ADOPTION AND IMPACT OF GENETICALLY MODIFIED (GM) CROPS IN AUSTRALIA:

20 YEARS' EXPERIENCE

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GM crops have been widely grown around the world and in Australia for 20 years. During this period, the technology has provided significant economic and environmental benefits to Australian farmers and citizens. Australian cotton and canola farmers have gained AUS $1.37 billion worth of extra income and produced an additional 226,000 tonnes of canola that would otherwise have not been produced if conventional technology had been used. The technology has enabled Australian farmers to reduce their use of insecticides and herbicides by 22 million kilograms of active ingredient, equal to a 26 per cent improvement in the environmental impact associated with pesticide use on these two crops. This reduced use of pesticides has also resulted in a saving of nearly 27 million litres of fuel use and 71.5 million kilograms less carbon dioxide being released into the atmosphere.

FOREWORD

This publication is intended for use by a wide range of people, from those with limited knowledge of agriculture and its impact on the environment, to others with good knowledge of, and interest in agriculture.

It provides insights into the reasons why many farmers in Australia have adopted crop biotechnology and continue to use it in their production systems since the technology first became available on a commercial basis.

It draws on the key findings relating to the global impact of genetically modified (GM) crops[1],[2] and focuses on the farm level economic impacts and the environmental effects associated with pesticide use and greenhouse gas (GHG) emissions.

1 See for example, Brookes G and Barfoot P (2015) Environmental impacts of GM crop use 1996–2013: impacts on pesticide use and carbon emissions. GM Crops 6:2, p103–133 and Brookes G and Barfoot P (2015) Global income and production impacts of using GM crop technology 1996–2013, GM Crops 6: 1, p13–46. Both papers are freely available at www.tandfonline.com.

2 The primary author of this brief is Graham Brookes, Agricultural Economist at PG Economics Ltd, UK who has been analysing the impact of GM crop technology around the world for 18 years and is the author of 21 peer reviewed papers on the economic and environmental impact of GM technology.

INTRODUCTION

All crops grown in the world are the product of thousands of years of breeding by humans to improve the quality and yield of the end product. Crop biotechnology is a modern extension of plant breeding techniques that allows plant breeders to select genes with desirable or beneficial traits for expression in a new variety. It represents a new step in the evolution of plant breeding because it allows for the transfer of genes with desirable traits between unrelated species (i.e. allows for the transfer of genes between species that are unlikely to have been possible using traditional plant breeding techniques). It is also a more precise and selective process than traditional cross breeding for producing desired agronomic crop traits.

The main GM traits (a trait is a desirable or target attribute such as pest resistance) so far commercialised have essentially been derived from bacteria and convey:

- Herbicide tolerance (HT) to specific herbicides (notably to glyphosate and to glufosinate). The technology allows a herbicide to be used to target weeds in the crop without harming the crop. For example, a glyphosate tolerant crop is tolerant to the herbicide glyphosate; and
- Resistance to specific insect pests (often called insect resistant or IR crops): here genes have been introduced into crops like corn, cotton and soybeans and make a crop resistant to a particular pest. For example, a cotton crop with resistance to the range of bollworm and budworm pests.

USE OF CROP BIOTECHNOLOGY

1996 was the first year in which a significant area of crops containing GM traits were planted both on a global basis (1.66 million hectares) and in Australia (40,000 ha). Since then there has been a dramatic increase in plantings and in 2015, the global planted area was about 180 million hectares and the area in Australia was 714,000 ha. GM traits have largely been adopted at a global level in four main crops—canola, corn, cotton and soybeans.

In Australia, GM technology was first made available to farmers in the cotton sector in 1996 (IR technology), with seed containing an HT trait (mostly to glyphosate) available, either as single traited seed or combined with IR technology from 2000. HT canola (mostly tolerant to glyphosate) was first made available to canola farmers in New South Wales and Victoria from 2008. Farmers in Western Australia were subsequently allowed to use this crop technology from 2010, leaving only South Australian and Tasmanian farmers not permitted to use canola seed containing this technology in 2016.

In 2015, almost all of the (270,000 hectare) Australian cotton crop used crop biotechnology, with 94 per cent of the crop having both HT (to glyphosate) and IR traits[3]. Twenty per cent of the 2015 Australian canola crop used GM HT technology (444,000 hectares)[4].

3 Almost all of the remaining 6 per cent was HT only.

4 Equal to 22 per cent of the canola crop in the states where the technology is allowed.

FARM LEVEL ECONOMIC IMPACTS

GM technology has had a significant positive impact on farm income of Australian cotton and canola farmers (Table 1). In 2015, the direct farm income benefit from GM crop technology in these two crops was AUS $100 million. This is equivalent to having added 3.5 per cent to the value of Australian production of the two crops[5]. Since 1996, the use of crop biotechnology has increased farm income by AUS $1.37 billion (if this extra value had to be obtained from conventional production, it would have required an additional planting of nearly 350,000 ha to cotton and canola).

The largest gains in farm income have arisen in the cotton sector, mainly from the use of the IR technology. The AUS $1.14 billion additional income generated by GM insect resistant (GM IR) cotton over the 20 years' accounts for 83 per cent of the total farm income gains arising from use of crop biotechnology. In 2015, the AUS $64.1 million farm income gain was equivalent to adding 4.1 per cent to the value of the crop.

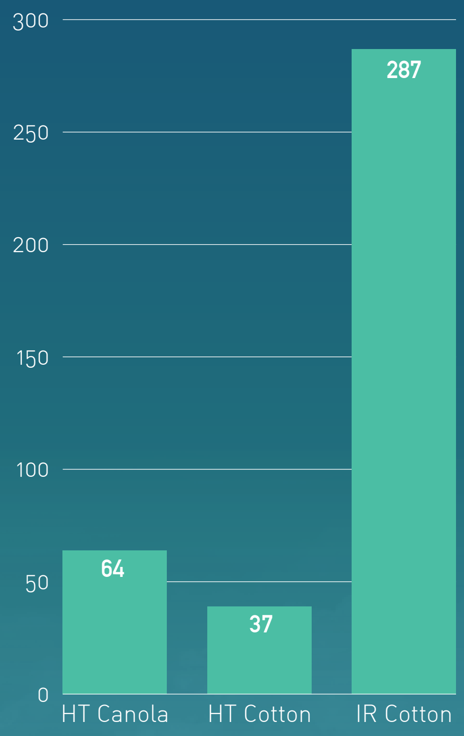
Table 1: Farm income benefits from growing GM crops in Australia 1996-2015

Trait	Increase in farm income 2015 US $	(AUS $)	Increase in farm income 1996–2015 US $	(AUS $)	Farm income benefit in 2015 as % of total value of production of these crops in Australia
GM herbicide tolerant cotton	10.2	(13.6)	101.6	(136.2)	0.9
GM herbicide tolerant canola	16.6	(22.2)	73.8	(98.9)	1.7
GM insect resistant cotton	47.9	(64.1)	849.6	(1,138.5)	4.1
Totals	**74.7**	**(99.9)**	**1,025.0**	**(1,373.6)**	**3.5**

Notes: All values are nominal. Farm income calculations are net farm income changes after inclusion of impacts on yield, crop quality and key variable costs of production (e.g. payment of seed premia, impact on crop protection and weed control expenditure).

5 If farmers wanted to obtain the same value from conventional cotton and canola in 2015, an additional 51,400 hectares of these (conventional) crops would have to be planted.

Figure 1: Average increase in farm income by trait 1996–2015 per hectare (AUS $)



Notes: IR cotton 1996–2015, HT cotton 2000–2015, HT canola 2008–2015.

In terms of returns per hectare, Figure 1 summarises the average farm income benefit by GM crop trait. This highlights the significant farm income benefits obtained by farmers using the technology, especially IR cotton.

These farm income gains have occurred from the following sources:

- **HT technology.** The benefits largely derive from more cost effective (less expensive) and easier weed control for farmers. Most users of this technology in the canola sector have also derived higher yields from better weed control (relative to weed control obtained from conventional technology), with the average yield gain obtained being +11 per cent. This has resulted in an extra 226,000 tonnes of canola being produced since 2008 which would have not been otherwise produced if conventional (non GM) canola had been grown[6]. The magnitude of these impacts varies by region and year, and is mainly due to costs of different herbicides used in GM HT systems versus conventional alternatives, the mix and amount of herbicides applied, the cost farmers pay for accessing the GM HT technology and levels of weed problems;
- **IR technology.** The substantial benefit to Australian cotton farmers from using this technology has arisen from highly effective pest control that has enabled farmers to significantly reduce the use of insecticides[7]. Cotton is a crop that has traditionally been subject to numerous insecticide treatments in order to control budworm and bollworm pests which can devastate cotton crops. Before the availability of IR cotton technology, most Australian cotton crops were typically sprayed with insecticides 11 times per season (range 5–19) in order to deliver effective control of these pests. The availability of IR cotton technology has enabled cotton farmers to substantially reduce the number of insecticide treatments to those necessary to control cotton pests that the IR technology does not target. Cotton crops are now typically subject to no more than 2–4 insecticide treatments per crop. This significantly reduced need to spray insecticides has resulted in substantial savings in expenditure for insecticides and their application.

6 Alternatively, if this extra production had to be produced using conventional technology, an additional 188,000 ha of conventional canola would need to be planted.

7 It is interesting to note that higher yields from the use of IR cotton technology have occurred in many user countries—in Australia this did not happen because the levels of Heliothis sp (boll and bud worm pests) pest control previously obtained with intensive insecticide use were good. The main benefit and reason for adoption of this technology in Australia has arisen from significant cost savings and the associated environmental gains from reduced insecticide use when compared to conventional (non GM) cotton.

ENVIRONMENTAL IMPACT
FROM CHANGES IN INSECTICIDE AND HERBICIDE USE

GM traits in cotton and canola have contributed to a significant reduction in the environmental impact associated with insecticide and herbicide use on the areas devoted to these GM crops in Australia (Table 2). Since 1996, the use of GM technology has directly resulted in insecticide and herbicide use on the Australian GM crop area falling by 22 million kilograms of active ingredient (a 23 per cent reduction).

Whilst changes in volume of pesticides applied to crops can be a useful indicator of environmental impact, it is an imperfect measure because it does not account for differences in the specific pest or weed control programmes used in GM and conventional cropping systems. Using a better measure of the environmental impact associated with pesticide use, the environmental impact quotient (EIQ8), this measure shows that the environmental impact associated with herbicide and insecticide use on the area planted to GM crops in Australia between 1996 and 2015 fell by 26 per cent.

In both absolute and per hectare terms, the largest environmental gain has been associated with the adoption of IR cotton. Since 1996, Australian cotton farmers have used 18.3 million kilograms less insecticide active ingredient in IR cotton crops (a 33.4 per cent reduction) and this has reduced the associated environmental impact of insecticide use on this crop by 34.5 per cent, compared to the levels of use that would have otherwise occurred if this crop area had used conventional (non GM) seed[9].

8 The EIQ distils the various environmental and health impacts of individual pesticides in different GM and conventional production systems into a single 'field value per hectare' and draws on key toxicity and environmental exposure data related to individual products. It therefore provides a better measure to contrast and compare the impact of various pesticides on the environment and human health than weight of active ingredient alone. However, it should be noted that the EIQ is an indicator only (primarily of toxicity) and does not take into account all environmental issues and impacts. For additional information about the EIQ indicator, see, for example Brookes and Barfoot (2015) Environmental impacts of GM crops 1996–2013, referred to on page 1.

9 In absolute terms, the use of insecticides (per hectare) on the largely GM IR cotton crop has fallen by nearly 90 per cent compared to levels of use on conventional cotton crops in the mid 1990s. GM IR seed technology has been a significant factor of influence in this reduction, together with new insecticides and improved methods of pest monitoring and management.

In recent years, where over 90 per cent of the cotton crop has used GM IR technology, the reduction in insecticide use has annually been equal to about -60 per cent compared to what would have been used if conventional (non-GM) cotton had been grown.

Also, the significant reduction in insecticide use through adoption of GM IR cotton, coupled with better pest management has made an important contribution to improving water quality in the North East rivers of Australia[10].

Table 2: Impact of changes in the use of herbicides and insecticides from growing GM crops in Australia 1996–2015

Trait	Change in volume of active ingredient used (million kg)	% change in ai use on GM crops	% change in environmental impact associated with herbicide and insecticide use on GM crops	Area GM trait 2015 ('000 ha)
GM HT canola	-0.79	-3.5	-3.0	444
GM HT cotton	-2.79	-14.7	-19.5	270
GM IR cotton	-18.33	-33.4	-34.6	253
Totals	**-21.91**	**-23**	**-26**	**714**

Note: The total GM crop area (714,000 ha) includes 253,000 ha of cotton containing both HT and IR traits.

10 Kennedy I et al (2013) Research and practice: environmental action for improving water quality in cotton catchments since 1990. Crop and Pasture Science 64: 1095–1110.

GREENHOUSE GAS EMISSION CUTS

GM crops have also delivered significant savings in greenhouse gas (GHG) emissions. At a global level this derives from two principles sources:

- Reduced fuel use from less frequent herbicide or insecticide applications and/or a reduction in the energy use in soil cultivation. The fuel savings associated with making fewer spray runs (relative to conventional crops) and the switch to conservation, reduced and no-tillage farming systems have resulted in permanent savings in CO_2 emissions;
- The use of 'no-till' and 'reduced-till' farming systems[11]. These production systems have increased signficantly with the adoption of GM HT crops because the HT technology has improved farmers ability to control competing weeds, reducing the need to partly rely on soil cultivation and seedbed preparation as means to getting good levels of weed control. As a result, tractor fuel use use for tillage is reduced, soil quality is enhanced and levels of soil erosion cut, leading to lower GHG emissions from soil. These soil-based GHG emission savings have occurred mostly in North and South America and mainly associated with corn and soybean crop production systems.

In Australia, the main GHG emission savings arising from the adoption of GM crops has been associated with reduced insecticide spraying on cotton[12]. Between 1996 and 2015, the widespread adoption of GM IR cotton has resulted in 31.9 million fewer spray runs on cotton crops, a saving of 26.8 million litres of fuel and a reduction in GHG emissions of 71.5 million kilograms of CO_2.

11 No-till farming means that the ground is not ploughed at all, while reduced tillage means that the ground is disturbed less than it would be with traditional tillage systems. For example, under a no-till farming system, soybean seeds are planted through the organic material that is left over from a previous crop such as corn, cotton or wheat, or wheat/barley is planted through the organic material of a previous canola crop.

12 Whilst soil-based GHG emission savings associated with no/reduced tillage production systems occur in Australia, these production systems were widely used before the availability of GM HT technology in canola and cotton. Therefore, these GHG savings are not directly attributable to the widespread adoption of GM HT technology in Australia even though the availability of this technology has probably helped many Australian canola farmers to continue to use no/reduced tillage production systems.

GLOSSARY

Genetic modification: Altering the genes or DNA of an organism using modern biotechnology techniques. This includes controlling gene activity, modifying genes and transferring genes in order to investigate gene function. This can be used to generate genetically modified organism or provide information that can be used to speed up conventional breeding.

Peer review: this means a report or paper has been subject to independent and anonymous review by specialists in the subject area before acceptance for publication in a journal

Pesticide active ingredient: refers to the amount of substance in a pesticide that is biologically active (and which targets a pest, in the case of an insecticide or a weed, in the case of an herbicide).

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