowed an easy uptake of no-till cropping
- Higher end profits (but not always)

But no technology is 100% positive and a number of issues have emerged, namely:

- Weed shifts;
- Weeds developing resistance to glyphosate;
- Gene flow in species and between species;
- HTGM cops require a strong degree of management to deal with issues like herbicide drift and volunteer weeds in following crops.

The Liberty Link system

Bayer has its own HTGM system called 'Liberty Link', which is based around the herbicide glufosinate. It is the only group N herbicide and marketed as Basta or Liberty. The system has not been as popular as Monsanto's but it's becoming more popular with Canadian canola growers. Growers in the U.S. feel that in soybeans and corn the varieties available aren't good enough and that the herbicide isn't as effective.

Monsanto announced in April of 2008 that from 2010 (subject to approval) that they will be adding the glufosinate tolerance gene to their corn varieties in what they call 'Smart Stax'. These varieties will be tolerant to glyphosate and glufosinate as well as having the Bt genes for both above and below ground insect control.

I do not look at the Liberty Link system at depth in this presentation. At this point in time glufosinate has a very limited use as a HTGM technology in southern Australian farming systems. Glufosinate needs day-time temperatures to be above 18 degrees Celsius at application and ideally for several days before and after. When Australian farmers would need to be applying the product on growing crops the temperature is rarely that high. It is also a herbicide that is not as effective on grass weeds. Most Canadian farmers that use glufosinate tank mix clethodim (a group A commonly known as Select) to help control grasses.

Positives of HTGM crops

There is little doubt that growers of HTGM crops have found that their weed management has been easier and more effective. Before the introduction of RR technology in North America, cotton, canola, soybean and sugar beet crops all had weeds that were difficult to control with existing herbicides. Most of the options were expensive and many did not do a very effective job, while some of the herbicides actually harmed the crop. Glyphosate on the other hand, is very effective at killing most weeds and, if used properly, does no harm to the HTGM crop. Management is made easier because growers can now just plant and spray. If the season is late or difficult growers know that they can get away without a knockdown because they will have effective and reasonably cheap in crop weed control.

The Canadian Canola Council surveyed growers in 2001 about their opinions to HTGM crops. Over 80% said that weed control was more effective and 59% indicated that HTGM canola helped them to manage or delay herbicide resistance. Another reason given for growing HTGM was that growers could use the technology to clean up weedy paddocks, especially broadleaf problems.

The take up of HTGM has been matched with a huge take up in reduced tillage and no-till systems. Now that growers had effective weed control many felt they no longer needed to cultivate. This has meant a massive reduction in the consumption of fuel. The Canadian Canola council estimates that Canadian growers are saving 31.2 million litre of diesel a year by reduced tillage. A study of the sugar beet industry conducted in Europe in 2004 concluded that energy requirements would be cut by 50% by growing HTGM sugar beet. This study looked at herbicide manufacturing, transport and field operations.

The adoption of HTGM crops has also seen a massive drop in the amounts of more toxic herbicides being put into the environment. Critics often refer to the amount of herbicide used and cite that more herbicide is being used. This can be true because glyphosate is not a low volume herbicide, but ignores the fact that glyphosate is replacing many herbicides that are far more toxic to both humans and the environment, even if they are used in smaller amounts. Depending on the crop, there can be dramatic reductions in herbicide use. In 2001 a review of the American soybean industry concluded that growers had replaced 3.27million kilograms of other herbicides with 2.45 million kilograms of glyphosate a saving of over 800 thousand kilograms.

Canola, soybean and cotton growers all have said that they are making more money by growing HTGM crops. Research seems to back them up as we will see when we look at each individual crop.

The Negatives of HTGM crops

Weed shift is when the species of weeds in the paddock changes and is not something unique to HTGM crops. Every time farmers change their management system weed shift occurs. Weeds respond to the changes in the system and the ones that the new system suits the most then dominate. Farmers have seen weed shift when they changed from cultivation to no-till systems.

Growing a HTGM crop once every three or four years should not have a big impact on weed spectrums. This is certainly the case in Canada where both growers and agronomists I spoke to hadn't perceived a change. When HTGM crops are grown continuously, however, there is definitely weed shift occurring with an increase in perennial weeds and weeds with a natural tolerance to glyphosate.

I was fortunate enough to visit a long term trial conducted by Kansas State University at Colby, Kansas. This trial, which has been running for 12 years, looks at weed shift with RR crops. The trial has been replicated at four other sites across Nebraska, Wyoming and Colorado.

At Colby they have grown either continuous RR corn or a rotation of RR corn and RR soy beans. It is all no-till and no pre-emergent herbicides except glyphosate have been used. Both rotations have received four different herbicide treatments, namely:

- Full rate of glyphosate
- Half rate of glyphosate
- Conventional in crop herbicides
- Alternate glyphosate one year and conventional herbicides the next.

The results show how much management effects weed populations.

1. *Conventional herbicides:* The plots were very weedy with lots of grass weeds. The crops were also showing damage from the herbicides.
2. *Full rate of Glyphosate:* These plots where the cleanest for weeds especially in the more competitive corn. There was an increase of perennial weeds like Kochia (*Kochia sp.*), Russian thistle (*Salsola iberica*) and Mares tail (*Equiseteum arvense*). Glyphosate resistant weeds have not yet happened despite the only weed control being 36 continuous applications of glyphosate. Dr Phil Stahlman who is head of these trials believes that resistant weeds are only two or three years away.
3. *Half rate of glyphosate:* These plots had lots of Palmer amaranth (*Amaranthus palmeri*) starting to take over as well as the species mentioned in the full rate trial above. It was interesting to note that after six years yield had dropped dramatically

because of weed competition. The yields for the continuous corn trial were over 40% lower in the half rate compared to the full rate trial.

4. *Alternating glyphosate and conventional herbicides:* These trials results were very similar to the half rate results.

In all the trials that received glyphosate the weeds had adapted by germinating after the last application of glyphosate. The corn/soybean rotation was also not effective because in the 20 inch rainfall site it is probably too dry for soybeans and so they don't compete with weeds very well.

This trial really shows that when you only use one herbicide (glyphosate) and one management technique (in crop herbicides), weed shift and resistance are inevitable. It also shows that weeds that have a natural tolerance to glyphosate like mares tail have an advantage. Farmers in Australia have already seen this with no-till and using glyphosate for a knockdown, with weeds like marshmallow (*Malva parviflora*) becoming more prevalent.

Weed resistance to glyphosate has happened because of an over reliance on just using glyphosate for weed control. When we look at the American experience of growing HTGM crops we will see how this has happened.

Gene flow in a species is an issue with crops like canola and corn. It is not something unique to HTGM crops as pollen has been moving genes within species since time began. It is something that the North Americans have done little to manage and therefore most of the canola and corn has some degree of contamination.

Research has shown how far pollen carries genetic material. One study conducted here in Australia by the CSIRO looked at pollen flow from imidazoline (group B non GM) tolerant (IT) canola to conventional canola. A total of 63 paddocks from South Australia, Victoria and NSW were surveyed, with samples taken in conventional canola 0-5 km away from the IT canola. Large samples of seed were collected at 3 sites in each paddock, the edge closest to the IT, the middle and the far edge. The results found that 69% of the sites had no IT genes and the remainder had less than 0.25%. This was lower than some overseas studies possibly because of our drier weather making pollen less viable and less bees.

The European Union which is possibly the most difficult market for GM products has accepted a tolerance level of 0.9%. Studies in the US have shown this to be workable using buffers. The width of those buffers is controversial with politics confusing the science. Those who would like to see a tolerance set at zero have unrealistic expectations about the ability to totally eliminate pollen movement and need to remember that the crops they grow are also contaminating their neighbours. This could become an issue if highly specialist GM crops (for medical or industrial purposes) are grown that need to be kept pure.

Gene shift between species is much less of a problem. The Canadians tried to cross HT canola with weeds like wild mustard and wild radish in both field and green house experiments. Hybrids between the crop and weed were extremely rare and the hybrid had poor vigour and was often sterile. It appears that the herbicide resistance gene is not very inheritable with only 50% of the first generation inheriting the trait. After four generations it was under 1%. The myth that Canada is overrun with a super weed of herbicide resistant wild mustard is just that – a myth.

Gene flow does raise the issue about what plants should be HTGM. As genetic technology advances and traits such as drought tolerance, frost tolerance and nitrogen efficiency are developed thought should be given to whether those plants should be herbicide resistant as well. A gene that gives a plant a fitness advantage could give that plant a competitive edge in the wild. If it is herbicide resistant to one or more herbicides it could make it a difficult plant to manage. This does not mean that we should not develop or use those traits, it just means we need to think through carefully how we use them.

HTGM crops are not plant, spray and forget. They still require a high degree of management and farmers need to be aware of issues such as herbicide drift, record keeping and volunteers as weeds. None of these issues are major but if ignored they can turn into disasters if not managed properly.

Growers need to be aware of herbicide drift. Even though farmers have been applying glyphosate for a long time it is usually at planting as a knockdown. With RR crops they are applying it during the growing season when spray drift can be quite damaging. If applied properly when conditions are right it shouldn't be an issue.

Record keeping is an imperative. Everyone involved with the management and care of a HTGM crop needs to know which crops are HTGM and which are not. This is not just for segregation at harvest but growers need to remember that non RR crops are just as susceptible to glyphosate as weeds are. In the early days of RR crops in North America more than one was wiped out with the wrong herbicide.

It is also important to have long term records so that growers are prepared to deal with volunteers as weeds in following crops. Farmers need to remember to add an extra product to their knockdown such as 2,4-D, bromoxinal, oxyfluorfen or a group B. Better still use a different herbicide group to glyphosate for their knockdown.

A Canadian study looked at the persistence of volunteers and found that most germinated in the first year after the HTGM crop. If the growers are using no-till, there were no volunteers germinating in the third crop grown after the HTGM crop. If the farmers are aware of the issue it's easy to deal with.

North American Experience

The Canadian experience

Over 90% of **canola** grown in western Canada is herbicide tolerant to glyphosate, glufosinate or imidazolinone. It is giving them effective weed control and higher profits. Take up was rapid and within five years of introduction over 80% was HTGM. Growers like the technology because of easier management and better control of weeds like mustard (*Sinapis arvesis*) stinkweed (*Thlaspi arvense*) cleavers (*Galium aparine*) and stork's bill (*Erodium cicutarium*). All of these had been difficult and expensive to control in conventional canola.

Most growers use canola as part of a rotation with wheat, barley and sometimes peas. The standard recommendation from agronomists is to grow canola only once every four years. Some growers have been growing it more often but are running into issues with disease and insect pests.

Canada is a good example of how growing HTGM crops has encouraged the uptake of no-till. Timeliness is important because of a short growing season, the combination of no-till and HRGM crops have allowed farmers to plant earlier. They now no longer need to wait for weeds to germinate before planting. Farmers can plant confident of good control of weeds in crop.

Weeds developing resistance to glyphosate has not been an issue yet. Most Canadian farmers practice good integrated weed management even though the tactics they are using often aren't specifically aimed at weed control. Farmers are using vigorous varieties and high seeding rates in both canola and cereals. Recommended rates for canola are 5-6 Kg/ha and for cereals 120Kg/ha. Nearly all of the canola varieties grown are hybrids. Growers like them because of their vigour and yields up to 30% higher than open pollinated varieties.

A lot has been said by some critics of GM about the amount of hybrids grown in Canada and the fact that you cannot keep seed from them. In reality, growers have a choice and they are choosing hybrids because they get better weed control because of the better seedling vigour and the higher yields put more money in their pockets. In 2008 there were eight seed companies offering a total of thirty varieties of Roundup Ready canola so growers do have choice.

Liberty Link canola is also popular with farmers. They have good varieties and growers like to rotate the technologies because some are concerned that they may be using too much glyphosate.

Effect of in-crop herbicide treatment on weed biomass and net returns in canola.

Herbicide	Weed biomass (kg/ha)	Net return ($/ha)
Glyphosate x 1	296	**354**
Glyphosate x 2	136	321
Ethalfluralin (E)*	1393	286
Sethoxydim (S) + Ethametsulfuron (Eth)	1182	245
E + S + Eth + Clopyralid	410	165

* Ethalfluralin was applied to the soil surface in the fall. Adapted from O'Donovan et al. (2006)

Farmers are achieving better profits from HTGM canola. Agriculture and Agri-food Canada conducted a three year trial beginning in 2001 looking at profitability and how effective weed management was with different herbicide regimes. The trial was conducted in three locations, Beaver Lodge, Lacombe and Lethbridge and the results were quite significant. The non-glyphosate treatments had more weeds and returned less dollars a hectare. It is not surprising that farmers have embraced HTGM canola.

Eastern Canada uses HTGM **soybeans** and **corn**. Around 65% of soybeans are HTGM and 40% of corn. They are usually grown in a rotation that includes winter wheat. Few growers practice no-till because low soil moisture is rarely an issue.

Just as in western Canada, growers like the technology because of better weed management and higher profits. They too have not had issues with weeds developing resistance to glyphosate. The fact that growers have at least three crops in the rotation, that they rotate herbicides and that they are still cultivating, is keeping them from problems.

The United States experience

Soybeans, corn & cotton

The United States of America grew 54.6 million hectares of genetically modified crops in 2006. Not all of those crops were herbicide tolerant but the vast majority were. The big three crops, soybeans, corn and maize make up a very high proportion of the total area.

Many farmers in the Midwest states of the U.S. grow a continuous rotation of just corn and soybeans. This is usually corn–soy–corn–soy, but in recent years some growers are extending the rotation to soy–corn–corn in response to record prices of corn. There is a mix of tillage systems with the wetter states like Iowa and Illinois tending towards cultivation while drier areas like eastern Kansas and Nebraska tend to no-till systems.

U.S. growers took up Roundup Ready (RR) soybeans very quickly. Within three years of their introduction, 95% of soybeans grown were HTGM. There were several reasons why growers embraced the technology so quickly. Weed control in soybeans had been difficult with the only options either a group B herbicide or a group G herbicide. The latter can damage the crop, so farmers were using group B's on approximately 80% of the crop. Water hemp (*Amaranthus rudis*) is a native North American plant that was regarded as a minor weed before it developed resistance to the group B herbicides. Prior to RR, weed control in soybeans was therefore not satisfactory and growers where resorting to hand-chipping of weeds. When RR soybeans became available growers took it up because weed control was good and management seemed easy.

Farmers in the U.S. seem to have a love/hate relationship with companies like Monsanto. They love the RR technology but don't particularly like paying the higher seed costs. One of the consequences has been a reduction in seeding rates by between 20–30%. Soybeans are a crop whose yields are not affected by seeding rate but a lower rate means that the crop is less competitive against weeds.

When **RR soybeans** were released the seed companies claimed the yields matched conventional varieties. While growers disputed this, they still embraced the technology because of the other advantages. Today the GM varieties are better and that is where most of the research money is going because GM has such a large share of the seed market. Approximately 5% of the market is conventional varieties for human consumption. As in Canada, they are receiving a premium and segregation is not an issue. Even with the higher seed costs, growers admit they are making higher profits growing GM and are unlikely to go back to conventional varieties.

RR corn was introduced in 1998 but the take up was slow. The early varieties didn't perform as well as conventional varieties and growers had plenty of effective herbicide options. As late as 2005 RR corn was only 20% of the market. That changed when Monsanto introduced the Bt gene for control of rootworm. Rootworm had been a big problem in places like Iowa and they were difficult to control. The only way growers could get seed with the new Bt gene was Roundup Ready. Now that they were paying for the RR technology whether they used it or not most decided to use glyphosate for their weed control. By using RR corn it also took away issues with drift from the RR soybeans.

This has led to a situation where a grower can just use glyphosate for weed control because they are growing a RR crop every year. The U.S. growers don't seem to like the Liberty Link system and so there is no rotation of herbicides.

"*Roundup Ready technology made ordinary farmers into good farmers........but only for a while*". Phil Stahlman, Weed Scientist, Kansas State University

Going to a total RR system in the corn-soybean rotation has, I believe, made farmers lazy with many just using glyphosate for weed control. When they started growing RR crops it was easy to just go out with glyphosate and the weed kill and profits were good. Many are trying to cut costs by cutting rates or delaying the in crop application of glyphosate as late as they can so that they only need one application. This is putting a lot of pressure on the herbicide to kill some very large weeds, some that have a natural tolerance to glyphosate. I feel that this is also false economy as what they save in herbicide they have lost in nutrient removal by the weeds. Where cultivation is the norm, because it is a form of non herbicide weed control they are currently staying on top of glyphosate resistant weeds. Even so there is an increasing incidence of fields with weeds like water hemp, giant ragweed (*Ambrosia trifida*) and horse weed (*Conyza canadensis*) becoming problems.

The better farmers are still using pre-emergent herbicides and are very aware about applying glyphosate in ideal application conditions and not cutting herbicide rates. Weeds scientists I spoke to believe that glyphosate resistance will explode in the next 5 years in the corn–soy rotation. With current practices farmers are removing susceptible weed populations by using glyphosate several times every year.

RR cotton was introduced to the U.S. market in 1997 and was taken up quite rapidly to where it is currently 85% of the area grown. The amount of RR cotton varies from region to region. In California less than 60% is RR while in the southern states like Georgia, Florida, Mississippi, Louisiana and Missouri RR accounts for 98-100% of cotton planted.

Before RR cotton growers typical weed management involved a pre-plant tillage, 3-5 herbicides applied at least 3 times during the cropping season and 2 in crop cultivations between the rows. When they went to RR this changed to one application of glyphosate before planting, and then 4 applications of glyphosate in crop. They no longer needed to cultivate so the majority became no-till farmers and today approximately 100 million hectares are no-till RR cotton. A survey of fields in Georgia in 1999 shows why no-till RR cotton became so popular.

Yield and returns from conventional and RR cotton in Georgia in 1999.

Technology	Tillage	Yield	Return @ 65c/lb	Variable costs	Gross margin
		Lbs/acre	$	$	$
Bt	Conventional	656	426	202	224
RR	Strip	1185	770	224	546

When it comes to weeds, cotton is a poor competitor and needs 8 weeks of weed-free growth following planting to make maximum yields. One of the biggest problem weeds for the southern states is Palmer amaranth. It is a weed that has vigorous growth and the ability to set seed. Before the advent of RR cotton growers had Palmer amaranth already resistant to group B's and atrazine. Up to 10 years of continuous cotton with the only weed control being from up to five applications of glyphosate a year has not surprisingly led to problems.

It's believed in the state of Georgia that there is somewhere between 100,000 and a million hectares of cotton country with some level of glyphosate resistant palmer amaranth. In the next couple of years this is expected to rise to 30% of the total cotton area. Even though they are having problems, growers are still using glyphosate on fields with resistant weeds because they are paying the tech fee.

This situation is as close as agriculture has come to the feared 'super weed' that opponents of GM technology rail about. It is probable that somewhere in the U.S. a field has Palmer amaranth that is resistant to group B's, atrazine and glyphosate. This has NOT occurred from gene shift but from very bad management on the part of the U.S. cotton industry. A field in that situation has very limited herbicide options. They do have a group G herbicide but how long can one herbicide last when it's the only option?

It is expected that new HTGM technologies won't be available till 2014 so major changes will have to be made in how cotton is grown. Growers are going to have to return to tillage, cover crops and rotations with other crops. One could easily argue that they should have been doing that all along. It is expected that growers will spend an extra $400 million a year in extra herbicide trying to deal with the situation they are in.

The reasons for failure

Why is it that a technology that is so successful in Canada has developed or is developing so many issues in their neighbour, the U.S.A? Opponents of GM are quick to say the technology is inherently flawed and doomed to failure but if that was the case Canada would be having just as many problems. At the end of the day the technology has not failed. What has failed has been the management of the technology and just plain out bad farming practices.

The lack of rotation of herbicide groups and crops together with a general lack of non herbicide methods has come together in creating a glyphosate resistant weed problem. The bad farmers reaped the rewards for awhile but now there is a price to pay.

"Tell the farmers of Australia to rotate their crops and their herbicides"

Herb Mattson, Farmer, Colby, Kansas

Growing HTGM crops doesn't automatically give you glyphosate resistant weeds. What management strategies growers adopt will determine if and when they get resistance. The U.S. cotton industry is a good example. They have now made the same mistakes three times, first with atrazine then group B's and now glyphosate.

Part of the reason of the poor management of HTGM crops in the U.S.A. lies at the feet of the Farm Bill and its programs. Corn, soybeans and cotton are three of the big five crops that receive the bulk of the government assistance. The U.S. National Research Council looked at the affect of farm programs and it found that they have an enormous influence on the way farmers manage their farms. It also found that the commodity programs promoted specialisation in one or two crops and penalised those farmers who adopted rotations. It concluded that farmers often are more responsive to subtle economic effects from the programs than the biological and physical constraints on their farms. I contend that some (not all) of the farmers in America are farming the government programs and therefore making bad agronomic decisions that are creating issues like glyphosate resistant weeds.

Criticism also needs to be levelled at Monsanto. Insisting that the Bt gene for rootworm in corn be only available with Roundup Ready was, I feel a short sighted decision that in the longer term will compromise the technology. I realise that developing GM technologies is a very expensive process and companies need to recoup their expenses and make a profit. When Monsanto insist on putting all their technologies in the one plant they are shortening the life of all the technologies and in the long run cutting their profits. As Monsanto is no longer conducting research into new herbicides where do they go as a company if and when most of the soybean, corn and cotton acreage in the United States is covered in glyphosate resistant weeds?

Despite the fact that glyphosate resistance has happened, at this point of time it is on a relatively small percentage of the area planted to HTGM crops. The better farmers who are not relying on glyphosate to do all the work of killing weeds are not having issues. They are using other herbicides as well as cultivation and crop rotation to manage their weeds. Even so there is a strong possibility that the area with glyphosate resistant weeds could increase both dramatically and quite quickly.

The mistakes of America are the lessons for Australia. HTGM crops need to be part of a much wider integrated weed management system and does not replace it.

Other pressures on glyphosate

HTGM crops aren't the only cropping systems that are placing pressure on glyphosate and having weeds resistant to glyphosate. Australia has the dubious distinction of being the first country in the world to develop resistance to glyphosate in a cropping system. This occurred on the Liverpool Plains in northern NSW with ryegrass (*Lolium spp*.)and barnyard grass (*Echinochloa spp*.).

A number of factors led to resistance developing. The region receives 60 % of its annual rain in the summer so growers can grow either summer or winter crops. They are almost exclusively no-till and relied on glyphosate to control weeds in their fallow period. They didn't use residual soil herbicides because they want to be able to opportunity crop and not be limited by residues.

Barnyard grass is a fast growing grass that can set seed in three weeks from emergence. This has often forced growers to apply glyphosate when conditions are less than ideal. Dust and heat can often reduce the effectiveness of the glyphosate applied. Again we see the dependence on just one herbicide leading to problems.

Australia is not alone in using lots of glyphosate for weed control in no till fallows. Low rainfall in the high plains of western Kansas and eastern Colorado means that farmers often only grow two crops in three years. They are also no-till farmers and they use fallows to store up moisture. Up to five applications of glyphosate can be used and it is often at the same timing as if it had been in crop with a HTGM. Problems have not yet developed but there are concerns weeds like Kochia are very close to developing resistance.

Local governments and landowners like the railways are also not very creative when it comes to weed management. Many tend to use glyphosate continuously without rotating herbicide groups or considering non herbicide options.

Recommendations for growing HTGM crops in southern Australian farming systems

The first question that should be answered is whether growing HTGM canola is something that Australian farmers should be doing? If we look to the Canadian experience the answer in my opinion is yes. I believe that growers will get better yields from RR canola than they do from the triazine tolerant varieties that most grow now. I also believe that weed control will be better and profits higher even with increased seed cost and technology fees. The big advantage as I see it will be in years when we have late and difficult starts. Farmers will be able to plant their canola dry confident that they will be able to get good weed control in crop.

Monsanto and the regulators are to be commended for putting into place a code of conduct. This should remain in place as it has with the Australian cotton industry. RR cotton has been grown in Australia since 2001 with no issues of glyphosate resistant weeds. The industry has a resistance management plan whose fundamental core is that farmers must go through their paddocks after application of glyphosate and control any resistant weeds.

Australian growers will need to be proactive in the management of HTGM crops and especially RR canola. These are the recommendations that I feel are needed to try and prevent weeds developing resistance to glyphosate:

- Use a pre-emergent herbicide and do not rely totally on glyphosate;
- Grow hybrid varieties with good seedling vigour to give weeds strong competition;
- Spray when conditions are good and when weeds are not stressed;
- Budget to apply glyphosate twice on a crop. It is better to kill the weeds when they are small and come back with a second application if needed;
- Check the quality of the water they are using to spray with. If it's not up to scratch add products like 'Liase' to get better weed kills;
- Grow canola only once every 3 or 4 years on an individual paddock. The more diverse the rotation and the less in crop applications of glyphosate should extend its life;
- Monitor their paddocks after application and be prepared to use another herbicide if results are not up to scratch;
- Rotate knockdown herbicides and be aware of volunteers;
- Use non-herbicide methods of weed control like increased seeding rates in the following cereals or burning everything that passes through the header either with a chaff cart or in the row;
- Do not expect HTGM crops to solve their herbicide resistance problems in one year. If the seed bank is high, one year of HTGM crops will not reduce it to zero. Farmers should possible look at making silage or brown manuring a problem paddock the year before planting RR canola; and finally
- Consider occasional cultivation.

Australian farmers will need to overcome the urge to sit back and relax about weed management because they have HTGM technology. If they use it as part of a wider integrated weed management strategy there is potential to drive down weed numbers to very low levels. The less number of weeds means a lower chance of resistance developing.

Australia has benefited from the uptake in no-till farming systems. Soil erosion has been reduced, soil carbon levels increased, and crops are using water more efficiently. A report recently released by the Australian Farm Institute looked at the value of environmental services provided by Australian farmers. It concluded that reduced tillage techniques in northern NSW between the 1970's and 2002 had an environmental value of $1.2 billion. The introduction of glyphosate has enabled farmers to adapt to their environment and farm in a way that suits the Australian climate. If there were widespread glyphosate resistant weeds it would limit farmer's ability to continue to no-till.

At the end of the day it is in everyone's interests that we make glyphosate last as long as we can. It has cost herbicide and seed companies a lot to develop this technology and understandably they want to see profits as quickly as they can.

I argue it is also in their interest to make the technology last. If companies won't make a mandatory period between HTGM crops the regulators should. As we have seen in the past, growers in Australia have pushed rotations with the consequence of weeds developing resistance quite quickly. With the long drought that we have recently endured, farmers need all the profits they can get and will be tempted to push the rotation. Glyphosate is too important to the Australian farming system to let that happen.

The last thing Australia needs is to return to the days of multiple cultivations and all the issues that went with that. The timeline for a glyphosate alternative is an unknown. We have to assume that there may not be another mode of action developed and that we need to care for the ones we have. If we as an industry use HTGM technology responsibly and sustainably the rewards will be there for all.

This paper is an abridged version of the report prepared for Nuffield Australia and the Grain growers Association

Session 3 - Chairman Neil Inall

UNDERSTANDING CONSUMER CONCERNS ABOUT GM FOODS

Clare Hughes – Senior Food Policy Officer, CHOICE

Consumers still have concerns about GM foods

Consumers are becoming increasingly interested in how their food is produced and they value information to help them identify what is and isn't in their food. The organic food market continues to grow as consumers seek to avoid pesticide residues in their foods and support more sustainable agricultural practices. Choosing eggs has never been so difficult. We can now choose from free-range, organic, barn-laid and caged eggs with varying degrees of accreditation and authenticity behind them. Labels are increasingly heralding products as 'pure', 'natural', 'preservative free' and much more.

Ever since public debate about genetic modification and GM foods began in the 90s consumers have expressed concerns. While public debate and media attention has subsided somewhat in recent years, many of these concerns remain. They include:

- Unknown adverse long term health impacts
- Unknown adverse environmental impacts
- Ethical and moral concerns about manipulating DNA and increasing control over the world's food supply by a small number of multinational companies.
- The capacity to choose between GM and non-GM foods

A recent News poll survey commissioned by Greenpeace found that 90% of the 1200 respondents across Australia thought that food labels should disclose whether a product contained GM ingredients. There appeared to be very little difference in responses between education and income levels, or between respondents who were the main grocery buyers and those who were not.

When asked what they would do if they knew a product contained ingredients from genetically modified plants or animals 54% said they would be less likely to buy it, only 2% said they would be more likely to buy it, while 42% said that it would make no difference. Here, there was a significant difference between those who were main grocery buyers and those who weren't with 60% of grocery buyers less likely to buy the GM product compared with 41% of respondents who weren't the main grocery buyer. There was also a small difference in the responses from different education and income groups; with more respondents from the middle income bracket ($39K - $70K) reporting that they would be less likely to buy a food that they knew contained GM ingredients, than respondents from higher or lower income groups.

So while reports released by Biotechnology Australia suggest that consumer awareness of GM crops is increasing and that concern about GM foods may be waning, it seems that consumer concern is nonetheless alive and well and that the vast majority of consumers want the right to choose between GM and non-GM foods.

What's in it for me?

Consumers might also be apprehensive or even ambivalent towards genetic modification because they don't feel that the technology is designed to benefit them. Most of the GM crops currently permitted in Australia are modified for herbicide tolerance and insect resistance. While GM foods were initially portrayed as having enormous consumer benefits, consumers are not necessarily seeing products that are healthier, better tasting or cheaper or deliver other immediate benefits. If consumers can't see that there is a problem with conventional crops and do not believe that they are directly benefiting from the technology they may be less likely to see a need for GM crops or be supportive of GM foods.

It's often suggested that consumer concerns stem from a lack of understanding about the technology and that those who are more informed about GM foods are less likely to have concerns about or objections to consuming them. But is more information about genetic modification the answer?

Consumer research conducted by Biotechnology Australia shows that consumers still believe that there are risks associated with genetic modification and GM foods, such as health and safety risks and the potential for cross-pollination with conventional crops. Theories of risk perception and the outrage that might be associated with a potential hazard help us to understand how consumers might think about GM food.

Public outrage to potential risks may be based on:

> **Personal autonomy –** Can I choose between GM and non-GM foods or are GM foods being forced upon me without my knowledge?
>
> **Visibility –** Can I see the particular hazard (or the GM foods or ingredient) so that I know if I'm exposing myself and my family to it?
>
> **Shared risk or benefit –** Are the risks and benefits of GM foods shared among society or is one particular group gaining from GM foods at the public's expense?

Scientific uncertainty – Are the potential risks associated with GM foods well understood by the experts or is there a degree of uncertainty about GM foods?

Natural or technical origin – Are the risks a result of natural occurrences or are they introduced?

Significance of the potential hazards – Are the potential dangers of GM foods catastrophic or fairly insignificant?

The right to choose

Most consumers continue to believe that they have a right to choose between GM and non-GM foods. Consumers will be less likely to support GM foods if they are forced on them and as the recent Newspoll survey suggests, while a sizable minority (42%) wouldn't necessarily stop buying a product labelled as genetically modified, the vast majority (90%) felt that GM foods should be labelled.

Most of the 30+ GM foods approved for use in the Australian food supply are varieties of corn, cotton, canola and soy. Cotton and canola are the only two crops approved for commercial production in Australia.

GM labelling laws are based on the GM content of the final food rather than the way it was produced. Yet a 2003 CHOICE Online poll suggests that consumers' concerns about GM foods are as much to do with the process of GM as they are the GM status of the final product. Seventy five per cent (75%) of respondents disagreed with the current GM labelling laws that would exempt GM canola oil from carrying a GM label simply because it does not contain GM proteins.

Our current labelling laws prevent consumers having meaningful information about the use of ingredients derived from genetic modification. Food labelling laws require GM foods to be labelled as 'genetically modified' or 'GM' *except* where it is:

- highly refined so that no GM protein is present
- a processing aid or additive that is not present in the final product
- a flavour present at low levels (≤1g/kg)
- unintentionally present at very low levels (≤ 10g/kg of ingredient)

Yet few foods in Australia actually carry GM labels because GM ingredients in the food supply are highly refined oils or corn syrup which don't require labelling. These GM ingredients may be present in margarine spreads, confectionery, biscuits, cakes, crisps, cooking oils and mayonnaise but consumers wouldn't be able to tell.

GM canola raises an additional concern, particularly as it is now approved for commercial production in Australia. Questions are raised over the extent to which GM canola can be contained and the potential threat of cross pollination and difficulty in segregating GM canola from non-GM canola. If segregation measures fail, non-GM canola crops will be threatened and consumers may not lose the ability to purchase products derived from non-GM canola.

Community awareness and perceptions of the benefits of GM and biotechnology may be improving but they still have a range of concerns about GM that haven't been addressed. Education isn't necessarily the answer but better communication will help. Consumers need to be able to make an informed choice about the foods they eat but they currently don't have enough information. If they feel their concerns are being addressed and that they have some control over whether they eat GM foods then consumers may be less resistant to purchasing them.

Links

http://www.greenpeace.org/australia/resources/reports/GE/rpt-gmpoll-190908

http://www.biotechnology.gov.au/assets/documents/bainternet/Eurekaoveralperceptions2007
20070731170144.pdf

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Seminar Organising Committee

Warwick Felton (Weed Society)
Neil Inall (AIAST)
Bob McKillop (AIAST)
Alan Murphy (Weed Society)
Jim Swain (Weed Society & AIAST)

Editing of the papers

Bob McKillop and Warwick Felton

Preparation of the Proceedings

Warwick Felton

Printing of the Proceedings

Coordinated by Dr Stephen Johnson and done by the New South Wales Department of Primary Industries, ORANGE

Publicity assistance by Lawrie Greenup, John Cameron and Peter Harper

Power point presentations coordinated by Erica McKay

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