Agricultural Biotechnology Council of Australia

GM Cotton in Australia: CELEBRATING 20 YEARS

A RESOURCE GUIDE

The following is a reference guide providing information about Australia's 20 year experience with genetically modified (GM) cotton. The guide provides information on the cotton industry, an overview of GM cotton varieties and the regulation surrounding them, future GM cotton varieties, the use of cotton in human and animal foodstuffs and further information resources.

Australia's 20th genetically modified (GM) cotton crop was planted in 2016. Australia's cotton growers planted the nation's inaugural GM crop in 1996, an insect resistant cotton variety known as Bt or Ingard® cotton. The technology has gone from strength to strength, and almost the entire cotton crop is now comprised of insect resistant and herbicide tolerant GM varieties, with seven current commercial release licences and a further six licences that permit the limited and controlled release (field trials) of GM varieties.

The use of GM varieties has resulted in many benefits for Australia's cotton farmers, their communities and the environment.

As a leader in the global deployment of GM cotton varieties, Australia's cotton growers were the first in the world to access a third generation of insect resistant GM cotton in 2016 – a fantastic new tool for the cotton industry which will increase the longevity of the technology and the sustainability of the industry.

Twenty years of benefits

According to a report titled *Adoption and impact of genetically modified (GM) crops in Australia: 20 years' experience*, Australian cotton farmers using insect resistant cotton varieties have seen the biggest financial gains of all the users of GM technologies in Australia, with the average increase in farm income between 1996-2015, valued at $287 per hectare. The $1.14 billion additional income generated by GM insect resistant cotton over two decades accounts for 83 per cent of the total farm income gains arising from the use of crop biotechnology in Australia. Herbicide tolerant cotton varieties allowed gains over the same period of $37 per hectare.

The gains attributed to insect resistant cotton use are largely savings in insecticide products and the associated application costs. Cotton is a crop that has traditionally been subject to numerous insecticide treatments in order to control devastating pests. Conventional cotton varieties were sprayed with insecticides between five and 19 times per season, and this has been reduced to between two and four insecticide treatments per crop with the use of GM varieties. In relation to herbicide tolerant GM cottons, the benefits largely derive from cheaper and easier weed control for farmers.

According to the report, the environmental benefits of GM cotton can be quantified as:

- Australian cotton farmers have used 18.3 million kilograms less insecticide active ingredient, a 33.4 per cent reduction since 1996.
- in recent years, the reduction in insecticide use annually has been equal to about -60 per cent compared to what would have been used if non-GM cotton had been grown.
- the significant reduction in insecticide coupled with better pest management has improved water quality in the rivers around cotton-growing communities.
- insect resistant cotton use has resulted in 31.9 million fewer spray applications, a saving of 26.8 million litres of fuel and a reduction in greenhouse gas emissions of 71.5 million kilograms of CO_2.

See more at www.croplife.org.au/factsheet/adoption-and-impact-of-genetically-modified-gm-crops-in-australia-20-years-experience/

According to the Cotton Research and Development Corporation (CRDC) Annual Report 2015-16, Australia is recognised as having the most pre-emptive, rigorous and successful resistance management system for GM cotton in the world. See: www.crdc.com.au/sites/default/files/pdf/CRDC%20Annual%20Report%202015-16.pdf

1 Industry background

Over a five year average between 2009 and 2014, the Australian cotton crop was worth $2 billion annually according to Cotton Australia.

There are around 1200 cotton farms in Australia, roughly half in New South Wales, and half in Queensland.

Cotton has many uses, the most common being the production of clothing. It is also used for familiar products such as cotton buds, and less known products like bank notes, x-rays and upholstery. Cotton seed is pressed to extract the oil from it, and this oil is used in the food industry, particularly by fast food and take-away outlets. The hull of the seed is also used as stock feed.

According to Cotton Australia, the world's main cotton exporters are the USA, India and Australia, and the main exports markets for Australian cotton are China, Indonesia, Thailand, South Korea, Bangladesh and Japan. See: http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-australian-cotton-industry

The Australian Oilseeds Federation (AOF) states that in 2015–16, Australia exported 148,000 tonnes of cottonseed, and China, Japan and the United States of America (USA) were the key export markets. See: www.australianoilseeds.com/oilseeds_industry/industry_facts_and_figures

2 Australia's GM cotton journey

Bt or Ingard®

In 1996, insect resistant GM cotton was grown commercially for the first time after six years of field trials. Known as Bt or Ingard® cotton, the cotton was developed by CSIRO, in partnership with Monsanto. This gene was sourced from the soil bacterium *Bacillus thuringiensis* (Bt), and it enabled the plant to produce a Bt protein which is a highly specific toxin for cotton's major pest, heliothis or the cotton bollworm.

Prior to the introduction of GM cotton, growers spent approximately $50 million annually on insecticides to control cotton pests. Insect resistant GM cotton provided growers with an opportunity to implement more effective integrated pest management strategies into their farming systems, and reduce chemical use.

According to CSIRO, the use of Ingard® cotton allowed the industry to reduce pesticide applications by 56 per cent each season, with reductions of up to 80 per cent in some years. The use of Ingard® cotton was capped at 30 per cent by the cotton industry to minimise the chances of the heliothis pest developing resistance to the protein. Ingard® cotton was superceded by Bollgard II®.

Roundup Ready® and Roundup Ready®/Ingard®

Roundup Ready® cotton and Roundup Ready®/Ingard® cotton, were commercially available for the first time in Australia in 2001. The Roundup Ready® characteristic makes the cotton plant tolerant of the herbicide glyphosate when applied according to label instructions, providing growers with greater flexibility in weed control options. Roundup Ready®/Ingard® cotton was achieved through conventional breeding of the two GM varieties.

According to the CRDC, Roundup Ready® cottons allowed growers to reduce their use of residual herbicides, benefiting land, water and biodiversity. For example, in the CRDC 2006–07 Annual Report, a 32.4 per cent reduction in residual herbicide use was reported since the introduction of Roundup Ready® technology.

Bollgard II®

Bollgard II® was the second insect resistant GM cotton to be approved for commercial release in Australia. Approved in 2003, it differed from Ingard® cotton in that it contained two genes from the soil bacteria *Bacillus thuringiensis* (Bt), rather than one. The genes, known as *cry1Ac* and *cry2Ab*, produce highly specific proteins toxic to the major cotton pests in the leaves of the cotton plant and when the pests eat the leaves they die.

Bollgard II® was phased in and completely replaced Ingard® cotton in 2004. As mentioned, while Ingard® cotton was capped at 30 per cent of the cotton crop to manage resistance this cap did not apply to Bollgard II®.

Growers were required to adhere to the Resistance Management Plan for Bollgard II, which required various resistance mitigation measures such as the planting of 10 per cent unsprayed cotton refuge or its equivalent, fixed planting windows, post harvest crop destruction, control of volunteer and ratoon cotton, pupae destruction and trap cropping.

According to CRDC, over the first three seasons of its use, Bollgard II® varieties, on average, required only 18 per cent of the insecticide required for conventional cotton to manage pests.

The CRDC Annual Report 2010–11, reported that the Bollgard II® technology made an enormous contribution to

Image: Courtesy of Cotton Australia

the viability of the Australian cotton industry over the past decade, and that due to a major resistance management effort since its introduction, the field efficacy of the technology remained unaffected.

Roundup Ready FLEX®

In February 2006, the Gene Technology Regulator approved the commercial release of Roundup Ready FLEX® cotton varieties. These varieties give growers greater flexibility in weed control by extending the period during which glyphosate can be applied to control weeds. Roundup Ready FLEX® varieties have replaced the Roundup Ready® varieties. They differ from Roundup Ready® cotton in that they contain two copies of a glyphosate tolerance gene derived from a soil bacterium rather than just one.

Liberty Link® cotton

In 2006, the GTR issued a commercial licence for Liberty Link® cotton, which has been genetically modified to tolerate applications of the broad-spectrum herbicide, glufosinate ammonium, marketed as Liberty®. While the Roundup herbicide, glyphosate, is a Group M herbicide, the Liberty herbicide, glufosinate, is a Group N herbicide, therefore it has a different mode of action for killing weeds.

WideStrike® cotton

The GTR approved an insect resistant variety, marketed as Wide Strike™, in 2009. This GM cotton contains two genes, the *cry1F* gene and the *cry1Ac* gene derived from different strains of the soil bacterium *Bacillus thuringiensis* (Bt), that have been shown to increase resistance to insect pests. This variety has not been grown commercially in Australia to-date.

Roundup Ready Flex® MON 88913 (pima cotton)

This herbicide tolerant variety, referred to as Roundup Ready Flex® pima cotton, received a commercial licence from the GTR in 2013. Pima cotton is the common name for the cotton species *Gossypium barbadense*, also known as Egyptian cotton. It produces a superior fibre to the more commonly grown cotton variety, but because of lower yields, different climate requirements and a longer growing season it represents only about one per cent of the total Australian cotton crop.

Bollgard® II and Bollgard® III x Roundup Ready Flex®

In February 2016, cotton growers in Australia became the first in the world to be able to access a third generation of insect resistant GM cotton, following its global launch locally. Bollgard® III, or Bollgard® 3, contains a third Bt gene, known as *vip3A*, in addition to the Bt proteins, *cry1Ac* and *cry2Ab*, found in Bollgard II, so it will increase the longevity of the technology by making it increasingly difficult for the heliothis pest to develop resistance to it.

GlyTol® and GlyTol TwinLink Plus®

GlyTol® cotton is herbicide tolerant and GlyTol TwinLink Plus® cotton is both insect insect resistant and herbicide tolerant. GlyTol® cotton contains one introduced gene for glyphosate herbicide tolerance, which was sourced from maize. The glyphosate tolerance gene, is in addition to two copies of an introduced gene that confers tolerance to the glufosinate herbicide. With tolerance to both glufosinate and glyphosate, farmers have increased weed control options.

The TwinLink Plus technology combines the Bt genes *cry1Ab* and *cry2Ae*, with the *vip3Aa19* Bt gene to manage major lepidopteran pests - cotton bollworm and armyworm, including fall armyworm.

XtendFlex™ and Bollgard® 3 XtendFlex™

This licence was issued by the GTR in December 2016. Xtend Flex™ cotton contains three introduced genes for herbicide tolerance: which makes it tolerant to glyphosate, glufosinate and dicamba herbicides. This allows farmers to use one, or all, of these herbicides for weed control without damaging their cotton crop.

In addition to the three herbicide tolerance genes, Bollgard® 3 Xtend Flex™ cotton contains three Bt genes that confer insect resistance - *vip3A*, *cry1Ac* and *cry2Ab*. The comination of these three different genes is expected to reduce the chance of insect pests developing resistance. Once again, growers are required to adhere to the Resistance Management Plan for this technology, which includes an unsprayed cotton refuge requirement of five per cent of the area of Bollgard III cotton or its equivalent.

Regulatory details and licence application information for all of these commercially licenced cottons, as per the table below, can be found at: www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/cr-1

Variety name	OGTR reference
Bt or Ingard®	DIR 066/2006*
Roundup Ready® and Roundup Ready®/Ingard®	DIR 066/2006*
Bollgard II®	DIR 066/2006*
Roundup Ready FLEX®	DIR 066/2006*
Liberty Link® cotton	DIR 062/2005
WideStrike® cotton	DIR 091
Roundup Ready Flex® MON 88913	DIR 118
Bollgard® II and Bollgard® III x Roundup Ready Flex®	DIR 124
GlyTol® and GlyTol TwinLink Plus®	DIR 143
XtendFlex™ and Bollgard® 3 XtendFlex™	DIR 145

Source: OGTR.

* Note: The DIR 066/2006 licence now authorises dealings with five GM cotton lines Australia wide. Previously, dealings with the same five GM cotton lines were authorised by five different commercial DIR licences (DIR 066/2006 in northern Australia and DIRs 012/2002, 022/2002, 023/2002 and 059/2005 in southern Australia).

3 GM cotton in the pipeline

In addition to the commercially released GM cotton varieties mentioned, a number of others are currently undergoing field trials in Australia.

Licence no.	Organisation	Modification
DIR 085/2008	CSIRO	Altered fatty acid composition of the cottonseed oil
DIR 113	Bayer CropScience Pty Ltd	Herbicide tolerance/insect resistance
DIR 115	CSIRO	Enhanced fibre yield
DIR 120	Monsanto Australia Ltd	Insect resistance/herbicide tolerance
DIR 133	Bayer CropScience Pty Ltd	Herbicide tolerance/insect resistance
DIR 136	CSIRO	Enhanced fibre quality

Source: OGTR

CSIRO's project to develop cotton with altered oil properties, or high-oleic acid content, is the first commodity GM crop with a consumer-orientated benefit to undergo field trials in Australia. Oil from conventional cotton requires extra processing (partial hydrogenation) to eliminate high levels of polyunsaturated fatty acids, however hydrogenation may increase human cholesterol levels. High oleic acid oils have a healthier fatty acid profile, and are expected to be more stable for frying purposes without the need for hydrogenation.

Further information on all of the above can be found by looking up the relevant DIR at: www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/ir-1?OpenDocument&status=Current

4 The global context

According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA), almost 180 million hectares of GM crops were grown around the world in 2015, with GM cotton the third largest GM commodity globally behind soybeans and corn.

Genetically modified cotton varieties represent about 75 per cent of the global cotton crop, and they are grown in the USA, Brazil, Argentina, India, China, Paraguay, Pakistan, South Africa, Australia, Burkina Faso, Myanmar, Mexico, Colombia, Sudan and Costa Rica.

The most dominant characteristics in GM crops are herbicide resistance (approximately 57 per cent), followed by the combined or stacked traits of herbicide tolerance and insect resistance (28 per cent) and insect resistance (15 per cent).

Image: Courtesy of Cotton Australia

The ISAAA also reports that GM crops are increasingly offering resource-poor farmers benefits. For example, insect resistant GM cotton was grown by 7.7 million small and resource-poor farmers across 11.6 million hectares in India in 2015, which is approximately 95 per cent of the nation's cotton crop.

ISAAA attributed the use of insect resistant cotton varieties in India, to it becoming the leading cotton producer in the world. Farmers benefitted through increased yields and a halving of insecticide applications, and the resulting positive environmental and health implications.

In China the impact of GM insect resistant cotton has also been impressive. In 2015, insect resistant cotton was planted by 6.6 million small and resource-poor farmers on about 3.8 million hectares, which is equivalent to 96 per cent of China's cotton crop. For more information: www.isaaa.org/resources/publications/briefs/51/executivesummary/default.asp

5 Food

Cottonseed oil is used extensively for frying by the fast food and take away industry. Cottonseed oil from commercially approved GM cotton varieties has been approved for use in the food chain.

Food Standards Australia New Zealand (FSANZ), is responsible for assessing the safety of GM foods before they are allowed to be sold in Australia and New Zealand. See more at: www.foodstandards.gov.au/consumer/gmfood/safety/Pages/default.aspx

In 2001 Australia adopted labelling laws for GM foods and ingredients. Standard 1.5.2 (food produced using gene technology) ensures that all GM crops, animals and microorganisms must be assessed and approved by FSANZ as safe before they can be used for food or in food processing.

Food products from eight GM commodities can be sold in Australian supermarkets. These are soybean, canola, corn, cotton, potato, lucerne, sugar beet and rice.

Food or ingredients labelled 'genetically modified' either contain new genetic material or protein as a result of genetic modification or have altered characteristics, for example improved nutritive values.

The labelling rules focus on the end food product, and not the plant or process involved in its production. For example, oil from GM cotton does not require a label because refined oils contain no genetic material, and are identical to oils from a non-GM crop.

For more information: www.foodstandards.gov.au/consumer/gmfood/labelling/Pages/default.aspx

6 Animal feed

By-products from cotton, including GM cotton are used as a high protein source of animal feed. The safety of using GM crops as an animal feed source has been investigated extensively around the world.

The research has examined the effect of feeding GM crops to animals on the animals themselves, and also the effects of these crops on animal by-products—such as meat, eggs and milk. The conclusions from these studies were consistent, showing no detrimental effects in livestock fed GM crops or their by-products.

For more information see: www.cast-science.org/news/?cast_issue_paper_examines_safety_of_consuming_foods_from_animals_fed_biotechnologyderived_crops&show=news&newsID=9881.

The Agricultural Biotechnology Council of Australia (ABCA) has produced a fact sheet on this topic which is available at: www.abca.com.au.

The stockfeed industry uses significant quantities of protein meals in their rations. The bulk of Australia's soybean meal is imported from South America, where GM varieties dominate the national soybean crop and segregation of GM and non-GM varieties is not standard practice. According to *Australian Feed Grain Supply and Demand Report 2016*, the importation of soybean meal has continued to grow, with over 700,000 tonnes being imported in 2014/15. See: www.feedgrainpartnership.com.au/items/1010/FGP%20Report%20October%202016.pdf

All of the cottonseed meal is also considered to be GM as almost 100 per cent of the domestic crop is planted to GM varieties which are not segregated due to a lack of demand for non-GM cottonseed meal or oil. See: www.cottonaustralia.com.au and www.isaaa.org

7 General and other references

Cotton Australia is the peak industry body for Australia's cotton growers: www.cottonaustralia.com.au.

Cotton Research and Development Corporation is a research and industry development partnership between the Federal Government and the cotton industry: www.crdc.com.au.

The Office of the Gene Technology Regulator has been established within the Australian Government Department of Health to provide administrative support to the Gene Technology Regulator in their role 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: www.ogtr.gov.au

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