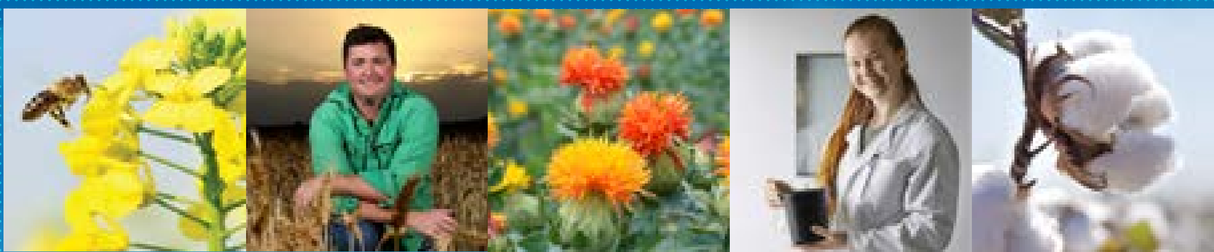
Agricultural Biotechnology Council of Australia

THE OFFICIAL AUSTRALIAN REFERENCE GUIDE TO

AGRICULTURAL BIOTECHNOLOGY AND GM CROPS



FOURTH 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 three founding members.

FOUNDING MEMBERS

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AUSTRALIA'S BIOTECHNOLOGY ORGANISATION

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- National Farmers' Federation
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Publication coordinated by CropLife Australia.

FOREWORD

MR KEN MATTHEWS AO
CHAIRMAN
AGRICULTURAL BIOTECHNOLOGY
COUNCIL OF AUSTRALIA

Few Australians may know that more than half of the Australian land mass is devoted to agriculture, that our Australian farmers produce up to 93 per cent of the food we eat, or that we are ranked as the sixth most food secure nation in the world. Australia's agricultural sector contributes three per cent to GDP and it is the largest employer in many rural and remote communities. It represents a significant part of our exports, with $49 billion of food products exported in 2017. Australian farmers are so efficient at producing food that two thirds of the people they feed live overseas, making our agricultural sector a world leader.

Innovation remains crucial for the growth and sustainability of Australia's agriculture and reflects our sustained investment in research and development. Our farmers' commitment to integrate science and technology in farming practices is securing the future of Australia's primary production. The industry relies on scientific advancements, ranging from plant sciences and genetics, to computer science and statistics, robotics and artificial intelligence. These new technologies not only help farmers achieve higher yields, they increase sustainability of farming practices, improve pest and disease management, and help protect the environment by using less land, energy and water.

With a rapidly growing world population, a changing climate and intensifying environmental concerns, agricultural biotechnology is increasingly recognised as a potential solution to some of the world's largest challenges. While public discussion and debate on biotechnology should be based on clear, accessible information, unfortunately it can be easily hijacked by fearmongers. It is vital for our future that decisions on agricultural biotechnology are built on credible, science-based information.

The fourth edition of the popular Official Australian Reference Guide to Agricultural Biotechnology and GM Crops provides objective information about genetically modified (GM) crops based on scientific evidence. On behalf of the Agricultural Biotechnology Council of Australia, I commend this information to all those looking for factual, evidence-based answers to the questions we all have about the science of genetic modification in plants.

AGRICULTURAL BIOTECHNOLOGY COUNCIL OF AUSTRALIA EXPERT SCIENTIFIC PANEL

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

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CONTENTS

A researcher from the Australian National University looks after transgenic plants in a growing cabinet.

1 WHAT IS CONVENTIONAL PLANT BREEDING?

'Conventional' is a term used for a wide range of breeding techniques that involve changing the genetic makeup of a plant to produce a new variety with improved characteristics.

A new variety can be conventionally bred by 'sexually crossing' two selected plants, with the aim to combine desirable traits from both parents. As both positive and negative traits can be inherited, plant breeders need to carefully evaluate the plants produced and only select the ones with the most promising traits.

These selected plants are then crossed back to one of the original parents. This is called 'backcrossing' and is an effective method to eliminate any negative traits inherited from the first cross. Backcrossing is a long process, taking place over several generations. This means it usually take years until the new variety has all the desirable traits from its parents and none of their negative ones.

Conventional breeding also includes techniques that introduce mutations in plant genomes in the hope of producing new varieties with desirable or innovative variations. Chemicals and irradiation are commonly used in conventional breeding programs to introduce random mutations in plant DNA. This process is referred to as mutagenesis.

Did you know?

Once upon a time, bananas were filled with large seeds, making them very hard to eat.

Over 4,000 years ago, exchanges between human tribes led to the production of natural banana hybrids with few or even no seeds but delicious flesh. That was the first step towards bananas as we now know them![1]

Small, seeded bananas are still found wild all over Papua New Guinea.

"As long as there is malnutrition in the world, there is a place for biotech. As long as there are farmers who cannot progress past subsistence, there is a place for biotech. As long as there are crop failures, there is a place for biotech."

Professor Wayne Parrott, University of Georgia

Tissue culture is used to generate GM plants after transformation.

Did you know?

Bread, beer, wine, chocolate, coffee, most of the plant-derived products we eat and drink taste the way they do as a result of breeding and selection.

This selection and breeding process has not been limited to plants, yeasts have also been carefully selected and bred for food and beverage production for centuries.

It is believed that humans started shaping the genome of yeasts in the 16th century, selecting strains that produced desirable flavours and textures.[2]

Other conventional plant breeding techniques used include:

- **artificial pollination** — manually transferring pollen from one flower to another, to create seeds when natural pollination is not possible
- **male sterility** — using natural sterility factors to ensure a cross from one parent to the other
- **tissue culture** — growing plant tissue in controlled in vitro culture conditions to generate whole plants
- **grafts and cuttings** — producing clones from an original plant.

Modern molecular breeding techniques help breeders to identify plants that carry a particular trait of interest and follow this trait in the offspring. By identifying the most promising candidates, these tools allow breeders to make better, more informed choices. However, it still does take multiple generations to obtain a new variety.

While molecular breeding methods (such as those involving sequencing DNA) involve an understanding of genes and genomes, they are not considered to be genetic modification if they do not involve introducing foreign DNA into the genome.

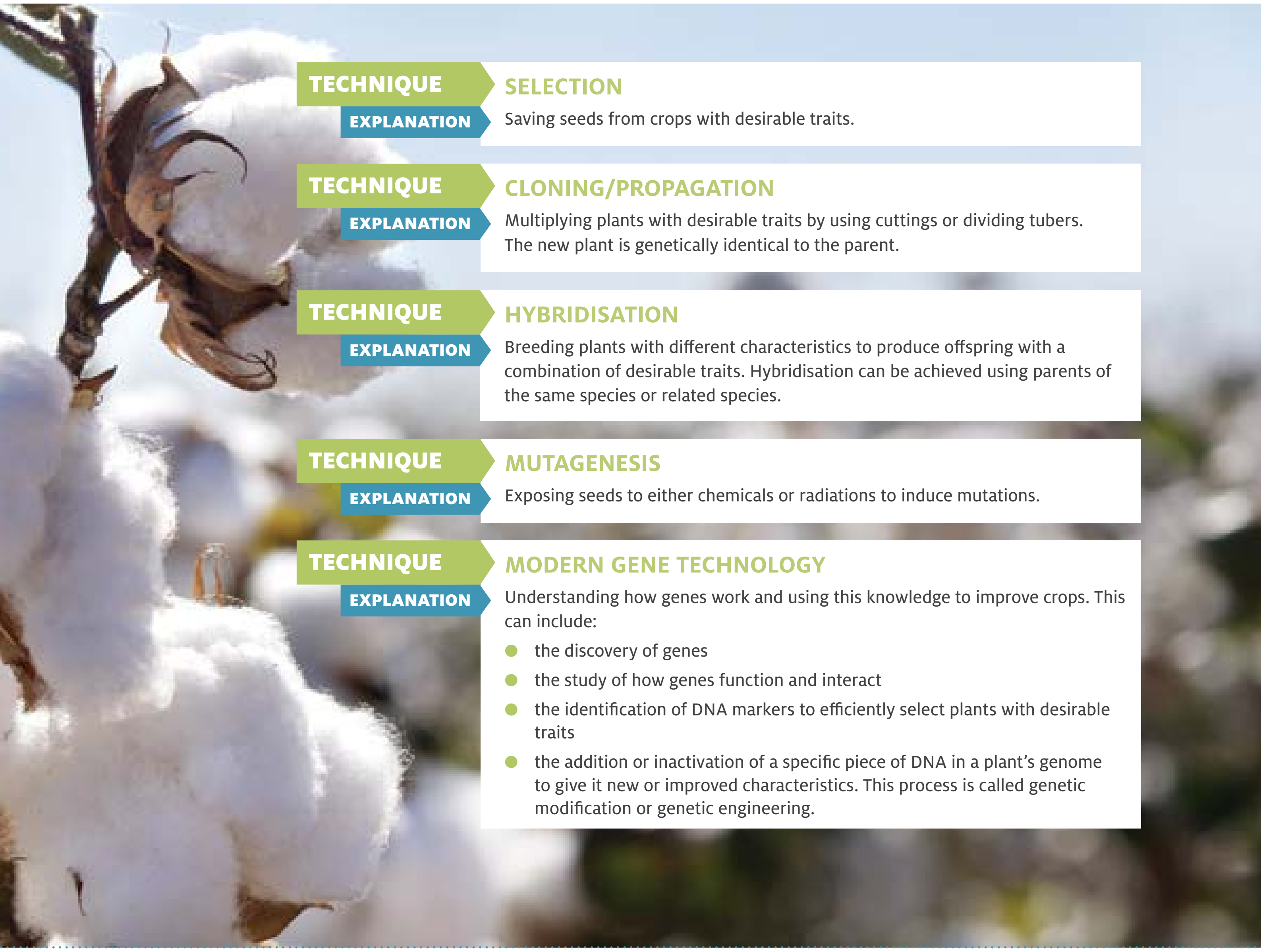
Plant breeding using conventional or modern techniques as well as genetic modification can be used to introduce desirable traits in crops. Depending on the plants and the traits, genetic modification or conventional breeding is the preferred approach.

2 WHAT IS AGRICULTURAL BIOTECHNOLOGY?

Biotechnology is a broad term describing the process of using living organisms or their components to produce goods and services.

Fermentation, such as the use of yeasts to brew beer or make bread, is a classic example of agricultural biotechnology. Agricultural biotechnology covers a wide range of disciplines and techniques, from plant grafting or plant cloning and plant propagating to molecular biology, gene technology or biochemistry.

Plant breeding and selection span thousands of years and has become increasingly sophisticated. We have used biotechnology for a very long time, with methods such as grafting or cloning. Recent advances in biotechnology have provided ways of introducing very precise changes to the genome of an organism. These new techniques, referred to as 'gene technology', have revolutionised research and have proved to be great tools for breeders.



TECHNIQUE: SELECTION
EXPLANATION: Saving seeds from crops with desirable traits.

TECHNIQUE: CLONING/PROPAGATION
EXPLANATION: Multiplying plants with desirable traits by using cuttings or dividing tubers. The new plant is genetically identical to the parent.

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

TECHNIQUE: MUTAGENESIS
EXPLANATION: Exposing seeds to either chemicals or radiations to induce mutations.

TECHNIQUE: MODERN GENE TECHNOLOGY
EXPLANATION: Understanding how genes work and using this knowledge to improve crops. This can include:

- the discovery of genes
- the study of how genes function and interact
- the identification of DNA markers to efficiently select plants with desirable traits
- the addition or inactivation of a specific piece of DNA in a plant's genome to give it new or improved characteristics. This process is called genetic modification or genetic engineering.

3 WHEN IS BREEDING CONSIDERED GENETIC MODIFICATION?

Breeding is considered to involve genetic modification (GM) when new DNA is transferred into cells and inserted in the genome of a plant using high precision techniques.

Genetic modification can add new genes to a plant's genome but can also turn the 'volume' of existing genes up/down or switch existing genes on/off. These subtle changes can provide significant agronomic, environmental or human health benefits without disturbing the rest of the genome and avoiding lengthy breeding processes to eliminate negative traits.

Gene technology is more targeted and faster than conventional breeding methods. It allows the transfer of only a small number of genes without mixing together the genomes of two parent plants. One prerequisite for gene technology to be used for crop improvement is that the genes conferring the trait of interest must have already been identified.

There is a long and productive history of using genetic modification for developing medical products and food processing aids.

Did you know?

Insulin is used to treat diabetes and its complications.

Historically, insulin was extracted from cattle and pigs. However, supply was limited and some adverse reactions were reported. GM insulin was approved in 1982 as the world's first GM drug product.[3]

Nowadays, most insulin is produced using microorganisms that have been genetically modified to carry the human gene for insulin.

Insulin can now be produced in very large amounts in fermenters, is less likely to trigger an adverse reaction and overcomes ethical concerns from vegetarians and religious groups.

Over 99.5% of the cotton grown in Australia is GM.

4 WHAT ARE NEW BREEDING TECHNOLOGIES?

The fundamental practices of plant breeders have not changed, they are based on the same principles that have been used for thousands of years: planting seeds, observing the characteristics of the plants produced and selecting for the most desirable or promising traits.

Breeding techniques, however, have changed drastically in recent times. New breeding technologies have been developed using recent scientific advancements.

From plant sciences and genetics to computer science, statistics, robotics or artificial intelligence, the toolkit that is now available to plant breeders represents one of the most compelling examples of the impact of science in the modern world.[4]

Genetic modification and gene-editing have delivered major advances in plant breeding.

Scientists and breeders can now make highly specific changes in existing genes, enabling plants to survive and thrive in changing climates, and develop tolerance or resistance to pests and diseases.

Did you know?

Genetic modification came to the rescue of a collapsing Hawaiian papaya industry.

In the 1990s, the Papaya Ringspot Virus, almost destroyed all Hawaiian plantations, after an uncontrollable spread of the disease.[5]

There are no known papaya varieties with natural resistance to the virus, but resistant varieties were produced by adding a gene to the papaya from the virus itself. Papaya was the first fruit crop to be genetically modified and commercialised.

Today, roughly 80 per cent of Hawaiian papaya farmers grow GM papaya.

5 WHAT IS GENE-EDITING AND HOW DOES IT WORK?

Gene-editing refers to a collection of molecular techniques that make precise, intentional, efficient and targeted changes in the DNA of plants and animals.[6] Mutations are a key element of improving plant varieties. Conventional breeding uses chemicals or irradiation to produce mutants. Breeders then characterise these mutants and select the ones with the most positive traits. However, the selection process is long, intensive and costly as the induced mutations are random and non-specific.

Over the last decade, scientists have developed proteins that can specifically recognise and target precise DNA sequences, paving the way for targeted gene-editing. These proteins, called site-directed nucleases (SDN), cut DNA in pre-defined locations like molecular scissors.[6] This in turn triggers the cell's DNA repair system. As the DNA repair system is prone to making 'mistakes', this can lead to the production of mutants. The change induced by the cell's repair system can be a small deletion, a change in a few letters of the cell's DNA code or the addition of a piece of DNA.

SDN applications are divided in three categories.[7] SDN-1 is based on a spontaneous repair of the DNA cut, leading to a small deletion or change in a few letters of the DNA code. For SDN-2 and SDN-3, a DNA repair template is provided to guide the cell's repair system. The difference between SDN-2 and SDN-3 is based on the type and size of the template.

Unlike chemical/radiation induced mutations that are random, SDN-induced changes with interesting traits can easily be identified as their target is known.[7]

CRISPR/Cas9 is the most commonly used SDN method for gene-editing. CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats and Cas9 for the CRISPR-associated protein 9. CRISPR-associated protein 9 enables researchers and plant breeders to turn genes on or off, to fix 'mistakes' or to precisely insert new DNA into a plant.

Gene-editing is considered a valuable addition to classic plant breeding and genetic modification methods to improve crop plants and ensure sustainable food production.[6,8]

OFF TARGET?

SDN such as CRISPR/Cas9 can potentially cut DNA, not at the pre-defined target but at a location that is an imperfect match, leading to off-target mutations. This can be a major concern when these techniques are used in the medical field, for example in gene therapy. Very little off-target activity has been detected in plants. Potential unwanted mutations can be eliminated through breeding. Just like for conventional breeding using chemicals or irradiation, the selection process naturally discards traits that have a negative impact on the crop.[7] Detecting what molecular changes have been made by gene-editing has been made more efficient by the development of rapid, low-cost methods for whole-genome sequencing.

REGULATIONS

There is currently no internationally consistent regulatory framework for gene-editing. The US Department of Agriculture (USDA) has ruled that gene-edited crops are exempt from regulation, while the European Court of Justice has decided that gene-edited products should be regulated in the same way as GM crops. Australia recently reviewed its regulations and decided that it would not regulate gene-edited crops if these crops had been produced without a DNA repair guide (SDN-1). Crops produced using a DNA repair guide (SDN-2 and SDN-3) are still regulated as GM crops.

A researcher from the Australian National University inspects genetically modified plants in a growing facility.

We need to continue the discussion and share with the general public, especially the youth, the real nature of biotech products. Scientists have to speak out because, if not, who else will?"

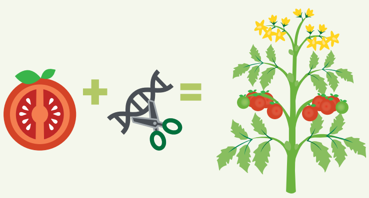
Dr Inez Slamet-Loedin, International Rice Research Institute (IRRI)

EXAMPLES OF USE

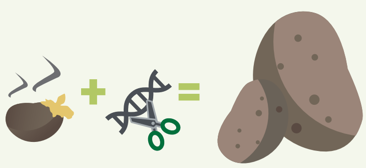
Gene-editing has been used in tomato, potato, maize, rice, citrus and wheat, among other crops.

GENE EDITING EXAMPLES

Gene editing has improved the flower production and early yield in tomato plants.



Gene editing has helped develop potatoes that keep for longer.



CASE STUDY: **GENE-EDITED SORGHUM**

Sorghum is the fifth most important cereal crop worldwide (after rice, wheat, maize and barley) and is a staple food for more than 500 million people. Grains can be used for human food or animal feed and vegetative material can be used as fodder or for bioethanol production.

Proteins in the sorghum grain are not easily digested by humans or animals, making sorghum less valuable than wheat or maize. Researchers from the University of Queensland have produced new sorghum lines, targeting seed storage proteins that are known for their role in the digestibility of the grain. These new GM lines of sorghum have larger grains with increased protein content. They are being grown and tested in the field under an Office of the Gene Technology Regulator (OGTR) licence and should provide end users, such as poultry and pig producers, with increased yields and more desirable grains.

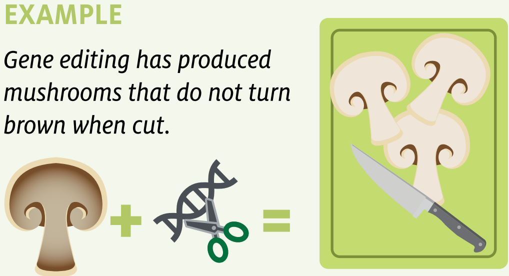
The review of the Gene Technology Regulations (2016–2019) led to SDN-1 being excluded from the scope of regulation. This means that new sorghum lines produced by the researchers using SDN-1 mediated gene-editing can be sown in the field for trials in the same way as plants produced via conventional breeding. This demonstrates the importance of having a sound, science-based regulatory system that keeps up-to-date with the latest scientific progress.

HOW CROPS ARE GENETICALLY MODIFIED

TYPE OF MODIFICATION	METHOD	RESULT	CROP TYPE	NO. GENES AFFECTED	TESTING + REGULATION
CONVENTIONAL BREEDING	Crossing plants and selecting offspring	Desired gene(s) inserted with other genetic material	ALMOST ALL CROPS	FEW GENES TO WHOLE GENOMES	No safety testing required UNREGULATED
MUTAGENESIS	Exposing seeds to chemicals or radiation	Random changes in genome, usually unpredictable		HUNDREDS TO THOUSANDS	No safety testing required UNREGULATED
RNA INTERFERENCE	Switching off selected genes using small RNA molecules	Targeted gene(s) switched off or 'silenced'		ONE TO DOZENS	Safety testing required HIGHLY REGULATED
TRANSGENICS	Inserting selected genes using recombinant DNA methods	Only gene(s) inserted at desired locations		ONE TO EIGHT	Safety testing required HIGHLY REGULATED
GENE EDITING	Modifying or switching genes on/off (CRISPR, TALENs, ZFNs, etc.)	Desired gene(s) modified or switched on/off only at known locations		ONE OR MORE	Safety testing required depending on jurisdiction CURRENTLY OVER-REGULATED

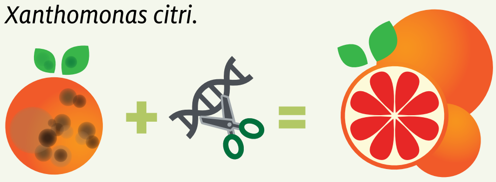
EXAMPLE

Gene editing has produced mushrooms that do not turn brown when cut.



EXAMPLE

Gene editing in citrus plants has increased resistance to citrus canker caused by Xanthomonas citri.



Undesirable, unintended effects rarely occur in the final product of any crop, regardless of which process is used.

Adapted from the Genetic Literacy Project infographic 'How crops are genetically modified' by Kayleen Schreiber, PhD + advisor Wayne Parrott, PhD.

6 WHY DO WE NEED AGRICULTURAL BIOTECHNOLOGY?

By 2050, the global population will have increased from its current 7.6 billion to 9.7 billion.[9] The Food and Agriculture Organization of the United Nations estimates that food production will need to double to feed the world.

Clearing new land for crop production is not a viable option. We instead need to protect the environment by using less land, less water and less energy. Making use of modern biotechnology, including GM, is a way to reduce pressure on agricultural resources. Gene technology can help in improving food quality and increasing the productivity of current crops. Gene technology can diminish the impact of environmental stresses, such as drought or salinity and resistance to pests and diseases.

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

“I believe in science, in the social responsibility of scientists, and in the use of progress in science for humanity. It has been established beyond any reasonable doubt that plant biotechnology does not carry any technology-inherent risk. It is a fact that the technology has the safest track record compared with any other technology in history. There is not a single documented case of harm since its use … It is immoral to prevent its use for public good. And it is criminal to prevent it from contributing to food and nutrition security.”

Professor Ingo Potrykus,
co-inventor of Golden Rice

CASE STUDY: GOLDEN RICE

Genetic modification can be used to enhance the nutritional value of crops for human food or animal feed. A well-known example of this is the Golden Rice Project, making rice a rich source of pro-vitamin A. According to the World Health Organization, vitamin A deficiency causes up to half a million children to go blind every year.[10] Vitamin A deficiency also increases the risk of disease and death from severe infections. The aim of the Golden Rice Project is to make sure people living in rice-dependent societies get a full complement of pro-vitamin A (also known as β-carotene) from their traditional diets.

Rice produces β-carotene in the leaves but not in the grain. All genes required are present in the rice genome but some of them are switched off during the development of the seed. Two genes were inserted into the Golden Rice genome by genetic modification to restart the carotenoid biosynthetic pathway in the grain, leading to the production of rice grains that synthetise and accumulate β-carotene.

The Golden Rice Project 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, the European Commission, Swiss Federal Funding and the Syngenta Foundation. Several companies provided free access to their patented technologies necessary to generate Golden Rice.

Hidden hunger (also known as micronutrient malnutrition) is a serious public health issue affecting billions of people globally. GM crops such as Golden Rice can help reduce the impact of hidden hunger in vulnerable populations.

Researchers from the University of Melbourne are running field trials for biofortified wheat. (Photo credit: University of Melbourne)

7 HAVE GM CROPS ACTUALLY DELIVERED BENEFITS?

Since the introduction of genetically modified crops in 1996, they have made a significant contribution to food security and sustainability. GM crops have helped reduce the impact of climate change. The use of GM crops has helped reduce herbicide, pesticide and fertiliser use. In turn, this has led to more sustainable practices such as no-till production systems, which limits soil erosion. Greenhouse gas emissions from cropping have decreased and higher yields have limited the need for conversion of forests into croplands.[11]

A meta-analysis of 147 studies showed that since 1996, GM crops have reduced pesticide use by 37 per cent, increased crop yields by 22 per cent and increased farmer profits by 68 per cent.[11,12]

GM crops worldwide have:

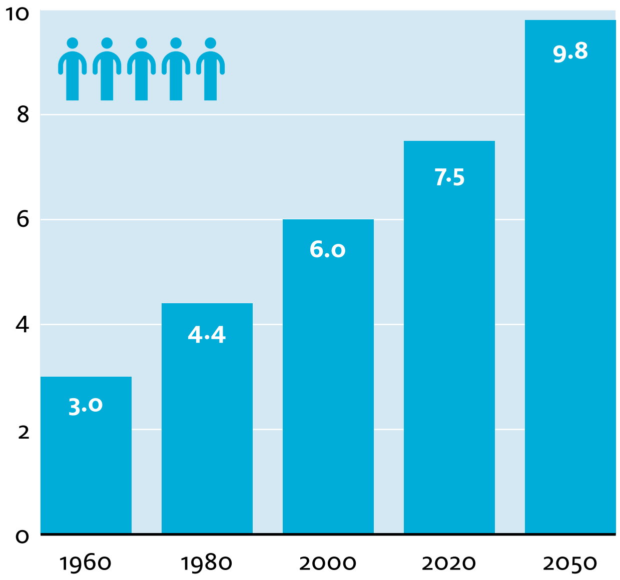
- increased farm income gains by US $186 billion
- reduced pesticide usage by around 775.4 million kilograms[13]
- saved 183 million hectares of land from clearing, thanks to increased productivity
- saved 27 billion kilograms of CO_2, which is the equivalent of taking 87 per cent of the passenger cars registered in Australia off the road for an entire year
- helped to alleviate poverty by increasing the incomes of 18 million smallholder farmers and their families, totalling over 65 million people.[13]

Globally, GM technology directly increased farm income by US $18.2 billion in 2016, with more than half of the gains going to farmers in developing countries.[13]

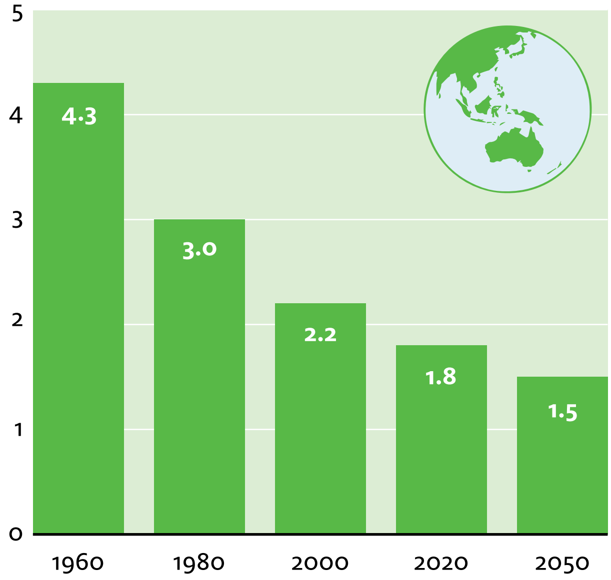
In Australia, the farm income benefits from GM cotton and canola between 1996 and 2015 are estimated to have been US $1.025 million.[15] These calculations take into account impact on yield and quality, and the cost of technology such as payments for seed.

MORE FOOD MUST BE PRODUCED ON LESS ARABLE LAND PER PERSON (FAO 2019)

GLOBAL POPULATION (BILLIONS)



ARABLE LAND (HECTARES) PER CAPITA



8 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 it has not been assessed to determine how different it is to foods that are already consumed.

GM crops 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. This ensures that new GM crop varieties are at least as safe to grow and eat as traditional varieties and new non-GM varieties, which are not tested in this way.

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. The World Health Organization, the Australian Academy of Science, the European Commission, the American National Academy of Sciences, the Royal Society of Medicine are amongst those to have assessed GM crops as safe.

Did you know?

Plant cells contain about 30,000 to 35,000 genes. Most GM crops will only contain an additional one to 10 genes in their cells. In fact, harmless bacteria and fungi present on the surface of plants carry hundreds of thousands of 'foreign' genes.

A researcher from the Australian National University performs a DNA extraction on plant samples.

9 WHAT ABOUT UNFORESEEN CONSEQUENCES?

There is no evidence that producing a new GM variety is more likely to have unforeseen consequences than producing a new variety using conventional breeding techniques.

Concerns have been expressed that the simple act of inserting new DNA into a plant genome could have unpredictable consequences. However, as scientific knowledge has increased, it has become evident that similar DNA re-arrangements happen frequently in plants. For example, some bacteria or viruses can insert new genes into the genome of the plants they infect.

Some plant genes can also 'jump' around the genome, moving from one location to another. Studying the genome of closely related plant species has shown that duplication, gain or loss of genes are very common.

Because of these natural processes, all varieties, old and new, GM or not, can include genes inserted in unknown parts of the genome. This means that there can be occasional unforeseen effects. These will be exceedingly rare and will occur in both GM and non-GM varieties.

Did you know?

In 1717, Thomas Fairchild produced the first artificial hybrid flower by crossing a sweet William and a carnation.

This was regarded by some as highly unnatural at the time and led to much uproar. Hybrids are now grown and sought after all over the world.

GM canola has been grown commercially in Australia since 2008. Over half a million hectare of GM canola was planted in 2018, or 30 per cent of total canola plantings.

10 HOW ARE GM CROPS AND PRODUCTS REGULATED IN AUSTRALIA?

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.

Federal legislation on gene technology protects the health and safety of people and the environment by identifying risks posed by or as a result of gene technology. The legislation details how those risks can be managed through regulating certain dealings with GMOs.

The Act defines a GMO as 'an organism that has been modified by gene technology or that has inherited traits that occurred because of 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 would be considered a GM product.

The Act also defines what is not a GMO. Plants produced as a result of conventional breeding techniques, such as mutagenesis, do not have to undergo the same rigorous testing as GM crops. A recent review of the Gene Technology Regulations concluded that organisms produced using gene-editing with no DNA template to guide the repair process (this is known as SDN-1) are not GMOs either. This decision was based on the fact that changes brought about through SDN-1 are no different to natural mutations and organisms produced using SDN-1 do not pose any different risks to natural mutants.

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

The Act does not, however, take into account trade or marketing considerations, which are at the discretion of the states and territories.

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 (TGA) 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 and 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 (ogtr.gov.au) contains a complete list of approvals from the other relevant regulatory organisations. This helps provide the community with easy access to information about GMOs and genetically modified products currently researched or used in Australia.

CURRENT POSITION OF EACH STATE AND TERRITORY ON GM CROPS

- No moratorium in place
- Moratorium in place — commercial cultivation possible
- Moratorium in place

WESTERN AUSTRALIA

- *Gene Technology Act 2006*
  - No GM crop moratorium
  - Large-scale commercial cultivation of GM canola

NORTHERN TERRITORY

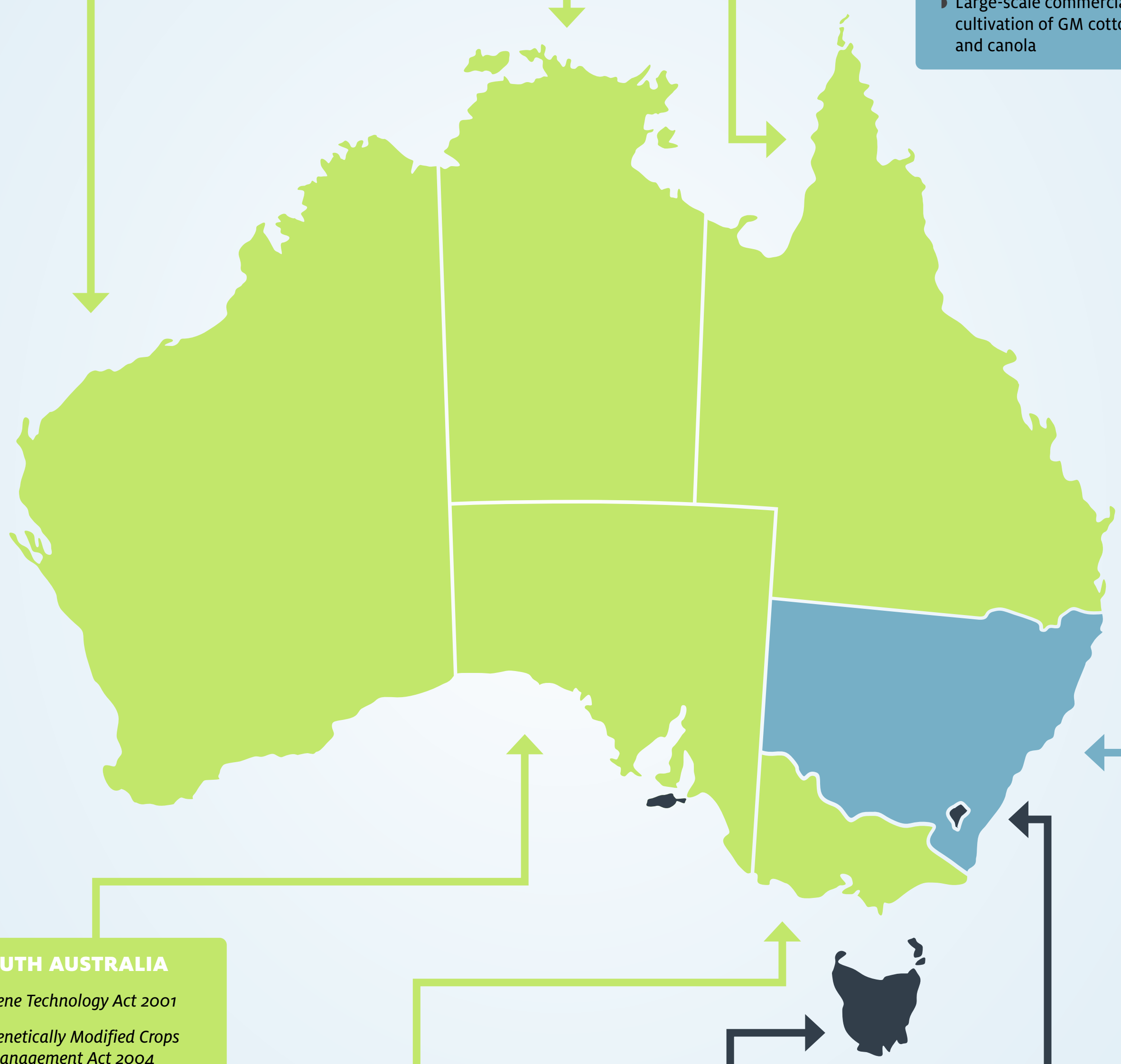
- *Gene Technology Act 2004*
  - No GM crop moratorium
  - No commercial cultivation of GM crops

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 and canola exempt from moratorium
  - Large-scale commercial cultivation of GM cotton and canola



SOUTH AUSTRALIA

- *Gene Technology Act 2001*
- *Genetically Modified Crops Management Act 2004*
  - Moratorium lifted on mainland South Australia in May 2020
  - Moratorium remains on Kangaroo Island
  - Local councils can apply until 30 September 2020 to become GM cultivation-free, for trade/marketing reasons
  - Exemptions granted for field trials under specific conditions in GM-free areas

VICTORIA

- *Gene Technology Act 2001*
- *Control of GM Crops Act 2004*
  - No current orders in place
  - Large-scale commercial cultivation of GM canola

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

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

ASSESSMENT OF GM CROPS AND FOODS

In Australia, the OGTR, FSANZ and the APVMA are the three main bodies responsible for the assessment, licensing and approvals of GM crops and food derived from them.

The OGTR carries out analysis to identify and manage any risks posed by new GM crops before allowing field trials, or before seeds can be commercially produced and sold to farmers. Risk analysis is conducted by comparing the risk of harm from a specific GM organism against the risk of harm from the parent (non-GM) organism. This ensures that any new GM crops that are approved for release are safe for the environment and human health.

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

- understanding whether a new characteristic of a GM crop may cause harm — 'what may go wrong and how serious might it be?'
- developing a case-by-case management plan to protect the people and the environment — 'What actions may be needed? What are the consequences of these actions and how can they be monitored?'
- seeking input and feedback from experts and the public on technical and ethical issues.

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

FSANZ has a rigorous and transparent process for assessing the safety of modified foods, based on internationally established scientific principles and guidelines. New products are assessed on a case-by-case basis as the questions to be addressed can vary depending 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. Any differences are 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.

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)

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

LABELLING

All approved GM foods available in Australia have been rigorously assessed and found to be safe by the Australian regulators. Therefore, labelling of genetically modified food has nothing to do with the health or safety of the food. Instead, it 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. 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 requirements. For example, the following products do not need to be labelled as containing GM:

- highly refined foods (such as sugars and vegetable oils) where all genetic material (DNA and proteins) 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 in restaurants 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 product has negligible levels of genetically modified DNA or proteins. In that case, as happens for highly refined oils or sugars, food derived from the GM source is identical at a molecular level to its non-GM counterpart.

STATE REGULATION

Economic and social considerations, such as risks to trade and markets, 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.

Since then, New South Wales, Victoria and Western Australia have allowed the commercial cultivation of GM crops.

11 COMMERCIALISED CROPS

GM cotton has been grown commercially in Australia since 1996, and now accounts for more than 99.5 per cent of production. Growing GM cotton that is either insect resistant, herbicide tolerant or a combination of both has reduced pesticide use by around 93 per cent when compared to previously grown varieties.[16]

GM herbicide-tolerant canola has been grown commercially in New South Wales and Victoria since 2008 and in Western Australia since 2010. It's estimated that more than half a million hectares of GM canola was planted in 2018, representing 30 per cent of total canola plantings.

GM safflower with high levels of oleic acid in the seed has been commercially available since mid-2018. The GM seeds are intended for use in industry, as a replacement for petroleum-based ingredients in the manufacture of plastics or lubricants.

GM carnations with colours ranging from blue-purple to light violet are commercially available in Australia. The Australian carnation industry produces flowers at a value of AUD$280 million annually across New South Wales, Victoria, South Australia and Western Australia. GM carnations were listed on the OGTR's GMO Register in 2007. This means they can now be sold as plants to home gardeners. There are no conditions imposed on the cut flower industry in terms of containment, inspections or other regulatory processes previously required. So far, GM carnations are the only organism to have been listed on the register.

Did you know?

A new GM canola, modified to produce high levels of long-chain omega-3 oils, like those found in fish oil, was approved for commercial release in 2018.[17]

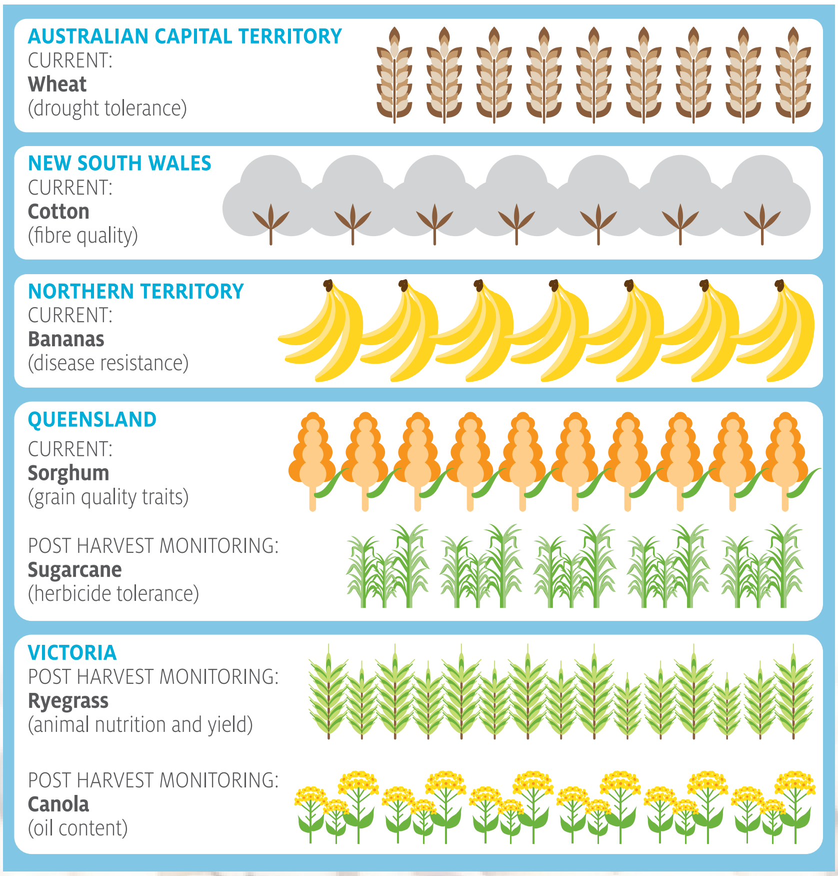
As humans do not synthetise these oils, they need be obtained through diet, with fish oil currently the main source of intake. The long-chain omega-3 canola will relieve pressure on wild fish stocks and maintain an adequate supply of this important nutrient by using a land-based, sustainable source. One hectare of this GM canola has the potential to provide the same omega-3 yield as 10 tonnes of fish!

A new GM safflower with increased levels of oleic acid in the seed has recently been commercialised in Australia. Oil from the seeds can be used to replace petroleum-based ingredients for industry.

12 CROPS IN THE PIPELINE

Licences have been granted by the OGTR for field trails for GM food and pasture crops. A map of these field trials is available on the OGTR website. More than 70 per cent of field trials currently approved by the OGTR are carried out by universities, public institutions such as CSIRO or state government agriculture research agencies.[18]

After harvest and cleaning, inspections must be performed regularly to remove any potential GM plant that could grow. This is called ‘post-harvest monitoring’. Field trial areas where GM crops were grown are inspected for at least one year. Post-harvest monitoring is considered complete once no GM plant has been detected for at least six months.



CASE STUDY: **BT COWPEA**

Australian researchers are helping smallholder farmers fight against devastating pests, thanks to GM technology.[19]

Cowpea is a staple crop for at least 200 million people in West Africa, including some of the world’s poorest people.[20] The crop is highly susceptible to pod borer that can destroy up to 80 per cent of a farmer’s production.

Work led by Dr TJ Higgins, CSIRO, and supported by the Rockefeller Foundation and USAID, has produced a GM cowpea, using a gene from the bacterium *Bacillus thurigiensis* (Bt).[20] This GM crop synthetises a protein that causes the caterpillar to stop feeding. The Bt protein produced by the plant is basically the same as the one that is commonly used as a spray by organic farmers to control caterpillars in their fields. This protein is harmless to other insects and to humans, and is already deployed widely in GM corn and cotton.

The crop has been approved for release at no cost to farmers in Nigeria. Once enough seed is available (expected in 2020), the Bt cowpea could yield as much as 25 per cent more than other cowpea varieties. Such a yield increase could be the difference between insufficient and sufficient food for the families of smallholder farmers.

To safeguard the technology from insects developing resistance, management plans have been developed for farmers and best practices are promoted.

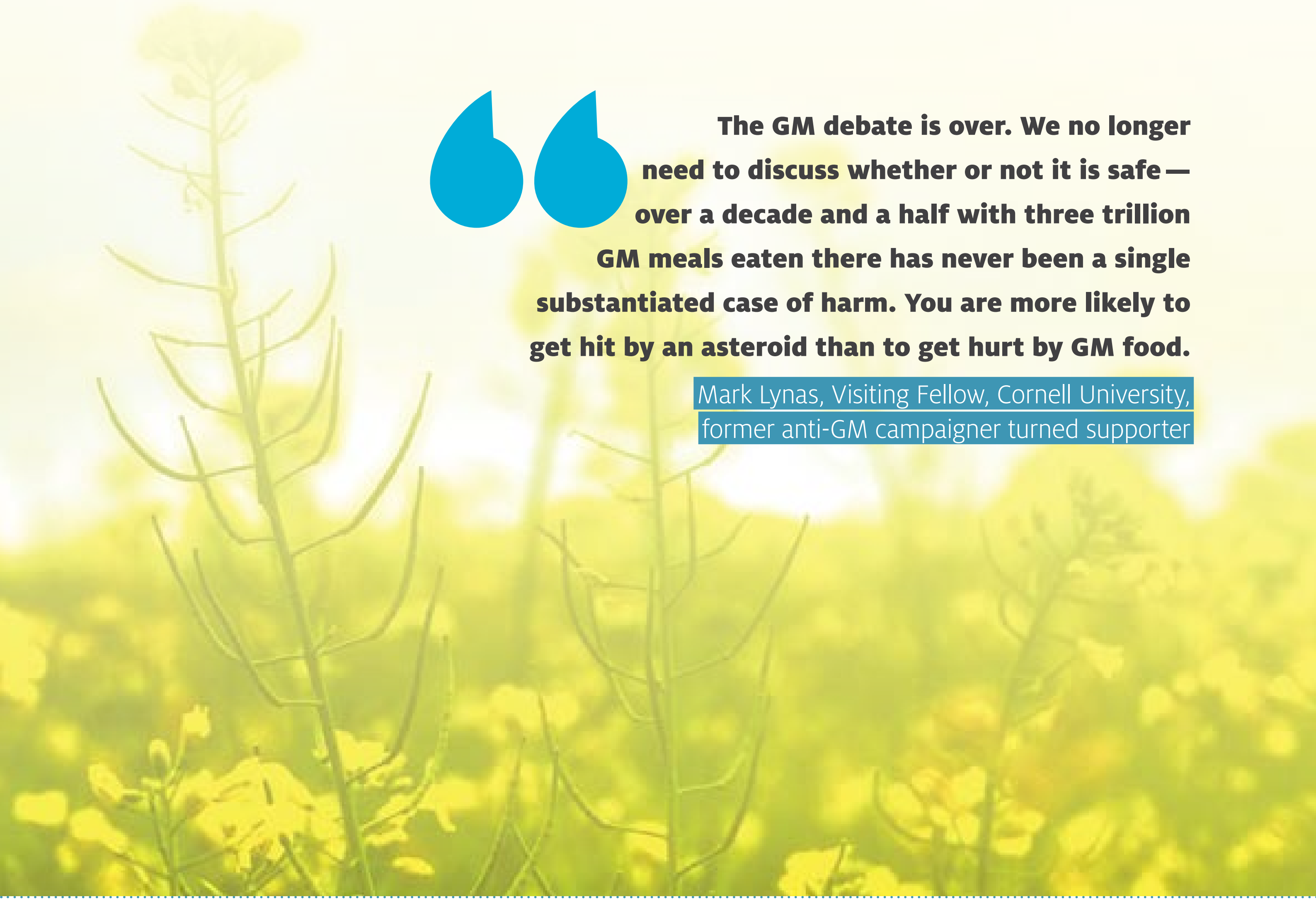
13 MARKETS

World trade in commodities such as soybean, corn, cottonseed and canola is dominated by the US, Canada, Brazil, Argentina and Bolivia, countries which have widely adopted genetically modified varieties.[14]

While some consumers may be concerned about food containing genetically modified ingredients, these concerns are not reflected in purchasing behaviour at the supermarket. Moreover, there are negligible trade barriers or price premiums for non-genetically modified products.

Even in the European Union, which has some of the strictest regulations regarding genetically modified imports and labelling, more than 50 genetically modified varieties of maize, soybean, canola, sugar beet and cotton are approved for use as food and feed.[14,22]

Identity preservation systems have been established to keep genetically modified, organic and conventional grains separate, from planting seeds to handling and processing. These systems, established by the grains industry, are based on years of experience segregating crops for different purposes.



> **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, Visiting Fellow, Cornell University, former anti-GM campaigner turned supporter

14 CONSUMER ATTITUDES

Local and international consumer surveys show that consumers around the world continue to eat food containing genetically modified ingredients.

A recent survey of 1,250 Australians found the majority were willing to eat food containing genetically modified ingredients. Respondents mentioned the importance of having regulations in place to ensure these GM products were safe. The survey showed that the overall levels of support for GM and gene technology have significantly increased between 2015 and 2019.[23]

Food choice is a complex domain, mixing a broad range of factors and values. Genetic modification plays only a minor role in food-based decisions.[24] In fact, the topic of GM crops in general is not top of mind for most people when compared to day-to-day concerns and priorities.[23]

When asked about GM, concerns voiced by consumers included the feeling that GM crops are somehow 'unnatural'[23] or a certain unease with modern farming methods.[24] Other consumers noted they lacked the information to judge whether GM crops are safe or the ability to influence decisions. However, consumers recognised the benefits of GM crops to meet a growing food demand, or to produce crops with improved traits, such as disease-resistance or enhanced nutritional profile.[23] Consumers highlighted the positive impact GM crops can have for farmers and for growing Australia's economy.[23]

Attitudes and responses to genetic modification vary depending on what it is used for, with less concern showed for medical or industry applications. Attitudes also depend on age. Younger people (16 to 30) are much more supportive of GM food than those aged 51 to 75.

15 GLOBAL ADOPTION

COMMERCIALISED CROPS

There is evidence that the GM crops grown around the world today have lowered farm-level production costs.[11,14] Other significant benefits include:

- higher crop yields
- increased farm profits
- improved soil health
- reduced CO_2 emissions from cropping.

GM plants approved for cultivation globally include alfalfa, apple, bean, canola, chicory, cotton, eggplant, eucalypt, maize, melon, papaya, plum, potato, rice, safflower, soybean, squash, sugar beet, sweet pepper and tomato.[14] Most have improved traits for herbicide tolerance, insect resistance or both. Some have been modified to resist devastating diseases, or to better tolerate stresses such as drought.

A record 191.7 million hectares of GM crops were grown globally in 2018, with an annual growth rate of one per cent. This global area of land grown with GM represents the equivalent of almost half of Australia's agricultural land. Crops with stacked traits (two or more, mainly herbicide tolerance and/or insect resistance) made up 80.5 million hectares, about 42 per cent of the GM crops grown.[14]

Since 1992, more than 4,100 regulatory approvals have been issued in 40 countries (Europe is counted as one country). Approximately half of these approvals have been for food use, and another third for feed use with the remaining approvals for planting or release into the environment.

Twenty-six countries grew GM crops in 2018. Another 44 non-planting countries from all continents have approved GM crop imports for food, feed and processing. Overall, 70 countries formally adopted 31 GM crops for food, feed and cultivation in 2018.

Did you know?

Up to 40 per cent of the apples grown are wasted in the US, due to unappealing bruising on perfectly edible fruits. A non-bruising GM variety, the Arctic™ Apple, using CSIRO technology, was approved for commercialisation in the US in 2018. This new variety could help mitigate a major source of food waste.

CASE STUDY: **BT EGGPLANT**

Eggplant is a staple crop in South Asia and an important source of income for many farmers. Up to 70 per cent of yield is lost every year due to the Eggplant Fruit and Shoot Borer, a moth which lays eggs on eggplant leaves.[25] Once the larvae hatch, they feed on leaves and bore into shoots and fruits. To save their production, many farmers end up spraying insecticides up to 80 times over a growing season. These are unsustainable practices.

A GM eggplant was developed in India in the early 2000s, using the Bt gene from the bacterium Bacillus thurigiensis. This GM crop, known as Bt eggplant, produces a protein that causes the larvae to stop feeding. The Bt protein produced by the eggplant is basically the same as the one that is commonly used as a spray by organic farmers to control caterpillars in their fields. This protein is harmless to other insects and to humans.

Four Bt eggplant varieties were approved for release by the Bangladeshi Government in 2013, making this crop the first GM food crop to be successfully introduced in South Asia. Since its introduction, more than 27,000 farmers have adopted the GM crop. Farmers have reported a three-fold increase in yield at half the production cost of non-GM varieties.[26] They have also reported input savings, as pesticide use on Bt eggplant was reduced by as much as 92 per cent.

A small-holder farmer from Bangladesh shows Bt eggplant he has been growing on his farm. (Image: Md. Arif Hossain, Farming Future Bangladesh).

IN THE PIPELINE

The second generation of GM crop research is focussed on both enhanced nutritional traits with direct benefits for consumers and on improved agronomic traits.

Both areas of research will have a tremendous impact, especially in developing countries. These new crops will enable farmers to increase yields and produce crops that are more nutritious. This will provide health benefits as well as increase profits.

CASE STUDY: THE NEXT GREEN REVOLUTION?

Photosynthesis, using the energy of the sun to turn CO_2 into food, is the most important chemical process on earth. It is also a highly promising target for crop improvement in the global race to increase the yield of staple crops and achieve global food security.[27]

An international research project, Realizing Increased Photosynthetic Efficiency (RIPE), funded by the Bill & Melinda Gates Foundation, the Foundation for Food and Agriculture Research and the UK Department for International Development, is engineering plants with improved photosynthetic processes to boost the productivity of food crops.[28]

As part of the RIPE Project, researchers from the Australian National University are using mechanisms present in cyanobacteria (also known as blue-green algae) to improve photosynthesis in crops. The team recently engineered small CO_2-capturing compartments from cyanobacteria into the cells of crop plants.[27] Building such concentrating compartments was, until recently, seen as science-fiction. This achievement is an important step in developing crops with increased growth and yield.[28]

It will take years before these new crops become available to farmers, but this technology could help sustainably feed a growing population, using less land, water and fertilisers. Higher yielding crops would also increase smallholder famers' income and opportunities.

16 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 and has done so for many years. Malting barley is kept separate from feed barley, durum wheat is segregated from other varieties. Efficiently segregating GM from non-GM grain is basically business as usual for the industry. For example, when GM canola was released commercially in Australia, an additional category was introduced under national trading standards. Producers now have the option to sell their crops under the CSO-1 (GM) standard, or under the CSO-1A (non-GM) standard, which allows for up to 0.9 per cent unintended presence of genetically modified material.

The Australian Department of Agriculture has recognised that maintaining product integrity — that is, keeping grain commodities separate from others along the supply chain — must 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 seed companies, as well as state and territory 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.

"We are only one disease outbreak away from global starvation. We have to keep one step ahead of plant pathogens — plant breeding using GM or conventional approaches must be encouraged and promoted."

Professor Ros Gleadow, Monash University, President, Global Plant Council

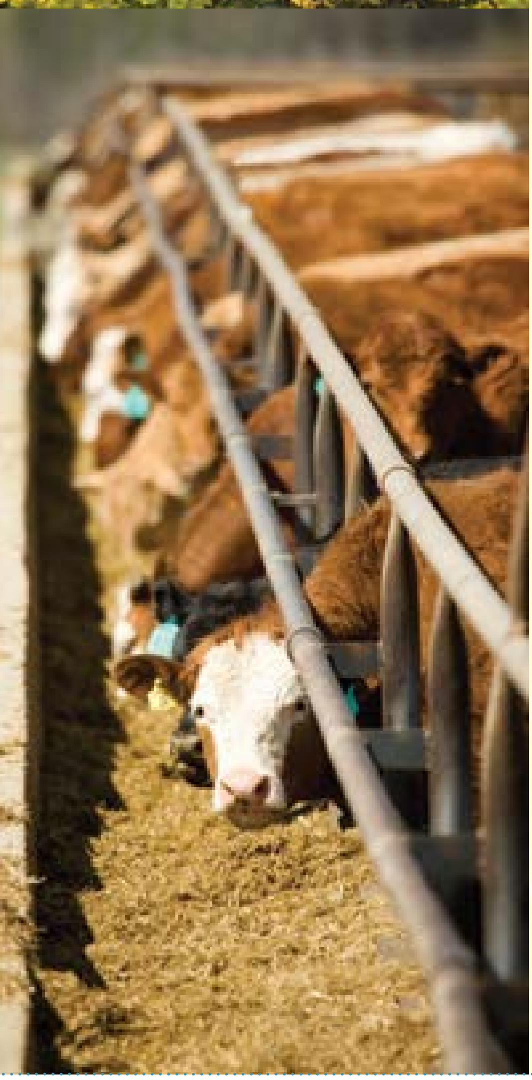
17 COMMON QUESTIONS ABOUT GENE TECHNOLOGY

DO FARMERS HAVE TO BUY NEW SEED EVERY YEAR?

All commercialised GM plants are as fertile as their conventional counterparts. The requirement to buy seed each year can arise from biological and/or contractual reasons.

The progeny of crosses between two varieties of a given crop usually show increased yield compared to its parents. This is known as hybrid vigour and is commonly used in modern farming systems. Hybrid varieties have been used by farmers for decades and are available in conventional, GM and organic agriculture. However, the following generation does not breed true to type. The seed obtained from hybrids may not grow into crops that are identical to the parents. This can lead to variations in yield and/or quality. Many farmers, no matter which farming system they use, prefer to buy new seed every year in order to maintain the improved yields and vigour offered by the hybrid varieties.

While several companies provide free access to their technology—particularly for humanitarian use in developing countries—as with the Golden Rice project or the Bt cowpea for smallholder farmers, 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 every year. As well as the agronomic advantages it provides, these contracts provide a means to ensure that GM crop stewardship is practised in accordance with regulatory requirements and are vital for funding ongoing research and development. It takes around 13 years and costs US $136 million to bring a new GM crop to market, much 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.



IS FOOD FROM GM INGREDIENTS DIFFERENT AND COULD EATING IT HAVE AN EFFECT ON MY GENES?

GM food crops are just as 'natural' as conventional crops. The only way to improve crops or breed new varieties is to modify the crop's genetics, using conventional or modern technologies. In many cases, genetic modification is simply speeding up what could be done through conventional methods.

Humans have always eaten DNA from plants and animals. Almost all of our food contains genes that are fragmented during the cooking process. Our digestive system breaks down these fragments without any effect on our DNA.

Our genes are made by our bodies from the DNA 'bricks' we obtain through digesting food. This is true of food from GM and non-GM sources, as the DNA composition of GM food is identical to that of non-GM food.

WHAT ABOUT GM STOCKFEED?

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

Studies investigating 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, DNA and proteins (genetically modified or not) are entirely broken down. This means the meat, milk and eggs from animals fed with 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.

ARE GM CROPS A CURE-ALL FOR GLOBAL FOOD AND NUTRITIONAL SECURITY?

GM crops are by no means the only solution to our global food shortages and nutritional inequalities. However, GM crops can significantly contribute to feeding the world by increasing yields and boosting the nutritional profile of staple crops, while leading to more sustainable farming practices by reducing the need for certain inputs.

It would have taken an extra 183 million hectares of conventional crops to produce the same tonnage grown using GM crops since their introduction in 1996. This represents the equivalent of a quarter of the Australian continent being saved from ploughing or clearing.

Farming systems have evolved since the introduction of GM crops. Global pesticide use has reduced by 37 per cent since 1996. There are fewer spray runs and therefore less fuel is used. No-till practices are cutting fuel use too and improving soil quality.

The next generation of GM crops currently engineered by scientists explore ways to better tolerate drought and salinity or to add micronutrients to staple food crops. These new crops will help alleviate hunger, malnutrition and poverty. They will also tackle challenges associated with a changing climate.

WHO IS CARRYING OUT RESEARCH INVOLVING GM CROPS?

More than 70 per cent of the field trials approved by the OGTR are carried out by universities, state departments of agriculture or public institutions such as 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 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 names of organisations and companies involved in GM crop development and their trial sites are publicly available at **www.ogtr.gov.au**

18 WHAT FARMERS SAY

WADE DABINETT, SA

Wade is a fourth-generation farmer in Parilla, two hours east of Adelaide. He farms with his parents, brother and sister-in-law. The family grows 5,500 hectares of barley, wheat, canola, lupin and hay. They also grow potatoes and run ewes and cows.

"South Australian growers now have access to GM technology, after waiting for 16 years. At last farmers get the freedom to grow the cereal, oilseed and legume varieties that best fit their farming system.

"We farm close to the Victorian border and have seen first-hand the benefits of GM crops for farmers. GM canola would have proven very successful in our area the last two seasons, thanks to higher yield and improved weed control. I look forward to growing it over the coming seasons.

"We are currently witnessing the impact of climate change in our state. In 2019, we experienced one of our worst frost events in twenty years and went through a devastating drought, leading us to cut over half of our cereal crop for the season.

In order to continue to grow, we need to have all options available to ensure we are better equipped to deal with these challenging events. GM crops are part of the solution and it is good that we can finally access these tools.

"The lifting of the moratorium on mainland South Australia will benefit farmers and consumers. It will also help boost agricultural research in the state, which will, in turn, give farmers access to crops specifically adapted for SA conditions.

"I am glad to see the GM moratorium is now lifted on mainland South Australia, as this will help us reach our full potential," said Wade.

BINDI MURRAY, WA

Bindi, together with her husband, parents, sister and brother-in-law, runs a farming operation in Woodanilling, three hours south-east of Perth, Western Australia. Their dryland farm system crops almost 3,000 hectares of winter crops, including canola varieties, wheat, barley, oats and oaten hay. They also produce wool and sheepmeat.

The family first grew GM canola on about 200 hectares in 2015, and it continues to be part of their rotation. The area dedicated to GM varieties has almost tripled in a few short years, delivering both weed control and higher yields.

"We chose GM canola for the weed control benefits it promised. We were looking to reduce the level of pressure on grass selective herbicides and provide a supplementary option to cutting hay so that we could improve the sustainability of our overall cropping program.

"GM canola is integral to the family's cropping rotation.The availability of the technology with its weed control benefits has helped them return several properties with significant weed issues to their full production potential in half the time, while producing a great crop.

"The use of GM canola in our shire is fairly widespread, with other farmers in the area looking for the weed control benefits," said Bindi.

Managing the segregation of GM canola and conventional and triazine tolerant canola and other cereals isn't an issue according to Bindi, as the family has managed segregated crops for years.

She says the main challenge GM canola presents is the upfront crop costs, which increases risk in a dryland system. "On the flipside, the vigour of GM crops has meant they finish well even in a dry spring.

"It would be great to see GM salt, frost and waterlogging tolerant crops, as there has been little headway made in improving these characteristics with conventional breeding techniques," said Bindi.

BEN DAL BROI, NSW

Ben grows GM cotton at a farm in Benerembah, 20 kilometres west of Griffith, New South Wales. The family grow Bollgard 3/Roundup Ready cotton, and biscuit, noodle and durum wheat varieties in winter.

After 17 years away from the family farm, for schooling, university, and work, Ben and his young family returned to farming on a 440-hectare property next to his parent's own GM cotton farm. The combined family farm is 1,000 hectares under irrigation. Ben's father has grown GM cotton for over eight years.

"Economically, GM cotton makes sense for our family farming enterprise with good commodity prices available and favourable water allocations," said Ben.

"We have experienced first-hand the benefits of using GM cotton, including reduced off-target damage from chemical spraying and with better weed control, a reduced need for cotton chippers to remove weeds. These benefits are good for the environment, my family and workers, and it saves time and money."

Ben said that one of the biggest challenges in growing GM cotton is that there is a lot more onus on stewardship for the grower. "The importance of stewardship in managing the longevity of the technology cannot be understated," he said.

In a traditional rice-growing area, the success of the cotton industry in Australia has allowed the Dal Broi's to enter the cotton market. The so-called southern valley, which includes the area around Griffith, Narrandera, Hay and Jerilderie in NSW is now a significant contributor to the cotton industry, with shorter season varieties bred to suit the local conditions and deliver comparable yields and quality to those in Australia's more traditional northern cotton-growing areas.

Without the availability of GM cotton, the Dal Broi's admit they would not have considered cotton for their farm.

"The use of chemicals associated with non-GM cottons, made it too complicated to grow other food crops. That's why the arrival of GM varieties and better suited regional varieties which employ insect resistance and herbicide tolerance have allowed our family to overcome these hurdles, be good neighbours and run a profitable enterprise," said Ben.

Ben's experience with the cotton industry has been extremely positive, crediting the industry's professional, supportive approach from researchers, seed technology developers, agronomists, policy advisers and ginners. "It feels like a community where everyone wants you to succeed," he said.

BRUCE WATSON, NSW

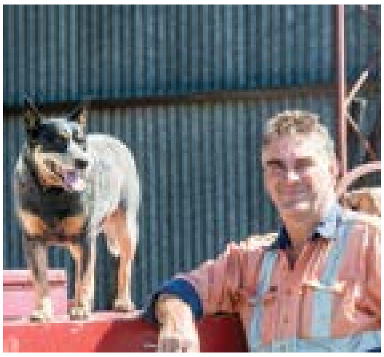
Bruce is a fourth generation farmer, continuous cropping 3,500 hectares near Parkes, New South Wales, using zero till and controlled traffic farming systems. His winter crops include wheat, barley, triticale, canola, chickpeas, lupins and faba beans. He's also introduced summer rotations with sorghum, 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."

JEMMA SADLER, WA

Jemma runs a 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."



JOHN CAMERON, QLD

John and his wife Rosalen farm 800 hectares on the Darling Downs, about 60 kilometres west of Toowoomba, Queensland. 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."

19 GLOSSARY

Biotechnology The use of biological systems, or living organisms, to make or change products. Modern biotechnology (often referred to as gene technology) includes the discovery of genes, the understanding of gene functions and interactions, the use of DNA markers, gene-editing and genetic modification.

Bacillus thuringiensis (Bt) A naturally occurring soil bacterium that produces proteins which are toxic to some insects and nematodes. Bt proteins are used in organic farming as a spray to kill pests. Bt genes have been inserted into plants such as cotton, maize, soybean, eggplant or cowpea, to provide protection from devastating pests.

Chromosomes Organised structures of densely packed DNA and proteins found in the nucleus of most living cells. Chromosomes carry genetic information in the form of genes.

CRISPR/Cas9 Currently the most commonly used site directed enzyme for DNA cleavage for gene-editing. CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats and Cas9 for the CRISPR-associated protein. CRISPR/Cas9 acts like a pair of molecular scissors, snipping a plant's DNA at a specific location.

DNA (deoxyribonucleic acid) Nucleic acid containing the genetic instructions used in the development and functioning of all known living organisms (and many viruses). DNA consists of two strands of nucleotides linked together in a double helix.

DNA marker (also known as molecular marker) A known DNA sequence located near a gene of interest. DNA markers are tools that help identify and track genes of interest in plants and animals.

Gene A segment of DNA that carries the instructions for heritable traits.

Gene-editing Gene-editing refers to a collection of molecular techniques that make precise, intentional, efficient and targeted changes in the DNA of plants and animals.

Gene expression The process by which a gene is made into a functional product, such as a protein.

Gene modification (GM) The process of altering the genetic makeup of an organism. This includes adding new genes or modifying gene activity. This can be done to understand how a gene works but also to produce new varieties with desirable traits.

Genetically modified organism (GMO) An organism whose genetic makeup has been altered using genetic modification.

Genome The complete genetic makeup of a cell or an organism.

Herbicide A natural or synthetic chemical effective at killing plants. Widely used in conventional, modern and organic farming systems to control unwanted plants (that are referred to as weeds).

Nucleotide An organic molecule that is the base unit of DNA.

Pesticide A substance used for controlling insects and other organisms harmful to cultivated plants.

SDN Site Directed Nucleases are proteins that can specifically recognise and cleave precise DNA sequences. SDN are used for gene-editing of crops.

Species A group of living organisms consisting of similar individuals potentially able to inter-breed and produce fertile offspring.

Transformation Inserting new DNA into an organism's genome, resulting in a genetically modified organism.

20 LINKS TO MORE INFORMATION ON GM

AUSTRALIA

The regulators and federal government websites:

- Office of the Gene Technology Regulator (OGTR): **ogtr.gov.au**
- Department of Agriculture, Water and the Environment: **agriculture.gov.au/ag-farm-food/biotechnology**
- Food Standards Australia New Zealand (FSANZ): **foodstandards.gov.au/consumer/gmfood**
- Australian Pesticides and Veterinary Medicines Authority (APVMA): **apvma.gov.au**
- Therapeutic Goods Administration (TGA): **tga.gov.au/guidance-21-medicines-produced-genetic-manipulation**

Agricultural Biotechnology Council of Australia (ABCA): **abca.com.au**

Australian Academy of Science **science.org.au**

Commonwealth Scientific and Industrial Research Organisation (CSIRO): **csiro.au**

INTERNATIONAL

Cornell Alliance for Science **allianceforscience.cornell.edu**

Genetic Literacy Project **geneticliteracyproject.org**

International Service for the Acquisition of Agri-biotech Applications (ISAAA) **isaaa.org**

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