# Economic impacts of GM crops in Australia

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Research Report 08.4 May 2008

abare.gov.au

ISSN 1037-8286

ISBN 978-1-921448-13-3

Acworth, W, Yainshet, A and Curtotti, R 2008, *Economic impacts of GM crops in Australia*. Prepared for the Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, May.

Australian Bureau of Agricultural and Resource Economics

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ABARE project 3199

# Acknowledgments

The authors gratefully acknowledge the assistance of Jammie Penm, Don Gunasekera and Benjamin Buetre for their comments on drafts of this report. We also thank staff members of the Biotechnology Policy Section of the Australian Government Department of Agriculture, Fisheries and Forestry for their comments.

Funding for this report was provided by the Rural Policy and Innovation Division of the Australian Government Department of Agriculture, Fisheries and Forestry under the National Biotechnology Strategy. No other sources were involved.

# Foreword

Farmers in Australia have rapidly adopted genetically modified (GM) cotton, which now accounts for more than 90 per cent of the land area planted to cotton. This has allowed farmers to maintain their competitiveness in the global export market for cotton lint and has benefited cotton-growing regions.

Apart from GM cotton and carnations, there has been no other commercial release of a GM field crop in Australia. The New South Wales and Victorian governments announced in early 2008 that the commercial growing of GM canola in these two states would be allowed from the 2008 season. It is likely other GM crop varieties will also become available for commercial plantings in the future.

This report focuses on the potential economic impact of GM crop adoption in Australia. For illustrative purposes, the benefits to states from early and delayed adoption of GM crops are simulated, highlighting the significant economic cost associated with delay of adoption of GM crops.

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May 2008

# Contents


## Summary

Benefits and costs of GM crop adoption 1
International and Australian experiences 3
Method for estimating economic impacts of GM crops in Australia 4
Regional/state income impacts 4

1 Introduction 6

2 Costs and benefits of GM crop adoption 8

Crops considered 8
On-farm benefits 9
On-farm costs 14
Environmental aspects 15
Economic costs and benefits to other sectors 17

3 Potential economic impacts of GM crops in Australia 19

Analytical framework 19
Assumptions 20
Results 22

4 Conclusion 25

References 31

Appendixes

A International adoption of GM crops and the Australian experience 26
Australia's adoption of GM crops 27
Prospective GM crops 28
B Research and development in GM crops in Australia 29

## Boxes


| | | |
|---|---|---|
| 1 | First generation GM crop traits | 8 |
| 2 | Yield effects by crop | 10 |
| 3 | Pesticide and herbicide cost reductions from GM crops | 13 |
| 4 | Empirical studies on the benefits to seed suppliers from the sale of GM seeds | 17 |


## Figures


| | | |
|---|---|---|
| A | Economic benefits of GM canola adoption cumulative from the adoption year to 2017-18 | 22 |
| B | Economic benefits of five GM canola adoption cumulative from the adoption year to 2017-18 | 23 |
| C | Global adoption of GM crops 1996–2006 | 26 |
| D | Land area planted to major GM crops globally in 2006 | 26 |
| E | GM cotton adoption in Australia: percentage of total cotton planted to GM | 27 |


## Maps


| | | |
|---|---|---|
| 1 | New South Wales Murray Catchment Management Area | 19 |


## Tables


| | | |
|---|---|---|
| 1 | Examples of economic impact of GM crops in selected countries | 11 |
| 2 | Assumed yield and cost changes with GM adoption by scenario | 20 |
| 3 | Examples of GM field crop trials currently under way | 29 |
| 4 | Examples of GM field crop trials in post-harvest monitoring phase | 30 |

# Summary

- Since the first commercial plantings in 1996, genetically modified (GM) crops have expanded rapidly and now constitute a significant proportion of the world's broadacre crop output. By 2007, GM crop coverage globally exceeded 114 million hectares. A key driver of the rapid adoption of GM crops is the benefit farmers gain by switching to these crops. Benefits include increased crop yield, reduced farm input costs, including pesticide, herbicide and farm labour, and more efficient farm management.
- GM varieties of cotton, soy bean, maize and canola are the principal GM crops grown. The main producing countries by volume are the United States of America (50 per cent of global total), Argentina (17 per cent), Brazil (13 per cent), Canada (6 per cent), India (5 per cent) and China (3 per cent).
- Australia's commercial experience with GM field crops is limited to GM cotton and carnations. GM canola has been approved for commercial release by the Office of the Gene Technology Regulator (OGTR) and for commercial production by the New South Wales and Victorian governments from the 2008 season. Over the longer term, other broadacre GM crops may also be available for adoption by Australian farmers.
- In this report the nature of costs and benefits from GM crop adoption is first discussed. A quantitative assessment is then presented to examine the potential economic benefits of further GM crop adoption in Australia at the regional and state levels. Crops considered include canola, soy bean, maize, wheat and rice.

## Benefits and costs of GM crop adoption

- The following discussion is based on international experiences and literature review.

### Yield effects

- In comparison to non-GM production systems, the adoption of GM crops could reduce yield losses through better protection against external factors such as insect pests and weeds. The yield benefit from GM crop adoption varies across regions and is determined by agronomic growing conditions and the level of pest/weed incidence in any given place and time.

## Pesticide and herbicide use

- Insect-resistant GM crops provide their own protection against pests and therefore reduce, or in some cases eliminate, the need for pesticides. Herbicide tolerant crops allow the use of relatively inexpensive broad spectrum herbicides which effectively control most weeds affecting the crop. This allows farmers to replace previous mixes of expensive and more toxic weed specific herbicides, and increases their flexibility in crop rotations as they are no longer affected by the slow breakdown of herbicide residues in the soil profile.

## Farm management and labour savings

- Managing GM crop production is generally easier and less time consuming than non-GM crop production. Also, GM crops reduce the number of annual sprays required and enable minimum tillage or no tillage cropping, therefore reducing labour, machinery and fuel costs.

## Environment and occupational health and safety

- Reductions in chemical applications could result in a reduction in environmental costs associated with spraying and reduced contamination of soils and groundwater. In addition, pesticide and herbicide-resistant GM crops provide occupational health and safety benefits by reducing the need for farmers to handle toxic chemicals.

## Flow-on effects

- Agricultural industries have many linkages with other sectors of the economy. Beyond the farm gate, crops may require storage, processing, transportation and handling. When new technologies such as GM crops are adopted, and total production rises, demand for those services will also rise.

## Off-farm income

- GM crop adoption may require farmers to spend less time in the field and they may be able to work off-farm to increase their household income.

## Seed prices, technology fees and user agreements

- Farmers opting to grow GM crops are likely to face additional costs in terms of higher seed prices, technology fees and restrictive user agreements. Higher GM seed prices and the charging by GM seed providers of technology fees to users — largely based on the area of land planted to GM crops —increases the cost of using GM seed compared with non-GM seed. Technology user agreements, imposed either by the technology provider or user industry groups, could entail additional costs to growers by requiring adherence to regulations such as mandatory buffer zones.

## Segregation cost

- On-farm segregation arrangements can mean higher costs because of the need for certified planting seed, various crop management techniques (including appropriate separation distances between crops and control of unintended presence of GM crops in non-GM crops), and the need to clean equipment after harvesting, handling, storing and transporting GM grain types.
- Additional costs in the central receival system include extra grain testing requirements and more labour because of a longer receival period. The additional costs are likely to be small relative to on-farm costs and benefits, reflecting the economies of scale with bulk handling of grain.

# International and Australian experiences

### *Yield gains*

- Australian field trials have demonstrated that GM canola has the potential to significantly increase yields in Australia. For example, the results of Monsanto field trials, conducted side-by-side with HT canola and alternative non-GM canola varieties, indicate that glyphosate tolerant canola provides significant yield gains compared with non-GM varieties through improved weed management. In North America, GM canola yield advantages have averaged 6–10 per cent.
- International experiences suggest yield gains from the cultivation of GM soy bean are likely to be limited. Although significant increases in yield have been reported by Romanian farmers, this could be because traditionally poor weed control before the introduction of HT soy bean has meant a greater yield increase following introduction than in other countries.
- For maize, Bt varieties in the United States, Spain and South Africa have achieved yield advantages of between 5 per cent and 11 per cent compared with non-GM varieties.
- GM wheat and GM rice are crops that may be adopted in the future. GM wheat field trials conducted in northern America show a yield advantage of 9 per cent for GM wheat resistant to glyphosate. Chinese field trials of GM rice have indicated yield advantages of 3–7 per cent.

### *Reductions in farm cost*

- There are international experiences showing overall cost reduction benefits for GM canola and GM soy bean production. These cost reductions are net of increases in GM seed cost and based on Canadian and United States commercial production experiences. The main contributor to cost reductions in GM canola and GM soy bean is reduced herbicide application and consequently less herbicide, labour and machinery use. Less machinery use implies reduced use of fuel and associated materials and also less machinery time.

- Similar to farmers in the United States, Australian maize farmers have only a small window of time in which to spray maize pests. Therefore the cost offset from using less pesticide by adopting pest-resistant GM maize will be smaller than for other GM crops. Experiences in the United States indicate there could be an increase in material costs for maize production because of the higher cost of GM seeds, which is not fully offset by reductions in other material costs.

## Method for estimating economic impacts of GM crops in Australia

- ABARE's regional general equilibrium model of the Australian economy (*Ausregion*) was used to analyse the economic impacts of changes in yield and costs of production in selected agricultural industries arising from the adoption of GM crop technology. The regional representation in *Ausregion* includes all of Australia's states and territories. The *Ausregion* model also offers the user the flexibility to separate out sub-regions. For the purpose of this report, the New South Wales Murray Catchment Management Area, the Rest of New South Wales and each of the major grain-producing states — Victoria, South Australia, Western Australia and Queensland — are separately identified. The Murray Catchment Management Area is separated out because it is a key canola growing region and to highlight the impact of GM crop cultivation on a regional economy.
- The reference case in *Ausregion* includes GM cotton. The period covered in the analysis extends to 2017-18.
- Two scenarios have been simulated and compared to the case of no new adoption, or the *reference case*. The 'canola-only scenario' examines the impact of adopting only GM canola crops. The other scenario, the 'five-crops scenario', analyses adoption of canola alongside four other GM food crops that are either commercially grown in other countries — soy bean and maize — or have undergone field trials, being wheat and rice.
- For each scenario, two alternative adoption time lines are considered: early adoption (from 2008-09) and delayed adoption (from 2013-14).

## Regional/state income impacts

- The potential economic impacts of cultivating GM crops at the state and regional levels are measured by changes in gross regional products (GRP) from the reference case, aggregated to 2017-18 and presented in 2006-07 present value terms (expressed as 'in 2006-07 dollars' hereafter).

### *Canola-only scenario*

- In the scenario where only GM canola is adopted, GRP is projected to increase for all states/regions. The highest increase in GRP in absolute terms is projected to occur in the 'Rest of New South Wales' region (that is, New South Wales excluding the Murray Catchment Management Area), at $273 million (in 2006-07 dollars) over 10 years to 2017-18, under the early adoption scenario. Under the alternative scenario of delayed adoption, the benefit for the 'Rest of New South Wales' is estimated at a total of $121 million (in 2006-07 dollars), over five years to 2017-18.
- Significant economic benefits of adopting GM canola are also projected for other states. For example, the estimated economic benefit to Western Australia from adopting GM canola from 2008-09 for the next 10 years would be around $180 million in 2006-07 dollars. Similarly, the cumulative benefit to South Australia from adopting canola over the same period is estimated to be around $115 million in 2006-07 dollars.
- Delaying the adoption of GM canola for five years would lead to an estimated forgone benefit of $97 million (in 2006-07 dollars) for Western Australia. Similarly, a delay of five years to adopt GM canola would lead to South Australia foregoing an estimated economic benefit of $66 million (in 2006-07 dollars).

### *Five-crops scenario*

- The cumulative benefits of adopting all five prospective GM crops over 2008-09 to 2017-18 are projected to be $174 million in Queensland, $551 million in the Murray Catchment Management Area, $1.1 billion in Victoria, $1.4 billion in South Australia, $2.4 billion in Western Australia and $2.9 billion in the Rest of New South Wales (all in 2006-07 dollars).
- Under the delayed adoption scenario, the cumulative benefits over 2013-14 to 2017-18 would be around $115 million in Queensland, $243 million in the Murray Catchment Management Area, $486 million in Victoria, $615 million in South Australia, $1.1 billion in Western Australia and $1.3 billion in the Rest of New South Wales (all in 2006-07 dollars).

# 1 Introduction

Genetically modified (GM) crops have been adopted in many countries in the past decade — in particular, in the United States, Argentina, Brazil, Canada, India, China and Australia. After a decade of commercial plantings, the global area of GM crops reached around 114 million hectares in 2007. Cotton, soy bean, maize and canola are the main GM varieties grown, accounting for — by area — 99 per cent of all GM crops planted in 2007 (see Appendix A).

The purpose of this report is to assess the potential economic gains from further GM crop adoption in Australia. Gains to a key canola growing region — the NSW Murray Water Catchment Management Area — and the main grain producing states of New South Wales, Victoria, South Australia, Western Australia and Queensland are quantified under two scenarios — a 'canola-only scenario' and a 'five-crops scenario' (adoption of GM canola alongside GM soy bean, GM maize, GM wheat and GM rice). These scenarios are examined under two alternative adoption timeframes: early adoption (from the 2008-09 financial year) and delayed adoption (from 2013-14), with the cumulative benefits from adoption accruing to 2017-18 in 2006-07 present value terms (hereafter described as 'in 2006-07 dollars').

A canola only scenario assesses the economic benefits from adoption of GM canola in each key canola-growing state in Australia — New South Wales, Victoria, South Australia and Western Australia. A five crops scenario is presented for illustrative purposes, estimating the potential cumulative economic benefits from adoption to 2017-18 under early and delayed adoption scenarios in the states mentioned above and in Queensland. Crops considered are canola, soy bean, maize, wheat and rice.

The benefits that farmers gain by switching to GM crop varieties have been a key driver of the rapid adoption of these crops. These benefits are mainly increased crop yield and reduced farm input costs — especially costs associated with the use of pesticide, herbicide and farm labour. GM crop adoption may also lead to indirect impacts on upstream industries (industries that produce agricultural inputs) and on downstream industries (industries that use agricultural products). The economic benefits derived from the adoption of GM crops are quantitatively assessed later in this report for key agricultural industries (canola, soy bean, maize, wheat and rice) and key producing states/regions in Australia. Other benefits from GM crop adoption, such as increased flexibility in farm management and environmental, occupational health and safety benefits, are less easily quantified but important, and are qualitatively assessed in this report.

A strict regulatory framework for the production and importation of GM products has been adopted in Australia. For example, all dealings in genetically modified organisms, whether domestically produced or imported, are monitored, assessed and approved by the Office of the Gene Technology Regulator (OGTR). In addition, Food Standards Australia and New Zealand provides a strict testing regime to ensure any food derived from crops containing GM modifications is safe for human consumption. State and territory governments are responsible for deciding whether to allow the growing of approved GM crops in their jurisdiction.

Australia's commercial experience with GM crops is largely limited to GM cotton and carnations. The introduction of GM cotton varieties has reduced input costs for cotton farmers, as the varieties planted have been modified to be resistant to insect pests and herbicide treatments, allowing less use of pesticides and labour for clearing cotton fields of weeds during crop rotations. More than 90 per cent of Australian cotton has been planted to GM varieties.

HT canola, a GM variety which is tolerant to herbicide applications, has been approved for commercial release by OGTR. Both the Victorian and New South Wales governments have approved GM canola production for the 2008 growing season, and commercial plantings are likely to commence. Over the longer term, other broadacre GM grain crops, such as wheat, soy bean, rice and maize, may also be approved for commercial plantings and adopted by Australian farmers. For example, wheat modified for drought resistance is currently undergoing field crop trials in Australia (Appendix B). Trials for GM rice have been undertaken in China.

# 2 Costs and benefits of GM crop adoption

This chapter gives an overview of the potential on-farm benefits and costs arising from the adoption of GM crops in Australia. It highlights the potential impact on yield, use of pesticides and herbicides, and labour inputs, using the Australian and international experiences where available. Potential effects on prices and environmental impacts are also presented.

## Crops considered

This report considers the adoption of first generation GM crops — that is, crops with modified traits that provide on-farm production benefits such as protection against insect pest infestation (Bt crops), crops that have been modified to be tolerant to herbicide treatments (HT crops) or crops with a combination of these modifications (stacked trait crops) (see box 1). These GM crops currently account for the bulk of commercial plantings of GM crops globally and in Australia.

### box 1 First generation GM crop traits

Within first generation GM crops there are currently two dominant traits: herbicide tolerance (the HT trait) and insect resistance (the Bt trait). Most of the global first generation GM crop area in 2007 was planted to crops with the HT trait (63 per cent), followed by the Bt trait (18 per cent), with stacked traits accounting for the remainder (19 per cent) (James 2007). Crops with stacked traits contain more than one GM trait — for example, two HT traits or a combination of HT and Bt traits.

Most HT crops have been genetically modified to be resistant to glyphosate. Glyphosate is a non-selective, broad spectrum herbicide that has been used extensively during the past two decades (Reddy 2001). The introduction of HT crops into crop production systems has enabled farmers to better manage weed infestations. GM crop varieties resistant to other herbicides such as sulphonyl urea, imazethapyr and glufosinate-ammonium have also been adopted by farmers to improve weed control (Norton 2003; Sanogo and Yang 1998).

For insect resistance, crops have been modified to include a gene found in soil bacteria *Bacillus thuringiensis* (Bt). This gene produces substances toxic to certain insects. The introduction of Bt crops has led to reductions in insect damage and/or pest control costs.

Second generation crops are expected to give enhanced value to consumers by incorporating traits that lead to enhanced quality attributes in farm products. Third generation crops are expected to produce pharmaceutical or industrial products. Second and third generation crops are still in their early stages of development and are not considered in this report.

# On-farm benefits

The adoption of GM crops is aimed at delivery of on-farm benefits such as higher yields and/or reduced operating costs. GM crop adoption may also lead to indirect impacts on upstream industries (industries that produce agricultural inputs) and downstream industries (ones that use agricultural products). Cumulatively, these benefits can result in increased trade flows and higher national incomes. These results are evaluated in a number of illustrative scenarios presented later in this report.

## Yield effects

Cultivation in Australia of GM crops could reduce yield losses to insect pest and weed infestations. The potential yield of a crop depends on a range of factors, including the genetic potential of a crop variety, farm size, scale, geographical location, water and nutrient availability, soil condition, climatic factors and farmers' management skills. However, in general, the higher the pest and weed incidence is, the greater will be the gain from growing GM crops (Fulton and Keyowski 1999; Marra et al. 2002; Qaim et al. 2006) (table 1 and box 2). To the extent that GM crops reduce yield losses from insect and weed pressures compared with non-GM crops, their adoption will increase farm output.

## Pesticide and herbicide cost savings

GM technology has led to a reduction in on-farm costs associated with pest and weed management. For example, Bt crops provide their own protection against pests and therefore reduce or eliminate the need for pesticide. Also, current HT crops allow the use of relatively inexpensive broad spectrum herbicides, such as glyphosate or glufosinate-ammonium, which effectively control most weeds commonly found in agricultural fields. This eliminates the need for complex herbicide application regimes that require a mix of different, expensive and more toxic weed-specific herbicide sprays.

There is significant variation among countries in the extent to which GM crops lead to cost reductions for pesticide and herbicide inputs. This variation arises from differences in pest/weed pressure, economic trends and conditions, input costs and farm management skills and techniques.

box 2 Yield effects by crop

Cotton: Australian farmers have not received significant yield benefits from Bt cotton adoption as they have been traditionally very effective in controlling helicoverpa caterpillar infestations (Brookes and Barfoot 2006). The main advantage of Bt cotton adoption to Australian farmers has been reduced operational and pesticide costs.

Existing literature indicates that Bt cotton has increased yields in many other countries, although with significant variations among them. Yield increases for cotton producers range between 9–11 per cent in the United States to 43–87 per cent in India (see table 1).

Canola: Australian field trials have demonstrated that GM canola has the potential to increase yields in Australia. The results of Monsanto field trials, conducted side by side with HT canola and alternative non-GM canola varieties and weed management systems, indicate that glyphosate-tolerant canola provides substantial yield gains (8–24 per cent) compared with non-GM varieties. Glyphosate-tolerant canola was found to have similar or higher oil content than currently available varieties. Bayer Crop Science trials of InVigor Canola also indicate yield gains of 9–38 per cent (ACIL Tasman 2007). Pratley and Stanton (2007) also conducted a five-year field trial, in Wagga Wagga, NSW, comparing HT canola to non-GM canola production systems. They reported that HT canola resulted in generally higher yields. Also, Norton (2003) estimated that HT canola has the potential to raise average Australian yields from 1.27 tonnes a hectare to 1.38 tonnes a hectare, an increase of 8 per cent.

In North America, GM canola yield advantages have averaged 6–10 per cent (Carew and Smith 2006; Mayer and Furtan 1999; Serecon Management Consulting Inc and Koch Paul Associates 2001).

Soy bean: On the basis of international experience, yield gains from cultivation of GM soy bean are likely to be limited. Some studies have reported marginal yield gains (Bernard et al. 2004; Fernandez-Cornejo and McBride 2002) and yield losses (Benbrook 2001); however, the small differences in yields reported in the literature are likely to be caused by differences in agronomic conditions and farm management skills. Although significant increases in yield have been reported by Romanian farmers, this could be because a tradition of poor weed control has meant a significant yield advantage with the introduction of HT soy bean (table 1).

Maize: Insect pests damage maize crops, resulting in losses in yields and in farm revenues. For example, in countries affected by the corn borer, such as the United States, or the helicoverpa caterpillar, such as Australia, there is only a limited time during crop rotations in which to apply a pesticide before the pest larva burrows into the stem of the plant. Bt maize has been engineered to provide protection against such pests, thus reducing yield losses in countries where it has been adopted. Bt maize varieties in the United States, Spain and South Africa have achieved yield advantages of between 5 and 11 per cent compared with non-GM varieties (table 1).

Prospective GM crops: GM wheat and GM rice are crops that may be adopted in the future. GM wheat field trials conducted in northern America show a yield advantage of 9 per cent for GM wheat resistant to glyphosate and 1 to 3 per cent yield advantage for fusarium-resistant wheat (Berwald et al. 2006). Chinese field trials of GM rice have indicated yield advantages of 3–7 per cent (Huang et al. 2005).

## 1 Examples of economic impact of GM crops in selected countries

| | yield increase | pesticide/ herbicide reduction | technology fee | labour savings | adoption rate | references |
|---|---|---|---|---|---|---|
| **Cotton** | | | | | | |
| Australia | 0% 1 | 56–75% 1,2 | $155/ha ($30/ha rebate) $245/ha before 1998 1 | 66% 1 | 92% | 1. Fitt (2003); 2. Knox et al. (2006) |
| USA | 9–11% a | US$63–74/ha a | US$58–68/ha a | | 52% a | |
| India | 43–87% 1 | 71–83% 2 | 300% price premium 1 | | 16% a | 1. Qaim (2003); Morse et al. (2005) 2. Bennett et al. (2006) |
| South Africa | 40–70% 1,2,3 | 53–63% 1,2,3 | 48–117% 3 SAR 163–570/ha 4 | 50% 3 | 57% a | 1. Ismael et al. (2001); 2.Thirtle et al. (2003); 3. Morse et al. (2005); 4. Gouse et al. (2002) |
| Argentina | 32–34% 1 | 50% 1 | | | 50% a | 1. Qaim and Janvry (2003); |
| Mexico | 20% 1 | | | | 95% a | 1. Traxler and Godoy-Avila (2004) |
| China | 7–15% 1 | 87% 2 | | | 65% a | 1. Huang et al. (2005) 2. Huang et al. (2003) |
| **Canola** | | | | | | |
| Canada | 6–10% 1, 2 | 40% 2 | C$10.47–15/ac 1, 2 | | 82% a | 1. Mayer and Furtan (1999); Carew and Smith (2006) 2. Serecon Management Consulting Inc and Koch Paul Associates (2001) |
| Australia | 8% 1 8–38% 2 | | | | | 1. Norton (2003); 2.ACIL Tasman (2007) |
| **Soy bean** | | | | | | |
| USA | –2–2% 1,2, a | US$25–34/ha a | €24– 28/ha US$14.82–9.77/ha a | | 93% a | 1. Bernard et al. (2004); 2.Fernandez-Cornejo and McBride (2002); Benbrook (2001) |
| Argentina | 0% 1 | US$24–30/ha 1 | US$3–4/ha 1 | 8% 1 | 99% a | 1. Qaim and Traxler (2005) |
| Romania | 31% 1 | 28.5% 1 | Seeds sold in a package with roundup – small premium 1 | | 67% a | 1. Brookes (2005) |
| **Maize** | | | | | | |
| USA | 5–8% 1 | Generally do not apply pesticide | US$20–25/ha a US$8/ac 1 | | 50% a | 1.Stone at al. (2002); 2.Marra et al. (2002); |
| South Africa | 11% 1 | US$7–8/ha (dry land) US$15–21/ha (irrigated) 1 | US$8–25/ha 1 | | 25% | 1. Gouse et al. (2005) |
| Spain | 4.7% 1 | €4.5 –20/ha 1 | € 3–35/ha 1 | No impact 1 | 11% 1 | 1. Gómez-Barbero and Rodríguez-Cerezo (2007) |

a Brookes and Barfoot (2006).

The evidence presented in Box 3 is taken largely from on-farm experiences around the world. Experiences from countries that have similar production systems to Australia, such as Canada, are likely to provide the best indication of possible advantages to Australian producers.

## Farm management and labour cost savings

Managing crops with GM traits is generally easier and less time consuming. For example, GM crops reduce the number of annual sprays required, therefore reducing labour, machinery and fuel costs. In addition, many HT crops enable farmers to switch to broad spectrum herbicides which allow more flexibility in cropping decisions. Because these herbicides bind to soil particles, they are insoluble and therefore non-persistent. They allow crop decisions to be made on a season-by-season basis without locking fields into particular crop rotations (Norton 2003).

The labour savings and convenience of GM production systems have been widely discussed in the literature and a number of studies have quantified the benefits.

In cotton production the labour savings arising from adoption of GM technology will vary according to seasonal conditions and, in particular, the pest and weed pressures. In Australia, Bt cotton provides savings to farmers through reduced labour and fuel costs and reductions in the time spent in the field applying pesticide. Fitt (2003) estimated spray applications were reduced 66 per cent on average over the first six years of Bt cotton production in Australia. In South Africa, Morse et al. (2005) estimated that, because of the reduced number of sprays, labour required for spraying fell by about 50 per cent. In India, available estimates indicate that Bt cotton can lead to a 75 per cent reduction in the number of sprays each year (Bennett et al. 2004; Marra et al. 2002; Qaim and Janvry 2003; Traxler and Godoy-Avila 2004).

Adoption of HT canola and soy bean has also resulted in fewer herbicide sprays and a movement toward no tillage or minimum tillage cropping — where seeds are sown into the ground with minimal disturbance to top soil — reducing costs through lower machinery, fuel and labour requirements. For example, Gómez-Barbero and Rodríguez-Cerezo (2007) reported 80 per cent of Argentine farmers growing GM soy bean had adopted minimum tillage practices compared with 42 per cent of those growing conventional soy bean. A report published by the Canola Council of Canada in 2001 quantifies fuel savings from GM canola adoption at 5.1 to 6.3 litres per acre. However, no attempt was made to quantify labour cost savings (Serecon Management Consulting Inc and Koch Paul Associates 2001).

Planting HT canola also enabled farmers to practise minimum tillage, saving C$7.50 an acre in operating costs. Qaim and Traxler (2005) have reported labour savings of 8 per cent (US$3.60 a hectare) and fuel and maintenance savings of 28 per cent (US$6.82 a hectare) for Argentine soy bean farmers.

HT technology may allow farmers greater flexibility in planning future crop rotations. Some herbicides used for weed control in crops remain in the soil for as long as 34 months and therefore restrict what can be cropped in future rotations. Herbicides used with HT crops, such as glyphosate or glufosinate-ammonium, typically do not persist in the soil following a crop rotation, thus increasing farmer flexibility in planning future crop rotations (Norton 2003). Early field trials also suggest crops following GM crops have higher yields than those following non-GM crops, because control of weeds reduces weed seed levels and possible hosts for pests in the subsequent crops (Pratley and Stanton 2007).

### box 3 Pesticide and herbicide cost reductions from GM crops

Cotton: In many countries, the introduction of GM cotton has resulted in a reduction of pesticide use of between 50 and 80 per cent. In Australia, for example, it has been estimated Australian farmers have achieved an average reduction in pesticide use of 56 and 75 per cent from adoption of Bt cotton varieties (Fitt 2003 and Knox et al. 2006). In the United States pesticide cost savings of between US$63 and US$74 a hectare have been achieved since commercialisation in 1996 (Brookes and Barfoot 2006). In South Africa, Bt cotton has led to a 53–63 per cent reduction in pesticide cost, with greater savings achieved in years of high pest incidence and in irrigated areas (Morse et al. 2005). In India, pests have traditionally had a devastating impact on cotton crops and so the use of GM cotton has enabled a reduction in pesticide use of 71–83 per cent (Bennett et al. 2006). Qaim and Janvry (2003) and Huang et al. (2003) have reported cost savings of around 50 per cent and 87 per cent for Argentine and Chinese cotton farmers respectively.

Canola: A survey commissioned by the Canola Council of Canada in 2001 found that 80 per cent of farmers reported a 40 per cent (C$9 an acre) reduction in herbicide use when using Liberty Link® or Roundup Ready® GM canola (Serecon Management Consulting Inc and Koch Paul Associates 2001). Similar results are presented in Fulton and Keyowski (1999), Mayer and Furtan (1999) and Gianessi (2005).

Soy bean: The major benefit of HT soy bean is easier and cheaper weed control. Gianessi (2005) compared the cost of weed control in the United States under HT soy bean to the most effective alternative and concluded HT soy bean deliver a saving of US$20 an acre. Brookes and Barfoot (2006) and Fernandez-Cornejo and McBride (2000) reported similar cost savings for United States soy bean farmers of US$22-34 a hectare. Qaim and Traxler (2005) have quantified the herbicide cost savings to Argentine farmers at US$24–30 a hectare. Cost savings of 29 per cent have also been achieved in Romania (Brookes 2005).

Maize: South African farmers have achieved pesticide cost reductions of US$7–21 a hectare, with larger cost savings occurring in irrigated GM maize crops where pest infestations are more prevalent (Gouse et al. 2005). Spanish farmers have reported cost savings of €4.50 to €20 a hectare (Gómez-Barbero and Rodríguez-Cerezo 2007).

From the literature survey, the impact of Bt maize adoption on labour and fuel input costs is uncertain. Where Bt maize adoption leads to a substantial reduction in the number of pesticide sprays, costs associated with spraying are likely to be reduced. In contrast, Gómez-Barbero and Rodríguez-Cerezo (2007) studied the impact of Bt maize on farm labour in Spain and concluded Bt maize does not affect the extent of paid or non-paid labour used.

### Off-farm income

Where adopting GM crops requires farmers to spend less time in the field, they may be able to work off-farm to increase their household income. This was supported by Fernandez-Cornejo et al. (2005), who found a positive relationship between off-farm income and HT soy bean adoption in the United States.

## On-farm costs

### Seed prices, technology fees and user agreements

Farmers opting to grow GM crops are likely to face additional costs in terms of higher seed prices, technology fees and restrictive user agreements.

GM seed providers' commercial practices in setting GM seed prices and charging technology fees to users — largely based on the area of land planted to GM crops — has led to significant variation in the costs faced by GM crop growers for different crops and in different countries (table 1). Gómez-Barbero and Rodríguez-Cerezo (2007) note that seed prices are correlated to pesticide cost savings for Bt maize in different regions in Spain, with premiums being highest where these cost savings are greatest. They also suggest the actual seed price appears to be influenced by farmers' bargaining power. However, where there is competition in the GM seed supply market, as has been the case with HT soy bean seeds in Argentina, seed prices appear to be lower.

The use of GM seed is normally accompanied by a technology user agreement, imposed either by the technology provider or user industry groups. The agreements are often designed to protect intellectual property rights, reduce or delay insect/weed resistance and protect the environment. These agreements could entail additional costs for growers in adhering to regulations such as mandatory buffer zones.

An example of such an agreement is a mandatory refuge area where non-GM crops must be grown. For example, when Bt cotton was first introduced in Australia, the cotton industry restricted adoption to 30 per cent of total farm area because of uncertainties about heliothis pest developing resistance to the Bt protein (Fitt 2003). Now, with improved technology, these restrictions have been removed. For Bt cotton in India, regulations require a minimum of 20 per cent to be planted to conventional cotton, with a five-row buffer zone around all Bt cotton plantings.

## Segregation cost

On-farm segregation arrangements can mean higher costs because of the need for certified planting seed; various crop management techniques (including appropriate separation distances between crops and control of 'volunteer' growth); and cleaning after harvesting, handling, storing and transporting GM grain types (Foster 2006).

Additional costs in the central receival system include extra grain testing requirements and more labour because of a longer receival period. The additional costs are likely to be small relative to on-farm costs and benefits, reflecting the economies of scale with bulk handling of grain (Foster 2006).

## Price premium/discount

If a GM crop is differentiated from its non-GM counterpart in the market, the possibility of either a price premium or price discount exists. A price premium occurs when a product is perceived to have enhanced quality attributes. Quality here refers to the quality of the grains and to the extent that it is free of weeds and other impurities.

As HT crops allow more effective weed control, it is possible they will result in a cleaner harvest and therefore attract a farm gate price premium. This has been observed in Canada where cleaner GM canola has received a price premium of 1.27 per cent over non-GM canola (Serecon Management Consulting Inc and Koch Paul Associates 2001).

GM canola also enables earlier sowing, favouring production of crops with higher oil content. Generally, a price premium is paid for canola with higher oil content. It has been estimated that, if grown in Australia, HT canola would attract a price premium of 1.5–3 per cent, based on the increase in oil content (Foster 2003; Norton 2003).

# Environmental aspects

Bt crops reduce the need for farmers to handle toxic pesticides, and hence improve the occupational health and safety environment for farmers (Marra et al. 2002). Reductions in pesticide applications also result in a reduction in environmental costs associated with spraying, such as spray drift and leaching to groundwater.

HT crops may also deliver environmental, occupational health and safety benefits to farmers. For some crops, such as canola and cotton, HT technology allows replacing more toxic herbicides (such as atrazine) with safer herbicides such as glyphosate or glufosinate-ammonium. It has been estimated that glyphosate is three times less toxic than most herbicides it replaces (Reddy 2001). HT technology also allows farmers to reduce tillage operations before sowing and rely on post-emergence weed control (Norton 2003). Minimum tillage helps to preserve soil structure and protects it from excess wind and water erosion.

Environmental and health issues associated with GM crops have been widely discussed in the literature. Morse et al. (2005) noted there had been fewer hospital admissions resulting from pesticide illness after introducing Bt cotton in South Africa. Pray et al. (2002) reported only 5–8 per cent of Bt cotton farmers in China suffered from pesticide illness compared with 22–29 per cent of other cotton farmers.

Knox et al. (2006) looked into the specific environmental benefits of Bt cotton in Australia. They reported Bt cotton has contributed considerable environmental benefits. Fitt (2003) also found evidence for environmental benefits associated with a reduction in pesticide use in cotton growing areas in Australia of 1.75 million litres. Qaim and Traxler (2005) reported the wider adoption of less toxic herbicides after introducing HT soy bean in Argentina.

Regarding biodiversity, a study conducted in Spain found there had been no detrimental effect of Bt maize on predatory insects (Gómez-Barbero and Rodríguez-Cerezo 2007). Morse et al. (2005) also found adoption of Bt cotton in South Africa led to an increase in on-farm biodiversity and a return of beneficial predatory insects owing to the reduced use of pesticides. These findings agree with a comprehensive review of the literature on the environmental impact of GM crops conducted by Romeis et al. (2006).

Minimising the impact of GM cropping technologies on the environment will require best practice farming techniques to be adopted and sustained. For example, the potential development of resistance in the weed spectrum from HT crop production systems arising from regular use of a single herbicide will require monitoring and changes to farming practices where appropriate.

Evidence for increased resistance in the pest/weed spectrum as a result of GM crop production is scant. These issues are considered on a case-by-case basis during the OGTR's approval process for the growing of GM crops and measures are put in place to manage resistance based on the level and nature of the risk.

# Economic costs and benefits to other sectors

Adoption of GM crops can have a number of indirect impacts on interrelated upstream industries such as seed, fertiliser and pesticide industries and downstream industries such as transport, storage, feed processing, livestock, food processing and textile industries. This section examines how interrelated industries may be affected by GM crop adoption.

## *Technology providers*

When a new technology enters the market, the total benefit of that technology is usually shared among the technology provider, technology users and consumers. The degree of competition in the market will determine how the total benefits of GM technologies are shared among the three groups (see box 4). In some instances GM seed supply companies hold a patent over their technology and have therefore been successful in retaining a share of the total benefits from their innovation. Farmers and consumers have also received benefits.

## *Herbicide and pesticide industries*

The introduction of GM crops may also affect herbicide and pesticide producers. Adoption of GM crops reduces the use of herbicide and pesticide and, as a consequence, the demand for these products decreases.

### box 4 Empirical studies on the benefits to seed suppliers from the sale of GM seeds

Empirical studies investigating the benefits to upstream GM seed suppliers have found benefits vary. Flack-Zepeda et al. (2000) studied data from the introduction of Bt cotton in the United States from 1996–98 and found seed companies were extracting 36 per cent (US$77.4 million) of the total benefit (US$215 million). The remainder of the benefit was shared between farmers (45 per cent of total) through increased productivity and consumers (19 per cent) through lower prices. In Argentina, Trigo and Cap (2003) estimated that, from 1998 to 2003, Bt cotton technology suppliers received 83 per cent (US$35 million) of the total benefits (US$42 million).

Other studies have estimated the gain to GM soy bean seed suppliers. Traxler (2004) reported that although lower prices have led US consumers to benefit the most from GM soy bean adoption, receiving 53 per cent of the total benefits, biotechnology companies are extracting a substantial proportion (34 per cent). The case is different for GM soy bean technology suppliers in Argentina. Weak protection of intellectual property rights for GM soy bean seed has enabled competition in the GM seed market, and benefits have largely been passed on to farmers. Trigo and Cap (2003) and Traxler (2004) have estimated seed companies are receiving only 4–8 per cent of total benefits.

The decrease in demand may put downward pressure on prices of conventional herbicides and pesticides. Bullock and Nitsi (2001) found herbicide prices in the United States fell by 50 per cent between 1996 and 1999. Part of the decline might be attributed to GM technology adoption during that period. Desquilbet and Lemarie (2002) also argued there would be substantial losses for conventional herbicide producers if HT rapeseed were to be introduced in France, as a result of lower sales and prices. In the case of a price fall, farmers who continue to produce non-GM crops will benefit.

As farmers adopt GM technology the demand for herbicides used on HT GM crops will increase, possibly leading to price increases for these herbicides. For example, Bullock and Nitsi (2001) reported the price of glyphosate increased between 1995 and 1998 as a result of the adoption of Roundup Ready® soy bean.

### *Downstream industry impacts*

As a cost-reducing technology, GM crop adoption is likely to lead to falls in crop prices. Assuming no change in the demand structure, downstream industries and consumers will all benefit from lower prices arising from the technology.

Economy-wide models can be used to conduct economic analysis of benefits from GM technology adoption. Huang et al. (2003) assessed the potential economic benefits of Bt cotton and Bt rice production in China. They estimated a 10.9 per cent decline in cotton prices as a result of the introducing Bt cotton. This resulted in a 4.8 per cent increase in supplies to the domestic textile sector. In the case of rice, which is currently in the pre-production trial stage in China, economic modelling indicates a 12 per cent reduction in price resulting from higher yield and lower production costs.

Anderson et al. (2006) studied the global impact of Bt cotton adoption using a global general equilibrium model. The results show a fall in the world price of cotton. As a result, cotton importing countries would receive benefits for their textile industries.

## Regional impacts

The impact of GM crop adoption on a regional economy will be determined by the importance of the agricultural and local processing sectors for that economy. For economies where agriculture contributes a larger share of gross regional product (GRP) the impact of GM crop adoption will be more pronounced.

# 3 Potential economic impacts of GM crops in Australia

In this chapter, the economic impacts of two alternative GM crop adoption scenarios for Australia are discussed and quantitatively assessed for key grain-growing states, and for illustrative purposes, a key region within New South Wales. The first scenario (the canola-only scenario) provides an estimate of the economic effects of a full adoption of GM canola. The second scenario (the five-crops scenario) provides an estimate of the economic effects of the full adoption of three GM crops commercially grown in other countries — canola, soy bean and maize and two other GM crops not yet available for commercial production but have undergone field trials, wheat and rice.

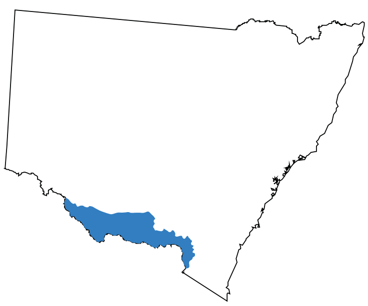
## Analytical framework

ABARE's *Ausregion* model — a dynamic multiregional computable general equilibrium model of the Australian economy — is used to assess alternative GM adoption strategies in Australia. The model incorporates the interactions and financial flows between sectors and economic agents, including consumers, governments and foreign buyers, and projects the economic impacts into the future, both at regional and national levels.

For the purposes of this report, *Ausregion* industry coverage has been aggregated to cover 29 industries including 16 agricultural industries. The regional representation includes the New South Wales Murray Catchment Management Area, which is separated out from New South Wales, the rest of NSW and the other key grain growing states — Victoria, South Australia, Western Australia and Queensland. The New South Wales Murray Catchment Management Area is a region of significant crop production (see map 1). It is separated out as a case-study region to highlight the estimated impact of GM crop cultivation for such an area.

The reference case represents the case where the only GM crop produced is cotton. It assumes that no other GM crops will be adopted in Australia. To analyse the effects of the introduction of new GM crop technologies in Australia, the reference case is used as a point of comparison for each alternative GM adoption scenario. A change of economic activity arising from implementing scenarios is represented as the deviation from the reference case.

**map 1** New South Wales Murray Catchment Management Area



# Assumptions

## *Productivity gains*

The potential economic impacts of GM crops on industries and the economy are simulated in *Ausregion* using changes in productivity. Increases in yield are represented by increases in overall output productivity, producing more with the same level of inputs. Similarly, savings in material, labour and capital inputs are implemented in the modelling.

Chapter 2 highlights that yield and cost savings attributed to GM crop adoption vary in different countries. Owing to the paucity of data available from field trials in Australia for the GM crops considered in the scenarios, proxy assumptions for yield changes, and material and labour/capital input cost savings have been drawn from international experience and used for the analysis (table 2). In particular, experiences of countries likely to have agricultural technologies most similar to Australia's, (namely Canada and the United States) are selected where available.

The potential yield increases in table 2 lie within the range of yield improvements from international literature (see table 1). The potential canola yield increase of 10 per cent is based on field trials and commercial production in Canada (Serecon Management Consulting Inc and Koch Paul Associates 2001) and field trials in Australia (ACIL Tasman 2007). In countries where it is currently grown, GM soy bean varieties were found to have little yield impact (Qaim and Traxler 2005). For maize, US experience has shown an average yield increase of 6.5 per cent (Stone et al. 2002; Marra et al. 2002). A yield increase of 9 per cent was reported from experimental field trials of wheat in Canada (Berwald et al. 2006). A yield increase of 5 per cent for GM

### 2 Assumed yield and cost changes with GM adoption by scenario a

| GM crop | yield | material cost | labour/capital cost |
|---|---|---|---|
| canola-only scenario | % | % | % |
| canola b | 10 | –2.4 | –3.8 |
| Five-crops scenario | | | |
| canola b | 10 | –2.4 | –3.8 |
| soy bean b | 0 | –13 | –11 |
| maize b | 6.5 | 13 | – |
| wheat | 9 | – | – |
| rice | 5 | – | – |

**a** Percentage change for GM crop compared with non-GM crop; **b** In *Ausregion*, canola is aggregated into the 'oilseeds' sector and soy bean and maize are aggregated into the 'other grains' sector. Hence, in each simulation, the yield improvements and cost savings shown in table 2 for canola are adjusted for each region to reflect the relative contribution of canola to each region's oilseeds sector. Similarly, the yield improvements and cost savings for maize are adjusted to reflect the relative contribution of maize to each region's 'other grains' sector.

rice was obtained from results of individual farm trials in China (Huang et al. 2002; Huang et al. 2005).

There are also cost reduction benefits for GM canola and GM soy bean production (see table 2). These cost reductions are net of increases in GM seed cost. The cost reductions for the two crops are estimated from Canadian and United States commercial production experiences respectively (Serecon Management Consulting Inc and Koch Paul Associates 2001; Brookes and Barfoot 2006). The cost reduction estimates are based on reduced herbicide application and consequently less herbicide, labour and machinery use. Less machinery use implies reduced use of fuel and associated materials and also less machinery time. The combined savings in herbicide, fuel and associated materials make up material cost reduction. Savings in labour and machinery time make up labour/capital cost reduction.

Like farmers in the United States, Australian maize farmers have only a small window of time in which to spray maize pests. Therefore the cost offset from using less pesticide by adopting pest-resistant GM maize will be smaller when compared to those for other GM crops. Positive values for material inputs in maize production in table 2 indicate increases in material costs resulting from higher costs of GM seeds which are not fully offset by reductions in other material costs.

### *Adoption rate*

Both the 'canola-only' and 'five-crops' scenarios assume full adoption of the GM crops in Australia starting in the first year of adoption. This assumption is designed to be purely illustrative. In reality GM crops are likely to be adopted progressively and not by all farmers. As a result, some form of identity preservation, or the ability to trace products back to their origin, for non-GM and GM crops may be required. The assumption of 100 per cent adoption of GM crops in the current analysis means identity preservation costs are not necessary and hence not incorporated.

### *Discount rate*

The overall potential impacts of cultivating GM crops for the state and regional economies are measured as the sum of changes in gross regional product of these economies, from the year of adoption to 2017-18. In order to convert future income flows to present value terms, an assumed discount rate of 5.0 per cent has been used for the analysis.

### *Adoption scenarios*

Two alternative adoption time lines are considered for the scenarios; adopting early (from 2008-09) and adopting late (from 2013-14). The economic effects in both scenarios are evaluated from the assumed adoption year in each respective scenario to 2017-18.

# Results

### *Regional/state income impacts*

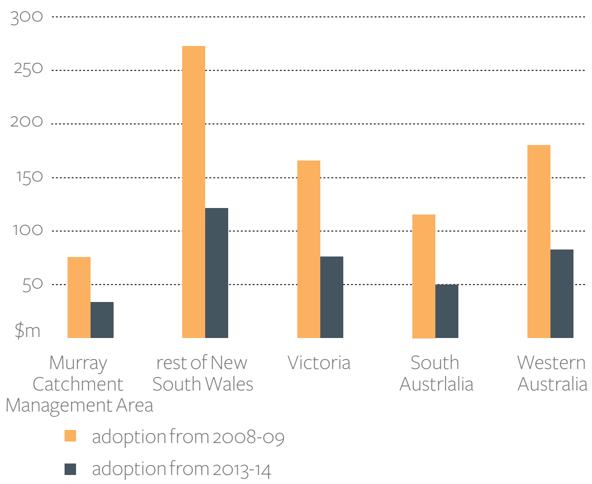
The estimated present values highlight the difference in economic gains under the early and delayed adoption scenarios. They also illustrate the comparative benefits of adopting GM canola only and the five prospective crops. Economic impacts for the respective states are presented to illustrate the relative importance of GM crop adoption to a particular state.

Under all scenarios economic activity increases most in the Rest of New South Wales region (that is, NSW excluding the Murray Catchment Management Area) and Western Australia. Substantial increases in GRP in Victoria and South Australia are also projected. These increases are attributable to the large potential for GM crop adoption in these region/states. However, the Murray Catchment Management Area gains the most relative to the size of its economy, as the cropping sector forms a substantial proportion of the regional economy.

## 'Canola-only' scenario

Under the 'canola-only' scenario, gross regional product is projected to increase in all canola producing regions/states. The highest cumulative increase is projected in the Rest of New South Wales region, at around $273 million (in 2006-07 dollars) under the assumption of early adoption and $121 million (in 2006-07 dollars) under the delayed adoption assumption (figure a). The difference between the gains under the two scenarios indicates that the Rest of New South Wales would lose substantially by delaying GM canola adoption.

**a** Economic benefits of GM canola adoption
in 2006-07 dollars cumulative from the adoption year to 2017-18



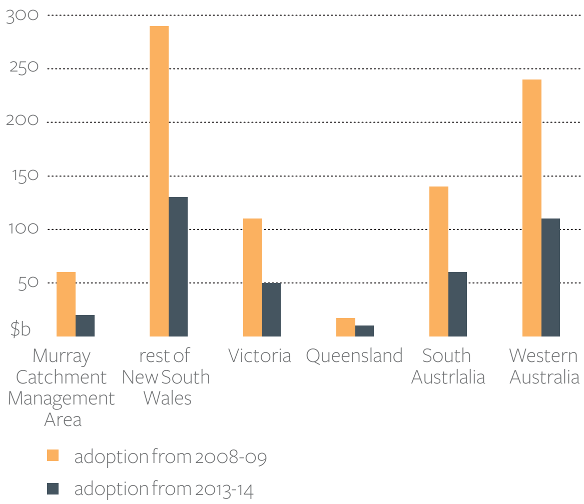
Significant economic benefits of adopting GM canola are also projected for other states. For example, the cumulative economic benefit for Western Australia to adopt canola from 2008-09 for the next 10 years would be around $180 million in 2006-07 dollars. Similarly, the benefit for South Australia to adopt canola over the next 10 years would be around $115 million in 2006-07 dollars. Delaying canola adoption for five years would lead to forgone benefits of $97 million (in 2006-07 dollars) for Western Australia and $66 million (in 2006-07 dollars) for South Australia.

The cumulative benefit of adopting GM canola for the economy of the Murray Catchment Management Area is projected to be $76 million (in 2006-07 dollars) under earlier adoption and $34 million (in 2006-07 dollars) under delayed adoption. However, compared with other regions/states, adopting GM canola in the Murray Catchment Management Area has the largest gain relative to the size of its economy.

## ‘Five-crops’ scenario

Under the scenario that GM canola is adopted alongside four other GM field crops — soy bean, maize, wheat and rice — the cumulative economic gains to states/regions are projected to range from $174 million (in 2006-07 dollars) in Queensland to $2.9 billion (in 2006-07 dollars) in the Rest of New South Wales over 2008-09 to 2017-18 (figure b). The cumulative economic benefit for Western Australia to adopt the five GM field crops from 2008-09 for the next 10 years would be around $2.4 billion in 2006-07 dollars. Similarly, the benefit for South Australia to adopt the five GM crops over the same period would be around $1.4 billion in 2006-07 dollars.

**b** Economic benefits of five GM crops adoption
in 2006-07 dollars cumulative from the adoption year to 2017-18



The benefits reduce where the adoption of these crops is delayed. If the adoption is delayed to 2013-14, the benefits to states/regions would range from $115 million in Queensland to $1.3 billion in the Rest of New South Wales. Under this scenario, significant benefits for major field crop producing states/regions are foregone through delaying adoption. For example, the Murray Management Catchment Area gains a cumulative $243 million (in 2006-07 dollars) under delayed adoption compared with a cumulative $551 million (in 2006-07 dollars) from earlier adoption.

Delaying adoption for five years would lead to foregone benefits totalling $1.3 billion (in 2006-07 dollars) for Western Australia and $814 million (in 2006-07 dollars) for South Australia.

# 4 Conclusion

Since the first commercialisation of GM crops in 1996, there has been rapid global adoption, suggesting GM crops are providing benefits to farmers. Australia's experience with GM field crops has been limited to GM cotton. Various GM cotton varieties are available to Australian cotton farmers and adoption has now exceeded 90 per cent of total cotton planting area.

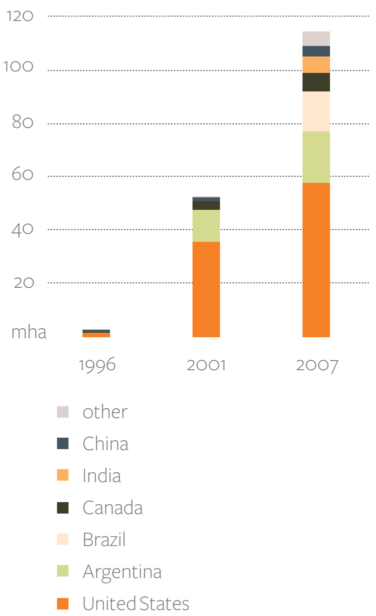
In this report the potential economic impacts of GM crop adoption in Australia are assessed. The analysis was conducted at the state and regional level. Adoption of GM canola is estimated to increase both state and regional gross income. The highest increase is projected in the Rest of New South Wales region, at $273 million (in 2006-07 dollars) over 10 years under an early adoption scenario and at $121 million (in 2006-07 dollars) over five years under a delayed adoption scenario. The difference between the estimated gains under the two scenarios indicates substantial fore-gone benefits are associated with delaying adoption. Significant economic benefits of adopting GM canola are also projected for other states.

The economic impact of the potential introduction of five GM crops — canola, soy bean, maize, rice and wheat — from 2008-09 and 2013-14 respectively was also considered. Under the scenario that GM canola is adopted alongside four other GM field crops — soy bean, maize, wheat and rice — the cumulative economic gains to states/regions are projected to range from $174 million (in 2006-07 dollars) in Queensland to $2.9 billion (in 2006-07 dollars) in the Rest of New South Wales over 2008-09 to 2017-18 (figure b). The benefits are reduced where adopting these crops is delayed. If the adoption is delayed to 2013-14, the benefits to states/regions would range from $115 million in Queensland to $1.3 billion in the Rest of New South Wales.

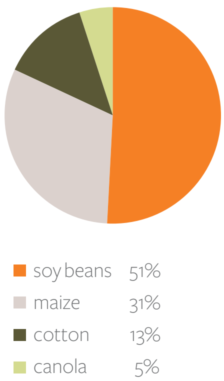
appendix

# A International adoption of GM crops and the Australian experience

## C Global adoption of GM crops




## d Land area planted to major GM crops globally in 2007




The first significant planting (1.7 million ha) of GM crops took place in the United States. Since then, global adoption of GM crops has increased rapidly, reaching 114 million hectares by 2007, with the United States accounting for 50 per cent of this area (figure C). Other principal adopters of GM crops are Argentina, Brazil, Canada, India and China, which together with the United States accounted for around 95 per cent of the global area grown to GM crops (James 2007). GM crops are also being increasingly adopted by farmers in other countries, with 17 countries accounting for the remainder of global GM crop production.

In terms of the area cultivated worldwide, the predominant GM crops planted to date have been soy bean (51 per cent), maize (31 per cent), cotton (13 per cent) and canola (5 per cent) (figure D) (James 2007). Other commercially planted GM crops include tomato, potato, sugar beet, tobacco, squash, alfalfa, melon and papaya. These accounted for less than 1 per cent of total GM crop plantings in 2006.

Soy bean is an important livestock feed and food crop. Critical to soy bean production is the effectiveness and efficiency of weed control. Accordingly, HT soy bean varieties have been rapidly adopted, reaching 64 per cent of the total world area planted to soy bean in 2006 — equivalent to 57 per cent of the area under all GM crops. The United States is the main producer of HT soy bean, with Argentina and Brazil also contributing significantly to world production (Gómez-Barbero and Rodríguez-Cerezo 2006).

Maize provides the largest share of global coarse grain production. GM maize varieties have been developed using the Bt trait to provide protection against losses in yields arising from insect pests. By 2006, Bt maize accounted for an area of 25.2 million hectares, or around 17 per cent of the global maize area. The majority of GM maize is grown in the United States, South Africa and Argentina. Small areas of GM maize are planted annually in the European Union (James 2007).

Cotton is the world's leading industrial crop in terms of area cultivated (Gómez-Barbero and Rodríguez-Cerezo 2006). Cotton is highly susceptible to a number of insect pests and is therefore heavily reliant on pesticides. Around a quarter of pesticide use worldwide is in cotton production. To reduce pesticide use and yield losses, cotton varieties have been engineered to produce a protein that is toxic to certain species of insects (Bt cotton).

The proportion of the global cotton area planted to GM varieties was around 43 per cent (15.0 million ha) in 2007. In 2007, most of these plantings were for Bt cotton (72 per cent), followed by Bt/HT cotton (21 per cent) and HT cotton (7 per cent) James (2007).

Canola is used for both human food and animal feed. Management of broad leaf weeds in canola crops is an important activity in production, as competition for nutrients by weeds reduces overall crop yields. HT canola contains genes, which provide tolerance to broad spectrum herbicides such as glyphosate and glufosinate-ammonium, providing a management tool for weed control. In 2006, the proportion of global canola area planted to GM varieties was around 18 per cent. Currently, the only producers of GM canola are Canada and the United States.

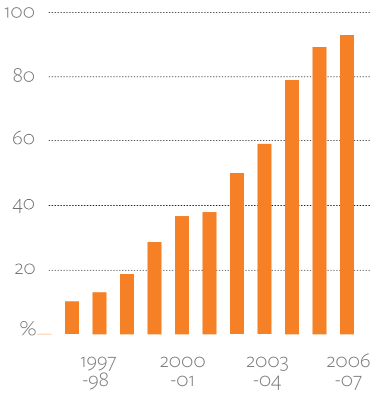
# Australia's adoption of GM crops

## GM cotton

Australia is a significant producer of cotton. In the period 2000–01 to 2005–06, Australia produced an average of 590 400 tonnes a year of cotton lint (ABARE 2006). Australia is also a significant exporter of cotton lint, ranking fifth. Currently GM cotton varieties account for around 90 per cent of total Australian cotton plantings (James 2007) (figure e).

**e** GM cotton adoption in Australia

per cent of total cotton planted to GM




Cotton is susceptible to attacks from insect pests, notably the helicoverpa caterpillar. A range of GM cotton varieties have been adopted by Australian cotton producers since 1996, resulting in a reduction in the use of pesticides and herbicides. Varieties such as Ingard and Bollgard II cotton contain proteins toxic to the helicoverpa caterpillar, and have been widely planted by cotton farmers. More recently, Australian producers have adopted cotton varieties incorporating HT traits resistant to the application of broad spectrum herbicides — such as Monsanto's Roundup Ready® Flex — allowing herbicide applications well into the later stages of the growing season. These GM cotton varieties are available with stacked Bt and HT traits and have been widely accepted by cotton producers, accounting for 80 per cent of the total area planted to GM cotton in 2007 (James 2007).

Currently both private and public research is being conducted into future varieties of GM cotton. For example, field trials are either being undertaken or planned for GM varieties resistant to water logging, can use water more efficiently, or improve the fungal resistance of the plant (Ministerial GMO Industry Reference Group 2007).

Over the longer term, it is possible GM cotton technology will enable cotton production to expand into areas where it is now unviable. For example, cotton production in the Ord River Irrigation Area ceased in the 1970s because of difficulties in controlling pests. However GM technology may make cotton production a viable option in this area (Ministerial GMO Industry Reference Group 2007).

### GM canola

HT canola has been licensed for release by the Office of the Gene Technology Regulator (OGTR) and has been approved for commercial release in Victoria. New South Wales has approved the release of GM food crops, including canola, but under a strict licence regime and subject to final ministerial approval. Other state and territory governments continue to review their moratoria on the growing of GM crops, apart from the Northern Territory and Queensland where no restrictions are placed on the growing of GM crops once approved by the OGTR.

## Prospective GM crops

### *Wheat*

In June 2007, the Victorian Department of Primary Industries was granted a licence from the OGTR to carry out field trials of drought-resistant wheat. Also, the CSIRO is currently conducting field trials for GM wheat with increased starch content (Glover et al. 2005). In addition, Grains Biotech Australia has conducted field trials of herbicide and salt-tolerant wheat (O'Niel 2005).

Significant research is also being undertaken into developing GM wheat varieties for commercial release overseas. For example, Syngenta, a Swiss-based company, is carrying out field trials in North America of a GM wheat variety resistant to the fungal disease fusarium, a disease which can stunt plant growth and reduce yields of wheat crops by around 1–3 per cent (Gianessi 2005). Fusarium-infected crops also pose a serious risk to consumers as toxins produced by the fungus can affect human health (GMO Compass 2006). GM wheat field trials are also under way in Mexico and China (Berwald et al. 2006).

### *Rice*

Research into developing suitable GM rice strains is in progress globally. A world leader in GM rice research is China, where several varieties of insect-resistant GM rice have passed field and environment release trials and are now being tested in farm trials (Huang et al. 2005).

appendix

# B Research and development in GM crops in Australia

Australian research institutions, state agriculture departments and local and international biotechnology companies are engaged in biotechnology programs and many of these involve field trials of GM crops (see table 3).

## 3 Examples of GM field crop trials currently under way

| State/territory | GM crop | GM trait |
|---|---|---|
| New South Wales | Cotton | Water use efficiency |
| Victoria | Canola and Indian mustard | Herbicide tolerance and hybrid breeding system |
| Victoria | Wheat | Drought tolerance |
| Victoria | Grapevines | Expression of modified colour, sugar composition, flowering and fruit development |
| Victoria | Rose | Altered flower colour |
| Victoria | White clover | Viral resistance |
| Queensland | Papaya | Delayed fruit ripening |
| Queensland | Sugar cane | Altered plant architecture, enhanced water or improved nitrogen use efficiency, Altered sugar content |
| Queensland | Pineapple | Reduction of blackheart, delayed flowering |

*Source*: Office of the Gene Technology Regulator, www.ogtr.gov.au.

In addition to the trials under way, a number of field trials are in the post-harvest monitoring phase (see table 4).

## 4 Examples of GM field crop trials in post-harvest monitoring phase

| State/territory | GM crop | GM trait |
|---|---|---|
| New South Wales | Rice | Herbicide tolerance |
| New South Wales | Cotton | Insecticidal, herbicide tolerance, and water logging tolerance |
| New South Wales | White clover | Viral resistance |
| Victoria | Canola | Herbicide tolerance, hybrid breeding system |
| Victoria | Indian mustard | Herbicide tolerance, hybrid breeding system |
| Queensland | Cotton | Water use efficiency, fungal resistance, insecticidal, herbicide resistance |
| South Australia | Canola | Herbicide tolerance, hybrid breeding system |
| South Australia | Indian mustard | Herbicide tolerance |
| Tasmania | Canola | Fungal and herbicide resistance |
| ACT | Wheat | Altered grain starch |

*Source*: Office of the Gene Technology Regulator www.ogtr.gov.au.

# References

ABARE 2006, *Australian Commodity Statistics*, Australian Bureau of Agricultural and Resource Economics, Canberra.

ACIL Tasman 2007, *GM Canola: An Information Package*, Prepared for the Department of Agriculture, Fisheries and Forestry.

Anderson, K, Valenzuela, E and Jackson, L A 2006, *Recent and Prospective Adoption of Genetically Modified Cotton: A Global CGE Analysis of Economic Impacts*, The World Bank, Washington DC.

Benbrook, C 2001, *Troubled Times Amid Commercial Success for Roundup Ready Soy bean — Glyphosate Efficacy is Slipping and Unstable Transgene Expression Erodes Plant Defences and Yields*, Northwest Science and Environmental Policy Centre, Idaho.

Bennett, R M, Ismael, Y, Kambhampati, U and Morse, S 2004, 'Economic impact of genetically modified cotton in India', *AgBioForum*, vol. 7, no. 3, pp.96–100.

Bennett, R M, Kambhampati, U, Morse, S and Ismael, Y 2006, 'Farm-level economic performance of genetically modified cotton in Maharashtra, India', *Review of Agricultural Economics*, vol. 28, no. 1, pp.59–71.

Bernard, J C, Pesek, J and Fan, C 2004, 'Performance results and characteristics of adopters of genetically engineered soy bean in Delaware', *Agricultural and Resource Economics Review*, no. 33, pp.282–292.

Berwald, D, Carter, C A and Gruere, G P 2006, 'Rejecting new technology: The case of genetically modified wheat', *American Journal of Agricultural Economics*, vol. 88, no. 2, pp.432–447.

Brookes, G 2005, 'The farm-level impact of herbicide-tolerant soy bean in Romania', *AgBioForum*, vol. 8, pp.235–241.

Brookes, G and Barfoot, P 2006, *GM crops: The First Ten Years — Global Socio-economic and Environmental Impacts*, ISAAA Briefs, Brief 36, Ithica, NY.

Bullock, D S and Nitsi, E I 2001, 'Roundup ready soy bean technology and farm production costs', *American Behavioural Scientist*, vol. 44, pp.1283–1301.

Carew, R and Smith, E G 2006, 'Assessing the contribution of genetic enhancements and fertilizer application regimes on canola yield and production risk in Manitoba', *Canadian Journal of Agricultural Economics*, vol. 54, pp.215–226.

Desquilbet, M and Lemarie, S 2002, *Exploring diversity in the European agri-food system*, Zaragoza, Spain.

Fernandez-Cornejo, Jorge, C H and Mishra, A 2005, 'Technology adoption and off-farm household income: The case of herbicide-tolerant soy bean', *Journal of Agricultural and Applied Economics*, no. 37, pp.549–563.

Fernandez-Cornejo, J and McBride, W 2000, *Genetically Engineered Crops for Pest Management in U.S Agriculture*, Resource Economics Division, Economic Research Service, USDA, Agricultural Economics Report No. 786.

–– 2002, *Adoption of Bioengineering Crops*, Agricultural Economic Report, Washington.

Fitt, G P 2003, 'Implementation and impact of transgenic Bt cottons in Australia', *The ICAC Recorded*, vol. 21, pp.14–119.

Flack-Zepeda, Traxler, G and R G, N 2000, 'Rent creation and distribution from biotechnology innovation', *Agribusiness*, vol. 16, no. 1, pp.21–32.

Foster, M 2003, *GM Canola: What are its Economics Under Australian conditions?*, Prepared for the Grains Research and Development Corporation, Canberra.

–– 2006, *GM grains in australia: identity preservation*, Australian Bureau of Agricultural and Resource Economics, Canberra.

Fulton, M and Keyowski, L 1999, 'The producer benefits of herbicide-resistant canola', *AgBioForum*, vol. 2, no. 2, pp.85–93.

Gianessi, L.P 2005, 'Economic and herbicide use impacts of glyphosate-resistant crops', Pest Management Science, vol. 61, pp.241–245.

Glover, J , Mewett, O , Tifan, M , Cunningham, D , Ritman, K and Morrice, B 2005, *What's in the Pipeline? Genetically Modified Crops Under Development in Australia*, Australian Government Bureau of Rural Sciences, Canberra.

GMO Compass 2006, *In Wheatcompass*, G (Ed). Available from URL: http://www.gmo-compass.org/eng/grocery_shopping/crops/22.genetically_modified_wheat.html

Gómez-Barbero, M and Rodríguez-Cerezo, E 2007, *GM Crops in EU Agriculture*, European Commission, DG-JRC, Institute for Prospective Technological Studies, Seville.

Gouse, M , Kristen, J F and Jenkins, L 2002, *BT Cotton in South Africa: Adoption and the Impact on Farm Incomes Amongst Small-Scale and Large-Scale Farmers*, Department of Agricultural Economics, Extension and Rural Development, Pretoria.

Gouse, M , Pray, C , Kirsten, J and Schimmelpfennig, D 2005, 'A GM subsistence crop in Africa: the case of Bt white maize in South Africa', *International Journal of Biotechnology*, vol. 7, pp.84-94.

Huang, J , Hu, R , Rozelle, S , Qiao, F and Pray, C 2002, 'Transgenic varieties and productivity of smallholder cotton farmers in China', *Australian Journal of Agricultural and Resource Economics*, vol. 46, no. 3, pp.367–387.

Huang, J , Hu, R , Pray, C , Qiao, F and Rozelle, S 2003, 'Bt cotton benefits, costs, and impacts in China', *AgBioForum*, vol. 5, no. 3, pp.1–14.

Huang, J , Hu, R , Rozelle, S and Pray, C 2005, 'Insect-resistant GM rice in farmers' fields: Assessing productivity and health effects in China', *Science*, vol. 308, no. 5722, pp.688-690. Available from URL: http://www.sciencemag.org/cgi/content/abstract/308/5722/688

Ismael, Y, Bennett, R and Morse, S 2001, 'Farm level impact of Bt cotton in South Africa', *Biotechnology and Development Monitor*, vol. 48, pp.15–19.

James, C 2007, *Global status of commercialized biotech/GM crops: 2007*, ISAAA Brief No. 37., Executive Summary, International Service for the Acquisition of Agribiotech Applications (ISAAA), New York.

Knox, O G G , Constable, G A , Pyke, B and Gupta, V V S R 2006, 'Environmental impact of conventional and Bt insecticidal cotton expressing one and two Cry genes in Australia', *Australian Journal of Agricultural Research*, vol. 57, pp.501-509.

Marra, M.P , Pardey, P and Alston, J 2002, 'The payoffs to transgenic field crops: an assessment of the evidence', *AgBioForum*, vol. 5, no. 2, pp.43–50.

Mayer, H and Furtan, W .H 1999, 'Economics of transgenic herbicide-tolerant canola: The case of western Canada', *Food Policy*, vol. 24, pp.431–442.

Ministerial GMO Industry Reference Group 2007, *GM Cotton in the Ord River Irrigation Area* Discussion paper, July 2007, Perth.

Morse, S , Bennett, R and Ismael, Y 2005, 'Bt-cotton boosts the gross margin of small-scale cotton producers in South Africa', *International Journal of Biotechnology*, vol. 7, pp.72–83.

Norton, R 2003, *Conservation Farming Systems and Canola,* The University of Melbourne, Melbourne.

O'Niel, G 2005, *Grain biotech harvests first salt-resistant wheat crop, Australian Life Scientist*. Available from URL: http://www.biotechnews.com.au/index.php/id;1548103697;fp;4;fpid;2

Pratley, J E and Stanton, R A 2007, *Genetically Modified Crops Moratorium Review,* E H Graham Centre for Agricultural Innovation, Wagga Wagga.

Pray, C , Huang, J and Rozelle, S 2002, 'Five years of Bt cotton in China: The benefits continue', *The Plant Journal*, vol. 31, no. 4, pp.423–430.

Qaim, M 2003, 'Bt cotton in India: field trial results and economic projections', *World Development*, vol. 31, no. 12, pp.2115–2127.

Qaim, M and Janvry, A.d. 2003, Paper presented at the 7th ICABR conference, Ravello, Italy.

Qaim, M , Subramanian, A , Naik, G and Zilberman, D 2006, 'Adoption of Bt Cotton and Impact Variability: Insights from India', *Review of Agricultural Economics*, vol. 28, no. 1, pp.48–58. Available from URL: http://www.blackwell-synergy.com/doi/abs/10.1111/j.1467-9353.2006.00272.x

Qaim, M and Traxler, G 2005, 'Roundup Ready soy bean in Argentina: farm level and aggregate welfare effects', *Agricultural Economics*, vol. 32, no. 1, pp.73–86. Available from URL: http://www.blackwell-synergy.com/doi/abs/10.1111/j.0169-5150.2005.00006.x

Reddy, K N 2001, 'Glyphosate-resistant soy bean as a weed management tool: opportunities and challenges', *Weed Biology and Management*, vol. 1, pp.193–202.

Romeis, J , Meissle, M and Bigler, F 2006, 'Transgenic crops expressing Bacillus thuringiensis toxins and biological control', *Nature Biotechnology*, vol. 24, pp.63–71.

Sanogo, S and Yang, X 1998, 'Herbicide-tolerant crops and plant diseases', *Integrated Crop Management*, vol. 1.

Serecon Management Consulting Inc and Koch Paul Associates 2001, *An Agronomic and Economic Assessment of Transgenic Canola*, Canola Council of Canada.

Stone, S , Matysek, A and Dooling, A 2002, *Modelling Possible Impacts of GM Crops on Australian Trade*, Staff Research Paper, Productivity Commission, Melbourne.

Thirtle, C , Beyers, L , Ismael, Y and Piesse, J 2003, 'Can GM technologies help the poor? The impact of Bt cotton in Makhathini Flats, Kwa-Zulu-Natal', *World Development*, vol. 31, pp.717–732.

Traxler, G 2004, *The Economic Impacts of Biotechnology-Based Technological Innovations*, The Food and Agricultural Organization of the United Nations, Auburn.

Traxler, G and Godoy-Avila, S 2004, 'Transgenic cotton in Mexico', *AgBioForum*, vol. 7, no. 1 and 2, pp.57–62.

Trigo, E J and Cap, E J 2003, 'The impact of the introduction of transgenic crops in Argentinean agriculture', *AgBioForum*, vol. 6, no. 3, pp.87–94.

RESEARCH FUNDING ABARE relies on financial support from external organisations to complete its research program. As at the date of this publication, the following organisations had provided financial support for ABARE's research program in 2006-07 and 2007-08. We gratefully acknowledge this assistance.

02.08

Asia Pacific Economic Cooperation Secretariat

Association of Southeast Asian Nations – secretariat

AusAid

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CRC Plant Biosecurity

CSIRO (Commonwealth Scientific and Industrial Research Organisation)

Dairy Australia

Department of Business, Economic and Regional Development, Northern Territory

Department of Primary Industries, Victoria

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