Sustainable weed management and the use of genetically engineered, herbicide tolerant crops

A look at the co-existence of genetically engineered crop growers, conventional crop growers and organic farmers.

A report for

by Jemma Sadler

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Scholar Contact Details
Jemma Sadler
Danubin Farm
1211 East Botherling rd, Goomalling

Phone: 0408721029
Fax: 0896721029
Email: jemmasadler@bigpond.com

NUFFIELD AUSTRALIA Contact Details

Nuffield Australia
Telephone: (03) 54800755
Facsimile: (03) 54800233
Mobile: 0412696076
Email: enquiries@nuffield.com.au
586 Moama NSW 2731

Executive Summary

- The evolution of weeds resistant to multiple different herbicides has led to annual in-crop weeds being one of the main challenges facing arable farmers in Australia.
- Genetically engineered herbicide-tolerant crops will play an important role in the management of problem weeds.
- Co-existence of genetically engineered, non-genetically engineered and organic crop growers is essential to ensure the continuation of all production systems and the continual development of new genetically engineered technologies to meet rising consumer demand.
- Government and technology providers must continue to improve their stewardship for growers on developing these co-existence measures.
- A review of the current thresholds for the adventitious presence of genetically engineered products in Australian organic production systems is required to ensure the sustainability of the organic industry.
- Growers who are receiving a premium for growing a specific product should bear all the costs associated with growing that crop.
- Australia is leading the way in the development of alternative non-chemical weed control strategies, but more research into practical control methods is required to achieve sustainable weed management.

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Foreword

The use of genetically engineered (GE) crops in Australian agriculture continues to be a source of great controversy. Many farmers have embraced the technology enthusiastically and benefitted from its use, whilst other farmers are more hesitant about the technology and believe their businesses are more profitable without the introduction of GE crops.

The co-existence of these two groups of farmers is a challenging issue. Agriculture is part of a natural environment and thus, is subject to a range of conditions such as adverse weather and human error that makes it impossible to keep properties mutually exclusive from one another. What one farmer does on his property will inevitably affect his neighbour's property. The level, impact and responsibility of these incidences are a subject of great debate.

Research has shown genetic engineering has the potential to offer many benefits to farmers and consumers. Herbicide tolerant genetic engineered crops have already shown to increase farmer profits through increased improved weed control. As weeds have become increasingly difficult to control through their evolution of herbicide resistance, herbicide tolerant genetically engineered crops have provided another important option to farmers for weed control. In the future, gene technology could offer a wide array of benefits to Australian farmers.

The aim of this study was not to discuss the merits of GE crops. GE products are legal products which have been evaluated by scientific experts and regulators and determined to be safe for humans and the environment (Russell, et al., 2012). With over 17 million farmers in 36 countries worldwide using GE crop varieties for over 15 years (James, 2011), GE is an important part of agriculture throughout the world. It is now imperative that the debate turns from health and safety to economics and marketing, with the ability of farmers to make the best choices for their own business, allowing consumer demand to drive production.

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Abbreviations

IWM – Integrated Weed Management

GEHT – Genetically Engineered Herbicide Tolerant

GE – Genetically Engineered

DAFWA – Department of Agriculture and Food Western Australia

Objectives

- To explore the challenges of the co-existence of GE, conventional and organic farmers in Agricultural production systems around the world.
- To examine mechanisms to aid in the co-existence of these different production systems in Australian farming systems.
- To investigate new, effective, integrated weed management strategies (IWM).

Chapter 1: Introduction

In the dryland cropping region of Australia, weeds are one of the main challenges facing arable farmers. They are estimated to cost Australian farmers over 4 billion dollars annually (www.daff.gov.au/natural-resources/invasive/weeds. The highly competitive annual ryegrass and wild radish are the two most problematic weeds of Western Australian cropping systems (Alemseged et al., 2001). Herbicide resistant weed populations have evolved in many parts of the world, however, nowhere has the evolution of herbicide resistance in weed populations been more dramatic than across the Australian dryland crop-production region (Walsh and Powles, 2007). A 2003 survey across the West Australian wheatbelt determined that only 6% of annual ryegrass and 15% of wild radish populations were susceptible to the most commonly used crop selective herbicides (Walsh and Powles, 2007).

Genetically Engineered Herbicide Tolerant (GEHT) crops are providing farmers with an option to control these problematic weeds. The ability to spray the knockdown herbicide glyphosate over crops to kill all susceptible weeds has given farmers the ability to dramatically lower weed populations.

In Australia, GEHT canola has been grown in NSW and Victoria since 2008 and in West Australia since 2009. South Australia and Tasmania have a moratorium on the growing of GEHT in their States. The introduction of GE crops into Australia has not been without considerable controversy. The natural environment in which agricultural production systems exist means that there is the potential for the adventitious presence of GE in non-GE crops, affecting the ability of farmers to market their crop. National thresholds have been set for the level of GE allowed to be present in conventional (non-GE) and organic production systems, being 0.9% and 0% respectively. Co-existence is the concurrent cultivation of conventional, organic, and GE crops consistent with underlying consumer preferences and farmers choices

(Redding et al., 2012). The need for enhancing co-existence between all sectors of agriculture is important, so that farmers have the right to make the best choices for their own businesses. Additionally, to ensure that technological innovation moves rapidly, an acceptance of the diverse nature of all agricultural production systems is essential. The potential dominance of glyphosate tolerant crops in Australian cropping systems creates a real risk of rapid development of glyphosate resistant weeds. The continuous growing of these crops in the United States of America (USA) has lead to major issues with the development of these problem weeds. The sustainability of this herbicide and any future herbicide resources will be greatly improved with the development of alternative, highly effective weed-control strategies (Walsh and Powles, 2007).

Chapter 2: Co-existence of GE, conventional and organic cropping systems

Co-existence of different production systems allows farmers to make a practical choice between growing conventional, organic and GE crops in response to market demand and in accordance with legal requirements for GE marketing (www.scimac.org.uk). It gives rise to two issues that need to be resolved. Firstly, how to stop the accidental presence of GE in a production system, and secondly, if a grower should be compensated when they incur economic loss as a result of the GE presence.

Co-existence of different production systems in Agriculture has existed for many years. For example, in the Australian grains industry feed and food grains are kept separate, as well as noodle and bread making wheat varieties. In Europe and the USA, oilseed rape grown specifically for industrial use has been kept separate from food grade oilseed rape. Certified seed and non-seed crops are kept separate all over the world. Co-existence is not new, but what needs to be done to achieve co-existence has changed with technology and market changes (Russell et al., 2012).

Why is co-existence important?

Co-existence of different crop types, products, and farming systems is essential to maintain a diverse and dynamic agricultural industry (Russell et al., 2012). The ability of farmers to amicably farm side by side has implications for communities, industry and policy makers.
Australian rural communities are already facing great challenges. With declining populations and volatile farm incomes many towns are facing extinction. The strength of a community relies on farmers being able to coexist.

The agricultural industry has the challenge of ensuring that new technologies for all production systems are continuously and rapidly brought to market to meet growing consumer demand. Both in terms of feeding a rapidly growing world population and servicing niche markets such as organic and non-GE products. The safety and regulated release of new technologies should not be ignored, but it is important that regulation and politics do not impede on technological innovation.

Government should aim to improve the role they play in the regulation and release of new agricultural technologies and the ongoing process to strengthen co-existence. There will never be a consensus on the use of biotechnology. Therefore, policy needs to be adopted that is proportionate, efficient, cost effective and specific to particular crop and farming systems and at the same time help farming communities understand the different agricultural practices (Fontes, 2007). Co-existence is important to create an agricultural system that has the ability to exploit all market opportunities, uphold cultural values, protect biodiversity and take advantage of environmental conditions (Fontes, 2007).

Challenges of GE co-existence

The ability of different production systems to co-exist is subject to the individual tolerance thresholds for the accidental presence of GE in the particular crop production system. Conventional and organic systems have their own maximum (%) threshold for the amount of GE that can be in their products before they are unable to be marketed as GE free. These thresholds are different for countries around the world (Table 1), and they have a huge influence on the ability of organic, conventional and GE production systems to coexist.

Table 1 Tolerances for the adventitious presence of GE in conventional and organic farming, and labelling requirements for GE in different countries (Carter and Gruere, 2003).

	% Adventitous presence of GE tolerated in conventional farming	**% Adventitous presence of GE tolerated in organic farming under National* Rules**	**Buffer zones required for organic farmers from GE crops**	**Labelling of GE required**
USA	n/a		No buffer zone specified	Voluntary
Canada	n/a		No buffer zone specified	Voluntary
European Union	0.9	0.9	No buffer zone specified	Mandatory >0.9% with exceptions
Australia	1	0	10km buffer zone	Mandatory > 1% with exceptions
Argentina	n/a			Voluntary
Japan	5			Mandatory
South Korea	3			Mandatory
Indonesia	3			Mandatory

* Different Certifying agents within the country may have different tolerances below this level.

The adventitious presence of low levels of GE in conventional or organic crops can occur through a) cross pollination or b) physical admixture; either in storage and handling, or through weather events causing crop residue to cross boundaries (Lederman, 2011).

The level of out crossing of different crops through cross pollination is dependent on the type of crop grown and should be taken into account when looking at co-existence measures. Australian research has shown that the probability of pollen flow between canola in adjacent fields is in the range of 0-0.07% (Salisbury, 2002). The five metre buffer zone recommended by the Australian GE canola stewardship programme, was found to be sufficient to maintain out crossing through pollen flow to levels below the current GE tolerance of 0.9% in non-GE canola.

The probability of physical admixture of GE with non-GE crops or products greatly depends on individual grower behaviour and the ability of storage and handling facilities to maintain segregation. Grower behaviour will be influenced by their understanding of the importance of farm hygiene, and their neighbours preferences and situation in regard to GE crops. Initial trials of GE segregation in Western Australia through the co-operative bulk handling system, found that the company was able to effectively maintain the separation of GE and non-GE varieties at the limit of 0.9%. Every load of non-GE delivered to a storage and handling site is tested for the presence of GE before the truck is unloaded. Today, five years of experience Australia wide is demonstrating that the segregation of GE and non-GE canola is achievable.

Steps to achieving co-existence

There is no easy solution or widely accepted model for putting co-existence into place. All parties in the development, breeding, marketing and management of crop production need to be involved in making co-existence work (Russell et al, 2012). The key to effective co-existence is an agreed definition of good practise that defines the boundaries of negligence in both GE and non-GE crop production (www.scimac.org.uk). Once these guidelines and boundaries have been set, it is a matter of farmer and consumer education, neighbourly respect and communication, and careful segregation of storage and handling.

Countries around the world have taken different approaches to effective co-existence, outlined in Chapter 3.

Chapter 3: USA

Genetic Engineering in the USA

Farmers in the USA have been growing GEHT crops since 1996. Today they continue to be a globally leading producer of biotech crops with over 69 million hectares sown, with an average adoption rate of 90% across all biotech crops (James, 2011). GEHT crops grown include glyphosate tolerant corn, soybeans, canola, alfalfa, and glufosinate tolerant canola. Crops are currently being introduced with stacked resistance to multiple herbicides including Dicamba and 2-4,D. There is no threshold set for the tolerance of regulatory approved GE products in non-GE conventional products in the USA (Table 1).

USA Organic Policies

The USA National Organic Policy (NOP) states no threshold for the adventitious presence of GE in organic products (McEvoy, 2012). Organic certification is process based; that is, as long as the producer adheres to all aspects of NOP production practises, and take reasonable steps to avoid contact with GE crops, then the unintended presence of GE will not affect the status of the organic operation or its organic products (NOP Policy Memo 11-3, 2000).

To avoid GE contamination, organic producers are advised to conduct seed testing, stagger planting times, have cooperative agreements with neighbours, post signs advising of organic status, practise good farm hygiene and use buffer zones. A survey of USA organic producers on the effects of GE on their business found some farmers indicated that their costs had been increased in order to avoid GE through different strategies; 19 % (of respondents) for wider buffer zones, 15% for differing sowing times, and by 9% to change rotations (Apted and Mazur, 2007).

USA policy on co-existence

The AC21 committee, a USA advisory committee on biotechnology and 21st Century Agriculture, was originally established by the USA government in 2003 to examine the long term impacts of biotechnology on the USA food and agriculture system. The AC21 is a broad-based committee representing a wide range of interests and agricultural expertise. The committee was recently revived to focus on the specific topic '*to develop practical* *recommendations for strengthening co-existence among different production systems*'. At the end of 2012, the committee released their final report which is briefly summarised below:

The primary objectives of the AC21 committee were;

1) What compensation mechanisms could be established to reimburse a farmer who's crop value was diminished due to the unintended presence of GE.
2) How do you test/measure for economic loss.
3) How else can the government facilitate co-existence.

The committee examined three different compensation mechanisms;

a) The establishment of a fund, financed by technology providers and/or farmers and/or the entire food supply chain.
b) A crop-insurance model funded by the farmer and the government, and
c) A risk retention group; a self insurance tool purchased by farmers at risk of economic loss.

The committee concluded that an insurance based model may be the best compensation mechanism. However, there was controversy within the group as to whether a compensation mechanism was entirely necessary as there has not been a case in the USA where a farmer had legally sought compensation from the loss of crop value due to GE contamination. The development of a compensation mechanism may also give rise to other issues.

Members of the committee felt that the establishment of a compensation mechanism could limit the incentives to develop technologies to avoid contamination risk and also created no incentive for containment within farm boundaries. The decision on who would pay for the insurance would also create many issues. The development of an insurance product would involve setting standards for tolerance levels and it was debated that government establishment of arbitrary thresholds for the presence of GE traits posed many risks.

The committee wanted to ensure that whatever they recommended did not send the message that the government is suggesting that legal GE products are unsafe. They concluded that IF a compensation mechanism was required, an insurance model which involved the creation of joint neighbourly co-existence plans was the best option. However, they emphasised that it would be better to prevent the problem in the first place through government facilitation of good stewardship leading to effective co-existence.

The AC21 committee suggested that the USA government should fund a comprehensive education and outreach program on co-existence. This would include:

- on farm practices
- neighbourly collaboration
- establishment of farmer-farmer contracts and risks involved, and
- the promotion of local and voluntary solutions.

Stewardship should focus on management practises to produce profitable crops, and also practises that support neighbour's efforts to do the same. This could be part of the technology providers' commercial seed contracts.

Finally, the committee suggested more research is required into the measure of economic loss from GE contamination. They also wanted more research on ways to decrease the risk of gene flow, and new crops developed that have genetic tools restricting the unintentional gene flow to other plants. An emphasis was placed on a challenge for the seed industry to ensure that the unintended presence of GE was not starting with the seeds sown.

Chapter 4: Canada

Genetic Engineering in Canada

Canada began growing GEHT crops in 1996 and they were rapidly adopted by the majority of Canadian farmers. Today they grow over 10.4 million hectares of GEHT canola, maize, soybeans and sugar beet (James, 2011). There is no threshold for the adventitious presence of GE in non-GE products in Canada, although if products are voluntarily labelled GE free, they must be below a 5% GE level (Table 1).

Canada Organics Policy

The Canadian national organic policy states no threshold tolerance for the unintentional presence of GE. The government does not set legislation on organic regulations but rather provides guidelines for organic certifying bodies. Guidelines recommend organic farmers must do everything they can to minimise the risk that crops they grow will not be subject to GE contamination but the unintentional presence of GE in the end product should not affect the organic status of the product or farm. There are some organic certifying bodies in Canada that do have tolerance thresholds for adventitious GE.

Since the introduction of GE into Canada, there has been some debate about the effect that it has had on the organic industry. In 2003, the Food and Agricultural Organisation (FAO) of the United Nations reported that since the advent of GE canola in Canada, farmers can no longer grow organic canola in Western Canada (www.agric.wa.com). In 2011, a group of Saskatchewan organic farmers brought action against Monsanto and Bayer for damaging the Canadian organic industry. The allegations were not proven and the case dismissed (Apted and Mazur, 2007). Figures show that the Canadian organic industry as a whole has not been limited by the introduction of GE and areas sown to organic have actually increased (Brookes and Barefoot, 2004).

Canadian Policy on Co-existence

GE herbicide tolerant canola was introduced into Western Canada without a co-existence plan (Entz and Martens, 2003b). The organic and seed production industry claim this has resulted in serious consequences for their production system (Entz and Martens, 2003b). On farm stewardship strategies are now being discussed to play an important role in future co-existence plans.

Chapter 5: European Union

Genetic Engineering in the European Union (EU)

The EU has a moratorium on the cultivation of all new GE products for human consumption, subject to the agreement of all member states for the regulatory approval of a new product. However, before the moratorium was put in place, approval was given for the cultivation of GE Maize in Spain and it has been grown there for the last eight years. There is a 0.9% tolerance for the adventitious presence for GE in conventional (non-GE) farming systems (Table 1).

EU organic policy

Organic standards for the EU are based on the restricted use of GE products in production procedures, rather than the adventitious presence of GE in the end product (Barefoot and Brooks, 2003). There is no EU legal level for the presence of GE in organic products; however, they still must abide by the tolerance threshold of 0.9% for the accidental presence of GE in all conventional products. Within the EU there are multiple different organic certifying agents and their range for the tolerance of GE varies from 0% to 0.9%.

EU policy on co-existence

The challenge of co-existence is one of the main arguments against the approval of GE products for the use of GE in agricultural production in the EU. With so many member states that have to agree on the approval of a GE product, it becomes almost impossible to pass approval of any products at all. If they were able to develop a strategy to ensure co-existence of GE with conventional and organic farming, then the approval of new GE products may become easier.

A commission recommendation to the EU to develop national strategies and best practices to ensure the co-existence of GE crops with conventional and organic farming in 2003 came up with the following;

1) no form of agriculture, GE, conventional or organic should be excluded from the EU

2) member states should be left to develop and implement their own management measures for co-existence

3) co-existence measures should be dynamic in that they leave room for improvement over time.

General principles that member states were advised to take into account when developing strategies included: basing decisions on scientific evidence, building on existing segregation practices, and ensuring proportionality and cost-effectiveness. The commission also concluded that, during the phase of the introduction of a new production type into a region, farmers who introduce the new production type should bear the responsibility of implementing the farm management measures necessary to limit gene flow.

This year (2013) the EU has launched a consultation to gauge views on the definition of organic food with respect to the level of GE in organic foods. The consultation is inviting views on whether the 0.9% threshold should be lowered, and whether the consumer would be happy to pay for this.

Chapter 6: International Standards

There are no international standards for the adventitious presence of GE in conventional non-GE products. Trade problems can arise when countries have different regulations regarding the testing and approval of GE products or they disagree about the labelling and identification requirements of GE products (www.wto.org).

The strict tolerances in the European Union for level of adventitious presence of GE in imported products lead to the USA, Canada and Argentina to file a WTO dispute against the EU for using GE presence as a form of trade protectionism (Davison, 2009). The WTO found in favour of the GE producing countries, and countries agreed to discuss and sort out the issues individually. To date Argentina and Canada have resolved the issues through establishing strict, regular dialogue about the approval of GE products. The USA and the EU are still to reach an agreement and in fact the USA now looks to be increasing its own regulation on the importation of non-approved GE products (Davison, 2009).

The Cartagena protocol on biosafety established in 2000 states a country that wants to export GE grain for seed must seek agreement in advance from the importing country before the first shipment. A country exporting GE for food or feed processing is not required to have this advanced agreement but they must provide importing countries with full documentation concerning the GE product (www.wto.org).

The USA government would like to be involved in the development and harmonisation of international standards for biotechnology testing and adventitious presence, with the WTO retaining the authority to influence the regulation of international trade in agricultural products enhanced by biotechnology (USA government, 2012).

There are no international standards for the allowable threshold of the adventitious presence of GE in organic end products (Apted and Mazur, 2007). The International Federation of Organic Agriculture and Movements (IFOAM) are opposed to the use of GE in all aspects of agriculture. They believe more stringent labelling of GE products is required. They want the cost of the accidental presence prevention and market loss to fall on the developers of the GE technology. However, they also accept organic crops cannot be completely isolated from the environment around them and, therefore, a realistic balance is required between the rejection of GE in organic production and the practicalities of keeping GE out of organic agriculture (www.ifoam.org).

IFOAM takes the position that the potential of GE contamination does not alter the traditional approach of certifying organic as a 'production method' rather than an end product guarantee(www.croplife.org/coexistence) For example, just as organic farmers cannot guarantee zero contamination from pesticides that they have not used, there is no way for them to guarantee that organic products will not be polluted by traces of GE products. IFOAM does not support a zero tolerance for GE contamination in organic end products as it has the potential to exclude organic producers from market access. They do understand that customer preferences may demand a 0% of GE in their products, in which case certain organic certifiers may aim for this tolerance. IFOAM believes that customers need to know that organic certification may not necessarily mean "GE Free", but rather "produced without the use of GE" (www.ifoam.org).

Labelling

The introduction of mandatory labelling for GE in some countries and not others (Table 1) is creating controversy in terms of world trade (Carter and Gruere, 2003). The decision on labelling of GE food is a major challenge for policy makers because of the difficulty in detecting GE in highly processed foods. On one side, consumers have a right to know whether they are eating GE foods but on the other, labelling products GE may imply a non-existent food safety risk. Also marketing and segregation costs would dramatically increase (Carter and Gruere, 2003). Internationally, there is no agreement on standards for GE labelling and this is creating debate (Carter and Gruere, 2003).

The Australian requirements for GE labelling are some of the most comprehensive in the world. Under Australian food labelling law, all foods sold in Australia (with few exceptions) with a GE presence greater than 0.9% must be labelled as containing GE.

Chapter 7: Australia

Genetic Engineering in Australia

The Gene Technology Regulator (GTR) was established in 2001 to regulate the use of gene technology in Australia. The *Gene Technology Act 2000* legislation aims to protect the health and safety of Australians and the Australian environment by identifying risks posed by or as a result of gene technology, and to manage those risks by regulating GE foods (Agrifood Awareness, 2007). The GTR must assess and license a new crop variety through the act. The GTR gave approval for GE herbicide tolerant canola in 2003. However, as states are allowed to make their own laws in relation to market and trade issues, the majority of states implemented legislation on GE crops (Agrifood Awareness, 2007). GE herbicide tolerant canola has been grown in New South Wales and Victoria since 2008, and in Western Australia since 2009. Tasmania and South Australia have a state moratorium on GE crops.

Australian National standards specify that conventional crops should have an adventitious level of GE less than 0.9%. The segregation of GE and non-GE is regulated by farmers subject to protocols, licensing and stewardship guidelines, and government policy and guidelines (Lee, 2012).

Australian Organics

There are two standards for the regulation of the Australian organic industry. The ‘Australian Standard’ (AS 6000-2009) is an industry self regulation (non-government) that applies for both the domestic and export market and is enforced by the ACCC. The ‘National Standard’ is government legislation regulated by AQIS for the export market only. The National Standard is adhered to by most certifying organic bodies. Both standards have a 0% threshold for the accidental presence of GE on any organic property or in any organic product. The Australian Organic Industry aims for an end product guarantee of “GE free”. This is different to the process based standards that other countries are adhering to.

There are seven different Australian organic certifying bodies. The AQIS audits and accredits these bodies to ensure they comply with the national standards for organic produce so that they can export organic products. Individually different certifying bodies can have their own regulation on the management of GE crops, however, they must all adhere to the minimum base standard of 0% tolerance to GE set by the National Standards.

In summary, under National Standards, organic certification in Australia means an organic farmer must have no GE inputs, grow no GE crops, and no GE presence in final product or on farm. Neighbours must be notified of organic status and certifier must be notified of any GE crops grown within 10km's. Growers also must have a risk management plan in place to avoid GE contamination (DAFWA, organic farming and GE fact sheet).

Australian Policy on Co-existence

Since the first Australian commercial crops of GE canola in 2008, the Australian Oilseeds Federation and Grain Trade Australia have published two annual reports outlining the results of their analysis of the Australian Grain Industry delivering successful "Market Choice" through co-existence. The reports for 2008/09 and 2009/10 concluded that there was effective segregation of non-GE canola throughout the value chain (Australian Oilseeds Federation and Grain Trade Australia (2009, 2011).

The Ausbiotech conference was held in 2012 in Canberra to discuss 'maintaining co-existence in the Australian seed and grain value chain'. It involved high level representatives from across the entire seed and grains supply chain to discuss co-existence and the delivery of market choice for canola in Western Australia. A detailed outcome from the conference has not been released, however, the media reported the message 'in the five years of growing, marketing and processing GE side by side with non-GE canola, the people and organisations involved with the segregation and product integrity are happy about the future'.

In Western Australia, a landmark case is evolving regarding co-existence. An organic farmer certified by National Association of Sustainable Agriculture in Australia (NASSA) lost the organic status of his property because of the discovery of the unintended presence of GE canola on his property, which allegedly came from his neighbour's property. The organic farmer has taken his neighbour to court for economic losses incurred through the loss of his organic status. The case is yet to be concluded but the case is the first of its kind in the world and the outcome will no doubt set a precedent for future cases of contamination and will have a huge influence on co-existence of GE and organic farmers.

Co-existence Law in Australia

There is little Australian case law with respect to the spread of agricultural organisms from one property to another (Ludlow, 2005). Australian law does not give immunity to those who have abided by the law in growing an approved GE crop and yet have caused contamination of another property (Ludlow, 2005).

Private Nuisance is defined as the “unlawful interference with a person’s use or enjoyment of the land...” (Ludlow, 2005). However, an activity does not have to be unlawful to be a nuisance. The decision on whether GE causes substantial and reasonable nuisance is an objective decision to be decided by the courts (Ludlow, 2005). The courts will take into account whether the GE contamination was unavoidable. That is, investigate whether the precautionary actions taken by the GE grower to avoid the contamination of his neighbour was enough (Lee, 2012). The compliance with regulations by the GE grower will not be enough; they could have taken extra precautions as they knew their neighbour was an organic producer (Lee, 2012).

The 0 % tolerance for the adventitious presence of GE in organic farming is creating a high level of risk of financial loss for organic growers. If someone was successful in suing their neighbour for contamination then it would undermine state and national regulation and may also have the potential to affect other agricultural practices (Ludlow, 2005).

Chapter 8: Building co-existence in Australia

Co-existence refers to the capacity for farmers to make a choice to use individual production systems to generate products that meet their customer specifications (Lee, 2012). Australia now has the challenge of cultivating co-existence between our diverse range of production systems.

Tolerances/Thresholds

Given the unpredictable nature of the environment in which commodities are produced and the shared infrastructure in the supply chain, it is widely accepted that the absolute purity of grains commodities is an impossible goal (Lee, 2012). Practical tolerances for impurities in grain standards are essential for the effective co-existence of different cropping systems (Lee, 2012).

The stringent Australian Organic GE Standards potentially makes Australian organic exporters less competitive on the world market compared to other countries. (McCauley et al, 2012). A 0% tolerance for the level of adventitious presence for GE in organic products or on organic properties will be very difficult to sustain. These have been developed with no input from the wider grains industry (Lee, 2012) and as such they are unique amongst regulatory standards and fail to take into account the practicalities of the unpredictable nature of agriculture. The standards for the adventitious presence of regulatory approved GE material are at odds with the standards for toxic chemicals such as pesticides. The tolerance thresholds for these chemicals can range from 5-10%.

The standards of local organic certifying agents can differ substantially from the minimum-base Australian National Organic Standards. Consistent standards between organic certifiers and national standards would create more certainty for consumers and understanding for all farmers.

Education

Co-existence of GE, conventional and organic crop production will require significant on farm stewardship efforts. Implementing a co-existence strategy has to start on the farm and in order for co-existence to work, farmers must be aware of the major issues and critical control points where problems could arise (Entz and Martens, 2003). Technology providers and the government could both aid farmer education.

Technology providers

In Australia the Monsanto agreement for the cultivation of glyphosate tolerant GE canola requires farmers to:

- Follow the Monsanto crop management plan and resistant management plan
- Only deliver GE canola to registered GE storage and handlers
- Not retain any seed
- Allow Monsanto auditors on farm to inspect canola
- Maintain a 5m buffer zone between GE and non-GE canola, and a 400m buffer zone between GE canola and non-GE canola kept for seed
- Control volunteers
- Keep records.

There are no strict co-existence guidelines, although it mentions 'just like other crops, it is important to talk to your neighbour'.

Technology providers are in a prime position to improve this stewardship and provide further education on co-existence. A framework for possible on-farm stewardship issues, practices and considerations is shown in Table 2 (Entz and Martens, 2003).

Table 2 Stewardship steps to improve co-existence and issues associated with those steps (Entz and Martens, 2003)

Stewardship Steps	Issues and Considerations
Separation distance	Management of Separation distance requires co-operation between neighbouring farmers
Land Tenure	When a high proportion of land is rented or leased, agreements between farmers becomes more difficult
Crop Rotation Planning	Crop rotation central to coexistence. Crop rotation interval depends on crop type and nature of the GM trait.
Seed Supply	Properly managed certified seed production system should allow farmers to purchase uncontaminated seed.
Tillage System	Tillage System will affect seed bank persistence and opportunities for volunteer plant control
Volunteer Management	Volunteer Plant Management critical
Insect Pollinator Mangement	Honey production or seed production may require alternative management
Harvest Management	Seed returning to land during harvest creates future problems. Physical weed seed management and machine sanitation is crucial.
Grain Transportation	Extra Care in grain transportation to avoid losses to the environment. Equipment Sanitation
Grain Storage	Segregated storage and handling equipment required. Spillage during on farm grain transfer is common.
Straw Management	Straw contains seeds. Movement of straw from farm to farm must be restricted or managed in new ways.

For example, it could be a mandatory requirement of a GE seed agreement that properties that border GE crops would require a contract that would discuss things such as buffer zones, planting dates and refuge plots. It is important however, that stewardship conditions are not too extreme. As the vast majority of farmers are not located near organic or conventional non-GE crops, there is a need for a case-by-case approach to co-existence (Barefoot and Brooks, 2003).

Government

The AC21 committee from the USA concluded that the government needed to assist the farming community to understand the contract requirements for different agricultural practices (Russell et al., 2012). They also suggested that the government needed to provide education to farmers on co-existence and also facilitate farmer to farmer dialogue

As part of the federal regulatory approval of GE products, co-existence measures could be considered. Segregation guidelines that stipulate exactly how a farmer was to keep their product separate from their neighbours, new testing measures for unintended presence, and actions to ensure seed purity, should all be investigated when a new product is brought to market. This would create more certainty and avoid any risks of liability (Lee, 2012).

Research

Further research into co-existence measures should also be funded by both the government and technology providers. The government has an obligation to find ways to ensure that all farmers are able to choose the production system that best suits their business. It is also in the best interest of technology providers to improve co-existence, as it will ensure the longevity of their products and the expansion of their businesses.

Investigations could include:

- Measurement of economic loss
- Gene flow risk and management
- Methods of measuring GE presence
- Development of new crops that have genetic tools restricting unintentional gene flow to other plants (Russell et al., 2012).

Costs of Coexistence

Other than further research and education, there are two real on-farm costs associated with the co-existence of GE, non-GE and organic production systems. The first one is avoidance cost. That is, the cost of avoiding GE presence through cross-pollination and physical admixture. This includes costs such as buffer zones, seed testing, sowing times, storage and handling. The second cost is the economic cost of accidental presence if this leads to loss of market premiums. The issue of who pays for these costs is a subject of much debate (Apted and Mazur,2007).

The economic losses incurred by an organic farmer to avoid GE presence can range from very small to very costly. One study in the USA found 15-20% of organic farmers said that their costs had increased through indirect costs of GE such as buffer zones and planting times. In the same study, 8% of organic growers reported that they suffered economic loss as a result of direct costs such as seed testing and lost sales (Apted and Mazur, 2007). A European study found that to meet GE tolerance thresholds of 0.1-0.3% that it could cost between 10-35% of gross margins (Apted and Mazur, 2007).

Organic organisations and farmers believe that it is a fundamental right for a farm to remain GE free. They believe basic fairness says that a farmer should not have the right to negatively impact on their neighbours operations or the marketing ability of their crop. The farmer affecting their ability to maintain GE-free status should bear some responsibility for containing the outflow of genes. Consequently, should their property be affected they should adequately compensated.

On the other side of the argument, many believe that when a farmer is growing a certain crop with a certain purity and specifications (with a premium), then the economic risk and extra costs of production associated with providing that crop should be covered by the premium they receive (Russell et al., 2012). Historically, the economic liability relating to the adventitious presence of unwanted material in any agricultural crop has had the onus placed on speciality producers (Brooks and Barefoot, 2004).

The question is, 'how far do individual producer rights extend before they are able to restrict the ability and freedom of adjacent farmers to make their own decision with respect to growing GE and non-GE' (Ludlow, 2005). There is potential to create further conflict between farmers in regards to other agricultural 'contaminants' such as pathogens, weed seeds and soil erosion, that all have the potential to cross farm boundaries.

Organic produce is a very small sector of agricultural production in Western Australia and this has to be taken into account when looking at co-existence. Because organic growers benefit from a specific quality standard that their neighbours do not, they should not expect their neighbours to bear the special management costs of meeting that standard. To do so would reverse fundamental concepts of freedom of economic activity and may establish a dangerous precedent (www.croplifeaustralia.com).

The debate over a compensation mechanism to reimburse a grower when they incur an economic loss as a result of the adventitious presence of GE is also complicated. An insurance mechanism like the one suggested in the AC21 report has the risk of being a disincentive for the management of co-existence and penalising farmers who have done nothing wrong. It could also potentially cost farmers and tax payers a significant amount (Russell et al, 2012).

Chapter 9: Unique examples of co-existence

Willamette Valley, Oregon

In Oregon, USA, the Willamette Valley has a unique system of co-existence. The area is renowned for its speciality seed production of different brassica crops. The Department of Agriculture runs a system where growers come in at the start of the season and 'pin' on a map what crops they are going to plant and where. The required buffer zone between crops is adhered to and through communication growers are able to plan their cropping rotations so that their neighbours are not negatively impacted through the cultivation of different crops.

In 2005, the area was declared a canola restricted zone and no canola was allowed to be grown because of the threat it had on the purity of the speciality seed brassica crops in the area. In 2013, this administrative rule was removed by the USA Department of Agriculture (USDA) despite the venomous opposition by the seed producers in the area. Under the new ruling, canola can be grown in certain areas of the Willamette Valley. Growers must apply every year they would like to grow canola and only 2,500 acres will be allowed to grow in any year. Each farmer growing canola has to enter into a contract with the department that specifies their obligations and responsibilities. Speciality seed producers are extremely concerned they will lose precious markets through a loss of purity from the adventitious presence of canola genes. This unique system of agriculture faces a great challenge in maintaining co-existence.

North Dakota; KTM farm, GE and non-GE soybeans, GE beets

KTM farm in North Dakota is producing and marketing non-GE soybeans in a state where 95% of soybeans grown are GE glyphosate tolerant. Pure seed is mainly sourced from private breeders. Buffer zones of 30cm are maintained between the non-GE soybeans and other GE crops and strict farm hygiene is adhered to in all farm machinery and storage facilities. For their market there is a 0.1% tolerance to GE contamination in their crops. Every load of non-GE soybeans that leaves the property is tested to ensure it does not exceed this threshold and to date they have had no issues meeting this tolerance level.

KTM farm also produce GE sugar beets. In the USA sugar beet seed producers are very opposed to the introduction of GE sugar beets because of the risk of contamination to their seed. The USA Sugar Beet Co-operative requires growers of GE sugar beet to follow a strict stewardship program that requires growers to remove all GE sugar beet that runs up into seed by hand and document every single plant. It is a huge cost to the operation and frustrating for the farmers as there are no sugar beet seed producers in the area. This is an example where it is important that the stewardship programs are proportionate to the level of risk associated with growing the crop in a certain area.

Kayla Miller removing a GE sugar beet that has run to seed, North Dakota, USA, July, 2012 (Sadler, 2012).

Sensitive Sites Map, Australia

The Western Australian Department of Agriculture have developed a ‘Sensitive Site Map’. Growers are able to register crops they believe are under threat from activities outside their farm boundary. It is designed to assist growers prepare risk assessment and mitigation plans for their unique production activities and help protect sensitive agricultural production systems. The map is placed on the department website and available to all growers. This system could be expanded and better utilised through further extension of the site map information to all Western Australian growers.

Chapter 10: Profitable Cropping and Sustainable Weed Management

In most world crop-production areas, the evolution of herbicide resistant weeds is becoming a major issue. This problem has become most severe across the Australian dryland crop-production region, where herbicide resistant weed populations are threatening the profitability and sustainability of crop production across 20 million ha (Walsh and Powles, 2007). The introduction of GE herbicide tolerant crops, such as Roundup Ready®, will increase the selection pressure for glyphosate resistant weeds, increasing the chances of the evolution of glyphosate resistant weeds. The over use of glyphosate tolerant crops in the USA has led to the rapid development of glyphosate resistant weeds. It is vital that alternative, highly effective weed control technologies are developed to prolong the effectiveness of our invaluable herbicides.

Dr Phil Stahlman in a Kansas paddock over run with the glyphosate resistant Kocha weeds, July, 2012(Sadler, 2012)

Integrated Weed Management

Integrated Weed Management (IWM) is a commonly used term to describe the use of multiple different control methods to manage weeds in agricultural practices. Herbicides have been, and remain, the most efficient technology for weed control across dryland cropping production areas in Australia. The use of IWM strategies will ensure that these valuable tools remain available to farmers.

Commonly used IWM used in Australian crop production systems include:

- delayed seeding with a knockdown herbicide application
- higher crop-seeding rates, crop rotation (including silage or hay)
- crop-topping harvest weed seed management such as burning windrows or chaff piles.

All of these strategies have their limitations and there is an urgent need for new technologies to be developed in this area.

Innovative non-chemical Integrated Weed Management tools

The Australian agricultural industry is investing a lot of time into researching and developing new weed management strategies. The Harrington Weed Seed Destructor (HSD), developed in Western Australia, is currently being trialled in the field. The HSD is towed behind the harvester, collecting the chaff component of the harvested crop and pulverises it so that weed seed is no longer viable. Studies have shown that the HSD is capable of destroying >95% of the weed seed in the chaff component. Of course, there are many challenges associated with running a machine of this nature in the field. The GRDC are now in the testing phase of seed destructor system that is in the back of the header rather than a tow behind machine. This eliminates many of the issues associated with running an extra engine and towing something behind the header. Developers are confident this mechanism will become a practical and efficient mechanism for harvest weed seed management.

The Aqua-slash has been developed in South Australia and is due to be trialled in the field this year. This machine uses extremely high pressure water that is sprayed between crop rows to cut and kill weeds. The machine is guided by an EcoDan® guidance system that ensures acute accuracy so that jets spray down the middle of the crop rows. The water is sprayed on a 45^{o} angle to the ground to ensure plants are cut off from the roots. It has the benefits of being able to work under all weather conditions and also kill stressed weeds which herbicides could not. There are issues associated with using a machine like this, one being the huge volume of water that would be required. A Weed Seeker® system, which detects weeds and only sprays water when weeds are present, could be used to overcome this problem. The system will require pin-point accuracy and large amounts of power. The South Australian No Till Farmers association are examining these challenges in the field this year.

A microwave weed killer is being developed which has the ability to kill weeds above the ground and also weed seeds under the soil surface. The machine essentially cooks the emerged plants and steams the weed seeds underground so that they are no longer viable. It has the potential to be used either as a knockdown weed control method or as a selective control measure in crop using precision guidance, directing the emitting microwaves between crop rows. It has the benefits of being able to be used in all weather conditions, widening the period of application timing. The machine has to heat the soil to very high temperatures and, thus, can only move at very slow speeds, requiring large amounts of energy. It also has the disadvantage of essentially pasteurising the soil and thus decreasing microbial activity on the top soil layer. The machine is only in early stages and further development is required.

A recent breakthrough by Monsanto has discovered a chemical that has the potential to reverse glyphosate resistance in weeds. This amazing technology has potential to dramatically affect agriculture in many parts of the world. Further work is required in this field but there is optimism that this will be another tool for weed management in the future.

Australia is leading the way in the development of alternative strategies to herbicides for weed management. Leading grain producer countries such as the USA, Canada and the EU still rely mainly on herbicides for weed management. Glyphosate resistant weeds are so dominant in parts of the USA arable cropping regions that land is rapidly becoming unviable for cropping. Despite witnessing this breakdown in the efficacy of chemicals, their research continues to be limited to developing different herbicide options and new herbicide tolerant crops.

The scientific principles of evolution will mean that weeds will continue to evolve resistance to any selection pressure (control measure) that are placed on them. There is an urgent need for improved and continuous research into alternative, practical weed control mechanisms. Researchers are investing a great deal of time and money into the science of herbicide resistance in different weed species. It is important that this information rolls into practical advice for farmers, developing the best management practices to decrease the risk of herbicide evolution, and also finding measures to control multiple herbicide resistant populations.

Glyphosate tolerant wheat

A new tool that could be used in the future to control problem in-crop weeds is GE glyphosate tolerant wheat. This technology has been developed but to date has not been utilised in agriculture around the world. The introduction of GEHT wheat into Australia would no doubt come with a great deal of controversy.

A widespread adoption of glyphosate tolerant crops has the potential to lead to an over reliance of the herbicide glyphosate. This would create a selection pressure for weeds to evolve resistance to the herbicide, and glyphosate resistant weeds could evolve at a rapid rate. There is also potential for the GEHT crop itself to become a weed in the following years crop if there was an over reliance on GEHT crops. However, if the technology is introduced with good farmer education and effective stewardship plans it could be beneficial to some farmers.

As more and more farmers realise the benefits of early sowing, the use of a glyphosate knockdown on weeds before the crop is sown is not often possible. In this situation, glyphosate tolerant wheat would give growers the opportunity to at least use the herbicide in their system. For Australian farmers that do not have the potential to grow canola, GEHT wheat gives them the opportunity to utilise the new technology.

The introduction and widespread adoption of GE wheat in Australia will put immense pressure on non-GE and organic growers to remain GE free and create a real challenge for co-existence. GE canola has been sufficiently segregated in the storage and handling process in Australia from non-GE conventional canola. However, canola is a small market constituting only 9% of arable acres sown in Australia each year compared to 60% sown to wheat. Testing for the presence of GE at delivery points has been shown to be an inexpensive and efficient way of maintaining GE free segregations. The segregation of GE and non-GE wheat in the storage and handling process will be a considerable but not unachievable challenge.

Wheat is primarily a self pollinating plant with very low rates of out-crossing facilitated by the wind. Under Australian conditions, pollen mediated gene flow through a small release of GE wheat was observed only at low frequencies (0.012% and 0.0037%) over short distances. The maximum distance of gene flow was no more than 8m (Gatford et al, 2006). It is extremely unlikely that the accidental presence of GE in non-GE wheat would occur through cross-pollination.

Monsanto’s initial investment into GEHT wheat was halted in 2004 because of lack of alignment between the direction of the US agricultural industry and Monsanto’s own research priorities. It also coincided with a decrease in US wheat hectares. Monsanto states it was purely a business decision. In 2009, wheat organisations from three major wheat producing countries, the USA, Canada and Australia outlined their support for GE wheat. They released a trilateral statement for increased investments into research and development of GE wheat. To date, although there has been ongoing research into GE wheat, there has been no release of the new technology to the agricultural sector in any country.

Chapter 11: Conclusion and Recommendations

- Co-existence strategies are required to enable GE, non-GE and organic production systems to farm and sell their product in accordance to market demand and consumer preferences. Cohesive co-existence will ensure that the Australian Agricultural industry is able to embrace new technologies and contribute to feeding the growing world population, while also maintaining biodiversity and important niche product markets to meet consumer demand.
- There is a need to review the current GE thresholds in Australian organic production systems to enable co-existence of our different production systems.
- It will be important that both government and technology providers continue to improve their stewardship for growers on co-existence measures. Further research and education is required so that growers are fully aware of their risk of liabilities when they are growing a crop and thus take appropriate measures to mitigate that risk.
- Growers who are receiving a premium for growing a specific product should bear all the costs of growing that crop and the costs covered by the premium they receive. Consumer demand will inevitably control the market.
- The development of a compensation mechanism for growers who suffer economic losses as a result of GE contamination will be a costly and challenging task.
- On-going research and development into practical alternative weed control methods is required to achieve sustainable weed management.
- The possible introduction of glyphosate tolerant wheat will pose many challenges to the Australian agricultural system in terms of co-existence measures and the evolution of herbicide resistance. A clear management strategy should be rolled out with the introduction of this new technology.

All agricultural systems deemed safe should have an equal opportunity to contribute to the agrifood production system. Farmers must understand the importance of working with their neighbours to ensure that both properties are able to make the best decisions for their business. The future of a diverse and dynamic agricultural food supply chain depends on it.

It is crucial that growers understand the risks of growing herbicide tolerant GE crops. Nowhere in the world has the evolution of herbicide resistance been as rapid as Australia. If growers are to maintain these vitally important weed management tools, they must use them wisely.

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Plain English Compendium Summary

Project Title:	Sustainable weed management and the use of genetically engineered, herbicide tolerant crops

Nuffield Australia Project No.:
Scholar: Jemma Sadler
Organisation: Danubin Farm, Wongan Hills

Phone: 0408721029
Fax: (08) 96721029
Email: jemmasadler@bigpond.com

Objectives

To explore the challenges of the co-existence of GE, conventional and organic farmers in Agricultural production systems around the world.

To examine mechanisms to aid in the co-existence of these different production systems in Australian farming systems.

To investigate new, effective, integrated weed management strategies (IWM).

Background

The evolution of weeds resistant to multiple different herbicides has led to weeds being one of the main challenges facing arable farmers in Australia. The development of crops that are tolerant to knockdown herbicides through genetic engineering is helping in the management of problem weeds. Some farming systems are opposed to the use of genetic engineering in agriculture and have little to no tolerance of GE crops in their system. The issue of the co-existence of these different agricultural systems has therefore become an issue for Australian agriculture.

Outcomes

Co-existence of genetically engineered, non-genetically engineered and organic crop growers is essential to ensure the continuation of all production systems and the continual development of new genetic engineered technologies to meet rising consumer demand.

Government and technology providers must continue to improve their stewardship for growers on developing these co-existence measures.

A review of the current thresholds for the adventitious presence of genetically engineered products in Australian organic production systems is required to ensure the sustainability of the organic industry.

Growers who are receiving a premium for growing a specific product should bear all the costs associated with growing that crop.

Australia is leading the way in the development of alternative non-chemical weed control strategies but more research into practical control methods is required to achieve sustainable weed management.

Implications

The use of GE crops in Australian agriculture will continue to be a topic of great controversy. The challenge of co-existence will require all parties to be flexible and willing to negotiate co-operatively. Ultimately, there will have to be sacrifices by some agricultural production systems to ensure the broader agricultural community is able to grow and develop to keep up with the rest of the world.