Agricultural Biotechnology Council of Australia

THE OFFICIAL AUSTRALIAN REFERENCE GUIDE TO

AGRICULTURAL BIOTECHNOLOGY AND GM CROPS

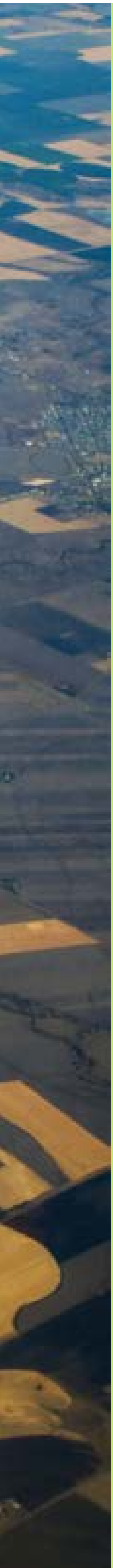
SECOND EDITION

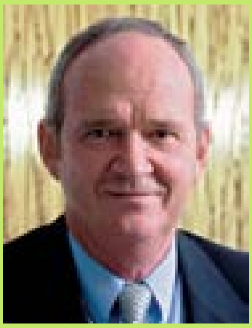
The Agricultural Biotechnology Council of Australia (ABCA) is the national coordinating organisation for the Australian agricultural biotechnology sector. Working broadly across the agriculture sector, ABCA is committed to providing quality, factual, science-based information about gene technology in agriculture.

ABCA is an industry initiative with four founding members.

Members of ABCA include the Academy of Technological Sciences and Engineering, Ag Institute of Australia, Animal Medicines Australia, AusBiotech, the Australian Oilseeds Federation, Australian Seed Federation, Canegrowers, Cotton Australia, CropLife Australia, Grain Growers, Grains Research and Development Corporation, Grain Trade Australia, the National Farmers' Federation, the South Australian Research and Development Institute and Science and Technology Australia.

Publication coordinated by the Public Affairs Working Group Chair, Ms Jaelle Bajada.





FOREWORD

MR KEN MATTHEWS AO
CHAIRMAN OF THE AGRICULTURAL BIOTECHNOLOGY COUNCIL OF AUSTRALIA

It is easy to forget that a lot of the food we eat and the fibre we wear is grown by Australian farmers — around 60 per cent of the Australian land mass is devoted to agriculture in one form or another.

Australia's agriculture sector, although a relatively small part of our economy, is a significant part of our exports and an important employer. We export $30.5 billion of food products annually and produce enough to feed the country at least twice over, while food creation is the biggest employer in rural and regional communities.

Innovation and productivity have long underpinned Australia's agricultural competitiveness. It is because of our sustained investment in research and development that our agricultural sector is the global leader it is. And it is our farmers' commitment to continuous improvement based on R&D that will secure Australia's agricultural future.

But our food production system isn't just about high yield agriculture and exports; it is also about ensuring our agricultural practices are sustainable, our management of pests and diseases is responsible and that our environment is conserved by finding new ways to use less land, less energy and less water.

With a rapidly growing world population (the Food and Agriculture Organisation of the United Nations forecasts 9.1 billion people by 2050), a changing climate and intensifying global environmental problems, agricultural biotechnology is increasingly seen as a potential solution to some of the biggest world challenges.

Although the potential importance of agricultural biotechnology is widely recognised, public discussion and debate has not always been based on clear, factual and accessible information. It is vital for our future that decisions on agricultural biotechnology be based on credible, science-based information.

The Official Australian Reference Guide to Agricultural Biotechnology and GM Crops provides factual information about GM crops based on scientific evidence. I trust you will find this a useful reference in informing your considerations.

ABCA EXPERT SCIENTIFIC PANEL

The Agricultural Biotechnology Council of Australia is supported in its function by an Expert Scientific Panel. The Panel is chaired by Dr TJ Higgins.

Prof Marilyn Anderson	Professor, Lab Head	LaTrobe University
Prof Jimmy Botella	Professor, Plant Biotechnology	University of Queensland
Prof James Dale	Director, Centre for Tropical Crops and Bio Commodities	Queensland University of Technology (QUT)
Prof Ros Gleadow	Associate Professor	Monash University
Dr Allan Green	Deputy Chief of CSIRO Plant Industry	CSIRO
Prof Robert Henry	Director, Queensland Alliance for Agriculture and Food Innovation	The University of Queensland
Dr TJ Higgins	Honorary Fellow	CSIRO
	Secretary for Biological Sciences	Australian Academy of Science
Prof Mike Jones	Foundation Director	State Agricultural Biotechnology Centre (SABC)
Prof Peter Langridge	Chief Executive Officer	Australian Centre for Plant Functional Genomics
Prof Ed Newbigin	Associate Professor	University of Melbourne
Prof Tony Peacock	Chief Executive Officer	CRC Association
Prof Jim Pratley	Research Professor of Agriculture	Charles Sturt University
Dr David Tribe	Senior Lecturer, Agriculture and Food Systems	University of Melbourne
Dr David Vaux	Laboratory Head, Cell Signalling and Cell Death Division	Walter and Eliza Hall Institute Biotechnology Centre
Prof Mike Goddard	Professorial Fellow in Animal Genetics at the Faculty of Land and Food Resources	University of Melbourne
Prof German Spangenberg	Executive Director, Biosciences Research Division	AgriBio Victoria

CONTENTS

1 BASIC FACTS ON GM

GMOs offer potential of increased agricultural productivity and improved nutritional values that can contribute directly to enhancing human health and development.

World Health Organization[1]

1.1

WHAT IS 'CONVENTIONAL' PLANT BREEDING?

'Conventional' is a term used for a wide range of breeding techniques that involve changing the genes of a plant so that a new and better variety is developed.

To conventionally breed a new plant variety two plants are 'sexually crossed'. The aim is to combine the positive traits from both parent plants and exclude their unwanted traits in a new and better plant variety. However, both positive and negative traits may be inherited.

Plant breeders have to look at all the new plants and select the ones with the most positive traits. They then cross the chosen plants back to one of the original parent plants to try and transfer more of its positive traits into the following generation.

This process, called 'back-crossing', takes place over a number of generations, which usually means a number of years, until the final plants have all the desirable traits and none of the negative ones of the original two parent plants.

Did you know?

Once upon a time, carrots were white or purple. Orange-coloured carrots are the product of a mutation selected by a Dutch horticulturist a few hundred years ago, because it was the colour of the Dutch Royal House of Orange-Nassau.

Conventional breeding also includes techniques that use chemicals and radiation to speed up mutation in plant DNA. This process is referred to as **mutagenesis**.

Other conventional plant breeding techniques used include:

- artificial pollination
- male sterility — using natural sterility factors to ensure a cross from one parent to the other, but not vice versa
- tissue culture — growing plant tissue in artificial culture conditions to generate whole plants.

These days, science allows conventional plant breeders to get right down to the molecular level. For instance, short segments of DNA called molecular markers can be used to identify plants with a particular gene or characteristic to use in breeding, and to show whether any offspring have inherited those characteristics.

While these methods above may involve using an understanding of genes to fast-track breeding, they are not considered to be genetic modification.

Did you know?

In Australia, molecular markers have been used to develop the wheat varieties 'MacKellar' (virus-tolerant) and 'Young' (rust-resistant). Both have provided farmers with higher yields compared with earlier varieties.

1.2

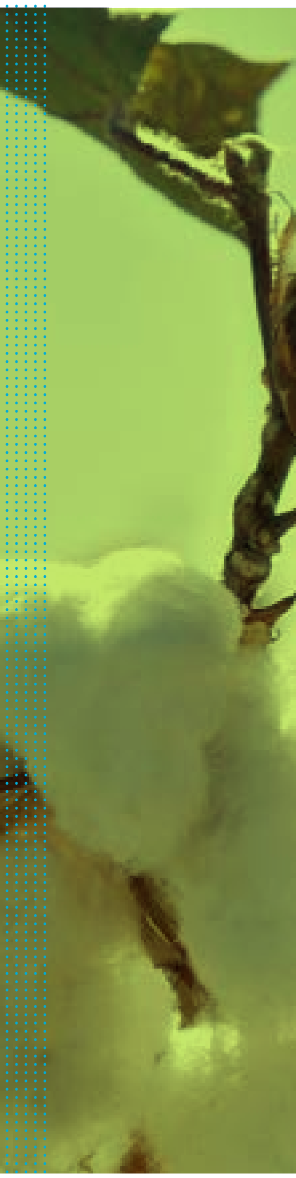
WHAT IS AGRICULTURAL BIOTECHNOLOGY?

Biotechnology is a broad term used to describe the process of using living things to create or change products — such as harnessing yeasts to brew beer and make bread.

Agricultural biotechnology is a natural progression of conventional breeding.

Over time, the spectrum of plant breeding has become increasingly sophisticated, moving from farmers who saved seeds from crop plants that performed the best in the field (selective breeding), to the deliberate crossing of different varieties from the same or closely related species (hybridisation), to gene selection through mutagenesis, to modern agricultural biotechnology.

All available breeding techniques remain important to the modern plant breeder — agricultural biotechnology is the latest tool available to speed up and make more accurate the development of new and improved crop plants.



TECHNIQUE
SELECTION
EXPLANATION
Saving seeds from crops with desirable features.

TECHNIQUE
HYBRIDISATION
EXPLANATION
Breeding plants with different characteristics to produce offspring with a combination of desired traits. Hybridisation can be achieved using individuals of the same species or closely related species.

TECHNIQUE
PHYSICAL OR CHEMICAL TREATMENTS
EXPLANATION
This includes exposing seeds to radiation (a process called irradiation) or mutagenizing chemicals, which can speed up natural mutation rates.

TECHNIQUE
MODERN GENE TECHNOLOGY
EXPLANATION
This is both the science of understanding how genes work and the practical application of that science. This includes:

- the discovery of genes (genomics)
- understanding how genes function and interact (functional genomics)
- the discovery of natural DNA markers to more efficiently select plants with desired characteristics
- directly inserting or deleting one or more genes, or turning them on or off (these processes are collectively referred to as genetic modification, genetic manipulation or genetic engineering. The resulting crops may also be referred to as 'transgenic').

1.3

WHEN IS BREEDING CONSIDERED GENETIC MODIFICATION?

Breeding is considered to involve Genetic Modification (GM) where scientists deliberately choose specific genes and switch them on or off, turn the 'volume' up or down, or move them between two species. The aim is to introduce, enhance or delete particular characteristics, depending on whether they are considered desirable or not, in the most targeted and undisruptive way possible.

Breeding using modern gene technology can produce quite subtle changes with the potential to provide significant agronomic, environmental or human health benefits without requiring many generations of back-crossing to eliminate the negative traits.

Modern gene technology methods, utilising recombinant DNA, are more targeted and faster than traditional breeding, because only those genes with known traits are deleted or transferred.

> **The chance of unintended changes with transgenic crops is less than the risk of unintended changes occurring in new crop varieties created by conventional breeding.**
>
> David Tribe
> Senior Lecturer in Food Biotechnology and Microbiology, Agriculture and Food Systems
> University of Melbourne[2]

1.4

WHY DO WE NEED AGRICULTURAL BIOTECHNOLOGY?

Global population growth is going to create some serious challenges in the years ahead, with the UN Food and Agriculture Organization (FAO) estimating that food supply will need to increase by 70 per cent to feed the nine billion people expected to be living on our planet in 2050.[3]

At the same time, we need to protect the environment by using less land, less water and less energy. In recognition of this, at the beginning of 2013 agricultural ministers from 80 countries signed a communiqué that emphasised the need for "sustainable agriculture, including its intensification".[4]

Making use of modern biotechnology, including GM, is one way to reduce pressure on agricultural resources, by improving food quality, increasing the productivity of current crops and helping crops adapt to environmental stresses such as drought.

For people in developing countries suffering from malnutrition, GM crops offer a way of dramatically increasing the dietary intake of micronutrients without changing their diet.

By allowing farmers to grow staple crops, such as rice and tubers, that have enhanced levels of provitamin A, for instance, modern gene technology could help to dramatically reduce vitamin A deficiency that affects 250 million pre-school children, causing blindness, illness and death.

›› See also the Golden Rice case study on page 20

There will be no silver bullet, but it is very hard to see how it would be remotely sensible to justify not using new technologies such as GM. Just look at the problems that the world faces: water shortages and salination of existing water supplies, for example. GM crops should be able to deal with that.

Sir John Beddington
Former UK Chief Scientific Advisor[5]

The Food and Agriculture Organization estimates that developing countries will have to boost their yields by half to meet the challenge of global hunger. We simply won't be able to meet that goal without using all the scientific tools at our disposal.

Bill Gates
Gates Foundation[6]

1.5

HAVE GM CROPS ACTUALLY DELIVERED BENEFITS?

Globally, since being introduced in 1996, GM crops have contributed to food security, sustainability and the abatement of climate change by:

- increasing the value of crop production by US $133 billion[7]
- reducing pesticide usage by around 500 million kilograms[8]
- saving 132 million hectares of land from clearing because of higher productivity of the agricultural land used to grow GM crops[9]
- reducing CO_2 emissions in 2013 alone by the equivalent of taking more than 90 per cent of the passenger cars registered in Australia off the road for one year, due to a reduced number of pesticide sprays and facilitating no- and low-till cropping systems.[10, 11]
- increasing the incomes of more than 16.5 million small farmers and their families — some of the poorest people in the world — and thereby helping to alleviate poverty.[12]

GM crops have also helped farmers financially. Globally, GM technology directly increased farm incomes by US $16.1 billion in 2013, with just over half of the gains going to farmers in developing countries.[13]

In Australia, the farm income benefits from 1996–2012 from GM cotton and canola are estimated to have been US $766 million. These calculations take into account impact on yield and quality, and the cost of the technology such as payments for seed.[14]

According to the 2014 'Meta-Analysis of the Impacts of Genetically Modified Crops' by Klümper and Qaim published on *PloS one*, 9(11), e111629, since 1996, GM crops have:

- reduced pesticide use by 37 per cent
- increased crop yields by 22 per cent
- increased farmer profits by 68 per cent.

1.6

IS IT SAFE TO GROW AND EAT GM CROPS AND FOOD?

All crops and pasture plants have the potential to impact negatively on natural or agricultural ecosystems, whether they are genetically modified or not. Similarly, any new food could potentially carry risks if we're not used to eating it and it hasn't been assessed by scientists to determine how different it is to foods we already eat.

Before GM crops are licenced for commercial release in Australia, the Gene Technology Regulator (the Regulator), assisted by the Office of the Gene Technology Regulator (OGTR) compares the risk of a genetically modified organism (GMO) against the risk of harm from the 'parent' organism to ensure that any new GM crops released are safe for the environment and human health.

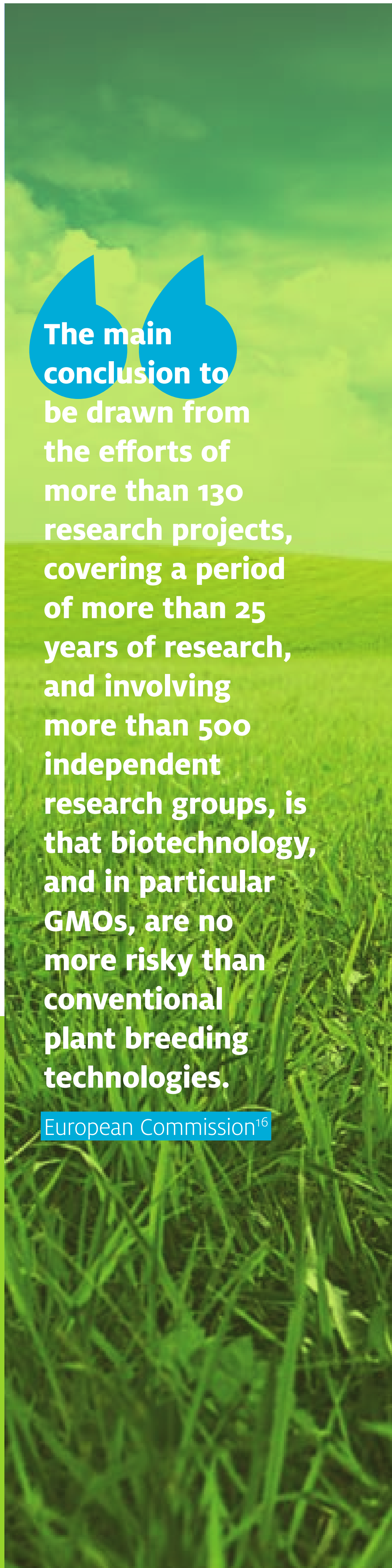
GM crops currently grown around the world and the food they produce have been studied extensively and repeatedly declared safe by scientific bodies and regulators globally.

This includes the Australian regulators responsible for pre-market assessment of live and viable GMOs — the Gene Technology Regulator — and food containing genetically modified ingredients — Food Standards Australia and New Zealand.

Every legitimate scientific and regulatory body that has examined the evidence has arrived at the conclusion that GM crops and the foods they produce are as safe as their conventional counterparts. This includes the World Health Organization, the Australian Academy of Science, the European Commission, the American National Academy of Sciences, the Royal Society of Medicine and many more.

The science is quite clear: crop improvement by the modern molecular techniques of biotechnology is safe.

American Association for the Advancement of Science[15]



The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are no more risky than conventional plant breeding technologies.

European Commission[16]

No effects on human health have been shown as a result of the consumption of such foods by the general population in the countries where they have been approved.

World Health Organization[17]

GM can deliver direct health benefits to consumers, such as important drugs, healthier food oils, removal of allergens from food.

Australian Academy of Science[18]

Gene technology has not been shown to introduce any new or altered hazards into the food supply, therefore the potential for long term risks associated with GM foods is considered to be no different to that for conventional foods already in the food supply.

Food Standards Australia New Zealand[19]

The GM debate is over. We no longer need to discuss whether or not it is safe — over a decade and a half with three trillion GM meals eaten there has never been a single substantiated case of harm. You are more likely to get hit by an asteroid than to get hurt by GM food.

Mark Lynas
Former anti-GM campaigner turned supporter[20]

2

HOW ARE GM CROPS AND PRODUCTS REGULATED IN AUSTRALIA?

2.1

FEDERAL REGULATION

Australia has a nationally consistent legislative scheme for gene technology, comprised of the Commonwealth *Gene Technology Act 2000* and corresponding State and Territory legislation.

The federal laws were enacted to protect the health and safety of people, and to protect the environment, by identifying risks posed by, or as a result of, gene technology, and by managing those risks through regulating certain dealings with GMOs.

The Act defines a GMO as (among other things) "an organism that has been modified by gene technology".

The Act defines a GM product as a thing derived or produced from a GMO — for example, corn chips produced from GM corn.

The Act also defines what is not a GMO — plants produced as a result of conventional breeding techniques, such as mutagenesis and irradiation, do not have to undergo the same rigorous testing as GM crops.

The Act is administered by the Regulator, who is responsible for making decisions on whether to approve field trials and the commercial release of GM crops.

The Act, however, does not take into account trade or marketing considerations, which is at the discretion of the States.

GM PRODUCTS

GM products are regulated by a number of authorities with specific areas of responsibility in addition to the OGTR:

- The Therapeutic Goods Administration ensures the quality, safety and efficacy of medicines, medical devices, blood and tissues in Australia. This includes GM and GM-derived therapeutic products.
- Food Standards Australia New Zealand (FSANZ) is responsible for setting the standards for the safety, content and labelling of food.
- The Australian Pesticides and Veterinary Medicines Authority (APVMA) is responsible for the registration, quality assurance and compliance of all pesticides and veterinary medicines up to the point of sale. This includes regulation of pesticides created by, or used on, GM crops.
- The National Industrial Chemicals Notification and Assessment Scheme (NICNAS) assesses new and existing industrial chemicals, including genetically modified products, for their effects on human health and the environment.

The OGTR website contains a complete list of approvals from the other relevant regulatory organisations to provide the community with ready access to information about GMOs and genetically modified products being researched or used in Australia.

ASSESSMENT OF GM CROPS AND FOODS

In terms of GM crops and the food produced from them, the OGTR, FSANZ and APVMA are the three main bodies responsible for assessment, licencing and approvals in Australia.

The OGTR carries out risk analysIs to identify and manage any risks posed by new GM crops before allowing field trials and before seeds can be commercially produced and sold to farmers.

If a new GM crop poses risks that the Regulator determines cannot be adequately managed, then a licence will not be granted.

Before a licence is granted, the Regulator prepares a risk assessment and risk management plan.
This includes:

- identifying if a new characteristic of a GM crop may cause harm, compared to its conventional counterpart — what may go wrong and how serious might it be?
- developing a management plan, on a case-by-case basis, to protect people and the environment — what actions might be needed, what are the consequences of those actions, and how can they be monitored?
- asking for input and feedback on the risk assessment and management plan — from experts and the public, on ethical as well as technical issues.

OGTR PROCESS FOR ASSESSING APPLICATIONS

APPLICATION

The body (university, research institute or company) seeking a licence for a new GM crop submits an application to the OGTR containing all necessary data on the crop, its safety and how it behaves in the environment.

RISK ASSESSMENT

- What could go wrong? (Identify risk)
- How likely is it? (Assess the likelihood)
- How serious is it? (Assess the consequences)
- Does it need to be managed? (Evaluate the level of risk)

EXPERT AND PUBLIC INPUT

Exchange of information, ideas and views between the Australian people, governments and interest groups about regulating GMOs.

RISK MANAGEMENT

- Does anything need to be done about any identified risk?
- What could/should be done?
- Will action create any new problems?
- How can the actions be monitored?

EXPERT AND PUBLIC INPUT

Exchange of information, ideas and views between the Australian people, governments and interest groups about regulating GMOs.

APPROVAL

- Risk management plan released
- Licence granted

FSANZ has a rigorous and transparent process for assessing the safety of genetically modified foods, based on internationally established scientific principles and guidelines. New products are assessed on a case-by-case basis, because the questions to be asked may depend on the type of food and the genetic modification.

Each genetically modified food is compared to an appropriate conventional (non-GM) food to determine if there are any differences from a molecular, toxicological and compositional point of view, and any differences then considered for safety and nutrition.

The goal is to make sure the genetically modified food has all the benefits and no more risks than those normally associated with conventional food. If the risks associated with any food assessed by FSANZ are too great to be managed, FSANZ will not grant approval for that food to be sold or consumed in Australia.

LABELLING

Labelling of GM foods and food ingredients allows consumers to make an informed choice about the foods they buy.

Australia has some of the most stringent food labelling requirements in the world, and any foods containing more than a negligible amount (one per cent) of GM ingredients must be clearly labelled. There is zero tolerance for the presence of an unapproved GM food or food ingredient. These requirements are overseen by FSANZ.

There are some pragmatic exemptions to the mandatory labelling requirement, which include:

- highly refined foods (such as sugars and vegetable oils) where genetic material is removed during the refining process
- flavours containing novel DNA or protein in a concentration of no more than 0.1 per cent
- instances where there is no more than one per cent (per ingredient) of an approved genetically modified food unintentionally present as an ingredient or processing aid in a non-genetically modified food
- foods prepared for immediate consumption, such as restaurant and take-away food, and catered meals.

The strength of the current Australian legislation is the link between labelling and the presence of genetically modified DNA or protein in the final product. Labelling is not necessary if the final food has negligible levels of genetically modified DNA or protein, such as highly refined oils and sugars, because the food derived from the genetically modified source is identical on a molecular level to its non-genetically modified counterpart.

Labelling of genetically modified food has nothing to do with the health or safety of the food. All approved genetically modified foods have been rigorously assessed and found to be safe by the Australian regulator.

2.2

STATE REGULATION

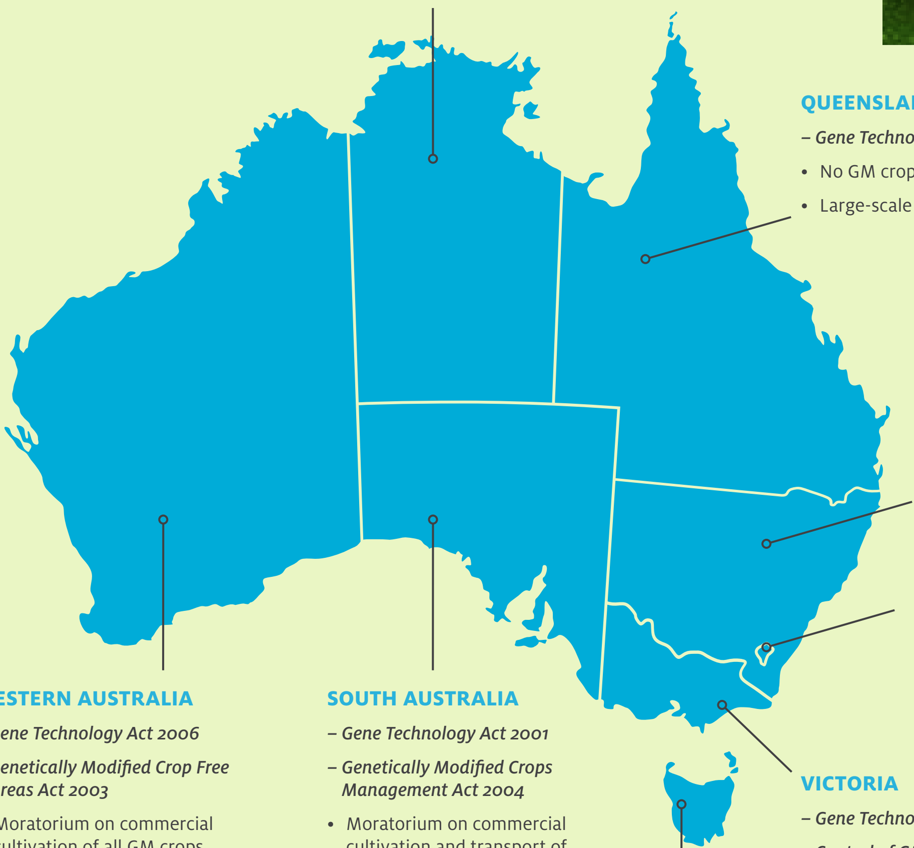
Economic and social considerations, such as risks to trade and marketing, may be taken into account by the states and territories. This means that even when GM crops are approved by the OGTR, each state or territory can decide whether or not production is allowed within its borders.

In 2003, licences were issued for the commercial release of two types of GM canola. All state and territory governments, except Queensland and the Northern Territory, subsequently established GMO-free zones to delay the release until marketing considerations had been addressed.[21, 22]

The global hectarage of biotech crops have increased more than 100-fold from 1.7 million hectares in 1996 to over 181.5 million hectares in 2014 — this makes biotech crops the fastest adopted crop technology in recent history.

International Service for the Acquisition of Agri-biotech Applications[23]

CURRENT POSITION OF EACH STATE AND TERRITORY ON GM CROPS



NORTHERN TERRITORY

– *Gene Technology Act 2004*

- No GM crop moratorium
- No commercial cultivation of GM crops

QUEENSLAND

– *Gene Technology Act 2001*

- No GM crop moratorium
- Large-scale commercial cultivation of GM cotton

NEW SOUTH WALES

– *Gene Technology (New South Wales) Act 2003*

– *Gene Technology (GM Crop Moratorium) Act 2003*

- Moratorium on commercial cultivation of GM food crops
- GM cotton exempt from moratorium and commercially cultivated
- Exemption for commercial cultivation of GM canola granted in 2008

AUSTRALIAN CAPITAL TERRITORY

– *Gene Technology (GM Crop Moratorium) Act 2004*

- Moratorium on commercial cultivation of all GM crops
- Exemptions permitted for trials under specific conditions

WESTERN AUSTRALIA

– *Gene Technology Act 2006*

– *Genetically Modified Crop Free Areas Act 2003*

- Moratorium on commercial cultivation of all GM crops
- Whole of state designated GM free area
- Exemptions for commercial production of approved GM cotton since 2008 and GM canola since 2010

SOUTH AUSTRALIA

– *Gene Technology Act 2001*

– *Genetically Modified Crops Management Act 2004*

- Moratorium on commercial cultivation and transport of GM food crops and/or seed
- Whole of state designated GM free area
- Exemptions granted for field trials under specific conditions

VICTORIA

– *Gene Technology Act 2001*

– *Control of GM Crops Act 2004*

- No current orders in place
- Commercial cultivation of GM canola since 2008

TASMANIA

– *Gene Technology (Tasmania) Act 2012*

– *Genetically Modified Organisms Control Act 2004*

- Moratorium on commercial cultivation of all GM crops
- Whole of state designated GM free area

3

WHAT GM CROPS ARE GROWN IN AUSTRALIA?

Embracing agricultural biotechnology research and the adoption of GM crops seems to me an economic, environmental and human health must.

The Hon John Anderson AO
Co-Patron of ABCA[24]

3.1

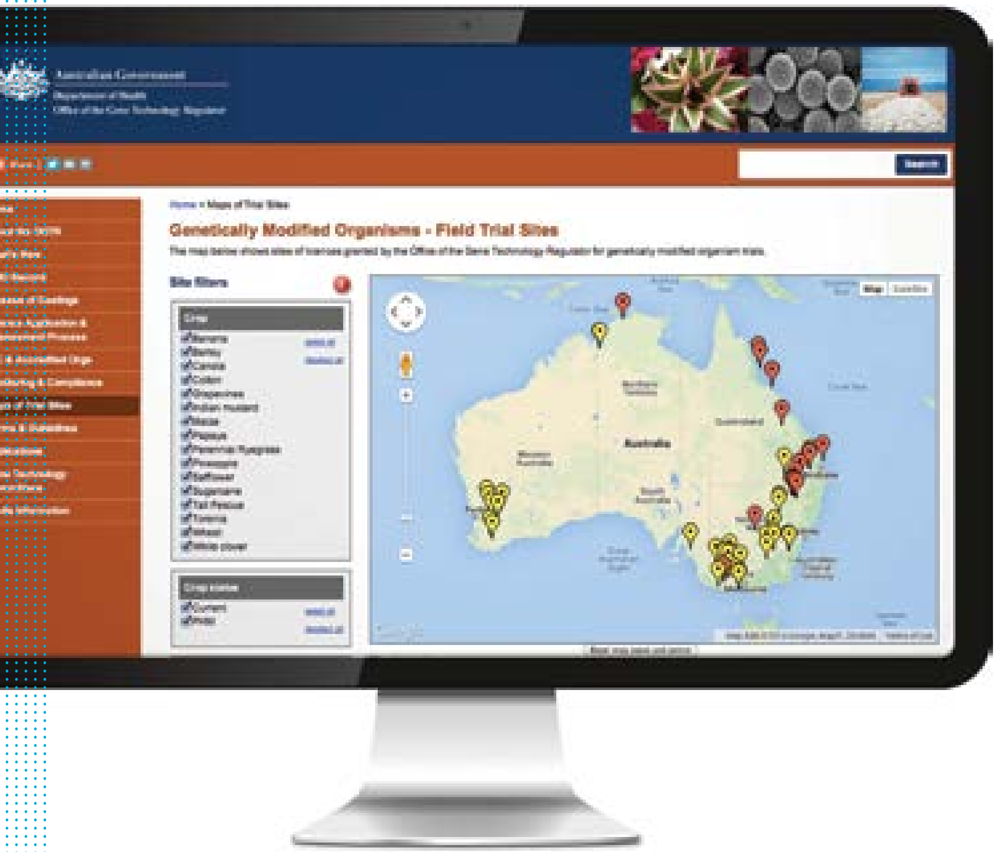
COMMERCIALISED CROPS

GM cotton has been grown commercially in Australia since 1996. GM cotton (either insect resistant, herbicide tolerant or a combination of the two) now accounts for more than 99 per cent of production and has reduced pesticide use by around 85 per cent when compared to previously grown conventional varieties.[25, 26]

GM herbicide-tolerant canola has been grown commercially in New South Wales and Victoria since 2008 and in Western Australia since 2010. Australia wide, it's estimated that 349,000 hectares of GM canola were planted in 2014, or 14 per cent of total canola plantings.[27]

GM carnations are commercially available in Australia, exhibiting colours from almost black, to blue-purple, through to light violet. The Australian carnation industry produces approximately 140 million flowers annually across Victoria, South Australia, Western Australia and New South Wales.

GM carnations are the first, and to date the only, GM organism to be listed on the OGTR's 'GM register'. This means they can now be sold as plants to home gardeners, and there are no conditions imposed on the cut flower industry as far as containment, inspections and the other regulatory processes previously required.



3.2

CROPS IN THE PIPELINE

Licences have been granted for a number of field trials in Australia for genetically modified food and pasture crops. A map showing their locations is maintained on the OGTR website, www.ogtr.gov.au

CURRENT FIELD TRIAL SITES

CROP	TRAIT	LOCATION	STAGE
BANANA	Human nutrition, disease resistance	NT, QLD	Current site
BARLEY	Human nutrition, yield, abiotic stress tolerance	SA, WA	Post-harvest monitoring
CANOLA	Herbicide tolerance, yield, hybrid breeding system, altered oil content	NSW, VIC, WA	Current site, Post-harvest monitoring
COTTON	Insect resistance, herbicide tolerance, enhanced fibre yield	NSW, QLD, WA	Current site, Post-harvest monitoring
PERENNIAL RYEGRASS	Animal nutrition	VIC	Post-harvest monitoring
SAFFLOWER	Altered oil profile	ACT, NSW, WA	Current site, Post-harvest monitoring
SUGARCANE	Herbicide tolerance	QLD	Current site, Post-harvest monitoring
WHEAT	Human nutrition, yield, abiotic stress tolerance, disease resistance, enhanced nutrient utilisation	ACT, NSW, SA, WA	Current site, Post-harvest monitoring
WHITE CLOVER	Disease resistance, viral disease resistance	NSW, VIC	Post-harvest monitoring

4 MARKETS

World trade in commodities such as soybeans, corn, cottonseed and canola is dominated by countries which have widely adopted genetically modified varieties. This would appear to indicate that, while some consumers are concerned about food containing genetically modified ingredients, these concerns are not reflected in buyer behaviour at the supermarket; nor do they result in widespread trade barriers or price premiums for non-genetically modified products.

Did you know?

Crops bred using agricultural biotechnology are the fastest adopted crop technology in the world. Biotech crop plantings continue to show year-over-year growth and global plantings have increased more than 100 fold over the past 19 years.

Even in the European Union, which has some of the strictest regulations regarding genetically modified imports and labelling, 50 genetically modified crops are approved for use as food and feed. These include maize, soybean, rapeseed, sugar beet and cotton.[28]

The barriers that have been erected in some countries in response to perceptions of consumer concerns about GM crops have increased the importance of identity preservation systems to keep genetically modified, organic and conventional grains separate, from planting seeds through to end use.

CONSUMER ATTITUDES

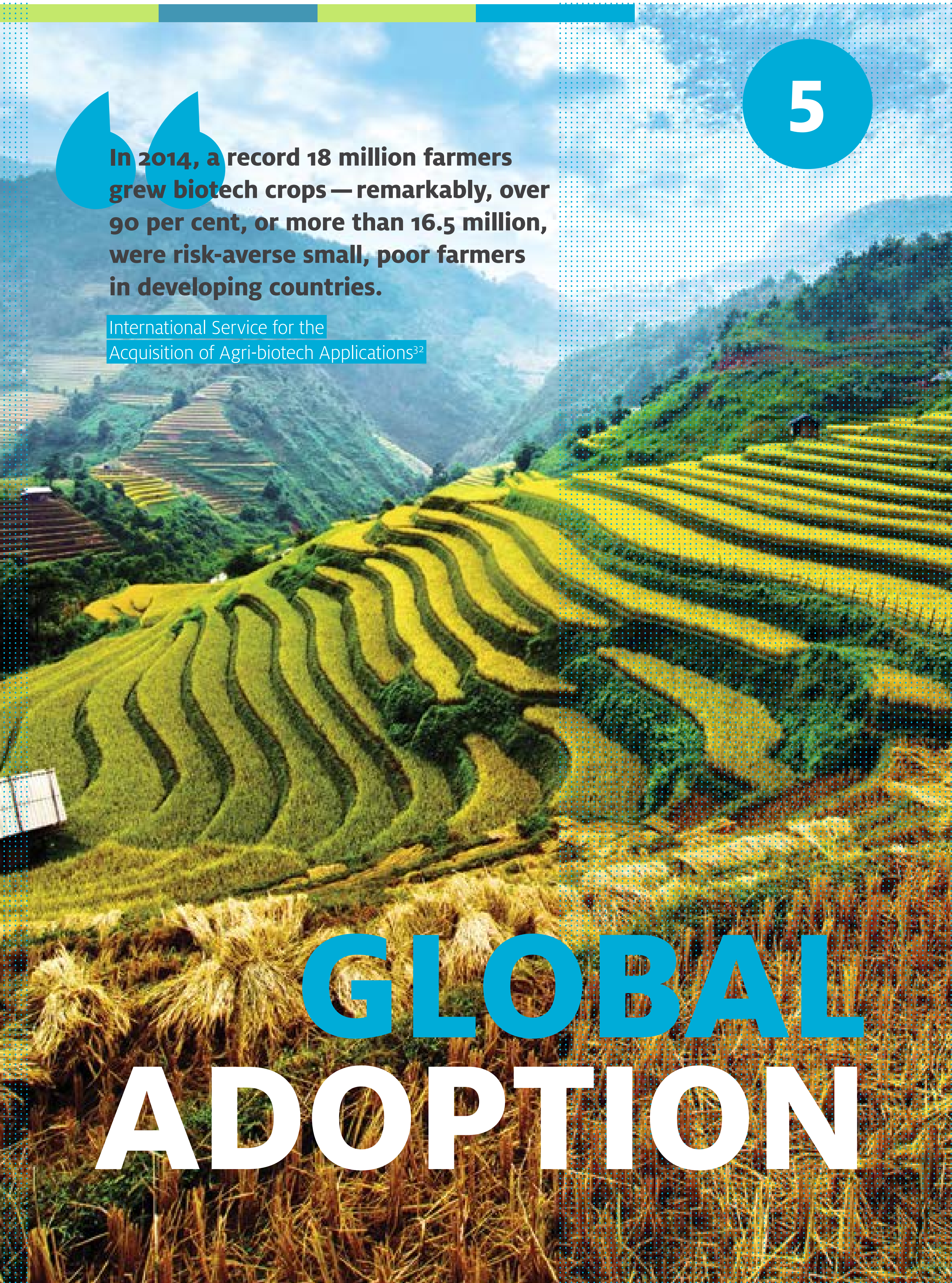
A series of local and international consumer surveys has found that consumers around the world are happy to continue to eat food containing genetically modified ingredients.

One of the most recent, conducted on behalf of the Australian Department of Industry, found that support for genetically modified foods and crops has remained fairly constant over the past few years.

Conducted in late 2012, the survey found about 60 per cent of the Australian population is willing to eat most food containing genetically modified ingredients. Approximately half of respondents also felt the benefits of modifying genes in plants to produce food outweighed the risks, while just one in six felt the risks outweighed the benefits.[29]

In another survey, conducted by FSANZ, 1,200 Australians were asked “which types of foods do you have concerns about?”. Fewer than three per cent nominated food containing genetically modified ingredients. They also listed 16 other elements before genetic modification when asked “what information do you usually look for” on a food label when purchasing a product for the first time.[30]

A 2010 Eurobarometer survey of 16,000 Europeans found that just eight per cent spontaneously nominated food containing genetically modified ingredients when asked about “possible problems or risks associated with food and eating”.[31]



In 2014, a record 18 million farmers grew biotech crops—remarkably, over 90 per cent, or more than 16.5 million, were risk-averse small, poor farmers in developing countries.

International Service for the Acquisition of Agri-biotech Applications[32]

5

GLOBAL ADOPTION

5.1 COMMERCIALISED CROPS

According to the International Service for the Acquisition of Agri-biotech Applications, GM plants approved for use globally include alfalfa, canola, cotton, maize, papaya, poplar, soybean, squash, sugar, eggplant, potato, apple, beet, sweet pepper and tomato. Most have improved traits for herbicide tolerance, insect resistance, or both.

A record 181.5 million hectares of biotech crops were grown globally in 2014, at an annual growth rate of three per cent. Crops with stacked traits (two or more) made up around 51 million hectares.[33]

More than half the world's population (60 per cent or approximately four billion people) live in the 28 countries planting biotech crops, 20 of which are developing and eight industrial.[34]

A total of 3,083 regulatory approvals involving 27 GM crops have been issued in 38 countries (37 + EU-27): 1,458 for food use; 958 for feed use; and 667 for planting or release into the environment.[35]

There is evidence that the GM crops being grown around the world today have lowered farm-level production costs. Other significant benefits include:

- higher crop yields
- increased farm profit
- improvements in soil health
- reduced CO_2 emissions from cropping.[36]

5.2

CROPS IN THE PIPELINE

The 'second generation' of GM crop research is focussed largely on increased nutritional traits that will have more direct benefits to consumers.

This will be particularly important in developing countries, where much of the population suffers health problems associated with poor nutrition.

Specific food crops being researched include:

- rice enriched with iron, vitamins A and E, and lysine
- potatoes with higher starch content, and inulin
- maize, banana and potatoes containing edible vaccines
- maize varieties with low phytic acid and increased essential amino acids
- soybean and canola with healthier oils
- allergen-free nuts.[37]

Creating or improving these 'functional foods' will also provide health benefits over and above basic nutrition. They are being developed to not only boost the level of nutrients, but also to increase the body's resistance to illness and/or remove undesirable food components.

Some of the work underway includes boosting levels of:

- phytosterols, which can lower the risk of cardiovascular diseases and levels of 'bad cholesterol'
- carotenoids, which are the yellow, orange and red pigments found in plants — they can be converted by the body into Vitamin A, which is essential for normal growth and development, immune system function and vision
- antioxidants, which can protect the body by neutralising the activity of free radicals (which cause damage to DNA and can eventually lead to degenerative diseases such as cancer)
- essential fatty acids, or 'good fats'– scientific studies suggest they help to reduce the risk of cardiovascular disease.[38]

Research is also continuing on new and improved crops with agronomic traits including:

- corn with better nitrogen use efficiency, increased ethanol, higher yields, drought and herbicide tolerance, and resistance to insects and fungus
- soybeans with increased oil and feed efficiency, higher yields, herbicide tolerance and resistance to insects, fungus, disease and nematodes
- cotton with drought and herbicide tolerance, and insect resistance
- rice with higher yields, herbicide tolerance and insect resistance
- canola with herbicide tolerance

CASE STUDY
GOLDEN RICE

According to the World Health Organization (WHO), Vitamin A deficiency causes 250,000 to 500,000 children to go blind and causes the deaths of 668,000 children under five each year. While the best solution is a better and more varied diet, rich in vegetables, fruits and animal products, it's not affordable for many. The second best approach is by way of nutrient-dense staple crops.

The aim of the Golden Rice Project is to make sure that people living in rice dependent societies get a full complement of provitamin A (beta-carotene) from their traditional diets, reducing the incidence of blindness and disease.

Rice produces beta-carotene in the leaves but not in the grain. Even though all required genes are present in the grain, some of them are turned off during the seed development phase. To counter this problem, two genes have been inserted into the Golden Rice genome by genetic modification to restart the carotenoid biosynthetic pathway, leading to the production and accumulation of beta-carotene in the grains.

From the beginning, Golden Rice was conceived as a public-good project. Funding has come from donors including the Rockefeller Foundation, the Bill & Melinda Gates Foundation, USAID, the Philippine Department of Agriculture, HarvestPlus, the European Commission, Swiss Federal Funding and the Syngenta Foundation. Several companies have provided free access to their patented technologies necessary to generate Golden Rice.

Golden Rice grains are easily recognisable by their yellow to orange colour. The stronger the colour, the more beta-carotene.

6

CAN GM CROPS BE GROWN ALONGSIDE NON-GM CROPS?

There is nothing unique about GM crops that makes them any more difficult to manage than their conventional equivalents.

Globally, the grains industry manages the segregation of different crops very effectively; for instance keeping malting barley separate from feed barley, or durum wheat separate from other varieties.

The Australian Department of Agriculture has recognised that maintaining product integrity — that is, keeping grain commodities separate from others the full length of the supply chain — has to be a priority so that all customers can be satisfied they are getting the product they have paid for.

There are many levels of regulation to ensure that farmers do what is required to stop GM and non-GM crops from mixing. These include industry protocols, contracts with the companies providing the seed, and state government policies and guidelines. On-farm management practices include the maintenance of buffer zones to maintain the integrity of both GM and non-GM crops.

When GM canola was released commercially in Australia, an additional category was introduced under national trading standards. Producers have the option to sell their crops under the CSO-1 standard with up to 100 per cent GM, or under the CSO-1A (non-GM) standard, which allows for up to 0.9 per cent unintended presence of genetically modified material.

7

COMMON QUESTIONS ABOUT AG BIOTECH

No other foodstuff has been so thoroughly investigated as GM. No scientist will ever say something is 100 per cent safe but I am 99.99 per cent certain from the scientific evidence that there are no health issues with food produced from GM crops. Just about every scientist I know supports this view.

Professor Anne Glover
former Chief Scientific Adviser to European Commission President Jose Manuel Barroso[39]

Q: DO FARMERS HAVE TO BUY NEW SEED EVERY YEAR?

All GM plants commercialised so far are as fertile as their conventional counterparts.

The requirement to buy seed each year can arise from biological and/or contractual reasons.

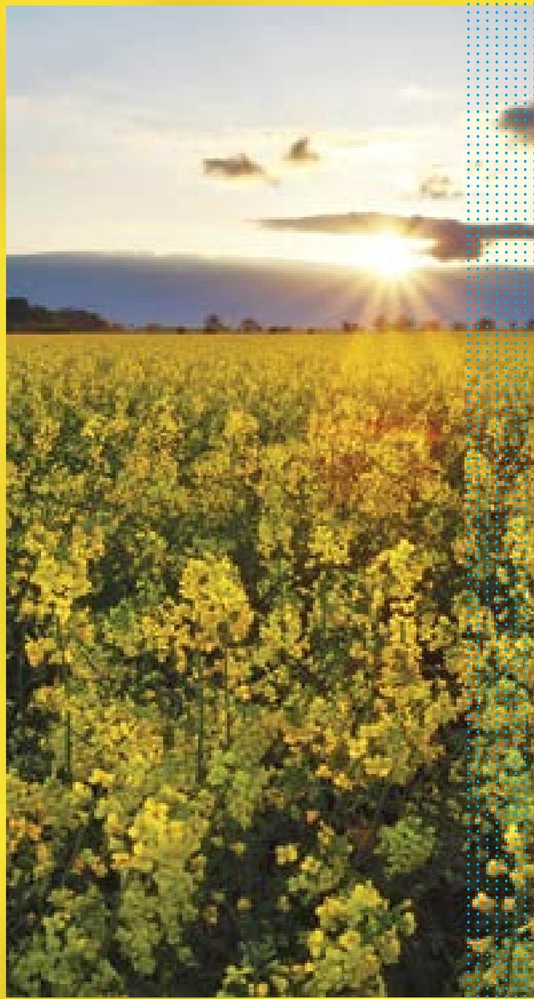
From a biological perspective, hybrid varieties of crops — which can be produced through both conventional breeding and GM methods and are permitted in organic agriculture — have been used by farmers for many years and are a normal part of modern farming systems. However, first generation hybrids do not breed true to type, meaning that the seed they set may not grow into crops that are identical to the parents. This can result in variations in yield and quality; therefore many farmers prefer to buy new seed each year in order to maintain the improved yields and crop vigour offered by the pure hybrid varieties.

While some companies provide free access to their technology, particularly for humanitarian use in developing countries, as with the Golden Rice project, most operate on a commercial basis.

In most countries, growers who choose to grow GM crops enter into an agreement with the technology providers to buy new seed each year. As well as the agronomic advantages this provides, these contracts are vital for funding on-going research and development. It takes around 13 years and costs US $136 million to bring a new GM crop to market, most of which goes towards gathering the data required by the regulatory system. This scale of private investment would simply not occur without the opportunity for commercial return provided by these contracts with growers.

Farmers would also be reluctant to enter into these contracts unless the technology was providing proven long term benefits. There has been continued and rapid growth in the adoption of GM crops around the world, with the latest figures showing 18 million farmers were growing them in 2014. The economic benefits for 2013 are estimated at US $16.1 billion and just over half of those gains went to farmers in developing countries.[40]

Q: IS FOOD WITH GENETICALLY MODIFIED INGREDIENTS DIFFERENT TO OTHER FOODS?



GM food crops are just as 'natural' as conventional crops. The only way to breed new varieties of crops is to modify genes in some way or another, whether through selective breeding or modern technologies such as genetic modification.[41]

In many cases, processes using genetic modification are simply speeding up what could be done through conventional methods. This is because genetic modification is much quicker and more targeted than traditional breeding — it involves the precise introduction of a single gene, or even taking a certain gene that's already present and turning the 'volume' up or down or turning it 'on' or' off'.[42]

In fact, genetic modification is more precise than the use of conventional technologies such as gamma irradiation or chemical mutagenesis of seeds that are permitted in organic agriculture. These create a lot random mutations, but most have no practical applications in food and agriculture.

Q: WHAT ABOUT GM STOCKFEED?

GM crops are becoming an increasingly important source of feed for farm animals.

Studies into the meat, milk and eggs from animals fed GM crops have found they are as wholesome, safe and nutritious as products derived from animals fed conventional crops.

As animals digest the feed, genetically modified DNA and proteins are entirely broken down. This means the meat, milk and eggs from animals which have eaten GM feed do not contain any genetically modified DNA or proteins.

As a result, there are currently no requirements in any country to label products from animals that have eaten GM feed.[43]

Q: ARE GM CROPS A CURE-ALL FOR ACHIEVING GLOBAL FOOD AND NUTRITION SECURITY SUSTAINABLY?

GM crops are by no means the only solution to our global food and nutritional shortages and inequalities. However, they can make a significant contribution through their potential to improve the sustainable use of crop inputs such as water, energy and pesticides, while at the same time increasing yields, using less land, and boosting the nutritional content of staple crops.

For instance, the ISAAA estimates it would have taken an extra 132 million hectares of conventional crops to produce the same tonnage grown using GM crops since their introduction in 1996. This has effectively saved native habitat and forests from clearing for agriculture.[44]

GM crops have also reduced the global use of pesticides by around 500 million kilograms between 1996 and 2012.[45]

Farming systems have also changed because of GM crops. There are fewer spray runs and therefore less fuel used. Minimum till practices are also cutting fuel use and increasing soil quality. This has saved an estimated 6,268 million litres of fuel and associated greenhouse gas emissions between 1996 and 2011.[46]

In the next generation of GM research, scientists are tackling farming challenges such as drought and salinity, and adding micro nutrients to traditional sources of food, in order to help alleviate poverty, malnutrition, and the predicted challenges associated with climate change.

Q: WHO IS CARRYING OUT RESEARCH INVOLVING GM CROPS?

Of the trials currently approved by the OGTR in Australia, more than 60 per cent are being carried out by universities, research councils and public institutions such as the CSIRO. The rest are carried out by private industry.

Due to the cost and time involved in developing new GM crops, public-private partnerships are currently the most effective way to enable the benefits of public research to reach farmers and consumers. These often involve not-for-profit and independent organisations contributing to research programs.

The companies involved in GM crop development and their trial sites are publicly available at **www.ogtr.gov.au**

8 WHAT FARMERS SAY

BRUCE WATSON

BUSINESS OVERVIEW: Bruce is a fourth generation farmer, continuous cropping 3,500 hectares at *Woodbine* near Parkes in New South Wales using zero till and controlled traffic farming systems. His winter crops include wheat, barley, triticale, canola, chickpeas, lupins and faba beans. He's also introducing summer rotations with sorghum, corn and mung beans.

“I have strict processes in place, as I'm growing both GM and non-GM canola at the same time, and have never had any issues with segregation. We make it really clear to our contractors when they arrive and the machinery is cleaned down properly in between paddocks. Our silos also get cleaned thoroughly, but being fastidious is just good management anyway. GM plants that shoot up between crops are no harder to deal with than non-GM plants bred to be herbicide tolerant.

JOHN CAMERON

BUSINESS OVERVIEW: John and his wife Rosalen farm *Kintyre*, 800 hectares on Queensland's Darling Downs, approximately 60 kilometres west of Toowoomba. They grow predominately dryland cotton with some sorghum in summer and wheat in winter.

GM has given us the social licence to continue to produce cotton. In the early 1990s, we had to use up to 12 applications of insecticide on each crop. With the GM varieties we use today, we're down to maybe one or two and the natural environment is far healthier. I think we would have been driven out of business because of community concern about levels of insecticide use without GM.

JEMMA SADLER

BUSINESS OVERVIEW: Jemma runs *Danubin Farm* near Wongan Hills in Western Australia in partnership with her brother and father. They crop around 4,800 hectares with wheat, canola, barley and lupins, and run 3,000 ewes on 1,000 hectares.

We've been rapidly running out of options for weed control in WA, with wild radish and rye grass almost impossible to kill in-crop. Dry starts to the season are becoming more common, with no weeds germinating before seeding, so we often don't get to use glyphosate as a knockdown herbicide. With GM canola, we now have a viable break crop and one which allows us to spray weeds at the most effective time. However, it's important that we use this tool wisely, in rotation with other weed management strategies, to avoid the onset of glyphosate resistance.

9 GLOSSARY & LINKS

DEFINITIONS OF COMMON TERMS USED IN BIOTECHNOLOGY AND GENETIC MODIFICATION

TERM	MEANING
Agrobacterium	A soil microbe which infects a wide range of broad-leaved plants and transfers a number of its own genes into a host plant's genome. Due to its ability to transfer genes to plant cells, scientists replace the normally-transferred bacterial genes in Agrobacterium with a specific gene. The gene is then transported directly into the DNA of the plant cell. The Agrobacterium method is the most common method used to transfer genes.
Arabidopsis thaliana	The 'lab rat' of plants, this small, flowering plant is ideal for studying plant biology and genetics as it has a short life cycle, it is easy to transform and its genome is small and has been fully sequenced.
Biotechnology	The use of biological systems, or living organisms, to make or change products. Modern biotechnology (also referred to as gene technology) includes the discovery of genes (genomics), understanding gene functions and interactions (functional genomics), use of DNA markers and genetic modification.
Bacillus thuringiensis (also known as Bt)	A naturally occurring soil bacterium that produces proteins which are toxic to some insects and nematodes (roundworms). Bt genes have been inserted into some plants, for example cotton, to provide protection from insects.
Chromosomes	Organised structures of DNA and proteins found in cells.
DNA (deoxyribonucleic acid)	Nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms and some viruses. DNA is usually double stranded (double helix) with four nucleotides — Adenine, Thymine, Guanine and Cytosine.
DNA marker (also molecular or genetic marker)	A known DNA sequence located near a gene of interest. DNA markers are tools that help locate genes of interest in plants and animals.
DNA sequence	The order of all nucleotides in a stretch of DNA.
Epigenetics	The study of how proteins and other molecules that bind to DNA and chromosomes can change gene expression without changing the DNA sequence.
Functional genomics	The study of the biological function of genes and their products.
Gene expression	The process by which heritable information from a gene is made into a functional gene product, such as protein or RNA.
Gene technology	The modern application of biotechnology, including the discovery of genes (genomics), understanding gene functions and interactions (functional genomics), use of DNA markers and genetic modification.
Genes	A segment of DNA that carries the instructions for heritable traits.
Gene silencing	A method of 'turning down' or 'switching off' the activity of genes.
Genetic engineering	See 'genetic modification'.
Genetic modification (GM)	Altering the genes or DNA of an organism using modern biotechnology techniques. This includes controlling gene activity, modifying genes and transferring genes in order to investigate gene function. This can be used to generate GMOs or provide information that can be used to speed up conventional breeding.
Genetically modified organism (GMO)	An organism that has been altered by genetic modification.
Genome	The entire genetic makeup, or all the genes, of an organism.
Genomics	The study of genomes, including the discovery of genes and the genetic basis of gene expression.
Genotype	Genetic makeup of an individual organism.
Herbicide	A natural or synthetic chemical effective at killing plants. Widely used in agriculture (including organic, conventional and modern farming), horticulture and gardening to control unwanted plants, referred to as weeds.

LINKS TO MORE INFORMATION ON GM

ACADEMICS REVIEW
www.academicsreview.org

AGRICULTURAL BIOTECHNOLOGY COUNCIL OF AUSTRALIA (ABCA)
www.abca.com.au

AUSTRALIAN PESTICIDES AND VETERINARY MEDICINES AUTHORITY (APVMA)
www.apvma.gov.au

BIOLOGY FORTIFIED
www.biofortified.org/genera/studies-for-genera/

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO)
www.csiro.au/en/Research/Farming-food/Innovation-and-technology-for-the-future/Gene-technology

DEPARTMENT OF AGRICULTURE
www.daff.gov.au/agriculture-food/biotechnology

FOOD STANDARDS AUSTRALIA NEW ZEALAND (FSANZ) — GENETICALLY MODIFIED FOODS
www.foodstandards.gov.au/consumer/gmfood/Pages/default.aspx

GENETIC LITERACY PROJECT
www.geneticliteracyproject.org

OFFICE OF THE GENE TECHNOLOGY REGULATOR (OGTR)
www.ogtr.gov.au

PROFESSOR PARROTT
www.parrottlab.uga.edu/ProfParrott/Index.html

THERAPEUTIC GOODS ADMINISTRATION (TGA)
www.tga.gov.au/industry/pm-argpm-guidance-21.htm

DEFINITIONS OF COMMON TERMS USED IN BIOTECHNOLOGY AND GENETIC MODIFICATION

TERM	MEANING
Metagenomics	Research using DNA sequencing technologies to sample the structure and function of the genomes of organisms inhabiting a common environment.
Microbe	A microscopic organism such as a virus, bacterium, fungus or protozoan (single-celled organism).
Nucleotide	Chemical compound consisting of three portions: a nitrogenous base, a sugar, and one or more phosphate groups. Nucleotides are the structural units of DNA and RNA.
OGTR	Office of the Gene Technology Regulator. Established according to the Gene Technology Act 2000 and responsible for developing, implementing and monitoring Australia's gene technology regulatory framework.
Phenome	A set of phenotypic traits expressed by a cell, tissue, organ, organism or species, as a result of genetic and environmental influences.
Phenotype	Visible traits or characteristics of an organism.
Promoter	A DNA sequence that acts as a control switch at the beginning of a gene that tells the cell when and how much RNA to produce.
Proteins	Large organic compounds made of amino acids. They are essential parts of organisms and participate in every cellular process.
Recombinant DNA	Usually used to describe how a portion of DNA from one organism is modified to work in a different organism. In the genome, the protein coding region of genes is flanked by controlling sequences at the start and stop. These 'alert' the cell how to regulate the amount of protein to make. It also informs the cell which parts of its DNA are genes and which are not. These start and stop controls are species-specific so researchers can artificially combine a piece of any protein coding DNA with the start and stop controls from a particular gene of the organism to be transformed, thus producing a new product. Recombinant DNA techniques can also be used to reduce the activity of a gene by reversing the protein coding region in the DNA as in RNA interference.
RNA (ribonucleic acid)	RNA consists of a long chain of nucleotide units. RNA is similar to DNA, but differs in a few important structural details. In the cell, RNA is usually single stranded, while DNA is usually double stranded. RNA nucleotides contain the nucleic acid ribose while DNA contains deoxyribose (a type of ribose that lacks one oxygen atom) and RNA has the nucleotide Uracil rather than Thymine which is present in DNA.
RNA interference	This process moderates the activity of an organism's genes.
Single nucleotide polymorphisms (SNPs sometimes pronounced 'snips')	Differences in just one of the DNA base pairs in the genetic sequence which can affect the functioning of a gene. SNPs are one form of gene (DNA) marker.
Species	Living things of the same kind that are potentially able to breed together and produce fertile offspring, that is offspring that can also reproduce.
Transcription	Synthesis of RNA under the direction of DNA.
Transcriptome	A set of messenger RNA molecules or transcripts produced in some or all the cells of an organism.
Transformation	Inserting recombinant DNA into an organism's genome which results in a genetically modified organism.
Transgene	The gene that has been transferred into a new host leading to a genetically modified organism.
Transgenic	An organism containing one or more deliberately inserted genes from another species.

Source: CSIRO, www.csiro.au/Outcomes/Food-and-Agriculture/Biotechnology-glossary.aspx, and www.csiro.au/Organisation-Structure/Divisions/Plant-Industry/Gene-technology-information-kit.aspx, accessed 26/02/2014

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